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Response distances of Chilean flamingo and American oystercatcher to human disturbance in a stopover site

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Á Deus e minha família.

"Se firme em tus actitudes y

perseverante em tu ideal"

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RESUMO

Atividades turísticas traz benefícios, aumentando o apoio à conservação. No entanto, também podem perturbar a fauna e ser análogo ao risco de predação. À medida que o turismo aumenta, é necessário um planejamento adequado. Realizamos experimentos de campo de aproximação de grupos de flamingo-chileno (*Phoenicopterus chilensis*) e Piru-Piru (*Haematopus palliatus*) simulando quatro estímulos (Caminhante individual, grupo de caminhantes, carro e caiaque) no Parque Nacional da Lagoa do Peixe para avaliar as distâncias de resposta e estimar distâncias mínimas de aproximação (DMA) para reduzir a perturbação das aves, controlando o efeito de fatores confundidores. A distância do início da fuga e a distância na qual o animal responde mudando sua orientação para monitorar uma ameaça que se aproxima (distância de alerta) foram definidos como distâncias de resposta. Usamos modelos lineares mistos para explorar os efeitos dos estímulos, e a influência de fatores potenciais nas respostas das aves. As distâncias de resposta foram diferentes entre as espécies e os estímulos antropogênicos. As aves permitiram abordagens mais próximas de caiaques e carros do que de caminhantes individuais e em grupo. O flamingo-chileno foi mais sensível à perturbação antropogênica. A distância inicial, o mês, o comportamento da ave antes da aproximação e a velocidade do vento influenciaram as respostas. Verificamos uma grande variação de resposta entre os indivíduos. Para minimizar a perturbação das aves limícolas no Parque Nacional da Lagoa do Peixe recomendamos uma DMA de 127 m para a aproximação de Piru-Piru no setor da praia e de 286 m para a aproximação de flamingo-chileno por caminhantes ou de 230 m para a aproximação por caiaques no estuário.

Palavras-chave: Distância do início da fuga; distância de alerta; Estímulos antropogênicos; Distância mínima de aproximação; Turismo; Impacto; Comportamento, aves limícolas.

ABSTRACT

Tourism activities provide benefits, increasing support for conservation. However, it can also disturb wildlife and be analogous to predation risk. As tourism increases, suitable planning is necessary. Chilean Flamingo (*Phoenicopterus chilensis*) and American Oystercatcher (*Haematopus palliatus*) were exposed to the approach of four stimuli (Single walker, group of walkers, car, and kayak) in a stopover site to determine their response distances, and then estimate minimal approach distances (MAD) to reduce bird disturbance, controlling the effect of potential influential factors. Flight initiation distance, and the response at which birds change their orientation to monitor an approaching threat (alert distance) were identified as response distances. Linear mixed models were used to explore the effects of the stimuli, and the potential factors on bird responses. Response distances were different between species and anthropogenic stimuli. Kayaks and cars allowed closer approaches than single and group of walkers. Chilean flamingo was more sensitive to disturbance. Potential factors such as starting distance, month, bird´s initial behavior before the approach and wind speed, including large variations among individuals influenced bird responses. Based on this data and in order to be conservative in reducing tourist’s effect in the bird’s behavior in an important stopover site, the minimal approach distance can be set at 127 m for the American oystercatcher in the beach, including for the Chilean flamingo a MAD of 286 m when walking and 230 m when kayaking in the estuary.

Keywords: Flight initiation distance; Alert distance; Anthropogenic stimuli; Minimum approach distance; Tourism; impact; Behavior, Shorebirds, Wetland birds

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THEORETICAL FRAMEWORK

Tourism and human disturbance

Tourism provides a series of benefits for the humans, however it can also cause disturbances that influence the normal behavior of the species (Blumstein *et al*. 2017; Fennell. 2002). These benefits are derived from recreation and leisure which involve those that are psychological (decreasing depression and managing stress), social (empowering communities to develop more recreational facilities), economic (good physical fitness leads to higher job efficiency) and environmental (greenways which conserve plants reduce pollution) (Fennell, 2002). On this basis, well-managed tourism benefits wildlife and their habitats by dissuading illegal hunting and logging, as well as urban development, while creating strategies to promote environmental education that promotes proper behavior of tourists (Blumstein *et al.* 2017).

However, given the popularity of this type of activity, as well as its increase in demand without proper management, impacts have been shown to occur (Fennell. 2002; Newsome *et al*. 2012). According to Edington and Edington (1986) wildlife observers have had impacts related to vulnerability, interference, parent–offspring bonds and habituation. Vulnerability is frequently associated with the arrival of tourists (their boats and other vehicles) that often leave a species, and their eggs or young vulnerable to predation, interference of tourist activities in relation with territorial behavior (essential processes of securing a mate and ensuring access to adequate sources of food), loss of parent–offspring bonds related with the interventions of tourist activities which can increase the mortality of young animals by separating them from their parents at times when recognition bonds are being recognized (young offspring separated before this bond is forged, are often not accepted by their parents, thus increasing the risk of being predated) and habituation defined as a process that leads to a decrease in the ability to respond to a stimulus, which can produce among other factors, changes in the behavior of the animal, being unpredictable and aggressive, which causes injuries in tourists (Edington and Edington, 1986; Blumstein. 2016).

From one point of view, these negative impacts are associated with how an animal can respond to human disturbance or to a disturbing stimuli defined as “human-related presence, object or sound that produces a disturbance (e.g., birdwatcher, motorized vehicle)” (Frid and Dill. 2002; Newsome *et al*. 2012). In many species the avoidance of human disturbance for example, involves an obvious behavioral response to stress which is associated with physiological responses in the form of hormonal changes (Newsome *et al*. 2012). These hormonal changes generate an increase in heart rate, respiratory rate and body temperature, as well as high levels of sugar in the blood, that can have adverse effects on the health of the species and could be important for those living in stressful environmental conditions (Newsome *et al*. 2012).

Other aspects that can harm wildlife are related to inadequate tourism management. Among them, it can mention the growing number of tourists in areas of national parks and protected areas, especially when the animals themselves are the focus of attention (Bateman and Fleming. 2017; Newsome *et al*. 2012). Infrastructure constructions for the visitor in important habitats for the species, air and soil pollution due to inappropriate use within the area, as well as excessive noise levels are factors that have to be taken into account in the inclusion of appropriate tourism planning and management strategies (Eagles *et al*. 2002).

On the other hand, factors involved in tourist activities are related with the timing (for example, when a disturbance stimulus are carried out during the breeding season, being considered more harmful), the predictability of the disturbance stimulus, its frequency and magnitude, and the location (related with the relative location of wildlife and disturbance) that can influence the responses of animals (Knight and Cole. 1995).

Conservation in the presence of tourism requires empirical data for informed action, with appropriate assessment methods that capture relevant responses for the study species and take into account the context and environment being tested (Bateman and Fleming. 2017). The key to successful planning of tourism is to minimize the adverse impacts and to maximize its benefit (Newsome *et al*. 2012). Some aspects directly linked with the minimization of impacts in a context of animal well-being and population sustainability, are related with providing environmental education services to the tourists, establishing clear guidelines for human access in the area, avoiding physical contact with and very close approach to wild animals (e.g., Identification of minimum approach distance also named here as set-back distance), among others (Blumstein *et al*. 2017).

This is how well-managed tourism can prevent relevant impacts on fauna, also considering that its execution must involve all stakeholders that allow the actions to be more effective, involving the needs and assertive communication for the resolution of specific conflicts in a given environment.

Animal tourism and avoidance responses

By tradition, animal tourism has primarily focused on the observation of vertebrate species, with bird watching being the most popular activity worldwide (Sekercioglu. 2002). This popular activity, with other recreational human activities, are growing in areas such as stopover sites, national parks and coastal areas (Hamza. 2020; Marasinghe *et al*. 2020; Sekercioglu. 2002).

Methods for measuring human disturbance in the literature are diverse, and typically an individual study can employ a variety of methods (Mengak *et al.* 2019). According with Bateman and Fleming (2017) there are three main categories of data assessing animal responses to tourist activities. The first category is time budget, characterized by the time a species spends on an activity which has consequences on the time available for other tasks and results in a "behavioral time budget” that reflects these trade-offs between the different activities (Blumstein *et al.* 2017). An animal's time budget can indicate changes in maintenance or vigilance behavior due to disturbance (Bateman and Fleming. 2017). The second are the physiological and breeding responses produced during disturbances through tourist activities (Bateman and Fleming. 2017). These responses have been measured, for example, with heart rate telemetry or markers for physiological stress in animals (e.g. Ellenberg *et al*. 2013; Seltmann *et al*. 2012). The last category corresponds to avoidance responses and have been used broadly across wildlife studies (Bateman and Fleming. 2017).

Most disturbance trials and theoretical investigations on escape focused on flight initiation distance (FID) – “the distance at which an animal moves away from an approaching threat” (Blumstein. 2003; Ydenberg and Dill. 1986). Researchers around the world have conducted many studies quantifying FID (Blumstein. 2019) and it has been used in the context of nature-based tourism through the development of minimum approach distance (Fernández-Juricic *et al*. 2005). FID can also provide other ways of managing disturbance such as the restriction of human presence through formed trails or barriers such as fences, among others uses (Weston *et al*. 2012).

