Revue d'Ecologie (Terre et Vie), Vol. 73 (3), 2018: 375-384

FLIGHT INITIATION DISTANCES IN RELATION TO PEDESTRIAN AND BOAT DISTURBANCE IN FIVE SPECIES OF WADERS BREEDING IN A MEDITERRANEAN LAGOON

Francesco SCARTON[1]

[1] SELC soc. coop., Via dell'Elettricità 3/d, 30175 Marghera (Ve), Italy. E-mail: scarton@selc.it

RÉSUMÉ.— *Distances d'envol de cinq espèces de limicoles nichant dans un lagon méditerranéen perturbées par des piétons ou des bateaux*.— Les distances d'envol (FID) en réponse à une perturbation pédestre (N = 137) ou en bateau (N = 111) ont été mesurées chez cinq espèces d limicoles nichant dans le lagon de Venise (Italie), l'un des plus importants sites méditerranéens pour les oiseaux d'eau. Des réponses différentes au même stimulus ont été observées selon les espèces. Les différences entre les deux causes de perturbation ont été significatives chez l'Avocette qui a montré une FID plus grande à l'approche d'un bateau (T de Student = 2,18 ; ddl = 28 ; $p < 0,05$) alors que l'Huîtrier pie affichait une plus FID plus élevée à l'approche d'un piéton (log_{10} données transformées : T = -5,82 ; df = 123 ; $p < 0,001$). Chez l'Avocette et l'Échasse, en réponse à un piéton, la FID augmentait de manière significative avec le nombre d'oiseaux concernés par le test. Chez l'Huîtrier pie, une tendance négative significative de la FID (r = -0,47 ; $p < 0,05$) a été observée au cours de la saison en réponse aux perturbations par des piétons. Les distances de dissuasion, *i. e.* les distances aux oiseaux devant être respectées par les humains et leurs activités, ont été calculées comme FID moyenne + 2 SD, s'étalant entre 55 m (pour les bateaux vis-à-vis du Chevalier gambette) et 102 m (pour les bateaux vis-à-vis de l'Avocette). Il est proposé une distance conservatrice de 100 m pour les bateaux et les piétons afin de protéger les colonies ou autres sites de nidification des limicoles et d'éviter de les déranger.

SUMMARY.— Flight Initiation Distances (FID) in response to pedestrian (N = 137) and boat (N = 111) disturbance were measured in five species of waders breeding in the lagoon of Venice (Italy), one of the most important sites for waterbirds around the Mediterranean. Different responses to the same stimulus were observed among species. Differences between the two causes of disturbance were significant in Pied Avocet, which showed a higher FID when a boat was approaching (Student's T = 2.18, d.f. = 28, $p < 0.05$), while Eurasian Oystercatcher exhibited higher FID when a pedestrian was the cause (log_{10} transformed data: T = -5.82, d.f. = 123, $p < 0.001$). In Pied Avocet and Black-winged Stilt, FIDs increased significantly with the number of birds involved in the tests, if a pedestrian was the cause of disturbance. In Eurasian Oystercatcher, a significant negative trend (r = -0.47, $p < 0.05$) was observed in FID through the season if a pedestrian was the cause of disturbance. Set-back distances, i.e. distances from birds to be observed by humans or humane activities, were calculated as mean FID + 2 SD and ranged between 55 m (Common Redshank, boat disturbance) and 102 m (Pied Avocet, boat disturbance). It is proposed a conservative distance of 100 m for boats and pedestrians to protect colonies or other nesting sites of waders and avoid disturbing these species.

It is widely recognised that disturbance caused by anthropogenic activities may disrupt bird behaviour, and above a certain threshold, they may prevent birds from using otherwise suitable places (Días *et al.*, 2008; Weston *et al.*, 2012; Schlacher *et al.*, 2013; Collop *et al.*, 2016). The effects are evident among waterbirds, and waders in particular, since intense and widespread human activities take place in most wetlands. Hunting, fishing, shell fishing, bait collecting, boat traffic, and birdwatching are among the most common of man-made activities causing disturbance to waders using coastal wetlands (e.g. Días *et al.*, 2008; Glover *et al.*, 2015). In the present paper, I use Nisbet's (2000) definition of human disturbance described as 'any human activity that changes the contemporaneous behaviour or physiology of one or more individuals'. Thus, other forms of landscape-level, man-made disturbances, such as land reclamation, urbanisation, land cover change, and fragmentation, which historically take place in Mediterranean wetlands (Malavasi *et al.*, 2009), are also of great importance in shaping bird communities, but will not be considered here.

As summarised by several authors (see Carney & Sydeman, 1999 and Borneman *et al.*, 2016), disturbance of breeding waterbirds, including waders, may have negative effects on reproductive behaviour, nesting success, and ultimately, population trends. These negative effects are of particular relevance in Mediterranean wetlands, which experience high and widespread levels of human disturbance (Pearce & Crivelli, 1994; Papayannis, 2008). Several Mediterranean coastal wetlands are important hotspots for breeding waterbirds (Erwin, 1996; Longoni, 2010; Galewski *et al.*, 2011; Mediterranean Wetlands Observatory, 2012). Considering historic and current high levels of anthropic activities in these wetlands (Papayannis & Pritchard, 2011) knowledge of disturbance impacts on waterbirds and possible ways to reduce effects is of critical importance in wetland management and conservation science.

