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ARTICLE

Monitoring human disturbance: Factors affecting escape behaviour of waterbirds in North African wetlands

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Abstract

Understanding the factors affecting escape behaviour in waterbirds can be useful in the management of human disturbances. A common measure of escape response is flight initiation distance (FID), the distance at which an approaching intruder disturbs an individual bird enough to make it move away. Here, we analyse the escape behaviour of a set of waterbirds for the first time within a North African context. We tested (one-way ANOVA and general linear model) how FID varied with the area where waterbirds were temporal scale, distance at which the observer start approaching to the sampled birds, body size, flock size, species composition of the flock and foraging activity of the sampled birds. We collected 866 individual FIDs for 19 waterbird species wintering at two north Algerian wetlands (the Mekhada marsh, RAMSAR site, El-taref District and the Sebkhet El-Mahmel, unprotected wetland, Khenchela District). The obtained FIDs ranged from 32.6 m in smaller species as the Kentish plover *Charadrius alexandrines* to 167 m in larger ones as the ruddy shelduck *Tadorna ferruginea*. The obtained models stated that differences in the absolute levels of FIDs were mostly related to starting distance (Effect size = 0.62), to which is added a relatively little effect of wetland status, taxonomic differences, temporal scale, body size, flock size, species composition of the flock and bird activity. More specifically, FID was lower in smaller and homospecific groups at early winter in the protected wetland. Reserve managers in North Africa could use species and context-specific FIDs in delineating appropriate buffer areas and in the design of management initiatives aimed at minimising eventual potential threat due to human disturbance and guaranteeing animal welfare and wildlife.

KEYWORDS
flight initiation distance, Mekhada marsh, Sebkhet El-Mahmel, wetland management, wintering season

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1 | INTRODUCTION

The concept of human disturbance and its implications in wetland management has been investigated in depth in different countries worldwide. Several lines of evidence suggest that human disturbance constituted a serious threat to the life and health of the wetland as a whole (Batey, 2013). However, a high proportion of scientific literature and conservation concerns have focused on the impacts to waterbirds (Borgmann, 2010; Carney & Sydeman, 1999; Price, 2008) on the basis that this class of animals are the most conspicuous and significant component of the wetland ecosystems; see Cooper & Blumstein (2015) for a complete review.

The most detrimental effect of the exposures to human activities on birds is the abrupt interruption of their regular activity. It does not matter whether a bird displays alert or escape behaviour, but whether and how the behavioural changes affect the birds or the species as a whole (Gill, 2007; Livezey et al., 2016). Behavioural deviation induced by human disturbance can alter several aspects of the bird's life history traits. The most critical ones are (1) the reduction of feeding rates in favour of predator surveillance (trade-off between food intake and vigilance) (Wilson et al., 2020) (2) habitat availability (leaving some areas no longer suitable for all water-related birds) (Fernández-Juricic, 2000; Peters & Otis, 2007) (3) altering physiological processes (hypothalamic-pituitary-adrenal axis, basal metabolic rate) (Møller, 2009; Price, 2008) (4) breeding failure (nest abandonment) (Carney & Sydeman, 1999) and (5) lower productivity (lower energy availability for reproductive activities) (Frid & Dill, 2002).

Many behavioural effect studies sought to assess through a quantitative approach the behavioural response of animals to human disturbance. Flight initiation distance (FID) was found to be the most standard quantitative method for this purpose. It has been used by behavioural ecologist to assess the cost of antipredator strategies on animal fitness or to monitor habituation to disturbances and often used by wildlife managers to mitigate human impacts on wildlife (Blumstein, 2003). Also called flush distance, buffer zone, set-back distance and approach distance (Coetzer & Bouwman, 2017), whatever terminology is used, it is often referred to the distance at which an approaching intruder disturbs an individual bird enough to make it move away (Blumstein, 2003, 2006a); methods to determine FIDs are soundly entrenched in Blumstein (2006b) and Møller (2010). FIDs variation and movement patterns of avian species, in general, are hypothesised to stem from a variety of causes including morphological traits, life history events, flock size, species composition of the flock and last but not least, spatial and temporal scales (Blumstein, 2003; Bregnballe et al., 2009; Møller, 2010; Morelli et al., 2019; Price, 2008).