Although FID is the response generally measured; there are other wildlife responses to external stimuli that have been quantified, such as alert distance (AD), the distance at which animal’s responds changing its orientation to monitor an approaching predator or threat (Blumstein *et al.* 2005; Cooper and Blumstein. 2014). In a specific way after becoming alert, an animal monitors the predator approaching previous to fleeing (Cooper and Blumstein. 2015). Alert distance has been recorded as a measure of response to tourists in several species of birds (e.g., Aikins *et al*. 2018; Fernández-Juricic *et al*. 2005, 2001).

Both AD and FID are useful for the characterization and management of wildlife disturbance, and have been used as indicators of the ability of birds to detect potential predators (Arroyo and Fors. 2020; Guay *et al*. 2016). Although it has not been precisely established which of the two metrics is the best, some of its limitations have been identified according with Weston *et al.* (2012); Fernández-Juricic *et al.* (2005) and others.

In relation to FID, some can be mentioned, such as: (i) The lack of standardized and suitable FID data (Weston *et al.* 2012); (ii) The influence of factors such as the direction of tangential approach on FID, that in some cases may be more influenced than direct approaches (Fernández-Juricic *et al.* 2005); (iii) The possibility that FID does not adequately reflect the distance at which normal activities are interrupted when the birds are aggressive or highly domesticated (Weston *et al.* 2012); and (iv) Although walkers approaches are a useful standard for comparative studies, the emphasis on a single walker as the stimulus detracts from the possible effect of other types of stimuli on birds (Hamza. 2020; Weston *et al.* 2012).

On the other hand, using the AD metric, the following limitations are considered: (i) AD is inherently more difficult to measure than FID (Blumstein. 2010; Guay *et al*. 2013a); and (ii) prey (birds in this case) may be aware of predators before adopting alert positions and may monitor them less intently (Cooper and Blumstein. 2015). Given these limitations in both measurements, several recommendations have been proposed, such as standardize the FID measurement protocol with a simple method (as described by Blumstein. 2003) (Weston *et al.* 2012). The use of FID rather than AD for comparative analyses that involves various observers (Guay *et al*. 2013). With exceptions and depending on the type of study and taxon it is recommended to include long starting distances of the approaching stimulus (See Blumstein *et al.* 2015; Weston *et al.* 2012 for more details).

Given some studies where both FID and AD have been measured (e.g., Aikins *et al*. 2018; Arroyo and Fors. 2020; Fernández-Juricic *et al*. 2005), it has been suggested the importance of measuring both distances when assessing risk response and escape behavior in birds (Arroyo and Fors. 2020).These two metrics have been evaluated in the same study independently (e.g., Arroyo and Fors. 2020; Fernández-Juricic and Schroeder. 2003) or including AD as a covariate (Fernández-Juricic *et al*. 2005). The measurement of AD and FID has also been useful to implement minimal approach distance (MAD) – "the closest distance at which anthropogenic activities can occur around an individual or group of individuals without causing disturbance" (Guay *et al*. 2016) and has been estimated with different methods (See Fernández-Juricic *et al*. 2005 for more details).

Some recommendations and considerations for its establishment have been cited, such as: (i) indicate MAD or set-back-distance by species and location to inform the development of a buffer zone (Mengak *et al*. 2019); (ii) at stopover sites where mixed species flocks congregate, the largest of the appropriate buffer distance may be considered (Koch and Paton. 2014); (iii) use only one buffer distance, since various distances in different species or recreational activities can confuse the public (Paton *et al.* 2000); and (iv) it may be viable to shorten these distances in zones where physical barriers impede direct visual contact between birds and quiet human activities (Rodgers and Smith. 1995).

The avoidance responses identified with the measurement of the alert and escape responses that allow the estimation of minimum approach distances must consider the needs and flow of tourists locally, temporally, and spatially, together with the degree of damage to the fauna that is considered appropriate to maintain if the objective is to seek sustainable management. Additionally, tourism needs tools to manage impacts that are standardized, as well as successfully evaluated in various studies. An example of a useful tool is the one based on avoidance responses, considered commonly used, popular and rigorous, especially when evaluating minimum distances, since they are based on the focal behavioral responses of a given species.

Theory: Decisions and escape responses

Animals can perceive humans as potential predators and react by fleeing the area (Cooper and Blumstein. 2015; Frid and Dill. 2002). Activities such as boating, walking and driving can be interpreted as predation events, and follow the same economic principles used by prey when they detect their predators (Gill *et al.* 1996; Ydenberg and Dill. 1986). According with Ydenberg and Dill (1986) FID may vary in an economic fashion that flight has cost as well as benefits. This economic modeling assume that prey begins to flee from an approaching predator when cost of fleeing and remaining are equal. Also assume that before starting the flight, the prey monitors the predator when it is detected. The shorter the prey-predator distance is, the cost of fleeing increases (Ydenberg and Dill. 1986). This cost is a consequence of losing feeding opportunities, participating in social activities such as courtship, mating, and territorial mate defense, and to performing other activities that increase fitness (Cooper and Blumstein. 2015).

On the other hand, the cost of remaining is expressed as cost associated with predation risk. In this context if a prey has the chance to feed (improving its fitness), the cost of fleeing is greater at all non-zero distances than that of a prey without an opportunity to feed (Cooper and Blumstein. 2015). In this situations or contexts, individuals can for example differ in behavioral types, being consistently bolder or more aggressive than others (Luttbeg and Sih. 2010).

According with Luttbeg and Sih (2010) individuals that are bolder (in which higher risk is assumed to provide more rewards) display how positive-feedback mechanisms can keep differential consistency in behavioral features. In this case, for example individuals that have a higher state (e.g., higher size, energy reserves, better condition) are better at defending themselves or fleeing from predators; decreasing the risk of predation (Luttbeg and Sih. 2010).

Continuing with the model of Ydenberg and Dill (1986), this has been modified by Blumstein (2003). The proposed modification suggests that species have two critical distances from the predator named minimal and maximum distance which produce three zones. Within zone I (where the distance is minimal), animals will always escape because they perceive a maximum risk from an approaching predator. In the zone II animals will optimize their escape dynamically as a function of the cost and benefits (as described by Ydenberg and Dill. 1986). Finally, in zone III animals will not respond by fleeing predatory stimuli beyond the maximum distance (due to inability to detect the predator, inattention to long-distance activities, and low levels of perception of an immediate threat) (Blumstein. 2003). These models have had great value and have been successful in empirical tests (Cooper and Blumstein. 2015).

Alternatively, Cooper and Frederick (2010, 2007) propose an optimally model where the optimal escape (escape associated with FID) is the product of predation risk (based on distance), the prey's initial fitness, benefits (won during the encounter with the predator), and energetic cost of fleeing. It is important to note that all of these terms excluding initial fitness vary with predator-prey distance; allowing calculation of fitness associated with each escape (Cooper and Frederick. 2007; 2010). The optimal escape is the predator-prey distance with the maximum expected fitness. In this scenario, if all benefits gained during the encounter are lost when the prey dies, the sum of initial fitness, benefits, and energetic cost is multiplied by the probability of survival to determine expected fitness (Cooper and Frederick. 2007; 2010). Also, if benefits are kept after death, as for successful reproduction, fitness is evaluated by adding the benefits and energetic costs to the product of the sum of initial fitness and energetic cost with the probability of survival (for an extended explanation of these model see fig 3-10, and 1-3 in Cooper and Frederick 2007 and 2010).

Cost of fleeing and cost of remaining

The cost of fleeing is mainly an opportunity cost, and it expands as FID increases because the prey has less time to complete favorable activities (Cooper and Blumstein. 2015). This cost of fleeing can be treated as an escape cost, which includes the energy expended by not performing daily activities to improve fitness as well as during the escape (Cooper and Frederick. 2007; Ydenberg and Dill. 1986).

In contrast, the cost of remaining (or not fleeing), it is inherently related to monitoring costs that involve spending energy to monitor predators (Cooper and Blumstein. 2015). This cost of not fleeing includes physiological costs, which are higher for example when FID is shorter because the stimulus has been monitored for a longer time and at a greater distance.

According to Cooper and Blumstein (2015), the cost due to predation risk and the sum of this physiological cost is the total cost of remaining.

It should be noted that the costs of continuous monitoring require attention to which is indicated as a finite entity; that results in focusing their finite attention on various tasks (Bushnell and Bushnell. 1998; Dukas. 2004). In relation to this and consistent with Blumstein (2010), the success of foraging is expected to be diminished if attention is needed to monitor a threat.

In this regard, a hypothesis called "flush early and avoid the rush" states that "animals should start flight soon after they detect a threat, so as to reduce or to minimize ongoing attentional costs of monitoring the approaching predators" (Blumstein. 2010). This can be reflected by a positive correlation between the predator's starting distance (SD) or AD and FID (Samia *et al*. 2013). Due to the difficulty of identifying alert responses when a threat is approaching, starting distance as a proxy for alert distance has been used (Blumstein. 2010).