One possible method to limit the effects of man-made disturbance at a local scale is to set up set-back distances, which should allow human activities and birds to coexist (Chatwin *et al.*, 2013; Whitfield & Rae, 2014; Koch & Paton, 2014). These limits are often based on the flight initiation distance (FID) — the point at which the bird flushes or otherwise moves away from the approaching disturbance source, showed by one or several species in response to a particular stimulus, such as an approaching pedestrian, car, boat, etc. (Whitfield *et al.*, 2008). FID has been used for estimating buffer zones around particular habitat patches, such as waterbird colonies (Rodgers & Smith, 1995; Ronconi & Clair, 2002; Rodgers & Schwikert, 2002; Collop *et al.*, 2016; Guay *et al.*, 2016), in order to prevent or reduce human disturbance to waterbirds in a crucial phase of their life cycle.

Researchers have calculated FID values for several waterbirds in North American, North European, and Australian wetlands (Rodgers & Smith, 1995, 1997; Triplet *et al.*, 1998, 2007; Møller, 2008; McLeod *et al.*, 2013; Mayo *et al.*, 2015; Collop *et al.* 2016; Guay *et al.*, 2016), with some values for Asian wetland species (Mori *et al.*, 2001). In contrast, very few data exist for Mediterranean wetlands. Navedo & Herrera (2012), McFadden *et al.* (2017), and Scarton (in press a) studied non-breeding waterbirds, while only Martínez-Abraín *et al.* (2008) presented data for breeding birds. Some additional data may be found in Merken *et al.* (2015), where the FID values derived from expert interviews, and they concern data from both Mediterranean and non-Mediterranean wetlands (E. Deboelpaep, personal communication).

As McLeod *et al.* (2013) remarked, most of the papers regarding FID in waterbirds come from data that are relative to just one type of stimulus —usually the occurrence of pedestrians. Only 8 of 100 articles that they considered dealt with boat disturbance, and only 13 compared two or more stimuli (that is, pedestrians, boats, cars, and buses; see Rodgers & Smith, 1997; Koch & Paton, 2014; Mayo *et al.*, 2015; Livezey *et al.*, 2016; Jorgensen *et al.*, 2016).

Given the differences observed elsewhere in response to different stimuli, it seemed appropriate to perform field tests to verify if two stimuli, namely pedestrians and boats, cause different responses in waterbirds breeding in a Mediterranean wetland. The present paper analyses FID data for five species of breeding waders in response to experimentally-induced pedestrian and boat disturbances. These FID values are then used to propose set-back distances, with the aim of describing management instruments that could be used to reduce boat and pedestrian disturbances on a local scale.

METHODS

STUDY AREA

The lagoon of Venice (NE Italy) is 55,000 ha and is the largest coastal lagoon along the Mediterranean coastline. A large part of the lagoon consists of an open body of water that is about 37,000 ha in size with shallow bottoms, 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 (Day *et al.*, 2011). The mean annual temperature is 14.5°C, and the rainfall is on average 800 mm per year (Solidoro *et al.*, 2010). As a breeding site, the lagoon hosts significant populations (i.e., >1% of those reported in Nardelli *et al.*, 2015 for the whole Italy) for several waders, such as Common Redshank *Tringa totanus* (1,600–1,800 breeding pairs), Black-winged Stilt *Himantopus*

himantopus (400–600 breeding pairs), Eurasian Oystercatcher *Haematopus ostralegus* (120–140 breeding pairs), Pied Avocet *Recurvirostra avosetta* (400–600 breeding pairs), and Kentish Plover *Charadrius alexandrinus* (80–100 breeding pairs: data from Scarton, 2017 and pers. obs.). Most of these pairs nest on saltmarsh islets (about 3,600 ha in size) and dredge islands (1,100 ha of artificial intertidal sites made with dredged sediments: Scarton & Montanari, 2015) scattered all over the lagoon. For its ornithological value as a wintering and breeding site, the whole lagoon was declared a Special Protection Area (IT 3250046 Laguna di Venezia) in 2007, according to the Birds Directive 2009/147/EC. Despite its well-recognized importance for waterbirds only a very small part of the lagoon, named Valle Averto and 500 ha in extent, was designated in 1989 as a Ramsar site.

Disturbance of waterbirds due to boat traffic and pedestrian activities takes place in the lagoon of Venice. At least 40,000 boats circulate each year for both professional purposes, such as fishing, leisure activities, and goods and tourist transportation (Ministero delle Infrastutture e dei Trasporti, 2017). About 600 of these boats are devoted to the professional harvest of the Manila Clam *Ruditapes philippinarum.* They navigate most of the year in areas with shallow bottoms that lay close to wader nesting sites. 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, adjacent to saltmarshes, where several hundred professional and non-professional fishermen walk during low tides to collect molluscs and other invertebrates.

The five species of waders I studied nest as single pairs (Eurasian Oystercatcher and Kentish Plover), colonially (Pied Avocet, Black-winged Stilt), or a mix of these two strategies (Common Redshank: for details on the coloniality of this species in the lagoon of Venice, see Hale *et al*., 2005). The breeding season begins as early as the end of February for the Eurasian Oystercatcher and may end in late July for the other species.

OBSERVATIONS AND MEASUREMENTS

Since 1989 all the colonies of seabirds occurring in the whole lagoon of Venice, with the only exception of fish farms which are privately owned and difficult to access, have been surveyed at least twice in the breeding season (Scarton & Valle, 2015). Moreover, since 2005 until 2017 all waterbirds species nesting on dredge islands have been surveyed almost each year, with at least two visits at each site in the breeding season. Visits to the nesting sites were done between the end of February and late July, by me and a few colleagues; for methodological details and results for the last years, see Scarton (2017). During the surveys made in 2014-2017, I did 248 FID measurements from the end of February through July, by approaching birds either on foot or by boat during the reproductive period of each species. Only birds performing typical breeding behaviours, such as alarming calls and distraction displays, or observed sitting on their nests were included in the analysis. Observations always took place between 07:00 and 14:00 hours, avoiding foggy or rainy days and tides >1 m a.s.l. I visited multiple sites throughout the lagoon to avoid problems of bias, habituation, and autocorrelation in the response of birds (Rodgers & Schwikert, 2002); the FID for an individual bird was measured only once.

