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Home range and habitat use by Aquatic Warblers *Acrocephalus paludicola* on their wintering grounds in Northwestern Senegal

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Abstract. The Aquatic Warbler *Acrocephalus paludicola* was once a common breeding bird in mesotrophic fen mires all over Central and Western Europe. In the last century large parts of its habitat have been destroyed by wetland drainage and agricultural intensification. Besides protecting the remaining breeding habitats, it is of great importance to preserve suitable migration stopover habitats and wintering grounds to avert the extinction of the species.
We determined home-range size and the use of vegetation associations of Aquatic Warblers on the wintering grounds in a flooded plain north of the Djoudj National Park in Senegal. Individual birds (11) were caught in mist nets and equipped with radio transmitters. Locations were assessed by radiotelemetry and a compositional analysis was conducted to determine which vegetation types were preferred within home ranges.
Similar to their behaviour on the breeding grounds, the Aquatic Warblers showed no territorial behaviour in their winter quarters. They used home ranges that averaged 4 ha in size, which they shared with conspecifics and other warblers. The home ranges overlapped 54% on average, with a maximum of 90% in an area used by four individuals. The vegetation structure of the wintering habitat is similar to breeding grounds and stopover sites of the species. Preferential vegetation had 80% to 100% cover and consisted of 60 to 90 cm high stands of *Oryza longistaminata*, *Scirpus maritimus* or *Eleocharis mutata*. Most birds stayed more often near the edge of open water, probably for foraging. A constant inundation seems essential, because Aquatic Warblers never occurred in desiccated parts of the study site.

Key words: *Acrocephalus paludicola*, Djoudj National Park, radio telemetry, transsaharan migrant, vegetation structure

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INTRODUCTION

The Aquatic Warbler is the only globally threatened passerine bird species in continental Europe. It is classified as vulnerable at the global level (BirdLife International 2008). The world population is estimated at 10,500–14,200 singing males (Flade & Lachmann 2008). As a habitat specialist the Aquatic Warbler breeds in mesotrophic or slightly eutrophic open fen mires as well as similarly structured marshy biotopes. In the 20th century these habitats have been destroyed by large scale wetland drainage and agricultural intensification. Today the Aquatic Warbler occurs in less than 40 regular breeding sites in only six countries (Tanneberger et al. 2009). The species has an extraordinary promiscuous mating system varying between polyandry and polygyny (Schulze-Hagen et al. 1999). Only the females provide parental care for the offspring and males do not occupy territories. At breeding sites, home ranges of individual birds can be up to 8 ha in size and are used by several birds (Schaefer et al. 2000).

The Aquatic Warbler is an insectivore. It forages near to ground in the cover of dense vegetation (Leisler 1975). The main prey species are among spiders Arachnida, dragonflies Odonata, beetles Coleoptera and caterpillars of butterflies Lepidoptera (Schulze-Hagen et al. 1989). Both in breeding grounds (Wawrzyniak & Sohns 1977) and at migration stopover sites (Kerbiriou et al. 2010) relatively large prey is preferred.

The currently most important wintering site of the species is the Djoudj National Park area in the Northwest of Senegal in Africa south of the Sahara in the western Sahel zone. Here the bird inhabits inundated plains dominated by waist-high gramineous vegetation, which are similarly structured wetlands as on the breeding grounds (Flade & Lachmann 2008). A larger number of wintering Aquatic Warblers were discovered in the Djoudj area in 2007 (Flade et al. 2011). In this study we present so far unknown information on the spatial behaviour of the species in winter habitat. We investigated home-range size and habitat use of Aquatic Warblers wintering in the buffer zone of the the Djoudj National Park with the help of radiotelemetry.

METHODS

Study site

The Djoudj National Park is situated in the center of the Senegal River delta in the northwest of Senegal close to the border to Mauritania (Fig. 1) Its 16000 ha extent comprises five percent of the river delta (Fig. 1). The Park was founded in 1971 and was listed as a Ramsar site in 1977. Declared a World Natural Heritage Site in 1981, it is an important wintering site for palaearctic migrants as well as a breeding habitat for numerous African waterbird species. The park consists of seasonal wetlands, lakes and oxbows of the Senegal River. Flood plains are, apart from some trees and bushes, dominated by gramineous vegetation like *Scirpus*, *Eleocharis* and *Sporobolus* species as well as wild rice *Oryza longistaminata*. In the last decades, invasive species, especially *Typha australis*, spread to the protected sites and today cover vast areas of the floodplains. The climate is semiarid and the annual precipitation of 200–250 mm is limited to the rainy season from July until September (Dia et al. 2002).

