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Trabajo Original

Risk-taking behavior in three *Fulica* species inhabiting an urban coastal lagoon in Mar del Plata city, Buenos Aires province, Argentina

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Abstract

1. Urbanisation is taking place globally at a rapid pace and is generally linked to negative impacts on biodiversity at local, regional, and global scales. Evaluating the behavioural response profiles to urbanisation helps identify which species show adaptive responses to changing landscapes and are thus more or less likely to persist in such environments.

2. For this, we experimentally approached and measured associated flight initiation distance (FID) in three taxonomically related aquatic bird species (*Fulica leucoptera*, *F. rufifrons* and *F. armillata*) inhabiting an urban wetland located in the large coastal city of Mar del Plata, Buenos Aires province. We also assessed how environmental, ethological and anthropic variables affected this behaviour for the overall studied coots.

3. Pooled together, coots' FID ranged from 3.0 to 18.7 m and showed no statistical differences between species.

4. The mean FID estimated for all coot species combined was only affected by wind direction, with wind blowing from the south being the most important environmental stressor affecting coots' FID.

5. When considering each coot species separately, the abundance of conspecifics also affected FID in *F. rufifrons*, decreasing it by half.

6. Implications. Overall, the studied coot species exhibit a passivity to the disturbance exerted by a pedestrian approach, given their relatively short flight initiation distances. This finding is in line with available research on other aquatic bird species dwelling in urban ecosystems, suggesting that certain waterbird taxa may be pre-adapted to persist in urbanised environments.

[Keywords: coot, disturbance, flight initiation distance; Buenos Aires province, Argentina]

Resumen. Comportamiento de riesgo de tres especies *Fulica* que habitan una laguna costera urbana en la ciudad de Mar del Plata, provincia de Buenos Aires, Argentina

1. La urbanización avanza a un ritmo acelerado a nivel mundial y, por lo general, se asocia con impactos negativos sobre la biodiversidad a escalas local, regional y global. Evaluar los perfiles de respuesta conductual a la urbanización ayuda a identificar qué especies muestran respuestas adaptativas a los paisajes cambiantes y que, por tanto, son más o menos propensas a persistir en dichos entornos.

2. Para tal fin, nos aproximamos experimentalmente y medimos la distancia de inicio del vuelo (FID) en tres especies de aves acuáticas taxonómicamente relacionadas (*Fulica leucoptera*, *F. rufifrons* y *F. armillata*) que habitan un humedal urbano ubicado en la gran ciudad costera de Mar del Plata, provincia de Buenos Aires. También evaluamos cómo las variables ambientales, etológicas y antrópicas afectaron este comportamiento para el conjunto de las gallaretas estudiadas.

3. En conjunto, la FID de las gallaretas varió de 3.0 a 18.7 m y no mostró diferencias significativas entre especies.

4. La FID media estimada para todas las especies de gallaretas solo se vio afectada por la dirección del viento, siendo el viento que sopla desde el sur el factor de estrés ambiental más importante.

5. Al considerar cada gallareta por separado, la abundancia de congéneres también afectó la FID en *F. rufifrons*, reduciéndola a la mitad.

6. Implicancias. En general, las especies de gallaretas estudiadas muestran pasividad ante la perturbación causada por la aproximación de un peatón, debido a su FID relativamente bajo. Esto concuerda con los hallazgos disponibles en otras especies de aves acuáticas que habitan ecosistemas urbanos, sugiriendo que ciertos taxones de aves acuáticas podrían estar preadaptados para persistir en entornos urbanizados.

[Palabras clave: gallareta, disturbio, distancia de iniciación al vuelo, provincia de Buenos Aires, Argentina]

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Introduction

Vulnerability to human activities is directly related to species distribution and habitat use, but also to species-specific features, including behavior (Møller 2008; Møller and Garamszegi 2012). Disturbance is defined here as a consequence of responses of an animal to stimuli, such as a potential predator or a human (Weston et al. 2012), and may vary from direct impacts such as habitat alteration, hunting or persecution (Brawn et al. 2001) to indirect effects including introduction of non-native species (Gill 2007; Kerbiriou et al. 2009). In many areas of the globe, urban ecosystems such as forests, green roofs, community gardens, wastelands and shallow lagoons are known to host important localized habitats in terms of their ecological values (Bolund and Hunhammar 1999; Berkowitz et al. 2003); however, they may increase threats to individuals, populations and communities if not properly controlled or managed (Kowarik 2011; Stanley et al. 2015). Disturbance of wildlife is an intrinsic issue that most urban ecosystems are currently facing (Sukopp and Starfinger 1999; Markovchick-Nicholls et al. 2008). Not surprisingly, urban ecosystems and their wildlife are of special interest for outdoor recreational activities as they allow the public to interact with nature, thus attracting many visitors and have been identified as an important growth area for human well-being within some regions (Barton and Pretty 2012; Douglas 2012; Remme et al. 2021). In human disturbance investigations using birds as case studies, it is important to understand that the distance at which individuals react to the presence of humans provides a standardized assessment of the risk that an animal is willing to take when encountering a potential predator (Blumstein 2003, 2006; Weston et al. 2012).

