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Research Papers

DISTURBANCE OF NON-BREEDING WADERS BY PEDESTRIANS AND BOATS IN A MEDITERRANEAN LAGOON

PERTURBACIONES A LOS LIMÍCOLAS NO NIDIFICANTES POR PEATONES Y EMBARCACIONES EN UNA LAGUNA COSTERA MEDITERRÁNEA

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SUMMARY.—Flight initiation distances (FIDs) were measured for nine wader species at the Venice lagoon (Italy), one of the most important sites for waterbirds around the Mediterranean. The response (277 instances) to boat and pedestrian disturbances caused outside the breeding season was observed. FID was positively and significantly correlated with the mean body size of the species. The correlation between FID and flock size was also positive and significant, irrespective of the type of disturbance. FID values ranged from 27.9 + 15.6 m (mean + SD, N = 32) in Common Snipe to 140.4 + 48.1 m (N = 30) in Eurasian Curlew, pooling data for both disturbance types. The same ranking was observed if pedestrian and boat disturbances were considered separately; differences were species-specific. For six species, the data allowed comparisons to be made between boat- and pedestrian-evoked FID; the observed differences were not significant. Thus, boat disturbances during the non-breeding season did not evoke a stronger response among waders, in terms of FID, compared to pedestrians. According to these results, set-back distances, expressed as mean FID + 2 SD, are suggested to reduce the effects of man-made disturbances to waterbirds at a local scale. These distances range from 59-74 m for the most confiding species (Common Snipe, Kentish Plover and Ruddy Turnstone) to 121-267 m for the most wary (Eurasian Oystercatcher, Grey Plover and Eurasian Curlew). To protect the multi-specific and often large winter roosts from disturbance caused by pedestrians or boats, a higher set-back distance, 270 m, is suggested. —Scarton, F. (2018). Disturbance of non-breeding waders by pedestrians and boats in a Mediterranean lagoon. *Ardeola*, 65: 209-220.

Key words: flight initiation distance, roost, shorebirds, tidal flats, Venice lagoon, waterbird.

RESUMEN.—Se midieron distancias de iniciación de vuelo [FID] en nueve especies de limícolas en la laguna costera de Venecia (Italia), que es uno de los lugares más importantes para las aves acuáticas en el Mediterráneo. Se observó la respuesta causada a las perturbaciones ocasionadas por peatones y embarcaciones fuera de la época de reproducción (277 casos). La FID se correlacionó positiva y significativamente con el tamaño medio de las especies; la correlación entre la FID y el tamaño de bando fue también positiva y significativa, con independencia del tipo de estímulo. Los valores de FID variaron entre 27,9 + 15,6 m

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(media + desviación estándar [SD], N = 32) en la agachadiza común a 140,4 + 48,1 m (N = 30) en el zarapito real, combinando los datos para ambos estímulos. El mismo ordenamiento se observó si las perturbaciones por peatones y embarcaciones se consideraban separadamente; las diferencias fueron específicas de la especie. Para seis especies, los datos permitieron la comparación entre FID estimuladas por peatones o por embarcaciones: las diferencias observadas no fueron significativas. Por tanto, las perturbaciones por embarcaciones durante la época no reproductora no provocó una respuesta más fuerte entre los limícolas, en cuanto a FID se refiere, en comparación con la provocada por peatones. Los resultados de este estudio de campo sugieren distancias de seguridad expresadas como FID media + 2 SD para reducir los efectos de perturbaciones antrópicas a los limícolas a escala local. Estas distancias varían entre 59-74 m para las especies más confiadas (es decir, agachadiza común, chorlitejo patinegro y vuelvepiedras común) a 121-267 m para las más huidizas (es decir, ostrero euroasiático, chorlito gris y zarapito real). Se sugiere una distancia de seguridad mayor, de 270 m, para proteger los bandos multiespecíficos, generalmente grandes, de las perturbaciones provocadas por peatones o embarcaciones. —Scarton, F. (2018). Perturbaciones a los limícolas no nidificantes por peatones y embarcaciones en una laguna costera Mediterránea. *Ardeola*, 65: 209-220.

