Wind patterns affect migration flyways and flock size of a soaring bird over sea

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ABSTRACT

Water surfaces are natural barriers for raptors mostly using soaring–gliding flight over land during migration. Among these, the European Honey Buzzard (*Pernis apivorus*) is a total migrant, breeding in Europe and wintering in central western Africa. Each spring thousands of buzzards undertake long sea crossings between Tunisia and southern Italy, concentrating over small islands en route to central eastern Europe. The aim of this research is to investigate the influence of wind patterns on the flyways used by these raptors during this critical phase of migration through field observations at four small Mediterranean islands (Pantelleria, Marettimo, Ustica and Panarea) and at the Straits of Messina between 20 April and 20 May 2006–2013. In our analyses, peak days were considered for each site. This eight year multisite study allowed the collection of a large data set. While crossing the Channel of Sicily, migrants concentrated over Pantelleria (southern side of the Channel) during moderate NW winds, and over Marettimo (northern side) during weaker southerly winds. Over the island of Ustica (north-western Sicily, Tyrrhenian Sea) raptors were observed mostly with weak southerly winds. Over the island of Panarea (north-eastern Sicily) and at the Straits of Messina, European Honey Buzzards passed with weak winds from W and NW, respectively. The average flock size during the peak days was significantly higher over the island of Pantelleria, where birds migrated during the stronger winds. The results of this study show that wind patterns affect both migration pathways and flocking behaviour of this species while crossing large water surfaces.

Keywords: migration, European Honey Buzzards, *Pernis apivorus*, water crossing, wind, flocking, spring

1. INTRODUCTION

Birds tend to minimise risks and energetic cost during migration by exploiting favourable winds and avoiding geographic and topographic barriers, and sometimes undertaking long detours en route to their breeding and wintering grounds (Liechti and Bruderer, 1998; Åkesson and Hedenström, 2000, 2007; Alerstam, 2001; Agostini *et al*., 2002; Erni *et al.,* 2005; Liechti 2006; Mellone *et al.,* 2011a, 2011b; Panuccio *et al.,* 2012; Vansteelant *et al*., 2014; Vidal-Mateo *et al*., 2015). Raptors (especially the heavier, broader and rounded-winged species) use soaring–gliding flight during their movements by exploiting thermals and updraft currents along mountain chains and avoiding crossing large water bodies (Bildstein, 2006; Agostini *et al*., 2015). Thermals are very weak and scarce over water, especially in temperate zones, thus birds are forced to use active (flapping) flight during the crossing. Soaring–gliding flight is significantly less expensive from an energetic viewpoint than active flight, but it depends on topography and circadian patterns in thermal convection (Baudinette and Schmidt-Nielsen, 1974; Hedenström, 1993; Mellone *et al*., 2012; Panuccio *et al.,* 2016). However, crossing water can save both time and energy when the ratio between the distance around the barrier and the distance across the barrier increases. Among Accipitriformes, Osprey (*Pandion haliaetus*), harriers (*Circus* spp.) and kites (*Milvus* spp.) show morphology and flight performances which allow them to undertake long water crossings, while the European Honey Buzzard (*Pernis apivorus*) has intermediate flight characteristics between them and *Buteo* spp., eagles (e.g. *Aquila* spp.) and vultures (e.g. *Gyps* spp.), which present flight characteristics less suitable for water crossings (Kerlinger, 1989; Bildstein *et al*., 2009; Agostini *et al*., 2015). Thus, although the European Honey Buzzard tends to use soaring–gliding flight over land like *Buteo* spp., eagles and vultures, unlike them it is able to cross large water bodies. Especially during spring movements, thousands of European Honey Buzzards undertake long water crossings through the Mediterranean Sea en route between the breeding and wintering grounds located in Europe and west-central equatorial Africa, respectively. Conversely, this Mediterranean area is a real ecological barrier for other soaring raptors such as the Short-toed Snake Eagle (*Circaetus gallicus*) and the Booted Eagle