To measure pedestrian disturbance ($N = 137$), I walked slowly at a constant speed, about 2 km/h, through saltmarshes and dredge islands towards one bird or a group of birds. Both saltmarshes and dredge islands were covered with low, 50 cm, halophytic vegetation, interspersed with tidal ponds and creeks; dredge islands had also large extensions of bare surfaces. I then measured the distance between me and the bird, or the closest bird if a group was approached, when it first flushed or ran away. Distances were estimated using a rangefinder Leica Rangemaster LAF 900 (accuracy ± 1 m) or in a few cases, by counting the paces made and multiplying them by 0.8 m. No observation was made if there were other boats or people within 300 m of the targeted birds. I did not record the starting distance; for some critical aspects in using this measurement in disturbance studies see Dumont *et al.* (2012) and Withfield & Rae (2014).

A 7-m fiberglass boat with a 140-horsepower outboard motor was used for boat disturbance ($N = 111$) There were always two people aboard the boat: a driver and myself. The boat approached the birds at a speed between 8 and 10 km/h until they flew away. The boat speed was considered as intermediate between the 5 and 20 km/h permitted in the lagoon of Venice. The sound pressure level 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. The distance from the boat to the birds was measured with the same rangefinder.

DATA ANALYSIS

Due to logistical constraints, sample size could not be balanced among species and type of disturbance; for each species, at least fourteen measurements were taken. In the study sites, Kentish Plover nested only in the interior parts of the dredge islands, far from navigable channels, so only FID due to pedestrian disturbance could be measured for this species.

It is known that FIDs may vary throughout the nesting season or according to the number of individuals involved (see Discussion); for Eurasian Oystercatcher, I was able to examine possible temporal trends both for boat and pedestrian disturbance in 2016.

Data were normally distributed apart from those relative to Eurasian Oystercatcher, for both stimuli (Shapiro–Wilk W test, $p < 0.05$, in both cases). Prior to ANOVA tests, all the data were $\log_{10}$ transformed, which normalised the distribution. Nevertheless, variances among species were unequal (i.e., heteroscedasticity of data, as shown by the Levene test, $p < 0.05$), so I used Welch's ANOVA (McDonald, 2014), which uses a highly conservative estimate of degrees of freedom to adjust for this assumption. Post-hoc Tukey tests were used when there were significant differences among species. Differences between FIDs relative to boat or pedestrian were tested with the Student's t-test in all the species apart from Eurasian Oystercatcher, for which the Mann-Whitney test was used; linear regression was computed between $\log_{10}$-transformed FID and dates. All means are reported with standard deviations (SD). Numerical and statistical analyses were performed using Statistica v. 7.2 and PAST v. 3.17 software. Following Laursen *et al.* (2005), the mean FID + 2 SD was used as a conservative set-back distance for each species.

RESULTS

Different responses among species were observed, considering each kind of stimulus, as shown by results of the Welch's ANOVA for boat disturbance (F = 5.81, $p < 0.01$) or pedestrian disturbance (F = 20.32, $p < 0.001$). In the first case, significant differences were observed between Pied Avocet, which had the largest FID, and both Eurasian Oystercatcher and Common Redshanks (Tab. I: Tukey's test, $p < 0.01$). If a pedestrian was the cause of disturbance, significantly different responses were observed among four species (Tukey's test, $p < 0.05$). Table I shows the FID values measured, according to the kind of stimulus.

TABLE I

*Descriptive statistics for FID (m) for pedestrian and boat disturbances. * denotes species with significant differences observed between the two stimuli (see text)*

	Boat						Pedestrian					
Species	N	Min	Max	Mean	SD	CI 95%	N	Min	Max	Mean	SD	CI 95%
Pied Avocet *	15	28	95	61.2	20.2	49.9-72.4	15	20	92	45.6	18.7	35.2-56
Black-winged Stilt	14	29	72	43.5	10.6	37.4-49.7	19	32	88	52.6	16.0	44.8-60.3
Kentish Plover							22	12	56	30.3	11.1	25.4-35.3
Eurasian Oystercatcher *	62	15	105	43.0	19.5	38.1-48.0	63	31	92	58.1	13.4	54.7-61.5
Common Redshank	20	21	55	39.0	7.8	35.3-42.7	18	21	58	39.6	10.2	34.5-44.7

In four species, data allowed comparisons between the two causes of disturbance. Differences between the two FIDs were significant in two species. Pied Avocet showed higher FID when a boat was approaching (Student t = 2.18, d.f. = 28, $p < 0.05$), while Eurasian Oystercatcher exhibited higher FID due to pedestrian disturbance (Student's t on $\log_{10}$ transformed data = -5.82, d.f. = 123, $p < 0.001$). Julian dates of experimental approaches were not different between the two stimuli both in Eurasian Oystercatcher (Mann-Whitney test: z = -0.41, p = 0.39) and in Pied Avocet (Mann-Whitney test: z = -0.56, p = 0.41), and the same result is obtained when considering the number of individuals involved (Eurasian Oystercatcher: Mann-Whitney test z = -1.2, p = 0.67; Pied Avocet: Mann-Whitney test z = -1.4, p = 0.72). Thus, the observed significant differences in FID linked to boats and pedestrians appear dependent only on the type of stimulus, not on other possible confounding factors.