The National Park area is flooded artificially after the rainy season with water from the Senegal River. All water resources evaporate completely during the dry season. The area around the Djoudj National Park and its buffer zone is broadly used for rice and sugar cane cultivation. The study site is located south of the village Tiguet (16°27′N, 16°17′W), within the Djoudj-National Park buffer zone.

Telemetry

Birds were caught in mist nets by pulling a rope over the vegetation to flush them into the net (Flade 2008) and equipped with radio-transmitters. This procedure was conducted from different directions several times a day to increase the capture success. Between 13. Dec. 2008 and 21. Jan. 2009 eleven birds were equipped with "Biotrack PIP3" (Wareham, United Kingdom) radio transmitters with an AG 337 battery. The weight of the transmitter is about 0.5 g and represents 4.5% of the birds' body mass (based on a mean mass of 11 g). The additional load should not have led to any negative effects to the condition or the behaviour of the bird (Naef-Daenzer et al. 2001). We choose a loop harness to attach the transmitter (Rappole & Tipton 1991). The bird's movements are less disturbed by this method because no flight muscles or larger fat deposits are affected (Naef-Daenzer 2007).

Signals were received with a handheld Yagi-antenna and a "Biotrack Sika" receiver. Bearing directions were determined with a compass, and locations were recorded using a handheld GPS device (Garmin eTrex). A simultaneous cross bearing from two locations was tested but rejected because of great inaccuracy. Signals over a 100 m distance were too weak to determine the correct original direction and so birds were followed by one person. The distance to the bird could be estimated by the strength of the signal, which was indicated by a numeric scale bar on the receiver. This was tested with a dummy transmitter prior to the study. The transmitter was placed at several known distances and the displayed amplitude was recorded. Thus, we were able to keep a distance of at least 25 m from the birds to achieve undisturbed behaviour patterns. Locations were recorded every fifteen minutes using the cross of two consecutive bearings taken from different directions within two to five minutes. In addition, direct observations of the birds were recorded using GPS. All intersection points were calculated with the radiotelemetry triangulation program Locate III (Nams 2006). Based on our short distance from the birds and the occasional observations that confirmed our locations, we assume a location accuracy of ± 3 m.

In total individual birds were followed for 11.4 hours on average (range: 10.8–12.5 hours) on six different days during two weeks, resulting in an average observation interval of 1.9 hours (± 0.2 hour) per day and bird. During every daily observation interval eight to ten fixes were taken of an individual bird, including locations of direct observations. From one of the transmitters no signal was received over several days. It is unclear whether the bird had left the study site or the transmitter failed. One transmitter failed and another bird was chased over 200 m far during the

