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Deteriorating weather conditions predict the use of suboptimal stopover sites by Aquatic Warblers *Acrocephalus paludicola*

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Abstract. The Aquatic Warbler *Acrocephalus paludicola* is a globally threatened songbird and its decline is related to habitat loss. Accordingly, most studies dealing with the stopover ecology of this species have been chiefly focused on the habitat use and the availability of suitable habitats along its route of migration. In contrast, much less attention has been paid to other environmental causes potentially explaining the use of stopover sites. Our aim here was to investigate whether the Aquatic Warbler at an apparently suboptimal stopover site with small area of suitable habitats stops over only during adverse weather conditions. We used data obtained at a suboptimal (Jaizubia marshland, northern Iberia) and another optimal (Villefranque, southwestern France) stopover sites during the autumn migration over four seasons (2007–2010). The Aquatic Warbler tended to stop over at Jaizubia in days with rain, a fact that was not so evident at Villefranque, supporting the hypothesis that they used the suboptimal site only, or mostly, when adverse weather conditions forced them to land. In contrast, the optimal habitat was used independently of weather conditions. To properly identify key stopover localities for the Aquatic Warbler, we should consider the potential influence of adverse weather in occurrence of individuals, especially in small areas without preferred habitat.

Key words: migration, stopovers, tailwind, weather, rain, western Pyrenees

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The Aquatic Warbler *Acrocephalus paludicola* is a globally threatened songbird, with a population size probably less than 14,000 individuals (BirdLife 2004). It breeds across western Palearctic between 47° and 59° N, east of 22° E, and its wintering areas are found in central-western Africa, mainly in Senegal (Schaffer et al. 2006, Walther et al. 2007). The Aquatic Warbler migrates through western Europe and Africa, where the known stopover sites seem to lie in northwestern France (Julliard et al. 2006). Some other relevant stopover sites also exist in Iberia (Atienza et al. 2001, Jubete 2001).

The species decline is chiefly caused by habitat loss, especially through its western distributional range (Kloskowski & Krogulec 1999, Kozulin & Flade 1999, Kozulin et al. 2004, Tanneberger et al. 2008). Accordingly, many studies have dealt with the habitat use and the restoration of suitable breeding habitats (e.g., Tanneberger et al. 2006, 2009). In contrast, little is known about other factors determining its presence along migration route (but see Jubete et al. 2006).

Migratory performance is strongly determined by weather; in particular, migration mostly takes place in days without rain and with tail wind (i.e., wind assistance) (reviewed in Newton 2008). Thus, adverse weather could strongly influence landfall of migrants at given stopover sites. Such an effect should be expected to be much more pronounced in suboptimal stopover sites, where migrants would land only in case of "emergency".

Our aim was to investigate whether at an apparently suboptimal stopover site with a very small area of suitable habitats, Aquatic Warblers tend to stop over only or mostly during adverse weather as compared to a site with optimal habitat where birds could land irrespective of weather conditions to stop over.

Data were obtained from a ringing station located in Jaizubia, Txingudi marshlands (43°21′N, 01°49′W, northern Iberia; for details see Mendiburu et al. 2009), and another one in Villefranque, La Nive river (43°27′N, 01°28′W, southwestern France), at a distance of 30 km from Jaizubia. The vegetation at Jaizubia consisted mostly of reed beds (*Phragmites australis*), thus lacking the habitat considered to be optimal for the species (grasslands with ca. 50 cm height vegetation of sedges and related species) (Jubete et al. 2006). Thus, Jaizubia could be considered to be a suboptimal stopover site for the Aquatic Warbler compared to Villefranque that had both reed beds and prairies with grass and sedge.

Birds were captured with mist nets (Jaizubia: 204 m of working mist nets; Villefranque: 108 m), placed always in the same site and open daily during a period of 4 h starting at dawn; Jaizubia: from 01/08 to 15/09 of 2007–2010; Villefranque: 09/08–24/08 of 2008, 02/08–08/09 of 2009, and 01/08–15/09 of 2010. At both stations, the Aquatic Warbler was attracted to mist nets using tape lures. The tape lure was used only during the sampling period (i.e., during 4 h starting at dawn), so we assumed that it did not affect the landfall of migrating Aquatic Warblers, but rather, improved capture success of already settled birds. Only the first capture event for each bird has been included in the analysis.