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(*Aquila pennata*; Agostini *et al.*, 2015). During these movements, European Honey Buzzards sometimes interrupt their continuous, powered flight over water and concentrate over small islands to exploit thermals and undertake further crossing at higher altitude (Agostini, 2002; Panuccio *et al.*, 2004, 2013; Meyburg *et al.*, 2010, 2013; Agostini and Panuccio, 2015). This strategy could lower the risk of facing unpredictable weather changes during the crossing, and may perhaps result effective from the point of view of a conservative strategy (Agostini *et al.*, 2005a, 2005b, 2007). When crossing the central Mediterranean, these raptors fly through the Channel of Sicily, between the Cap Bon Peninsula (Tunisia) and western Sicily (approx. 150 km wide), concentrating over the islands of Marettimo and Pantelleria. Once reached the Sicilian mainland, most of them head towards the Straits of Messina (the shorter water crossing between Sicily and Italian Peninsula) while others bypass the Straits crossing the Tyrrhenian Sea *via* the islands of Ustica and Panarea (Figure 1). Here, we analyse the influence of wind patterns on the spring pathways of European Honey Buzzards flying through this portion of the Mediterranean area, through field observations performed during eight years at these five watch sites.

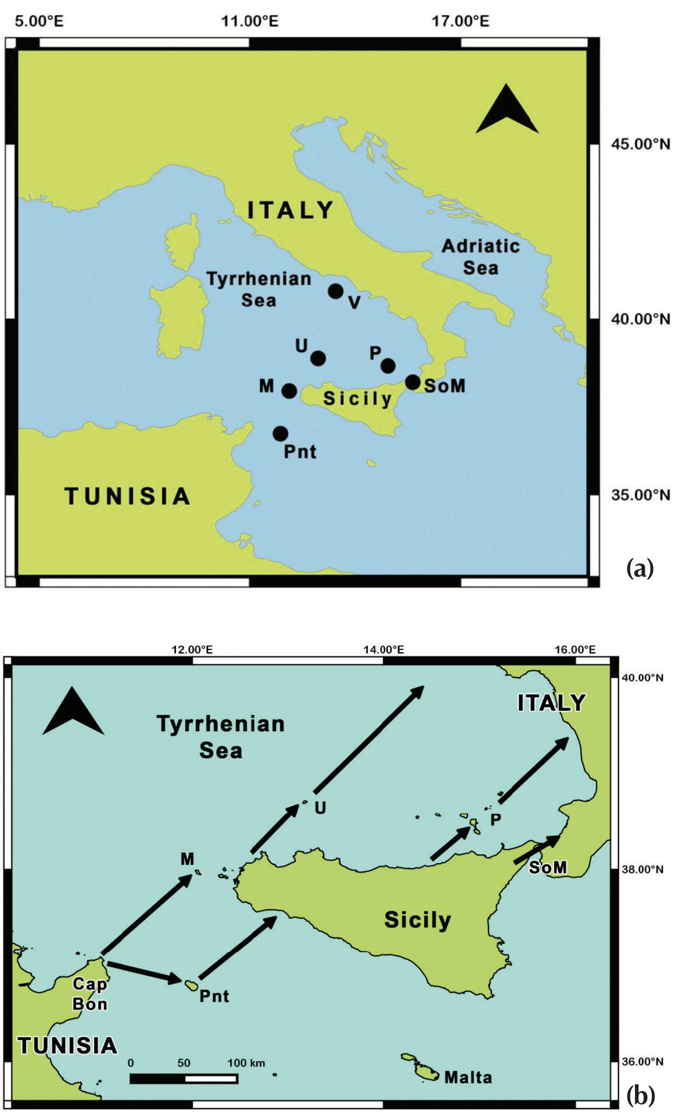


Figure 1 The study area (Pnt = Pantelleria; M = Marettimo; U = Ustica; P = Panarea; SoM = Straits of Messina; V = Ventotene) (a) and approximate paths over water used by European Honey Buzzards during spring migration across the central Mediterranean (b).

