Avocetta 35: 13-17 (2011)

A comparison of two methods for monitoring migrating broad-winged Raptors approaching a long water crossing

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Abstract – Observations on raptor migration were carried out at the island of Marettimo (Central Mediterranean) during the first half of October 2007. Raptors concentrate at this site before crossing the Channel of Sicily en route to Africa (130 km). We used and compared two different census methods in order to limit the problem of double-counting of migrating raptors. A total of 510 and 299 individuals were respectively counted using two different methods: the first one is the standard method in use to count migrating raptors (all-occurrence), the second one consists in considering the maximum number of raptors observed together for each observation day (maximum-daily-count). Raptors observed were almost juveniles and immatures (inexperienced individuals). For short-toed snake eagle *Circaetus gallicus*, booted eagle *Aquila pennata* and common buzzard *Buteo buteo*, the results show significant differences in counts. Weather conditions affected observed numbers of these species at the site, although they did so similarly for both methods. Results show that, at Marettimo, it is not possible to make an accurate count of inexperienced broad-winged raptors approaching the long water crossing. For this reason we suggest to consider as an activity index the daily count of the maximum number of birds of the same species observed together during each day of field work.

INTRODUCTION

During migration *Accipitriformes* mostly use soaring flight, thus optimizing the use of thermal currents, and avoiding long water crossing to limit powered flight over water and to reduce energetic costs (Kerlinger 1989). The wing morphology of raptors plays a role in the evolution of migration strategies; in particular, species with relatively broad wings (low aspect ratio) are less suited to undertake the crossing of large bodies of water while the same, heavier, species maximize their flight speed over land. In particular Kerlinger (1989) proposed the aspect ratio [(Wing Span)^2/(Wing Area)] as one of the most important morphologic features explaining water crossing tendency of raptors, while other authors highlighted the weight differences (Spaar and Bruderer 1997, Åkesson and Hedenström 2007, Pennycuik 2008). As a result, large soaring raptors like vultures, eagles and common buzzards are observed in small numbers during spring and autumn migration in Central Mediterranean. Observations of broad-winged raptors in this area do not generally reflect the existence of a true migration flyway, but rather they mostly concern inexperienced and/or young individuals (Agostini 2005, Agostini and Malara 1997, Agostini *et al*. 2000, 2004a, 2004b, 2005).

When a raptor faces open water, several factors influence its decision of whether or not to attempt a crossing: the morphology, the distribution of landmarks and leading lines, the length of the water crossing, the physiological condition of the bird, flocking behaviour, time of day, and previous experiences; moreover, weather conditions strongly affect water crossing behaviour (Kerlinger 1985, 1989, Agostini *et al*. 1994, 2002, 2003, 2005, Agostini and Duchi 1994, Agostini and Panuccio 2003a, 2003b, Klaassen *et al*. 2010, Meyer *et al*. 2000, 2003, Panuccio 2005, 2011, Thorup *et al*. 2003). Thus, it is not surprising that at some sites, accurately counting migrating raptors approaching a water crossing can be difficult; indeed, in such cases Accipitriformes sometimes interrupt migration, disappear from view and pass again through the study site after several hours. Raptors flocks sometimes hesitate and split up when faced with a water crossing and sometimes fly in the opposite direction of migration (Bildstein *et al*. 2007). Because of this behaviour many coastal are-

as (like Cap Bon Peninsula, Mount Conero, Circeo Promontory), were previously considered unsuitable for counting migrating raptors (Agostini 2005, Agostini *et al*. 1994, Agostini and Duchi 1994, Agostini and Panuccio 2003a, 2003b, Panuccio 2005, Panuccio *et al*. 2004, Premuda *et al*. 2008).