Weather data were obtained from a meteorological station located at the top of the Jaizquibel mountain (525 m asl), 3.5 km from Jaizubia ringing station. We assumed that (1) weather at Jaizquibel was representative of weather conditions en route within the region (southwestern France, Basque region), and (2) that flying time lasted during a period of maximum 8 h starting at dusk. Thus, weather conditions through the night from the day t-1 to t were considered to affect the presence of migrants during the day t at both sampling localities.

Weather data considered here were: rain (originally in mm, here coded as a binary variable of nights with or without rain), wind velocity (m/s), wind direction (°). We integrated wind data as a tailwind component (*b*) following Akesson & Hedenstrom (2000) equation: $b = V \times \cos[\alpha_T - (180° + \alpha_W)]$, where V is wind velocity, α_T is the (presumed) departure direction (225°, i.e., a south-western migratory direction), and α_W the direction the wind comes from. High, positive tailwind values correspond to strong tail wind, whilst high, negative tailwind components correspond to strong head wind.

Differences in the proportion of days with or without rain between ringing stations were compared using contingency tables and differences in tailwind values were compared by parametric t-tests. In these tests, a Levene's test was used in order to check whether there were equal or unequal variances between samples.

Such analyses were run for a set of different numbers and indices indicating Aquatic Warbler's abundance (absolute number of captures, standardized number of captures per sampling effort at each site, Acrola index, which was the number of captures of Aquatic Warbler in relation to number of capture of all the *Acrocephalus* species, including focal species). Repeated measures ANOVA was used to test whether tailwind differed between the two days preceding and the two following the capture day. In all cases significance level was set at $p = 0.05$. Logistic regression was applied to predict the presence of Aquatic Warbler (i.e., captures introduced as a categorical variable) according to rain and tailwind for each sampling site. We used SPSS version 18.0; unless stated otherwise values are given as means ± SE.

Overall, we captured 39 Aquatic Warblers at Jaizubia and 91 at Villefranque (30 and 90 if we only consider days of common survey at both sampling sites (Table 1). The warblers were more abundant at Villefranque than at Jaizubia, both in terms of absolute captures, standardized number of captures per sampling effort and the Acrola index (Table 2). The data therefore support the conclusion that Villefranque is a better stopover site for the Aquatic Warbler than Jaizubia.

Captures tended to happen in days with rain at Jaizubia, but no such tendency was observed at Villefranque (Table 3). Similarly, an almost significant effect of rainy days was observed for the Acrola index at Jaizubia ($U = 3017.0$, $p = 0.057$), but not at Villefranque ($U = 963.0$, $p = 0.701$).

Table 1. Number of Aquatic Warblers captured at each sampling site and year. Captures from days of common survey at both sampling sites are shown in parenthesis (Jaizubia).

Site	2007	2008	2009	2010
Jaizubia	8 (0)	5 (4)	12 (12)	14 (14)
Villefranque	No sampling	23	48	20

Table 2. Comparison of Aquatic Warbler captures at the two sampling localities. Numbers and indices of Aquatic Warbler abundance calculated: Totals — for all trapping days; Common survey — only for periods when both ringing sites were working. Captures — absolute number of captures; Sd. captures — standardized number of captures/100 linear m of mist nets, Acrola index — the number of Aquatic Warbler captures in relation to captures of all the *Acrocephalus* species (including focal species).

	Jaizubia	Villefranque	Statistics
Totals			
Captures	39	91	χ^2 = 20.800, p < 0.001
Sd. captures	0.11 ± 0.02	0.85 ± 0.14	U = 6070.0, p < 0.001
Acrola index	0.012 ± 0.004	0.077 ± 0.014	U = 5868.5, p < 0.001
Common survey			
Captures	30	91	χ^2 = 30.752, p < 0.001
Sd. captures	0.16 ± 0.04	0.85 ± 0.14	U = 3504.5, p < 0.001
Acrola index	0.015 ± 0.004	0.077 ± 0.014	U = 3402.0, p < 0.001

Mean tailwind values did not differ between days with or without Aquatic Warbler captures at either ringing station (Table 3).