2. STUDY AREAS AND METHODS

2.1 Fieldwork

Observations, using binoculars and telescopes, were made over the islands of Marettimo, Pantelleria, Ustica, Panarea, and at the Straits of Messina, between 09:00 and 19:00 (local time) from 20 April to 20 May 2006–2013, during the peak of the spring migration of the European Honey Buzzard in the Mediterranean basin (Agostini and Panuccio, 2005). This 8 year multisite study allowed the collection of a large data set. Marettimo is a small (12 km^2) mountainous island, approximately 30 km distant from western Sicily. This island is located about 130 km NE of the Cap Bon Promontory (Tunisia, Figure 1). Monte Falcone is its highest point, at 686 m above sea level. Pantelleria is a volcanic island (84 km^2), approximately 110 km SW of western Sicily and 70 km SE of the Cap Bon Peninsula, in the southern part of the Channel of Sicily (Figure 1). In this island the highest elevation (Montagna Grande) reaches 836 m. Ustica is a small volcanic island (8.5 km^2) about 60 km N of western Sicily, 270 km NE of the Cap Bon Promontory (Tunisia), 140 km NE of the island of Marettimo and 230 km W of the Italian Peninsula (Figure 1). Like Pantelleria and Ustica, Panarea is a volcanic island (3.5 km^2), located approximately 65 km NW from the Straits of Messina (Figure 1). At each site the monitoring was made using the observation post of previous surveys (see Agostini *et al.*, 2005b, 2007). To investigate the circadian pattern of migration, each observation day was divided into three time periods: morning (09:00–11:59), midday (12:00–14:59) and afternoon (15:00–19:00, solar time). In the analysis, we considered for each watch site only peak days, *i.e.* those in which at least 9% of the total number of birds counted in the season was reported.

2.2 Wind data

Wind fields were obtained from ERA-Interim (Dee *et al.*, 2011), a global atmospheric reanalysis product realised by assimilating available meteorological measurements within a state-of-the-art forecast model in order to estimate the evolving state of the global atmosphere. Gridded fields of relevant atmospheric variables are available at