Palabras clave: aves acuáticas, distancia de iniciación de vuelo, dormidero, laguna de Venecia, limícolas, planicie mareal.

Introduction

It is well known that disturbances caused by anthropic activities may disrupt bird behaviours, in particular feeding, resting and breeding, as well as mortality rates (see Fitzpatrick & Bouchez, 1998; West *et al*., 2002; Beale & Monaghan, 2004; Colwell, 2010; Martínez-Abraín *et al*., 2010). Above a certain threshold, disturbances may prevent birds from using their nesting, feeding and roosting sites (Carney & Sydeman, 1999; Dias *et al*., 2008; Weston *et al*., 2012; Schlacher *et al*., 2013; Collop *et al*., 2016; Cherkaoui *et al*., 2016).

Possible negative effects caused by human disturbances may be particularly evident among waterbirds, and specifically waders, due to the often intense and widespread human activities that take place in most wetlands (see Battisti *et al*., 2016, for several definitions and an analysis of the topic). Waterbird populations have shown declining trends worldwide due to wetland degradation and loss (Boere *et al*., 2006). Finding sufficient food during non-breeding periods is an essential requirement for migrating and wintering birds, which use wetlands as stopover or overwintering areas. Degradation of wetlands could lead to sharp decreases in waterbird populations during non-breeding periods (van de Kam *et al*., 2004). The number of waders has decreased at several wetlands, for reasons that may include climate change and wetland fragmentation and loss (Maclean *et al*., 2008; Hughes, 2004), as well as other disturbances caused by humans, as reported by Burton (2007), Navedo & Masero (2007) and Navedo & Herrera (2012).

Hunting, fishing, shell fishing, bait collecting, boat traffic and birdwatching are the most common man-made activities that disturb the waders that use coastal wetlands (Carney & Sydeman, 1999; Glover *et al*., 2011; Dias *et al*., 2008). Many Mediterranean coastal wetlands are important hotspots for non-breeding waterbirds (Boere *et al*., 2006). Given the high level of anthropic activities that historically take place at these wetlands, the issue of disturbances to waterbirds and the ways in which those disturbances can be reduced are critical to wetland management and conservation science.

One possible method for limiting the effects of disturbances is to establish set-back distances, or buffer zones, which should allow human activities and birds to coexist (Rodgers

& Schwikert, 2002; Blumstein *et al*., 2003; Chatwin *et al*., 2013; Whitfield & Rae, 2014; Koch & Paton, 2014). Buffer zone limits are often based on empirical data concerning the flight initiation distance (FID) — that is, the point at which the bird flushes or otherwise moves away from the approaching disturbance source, as shown by one or several species in response to a particular stimulus, such as an approaching pedestrian, car or boat (Whitfield *et al*., 2008). FID has been considered useful for estimating the extent of buffer zones, sometimes referred to as minimum approach distances, around particular habitat patches, colonies or roosts (Rodgers & Schwikert, 2002; Ronconi & Clair, 2002; Collop *et al*., 2016; Guay *et al*., 2016).

FID values are available for several waterbird species in North American, Northern Europe or Australian wetlands (Rodgers & Smith, 1995 and 1997; Triplet *et al*., 1998 and 2007; Møller, 2008; McLeod *et al*., 2013; Mayo *et al*., 2015; Collop *et al.,* 2016; Guay *et al*., 2016), with some additional data available from Asian wetlands (Mori *et al*., 2001). In contrast, there is notable lack of FID data from Mediterranean wetlands; there are articles by Martínez-Abraín *et al*. (2008) dealing with Yellow-legged Gull *Larus michahellis* colonies, by Navedo & Herrera (2012) about non-breeding waders and by McFadden *et al*. (2017) regarding FIDs in response to wildlife boat tours. In a paper by Merken *et al*. (2015), the FID values reported were derived from expert interviews, and they concern data from both Mediterranean and non-Mediterranean wetlands (Deboelpaep, pers. comm.; see also Conclusions).