Both rain and tailwind tended to differ between the days preceding and following days with Aquatic Warbler captures (Fig. 1), but the difference was not significant for any of the sampling localities (rain: contingency test, Jaizubia: χ^2 = 0.875, df = 2, p = 0.756; Villefranque: χ^2 = 4.151, df = 2, p = 0.140; tailwind: repeated measures ANOVA, factor: $F_{2,67}$ = 2.446, p = 0.094; factor×site: $F_{2,67}$ = 0.251, p = 0.779). We show in Fig. 2 the number of captures and the days of rain for both localities in 2010 (the only year when the sampling was extended from 01/08 to 15/09 at both stations).

A stepwise logistic regression revealed that only rain over the night previous to the capture day predicted the presence of Aquatic Warbler at Jaizubia (β-parameters: constant ± SE, -1.149 ± 0.318, Wald statistics = 13.022, p < 0.001; rain(t), -0.853 ± 0.421, Wald statistics = 4.110, p = 0.043). In contrast, the rain over two nights before the capture day had a significant weight in the regression for Villefranque (constant, 0.452 ± 0.342, Wald statistics = 1.748, p = 0.186; rain(t-2), -1.217 ± 0.436, Wald statistics = 7.795, p = 0.005).

The Aquatic Warbler was less numerous at Jaizubia than at a nearby stopover site at Villefranque, supporting the hypothesis that Jaizubia was a suboptimal site compared to Villefranque. Such a difference is most likely

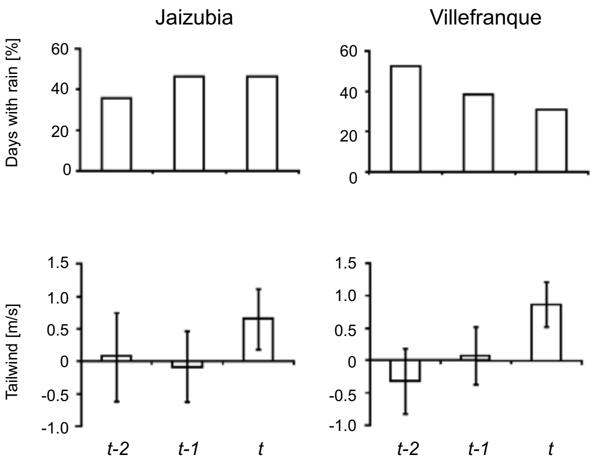

Fig. 1. Proportion of days with rain and tailwind values (mean ± SE) during the nights before and within the capture day (*t*) at Jaizubia (suboptimal) and Villefranque (optimal) stopover sites.

Table 3. Weather conditions (data obtained over an 8-h period starting at dusk of the day before the capture day) of days when Aquatic Warblers were and were not captured at a suboptimal (Jaizubia) and optimal habitat (Villefranque) used to stop over. * — Levene's test, p < 0.05.

	Days with captures	Days with no captures	Statistics	df	p-values
Jaizubia					
Rain	46.4%	27.0%	χ^2 = 4.262	1	0.036
Tailwind (± SE)	0.6 ± 0.5 m/s	0.1 ± 0.3 m/s	t = 0.772	178	0.441
Villefranque					
Rain	40.0%	36.8%	χ^2 = 0.372	1	0.347
Tailwind (± SE)	0.9 ± 0.3 m/s	-0.1 ± 0.5 m/s	t = 1.477	94.955*	0.118

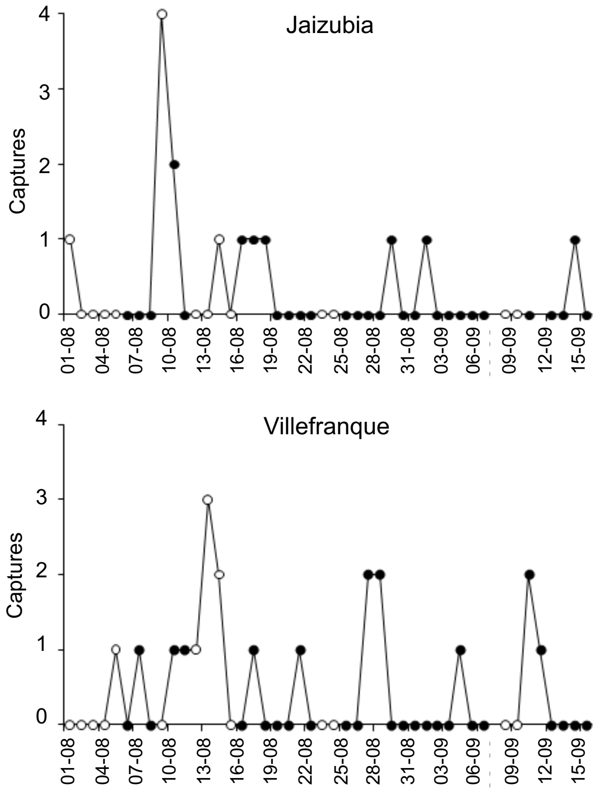

Fig. 2. Number of captures at Jaizubia (suboptimal) and Villefranque (optimal) stopover sites, during the autumn migration in 2010; open dots — days with rain; dark dots — days without rain. On 7 and 11 September, trapping was not performed due to adverse weather or spring tide.