The probability of a response of a bird is inversely related to the distance between the animal and stimulus (Weston et al. 2012). Thus, the distance at which individuals react to the presence of humans is a useful trait for conservation purposes as it serves for planning and distributing spatial use and setting buffer areas (i.e., areas of minimum approach distance of visitors to birds) (Fernández-Juricic et al. 2001a; Livezey et al. 2016). Most reported responses of birds to disturbance are behavioral and, though they may take many forms, can be broadly divided into vigilance (e.g., the bird stops current activity and shows alert behavior towards an approaching potential predator such as a human; Fernández-Juricic et al. 2001b) and flight responses (e.g., the bird escapes on foot or flies away, or swims including diving; Stankowich and Blumstein 2005).

Response to disturbance varies by species (both intra- and interspecifically) (Weston et al. 2012), by body size (Blumstein 2006), flock size (Yasué 2005), food availability (Goss-Custard et al. 2006), distance to other suitable foraging areas (Dias et al. 2006), time of day (Sitters et al. 2001), and season (Stillman and Goss-Custard 2002). In addition, response to disturbance can be modified by type and frequency of disturbance (Pease et al. 2005), angle (Rodgers and Smith 1997) and speed of approach (Lethlean et al. 2017), nature of stimulus (Bernard et al. 2018), and behavior of the approaching human (Radkovic et al. 2019).

Regarding birds, several studies have demonstrated adverse effects of human disturbance on different behavioral and reproductive parameters (Fernández-Juricic 2002; Møller 2008; Kang et al. 2015; among others). Still, available literature strongly suggests that disturbance from recreational activities in urban ecosystems may have at least contemporary effects on the behavior and movement of birds within a habitat or localized area (Burger 1981; Rodgers and Smith 1997), and even some groups of birds may show a positive response to urbanization in terms of their productivity (Chamberlain et al. 2009; Kettel et al. 2018). Regardless, and depending on the species (especially migrants vs. residents), some birds may habituate to different types of recreational disturbance and either not be disturbed or immediately return after the initial disturbance (Madsen 1995; Guay et al. 2013; Villanueva et al. 2014). In fact, birds inhabiting urban ecosystems may be more tolerant to human disturbances than rural congeners and/or less disturbed populations (Bonier et al. 2007; Samia et al. 2015).

Few studies concerning the response to humans by vertebrate taxa, particularly birds, have been reported in Argentina (Steven et al. 2011), a country currently holding a large myriad of urban ecosystems given that more than 90% of its population lives in urban areas (Gamundi 2025). In northern Argentine Patagonia, studies reporting the behavioral responses of diverse species of birds to human disturbance are restricted to coastal natural protected areas (Yorio and Quintana 1996;

Walker et al. 2006; Cossa et al. 2016; among others). Less information is available for urban ecosystems located within large cities like Mar del Plata, a coastal metropolitan area located in the southeastern corner of Buenos Aires Province, Argentina, the latter being the largest Argentine province both in terms of its surface and number of inhabitants. Thus, the Mar del Plata area represents a good model to study human-wildlife interactions given that it holds a number of different types of urban ecosystems, particularly along its coasts including the Punta Mogotes lagoon complex; the latter concentrates more than 40% of tourism on the coast of Mar del Plata (Richeri 2011; Romero and Fernández 2024).

In order to expand the knowledge about the theory of anti-predator behavior to better understand and predict how species might respond to humans, here we present data on the risk behavior undertaken by three species of taxonomically related aquatic birds, all pertaining to the *Fulica* genus, which have historically been described as amongst the most abundant and widespread year-round resident birds in relation to other aquatic birds within the Punta Mogotes lagoon complex (De Marco et al. 2005). In this study, we present 1) pre-disturbance activity; 2) flight initiation distances and responses to disturbances, and 3) minimum approaching distances and buffer areas in three coot species co-inhabiting the Punta Mogotes lagoon complex, in the city of Mar del Plata.

Materials and Methods

Study area and species

The study area encompassed the Punta Mogotes lagoon complex (38°03’ S - 57°32’ W), located within Mar del Plata city, General Pueyrredon district, in the southeastern region of Buenos Aires province, Argentina. This lagoon system, listed as a locally protected area (Municipal Ordinance No. 11038/97), consists of four interconnected shallow lagoons (<2 m deep) arranged parallel to the coastline (Figure 1). The lagoon complex is located within an urban area where a diverse range of human activities (i.e., commercial