Although the relationship between SD and FID is common; it can in some cases be used as a mathematical artifact (Cooper. 2008; Dumont *et al*. 2012), not always be present (Cooper. 2005) and can be modified by other risk factors (Cooper *et al*. 2009).

Factors associated to escape decisions

Bird's escape decisions are not only determined by the presence of the predator as it approaches, but also by a range of factors that can affect the optimal escape decisions of the prey (Stankowich and Blumstein. 2005). These factors have been evaluated in a variety of studies using FID (e.g., Blumstein. 2006; Glover *et al*. 2011; Guay *et al*. 2013). In this sense, those considered most important according to the evaluations carried out through meta-analysis applied to various taxonomic groups are included as additional factors that can also cause such variation.

Causes of variations in FID

Habitat contrast: Animals living in habitats with more intensity of human occupation or in close proximity of humans often results in a reduction in fearfulness of animals, and this also applies to FID (Luniak, 2004; Møller, 2010, 2008). Bird studies have shown that populations in areas with less exposure to humans have greater FIDs compared with populations with more exposure to humans and these findings are corroborated across different studies as Samia *et al*. (2015b); Cooke (1980), Tatte *et al*. (2019), among others. According with Møller (2008) species with relatively short FID in urban populations had a long history of adaptation to urban environments, as reflected by a large number of generations since start of urbanization. If these populations with high human occupation have become habituated to humans they are likely to recognize less risk when approached by a human than would an individual from a population where contact with humans is rare (Stankowich and Blumstein. 2005).

Body mass (size): Body mass has been shown to explain substantial variation in risk-taking behavior (e.g., Samia *et al*. 2015a). Furthermore, it is established that large animals are less tolerant of human presence than small animals (Fernández-Juricic *et al*. 2006; Witter *et al*. 1994). This is associated to higher predation risk produced by their conspicuousness, or because a flight at earlier distance becomes mainly energetically costly as body size increases (Tatner and Bryant. 1986). Studies that included birds such as Samia *et al*. (2015b), Glover *et al*. (2011), Mayer *et al*. (2019) among others, have verified this. However, in the study by Samia *et al*. (2015b) it was found that large birds were those that had the greatest decrease in FID as human disturbance increased. This apparent "tolerance" may be due to a higher energy cost of not finding food (opportunity cost) (Stankowich and Blumstein. 2005), reduced predation on larger birds due to body size (Werner. 1983), allowing better tolerance to common stimulus (which is less likely to occurs because larger size is more attractive in energetic terms for a predator, unless that predator is absent in the area), and the size of the brain (with greater cognitive capacity) that can better assess the risk (Samia *et al*. 2015a). However, the arguments that large animals are less tolerant of human approaches are considered stronger due to the amount of empirical evidence and hypotheses generated (Samia *et al*. 2015b).

Predator speed: The risk of death in a given encounter with a predator should increase with the speed of the predator's approach (Møller. 2015). Animals adjust the escape velocity according to the perceived risk (Blumstein. 2003; Ydenberg and Dill. 1986). Several studies including a meta-analysis report a considerable effect on the speed of an approaching potential threat for various taxonomic groups (e.g., Lethlean *et al*. 2017; Lord *et al*. 2001; Stankowich and Blumstein. 2005). In the case of birds, studies that verify differences in the speed of a certain threat (such as the approach of vehicles) have indicated that birds change their FID according to speed limit rather than car speed (Legagneux and Ducatez. 2013). On the other hand, Schlacher *et al.* (2013) observed that increasing the separation distance between vehicles and birds was more important to reduce responses to disturbances than changing vehicle speed, not finding a significant effect of speed on the probability of flushing. Although it was found that in several taxonomic groups speed is indicated as a considerable threat, it cannot be said that this same effect is maintained for birds. Only one study was indicated in the Stankowich and Blumstein, meta-analysis for this taxonomic group when evaluating speed, and there are still very few studies that compare anthropic stimuli at different speeds.

Directness of approach: Information assessment in the interaction between predators and prey may depend on the behavior of the approaching predator (Møller and Erritzøe.

2014). It has been indicated that the type of approach (either directly or tangentially) influences the prey escape decisions as reported by Stankowich and Blumstein, (2005). Studies focused on birds have identified that there is a distinction between the type of direct and tangential approach and it can be a way of evaluating the effects of cognitive skills on FID (Bateman and Fleming. 2011; Cooper and Blumstein. 2015). In contrast, Burger and Gochfeld (1981) collected data for two seabirds, finding minimal differences for this factor in the specie *Larus marinus*. Although a direct approach is more threatening, among other reasons, to the predator's intention to attack; its threat is also influenced by other predator factors such as speed, and size, that may not be taken into account in this type of study, influencing results in a greater or lesser effect on the direction of approach. Meta-analyses considering only the taxonomic group of birds are necessary.

Predator size: With a modest effect, predator size can influence escape decisions with larger predators inducing greater FID than smaller predators (Stankowich and Blumstein. 2005). This less studied factor has been described more than all for the group of fishes (Helfman and Winkelman. 1997). In the group of birds, it has not been addressed as the main factor, but rather being involved as an indirect evaluation and included as an attribute of the approaching stimulus (Schlacher *et al*. 2013).

Clutch size: Birds with small clutch-size might be more energetically stressed than those that produce more eggs due to the large parental investment per offspring (Trivers. 1972). Leaving a profitable area, in addition to the energy cost of flying, is seen to be costly for these species (Samia *et al*. 2015b). This factor has been considered an important factor in the responses of birds to human disturbance (Samia *et al*. 2015b). However, in another study cited by the same author, although it was considered as an influential factor, it was not considered one of the most relevant in relation to the variation of the escape strategy at the specific level of birds (Samia *et al*. 2015a). It is important to note that these two meta-analyses were based on the mean clutch size of a species per reproductive period (taking information from the literature), without taking into account field studies showing clutch size in an area (probably due to the small number of studies that prevents its evaluation in a meta-analysis) which leads to the need for more studies with field data. Regardless of clutch size, the reproductive status of an individual can influence the escape response, as they may indicate that a change in anti-predatory strategy occurs during pregnancy or shortly after giving birth due to low locomotor ability (in gravid animals such as reptiles) or the need to stimulate the young with developed escape tactics so as not to flee earlier, which gives them more time to reach a safe place (Stankowich and Blumstein. 2005).

Diet: Few studies have evaluated FID with diet (Cooper and Blumstein. 2015). However, it has been considered an important factor in explaining the tolerance of species in rural and urban environments (Samia *et al*. 2015b). Studies in favor have been identified in Blumstein (2006) which found that carnivorous and omnivorous species of birds were more likely to be flighty, than species with other diets. In particular, it is justified in part because carnivorous species, for example, have better visual acuity and sensitivity to movement (Cooper and Blumstein. 2015). Other studies such as Møller and Erritzø (2010) did not find evidence for species eating mobile prey having different FIDs compared with species consuming immobile food. Although few studies have been evaluated, the results shown by Samia *et al* (2015b) are more robust, considering that a meta-analysis was performed.

Brain size: Brains and cognition should play a role in predator and prey interactions because prey collect information on the whereabouts and predator behavior with sense organs (Samia *et al*. 2015a). It has been indicated that escape strategy, specifically a type of caution, in the case of different species of birds is related to the cost of monitoring a potential predator.

These costs are linked with the relative brain size that determines the ability to perform monitoring and the effort of this task as a result of habitat and social complexity (Samia *et al*. 2015a). In this regard, studies have shown a relation between brain size and FID (Møller and Erritzøe, 2014; Samia *et al*. 2017, 2015a), while others studies such as Guay *et al.* (2013b) did not find significant association between these two variables. The results for or against this factor may be subject to studying different groups of birds, obtaining different results when comparative analyses are carried out, as indicated by Shultz & Dunbar (2007). For example, the cited study by Guay *et al* (2013) focused on shorebirds (terrestrial species especially exposed to human presence) of a single order to avoid biases, which could influence the results with other studies.

Habitat openness: The degree of habitat openness has been suggested to influence prey escape strategies (Cooper and Blumstein. 2015). Studies, including meta-analysis, have indicated a distinction and effect between prey fleeing in open and closed habitats, evaluating this factor with a considerable effect size (Samia *et al*. 2015b, 2015a). Its influence is based on the fact that anthropogenic approaches in closed habitats may decrease the continuous monitoring of the bird when it detects the threat, fleeing earlier and causing a longer FID than in open habitats (Samia et al. 2015b, 2015a). On the other hand, other studies such as Blumstein (2006) found no effect in relation to this factor. Despite this result, their prediction indicated a potential influence on the FID in which species found in dense habitats would be more cautious than those found in more open habitats so as not to be surprised at close range by an unseen predator.

Group size: Group size may affect escape responses of birds (e.g., Samia *et al.* 2015a; Mayer *et al*. 2019). Two meta-analysis conducted by Stankowich and Blumstein (2005) and Samia *et al.* (2015b) found an intermediate-sized effect in most studies and relatively less importance factor. Studies in which an important effect has been detected, are divided responses between an early and late escape in large groups of birds (Laursen *et al*. 2005; Mayer *et al*. 2019; Scarton. 2018). However, other studies do not report any effect (Li *et al*. 2011; Mikula *et al*. 2018).