caused by a lack of suitable, optimal habitat for the species at Jaizubia (Arizaga et al. in press).

The Aquatic Warbler tended to be captured at Jaizubia in days with rain, which was not detected at Villefranque. This supports the idea that those birds used the suboptimal area only, or mostly, when adverse weather forced them to land. In contrast, the optimal habitat was, or seemed to be, used independently from weather conditions, as could be expected for a stopover site with preferred Aquatic Warbler habitat.

An increasing number of wetlands in northern Africa and Iberia have recently been reported to be used by stopping-over Aquatic Warblers (Robles & Arcas 2004, Miguélez et al. 2009, Onrubia et al. 2009, Arizaga et al. 2011), yet, the importance of some of these areas for the species may be questionable. In our opinion the identification of key stopovers for the species should consider the potential influence of adverse weather, especially in small areas or places without proper habitat. Although some of these sites could be used only accidentally, they still could play a role for the conservation of Aquatic Warbler because they could help to minimize mortality during migration. Furthermore, wetlands suboptimal for the Aquatic Warbler could be still adequate for other birds

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STRESZCZENIE

[Użytkowanie suboptymalnych miejsc przystankowych przez wędrujące wodniczki w związku z pogorszeniem się warunków pogodowych]

Spadek liczebności wodniczki związany jest z zanikaniem odpowiednich dla tego gatunku siedlisk. Większość prac dotyczących okresu wędrówki także analizuje dostępność i wykorzystanie środowisk wzdłuż trasy wędrówki. Natomiast znacznie mniej uwagi poświęca się innym czynnikom potencjalnie wpływającym na wykorzystywanie poszczególnych miejsc przystankowych. Celem pracy było zweryfikowanie hipotezy, że w suboptymalnym miejscu przystankowym, z niewielkim udziałem preferowanych siedlisk, wodniczki zatrzymują się tylko podczas niekorzystnych warunków pogodowych. Do analiz wzięto pod uwagę dane zbierane w trakcie czterech sezonów wędrówki jesiennej (2007–2010) w dwóch punktach obrączkowania ptaków: Jaizubia na terenach podmokłych Txingudi w północnej Hiszpanii oraz Villefranque w południowo-zachodniej Francji, oddalonych od siebie o ok. 30 km. Oprócz całkowitej liczby schwytanych wodniczek, jak również przeliczonej na długość wykorzystywanych sieci, w analizach uwzględniono także „współczynnik acrola" — liczbę wodniczek w stosunku do wszystkich schwytanych ptaków z rodzaju *Acrocephalus*. Wśród danych pogodowych analizowano występowanie opadów deszczu oraz prędkość i kierunek wiatru w noc poprzedzającą dzień złapania ptaka.

Liczba schwytanych wodniczek, była mniejsza w punkcie Jaizubia niż Villefranque (Tab. 1, 2), co w połączeniu z danymi siedliskowymi wskazuje, że te ostatni teren jest lepszym miejscem przystankowym dla tych ptaków.

Wodniczki częściej były chwytane na miejscu suboptymalnym po nocach z opadami deszczu, co nie było tak wyraźne dla Villefranque (Tab 3. Fig. 1, 2), Wydaje się wiec, że pogorszenie pogody zmusza wodniczki do przerwania wędrówki i lądowania w miejscu suboptymalnym.

Uzyskane wyniki wskazują, że w celu odpowiedniego zidentyfikowania istotnych miejsc przystankowych, z których korzysta ten zagrożony gatunek podczas wędrówki, należy brać pod uwagę nie tylko jego obecność, ale także warunki pogodowe panujące podczas stwierdzeń ptaków, szczególnie, jeśli w danym miejscu mało jest optymalnych, preferowanych przez wodniczkę środowisk.