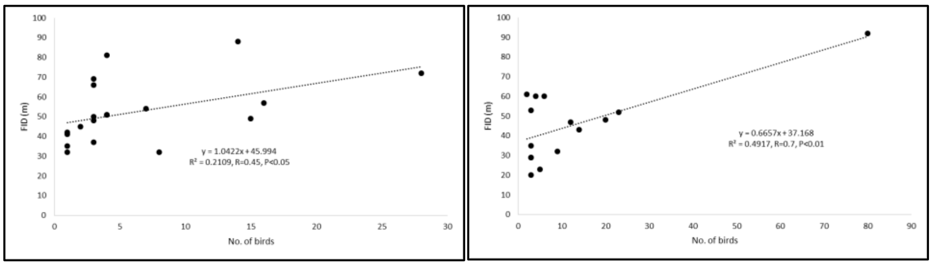


Figure 1.— Pedestrian disturbance: FID versus number of birds in Black-winged Stilt (left) and Pied Avocet (right).

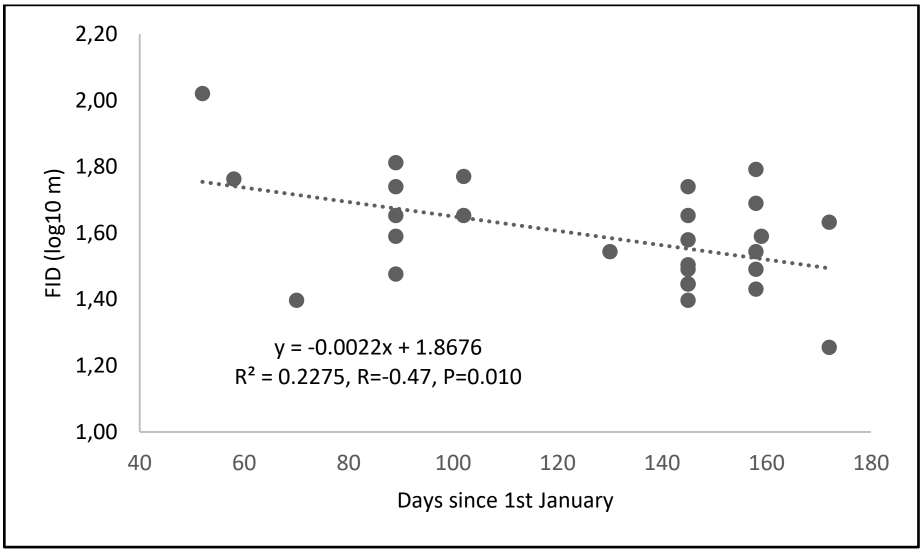
The effects of group size on the observed FID were assessed in two colonial species, i.e. Pied Avocet and Black-winged Stilt. FID was positively and significantly related with the numbers of birds disturbed during the test if a pedestrian was the cause of disturbance, in both species (r = 0.7 and r = 0.45; Fig. 1). If a boat was approaching, the relationship was significant only for Black-winged Stilt (r = 0.56, $p < 0.05$, data not shown).

Table II shows set-back distances for the two stimuli in four species, and only pedestrian disturbance for Kentish Plover. The largest set-back distance is for boats near Pied Avocet and pedestrians near Black-winged Stilt.

TABLE II

Set-back distances (m, rounded) for breeding species according to the type of stimulus

Species	Boat	Pedestrian
Pied Avocet	102	83
Black-winged Stilt	65	85
Kentish Plover	n.a.	53
Eurasian Oystercatcher	82	85
Common Redshank	55	60



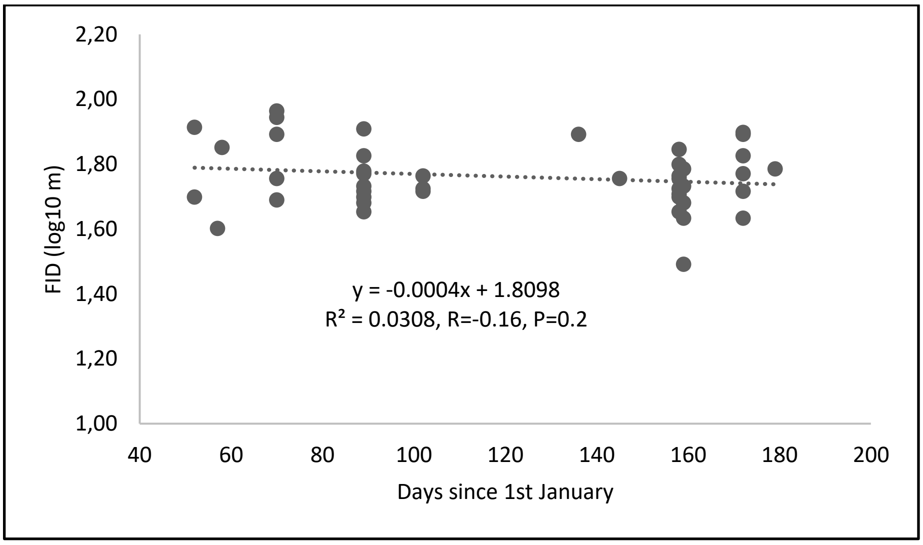


Figure 2.— Correlation between date (number of days since the 1st January 2016) and the FID in Eurasian Oystercatcher, for boat (above) and pedestrian (below) disturbance.

For the Eurasian Oystercatcher, data allowed an analysis of FID trends throughout the 2016 breeding season, for boat (N = 28) and pedestrian (N = 43) instances of disturbance. In the first case, there was a significant negative trend (r = -0.47, $p < 0.05$); there was no significant trend for pedestrian disturbance (r = -0.16, p = 0.29, Fig. 2). No attempt was made to discriminate among birds with chicks, alone or on their nests.