These aspects of the bird's response to human disturbance have been largely gouged in many studies worldwide as mentioned above. Similarly, in the context of European countries, FID has also been extensively studied on the basis of urbanisation and latitudinal gradients (Díaz et al., 2013; Samia et al., 2017), and also regarding the indirect disturbance caused by hunting, which is perhaps the strongest disruption of waterbird behaviour caused by humans (Madsen & Fox, 1995). However, in the context of African countries, empirical data and monitoring human-induced impacts on birds are very scarce; there are only a few published studies (Braimoh et al., 2018; Magige et al., 2009; Nyahongo, 2008; Tarakini et al., 2014) and to date none that we are aware of in a North African context. This is of paramount importance, firstly because the region is subject to uncontrolled urbanisation (Brahmia et al., 2021), which is undoubtedly one of the main drivers of the current global biodiversity crisis (McDonald, 2008), and secondly its population is growing rapidly which increase the trade-off between sustainable environment, nature conservation and development interests.

In fact, the core aim of this pioneer study is dealing with the framework of understanding how waterbirds react to human disturbance in a North African context. Thereby, this treatise aims to determine the impact of the following factors on escape distances variability: (1) the area where waterbirds were studied (protected wetlands versus unprotected ones) (2) temporal scale (early winter versus late winter) (3) distance at which the observer starts approaching the sampled birds (4) interspecific differences in body size (5) flock size (6) species composition of the flock (conspecific versus heterospecific group) and (7) foraging activity (feeding versus resting).

2 | METHODS

2.1 | Study area

The Mekhada marsh (RAMSAR site) (36°47'16.26''N, 8°00'33.40''E) with a total surface area of 16,000 ha is a freshwater marsh of the north-eastern coastal region of Algeria (Khemis et al., 2017). Almost 90% of the area is covered by halophytes and aquatic plants dominated by *Scirpus lacustris*, *S. maritimus*, *Phragmites australis*, *Typha angustifolia*, *Myriophyllum spicatum*, *Lemna minor* and *Ranunculus baudotii* (De Bélair & Bencheikh Le Hocine, 1987). In all its sectors, this marsh is frequented by a very significant number of waterbirds, probably exceeding 50,000 individuals during the winter season (Khemis et al., 2017). This wetland is embedded into an agricultural and urbanised matrix, and it is crossed by the national road number 44 linking Algeria with Tunisia (Figure 1).

Sebkhet El-Mahmel (the Arabic word 'Sebkhet' is consistently used in Algeria and Tunisia to indicate a saline marsh) (35°23'39.60''N, 7°19'53.57''E) with 950 ha is a saline marsh located in the heart of the Northern Algeria's wild and arid land (high land), Khenchela District (Figure 1). This natural wetland comprised different aquatic plants and surrounded by several cereal crops and harbours an important avifauna (Bouakkaz et al., 2017).

2.2 | Flight distance

We adopted the following protocol for recording flight initiation distances. When an individual bird has been located, the observer, while looking at the bird, should move to a normal walking speed (±3 km/h)