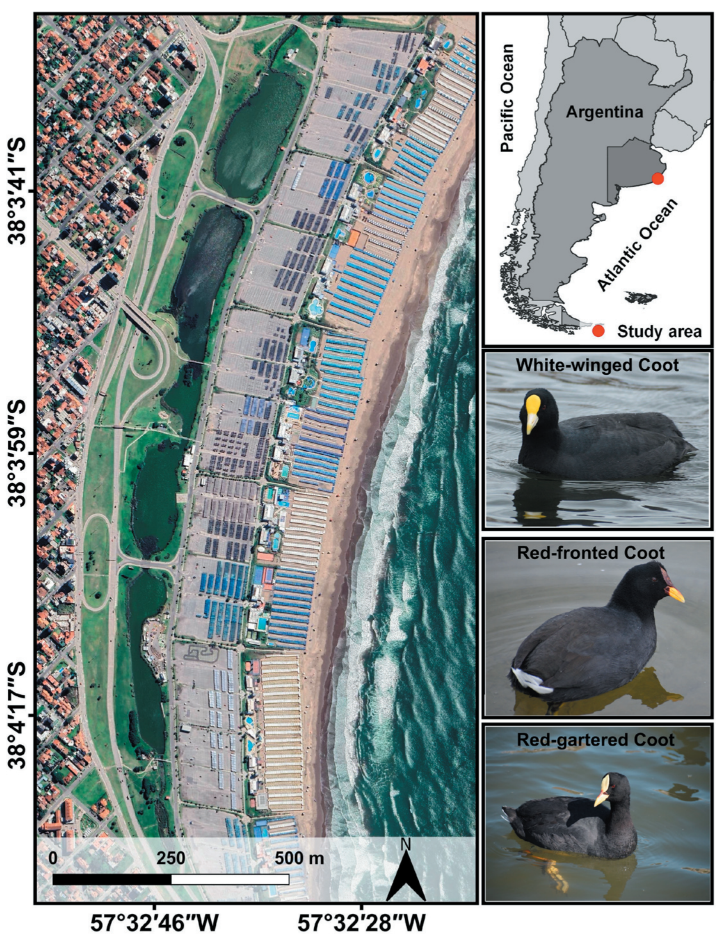

Figure 1. Punta Mogotes lagoon complex, General Pueyrredon district, Buenos Aires province, Argentina (study area). Species under study: white-winged coot (*F. leucoptera*), red-fronted coot (*F. rufifrons*) and red-gartered coot (*F. armillata*). Photo credits: M. M. Hernandez.

Figura 1. Complejo laguna Punta Mogotes, partido de General Pueyrredon, provincia de Buenos Aires, Argentina (área de estudio). Especies en estudio: gallareta chica (*F. leucoptera*), gallareta escudete rojo (*F. rufifrons*) y gallareta ligas rojas (*F. armillata*). Crédito de las fotos: M. M. Hernandez.

port, industrial, commercial, tourism-related) take place in its surroundings (De Marco et al. 2005). With regard to the lagoon complex, a great diversity of recreational activities take place there, with those related to leisure and sports (e.g., walking, jogging, bicycling) being the most frequent. Thus, this area is used year-round by an important number of visitors, with a significant increase during the austral summer months and holiday periods (Richeri 2011) (puntamogotes.gob.ar/web). In terms of biodiversity, both the study area and the adjacent Provincial Nature Reserve (Provincial Law No. 14688) host a wide range of organisms, including amphibians, reptiles, fish, birds, and mammals that use the area throughout the year. Among birds, waterbirds (e.g., coots, geese, ducks) are the most prominent group within the study area (De Marco et al. 2005).

The studied birds included three species of coots: white-winged coot (*Fulica leucoptera*), red-fronted coot (*F. rufifrons*), and red-gartered coot (*F. armillata*); species recorded co-occurring throughout the year in the Punta Mogotes lagoon complex (De Marco et al. 2005). These species are small-sized, dark-plumage birds, herbivorous and feed by grazing mainly on shallow waters, although they may also include insects, mollusks, and even crustaceans in their diets (García et al. 2008; Olguín et al. 2013; Velásquez et al. 2019). See more in Supplementary Material 1. The breeding periods of these species typically begin in August, with peak egg-laying occurring in December and January (Salvador 2012; Echevarría et al. 2022). Although no active nests have been recorded to date, juvenile birds of the three coot species have been observed in some breeding seasons making use of the study area (personal observation JPSP, MPB).

Data collection

Flight initiation distance. In a pilot study, we found that an observer could estimate alert behaviors of coot species at least up to 40 m. One of the authors (A.I.) gathered all the data. We conducted the pilot study in a previous season (between mid-September and mid-December 2023) in the area used for collecting data subsequently. Still, we began to approach birds from a pre-established starting distance (40 m) constant for all birds, aided with a digital rangefinder (Bushnell Pro Sport 412 m, accuracy ± 1 m), thus avoiding variability in flight initiation distance associated with fluctuating starting distance (Rodríguez-Prieto et al. 2009). Alert distances were measured as the distance at which birds showed alert behavior towards approaching pedestrians (see Fernández-Juricic et al. 2001b). The observer dropped a marker when the focal individual became alert or flushed. We assessed the flight initiation distance (hereinafter FID) as the point at which the bird flushed away from the approaching observer. Focal individuals were not marked; instead, we recorded responses to our approaches from randomly selected locations within the studied sites to reduce the likelihood of sampling the same individual.