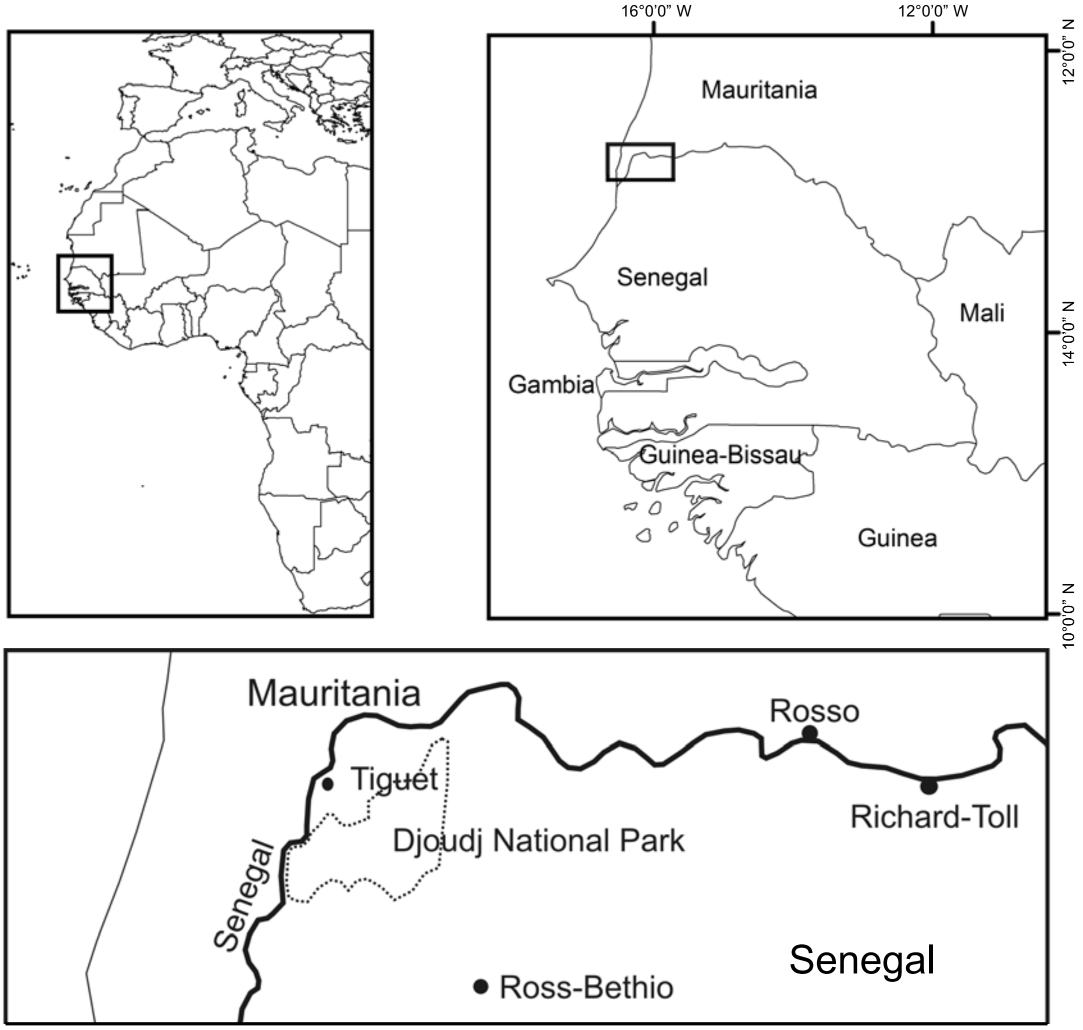

Fig. 1. Location of Djoudj National Park and the study site Tiguet.

catching attempt and therefore excluded from analysis. For eight birds we were able to record a total of ≥ 50 fixes per bird enabling us to calculate an accurate kernel home range (Seaman et al. 1999). We conducted an asymptote analysis to evaluate our sample size using the Home Range Analysis Toolbox for OpenJUMP GIS Software (Steiniger & Bocher 2009). The calculation is used to find the number of locations required to obtain a stable estimate of home-range size. The program randomly selects locations with replacements from the entire data set of the 95% kernel estimate, starting at five locations and increasing by increments of ten until the respective sample size is reached. Sample size-area curves approached an asymptote on average at 29 fixes (SD = 5.5, range: 23–38 fixes). With increasing sample size home-range size tend to decrease with kernel estimators (Barg et al. 2005). Therefore, we assume that we used a sufficient number of fixes for home range estimation.

Habitat composition

In order to analyse how habitat characteristics influence the Aquatic Warblers' home ranges, we mapped the vegetation at the study site Tiguet. Vegetation units were defined by dominant plant species, which means that at least 80% of the vegetation cover consisted of *Oryza longistaminata* (ORY), *Scirpus maritimus* (SCM), *Eleocharis mutata* (ELM), *Typha australis* (TYP), *Scirpus littoralis* (SCL) or *Sporobolus robustus* (SPO). All gaps without vegetation were classified as water (WAT). Water comprised in mean 6.7% (range: 4.5%–7.4%) of every home range and was included into range estimation, because these small to medium sized open structures seemed to be important for the habitat use of the Aquatic Warbler.

Between 16. Jan. and 21. Jan. 2009 the vegetation was mapped in an area of 46 ha size, which contained all observations of Aquatic Warblers. The extent of the vegetation units was determined within a GPS grid and later mapped in ArcGIS 9.2 (ESRI 2009). One grid cell had an edge length of 30 m. Within each grid cell, structural aspects of the vegetation units like the height and the percentage of cover were recorded once in every square meter. Vegetation height (in cm) was measured above ground and the cover (in %) was estimated as the proportional cover of a plant species from the respective area. The water level (in cm) was recorded at random locations over the entire field season. Using ArcGIS 9.2, we were able to define the vegetational composition of every home range.

Data analysis

Radiotelemetry studies always face the issue of autocorrelation, because several fixes are taken from the same individual, often within short time frames. White & Garrott (1990) state that sufficient time between locations should pass for an animal to move from one end of its home range to the other. The time interval between locations during one observation interval was 15 minutes, which exceeds the time necessary to bridge any recorded home range boundary by far. Furthermore, the constant time interval of 15 minutes between successive observations should also reduce the effect of autocorrelation on the validity of the home range estimate (De Solla et al. 1999). If the experimental unit is the individual, not the single observation, the radio locations represent a subsample of an individual's use of the habitat, and the autocorrelation between fixes can be considered irrelevant in this case (Otis & White 1999). Barg et al. (2005) argue that in utilization studies statistical independence is less important than the biological independence of data, which can be assumed in our case.