The distance between Africa and Italy is narrowest at the Channel of Sicily between the island of Marettimo and the Tunisian peninsula of Cap Bon; in this area thousands of migrating raptors are regularly observed during autumn (Agostini *et al*. 2000, 2004b). In particular, between mid-August and the end of September large numbers of black kites *Milvus migrans*, honey buzzards *Pernis apivorus* and marsh harriers *Circus aeruginosus* are observed. Later in the season, a smaller number of raptors, mostly juvenile short-toed snake eagles *Circaetus gallicus* are recorded (Agostini *et al*. 2004a, 2005).

The aim of this paper is to verify whether it is possible to make an accurate count of large soaring raptors migrating through the island of Marettimo en route to Africa, and to compare two different methods for doing so.

STUDY AREA AND METHODS

The island of Marettimo (Fig. 1) is located 30 Km off Western Sicily and 130 Km NE of the Cap Bon Peninsula (Tunisia). Observations were made from the 3rd to the 15th October 2007 using a single watch point located along the main ridge of the island at an elevation of 500 m above sea level. Two observers with binoculars and telescopes were employed. Observations were made from 9:00 (solar time) until dusk.

Two different methods were used to count raptors. The first method is the standard one in observation studies (Bibby *et al*. 2000, Bildstein *et al*. 2007) and hereafter called "all-occurrence": it consists in counting raptors when they passed over the watch point; in order to avoid counting them again, birds were followed with binoculars and telescope in order to ensure individuals and flocks really were leaving the island. Raptors observed flying in the opposite direction of the presumed optimal migration were not considered in the count (Bibby *et al*. 2000, Panuccio 2005).

The second method, hereafter called "maximum-daily-count", consists to count the maximum number of individuals of the same species observed together on each day. In both cases, we noted whether any individual birds could be identified by plumage peculiarities; moreover, birds roosting at the site were counted only if they were not observed the following morning.

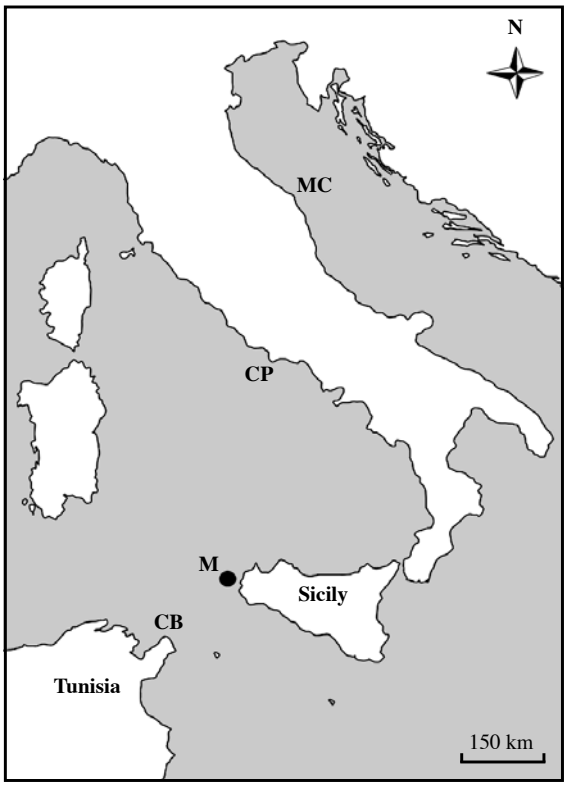

Figure 1. Study area (M = Island of Marettimo, CB = Cap Bon Peninsula, CP = Circeo Promontory, MC = Mount Conero).

We tested the hypothesis that local weather conditions affect the count of migrating raptors. We considered the daily counts of the three species that show significantly different results with the two census methods: the short-toed snake eagle, the booted eagle *Aquila pennata* and the common buzzard *Buteo buteo*. A Generalized Linear Model (GLM) with negative binomial distribution was applied using as independent factors: i) wind direction, ii) wind speed (km/h), iii) temperature (°C), iv) air pressure (mbar) and v) humidity (%) to explain variation in daily counts of each species. These variables were obtained from the meteorological station of the Trapani Airport every day at 13.20. Wind direction was divided into two categories according to the most common winds in the study period: northerly and southerly winds. The GLM was repeated with the results of both census techniques. A Spearman test was run to avoid collinearity between the 5 variables; air pressure was excluded from the analysis since it correlates with wind direction ($Rho=-0.63$; $P<0.05$). We verified the statistical power of each GLM by applying a Shapiro-Wilk test on the residue of the model. It was non significant in all cases ($P>0.05$).