DISCUSSION

The main findings of this study are in partial agreement with the results of similar research studies. I found a positive correlation between FIDs and flock size, as often but not always observed by other authors (see Glover *et al*., 2011), for Black-winged Stilt and Pied Avocet. It is generally assumed that larger flocks more easily scan for possible predators and thus, may see predators earlier than smaller groups or individual birds (Weston *et al.*, 2012; Møller, 2015). In the non-breeding period, a positive correlation between these two variables among six species of waders, and in Greater Flamingo, has been observed in the lagoon of Venice (Scarton, in press a & b); this supports the hypothesis that early response of large groups is widespread among waterbirds in Mediterranean wetlands.

The results of this study showed that FID due to boat disturbance was not greater than pedestrian FID in three out of four species. In Common Redshank and Black-winged Stilt, pedestrians and boats did not cause different FIDs. In Eurasian Oystercatcher, pedestrians caused larger FIDs than boats, whereas the opposite was true for Pied Avocet. Several works have dealt with boat disturbance among waterbirds (Keller, 1991; Rodgers & 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 disturbance. Mayo *et al.* (2015) did not find significant differences among FIDs caused by the two different stimuli in waterbirds. Rodgers & Smith (1997) found no differences between pedestrian and boat FIDs in foraging or loafing Brown Pelican *Pelecanus occidentalis* and Great Egret *Ardea alba*. Rodgers & Smith (1995), studying nesting waterbirds, found that colonial waterbirds generally exhibited greater FIDs in reaction to a pedestrian than to a boat; Klein (1993) also found that waterbirds were more disturbed from pedestrian traffic than car traffic. None of these authors suggest possible explanations for this. Motor vehicles caused shorter FIDs than humans in a detailed study made by McLeod *et al.* (2013), and the same could be true for boats. Thus, it is possible that at least some waders do not perceive a boat as more dangerous than a pedestrian, similar to what happens in the case of motor vehicles (Lima *et al.*, 2015).

Moreover, boat passing is surely more frequent than pedestrian occurrence near saltmarshes and dredge islands, suggesting some species become habituated to boats but not to humans (see later). Nevertheless, the finding that Pied Avocet was more disturbed by boats than pedestrians indicates response variations even among closely related species, and warrants further investigation.

In the present study, FID varied through one breeding season in Eurasian Oystercatcher, with birds seeming more tolerant towards the end of the season, if boat disturbance was involved. Even if date is a poor indicator of breeding status, it is reasonable to assume that breeding adults disturbed during the tests late in the season had eggs or chicks of various ages. The scientific literature about this topic is inconclusive. Variation in FID with time was non-significant in breeding waterbirds studied by Erwin (1989), while Buxton *et al.* (2017) found the effects of disturbance varied with breeding cycle in cormorants. Chatwin *et al.* (2013) did not find significant variation in the proportion of birds agitated among three breeding periods in one season. Barter (2004) found increasing tolerance over time, indicating short-term habituation, while de Jong *et al.* (2013) found that FID decreased with time in Eurasian Curlew *Numenius arquata*. In the Lagoon of Venice, Eurasian Oystercatcher nest primarily along the edges of dredge islands and saltmarsh islets, sites relatively higher than the surroundings less prone to flooding and often where heaps of shell fragments or seagrass leaves build up. These nesting sites are also closer to navigable channels than the inner sites, well into the islets, where pied avocets, black-winged stilts, and common redshanks usually nest. For a breeding Eurasian Oystercatcher, flying too often in response to a passing boat would be detrimental for chicks or eggs in the abandoned nest. It is thus likely that breeding Eurasian Oystercatcher adults become more and more habituated to boat traffic, which increases dramatically in the study area in late spring and summer due to outdoor leisure activities. Habituation to boat traffic by nesting American Oystercatcher *Haematopus palliatus* has been reported by Chatwin *et al.* (2013) and, for wintering birds, also in Eurasian Oystercatcher (Triplet *et al.*, 2002).

The set-back distances proposed in this study for breeding waders ranged between 55 m (Common Redshank, boat disturbance) to 102 m (Pied Avocet, same stimulus). Considering that quite often wader colonies are multispecific, it seems appropriate to adopt the set-back distance of the most sensitive species: Pied Avocet (102 m) for boat disturbance and the Black-winged Stilt (85 m) for pedestrian disturbance. If only one measure has to be suggested to protect colonies or other nesting sites of waders, 102 m are proposed as a conservative distance.

These distances agree fairly well with those already proposed by several authors for breeding waterbirds, based on FID or other indicators of man-made disturbance (see Valente *et al.*, 2011 for a detailed synthesis): 100 m for common terns *Sterna hirundo* (Burger 1998); 160 m for Wood Sandpiper *Tringa glareola* (Whitfield & Rae, 2014); 118 m for Black Skimmer *Rynchops niger* (Burger *et al.*, 2010); >50 m for Sternidae and Black Skimmer (Hillman *et al.*, 2015); >50 m for seabird breeding sites (Chatwin *et al*., 2013); 50 m for the Hooded Plover *Thinornis rubricollis* (Weston *et al.*, 2012); 100 m for wading birds and 180 m for mixed terns/Black skimmer colonies (Rodgers & Smith, 1995); and 100 m for nesting colonies of Arctic waterbirds (Mallory, 2016).