As McLeod *et al*. (2013) remark, most of the available papers regarding FID in waterbirds come from data that are relative to just one type of disturbance — usually the occurrence of pedestrians. Only eight of 100 articles that they considered dealt with boat disturbance, and only 13 compared two or more stimuli (that is, pedestrian, boat, car, buses) (see also Rodgers & Smith, 1997; Koch & Paton, 2014; Mayo *et al*., 2015; Livezey *et al*., 2016; Jorgensen *et al*., 2016).

The present paper describes FID data for nine wader species in response to experimentally caused pedestrian and boat disturbances during the non-breeding period. These FID values are used to propose set-back distances for six wader species that regularly use Mediterranean wetlands, with the aim of describing management instruments that could be used to reduce disturbances by boats and pedestrians at a local scale.

Study area and methods

The 55,000 ha Venice lagoon (Italy) is the largest coastal lagoon of the Mediterranean Sea. A large part of the lagoon (37,000 ha) is open water, with shallow sectors, deep channels and 5,000 ha of tidal flats. The mean tidal amplitude is about 1 m, one of the highest values in the Mediterranean. The mean annual temperature is 14.5°C, and the mean rainfall is 800 mm per year (Solidoro *et al*., 2010). The Venice lagoon is the most important waterbird wintering site in Italy and one of the most important in the whole Mediterranean (Zenatello *et al*., 2014). In mid-January 2012-2016, about 386,000 waterbirds were counted on average, with nine species regularly exceeding 1% of their biogeographical populations, these including Dunlin *Calidris alpina* (35,000 birds on average) and Pied Avocet *Recurvirostra avosetta* (2,400 birds; Basso & Bon, 2016). Thousands of other waders use the extensive tidal flats at low tide to search for food. High-tide roosts are located on saltmarshes, dredge islands (artificial islands made with sediments dredged from lagoon channels; Scarton & Montanari, 2015) and sand bars. These roosts host Dunlins, Eurasian Curlews, Grey Plovers *Pluvialis squatarola* and Kentish Plovers *Charadrius alexandrinus*. On account of its ornithological importance, in 2007 the whole lagoon was declared a Special Protection Area (IT 3250046 Laguna di Venezia), according to the E.U. Birds Directive 2009/147/EC (Scarton, 2017).

Disturbances of waterbirds due to boat traffic and pedestrian activities occurs in the Venice lagoon. At least 40,000 boats circulate each year for both professional purposes (for example, fishing and goods and tourist transportation) and for leisure activities (Ministero delle Infrastrutture e dei Trasporti, 2017). About 600 of those boats are devoted to the professional harvest of the Manila Clam *Ruditapes philippinarum*. They navigate most of the year in shallow areas close to the saltmarshes and tidal flats used by waterbirds for nesting, resting or feeding. Pedestrian disturbances of waterbirds may occur along a few trails bordering the inner lagoon that are used by tourists, photographers and birdwatchers. However, it is most common and widespread on the tidal flats, where several hundred professional and non-professional fishermen walk at low tide to collect molluscs and other invertebrates. About 600 hides, reachable only by boat and used by hunters between mid September and the end of January, are scattered throughout the lagoon and along the edge of large tidal flats.

I did 277 FID measurements in April-November 2014, January-May and August-December 2015, and January-September 2016, by approaching the birds either on foot or by boat at different tide heights. Observations were only made if there were no other boats or people within 300 m of the targeted birds. In the first case, I walked slowly at a constant speed (2-3 km/h) through saltmarshes, dredge islands and exposed tidal flats toward one bird or a group of birds. Both saltmarshes and dredge islands are covered with low (< 50 cm) halophytic vegetation, interspersed with tidal ponds and creeks; dredge islands also large bare expanses. I measured the distance between me and the bird, or the closest bird if a flock was approached, when it first flushed or ran away. Distances were estimated using a rangefinder Leica Rangemaster LAF 900 (accuracy ± 1 m) or paced out.