Part of this variation in the results of these studies may be due to the methodologies that were identified to calculate the group size of the species. For example, in the two meta-analyses carried out, their estimation consisted of coding the species in individual or pair categories and in groups of small and large size (without explaining whether it was taking into account what was cited in the literature according to the species or being an average value extracted by species from the evaluated studies). On the other hand, studies such as Laursen *et al* (2005); Mayer *et al* (2019) and Mikula *et al* (2018) the number of individuals in a group at each approach event was calculated in the field. Additionally, the low variability in the number of individuals of the groups evaluated for a species, could influence the lack of effect of this factor on the response distances.

<u>Distance of prey from their refuge</u>*:* Animals far from their refuge systematically flee at greater distances (Stankowich and Blumstein. 2005; Ydenberg and Dill, 1986). This variation has been described mainly in reptiles, fishes and mammals (Stankowich and Blumstein. 2005). However, there are limited evidence of the influence of distance of refuge in FID exists of birds (Martín *et al*. 2004). According with Guay *et al.* (2013) during the results of their research with waterfowls realized that instead of using burrows, trees, holes in a reef or vegetation groups, waterfowls change habitat from terrestrial to aquatic when disturbed and this is likely to be related with comparatively high costs of escape, potentially leading to a strong influence of distance to refuge on FID.

Other factors

Including other no less important factors we can distinguish the variations within and among populations that could reflects differences among species as indicated in Blumstein (2003) who suggest that FID can therefore be viewed as a species-specific trait. Several studies, have identified interspecific variation in birds within taxonomic groups (e.g., Møller. 2010b; Glover *et al*. 2011; Samia *et al*. 2013) a result that according to Samia *et al*. (2013) suggests that species could assess growing threats in different way. This factor also can be used to define the effect of disturbances on rare or threatened species (Mikula *et al*. 2018).

Others factors included in the prey and predator aspects such as the type of predator (that integrate auditory and visual cues), (McLeod *et al.* 2013; Radkovic *et al*. 2019), starting distance at which a threat is approaching (Blumstein. 2003; Cooper. 2005; Samia *et al*. 2013), age (related to fecundity or reproductive status) (Koch and Paton. 2014) and bird´s initial behavior before the approach (factor less studied) (Blumstein *et al*. 2015) , can also influence their escape decisions. Other factors, such as wind speed (Dehnhard *et al*. 2020; Reynolds *et al.* 2020), month (related with seasonal variation) (Donaldson *et al*. 2007), and latitude (Samia *et al.* 2017) have also been proposed to generate variations in the escape responses.

Despite the aspects related to experience and habituation (factors that also are related with escape responses), which have been investigated in studies such as Laursen *et al.* (2005), Thibault *et al.* (2020) and Fox and Madsen (1997), it is important to highlight that the apparent tolerance of wildlife to human presence does not mean that tourism activities are harmless to focal species (Higham and Shelton. 2011). According to Blumstein (2016) habituation is a process that occurs over time, and predicts changes in tolerance (that is, the intensity of the disturbance that an individual tolerates without responding concretely). More specifically, tolerance is a "state" and changes in it evidence previous experiences. Highman and Shelton, (2011) specifies that the tolerance or the apparent tolerance can be explained by (i) the migration of less tolerant individuals, leaving more tolerant individuals in the site; (ii) the physiological deterioration that prevents individuals from reacting to human presence; and (iii) the non-existence of a suitable habitat to which animals can be relocated. Consequently, the development of empirical studies to inform and monitor the best practices of tour operators are assumed as valuable management tools (Higham and Shelton. 2011).

It is also important to note that at a methodological level and depending on the study objectives, part of these factors can usually be controlled during the measurement of an individual's escape. In this regard, Blumstein *et al.* (2015) recommend collecting data referring to location, date, time, species, sex, initial behavior, starting distance and number of conspecifics (and potentially heterospecifics) (See Blumstein *et al*. 2015 for additional information).

In general terms and in relation to the last two sections described here, it is important to indicate that the influence of a single factor in studies to evaluate the responses to which a bird alerts or flees, can take into account joint analysis of other potentially influential factors (direct and indirect) for a bird in a given study area. A single factor does not give reference to a significant effect if it is not evaluated together with other types of factors (For example, in relation to the physical condition of an animal, factors such as reproductive status, age, sex or temperature are included, as indicated in Stankowich and Blumstein. 2005). Additionally, despite the fact that the incidence of factors has been studied in several taxonomic groups that have allowed the generation of meta-analyses, specific studies are needed in birds that evaluate the incidence of less studied factors for this group, such as the direction of approach, size of predator, speed or distance of refuge.

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CAPÍTULO I

Response distances of Chilean flamingo and American oystercatcher to human disturbance in a stopover site

Response distances of Chilean flamingo and American oystercatcher to human disturbance in a stopover site

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Abstract

Tourism activities provide benefits, increasing support for conservation. However, it can also disturb wildlife and be analogous to predation risk. As tourism increases, suitable planning is necessary. Chilean Flamingo (*Phoenicopterus chilensis*) and American Oystercatcher (*Haematopus palliatus*) were exposed to the approach of four stimuli (Single walker, group of walkers, car, and kayak) in a stopover site to determine their response distances, and then estimate minimal approach distances (MAD) to reduce bird disturbance, controlling the effect of potential influential factors. Flight initiation distance, and the response at which birds change their orientation to monitor an approaching threat (alert distance) were identified as response distances. Linear mixed models were used to explore the effects of the stimuli, and the potential factors on bird responses. Response distances were different between species and anthropogenic stimuli. Kayaks and cars allowed closer approaches than single and group of walkers. Chilean flamingo was more sensitive to disturbance. Potential factors such as starting distance, month, bird´s initial behavior before the approach and wind speed, including large variations among individuals influenced bird responses. Based on this data and in order to be conservative in reducing tourist's effect in the bird's behavior in an important stopover site, the minimal approach distance can be set at 127 m for the American oystercatcher in the beach, including for the Chilean flamingo a MAD of 286 m when walking and 230 m when kayaking in the estuary.

Keywords: Flight initiation distance; Alert distance; anthropogenic stimuli; minimum approach distance; tourism; impact; behavior; shorebirds; wetland birds.

Introduction

Tourism activities benefit from ecosystem services provided by natural areas and can increase the support for biodiversity conservation, but also have the potential to disturb wildlife (Roe *et al*. 1997; Taylor and Knight. 2003). As tourism in protected areas increases in demand and pressures, so does the need for careful planning. Activities such as boating, walking and driving, when approaching birds, can be interpreted as predation events, and follow the same economic principles used by prey when they detect their predators (Ydenberg and Dill. 1986; Gill *et al*. 1996). Some of these human activities are conducted in coastal habitat, including stopover sites that concentrate large numbers of shorebirds which are particularly vulnerable because they need time to quickly refuel their energy reserves, rest and feed (Murchison *et al.* 2016; Hamza. 2020).

The effects of human disturbance on birds inhabiting coastal habitats have been studied using various methods (Bateman and Fleming, 2017). Two of the most commonly used is the quantification of the flight initiation distance (FID) – “The distance at which an animal moves away from an approaching threat” (Ydenberg and Dill, 1986; Blumstein. 2003) and the Alert Distance (AD) – the distance at which animal’s responds changing its orientation to monitor an approaching predator or threat (Blumstein *et al*. 2005; Cooper and Blumstein. 2014). These indexes provide different clues on the responses of birds to human approaches (such as recognition of a greater or lesser avoidance response to stimuli) and can be used in tandem (e.g., Fernández-Juricic *et al*. 2005; Aikins *et al*. 2018; Arroyo and Fors. 2020).

The estimation of these bird's responses is useful for the development of several management strategies, such as the implementation of minimal approach distance (MAD) – "the closest distance at which anthropogenic activities can occur around an individual or group of individuals without causing disturbance" (Guay *et al*. 2016; See Fernández-Juricic *et al.* 2005; for a review of several methods to calculate MAD). The bird's responses to human disturbances are also influenced by several human factors, such as the distance at which an approach commences (Blumstein. 2003; Cooper. 2005; Samia *et al*. 2013), prey factors, such as the flock size, bird´s initial behavior before the approach (Blumstein *et al*. 2015; Samia *et al*. 2015a) or environmental factors, as the season or meteorological conditions (Donaldson. 2007; Dehnhard *et al*. 2020; Reynolds *et al.* 2020). Additionally, previous experiences with humans may either result in greater avoidance (in areas with less exposure to humans) or in habituation (Møller. 2008; Samia *et al*. 2015b).

The responses of the Chilean flamingo and the American oystercatcher were evaluated, being indicated as model species to identify their effect on tourist activities in two main sectors within the park. Both species were selected mainly for their size and their common observation in the study sectors (The American oystercatcher is a coastal bird that uses the beach as a resting and feeding habitat, identifying itself in the beach sector within the park, while the Chilean flamingo is associated with shallow habitats, being observed exclusively in the estuary sector). Since previous studies have shown that larger birds are less tolerant of human disturbance (flight over shorter distances is energetically costly as body size increases or because larger birds will flush sooner to decrease the higher predation risk due to its visibility) (Tatner and Bryant. 1986; Blumstein. 2006; Samia *et al*. 2015a) and based on the effect of the type of anthropic stimulus (which depends on its own characteristics) (e.g., McLeod *et al*. 2013; Radkovic *et al.* 2019), combined with other factors of potential influence such as those described above, we expect to find variations in response distances, with the Chilean flamingo being more sensitive to disturbance.