Home range boundaries were calculated with a fixed kernel estimator (Hooge & Eichenlaub 1997). Core areas were not defined, because birds did not visit certain spots frequently, and analysis was only performed for the 95% home range contour. The smoothing factor was determined by least squares cross-validation and equally used for all calculations to get comparable results. Home range size was calculated in GIS, and the overlap rate was expressed as the proportion of the area shared with other birds compared to the bird's own total home range size (Millspaugh & Marzluff 2001).

The preference for certain vegetation units within home ranges was analysed with a compositional analysis (Aebischer et al. 1993). The proportional composition of the available vegetation in each home range was compared with the proportion of use. Use within home ranges was described by the distribution of radio locations over the different vegetation units. In this case the serial correlation between fixes can be neglected, because the radio locations in each habitat estimate the proportion of the trajectory of each individual bird (Aebischer et al. 1993). To test for overall selection a Wilk's lambda test was conducted. Logs of the selection ratios for each vegetation unit were composed of the proportion of the used (x_u) to the available (x_a) proportion for each analysed vegetation unit (i) and a reference vegetation unit (j). As reference vegetation unit we choose open water (WAT), because it occurred in every home range but was used least due to the absence of vegetation. The differences $d_i = \ln(x_{ui}/x_{ai}) - \ln(x_{uj}/x_{aj})$ between the log ratios were calculated for each home range. Because in some cases a vegetation unit was available but not used, the value for x_u had to be substituted. We used the formula Aebischer et al. (1993) suggested to calculate a replacement value of 0.01, which was smaller than any observed value. The mean differences in each vegetation unit were then compared with a one-sample t-test to the value 0 to find the selection in relation to WAT. To compare the other vegetation units a paired t-test was used. Aebischer et al. (1993) stated that six radio-tagged animals are an absolute minimum for a compositional analysis. All vegetation units were available for all eight birds, except for SCM, which only occurred in three home ranges; therefore SCM was excluded from the analyses.

In order to examine whether the edge of open water had an effect on warbler locations, using GIS, we separated home ranges into zones, which each zone being another 5 m inward from open water. Because no location was farther than 30 m from open water, the last interval was >25 m, resulting in seven categories. The available area of each distance interval was used to calculate expected values. Locations were counted in every zone and the distribution was analysed for every bird individually. A G-test for goodness-of-fit was conducted to find whether locations were distributed non-randomly or proportional to the available area. All statistical analyses were performed using the program R (version 2.10.1, available at: http://cran.r-project.org).

RESULTS

Home-range size and overlap

Locations of individual birds appeared to be clustered during each observation interval, indicating that Aquatic Warblers do not move long distances for daily activities. Home ranges varied in shape and size between individuals and some formed discontinuous patches (Fig. 2). Home-range size was on average 3.9 ha (± 1.9 ha, n = 8, Table 1). Aquatic Warblers occupied larger areas in the beginning of the survey than later on in the season. The mean home-range size in the last two weeks of December was 4.1 ha (n = 3) whereas in the same time period of January the average home range was 2.4 ha (n = 3). Home-range size increased significantly with hours of observation