In the second case, a 7-m fibreglass boat with a 140-horsepower outboard motor was used. The noise emission at a distance of 1 m from the engine was about 85 dB(A). The boat used was of the same type owned by many professional shell fishermen. There were always two people aboard the boat: a driver and me. The boat approached the birds at 8-10 km/h until they flew away. The boat speed was intermediate between the 5 and 20 km/h permitted in the Venice lagoon. The distance from birds was measured with the rangefinder or, in a few cases, visually estimated. I approached the birds directly ($N = 171$, 59.1 ± 44.8 m, mean ± 1 SD) or tangentially ($N = 106$, 59.5 ± 38.4 m), but since no differences were detected between the two approach directions during initial data analysis (Mann-Whitney U-test: $Z = -0.79$, NS), data were pooled together.

Due to logistical constraints, sample size could not be balanced among species and types of disturbance; for each species, at least 14 measurements were taken, with a mean of 30.8 ± 14.3 (1 SD). I did not record the starting distance; see Dumont *et al.* (2012) for some critical aspects of using this measure.

Observations took place always between 07:00 and 14:00 hours, avoiding foggy or rainy days and tides > 1 m above sea level. I visited multiple sites throughout the lagoon to avoid problems of bias, habituation and autocorrelation in bird responses (Rodgers & Schwikert, 2002). The FID for an individual bird was measured only once. Data refer to nine wader species: of these, Dunlin, Grey Plover, Eurasian Curlew, Common Snipe *Gallinago gallinago,* Ringed Plover *Charadrius hiaticula*, Ruddy Turnstone *Arenaria interpres* and Common Sandpiper *Actitis hypoleucos* do not nest at the lagoon. Kentish Plover and Eurasian Oystercatcher *Haematopus ostralegus* regularly nest at the lagoon but their FIDs in the present paper refer only to the non-breeding period. Among the nine species considered, only the Common Snipe may be hunted. Field data have never been collected in any September during the last decade. The mean species weights are from Brichetti & Fracasso (2004).

Data were not normally distributed (Shapiro-Wilk W: 0.84, $P < 0.00001$), nor could they be normalised using standard methods. For this reason, non-parametric tests were used, including Spearman rank correlation (r_s), Mann-Whitney and Kruskal-Wallis tests. Means ± 1 SD are reported for ease of interpretation. Numerical and statistical analyses were performed using the software Statistica vers. 7.2. and PAST version 2.9 (Hammer *et al.*, 2001). Following Laursen *et al.* (2005), the mean FID plus 2 SD was used as a conservative set-back distance for each species.

Results

Table 1 shows the FID values measured according to the disturbance type. For six species, the data allowed for comparisons to be made between the two causes of disturbances. Differences between nine species (for pedestrian disturbance: Kruskal-Wallis $\chi^2 = 60.9$, degrees of freedom [d.f.] = 8, $P < 0.001$) or six species (for boat disturbance: Kruskal-Wallis $\chi^2 = 42.6$, d.f. = 5, $P < 0.001$) were highly significant. FID correlated positively and significantly (Spearman rank correlation, $r_s = 0.22$; N = 277, $P < 0.001$) with the number of individuals and the mean body mass of the species (Spearman rank correlation, $r_s = 0.50$; $P < 0.001$; see Figure 1).

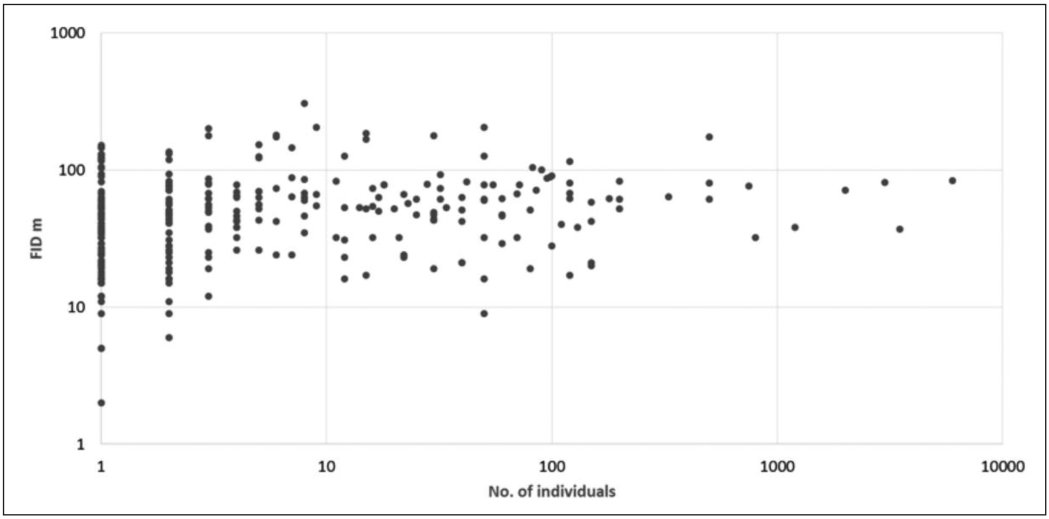
For six species, it was possible to compare FIDs for the two stimuli. If a boat was the cause of the disturbance, the highest mean FID