The aim of our study is to examine the responses of the Chilean Flamingo (*Phoenicopterus chilensis*) and the American Oystercatcher (*Haematopus palliatus*) evoked by different modes of anthropogenic stimuli (single walker, group of walkers, car, and kayak) in a stopover site. More specifically, we experimentally approached birds in the field in order to evaluate the effect of different stimuli on the alert and flight initiation distances, and to determine suitable minimal approach distances to avoid bird disturbance, controlling for the effect of other potential influential factors (flock size, month, season, temperature, bird´s initial behavior before the approach and wind speed). Using these AD and FID estimates, we determined for each bird species a recommended minimal approach distance.

Methods

Study area and site selection

We carried out the study at the Lagoa do Peixe National Park – LPNP (31°20’19’’S; 51°58’19’’W), a Ramsar Site and a stopover site of international importance in South America (WHSRN. 2021) (Fig. 1). Mean temperature, wind speed and rainfall during the study period were 21.5 °C, 6.6 m/s, 0.015mm, respectively (INMET. 2020). The variability and mobility of the environment in short periods of time as a function of the meteorological conditions is characteristic of this area (Tagliani *et al*. 1992). This factor has also contributed to the fact that the temporary presence of both fishermen and tourists varies daily in the area. Access to the park is free and unrestricted for visitors. Shorebirds and wading bird at the LPNP are exposed to low tourist activity (583 visits made annually in 2019) , less than evident in relation to the number of visits registered annually in the National parks of Brazil (Breves *et al*. 2020). Monthly the park has received between 162 and 8000 visits approximately, being the highest peaks in the summer season. Since 2015, the number of registered monthly visits has decreased, identifying a maximum value of 733 (ICMBio. 2021).

We conducted the field study in the two major habitats used by birds and tourists, the beach and the estuary (Fig.1; Appendix 1). The beach sector corresponds to a sandy strip of 17 kilometers used as a route to other main destinations in the park and fishing spots by authorized artisan fishermen (Knak. 1999). Most of the access and movement through the beach sector is done in vehicles rather than on foot.

The estuary sector is the open-closed estuary, where the lagoon opens to the ocean (Knak. 1999). In this sector the presence of artisan fishermen occur during the shrimp season, from October to March (spring and summer) (Loebmann and Vieira. 2006). They use traditional boats made of woods, without motor to routinely check shrimp nets (Knak. 1999). Fishermen in general frequent the night and early morning to carry out their fishing tasks in places authorized by the environmental authority, with 202 people authorized for artisanal fishing within the park (ICMBio. 2020).

The field study was conducted over six-months, covering the spring and summer seasons (between September, October, and December 2019 - January, March, and November 2020), when migratory birds, fishermen and tourists gather at the park at greater number (Benedetti. 2018; Knak. 1999).

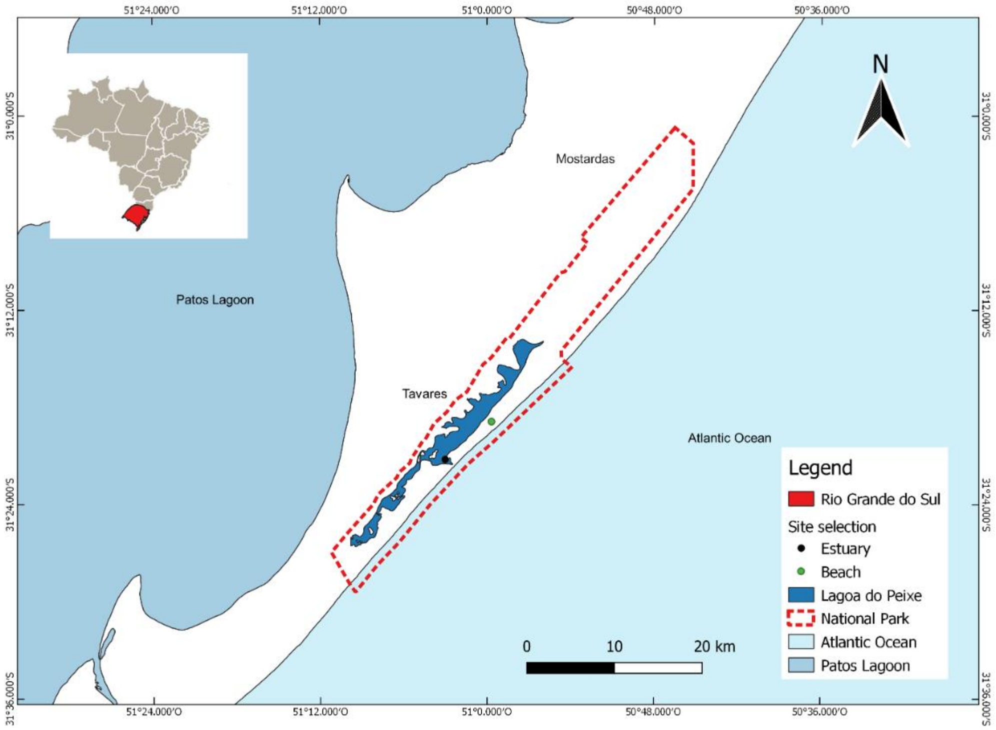

Figure 1. Lagoa do Peixe National Park, South Brazil, showing the location of the study sites.

Studied species

We focused two species in the study – the Chilean flamingo (*Phoenicopterus chilensis*) and the American oystercatcher (*Haematopus palliatus*) as models to represent the responses of human disturbances of birds in the park (Appendix 2).

The Chilean flamingo is both a conservation and a visitation target, being one of the park's main focus of attention. They are found in the estuary sector, always in shallow waters. It has a length range of 79 to 145 cm and a mass range of 2500 to 3500 g (Grinfeld. 2007). This species is distributed from western Peru and Ecuador to southern Chile and Argentina, breeding mainly in the high regions of Argentina and Chile, moving to low and coastal regions frequently during winter, as in Brazil, in the non-breeding season (del Hoyo. 1992; Mascitti and Bonaventura. 2002). Some individuals that remain in their breeding sectors do not return to these areas for several years, identifying a resident population in the park area that occurs throughout the year (Antas. 1994; Delfino and Aldana-Ardila. 2020).

They are gregarious species and form groups of many individuals where dominance in the flock is related to sex and age, with adult males being the most aggressive and dominant individuals (Pickering. 1992; Rose and Croft. 2018). According to Delfino and Caio, (2020) in natural areas such as Lagoa do Peixe, the environmental richness as well as the human presence is not remarkable enough for the animals to allow altering or showing specific behaviors because there is no considerable human influence in the area. Chilean flamingo is classified globally by the IUCN as near threatened (NT) and at the local level it is evaluated with criteria not applicable (NA) (ICMBio, 2018).

The American oystercatcher is a resident species that uses mainly the sandy beach as resting and feeding habitat, although local movements are believed to occur (Belton. 1984). It has a length range of 40 to 44 cm and a mass range of 400 to 700 g (Hardin. 2014). It is a shorebird distributed along the Atlantic and Pacific coasts from North America to South America (Clay *et al*. 2014). On the southern coast of Brazil, where the park is located, a considerable concentration of this species has been identified (Clay et al. 2014; Sanabria. 2012). This abundance may be related to a better food supply favored by the estuary, non-urbanized areas, and an apparent preference for nesting in dunes with grasslands and scarce vegetation (Lara-Resende 1988; Canabarro and Fedrizzi, 2010; Sanabria. 2012). Given the greater breadth of breeding habitat that this species may have (use of dunes and a variety of nesting substrates, including sandy beaches, saline marshes, and mudflats), its protection may also aid birds with more restricted breeding zones, being considered as a good umbrella species on a regional scale (Maslo et al. 2016). It is listed globally as a bird of least concern (LC) by the IUCN and at the local level it is classified as near threatened (ICMBio. 2018).

Measurements of human approaches

The methods for measuring AD and FID follow those reported in Blumstein (2003), McLeod *et al.* (2013) and Fernández-Juricic *et al.* (2001). We selected two types of stimuli (treatments) to one species: flamingos were approached in shallow waters by single walker (0.8 m/s) and kayak (1 m/s), while oystercatchers were approached in the sand beach by three stimuli: Car (2.7 m/s), single walker and groups of three walkers (same speed: 0.8 m/s).

Before starting an approach, we observed the focal bird for 1 minute or less to check its behavior (Appendix 3). All approaches were made to single-species groups, non-nesting individuals, non-vigilant birds, and in open habitats (without interruption of visibility). Occasionally, various other external factors such as tourists, boats, cars, other birds, among others passed or stopped near the focal bird; therefore, during these events no approach events were performed and we allowed a maximum of half an hour between our approaches. The stimulus type was randomly selected in each area. Once a focal individual or flock was approached, no other individuals were observed within a minimum 50m radius of the location.