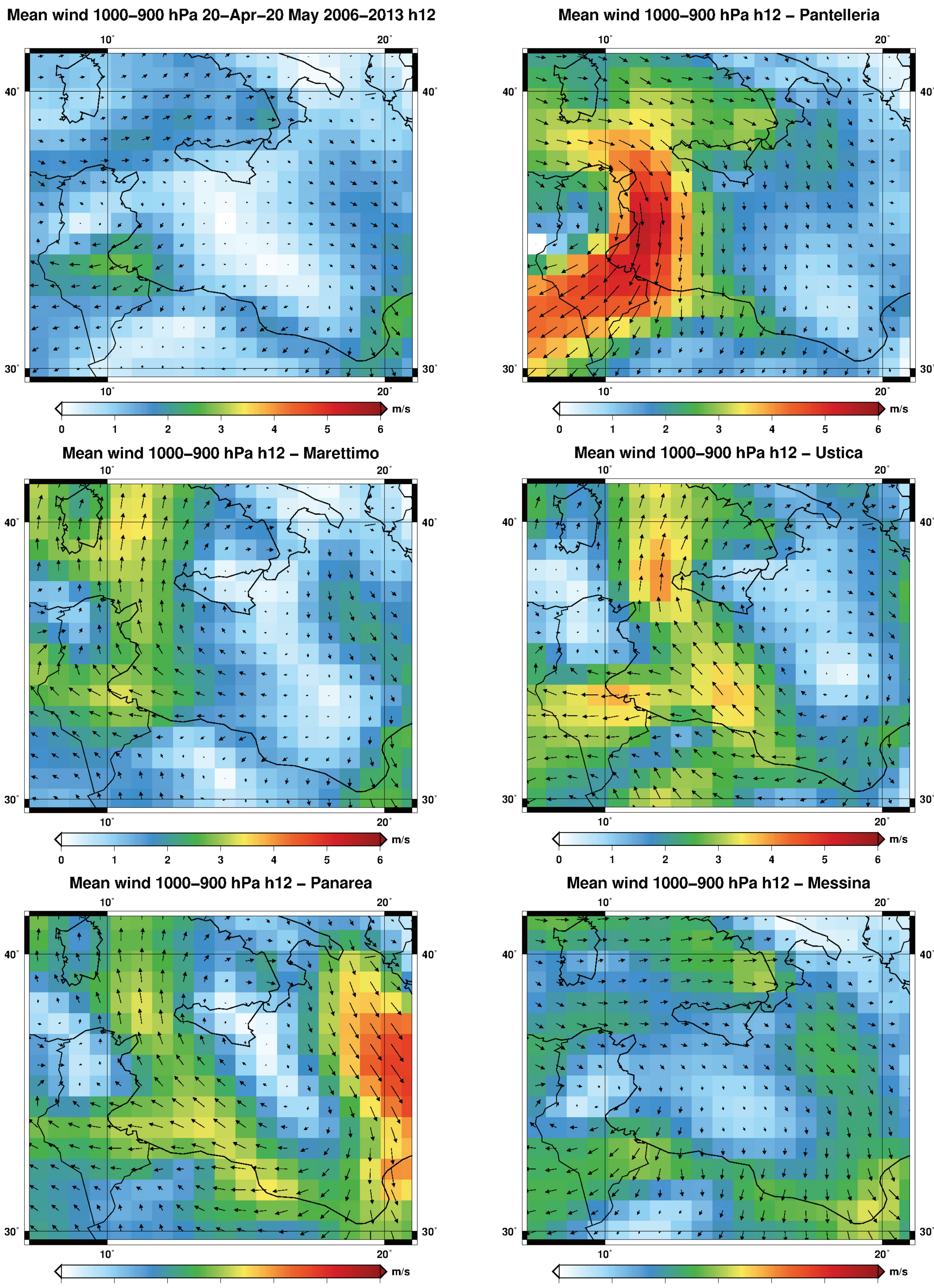


Figure 2 Average winds (strength and direction at 12:00 UTC) in the central Mediterranean region, averaged along the whole period (between 20 April and 20 May 2006–2013, first box) and only at the peak days for each watch site.

0.75° resolution at 6 hour time frequency, on vertical pressure levels spaced 25 hPa in the lower troposphere. In particular, in this work, we use the winds on pressure levels, provided by ERA-Interim for 12:00 UTC, averaged between 1000 hPa and 900 hPa and representative of the average winds in approximately the first 1000 m of altitude above sea level. Migrating raptors tend to fly within this altitude range, higher when using soaring–gliding flight over land and sometimes very low when flying over the open sea (Kerlinger, 1989; Agostini *et al*., 2012).

3. RESULTS

Average wind conditions, recorded in the study area during the whole observation period (20 April to 20 May 2006–2013), were weak (≤2 m s^{-1}) from the west (Figure 2). On average 6153±1499 (SE) birds passed each year over the islands of Pantelleria and Marettimo (maximum: 13657 in 2012, minimum: 2647 in 2011) while 24752±1057 birds (maximum: 29356 in 2009, minimum: 21640 in 2008) were counted yearly along the Tyrrhenian flyway and at the Straits of Messina. On average 25% of birds counted along the Tyrrhenian flyway and at the Straits concentrated over the island of Marettimo and Pantelleria when crossing the Channel of Sicily.

3.1 Pantelleria–Marettimo

During the crossing of the Channel of Sicily, European Honey Buzzards were seen concentrating over the island of Pantelleria with moderate NW winds (4–5 m s^{-1}; Figure 2) during midday and afternoon (Figure 3). They reached this island from NW, apparently moving from the Cap Bon Peninsula where they probably exploited a slighter stronger wind when soaring at higher altitude before leaving the mainland. On average 4615±1461 (SE) birds were counted yearly over this island (Figure 4a) and a total of 27 peak days were reported (maximum: 4 days in 2006, 2009 and 2012; minimum: 2 days in 2008). During the peak passage, on average 1088±216 (SE) birds per day were counted (maximum: 5748 on 2 May 2012) in flocks of, on average, 37 individuals (Figure 4b; Table 1). As for Pantelleria, few birds were seen over Marettimo in the morning (Figure 3). At this watch site, on average 1538±258 European Honey Buzzards were seen yearly (Figure 4a), mostly during weak S–SE winds (2–3 m s^{-1}; Figure 2). A total of 22 peak days were reported (maximum: 4 days in 2010 and 2011; minimum: 2 days in 2006, 2008, 2009, 2012) with 406±96 (SE) birds per day (maximum: 2075 on 18 May 2009) in flocks containing on average 17 European Honey Buzzards (Figure 4b; Table 1). No significant correlation was found ($r=-0.04$, $P>0.05$) for the counts recorded at these two islands during the eight year period.