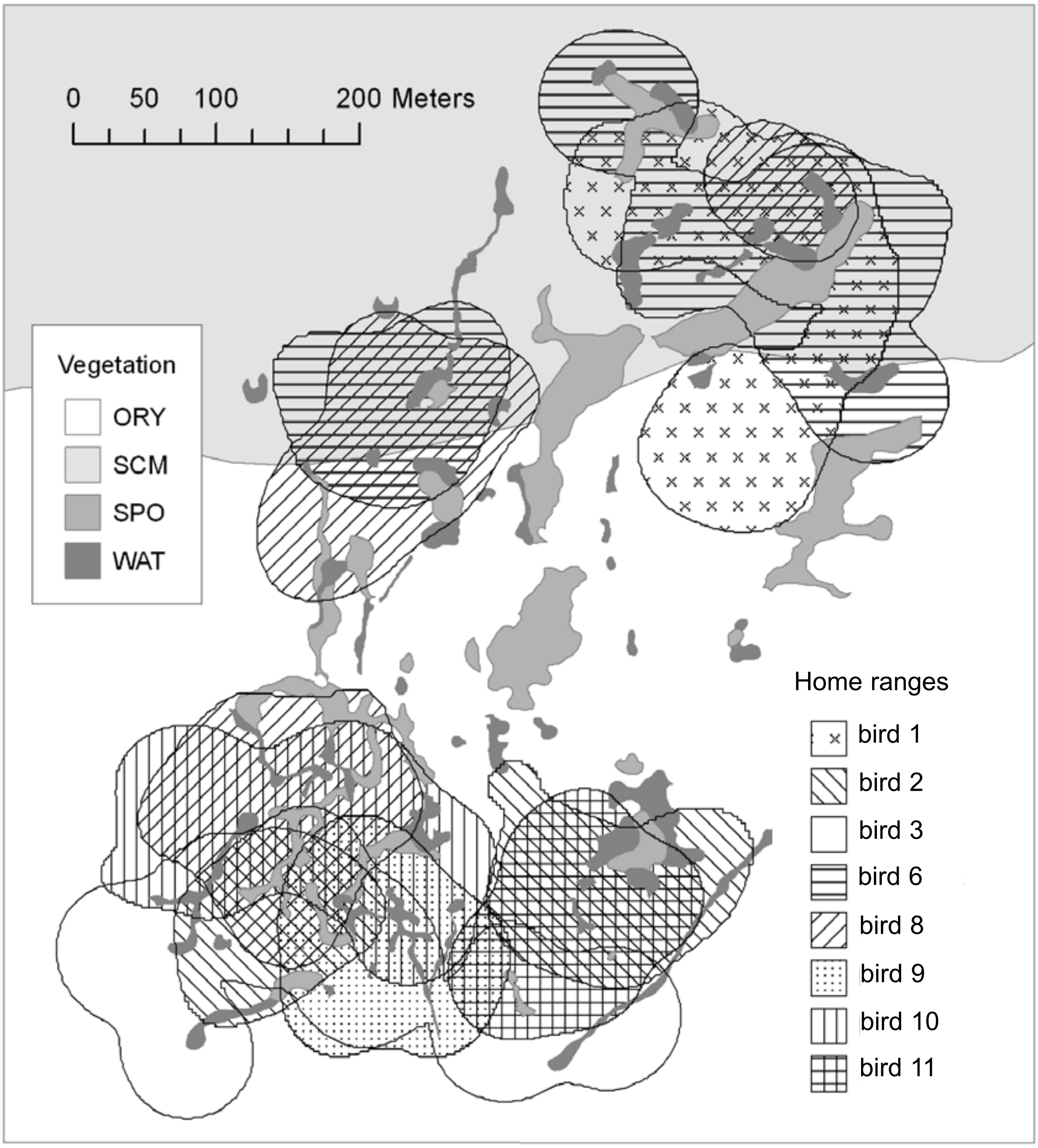

Fig. 2. Fixed kernel 95% home ranges of eight radio-tracked Aquatic Warblers and exemplary vegetation units at the study site Tiguet, Senegal. Vegetation: ORY — *Oryza longistaminata*, SCM — *Scirpus maritimus*, SPO — *Sporobulus robustus*, WAT — water.

Table 1. Size and simultaneous overlap of fixed kernel 95% home ranges of Aquatic Warblers radio-tracked on the wintering ground at Tiguet, Senegal.

Bird no.	No. of fixes	Home range (in ha)	Shared area in ha (no. of birds involved)	Overlap in %	No. of observation hours	Period of observation
1	51	3.9	0	0	11.2	15–31.12.08
2	50	3.4	1.6 (2)	47.9	10.8	19–31.12.08
3	55	5.0	1.6 (2)	31.3	11.4	19–31.12.08
6	53	5.8	1.9 (2)	33.4	11.3	01–14.01.09
8	57	5.6	4.3 (4)	77.2	12.5	01–14.01.09
9	51	2.0	1.7 (4)	83.8	11.7	04–18.01.09
10	55	3.2	2.9 (4)	89.4	11.8	04–19.01.09
11	52	2.0	0.3 (3)	13.9	11.0	11–21.01.09
mean	53	3.9	2.0 (3)	53.9	11.4	

(Spearman rank correlation, rho = 0.92, $p = 0.001$), but not significantly with number of fixes (Spearman rank correlation, rho = 0.43, $p = 0.28$).