Table 1. Numbers of raptors counted by two census methods.

SPECIES	ALL-OCCURRENCE	MAXIMUM-DAILY-COUNT
Short-toed snake eagle *Circaetus gallicus*	210	123
Booted eagle *Aquila pennata*	44	23
Lesser spotted eagle *Aquila pomarina*	10	6
Bonelli's eagle *Aquila fasciata*	1	1
Egyptian vulture *Neophron percnopterus*	1	1
Common buzzard *Buteo buteo*	144	53
Honey buzzard *Pernis apivorus*	11	10
Black kite *Milvus migrans*	33	32
Marsh harrier *Circus aeruginosus*	51	44
Hen harrier *Circus cyaneus*	2	2
Pallid harrier *Circus macrourus*	1	1
Circus pygargus/macrourus	2	2
TOTAL	**510**	**299**

RESULTS AND DISCUSSION

During the entire survey, we counted 510 raptors with the "all-occurrence" method and 299 with the "maximum-daily count" method, for a total of 12 species (Tab. 1). For comparisons involving more than 10 birds, the differences in counts between the two methods appear to be significant for three species: the short toed snake eagle (χ^2=22.2, d.f. 1, P< 0.01), the common buzzard (χ^2=41.2, d.f. 1, P< 0.01) and the booted eagle (χ^2=5.9, d.f. 1, P< 0.05). For the marsh harrier, the black kite and the honey buzzard the differences are not significant, but only few individuals of each were observed. Broad-winged raptors hesitated in front of the water crossing and in four cases flocks of short toed snake eagles and common buzzards were observed flying east towards Sicily, while eagles were observed undertaking the water crossing toward Africa in only three cases.

For all these three species, weather conditions influenced the number of individuals recorded, to a similar extent for both census techniques (Tab. 2). Wind speed in the case of short-toed snake eagle and booted eagle and wind direction in the case of common buzzard strongly affected observed number of migrants. In particular, with increasing wind speeds numbers of short-toed snake eagles and booted eagles decreased, while with southerly winds (head-winds) lower numbers of common buzzards were recorded. These results are expected, since raptors tend to avoid water crossings when wind conditions require an extra amount of energy consumption, as such as when strong winds or headwinds are blowing (Meyer *et al*. 2000, 2003, Panuccio 2011, Panuccio *et al*. 2002). In the case of short-toed snake eagles and common buzzards, observed numbers were also positively correlated with temperatures; however, since temperature decreased as the days passed (Rho=-0.72; P<0.01), we suggest that this correlation could be related to the migration timing of the two species. Results suggest that weather conditions influence daily counts similarly for both methods probably because raptors do not reach the island of Marettimo with unfavourable wind conditions, as in these cases they do not undertake the short water crossing between Sicily and Marettimo (approx. 30 km).

Previous studies which were carried out at the same site showed that other species of Accipitriformes, such as black kites, honey buzzards, egyptian vultures *Neophron percnopterus* and marsh harriers were more likely to undertake the water crossing en route to Africa (Agostini *et al*. 2000, Agostini *et al*. 2004b, Ceccolini *et al*. 2009, Panuccio 2005). Different behaviours also reflect different migration strategies: indeed, the migration flyways of those species pass over the Central Mediterranean area and the island of Marettimo. On the other hand, short-toed snake eagles, booted eagles and common buzzards rarely cross the central Mediterranean, preferring to use alternative flyways or wintering mostly in Europe (Agostini *et al*. 2000, 2004a, 2005, Agostini and Malara 1997, Isenmann *et al*. 2005). Additional support for the above hypothesis comes from an analysis of the age classes of birds observed in the present study, which were mostly young, inexperienced individuals (Tab. 3).