Setting set-back distances are one of the simplest methods managers may adopt to reduce human disturbance at the local scale. After recommending set-back distances based on empirical observations, the effectiveness of these should be evaluated. Set-back distances rely on the attitudes of people and recognition of its importance (Glover *et al.*, 2011); distances should be realistic for application, but also allow birds to carry out their normal behaviour (Jorgensen *et al.*, 2016). Examples of successful adaptive management to reduce disturbance to coastal waterbirds are known (Burger *et al.*, 2004). In Mediterranean countries, where the enforcement of limits and bans seem to be quite difficult in general, the adoption of set-back distances implies a necessary cultural change among people who share wetlands with waterbirds. The adoption of new rules, which include the duty to maintain a distance of at least 100 m from colonies, is thus recommended in the lagoon of Venice and at other Mediterranean wetlands. At the same time, information campaigns among the many people who use the wetlands for leisure (anglers, hunters, birdwatchers) or work (tourist and goods transport boat pilots, clam collectors) should also be launched to increase awareness about possible direct and indirect effects of boat traffic to waterbird nesting sites.

ACKNOWLEDGEMENTS

Colleagues E. Checchin and D.Longo helped conduct the fieldwork. The Associazione Faunisti Veneti (ASFAVE, Venice) loaned the rangefinder. Evelien Deboelpaep (Vrije Universiteit, Brussel) kindly provided data from the following experts: Dr. Clemens Küpper, Dr. Michel Gauthier-Clerc, Dr. Zdenek Hubálek, Milan Vogrin, Dr. Esther Sebastián-González, Dr. Savas Kazantzidis, Dr. Olivier Beauchard, Ahmad Barati, Prof. Åke Lindström, Prof. Ben Sheldon, Dr. Colin Rogers, Alexandros Gassios, and Prof. John O'Halloran. Four anonymous referees greatly improved the manuscript.

REFERENCES

BARTER, M. (2004).— *Human disturbance to colonially breeding seabirds and guidelines for visitor management on Islands off the coast of Western Australia*. Murdoch University.

BORNEMAN, T.E., ROSE, E.T. & SIMONS, T.R. (2016).— Off-road vehicles affect nesting behaviour and reproductive success of American Oystercatchers *Haematopus palliatus. Ibis*, 158: 261-278.

BURGER, J. (1998).— Effects of motorboats and personal watercraft on flight behavior over a colony of Common Terns. *The Condor*, 100: 528-534.

BURGER, J., GOCHFELD, M., JENKINS, C.D. & LESSER, F. (2010).— Effect of approaching boats on nesting black skimmers: using response distances to establish protective buffer zones. *J. Wildl. Manage.*, 74: 102-108.

BURGER, J., JEITNER, C., CLARK, K. & NILES, L.J. (2004).— The effect of human activities on migrant shorebirds: successful adaptive management. *Envir. Conserv.*, 31: 283-288.

BUXTON, R.T., GALVAN, R., MCKENNA, M.F., WHITE, C.L. & SEHER, V. (2017).— Visitor noise at a nesting colony alters the behavior of a coastal seabird. *Mar. Ecol. Progr. Ser.*, 570: 233-246.

CARNEY, K.M. & SYDEMAN, W.J. (1999).— A review of human disturbance effects on nesting colonial waterbirds. *Waterbirds*, 22: 68-79.

CHATWIN, T.A., JOY, R. & BURGER, A.E. (2013).— Set-back distances to protect nesting and roosting seabirds off Vancouver Island from boat disturbance. *Waterbirds*, 36: 43-52.

COLLOP, C., STILLMAN, R., GARBUTT, A., YATES, M.G., RISPIN, E., YATES, T. & SMART, J. (2016).— Variability in the area, energy and time costs of wintering waders responding to disturbance. *Ibis*, 158: 711-725.

DAY J., IBÁÑEZ C., SCARTON F., PONT D., HENSEL P., DAY, J. & LANE R. (2011).— Sustainability of Mediterranean deltaic wetlands with sea-level rise: the importance of river input. *Estuaries and Coasts*, 34: 483-493.

DE JONG, A., MAGNHAGEN, C. & THULIN, C.G. (2013).— Variable flight initiation distance in incubating Eurasian curlew. *Behav. Ecol. Sociobiol.*, 67: 1089-1096.

DIAS, M.P., PESTE, F., GRANADEIRO, J.P. & PALMEIRIM, J.M. (2008).— Does traditional shellfishing affect foraging by waders? The case of the Tagus estuary (Portugal). *Acta Oecol.*, 33: 188-196.

DUMONT, F., PASQUARETTA, C., RÉALE, D., BOGLIANI, G. & VON HARDENBERG, A. (2012).— Flight initiation distance and starting distance: Biological effect or mathematical artefact? *Ethology*, 118: 1051-1062.

ERWIN, R.M. (1989).— Responses to human intruders by birds nesting in colonies: Experimental results and management guidelines. *Colonial Waterbirds*, 12: 104-108

ERWIN, R.M. (1996).— The relevance of the Mediterranean Region to colonial waterbird conservation. *Colonial Waterbirds*, 19: 1-11.

GALEWSKI, T., COLLEN, B., MCRAE, L., LOH, J., GRILLAS, P., GAUTHIER-CLERC, M. & DEVICTOR, V. (2011).— Long-term trends in the abundance of Mediterranean wetland vertebrates: from global recovery to localized declines. *Biol. Conserv.*, 144: 1392-1399.

GLOVER, H.K., GUAY, P.-J. & WESTON, M. (2015).— Up the creek with a paddle; avian flight distances from canoes versus walkers. *Wetlands Ecol. Manage.*, 23: 775-778.