Table 1

Descriptive statistics for Flight Initiation Distance (FID) (m) and significance test (Mann-Whitney U test) for differences between pedestrian (nine species) and boat (six species) disturbances.
[Estadística descriptiva para las distancias de iniciación del vuelo (FID, m) y test de hipótesis (U de Mann-Whitney) para las diferencias entre perturbaciones por peatones (nueve especies) y embarcaciones (seis especies).]

	Pedestrian					Boat						
	N	Mean	Min	Max	SE	N	Mean	Min	Max	SE	Z	P
Common Sandpiper	23	46.7	17	82	3.3	6	40.5	15	56	7	-0.45	0.64
Dunlin	40	39	5	81	3.4	23	52.3	9	175	7.5	-1.4	0.15
Eurasian Curlew	11	140.5	59	305	19	19	140.3	70	205	9	-0.34	0.74
Eurasian Oystercatcher	13	76.7	50	122	6.2	10	74	32	115	7.9	0	0.98
Grey Plover	24	77.1	43	205	7.2	16	75.8	46	167	7.9	-0.2	0.85
Kentish Plover	14	44.6	18	71	3.9							
Ringed Plover	18	47.7	25	76	3.4							
Ruddy Turnstone	11	29.9	2	63	6.6	17	36.4	9	86	5.2	-0.82	0.4
Common Snipe	32	27.9	9	79	2.8							

was shown by the Eurasian Curlew (140 m) and the lowest by the Ruddy Turnstone (36 m). If a pedestrian was the cause of the disturbance, the same ranking was obtained: 140 m for the Eurasian Curlew and 30 m for the Ruddy Turnstone. None of the differences between the two stimuli for each of the six species were significant (Mann-Whitney U test). Table 2 presents the set-back distances proposed here for the nine wader species; the maximum values refer to the Eurasian Curlew when disturbed by pedestrians (267 m) and the lowest to the Snipe if disturbed by pedestrians (59 m).



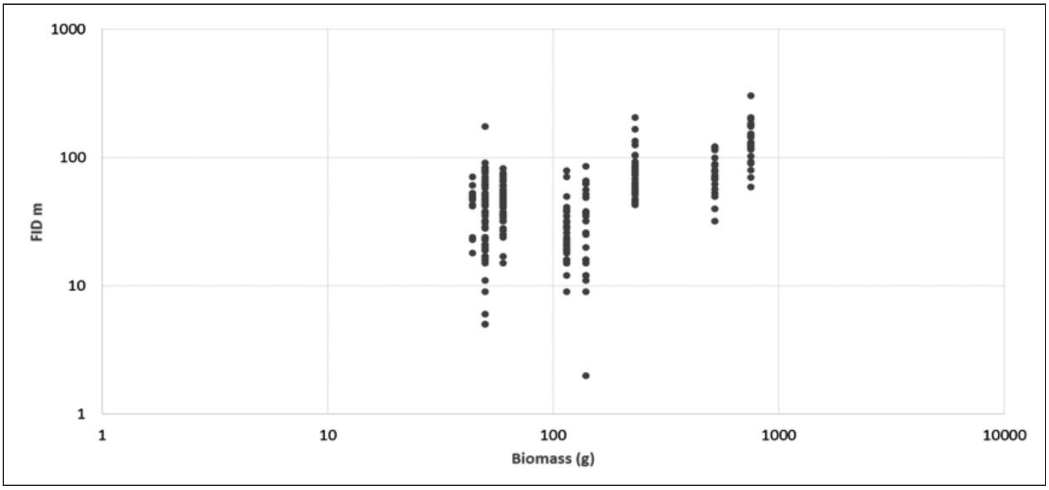


FIG. 1.—Relationships on a log scale between Flight Initiation Distance (FID) and number of individuals (above) and mean body mass (below). Two species have similar body mass.
[Relación entre las distancias de iniciación del vuelo (FID) y el número de individuos (arriba) y peso corporal medio (abajo) en escala logarítmica. Dos especies tienen similar peso corporal medio.]