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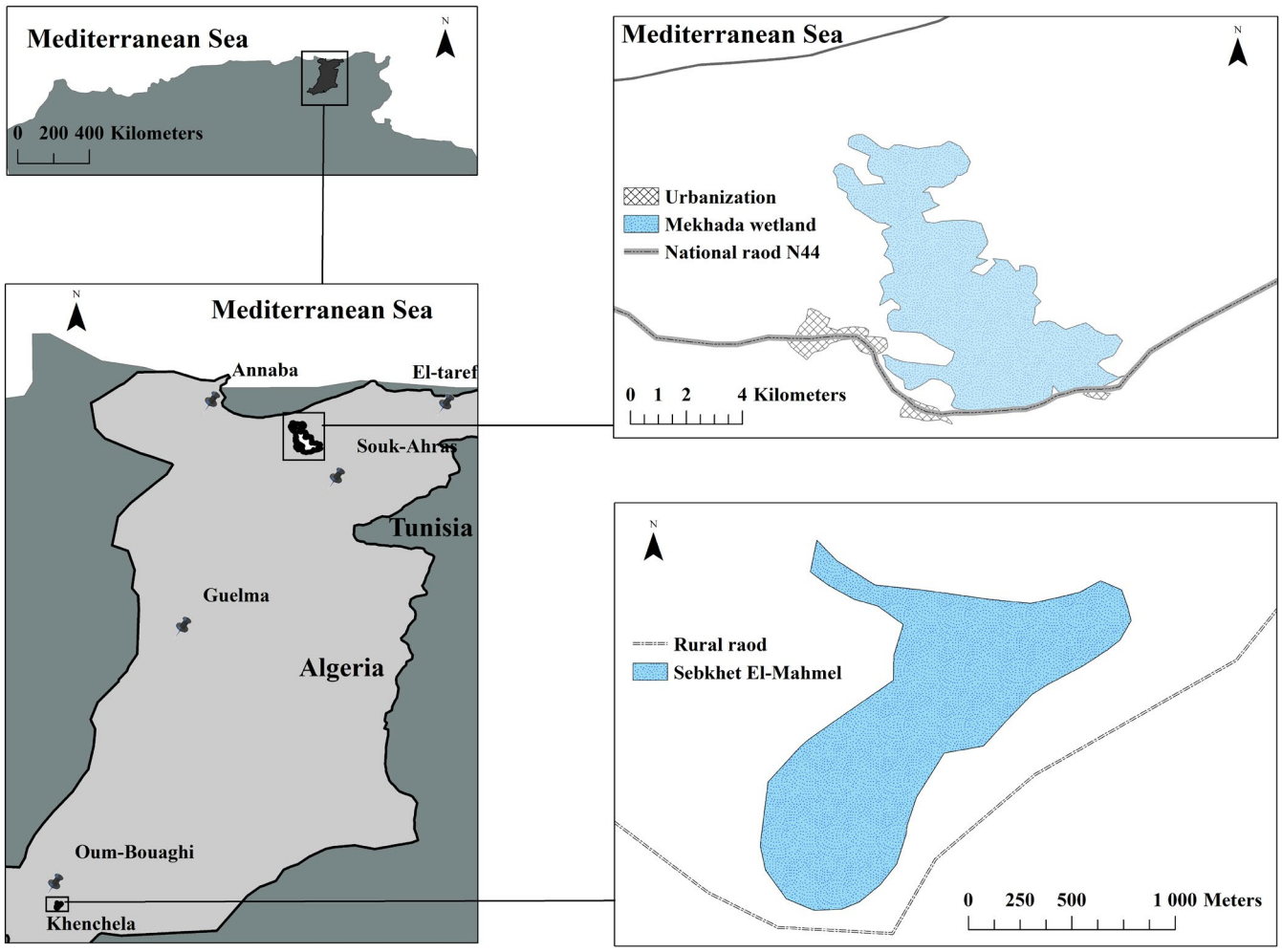

FIGURE 1 Location of the two study sites across North Africa

towards the individual, while recording the number of steps (which approximately equals the number of metres) (Møller, 2010). The person approaching the animals was the same each time and approached at a similar pace (normal walking pace) each time.

The distance at which the individual takes flight is defined as flight initiation distance, while the starting distance is the distance from where the observer started walking up to the position of the bird (Blumstein, 2006b; Anders Pape Møller, 2010). We sampled only species and individuals which we are able to reach their initial location.

2.3 | Statistical analyses

Statistical analyses were performed using PASW Statistics for Windows version 25 (IBM Corp. Released 2017). To fit the regression modelling assumptions (normality of variables and homogeneity of variance), we proceeded to transform the variables when appropriate (FIDs were square root transformed and starting distances were Log transformed). Univariate analyses of variance and linear regression models were used, using $p < 0.05$ as significant. In the modelling process, FIDs were included as the dependent variable, starting distance as a covariate variable, and (1) the area where waterbirds were studied (2) temporal scale (3) interspecific differences in body size (4) flock size (5) species composition of the flock and (6) foraging activity (feeding versus resting) were included as independent factors.

3 | RESULTS

3.1 | Flight initiation distance

During the time frame of the study, we recorded 866 individual FIDs for 19 waterbird species wintering at two north Algerian wetlands (Table 1). Our focal species differed in their mean escape distances, the obtained FIDs ranged from 32.6 m to 167 m. Species with the shortest escape distances, less than 40 m were Kentish plover *Charadrius alexandrinus* and common moorhen *Gallinula chloropus*, while species with the longest escape distances, greater than 130 m were ruddy shelduck *Tadorna ferruginea* and Grey Heron *Ardea cinerea* (Table 1).