This study shows that at the island of Marettimo it is better do not use the same census method for all species of migrating raptors. Since an accurate count of raptors mi-

Table 2. Results of the GLM investigating the relationship between daily count numbers (dependent variable) and weather variables. The asterisk indicates the significance of the weather variable in the model.

		Explanatory Term	Estimate	S.E.	*Z* value	*P* (>|z|)
Short- toed snake eagle	All occurrence	Wind direction	1.0	0.7	1.41	>0.05
		Wind speed	-0.1	0.04	-2.7	<0.01*
		Temperature	-0.7	0.2	-3.0	<0.01*
		Humidity	-0.07	0.04	-1.8	>0.05
	Maximum daily count	Wind direction	1.0	0.7	1.4	>0.05
		Wind speed	-0.1	0.04	-2.8	<0.01*
		Temperature	-0.7	0.2	-3.1	<0.01*
		Humidity	-0.07	0.04	-1.8	>0.05
Booted eagle	All occurrence	Wind direction	1.2	0.7	1.9	>0.05
		Wind speed	-0.1	0.05	-2.5	<0.05*
		Temperature	-0.3	0.2	-1.2	>0.05
		Humidity	-0.04	0.04	-1.2	>0.05
	Maximum daily count	Wind direction	1.2	0.7	1.8	>0.05
		Wind speed	-0.1	0.05	-2.5	<0.05*
		Temperature	-0.3	0.2	-1.1	>0.05
		Humidity	-0.04	0.03	-1.2	>0.05
Common buzzard	All occurrence	Wind direction	1.8	0.8	2.4	<0.05*
		Wind speed	-0.02	0.04	-0.6	>0.05
		Temperature	-0.9	0.3	-3.6	<0.01*
		Humidity	-0.03	0.04	-0.8	>0.05
	Maximum daily count	Wind direction	1.8	0.8	2.4	<0.05*
		Wind speed	-0.03	0.04	-0.6	>0.05
		Temperature	-0.9	0.3	-3.6	<0.01*
		Humidity	-0.03	0.03	-0.8	>0.05

Table 3. Percentage of adults and juveniles/immatures observed at the site.

Species	**Adult** (%)	**Juveniles/immatures** (%)	**Sample size**
Short-toed snake eagle	4.2	95.8	95
Booted eagle	12.5	87.5	8
Lesser spotted eagle	0	100	6
Common buzzard	15.1	84.9	33
Honey buzzard	0	100	9
Black kite	7.1	92.9	28
Marsh harrier	42	58	31

grating through Marettimo is unrealistic, we suggest that broad-winged raptors should be "counted" by considering the maximum number of individuals of the same species observed at the same time on each day. Since recent studies using satellite tracking showed a high degree of flexibility between different individuals and years (Mellone *et al*. 2011, Vardanis *et al*. 2011), we cannot exclude that the proposed census technique could also be flawed and bias the data. For this reason, this method should be seen more as an "*activity index rather than an actual estimate of the numbers of individuals passing through*" (Bildstein *et al*. 2007) the island of Marettimo, mainly considering that an accurate count is not possible in the case of inexperienced broad-winged raptors approaching a long water crossing.

Acknowledgements – This study has been made on behalf of the LIPU BirdLife Italy (Lega Italiana Protezione Uccelli). We would like to thank Antonino Provenza and Vito Vaccaro for their help.

We would like to thank MEDRAPTORS (www.raptormigration.org), a network of ornithologists and birdwatchers involved in the research and the protection of migrating birds of prey through specific projects and observation camps.

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Associate Editor: ***G. Tellini Florenzano***