Birds tallied at the beginning of the experimental approaches showed a likely population of 183 white-winged coots, 56 red-fronted coots, and 253 red-gartered coots at the study area. Measuring FID distances from unmarked individuals of the same population has been previously reported in the literature, in particular for herbivorous bird species (Madsen et al. 2009; Glover et al. 2011). From mid-September to mid-December 2023, a total of 90 experimental approaches towards coots were made (n=30 approaches per coot species), where FID distances and other behaviors were recorded (see below). The order and time of day in which the samplings were conducted were assigned randomly, with at least a one-day interval between visits to the site, including weekends. We did not collect two observations from the same focal individual from contiguous sites (with contiguous sites separated by 300 m from each other) in order to avoid affecting responses between approaches (Fernández-Juricic et al. 2001b, 2004). We approached selected individual birds taking the precaution that no other person was within 40 m of the focal individual, and that the selected bird did not show any type of alert behavior before the approach (see Fernández-Juricic et al. 2001a). All individuals approached were on the ground; hence we excluded birds flying or on water surfaces. Pre-disturbance activity was determined before commencing the approach (i.e., foraging, self-maintaining, resting, or agonistic behavior). When the observer began approaching a group of birds, with a steady pace (approximately one step per second), he/she focused on a single individual within the group chosen before the approach, though we also registered the number of attending conspecifics. The approach was linear and continuous with no obstacle preventing the observer and bird from seeing each other (Fernández-Juricic et al. 2004). The observer measured reaction distances with a measuring tape (±0.01 m). The cardinal direction from which one of the authors (A.I.) advanced from his/her initial position towards the focal individual was aligned with the opposite wind quadrant from which the wind was blowing at the time of the sampling. Once the focal individual had fled, we recorded several environmental, ethological, and anthropic variables during a five-minute period within the area. Ethological variables included the abundance (i.e., total number of individuals) of coots pertaining to 1) the focal species (hereby conspecifics), and 2) other non-focal coot species (hereinafter heterospecifics). Anthropic variables encompassed the abundance of dogs (both supervised and non-supervised), users (pedestrians, joggers, and cyclists combined), and motor vehicles (number of motorcycles, cars, and trucks). Although Gompper (2014) previously identified two ecotypes of dogs, here we considered this category to include both supervised domestic dogs (i.e., dogs with or without a leash accompanied by their owner/s) and unsupervised dogs (i.e., dogs roaming freely). Environmental variables included air temperature (°C), wind intensity (km/h), and wind direction (from two quadrants: North and South). The latter variables were all retrieved from the hourly weather report provided by the Mar del Plata airport weather station, and adjusted to the local time of our samplings.

<u>Approach distance and buffer areas</u>. Areas where human activity is restricted, thus, to reduce human disturbance on wildlife —often termed buffer areas— are created by managers focused on trying to maintain species diversity within certain areas (Madsen et al. 1998). Such buffer areas can be estimated with a formula based on empirical estimates of the distance at which humans disturb birds (or other animals) (Rodríguez-Prieto et al. 2009). In order to develop buffer areas, researchers or managers first assess the distance at which humans should be kept from wildlife (known as minimum approaching distance), and then the areas where humans should not trespass to avoid displacing wildlife (known as buffer areas) (Fox and Madsen 1997; Rodgers and Smith 1997). We used the methods described in Fox and Madsen (1997) to estimate minimum approaching distances and buffer areas for each coot species. The minimum approaching distance was calculated as three times the mean FID. The minimum approaching area was estimated as $\Pi * (1.5 * \text{FIDm})^2$, where FIDm is the mean FID (Fox and Madsen 1997). Though other methods exist (see Guay et al. 2016 and references therein), this method assumes that the probabilities of an individual becoming alert and/or fleeing from disturbance are equal in all directions at any given time, habitat quality does not vary throughout the study system, and an individual's use of the buffer area is equal and constant to the carrying capacity of the study system (Fox and Madsen 1997). The estimated area was considered to have a circular shape.

Data analysis

To investigate the variation in the type of important daily activities (based on presence/absence data) among coot species, a Chi-square test was performed. Due to the presence of low expected frequencies ($n<5$) in some cells of the contingency table, the P-value was computed using Monte Carlo simulations (based on 2000 replicates) to ensure the robustness of the results; the function chisq.test from the R-base stats package was employed. Following the detection of significant global differences, a post-hoc analysis was conducted using standardized Pearson residuals. Residuals with an absolute value greater than 1.96 were considered statistically significant, corresponding to a 95% confidence level. Additionally, pairwise comparisons of proportions were performed with Bonferroni correction to adjust P-values for multiple comparisons, employing the rcompanion package version 2.5.2 (Mangiafico 2020). We used a Pearson correlation analysis to evaluate the relationship between alert distance and FID. Previous studies have suggested a significant correlation between these metrics among birds (Fernández-Juricic et al. 2001b; Blumstein 2003). In our case this happened only with white-winged coot (Pearson $r=0.167$, $P=0.028$), but not with red-fronted coot (Pearson $r=0.249$, $P=0.062$) or red-gartered coot (Pearson $r=0.343$, $P=0.118$). Still, all statistical analyses were conducted using only FID. Hence, alert distances were excluded as covariates in all models. Nonetheless, there is scarce information regarding AD values for coot species dwelling in the Southern Hemisphere (Livezey et al. 2016) (Supplementary Material 2-Table S1). We used a one-way ANOVA to investigate the effect of studied species on the mean FID. The rationale for this approach was that FID could be used to achieve conservation measures that may reduce human disturbance on overall and/or separate coot species.