TABLE 1 Mean flight initiation distance (m) with the standard error for the most common waterbird species sampled at Mekhada marsh and Sebkhet El-Mahmel

Families	Species	Scientific names	Number of records	FID	SE
Anatidae	northern shoveler	*Spatula clypeata*	74	94.6	1.2
	eurasian wigeon	*Mareca penelope*	24	99.5	2.5
	eurasian teal	*Anas crecca*	32	86.0	1.8
	common redshank	*Tringa totanus*	82	61.5	1.3
	mallard	*Anas platyrhynchos*	48	105.7	2.3
	common shelduck	*Tadorna tadorna*	32	97.3	2.3
	ruddy shelduck	*Tadorna ferruginea*	24	167.0	4.8
Ralidae	common moorhen	*Gallinula chloropus*	42	30.0	3.1
	western swamphen	*Porphyrio porphyrio*	38	111.3	1.5
	eurasian coot	*Fulica atra*	80	82.2	1.9
Ardeidae	grey heron	*Ardea cinerea*	26	134.7	2.7
	little egret	Egretta garzetta	26	60.0	2.3
Scolopacidae	common snipe	Gallinago gallinago	44	57.0	3.9
	eurasian curlew	*Numenius arquata*	24	117.0	1.6
Recurvirostridae	black-winged stilt	Himantopus himantopus	44	62.7	2.0
Charadriidae	northern lapwing	Vanellus vanellus	80	88.8	2.0
	kentish plover	Charadrius alexandrinus	42	32.6	1.4
Phoenicopteridae	greater flamingo	*Phoenicopterus roseus*	62	97.6	3.1
Threskiornithidae	glossy ibis	*Plegadis falcinellus*	42	71.8	2.1

TABLE 2 Complete model of both FID and AD against all factors (Univariate Analysis of Variance)

Factors	Sum of Squares	*df*	*F*	*p*	Effect size
Corrected Model	3594.29	24	164.61	<0.001	0.82
Species	126.40	17	8.17	<0.001	0.14
Locality	156.79	1	33.11	<0.001	0.04
Seasons	43.96	1	48.32	<0.001	0.05
Composition of the flock	66.55	1	13.76	<0.001	0.02
Activity	7.60	1	8.35	0.003	0.01
Starting distance	1316.91	1	1447.50	<0.001	0.62
Body masse	1110.23	1	302.67	<0.001	0.25
Flock size	5.84	1	6.42	0.010	0.01
Error	791.51	870			

Note: The model had the statistics $F = 164.61$, $df = 24$, $p < 0.000$, $r^2 = 0.82$. The effect size was the Partial Eta squared.

3.2 | Factors affecting response to disturbance

3.2.1 | Spatial and temporal scale

The analysis of variance revealed a significant effect of starting distance, wetland status and taxonomy on flight distance (Table 2). Most variation was related to starting distance (higher effect size 0.62), flight initiation distance increased significantly with increasing starting distance (Figure 2, $R^2 = 0.77$), with additional effect of wetland location differences (Table 2). Waterbirds of the same species wintering in RAMSAR sites (Mekhada marsh) had consistently shorter flight distances than those wintering in unprotected sites (Sebkhet El-Mahmel) (Figure 3; $p < 0.001$ under *Bonferroni* pairwise comparison weighted by sample size). Species that are the most influenced by wetland categories are presented in Figure 4. The mean flight distance differences between unprotected and protected wetlands (mean FIDs of the unprotected population minus mean FIDs of the RAMSAR site population) was + 24.77 m (SE = 0.36), for example the Northern lapwing flee at 126.25 m from an approaching intruder in the unprotected wetland and at 79.44 m in the RAMSAR site (Figure 4).

Between seasons, we noticed a significant seasonal effect on escape distances among species (Table 2). Waterbirds modified their