3.2 Tyrrhenian flyways–Straits of Messina

As for Marettimo, over Ustica, European Honey Buzzards were mostly seen in the afternoon during weak S winds (Figure 2 and 3), in 21 peak days (maximum: 4 days in 2008 and 2011; minimum: 1 day in 2010 and 2013). At this site, on average 1495±253 birds were counted yearly (Figure 4a), 397±114 birds per day during the peak passage (maximum: 2165 on 2 May 2010) in flocks containing on average 23 birds (Figure 4b; Table 1). As for Pantelleria, buzzards reaching this small island probably exploited stronger winds when soaring over the mainland of Sicily. Although the passage over Marettimo and Ustica had similar magnitude and occurred during similar wind conditions, no significant correlation was reported at these two sites in the eight year period ($r=0.39$, $P>0.05$). Over the island of Panarea on average 3102±530 (SE) buzzards were counted yearly (Figure 4a) and a total of 27 peak days (maximum: 6 days in 2007; minimum: 1 day in 2011) was recorded. During the peak passage, 593±134 European Honey Buzzards were counted per day (maximum: 3454 on 6 May 2011) during very weak westerly winds (≤2 m s^{-1}) and mostly during midday (Figure 2 and 3). During these days, flocks contained 22 birds on average (Figure

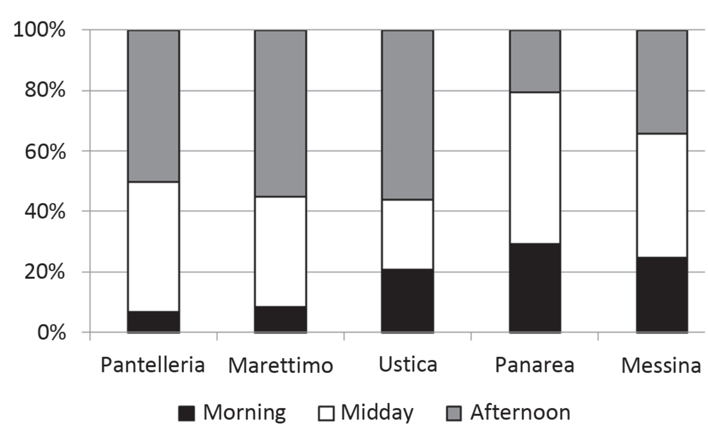
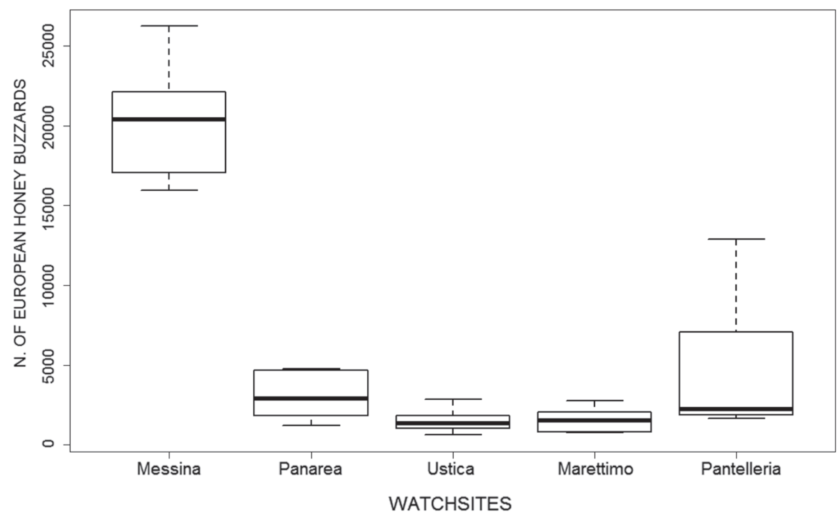


Figure 3 Circadian pattern of migration at each site during the three time periods: morning (09:00–11:59), midday (12:00–14:59) and afternoon (15:00–19:00, solar time).