Generalized Linear Models (GLM) with Gaussian error structure and identity link function were used to evaluate the effect of environmental, ethological, and anthropogenic variables on the flight initiation distances of coot species (Crawley 2007) using the R-package stats version 4.3.0 (R Development Core Team 2023). Four models were performed: one for all three coot species pooled together and one for each coot species separately. To identify potential correlations between predictor variables, a ggcor matrix plot was used employing the GGally package version 2.1.2 (Schloerke et al. 2021). All predictor variables showed low correlation values ($-0.5<\text{rho}<0.5$), and hence were included in the model selection process. Thus, in all models we tested the following fixed environmental variables: temperature (continuous variable), wind force (continuous variable), and wind direction (categorical variable: wind direction S and N); fixed anthropogenic variables (all discrete variables): numbers of dogs, users, and vehicles; and fixed ethological variables (all discrete variables): conspecific and heterospecific abundances. For the model comprising all coot species, the model also incorporated coot species as a fixed variable (categorical variable: white-winged, red-fronted, and red-gartered coot). The fit of models was checked using DHARMa diagnostic plots employing the DHARMa package version 0.4.6 (see Hartig 2022).

All statistical analyses were carried out using R software version 4.3.0 (R Development Core Team 2023). All tests were two-tailed with a significance level of $P \leq 0.05$. Maps were created using QGIS software version 3.22.11 (QGIS Development Team 2022).

Results

Occurrence of selected activities

Overall, all three coot species spent 52.2% of observation bouts in foraging, 31.1% in self-maintaining, 13.3% in resting, and 3.3% in agonistic interactions (Supplementary Material 2-Table S2). Of these, overall allocations were negatively correlated (feeding and self-maintaining: Pearson $r=-0.704$, $P=0.496$; feeding and resting: Pearson $r=-0.411$, $P=0.169$; and self-maintaining and resting: Pearson $r=-0.259$, $P=0.067$). Significant differences were found in behavioral activities among coot species ($\chi^2=14.27$, $P=0.005$, Pearson's Chi-squared test with 2000 Monte Carlo simulations). Analysis of the Pearson standardized residuals (Supplementary Material 2-Table S3) revealed that these differences are primarily driven by the red-gartered coot, which showed a significant positive association with self-maintaining (residual=2.14). The post-hoc proportion comparison test with Bonferroni adjustment revealed that the red-gartered coot exhibits a significantly higher frequency of self-maintaining than the white-winged coot ($P<0.01$), but shows no significant differences compared to the red-fronted coot ($P=0.28$). Humans (pedestrians, joggers, and cyclists) other than researchers were in relative proximity to focal coots on 70.3% of occasions (maximum of three pedestrians or joggers and 10 cyclists), and conspecifics were in relative proximity on 71.4% (maximum of 63 birds) of occasions.

Coot responses to experimental disturbance

Almost all birds (94.5%) were relatively disturbed and moved when disturbed. They responded to the experimental approach chiefly by moving on foot but staying in the proximity of the observer (63.9%) or by flying toward some water source (24.4%) (Supplementary Material-Table S4).

Flight initiation distances

The FID of all three coot species ranged between 3.0 and 18.7 m (Figure 2). This variation was not significantly different between coot species (ANOVA $F=0.07$, $P=0.936$). The minimum and maximum FID of the white-winged coot ranged between 4.8 and 18.2 m (mean±SD=11.6±3.7 m), while in the case of the red-fronted and the red-gartered coots this metric ranged between 4.2 and 18.7 m (mean±SD=11.4±3.9 m) and between 3.0 and 18.1 m (mean±SD=11.2±4.0 m), respectively (Figure 2).

Effect of environmental, ethological and anthropogenic stressors

The model comprising all coot species showed a good fit of the data, with non-significant dispersion ($P=0.390$). Wind blowing from the south was the only variable affecting overall coots' FID (GLM, $t=2.82$, $P<0.01$), increasing it threefold (Table 1). When considering each coot species separately, the models also showed a good fit of the data, with non-

Table 1. Model coefficients for predictor variables of flights initiation distances in overall coot species. Wind blowing from the north and white-winged coot were set as reference categories. Significant differences are in bold (P<0.05).

Tabla 1. Coeficientes del modelo para las variables predictoras de las distancias de inicio de vuelo en todas las especies de gallaretas. El viento de dirección norte y la gallareta chica se establecieron como categorías de referencia. Las diferencias significativas se indican en negrita (P<0.05).