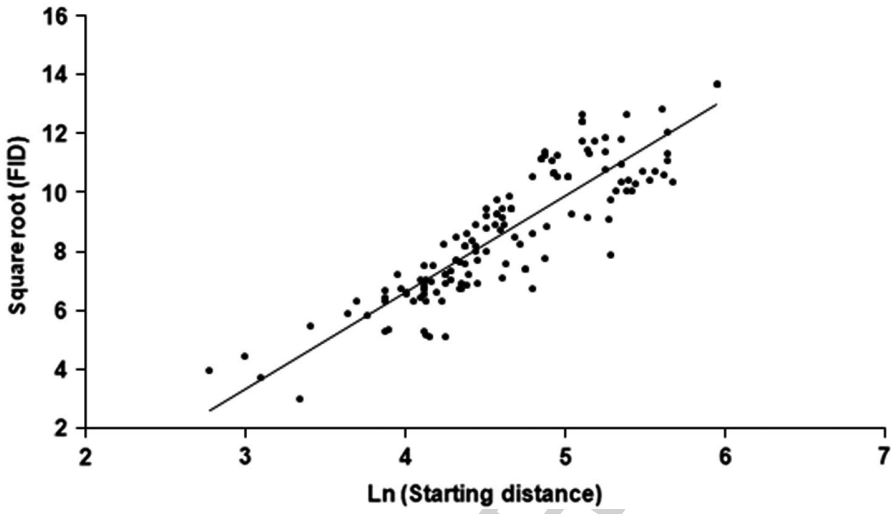

FIGURE 2 Flight initiation distance in relation to starting distance (y = 3.261x - 6.397; $R^2 = 0.776$, $p < 0.001$)

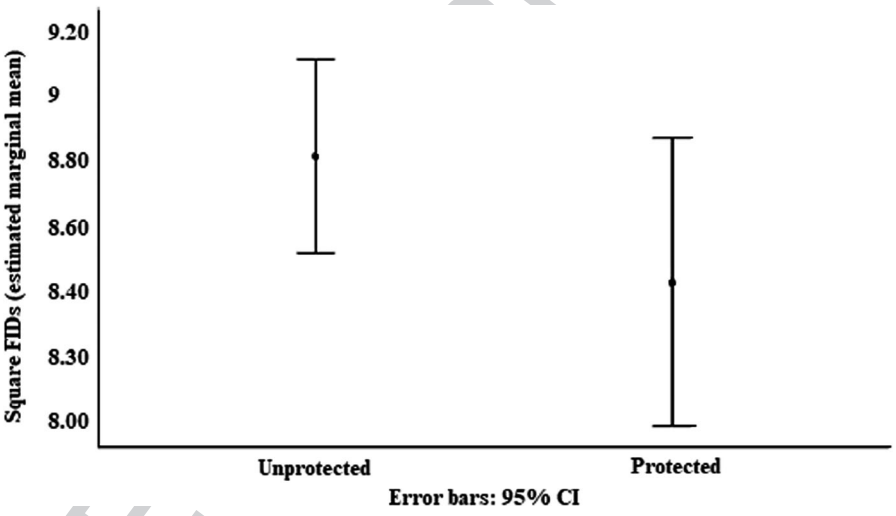

FIGURE 3 Mean flight distance (square root transformed) of the most common waterbirds in relation to the wetland conservation status

FIDs in response to seasons in the direction that FIDs decrease in early winter and increase in late winter (Figure 5).

3.2.2 | Body mass, flock size, flock composition and foraging activity

We found a positive and significant correlation between body mass and FID ($r^2 = 0.12$, $F = 107.21$, $p < 0.001$); smaller species had a shorter escape distance and between FID and flock size ($r^2 = 0.10$, $F = 89.42$, $p < 0.001$); smaller flocks had a relatively shorter FID (Figure 6).

Flocks composition has also a significant effect on escape distance of waterbirds (Table 2). Individual birds tend to have shorter FIDs if they belong to the same species and have longer FIDs in larger heterospecific flocks (Figure 7).

For comparison between feeding and resting activities, FIDs were significantly affected by the bird activity (Table 2). The sampled waterbird species tend to have a lower escape distance when feeding (Figure 8).

4 | DISCUSSION

Through this study, we have established the first global look at how waterbirds react to human disturbance in the North African wetlands. In general, our findings corroborate the optimal escape theory, which states that species or individuals of waterbirds did not react similarly to human disturbance, they adjust their behavioural decisions to different circumstances (Blumstein, 2003; Bregnballe et al., 2009; Livezey et al., 2016; Møller, 2010; Morelli et al., 2019; Price, 2008).

Firstly, we found that the area where waterbirds were studied influenced the overall distance at which they fled an approaching human. We recorded a significantly lower FID in the RAMSAR site (Mekhada marsh) compared with the unprotected site (Sebkhet El-Mahmel). This difference might be due to the factors surrounding each site. Both of them faced different environmental circumstances. The first site (Mekhada marsh) is embedded into an agricultural and urbanised matrix (Khemis et al., 2017). This coastal marsh facing excessive pressure (higher pedestrian traffic rate) since it is in a tourist region leading eventually to more frequent disturbances.