All home ranges highly overlapped with each other (Fig. 2), showing more overlap later in the season. Nevertheless, that does not imply that birds stayed simultaneously together in the overlapping areas. Some of the birds shown in Fig. 2 were not radio-tracked during the same time interval. Thus, the use of the same area might be consecutive. Therefore, overlap rates (Table 1) were only calculated for birds tagged at the same time period. The overlap rates were on average 54% and involved from two to four individuals. One Aquatic Warbler shared 89% of its home range with others. In four cases two different radio-tagged birds were observed simultaneously at the same place. Occasionally, untagged conspecifics were found in the home ranges of tracked birds. The Aquatic Warblers did not show any aggressiveness or territorial behaviour against other Aquatic Warblers. Sedge Warblers *Acrocephalus schoenobaenus* and Yellow Wagtails *Motacilla flava* were also observed in close proximity to the Aquatic Warblers, but never elicited aggressive reactions.

Habitat use

The vegetation height above ground at the wintering site of Aquatic Warblers near Tiguet ranged between 50 cm and 170 cm. The mean vegetation height within home ranges was 79.8 cm (SD = 5.8, range: 69.6–85.5 cm). The vegetation cover was on average 91.4% (SD = 8.6, range: 83.1–98.7%). The water level was at least 10.0 cm (mean 15.3 cm, SD = 4.1) in all home ranges. No bird was relocated at a desiccated spot at any time. *Scirpus maritimus* only occurred in three home ranges, but was the dominant vegetation unit in two of these home ranges. *Scirpus maritimus* was more used than available, but could not be included into compositional analyses due to small sample size. The Wilks lambda test showed a significant overall selection of vegetation units ($\lambda = 0.076$, $p < 0.001$), indicating non-random vegetation use by the Aquatic Warbler. In six home ranges *Oryza longistaminata* was the dominant plant species. *Oryza longistaminata* was significantly selected over open water, *Sporobolus robustus* and *Scirpus littoralis*, but showed no significant difference in selection to *Eleocharis mutata* (Table 2). *Eleocharis mutata* was preferred to *Scirpus littoralis*, the latter showing no difference with *Sporobolus robustus*. *Typha australis* showed no significant difference in selection compared to open water, indicating that Aquatic Warblers avoid *Typha australis*. According to the compositional analyses the vegetation units can

Table 2. Compositional analysis comparing the vegetation units used by wintering Aquatic Warblers with the availability in their home ranges at Tiguet, Senegal. Vegetation units: WAT — water, ORY — *Oryza longistaminata*, ELM — *Eleocharis mutata*, SPO — *Sporobolus robustus*, SCL — *Scirpus littoralis*. The mean differences in selection log ratios were tested with one-sample and paired t-test (with df = 7). Significance (* — $p < 0.05$, ** — $p < 0.01$) indicates that the vegetation unit in the line is selected over the vegetation unit in the column, no significance indicates no difference in selection.

Vegetation unit	WAT	TYP	SCL	SPO	ELM
ORY	4.562 **	3.214 **	2.079 **	2.881 *	0.216
ELM	4.333 **	2.998 *	2.254 *	1.465	
SPO	2.868 *	1.534 *	0.789		
SCL	2.079 **	1.912 *			
TYP	1.335				

be ranked in the following order: *Oryza longistaminata* and *Eleocharis mutata* were selected over *Sporobolus robustus* and *Scirpus littoralis*, which were prefered to *Typha australis* and open water.

Analysis of the distances of the locations to open water showed that most of the Aquatic Warblers stayed closer to open water than expected by the available area within their home ranges. Except for bird no. 1, all locations of the Aquatic Warblers showed a significant deviance from a random distribution (Table 3). Six birds were found most frequently 0–5 m away from open water. The fixes of bird no. 1 and no. 8 were mostly between 5 and 10 m from open water. In all cases the area intervals more than 10 m from water were used less than expected based on their availability.

Table 3. Distribution of fixes in relation to open water within home ranges of Aquatic Warblers wintering at Tiguet, Senegal. G-test for goodness-of-fit (df = 6) analysed whether fixes were randomly distributed in relation to open water.