TABLE 2

Proposed set-back distance (m) calculated as mean Flight Initiation Distance (FID) + 2 SD (Laursen *et al*., 2005) for nine wader species in the non-breeding period.
[Distancias de seguridad propuestas (m) calculadas como FID media + 2 SD (Laursen et al.*, 2005) para nueve especies de limícolas en el periodo no reproductor.]*

	Pedestrian disturbance FID (m)	**Boat disturbance FID (m)**
Common Sandpiper	79	75
Dunlin	82	124
Eurasian Curlew	267	219
Eurasian Oystercatcher	121	124
Grey Plover	148	139
Kentish Plover	74	n.a.
Ringed Plover	77	n.a.
Ruddy Turnstone	74	79
Snipe	59	n.a.

DISCUSSION

FID values observed in this study increased significantly with the body mass of the species and with flock size. The positive relationship between FID and body mass has been observed in many different wetlands for different species (Bregnballe *et al*., 2009; Weston *et al*., 2012; McLeod *et al*., 2013). It has been assumed that this finding is due to larger species having more difficulty taking flight and being less able to manoeuvre, thus requiring to maintain larger distances from an approaching predator or source of disturbance (Weston *et al*., 2012; Møller, 2015). The positive relationship between FIDs and flock size has also been observed elsewhere; it is generally assumed that larger flocks have more individuals that can scan for possible predators and thus may see predators earlier, when compared to smaller groups or single birds (Weston *et al*., 2012; Møller, 2015).

In the present study, the FIDs observed in response to pedestrian or boat disturbances for each of the six wader species were not significantly different from each other. Comparisons with similar results from other wetlands must be made with care, given the differences in the degree and type of human disturbance occurring locally and the different habitats used by the observed birds (Glover *et al*., 2011; Collop *et al*., 2016; McFadden *et al*., 2017). Nevertheless, apart from the general rule that larger species (such as the Eurasian Curlew) are warier and smaller species (such as the Dunlin and Ruddy Turnstone) are more confiding, the FIDs obtained for selected species in this study area are shorter than several comparable values found in the scientific literature for the same stimuli and the same species. For instance, non-breeding birds disturbed by pedestrians showed larger FIDs in the Dutch Wadden Sea (Smit & Visser, 1993), Danish Wadden Sea (Laursen *et al*., 2005), Eastern England (Collop *et al*., 2016) and the Bay of the Somme (Triplet *et al*., 1998, 2007) when compared to the present study. The few data available to date for Mediterranean wetlands seem also to indicate shorter FIDs. For example, Navedo & Herrera (2012) observed seven waterbird species, including waders, and determined a mean FID of 31.7 m caused by pedestrian disturbances in a Spanish wetland, which is lower than my overall mean value of 52.3 m observed for the same stimulus. The data supplied by E. Deboelpaed (pers. comm.) and analysed in Merken *et al*. (2015) indicate even shorter FIDs for selected species at other Mediterranean wetlands; among the species studied by McFadden *et al*. (2017), the Eurasian Curlew showed an FID of just 25 m. Thus, it is possible that in wetlands where human activity is intense and widespread, such as in the Venice lagoon and probably at several other Mediterranean wetlands, birds may have habituated to these circumstances and allow intruders to get closer before escaping. For a review of possible habituation in birds, see Tarlow & Blumstein (2007) and Samia *et al*. (2015). Laursen *et al*. (2005), Glover *et al*. (2011) and Collop *et al*. (2016) propose a similar explanation when discussing FID values observed at wetlands with different degrees of man-caused disturbances. Nevertheless, other studies did not find habituation to human disturbance in coastal birds (Navedo & Herrera, 2012; Lafferty, 2001). More field data are needed for waders observed in Mediterranean wetlands and their FIDs in response to different sources of disturbances to confirm this apparent shortening of FID. The analysis of FID in response to two disturbance types (pedestrian vs boat) observed in my study showed no significant differences between these two types in any of the six species for which comparisons could be made. Several works have dealt with boat disturbance of waterbirds (Keller, 1991; Rodgers and Schwikert, 2002; Ronconi & Clair, 2002; Chatwin *et al*., 2013; Glover *et al*., 2015), but few of these included waders and even fewer compared boat vs pedestrian disturbances. Of these, Mayo *et al*. (2015) did not find significant differences in FID caused by the two different stimuli. Keller (1991) found pedestrian disturbances to result in greater FID compared to water-based disturbances in Common Eider *Somateria mollissima*. Rodgers & Smith (1997) found no differences between FID caused by pedestrian and boat disturbances in Brown Pelican *Pelecanus occidentalis* and Great Egret *Ardea alba*. None of these authors suggest possible explanations for this. Motor vehicles caused shorter FIDs than human pedestrians according to a detailed study by McLeod *et al*. (2013), and the same could be true for boats. It is thus possible that birds do not perceive a boat as more dangerous than pedestrians in wetlands with frequent and widespread boat activity, as in my study area.