(a)



(b)

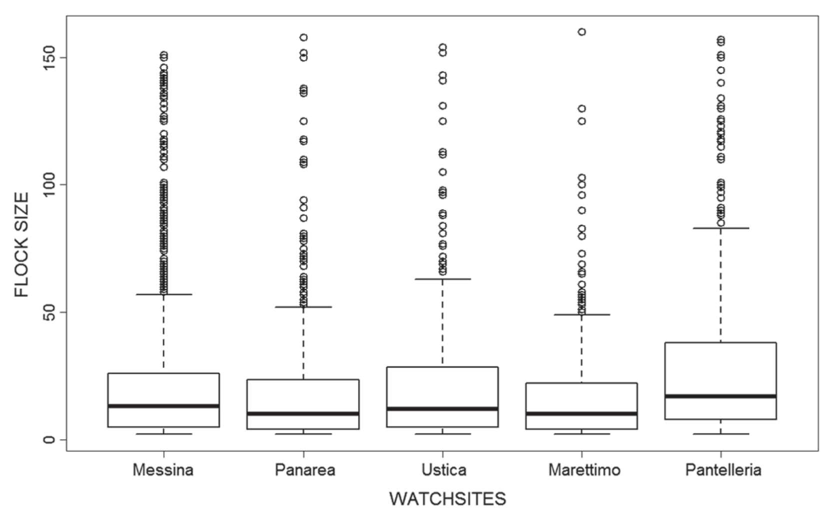


Figure 4 Average number of European Buzzards observed at the five watch sites between 20 April and 20 May 2006–2013 (a) and flock size during peak days (b).

Table 1 Flock size of Western Honey Buzzards at each watch site during the peak days

	Pantelleria	Marettimo	Ustica	Panarea	Messina
Number of flocks	786	519	362	716	3188
Mean flock size ± SE	37 ± 2.4	17 ± 0.9	23 ± 1.6	22 ± 1.3	23 ± 0.7
Median flock size	18	10	13	11	13
Maximum flock size	1000	250	230	367	1500

4b; Table 1). At the Straits, European Honey Buzzards were mostly seen with slightly stronger NW winds (2–3 m s^{-1}) during midday and afternoon (Figure 2, 3). At this watch site, on average 20154 ± 1217 (SE) birds were counted yearly (Figure 4a) and a total of 25 peak days (maximum: 4 days in 2006, 2008 and 2013; minimum: 1 day in 2012) was reported. During the peak passage, on average 2990 ± 221 (SE) birds were recorded per day (maximum: 5465 on 30 April 2010) in flocks containing 23 individuals on average (Figure 4b; Table 1). When comparing the passage at this site with that along the Tyrrhenian flyway (by summing numbers recorded at Ustica and Panarea), on average 81% of migrants were counted yearly (maximum: 92% on 2012, minimum: 70% on 2013) and no significant correlation was reported between the passage through Panarea–Ustica and that at the Straits during the eight year study ($r = -0.45$, $P > 0.05$). Migrants concentrating at Panarea and at the Straits of Messina were expected to cross the Channel of Sicily the day before. When considering the wind conditions