One person (NLC), positioned far from the focal bird, was in charge of observing its behavior, helped by binoculars (8x42; Bushnell). Another person (GR) measured the distances in meters using a laser rangefinder (Bushnell 1-mile ARC; Accuracy +/- 4.5 m). A single walker or the groups of walkers approached the focal bird moved directly at a constant speed. All participants kept silent, wore dull-clothes, and made no sudden body movements since the onset of the preliminary observations. Walk-talkies were used for communication among the participants.

The distance at which we started an approach to the focal bird was recorded as the Starting distance (SD). We then measured the distance at which the bird changed its behavior in response to the approach, recorded as Alert Distance (AD). Finally, we measured the distance at which the bird walked or flew away in response to the approach, recorded as Flight Initiation Distance (FID). In the approaches by walkers and car a marker was dropped by the approached at the starting point and at AD and FID. Later the distances were measured with the rangefinder. In the Kayak approaches all observers positioned at the SD and the distance to focal bird was taken. Then, while one assistant performed the direct approach by paddling, an observer recorded the responses (AD and FID) of the focal bird from the starting point, and communicated to the second observer, who measured the distances between them and the kayak.

We also recorded the bird´s initial behavior before the approach (Bba) (Appendix 3), month, season, temperature, wind speed and flock size (Number of individuals of the same species in the group), in order to control for their potential effect in the behavior of the focal bird. In relation to flock size, the most conspicuous and adult focal individual was selected in each approach event because it was most visible to the observer, avoiding the potential influence of juvenile individuals on response distances.

Estimation of minimum approach distances

We used four formulas to estimate minimum approach distances (MADs) for each species. To do this, MAD were calculated according to Fernández-Juricic, *et al.*(2005) based on the formulas cited in Rogers and Smith (1997, 1995); Fernández-Juricic *et al.*(2001) and Galarnyk. (2018) as follows:

(i) $MAD_1 = (\overline{FID} + 1.6495SD) + \overline{AD}$, where $\overline{FID}$ is the mean of flight initiation distance, SD is the standard deviation of $\overline{FID}$, and $\overline{AD}$ is the mean of alert distance.

(ii) $MAD_2 = \overline{x} + 2SD$, where $\overline{x}$ is the mean of AD or FID plus two standard deviation. The same formula and two different response distances are used for its estimation ($MAD2_{AD}$ and $MAD2_{FID}$).

(iii) $MAD_3 = \overline{x} + 1SD$, where $\overline{x}$ is the mean of AD or FID plus one standard deviation. The same formula and two different response distances are used for its estimation. ($MAD3_{AD}$ and $MAD3_{FID}$).

(iv) $MAD_4 = \overline{AD}$, where $\overline{AD}$ is the mean of alert distance.

Data analysis

We used Linear mixed models (LMMs) to assess the effect of treatment (fixed effect, stimulus type) on FID and AD (response variables) controlling for the potential influence (random effects) of the starting distance (SD), flock size, month, season, temperature, bird´s initial behavior before the approach (Bba) and wind speed as covariates specified as random effects. Initially, individual models were run for each specie, adding one single random factor. Non-important covariates, those with close to zero variance components (Chen and Dunson. 2003) were eliminated from subsequent analyses. Consequently, three factors of each model were eliminated – American Oystercatcher: season (from the AD model), flock size and temperature; Chilean Flamingo: temperature (from the FID model), flock size and Bba. Afterwards, were generated the global models and all submodels for AD and FID for each species. We used Akaike's Information Criterion for small sample size (AICc) and weights, selecting the model with the lowest AICc value that best fit the data. Models within $\Delta AIC \leq 2$ were considered to have significant support from the data (Burnham and Anderson. 2002). All numeric covariates factors were centered and standardized to improve model performance and interpretability (Schielzeth. 2010). Additionally, the conditional (variance explained by both fixed and random factors) and marginal (variance explained by fixed factors) R^2 were calculated to assess the relative contribution of each random and fixed factor. All analyses were performed in R v.3.6.3 (R Core Team. 2021) using the packages lme4 v. 1.1-26 (Bates *et al*. 2015), MuMIn v.1.43.17 (Barton. 2020) and the r-squared.glmm function (Nakagawa and Schielzeth. 2013).

Results

We conducted a total of 212 AD and 209 FID approaches to the two bird species (American oystercatcher – *single walker*: 58 AD, 48 FID; *group of walkers*: 50 AD/FID; *car*: 46 AD, 51 FID); and Chilean flamingo (– *single walker*: 29 AD, 32 FID; *kayak*: 29 AD, 28 FID; Appendix 4).

The response distances of the Chilean flamingo varied according to the anthropogenic stimulus (Table 1). The Chilean flamingo fled earlier to single walker (AD = 204.3±15.11 m; FID = 148.8±14.44 m) than kayak approaches (AD = 153.4±14.27 m; FID = 94.25±13.21 m;) (Table 1; fig.2a). The AD and FID also varied according to the starting distance, wind speed and month (AD $R^2c = 0.74$; FID $R^2c = 0.66$; Table 2).

Regarding the American oystercatcher, the response distances also varied according to the anthropogenic stimulus (Table 1). This species reacted earlier to group of walkers (AD = 77.47±3.51 m; FID = 59.74±3.29 m) than single walker (AD=70.97±5.22 m; FID=52.56±4.15 m) and car approaches (AD = 64.61±2.82 m; FID = 46.96±3.28 m), with minimal differences between their estimated means for each stimulus (Table 1, fig.2b). The starting distance, Bba, wind speed and month, explained a large amount of the variance in AD and FID (AD $R^2c = 0.59$; FID $R^2c = 0.38$; Table 2).

The Chilean flamingo exhibited larger average response distance, independent of the type of stimulus, compared with American oystercatcher. Taking both models into account, an unexplained variation was observed for the American oystercatcher models (AD R^2m =

0.081; FID $R^2m = 0.088$) and to a lesser extent for the Chilean flamingo, explained by the fixed effects (AD $R^2m = 0.23$; FID $R^2m = 0.25$; Table 2). Additionally, no influence of the group size factor was found in the generated models because the variation between groups was mostly small (Appendix 5).

Table 1. Alert Distance (AD) and Flight Initiation Distance (FID) in meters, of the American oystercatcher and the Chilean flamingo exposed to different types of anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil. Results of Linear Mixed Models (LMM).

Species	Variable	Parameter	N	Mean ± SE	t -Value	Pr(>|z|)
Chilean flamingo	AD	kayak (Intercept)	29	153.4±14.27	10.749	1.10E-05 ***
		Single walker	29	204.3±15.11	3.368	0.00175 **
	FID	kayak (Intercept)	28	94.25±13.21	7.134	0.000 ***
		Single walker	32	148.8±14.44	3.784	0.001 ***
American Oystercatcher	AD	Single walker (Intercept)	58	70.97±5.22	13.598	5.33E-07 ***
		Group of walkers	50	77.47±3.51	1.851	0.0663 .
		Car	46	64.61±2.82	-2.253	0.0257 *
	FID	Single walker (Intercept)	48	52.56±4.15	12.655	1.32E-06 ***
		Group of walkers	50	59.74±3.29	2.178	0.0314 *
		Car	51	46.96±3.28	-1.708	0.0898 .

Table 2. Best fit and effect of covariates on the Alert Distance (AD) and Flight Initiation Distance (FID) of the American oystercatcher and the Chilean flamingo exposed to different types of anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil. Results of Linear Mixed Models (LMM).

Species	Variable	Model	logLik	AICc	Delta	Weight	*R2m*	*R2c*
Chilean flamingo	AD	~ EST + (1 | SD) + (1 | Month)	**-289.92**	**591**	**0.00**	**1**	0.229	0.736
		Null model	-298.33	605.4	14.4	0		
	FID	~ EST + (1 | SD) + (1 | Month) + (1 | Wind speed)	**-304.74**	**623.1**	**0.00**	**1**	0.248	0.661
		Null model	-313.84	638.8	15.7	0		
American Oystercatcher	AD	~ EST + (1 | SD) + (1 | Month) + (1 | Bba)	**-611.39**	**1238**	**0.00**	**1**	0.081	0.589
		Null model	-621.53	1254	15.9	0		
	FID	~ EST + (1 | SD) + (1 | Wind speed) + (1 | Bba)	**-611.85**	**1239**	**0.00**	**1**	0.088	0.382
		Null model	-622.84	1256	17.6	0		

Covariates: SD*; Starting distance; Bird´s behavior before the approach (Bba); Month and Wind speed* (*values centered and standardized). AICc: Akaike’s Information Criterion for small sample size; R^2m: Marginal R squared value; R^2c: Conditional R squared value.