Bird no.	% of fixes in distance (m) to open water 0–5	5–10	10–20	> 20	G test	p
1	17.6	37.3	15.7	29.4	5.54	0.48
2	34.0	26.0	28.0	12.0	14.63	0.02
3	27.8	25.9	22.2	24.1	13.32	0.04
6	35.3	27.5	21.5	15.7	25.71	< 0.001
8	21.2	34.9	28.1	15.8	19.47	0.003
9	49.0	39.2	9.8	2.0	44.19	< 0.001
10	36.4	32.7	18.2	12.7	17.08	0.01
11	32.7	21.2	19.2	26.9	13.21	0.04
mean	31.8	30.6	20.3	17.3		

DISCUSSION

Home range size and overlap

On the breeding grounds the spatial organisation of the Aquatic Warbler differs among sexes due to their breeding system. While males use areas up to 8 ha (mean 4.6 ha), female activity ranges can be 120 ha large and show less overlap. Within these ranges they occupy isolated patches of on average 4.2 ha size. During incubation females use areas of less than 1 ha size (Schaefer et al. 2000). Because it is not possible to determine the sex of the Aquatic Warbler outside the breeding season by sight, we were not able to analyse differences in behaviour among sexes on the wintering grounds. The average home range size of 3.9 ha is similar to that on the breeding grounds (Schaefer et al. 2000). On migration stop-over sites the home ranges of the Aquatic Warbler were on average 9 ha (range 0.48–42.5 ha), showing a large variation among individuals (Provost et al. 2010). Daily foraging ranges were on average 4.2 ha (± 3.8 ha), indicating that food availability might be the relevant driver of home range size (Provost et al. 2010). Our home-range sizes should be considered to be minimum estimates, because transmitter battery life limited the observation period to fourteen days. In that time period, birds moved around without specific patterns and core areas. Schaefer et al. (2000) observed individual birds for up to 38 days and found that home range sizes did not stabilise. In addition, if tagged birds move out of reach, their home range might be larger than it is possible to detect with this kind of radiotelemetry study. One bird probably left the study site after tagging. The information on its home range extent is missing in our analysis. In our study home-range size increases with hours of observation, indicating that with potential longer observation, home ranges would be larger. So it is very likely that the birds cover much wider areas during the entire wintering season.

Furthermore, the average home-range size may deviate from our results if more than eight birds had been tracked. Between 13. Dec. 2008 and 21. Jan. 2009 we captured in total 20 Aquatic Warblers. Eleven of them were equipped with radio transmitters. We were able to track at most three birds simultaneous, to achieve sufficient fixes for home range estimation within the battery life of two weeks. Due to the rareness of Aquatic Warblers and technical time limitations we were not able o track more individuals during this field season.

A high proportion of home range overlap is also known from the breeding habitats. According to Schaefer et al. (2000) male birds share up to 74% of their breeding home ranges with other Aquatic Warblers. Up to eleven radiotracked males were observed in the home range of a single male (Schulze-Hagen et al. 1999). Due to the high overlap rate, Schaefer et al. (2000) concluded the Aquatic Warbler is not territorial in the breeding season. The mean overlap rate is about 50% both in the breeding and the wintering site. In Tiguet the highest proportion of shared area was almost 90%. Other species of *Acrocephalus* warblers show territorial behaviour year round. Marsh Warblers *Acrocephalus palustris* defend territories in their wintering sites with song, although the singing is less intensive than in the breeding season. These territories are of similar size and show no overlap (Kelsey 1989). Aquatic Warblers never showed territorial behaviour or aggressiveness towards other birds. This and the high overlap rate confirm that they do not occupy territories in their winter quarters but widely share their home ranges with conspecifics and other warblers.

Because home ranges show substantial overlap, the area required by a single bird is difficult to determine. Densities of birds seem to increase later on in winter. The low inundated area rapidly dries up in January due to strong Saharan winds. The birds concentrate then on the remaining wet areas, where their home ranges are smaller and show more overlap. This behaviour is already known from the breeding sites, where Wawrzyniak & Sohns (1977) observed that Aquatic Warblers retreat to ditches and remaining wet parts when their habitat dries up. Therefore, it is problematic to estimate the number of Aquatic Warbler residents at the study site or for the whole Djoudj area. Vegetation compositions and other habitat conditions like the water level rapidly change over space and time. The water regime depends mainly on the water supply of the rain season and may vary between different years. Home-range size and the number of wintering Aquatic Warblers are probably closely connected to inundation and vegetation structure. It is not assured whether our results at Tiguet were based on optimal site conditions. The actual extent of suitable and, essentially, occupied habitats in the Djoudj area and their seasonal and inter-annual dynamics still needs to be further investigated.