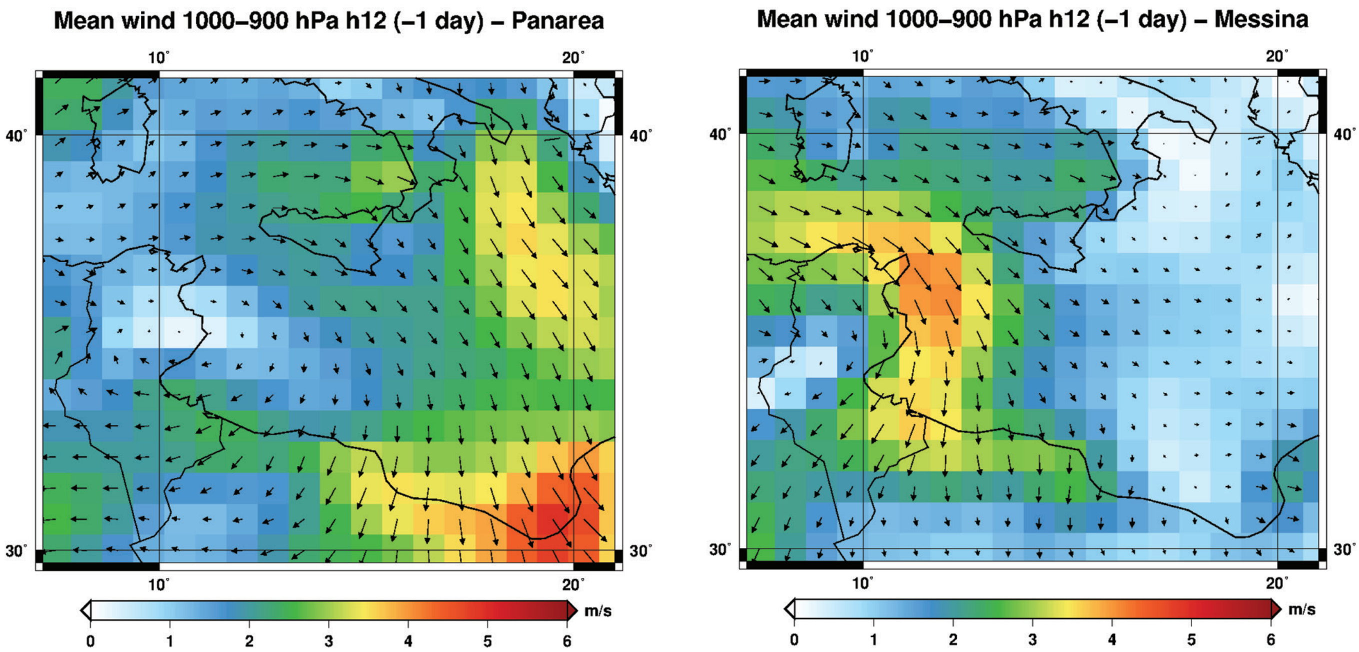


Figure 5 Strength and direction of the winds averaged only for the days before (–1 day) a peak passage at Panarea and at the Straits of Messina.

at the Channel of Sicily the day before the peak at these two watch sites we noted a difference due to very weak (≤ 2 m s^{-1}) westerly and lightly stronger (3–4 m s^{-1}) north-westerly winds, respectively (Figure 5). Finally, when comparing the medians of flock size reported at each site (Table 1), the difference was significant with larger flocks observed at Pantelleria and smaller ones over Marettimo (Kruskal–Wallis test, $H = 98.3$, df $= 4$, $P < 0.001$).