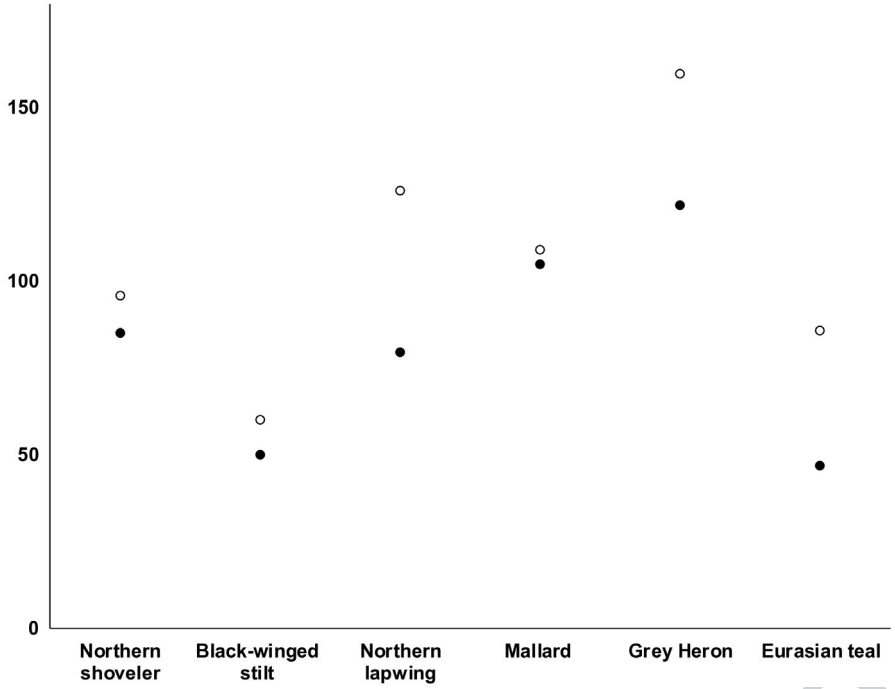

FIGURE 4 Mean flight distance of six waterbird species the most influenced by wetland categories (unprotected wetland versus RAMSAR site)

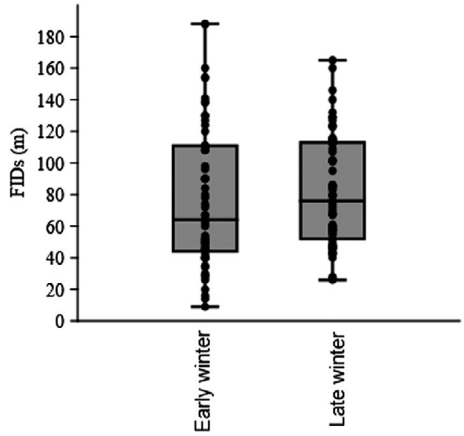

FIGURE 5 Seasonal patterns of flight initiation distance. Quartile method with the standard error is shown. Sample size (Early winter = 310 records, late winter = 585)

Additionally, the national road (NR 44 see Figure 1) leading to Tunisia (the most attractive country for Algerian tourists) runs through its southern part where millions of passengers travel annually, while the second site (Sebkhet El-Mahmel) is a small wetland more wilderness than the first one since it is located in the heart of the Northern Algeria's wild and arid land (high land), where human presence is very limited. This fact seems likely to have an even greater effect on animal wariness. Faced with this situation (higher or lower disturbance regime), waterbirds increasing tolerance to human presence in order to fit the urban characteristics (Piratelli et al., 2015). The propensity to habituate increased human disturbance (urbanisation) is an adaptation scenario in avian species including waterbirds (Møller, 2008). Several studies have demonstrated that individuals could be habituated to repeat human exposure, leading thereby to a significant reduction in their escape distances when approached by a human compared with rural or wilder populations (Blumstein, 2006a; Runyan & Blumstein, 2004). This behavioural plasticity allows birds to coexist with humans in specific areas such as urban and recreational areas (Møller et al., 2013).