The FIDs observed in this study were used to calculate standardised set-back distances in an effort to reduce disturbances to non-breeding waders. The finding that larger flocks have larger FIDs than smaller groups or single birds is certainly not new (see, for example, Geist *et al*., 2005 and Piratelli *et al*., 2015); nevertheless, it may have important consequences for conservation measures. As already highlighted by Fox & Madsen (1997), birds congregating in large roosts are more prone to disturbances than small flocks. The proposed set-back distances in the Venice lagoon for non-breeding birds range between 59 m (Common Snipe, if pedestrians are the cause of disturbance) to 267 m (Eurasian Curlew, if pedestrians are the cause of disturbance). Roosts are usually multi-species and very often include the Eurasian Curlew, which is the most sensitive species to human approach that was identified in this study. As a management recommendation, it seems advisable to adopt the maximum proposed set-back distances for this species (267 m) as the distance to avoid disturbance caused by boats or pedestrians to multi-species roosts. The use of set-back distances is one of simplest and most straightforward ways of reducing disturbances at a local scale effectively.

After recommending set-back distances based on empirical observations, the effectiveness of these among management practices should be assessed. Set-back distances rely on the attitudes of people and the recognition of the importance of environmental management practices (Glover *et al*., 2011). Moreover, set-back distances should be realistic in practice, but should also allow birds to carry out their normal behaviour (Jorgensen *et al*., 2016). Examples of successful adaptive management practices to reduce disturbances to coastal waterbirds are known, for example, in Delaware Bay, USA (Burger *et al*., 2004). In Mediterranean countries, where the enforcement of limits and bans seems to be quite difficult, the adoption of set-back distances implies a necessary cultural change among people who share wetlands with waterbirds. Finally, an important issue, which I was unable to address in this study, is whether the disturbances that cause birds to fly or to move from an occupied area are able to reduce individual fitness and, thus, population size on a broader scale, such as a whole lagoon, estuary or lake (Burton, 2007). It is possible or likely that in large wetlands, with different available feeding and roosting sites, birds may find alternative places to exploit when disturbed and forced to leave from a previously occupied location. According to the IWC counts from the Venice lagoon during 1993-2016 (Scarton & Bon, 2009; Basso & Bon, 2016), the population increased significantly (Spearman r test, $P < 0.05$) for six of the wader species I studied, and the population remained stable for the other three species (Spearman r test, not significant). Among the species that showed an increase in their wintering populations, three, the Eurasian Curlew, Grey Plover and Eurasian Oystercatcher, had the highest FIDs found in this study. Detailed studies with multiple approaches must be performed to clarify the impact of disturbance on the wader populations that use large Mediterranean wetlands during the non-breeding season.

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