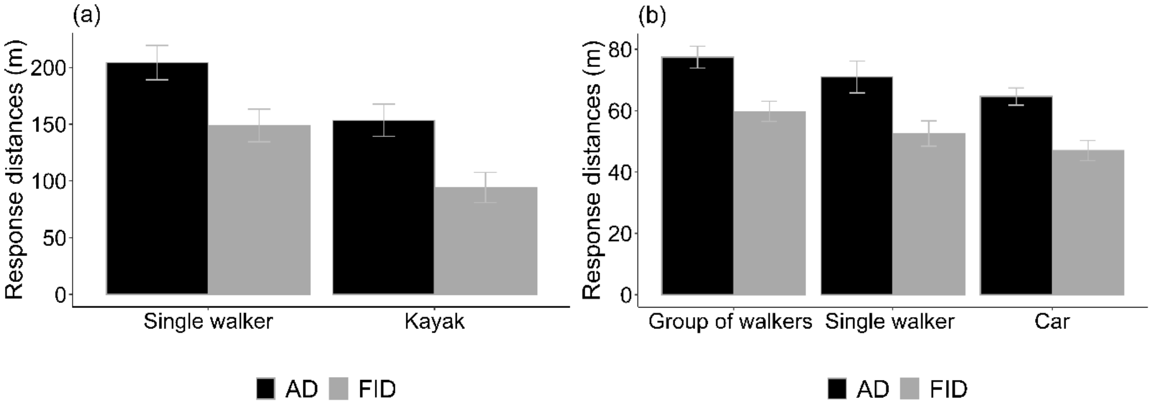

Figure 2. Mean (± SE) response distances of the (a) Chilean flamingo, and (b) American Oystercatcher exposed to different types of anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil.

Estimation of minimum approach distances

Recommended MADs varied between formulas, species and stimuli. MADs from Chilean flamingo ranging from 153 to 363 m in the Kayak approaches and from about 204 to 488 m in the Single walker approaches (Table 3a; Appendix 5). In relation to the American oystercatcher, minimum approach distances were identified between 77 to 176 for groups of walkers and from 65 to 150 for Car approaches (Table 3b; Appendix 6). The Chilean flamingo allowed closer approaches from kayaks than from single walkers. The American oystercatcher fled earlier when approached by groups of walkers than by cars.

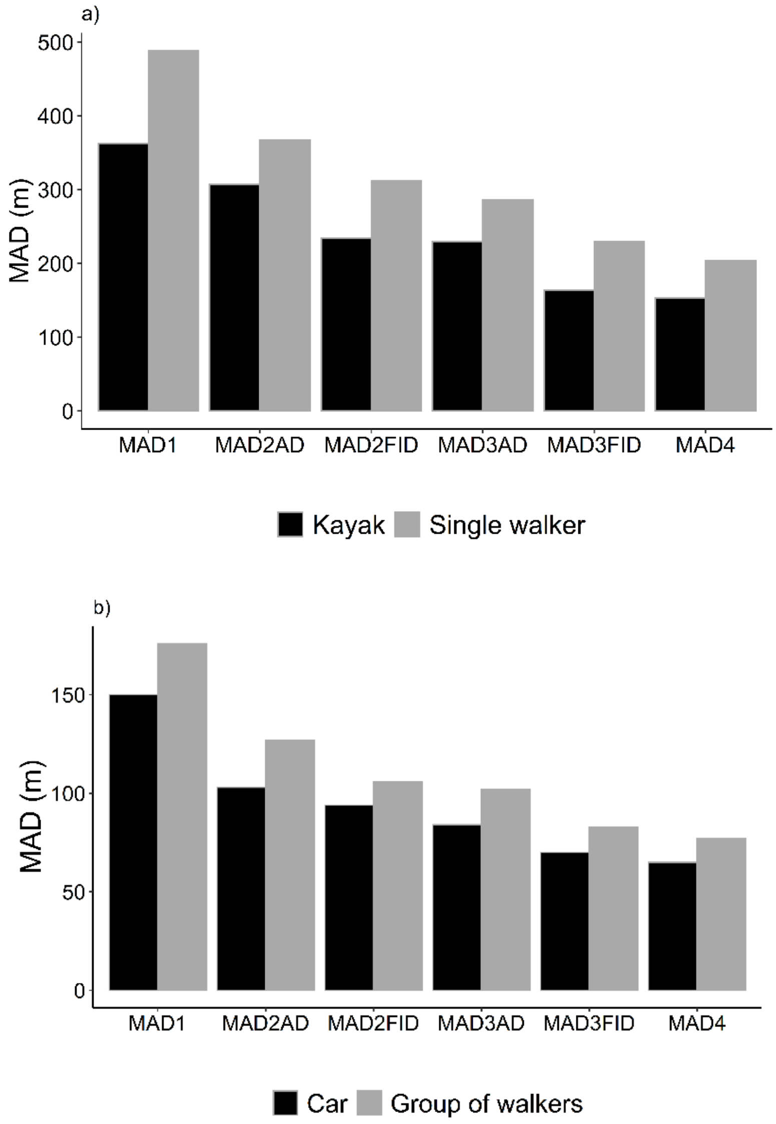

Figure 3. Minimum approach distance (m) of the (a) Chilean Flamingo, and (b) American Oystercatcher exposed to different anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil.

Discussion

Our study shows how the exposure to different anthropogenic stimuli affect the response distances of two model bird species, the Chilean flamingo and the American Oystercatcher to typical approaches by tourists at an important stopover site. We found that walkers tend to provoke earlier reactions than persons in kayaks or cars, and that the Chilean flamingo tends to react earlier than the American oystercatcher. We also found that the bird's responses vary largely among individuals, partially related with biological and environmental factors as the starting distance, wind speed, bird's behavior before the approach, and month.

Our results suggest that, in order to be conservative in reducing tourist's effect in the shorebird's and wading bird behavior at the Lagoa do Peixe National Park, the minimum approach distance to Chilean flamingo in the estuary can be set at, 286 m for single walker, including 230 m when kayaking (based on formula No 3) and 127 m for American oystercatcher (based on formula No 2) in the beach without discriminate type of stimuli.

Both species fled earlier to walkers than people in boats or cars, consistent with several studies which recognized people as most disturbing (Glover *et al.* 2015; Guay *et al*. 2014; McLeod *et al.* 2013; Pease *et al.* 2005). The earlier reactions of the Chilean flamingo to walker approaches than kayaks is supported by some studies comparing the effects of non-motorized boats vs single walker stimulus (Glover *et al.* 2015; Paton *et al.* 2000), but not when using motorized boats (Rodgers and Smith. 1997; Scarton. 2018b, 2017 but see Rodgers and smith. 1995). In our case, flamingos could be habituated to non-motorized boats due to the long history of presence of artisan fishermen boating in the lagoon. The risk perception of a potential threat can be influenced by other factors such as noise or speed, as reported in various studies (Lethlean *et al.* 2017; Weston *et al.* 2012; Stankowich and Blumstein. 2005). The American oystercatcher fled earlier to groups of walkers than to single walkers and car approaches, without noteworthy differences between these later two stimuli. Few studies compared approaches by cars vs single walkers, having found similar results (Guay *et al*. 2014; McLeod *et al*. 2013). This may be explained by the low speed of cars in these studies (Guay *et al*. 2014; McLeod *et al*. 2013).

The FIDs of both species are large, as expected for birds living in habitats with less human pressure or non-habituated birds (e.g., Piratelli *et al*. 2015; Samia *et al*. 2015b; Møller. 2008; Stankowich and Blumstein. 2005). The mean FID of Chilean flamingo in this study relies in the range for walker approaches of other flamingo species in protected areas using similar methods (100 to 204 meters; Coetzer and Bouwman. 2017; Scarton. 2017; Reynolds *et al*. 2020). In contrast, the mean FID of American Oystercatcher obtained in this study is included within the ranges for walker approaches of other Oystercatcher species (between 27 to 74 meters) in areas with low to medium levels of human disturbance (Carless. 2005; Dwyer. 2010; Scarton. 2018a). Other studies that evaluated the same species but in areas with an increase in tourist activity identified shorter response distances in relation with our study. In the case of the Chilean flamingo, average values of AD and FID for an individual walker were identified at 111 m and 88.4 m (Torres et al. 2016). According with Schlacher *et al.* (2013) the American Oystercatcher allowed a car to approach 20 m in average in an area with frequent interactions between vehicles and birds.

The longer FID of Chilean flamingo, compared with that of the American oystercatcher, is consistent with the evidences that response distances increase with body mass because a flight at closer distance is energetically costly as body size increases, or also because larger birds will flush earlier to decrease the higher predation risk due to its conspicuousness in open habitats (Tatner and Bryant. 1986; Blumstein. 2006; Samia *et al.* 2015a but see Samia *et al*. 2015b). Additionally, aspects related with less habituated birds due to habitats with low human pressure (e.g., Ikuta and Blumstein. 2003; Moøller and Tryjanowski. 2014; Samia *et al*. 2015b), and habitats with temporary human presence, both tourism and fishermen, could also influence the detection of a longer FID. In our study, the influence of the month of study could be attributed to this temporary human presence (e.g., Donaldson *et al*. 2007). Also the variation in the abundance of shorebirds along the migration could also contribute to this effect, as found by Møller *et al*. (2014).

As expected, AD and FID were also influenced by the starting distance (Blumstein. 2003; Cooper. 2005; Samia *et al.* 2013), which could be related with an increase in the cost of monitoring the predator when it is seen at a larger distance (Blumstein. 2003). Alternatively, it has been suggested that the influence of starting distance is a mathematical artifact (Dumont *et al*. 2012) related to spontaneous movements (Cooper. 2008) or modified by other factors (Cooper *et al*. 2009). As well, wind speed was also expected to influence FID due to a more agile and faster takeoff when the bird flees (but see Dehnhard *et al*. 2020 and Reynolds *et al*. 2020). The bird's behavior before the approach for the American oystercatcher influenced flight decisions when a threat approaches (Blumstein *et al*. 2015; Blumstein and Pelletier. 2005), probably reflecting variations of predation risk perception when feeding or resting. Based on our results we recommend for future studies to measure the alert distance, as well as those potential factors, when estimating minimum approach distance in a specific area.