Variables	Estimate ± SE	t	P
Temperature	0.21 ± 0.15	1.37	0.17
Wind force	-0.09 ± 0.1	-0.41	0.67
Wind direction south	3.02 ± 1.06	**2.83**	**<0.01**
Red-fronted coot	0.07 ± 1.33	0.05	0.95
Red-gartered coot	-0.17 ± 1.27	-0.13	0.89
Dogs	-0.49 ± 0.46	-1.07	0.28
Conspecifics	-0.12 ± 0.04	-0.27	0.78
Heterospecifics	0.01 ± 0.02	0.58	0.55
Users/pedestrians	-0.33 ± 0.25	-1.31	0.19
Vehicles	0.20 ± 0.26	0.76	0.44

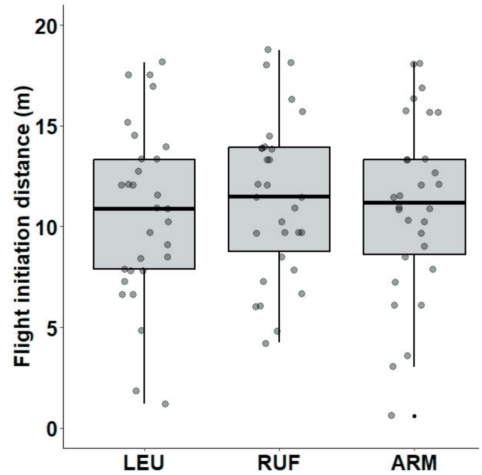

Figure 2. Boxplots of flight initiation distance recorded for each coot species under study. LEU: white-winged coot. RUF: red-fronted coot. ARM: red-gartered coot. The boundaries of each box represent the first (lower) and third (upper) quartiles, while the line inside the box indicates the median. The whiskers show the maximum and minimum values or 1.5 times the interquartile range, and the black dots represent outliers. Gray circles represent raw data.

Figura 2. Diagramas de caja de la distancia de inicio del vuelo registrada para cada especie de gallareta estudiada. LEU: gallareta chica. RUF: gallareta escudete rojo. ARM: gallareta liga rojas. Los límites de cada caja representan el primer (inferior) y el tercer (superior) cuartil, mientras que la línea dentro de la caja indica la mediana. Los bigotes muestran los valores máximo y mínimo, equivalentes a 1.5 veces el rango intercuartil, y los puntos negros representan valores atípicos. Los círculos grises representan datos brutos.

significant dispersion (all three coot species, P=0.300). In the case of the white-winged coot, again wind blowing from the south was the sole stressor affecting FID in this species (GLM, t=2.48, P<0.05), increasing it fourfold (Table 2). For the red-fronted coot, the abundance of conspecifics affected FID in this species (GLM, t=-2.13, P<0.05), decreasing it by half. For the red-gartered coot, no explanatory variable significantly affected FID in this species (Table 2).

Minimum approaching distances and buffer areas

For minimum linear approaching distances, we estimated the following values for each coot species: white-winged coot=32.07 m; red-fronted coot=34.23 m, and red-gartered coot=33.14 m. Minimum approaching areas were estimated for the overall studied coots as: white-winged coot=8400 m² (0.84 ha); red-fronted coot=9200 m² (0.92 ha), and red-gartered coot=9800 m² (0.98 ha).

Table 2. Model coefficients for predictors of flights initiation distances for studied coot species. Wind blowing from the north was set as reference category. Significant differences (P<0.05) are in bold.

Tabla 2. Coeficientes del modelo para los predictores de las distancias de inicio de vuelo de las especies de gallaretas evaluadas. El viento de dirección norte se estableció como categoría de referencia. Las diferencias significativas se indican en negrita (P<0.05).

	White-winged coot			Red-fronted coot			Red-gartered coot		
Variables	Estimate±SE	t	P	Estimate±SE	t	P	Estimate±SE	t	P
Temperature	0.29±0.22	1.28	0.21	-0.25±0.26	-0.97	0.34	0.09±0.38	0.23	0.81
Wind force	-0.03±0.31	-0.10	0.92	-0.35±0.37	-0.96	0.34	0.19±0.61	0.31	0.75
Wind direction south	4.76±1.71	**2.78**	**<0.05**	1.94±1.68	1.15	0.26	-1.38±2.62	-0.52	0.60
Dogs	-5.66±3.39	-1.66	0.11	-0.16±0.44	-0.35	0.72	2.79±2.50	1.11	0.27
Conspecifics	-0.03±0.05	-0.73	0.47	-0.55±0.26	**-2.13**	**<0.05**	0.28±0.15	1.87	0.07
Heterospecifics	0.06±0.06	1.02	0.31	-0.01±0.03	-0.23	0.81	0.08±0.05	1.60	0.12
Users/Pedestrians	0.09±0.45	0.21	0.83	0.29±0.35	0.45	0.65	-0.53±0.43	-1.23	0.23
Vehicles	-0.11±0.41	-0.27	0.78	0.26±0.56	0.47	0.64	0.73±0.47	1.56	0.13

Discussion

Alert distance has been suggested as a potential indicator of tolerance mainly in waterbirds (Fernández-Juricic et al. 2001a); however, in this study we focused on flight initiation distance as a proper, less debatable measure of a bird's tolerance to human-caused disturbance (Møller et al. 2019) and a better management guide when designating areas devoted to birds' activities to mitigate the impact of human disturbance, particularly in highly urbanized areas (Lin et al. 2012; Glover et al. 2011; Braimoh et al. 2018).