4. DISCUSSION

Our study shows that wind patterns affect migration flyways and flock size of European Honey Buzzards crossing water surfaces. Raptors select weak tailwind conditions when facing long flights over water, and show a curvilinear path when crossing during moderate crosswinds. In agreement with the preliminary study realised in a single season in spring 2004, European Honey Buzzards reach the island of Pantelleria when they can exploit moderate NW winds (Agostini *et al.*, 2007). During this first stage of the crossing between the Cap Bon Peninsula and western Sicily, they probably save energy thanks to the tail support of such winds, with Pantelleria located SE of the Tunisian peninsula. Observations made at the Cap Bon Promontory reported flocks of European Honey Buzzards leaving the coast and heading SE, apparently towards this mountainous island that they probably see when soaring at several hundred metres above sea level before crossing (Thiollay, 1975; Agostini *et al.*, 1994). However, during the following flight between Pantelleria and south-western Sicily (*ca* 110 km long), they have to fly through lateral winds blowing on average 5 m s^{-1}, and are forced to compensate their drift effect. This wind condition was the worst recorded during the peak passages in our study. European Honey Buzzards observed at the Cap Promontory tended to cross the open sea heading NE during weak lateral winds (≤ 4 m s^{-1}), such as Black Kites (*Milvus migrans*), when migrating in larger flocks. In particular, they showed a strong tendency to remain together in front of the water barrier since the first individuals taking a decision (crossing or not) were followed by the others (Agostini and Duchi, 1994; Agostini *et al.*, 1994). Since migrants of both species often hesitate in front of the open sea waiting for better wind conditions for crossing (e.g. weaker lateral winds), it has been suggested that flock size affects the water crossing tendency in these species because an increase in flock size increases the probability that the flock will contain one or more individuals with a pronounced tendency to continue migrating. The physiological state of the bird such as a previous experience could play a role in this decision (Kerlinger, 1989). This behaviour would explain why the flock size recorded over Pantelleria was the larger one. As a matter of fact, during such wind conditions (lateral wind >4 m s^{-1}), we can expect a greater hesitation and the formation of larger flocks at the Cap Bon Peninsula among birds facing the Channel of Sicily and trying to cross the water barrier heading NE, before some birds decide to fly towards SE dragging the flock. Conversely, birds passed *via* Marettimo in smaller flocks during weak S–SE winds. Perhaps, during such favourable wind conditions, few birds passed *via* Marettimo, while most flew directly towards western Sicily exploiting its tail component (see also Agostini *et al.*, 2007). This would explain why the passages over Pantelleria and Marettimo did not show any significant correlation. Weak tail winds were apparently the better wind conditions to fly both through the Channel of Sicily and the western side of the Tyrrhenian Sea *via* Ustica. We cannot exclude that during such wind conditions a significant number of migrants flew directly from Tunisia to central Italy undertaking a water crossing of about 500 km. In particular, on 6 May 2012 at least 300 European Honey Buzzards were seen reaching central Italy *via* Ventotene, a small island located about 500 km NE of Tunisia and 230 km NNE of Ustica (Figure 1), passing during late afternoon (16:00–20:00; Ferri pers. obs.). At the same time that day, 398 birds were counted at Ustica, while few birds were recorded over Marettimo. Although European Honey Buzzards travel significantly faster and farther in tail winds (Vansteelant *et al*., 2014), and a stronger tail wind would allow birds to save both time and energy during the crossing, radar studies showed that unlike smaller birds (*e.g.* passerines), larger birds like raptors do not fly as fast as they can by selecting altitude with the best tail wind support; in addition, they are limited to speeds close to their optimal speed of minimum power consumption (Bruderer and Boldt, 2001; Mateos-Rodriguez and Liechti, 2012). In a preliminary study made along the continental slope of the Straits of Messina during spring migration, European Honey Buzzards were seen flying close to the ground, making abrupt rises followed by dives toward the ground, with tail winds blowing at 9–10 m s^{-1} (Agostini, 1992). Since raptors fly at lower altitudes over open water, the crossing during weak tail winds would allow them to maintain a steady forward movement. This flight strategy could be the result of a conservative strategy (*i.e.* fly slower but safer) to avoid grounding that results in death (Agostini, 1992; Agostini *et al*., 2005b). This conclusion is in agreement with recent research made using radar, concerning the behaviour of soaring birds, storks and raptors (and, among them, the European Honey Buzzard) while exploiting thermals over land. In particular, it confirmed that large birds did not fly as fast as they could, but they glided in a risk-sensitive manner to avoid "the grounding/flapping risk associated with a failure to detect adequate thermals farther ahead" (Horvitz *et al*., 2014). While it is a conservative strategy over land, it is even more over water where, as mentioned above, thermals are weak and scarce and grounding would result in death since raptors cannot rest at sea. At the Straits of Messina the greatest concentration of European Honey Buzzards occurred during both spring and autumn (Agostini and Panuccio, 2005). This is expected for a soaring bird, since this is the shorter water crossing between Sicily and the Italian Peninsula and thus the safer pathway. Moreover, the benefits associated to the pathway *via* Panarea are not great considering the distance of the crossing relative to the distance around the water barrier. However, during very weak westerly winds, a substantial number of migrants concentrate over Panarea bypassing the Straits. In this view, we cannot exclude that the passage through this island could be the result of wind conditions on the Channel of Sicily the day before the peak. In particular, migrants could have concentrated their passage along the Tyrrhenian coast of Sicily and over Panarea, such as other Aeolian islands, when wind conditions (weak westerly winds) on the Channel the day before allowed them to reach north-western Sicily exploiting their tail component, but did not support their flight towards Ustica. Conversely, the day before the peak at the Straits, weak north-westerly winds (≤ 4 m s^{-1}) occurred over the Channel of Sicily, a favourable condition for the water crossing bypassing both Pantelleria and Marettimo, but with a probable drift effect towards SE. In conclusion, this study shows that wind conditions promote route flexibility and inter-annual variability in a soaring raptor, with longer flights over sea performed with tailwind assistance (see also Panuccio *et al*., 2011). In agreement with the 'optimal use of wind' hypothesis (Alerstam, 1979), with less favourable winds for sea crossing (moderate lateral winds) European Honey Buzzards use a curvilinear path over the Channel of Sicily. In doing so, they fly in larger flocks exploiting the tail component to reach a mountainous island (Pantelleria) minimising the risk of long non-stop flapping flight over water, and are expected to overcompensate during the final stage of the crossing to reach their goal.

5. ACKNOWLEDGEMENTS

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