Secondly, we found that temporal scale can also influence how waterbirds react to human disturbance. Our sampled species showed an increase in escape distances as the wintering season progressed. It is known that migratory birds start arriving at the studied sites early winter (Palearctic–African migration) (Elafri et al., 2016), these arrivals, often with higher ratios of juveniles, faced new environmental conditions different from which they came (breeding or wintering grounds), allowing thereby closer approach to the source of human disturbance despite the perceived threat it constitutes due to their inexperience at this time, as demonstrated for grey herons *Ardea cinerea* by Bregnballe et al. (2009). Another plausible explanation for the divergences we have observed between the different seasons is that during the seasons when high energy and nutrient input is required, such as early winter, animals pay heavier costs for foraging than wariness behaviour (Uchida et al., 2016).

Other results with respect to the confounding variables are also consistent with predictions of optimal escape theory: (1) Starting distance was positively related to FID consistent with many studies (Blumstein, 2003; Cooper, 2005; Geist et al., 2005) and it explains a large part of the variation in FID, confirming thereby that starting distances should be considered an important covariable to include in FID studies, as previously indicated by several researchers (Braimoh et al., 2018; Dumont et al., 2012). (2) We have found a significant positive linear correlation between mean FIDs and body mass variations across the focal bird species we sampled. The concept that interspecific differences in body size can influence the behavioural decisions of birds to human

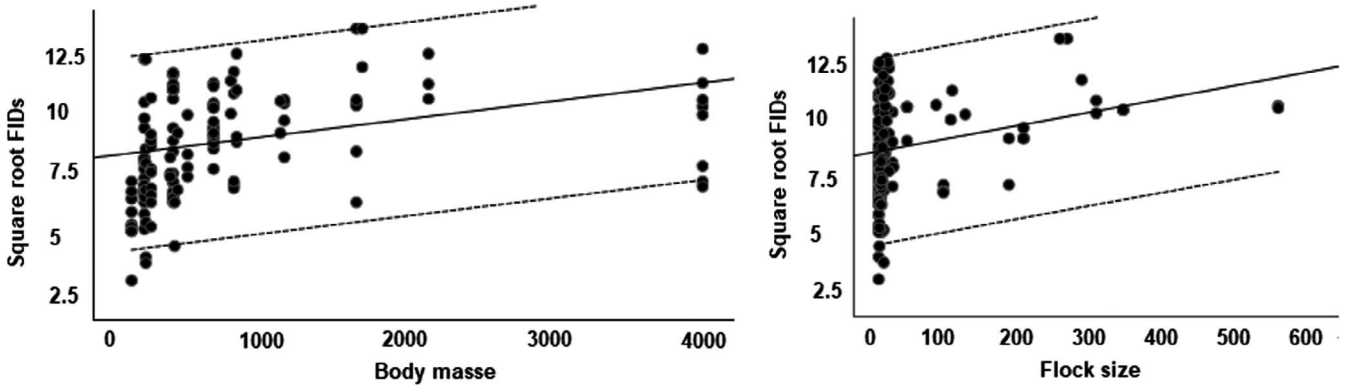

FIGURE 6 Linear regression for body mass (g) x FID and flock size x FID

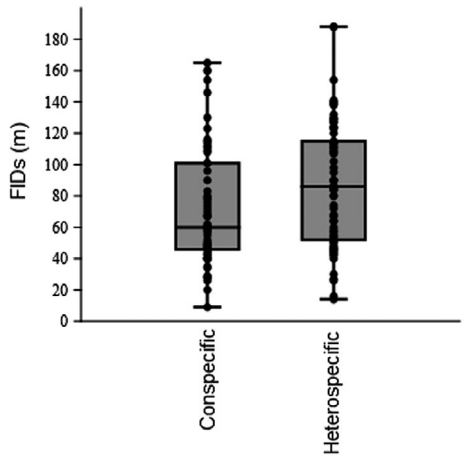

FIGURE 7 Mean flight distance (square root transformed) of the most common waterbirds in relation to the bird's population composition (Conspecific versus Mixed flock)