Our study shows that feeding was the main activity elicited by both white-winged and red-fronted coots, while for red-gartered coots it was self-maintaining; agonistic interactions were the least recorded activity among all coots. Our results show that feeding was the main activity outside the water for both white-winged and red-fronted coots prior to disturbance. Interestingly, coots are generalist herbivores and regularly occupy habitats dominated by submerged aquatic vegetation. Still, they are capable of walking on land in search of food within (land-based) vegetation bordering these aquatic environments (Jones 1940). On the other hand, self-maintaining dominated the behavioral profile of the red-gartered coot, being more frequently observed in this species when compared to the white-winged coot. A previous study based on the daily and intra-daily behavioral activity budgets of the same three coot species inhabiting the study area showed that all three species spent the most time feeding and swimming, and interacting agonistically the least (Hernandez et al. 2026). Thus, our results are in line with previous information for the study area. Similarities in the feeding behavior of two of the three studied coot species may indicate that, at least these aquatic birds, might synchronize their activity when they are feeding. This inter-specific synchronized activity may in turn decrease individual vigilance, as white-winged and red-fronted coots gathered in large groups while feeding share collective vigilance benefits, and thus avoid being captured (Kong et al. 2021). Hence, shorter FID are expected in birds displaying synchronized daily activities. Another explanation remains that the peak in foraging activity of these two coot species occurs in the early hours of the morning immediately prior to the high visitation rate to the Punta Mogotes lagoon complex, or in the late afternoon when visitation to the area decreases; a time frame not evaluated in this study. Interestingly, during the experimentation, there was a high presence of humans, in addition to the researchers, in relative proximity to experimental birds. Thus, we did not expect that such a variable would have affected the activities performed by the overall coot species.

In this study, we found that the three species of coots were disturbed by human presence. Still, the escape responses of at least white-winged and red-fronted coots (i.e., fleeing on foot but staying within the sampling area) suggest that these birds may allow a closer human approach. This could be related to either (a) relatively few costs incurred by moving to a distinct habitat (Stillman and Goss-Custard 2002) or (b) some degree of habituation to people (Nisbet 2000). If either of these mechanisms is the main cause of the response, these birds could be considered more resilient to disturbance (Yasué 2006). Resident (Burger and Gochfeld 1991; Morelli et al. 2022a) and larger birds —in terms of their body size (Blumstein 2006)— may habituate to some types of recreational disturbance and either are not disturbed or will immediately return after the initial disturbance (Madsen 1995; Fox and Madsen 1997). When disturbed, red-gartered coots flee on the wing to a source of water. It has been observed in other species of aquatic birds that the most common response to human presence is to move away from the source of disturbance (Gill 2007; Weston et al. 2012). Moreover, aquatic birds that are sufficiently disturbed may either escape by relanding at the position they were, or they can fly elsewhere, or rely on their camouflage and remain motionless (Lima and Dill 1990; Davidson and Rothwell 1993). In the former case, water bodies (e.g., ponds, wetlands, bays) may in turn become the most selected places by relocated disturbed birds, as proximity to water seems to confer some safety advantage (Burger 1981; Fox et al. 2014). It is known that human-caused disturbances may affect the energetic costs of birds, either by resulting in increased energetic expenditure or lost feeding time (Madsen 1995; Riddington et al. 1996); however, none of this information is currently available, and this will require further research.

We concluded from the results that the mean FID did not vary among the studied coot species. Similarity in FID among the three evaluated coot species may result from non-differential habituation to types of recreational disturbance within the Punta Mogotes lagoon complex. It is also possible that the lack of a significant difference in FID between coot species was due to a relatively low potential predation risk exerted by human activities within the lagoon complex. Another explanation remains that the stimulus of a person heading directly towards the bird is markedly different from the stimulus of normal visitors passing by, so that any difference in habituation to human presence would not be apparent in their response to surveyors (Fernández-Juricic et al. 2005). Not surprisingly, visitors to urban ecosystems can be regarded as a relatively non-threatening source of disturbance given that in general the birds are not killed or pursued (Lowry et al. 2013), though humans may cause fitness-related effects such as a decrease in foraging time (Frid and Dill 2002; Navedo et al. 2019). Hence, it is expected that individuals have learned to cope with human visitation (García et al. 2017). Taken together, our results indicate that FID can be viewed as a non-species-specific trait for a complex of taxonomically related coot species. This may lead to the postulation that the risk perceived by coots is a conserved trait within the genus. However, as our experimentation was performed solely based on birds on the ground, it is feasible that we have overestimated the species' actual sensitivity in their primary habitat (i.e., water bodies). Thus, collecting data on coots' response (measured as FID) on water surfaces may be particularly useful for decision-makers as 1) such a scenario will include the main bird habitat where the species spend an important part of their time swimming, and 2) these bodies of water also act as sites of aquatic activities within the study area. However, further studies should replicate our methodology and compare coots' response to human presence (measured as FID) in a non-anthropogenic shallow coastal lagoon and also a control area like the Punta Mogotes lagoon complex for a better understanding of the anti-predator behavior of these waterbird species under anthropogenic pressure.