GLOVER, H.K., WESTON, M.A., MAGUIRE, G.S., MILLER, K.K, & CHRISTIE, B.A. (2011).— Towards ecologically meaningful and socially acceptable buffers: Response distances of shorebirds in Victoria, Australia, to human disturbance. *Landscape and Urban Planning*, 103: 326-334.

GUAY, P.J., VAN DONGEN, W.F.D., ROBINSON, R.W., BLUMSTEIN, D.T. & WESTON, M.A. (2016).— Avian buffer: An interactive tool for characterising and managing wildlife fear responses. *Ambio*, 45*:* 841–851.

HALE, W.G., SCARTON, F. & VALLE, R. (2005).— The taxonomic status of the Redshank *Tringa totanus* in Italy. *Bull. Brit. Ornithol. Club*, 125: 261-275

HILLMAN, M.D., KARPANTY, S.M., FRASER, J.D. & DEROSE-WILSON, A. (2015).— Effects of aircraft and recreation on colonial waterbird nesting behavior. *J. Wildl. Manage.*, 79: 1192-1198.

JORGENSEN, J.G., DINAN, L.R. & BOMBERGER BROWN, M. (2016).— Flight initiation distances of nesting Piping Plovers (*Charadrius melodus*) in response to human disturbance. *Avian Conserv. Ecol.*, 11: 5.

KELLER, V.E. (1991).— Effects of human disturbance on eider ducklings *Somateria mollissima* in an estuarine habitat in Scotland. *Biol. Conserv.*, 58: 213-228.

KLEIN, M.L. (1993).— Waterbird behavioral responses to human disturbances. *Wildl. Soc. Bull.*, 21: 31-39.

KOCH, S.L. & PATON, P.W.C. (2014).— Assessing anthropogenic disturbances to develop buffer zones for shorebirds using a stopover site. *J. Wildl. Manage.*, 78: 58-67.

LAURSEN, K., KAHLERT J. & FRIKKE, J. (2005).— Factors affecting escape distances of staging waterbirds. *Wildl. Biol.*, 11: 13-19.

LIMA, S.L., BLACKWELL, B.F., DEVAULT, T.L. & FERNÁNDEZ-JURICIC, E. (2015).— Animal reactions to oncoming vehicles: a conceptual review. *Biol. Rev. Cambridge Phil. Soc.*, 90: 60-76.

LIVEZEY, K.B., FERNÁNDEZ-JURICIC, E. & BLUMSTEIN, D.T. (2016).— Database and metadata of bird flight initiation distances worldwide to assist in estimating human disturbance effects and delineating buffer areas. *J. Fish & Wildl. Manage.*, 7: 181-191.

LONGONI, V. (2010).— Rice fields and waterbirds in the Mediterranean region and the Middle East. *Waterbirds*, 33*:* 83-96.

MALAVASI, R., BATTISTI, C. & CARPANETO, G.M. (2009).— Seasonal bird assemblages in a Mediterranean patchy wetland: corroborating the intermediate disturbance hypothesis. *Pol. J. Ecol*, 57: 171-179.

MALLORY, M.L. (2016).— Reactions of ground-nesting marine birds to human disturbance in the Canadian Arctic. *Arctic Science*, 77: 1-27.

MARTÍNEZ-ABRAÍN, A., ORO, D., CONESA, D. & JIMÈNEZ, J. (2008).— Compromise between seabird enjoyment and disturbance: the role of observed and observers. *Envir. Conserv.*, 35: 104-108.

MAYO, T.W., PATON, P.W.C. & AUGUST, P.V. (2015).— Responses of birds to humans at a coastal barrier beach: Napatree Point, Rhode Island. *North-eastern Naturalist*, 22: 501-512.

MCDONALD, J.H. (2014).— *Handbook of biological statistics* (3rd ed.). Sparky House Publishing, Baltimore, Maryland.

MEDITERRANEAN WETLANDS OBSERVATORY (2012).— *Biodiversity, status and trends of species in Mediterranean wetlands*. Thematic collection, issue # 1. Tour du Valat, France.

MCFADDEN, T.N., HERRERA, A.G. & NAVEDO, J.G. (2017).— Waterbird responses to regular passage of a birdwatching tour boat: Implications for wetland management. *J. Nat. Conserv.*, 40: 42-48.

MCLEOD, E. M., GUAY, P.-J., TAYSOM, A.J., ROBINSON, R.W. & WESTON, M.A. (2013).— Buses, cars, bicycles and walkers: the influence of the type of human transport on the flight responses of waterbirds. *PloS One*, 8: 1-11.

MERKEN, R., DEBOELPAEP, E., TEUNEN, J., SAURA, S., & KOEDAM, N. (2015).— Wetland suitability and connectivity for trans-Saharan migratory waterbirds. *PLoS ONE*, 10: 1–20.

MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI (2017).— *Piano per il recupero morfologico e ambientale della laguna di Venezia*. http://provveditoratovenezia.mit.gov.it. Last access: 21st July 2017.

MØLLER, A.P. (2008).— Flight distance and population trends in European breeding birds. *Behav. Ecol.*, 19: 1095-1102.

MØLLER, P. (2015).— Birds. Pp 88-112 *In*: W.E. Cooper & D.T. Blumstein (eds.). *Escaping from predators: An integrative view of escape decisions*. Cambridge University Press.

MORI, Y., SODHI, N.S., KAWANISHI, S., & YAMAGISHI, S. (2001).— The effect of human disturbance and flock composition on the flight distances of waterfowl species. *J. Ethol.*, 19:115-119.