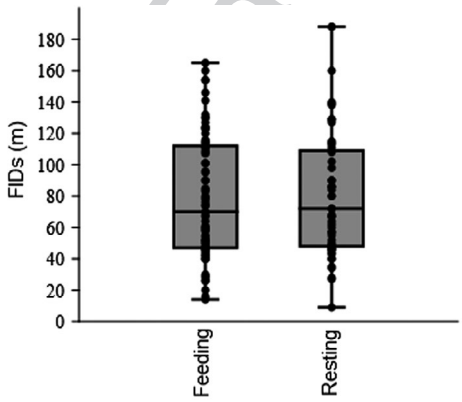

FIGURE 8 Mean flight distance (square root transformed) of the most common waterbirds in relation to the bird activity (Feeding versus Resting)

disturbance was confirmed by many studies to the extent that these species traits can be considered one of the foremost predictors of survival rates (Blumstein et al., 2005; Braimoh et al., 2018) and one of the major measured determinants of flightiness in birds (Blumstein, 2006a). Larger species are known to have the greatest escape distances than smaller birds thus under similar circumstances of disturbance benefits of early escape will be higher for large-bodied species than for smaller ones (Blumstein, 2006a). If larger birds are heavier and less agile, more conspicuous and less likely to depend on crypsis they would need for more space to take off compared to smaller birds (Blumstein et al., 2005; Borgmann 2010; Braimoh et al., 2018; Bregnballe et al., 2009). In addition, taller species might be better able to detect approaching intruder because they are less restricted by obstructive vegetation (Coetzer & Bouwman, 2017). Even though body size had a large and significant effect in explaining variation in flightiness, differences in other ecology and life history traits (Blumstein 2006a; Bregnballe et al., 2009) should also be taken into account in the context of envisaged improvements of our knowledge about the interspecific variation in FID among bird species. (3) Flock size was by far the next variable also affected when individuals respond to a disturbance. Our statistical model confirmed the positive association between FIDs variation and number of birds already shown in other studies (Morelli et al., 2019). Because a flight response by one individual (generally the most sensitive one in the flock) will often cause the entire group to take flight (the contagious fear hypothesis) (Morelli et al., 2019), and since larger flocks have more individuals scanning the surrounding environment which increased their capacity to detect any approaching intruder (the many eyes effect hypothesis) (Hingee and Magrath, 2009); consequently, large flocks tended to flee sooner than smaller flocks at the approach of a threat. (4) Species composition of the flock in the present study was also found to be somewhat contributing factors in determining escape distances in waterbirds. Mixed flocks had significantly longer escape distances than single species flocks, presumably due to the fact that flight response by the most sensitive species in the flock would directly affect the least sensitive one inducing eventually the entire group to take flight (Bregnballe et al., 2009; Morelli et al., 2019). (5) Finally, we found that the activity at which the bird engaged possibly affect the manoeuvrability of escape response. FIDs were reduced in individuals engaging in foraging activities compared with those engaged in resting behaviour. It is plausible that birds might have a decreased FID due to higher benefits of remaining feeding than

escape, especially in habitats with high food availability (Mayer et al., 2019), it is a trade-off between predation and starvation (Bonter et al., 2013).

In conclusion, understanding what factors affect escape behaviour in waterbirds is the cornerstone of a strong monitoring of human disturbance. It can be the most tangible tool for delineating appropriate buffer areas and can be of help in the design and discussion of management initiatives aimed at minimising eventual potential threat due to human disturbance and guaranteeing animal welfare and wildlife. In this study, we have picked up strong insights into all possible ideas relevant to how waterbird react against human disturbance in a North African context. We stated that differences in the absolute levels of FID were mostly related to starting distance confirming that it should be included in FID studies as a covariate to which is added a relatively little effect of wetland status, taxonomic differences, temporal scale, body size, flock size, species composition of the flock and the bird activity. This, however, does not prevent us from stressing some limitations that must be remedied in future studies, and new fronts are still being open. Escape distances in this study were stimulated by a single person thus data on other stimuli as larger parties of people (mainly fishermen) and agricultural machinery needed to be accomplished. Also, number of observations for each level of factors (species, habitats, season etc.) is unequal in the present study we assert therefore that future FIDs investigations should respect as much as possible an even sampling effort among all factors. Finally, for further similar studies we suggest recordings FIDs during the breeding season that could provide supplementary support in monitoring human disturbance.

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CONFLICT OF INTEREST

No financial support or benefits have been received by nor any individual or entity with whom or with which I have a significant relationship from any commercial source which is related directly or indirectly to the scientific work which is reported on in the article. Moreover, neither I nor any individual or entity with whom or with which I have a significant relationship has a financial interest in the subject matter discussed in the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available within the article, and supplementary data are available from the corresponding author, [EA], upon reasonable request.

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