Based on our results, we found that the response to human presence (measured as FID) is environmentally related to habitat use in the overall coot species, in particular the white-winged coot, with wind blowing from the south being the most important environmental stressor affecting FID. At the local scale, the influence of sea breezes - blowing from the southern quadrant - is of considerable importance as a local wind, affecting the apparent temperature for residents and wildlife alike, especially during the austral summer season (García 2013). Apparent temperature has a strong impact on humans visiting recreational areas (Song and Wei 2024). In fact, on sampling days when wind blowing from the south was encountered, a low presence of humans (~13%) was observed in relative proximity to experimental birds. Our results are in line with previous investigations conducted in other urban ecosystem areas of the globe showing the significant effect of environmental conditions such as wind and its direction on the response of birds to human disturbance (Collop et al. 2016; Hammer et al. 2022). When disentangling the studied species, we found that the response to human presence is ethologically related in one of the studied species (i.e., the red-fronted coot), with conspecifics being a significant stressor affecting FID in this species. This was not unexpected, as the escape behavior of urban birds is strongly linked to the variation in conspecific flock size (Morelli et al. 2019; Ardilla-Villamizar et al. 2022). Thus, birds that forage in smaller conspecific flocks are expected to show a less tolerant response when approached by humans (i.e., longer FID) when compared to birds foraging in larger flocks (Ardilla-Villamizar et al. 2022). Birds may experience a decrease in vigilance synchrony with increased disturbance and shift to coordinated vigilance, especially in small groups (Wickler 1985). Thus, our results (i.e., lower FID with a larger group) can be used —at least for the red-fronted coot— as a strong indicator of the effect on FID of many birds scanning or eliciting shared detection, and that FID could actually be the result of a collective decision rather than a single (more vigilant) individual igniting escape.

In terms of management, the average buffer zone estimated in this study was 33 m (for all coot species combined). This is in line with other set-back distances or buffer zones reported for other breeding aquatic birds in the Southern Hemisphere (see Weston et al. 2012). Although buffer zones are a very commonly used management option aimed at reducing disturbance impacts (Rodgers and Schwikert 2002), the existing research demonstrates that avian response to disturbance is affected, for example, by approach angle, with direct approaches causing greater disturbance than tangential approaches to birds (Burger et al. 2010). Thus, the recommended 33 m as an adequate buffer against visitors for the three studied coot species may be reduced if, for example, pedestrian traffic is directed tangentially rather than directly towards birds. Still, the management implications of our study are relevant to the study area but, to be effective, the human dimensions of local waterbirds should be considered (Bennett 2016). This is because management approaches like buffer areas are dependent on high compliance among users (Braimoh et al. 2018). Thus, assessment of local perception of wild birds, including willingness to comply with buffer areas devoted to waterbirds, is encouraged within the study area. This may assist researchers and managers not only with the material or utilitarian importance of birds, either positive or negative, but also reveal aspects of the coexistence between birds and social activities, and compliance with the latter from a management perspective (Morelli et al. 2022b). Finally, further studies should include distance to refuge, duration of the response, the bird's activity (e.g., foraging, defending territories) and/or some reproductive measures (e.g., clutch size, egg volume, hatching success, fledging success), and the type and duration of human activity along with other important factors affecting FID in these species.

Finally, the results of this study show for the first time one important aspect of the ecology of the three species of aquatic birds inhabiting urban lagoons in the city of Mar del Plata, Argentina: response to human disturbance, with information on AD and FID, minimum approaching distances and buffer areas. Furthermore, this study was conducted at a coastal urban ecosystem located in the core distribution of the three coot species in Argentina, and intensively visited by people during the species' breeding season. However, we are aware that the data presented here are not compared with breeding parameters; in spite of several efforts, nests were not found; hence no information of that nature was available for this study. Nevertheless, we strongly support studies on FID, as these are being increasingly used to assess human distance and its effect on wildlife. This is particularly valuable from an ecotourism perspective (Livezey et al. 2016), as our results may provide a valuable baseline against which to detect changes in the main daily activities and responses to disturbance of coots. Although none of the studied coot species is currently listed as vulnerable within Argentine territory (MADyS/AA 2017), responses of a physiological nature should also be assessed considering recreational activities as a stressing factor. Given that human disturbance of resident or migratory aquatic birds concerns both ornithologists and managers of wildlife populations and urban ecosystems, it is therefore essential to better understand the effects of anthropogenic activities on the immediate behavior, physiology, and population level of aquatic birds, including South American coots.

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