Habitat use

The wintering site of the Aquatic Warbler in Tiguet mainly consists of *Scirpus*, *Eleocharis* and *Oryza* spp. This homogenous and gramineous vegetation is similar to that at migration stopover habitats and breeding grounds. On migration, Aquatic Warblers have been found in temporarily flooded habitats characterised by a helophytic vegetation that is dominated by *Scirpus* and *Juncus* spp. (Miguélez et al. 2009) or by *Juncus*, *Cladium* or *Schoenoplectus* spp. (Poulin et al. 2010). Schaeffer et al. (2006) refer to African records of Aquatic Warblers in dense grasses and vegetation consisting of *Carex*, *Juncus* and *Phragmites* spp. in freshwater or brackwater marshes and wet meadows. The breeding habitats in Poland and Belarus are also dominated by *Carex* associations, and some are situated in calcareous marshes with *Cladium mariscus* (Flade & Lachmann 2008). The similar habitat composition of breeding, stopover and wintering habitats underlines that the Aquatic Warbler is a habitat specialist, that depends on particular habitat parameters.

Specifically, we found preferential vegetation height to range between 70 and 90 cm. Kozulin & Flade (1999) found that Aquatic Warblers prefer 60 to 70 cm high vegetation in the breeding grounds in Belarus and that birds were less abundant in stands higher than 100 cm. Thus, keeping the vegetation low is an important management task in most breeding habitats (Tanneberger et al. 2010). At Tiguet the vegetation, mainly *Oryza longistaminata*, was also grazed by cattle. Kloskowski & Krogulec (1999) state that at some sites the Aquatic Warbler benefits from low-intensity grazing because it prevents the overgrowth with trees and bushes. In addition, grazing may provide better structural conditions for the larval development of several arthropod species like spiders Arachnida, grasshoppers Orthoptera and beetles Coleoptera (Schmidt et al. 2005), which are the main prey of the insectivorous Aquatic Warbler (Schulze-Hagen et al. 1989). Therefore, the present extensive grazing at Tiguet can be continued, if it is not intensified in the future.

The vegetation cover is on average 70% in breeding sites in Belarus (Kozulin & Flade 1999) and about 60% in western Poland (Tanneberger et al. 2010). On the wintering ground the vegetation cover was with 80% to 100% higher than in most breeding grounds. Especially the dominant and preferentially used *Oryza longistaminata* (Table 2) provides a high density. Aquatic Warblers prefer a dense vegetation structure in which they move as agile climbers (Leisler 1975). *Oryza longistaminata* was often associated with *Scirpus maritimus* and *Sporobolus robustus*, leading to a less dense vegetation structure. That may provide even more favourable conditions for the Aquatic Warbler. However, this could not be substantiated with the compositional analyses. Even *Eleocharis mutata* and *Scirpus littoralis* occurred as small islands over the study site, the use of this vegetation units by the Aquatic Warbler was detectable (Table 2). There were records of Aquatic Warblers in pure stands of *Eleocharis mutata* and associations dominated by *Scirpus littoralis* in 2007 and 2008 (Tegetmeyer, unpublished data), which confirmes the importance of these plant species for the Aquatic Warbler. The avoidance of *Typha australis* has been already observed in former investigations. Aquatic Warblers have never been recorded in pure stands of *Typha australis* so far, although Reed Warblers *Acrocephalus* *scirpaceus* and Sedge Warblers *Acrocephalus schoenobaenus* were abundant there (Flade 2008). Aquatic Warblers may avoid *Typha australis* because of its open and tall structure, or because they are poorly adapted to hold on thick stems (Leisler 1975).

The Aquatic Warblers were found more frequently ≤ 5 m from open water, which comprised a high proportion of every home range (Table 3). Baldi & Kisbenedek (1999) found that several other *Acrocephalus* species prefer edges in their breeding habitats. Birds often forage at edges, because here the trade-off between shelter and predation is optimally balanced (Wilson et al. 2005). Due to ecotone effects, edges harbour more insects than the interior of dense vegetation (Baldi & Kisbenedek 1999). Also Tanneberger (2008) found that foraging females show a preference for edges and ditches in the Pomeranian population of the Aquatic Warbler. The high density of the vegetation at Tiguet and hence the better conditions for foraging at the edges can probably explain why the birds stayed close to open water.

Furthermore, constant inundation of vegetation seems important since no Aquatic Warbler was located at desiccated parts of the study site. In breeding habitats, Aquatic Warblers were also most abundant in areas with a low (1–10 cm above surface) but constant water level (Kozulin & Flade 1999). One reason is probably the larger food supply in wet conditions. Dip-net catches on the study site at Tiguet showed significantly higher insect biomass in wet than in dry parts of the same habitat (Bulte 2009).

In conclusion, we found Aquatic Warblers in Tiguet use winter habitat that is similar to the breeding habitat. Future management should concentrate on maintaining large inundated areas of emergent vegetation over the whole wintering season, and preventing the over growth of invasive *Typha australis*, to conserve this wintering site for the Aquatic Warbler.

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