NARDELLI, R., ANDREOTTI, A., BIANCHI, E., BRAMBILLA, M., BRECCIAROLI, B., CELADA, C., DUPRÉ, E., GUSTIN, M., LONGONI, V., PIRRELLO, S., SPINA, F., VOLPONI, S. & SERRA, L. (2015).— *Rapporto sull'applicazione della Direttiva 147/2009/CE in Italia: dimensione, distribuzione e trend delle popolazioni di uccelli (2008-2012)*. ISPRA, Serie Rapporti, 219/2015.

NAVEDO, J.G. & HERRERA, A.G. (2012).— Effects of recreational disturbance on tidal wetlands: supporting the importance of undisturbed roosting sites for waterbird conservation. *J Coast Conserv*, 16: 373-381.

NISBET, I.C.T. (2000).— Disturbance, habituation, and management of waterbird colonies - commentary. *Waterbirds*, 23: 312-332.

PAPAYANNIS, T. (2008).— *Action for culture in Mediterranean wetlands*. Med-INA, Athens, Greece.

PAPAYANNIS, T. & PRITCHARD, D.E. (2011).— *Culture and Wetlands in the Mediterranean: an evolving story*. Athens, Med-INA.

PEARCE, F. & CRIVELLI, A. (1994).— *Characteristics of Mediterranean wetlands*. Publications MedWet/Tour du Valat – number 1. Tour du Valat, Arles – (France).

RODGERS, J. JR. & SCHWIKERT, S.T. (2002).— Buffer-zone distances to protect foraging and loafing waterbirds from disturbance by personal watercraft and outboard-powered boats. *Conserv. Biol.*, 16: 216-224.

RODGERS, J.A & SMITH, H.T. (1995).— Set-back distances to protect nesting bird colonies from human disturbance in Florida. *Conserv. Biol.*, 9: 89–99.

RODGERS, J.A. & SMITH, H.T. (1997).— Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. *Wildl. Soc. Bull.*, 25: 139-145.

RONCONI, R.A. & CLAIR, C.C.S. (2002).— Management options to reduce boat disturbance on foraging black guillemots (*Cepphus grylle*) in the Bay of Fundy. *Biol. Conserv.*, 108: 265-271.

SCARTON, F. (2017).— Long-term trend of the waterbird community breeding in a heavily man-modified coastal lagoon: the case of the Important Bird Area "Lagoon of Venice". *J. Coast Conserv.*, 21: 35-45.

SCARTON, F. (*in press a*).— Disturbance of non-breeding waders by pedestrians and boats in a Mediterranean lagoon. *Ardeola*.

SCARTON, F. (*in press b*).— Environmental characteristics of shallow bottoms used by Greater flamingo (*Phoenicopterus roseus*) in a northern Adriatic lagoon. *Acrocephalus*.

SCARTON, F. & MONTANARI, M. (2015).— Use of artificial intertidal sites by birds in a Mediterranean lagoon and their importance for wintering and migrating waders. *J. Coast Conserv*, 19: 321-334.

SCARTON, F. & VALLE, R. (2015).— Long-term trends (1989-2013) in the seabird community breeding in the Lagoon of Venice (Italy*). Research in Ornithology*, 85: 21-30.

SCHLACHER, T.A., WESTON, M.A., LYNN, D. & CONNOLLY, R.M. (2013).— Set-back distances as a conservation tool in wildlife-human interactions: testing their efficacy for birds affected by vehicles on open-coast sandy beaches. *PLoS ONE*, 8(9): e71200.

SOLIDORO, C., BANDELJ, V., BERNARDI, F., CAMATTI, E., CIAVATTA, S., COSSARINI, G., FACCA, C., FRANZOI, P., LIBRALATO, S., MELAKU CANU, D., PASTRES, R., PRANOVI, F., RAICEVICH, R., SOCAL, G., SFRISO, A., SIGOVINI,

M., TAGLIAPIETRA, D. & TORRICELLI, P. (2010).— Response of Venice lagoon ecosystem to natural and anthropogenic pressures over the last 50 years. Pp 453-511 *In:* M. Kennish & H. Paerl (eds.). *Coastal lagoons: critical habitats and environmental change.* CRC Press, Taylor and Francis, Boca Raton, Florida, USA.

TRIPLET, P., BACQUET, S., MORAND, M.E. & LAHILAIRE, L. (1998).— La distance d'envol, un indicateur de dérangements: l'exemple de quelques oiseaux en milieu estuarien. *Alauda*, 66: 199-206.

TRIPLET, P., MEQUIN, N. & SUEUR, F. (2007).— Prendre en compte la distance d'envol n'est pas suffisant pour assurer la quiétude des oiseaux en milieu littoral. *Alauda*, 75: 237-242.

TRIPLET, P., URBAN, M. & AULERT, C. (2002).— Adaptation de la réponse de l'Huîtrier pie *Haematopus ostralegus* aux dérangements liés à des activités humaines en estuaire Seine. *Alauda*, 70: 393-397.

VALENTE, J.J. & FISCHER, R.A. (2011).— *Reducing human disturbance to waterbird communities near Corps of Engineers projects.* (No. ERDC TN-DOER-E29). US Army Engineer Research and Development Center.

WESTON, M., MCLEOD, E.M., BLUMSTEIN, D.T. & GUAY, P.J. (2012).— A review of flight-initiation distances and their application to managing disturbance to Australian birds. *Emu*, 112: 269-286.

WHITFIELD, D.P. & RAE, R. (2014).— Human disturbance of breeding Wood Sandpipers *Tringa glareola*: Implications for "alert distances" in prescribing protective buffer zones. *Ornis Fennica*, 91: 57-66.

WHITFIELD, D.P., RUDDOCK, M. & BULLMAN, R. (2008).— Expert opinion as a tool for quantifying bird tolerance to human disturbance. *Biol. Conserv.*, 141: 2708-2717.