We found a large variation among individuals in their response to approaches, greater for the American oystercatcher and lower for the Chilean flamingo. This unexplained variation could be related with specific bird condition or situation, as the profitability of the feeding patch, habitat openness, stress levels, territoriality, body condition, or personal previous experiences (Öst *et al*. 2015; Seltmann *et al*. 2012; Stankowich and Blumstein. 2005; Frid and Dill. 2002). Other, unmeasured factors, such as the distance from refuges could also have an influence (Guay *et al*. 2013).

Even though we studied only two species, taken as models for the major interactions with tourism in the study area, our results obtained are consistent with previous studies (e.g., Arroyo and Fors. 2020; Reynolds *et al*. 2020), highlight the effect of human disturbance and other factors on the alert and flight responses of shorebirds, and are able to guide decision-making regarding the touristic use of this Ramsar site. Focusing on priority, sensitive species and habitats is an appropriate management strategy.

Some limitations of our work should also be mentioned. First, walker group approaches for the Chilean flamingo were omitted, which prevents a comparison of the responses to these stimuli in both species. We selected the most common stimuli according to the disturbance pattern expected by visits to the study sectors. Additionally, we consider as a higher priority to restrict the number of stimuli in the case of the Chilean flamingo so as not to stress and habituate the focal bird with repetitive observations. Second, short response distances to car approaches may be related to vehicle speed. We used a low speed, imitating one of the correct speed limit to use in the area that would also allow us to properly identify the behavioral responses. Although it has been suggested that a faster stimulus is associated with a greater avoidance response, car speed has been found to have no effect on FID, despite increases with the speed limit (Glover *et al*. 2011; Legagneux and Ducatez. 2013). Another reason may be associated with small birds (or medium-sized birds such as the American oystercatcher) that are more agile and efficient when taking flight (Blumstein. 2006).

On the other hand, regarding the methodology used we made some adjustments to the standard methodology employed in experiments of kayak approaches. We approach the focal birds without stopping the kayak, while an external observer took the measures and notes. We judge this as more realistic simulation of touristic kayaking.

The choice of a minimum separation distance from birds is a compromise between conservation and sustainable use (Reynolds *et al*. 2020). Based on our findings we advocate that at critical sites, as in the case of stopover, Ramsar sites, the permissible distances of approaching birds are conservative. The large variation among individuals raise concern that taking average distances as buffer distances means that some individuals will flee, with potential negative energetic costs.

Several indexes have been proposed of minimal approach distances. We suggest to apply the MAD formula 2 and 3 in cases as the Lagoa do Peixe Ramsar Site, as one of the most sensitive and conservative. MADs formulas 2 and 3 based on the AD or FID plus one or two SD, corresponds to the protection of about 68 and 95 % of the individuals of a given population. It corresponds to a conservative measure, given the degree of protection suggested, also including that its calculation is based on the alert and escape distance. MAD formula 1 has been identified as robust, sensitive and conservative (Fernández-Juricic et al. 2005; Rodgers and Schwikert. 2002; Rodgers and Smith. 1997). However, considering that birdwatching in the park has an economic weight that can promote tourism in the region, generating both income and jobs (Kaiser *et al*. 2022), and that the minimum distances can be seen as a balance between conservation and tourism needs (option of minimum feasible distances for bird watchers, as cited in Reynolds *et al*. 2020), we recommend the suggested MADs that are equally valid and appropriate. MAD formula 4, although also a reasonable alternative (Fernández-Juricic *et al*. 2001), is the least conservative one.

We thus recommend a minimum approach distance of 127 m for American oystercatcher without discriminate type of stimuli in the beach (based on formula No 2)., including a minimum approach distance of 286 m when walking and 230 m when kayaking in the estuary (based on formula No 3) according with the response distances of the Chilean flamingo to reduce tourist’s effect in the shorebird’s and wading bird behavior at the Lagoa do Peixe National Park. In the case of the Chilean flamingo, due to the common observation and permanence of fisherman in the area, it is suggested not to apply a minimum distance for this type of activity.

It is important to emphasize that any of the options estimated in this study are equally viable for tourism management in the park. Thus, depending on the proposed management strategies, the decision is political for the park managers (impacts on birds may be accepted in favor of other benefits associated with public use, at least in some sector) who can also choose and suggest any of these options.

According to Kaiser *et al* (2022), the park area has a special importance for the conservation of biodiversity, because it annually receives a variety of migratory birds, having a local richness. Likewise, this area points to ecotourism, which has the conditions to help in the implementation of a local tourist chain (Kaiser *et al*. 2022). For this, having other aspects such as an adequate flow of visitors in the area, improvement of infrastructure at the local level, and inclusion of tourist activities (not allowed today, such as kayaking) are a contribution to the generation of an economic increase that generates benefits for the local community. For its part, management alternatives that contribute to the mitigation of impacts on birds, such as the implementation of minimum approach distances, can be combined with other measures such as their adaptation in time and space, environmental education or the creation of norms to regulate the different activities in the area (Knight and Cole. 1995; Mengak *et al*. 2019).

We also emphasize the importance of implementing a monitoring scheme together with the politics of minimum approach distances in order to evaluate their efficiency (Rodgers and Schwikert. 2002). Additionally, because MAD depends on high compliance to be effective, social support is essential (See Best practices for management in Mengak *et al*. 2019). Finally, this study provides information for bird´s conservation strategies and management of different anthropogenic stimuli focused on reducing human impacts in a stopover site that allow birds and humans coexist in a sustainable way.

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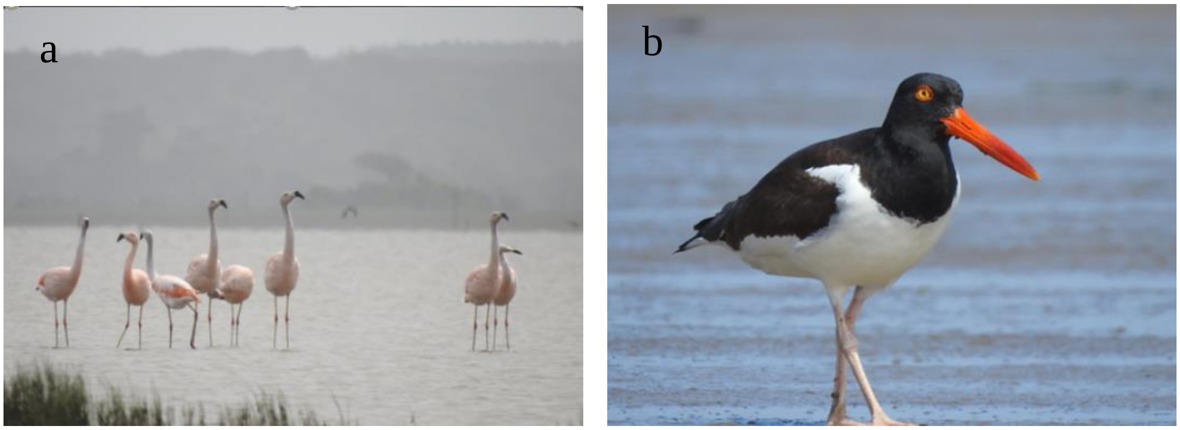
Supporting Information

Appendix 1. Location of the study sites: Beach sector (a, b); and estuary sector (c, d)

Appendix 2. Studied species (a) Chilean flamingo (*Phoenicopterus chilensis*) (b) American oystercatcher (*Haematopus palliatus*)



Appendix 3. Behavioral categories of Chilean flamingo and American oystercatcher identified prior to the start of approach events in the Lagoa do Peixe National Park, South Brazil.

Behaviour	**Definition**
	Chilean flamingo (*Phoenicopterus chilensis*)
Feeding	Flamingos collect food or prey either in the water or in the mud using their bills. Three types of behavior were identified in this study defined as (i) "feeding without displacement": The bird's body is static, it uses its bill to pick up something from the ground and its head remains underwater for a few seconds (according to the -pecking up behavior- described in Delfino and Caio. 2021), (ii) "feeding with displacement": A flamingo walks forward moving the bill in the substrate (according to the -walk feed behavior- described in Brown and King. 2005) and (iii) "trampling": The flamingo submerges its bill in the water and with its legs performs a trampling that includes circular movements (according with -feet-trembling behavior- described in Delfino and Caio. 2021).
Maintenance	Links behaviors such as (iv) "sleeping": One leg is identified with the neck folded along the back and the bill submerged in its feathers. It also includes (v) "Stretching and resting" behavior: The bird is in one place with the legs and neck in a relaxed position, movement of one leg stretched out as well as resting on one or both feet. Finally, (vi) "Preening" behavior is included: the bird scratches, aligns its feathers, and preens with its bill on various parts of its body, such as the neck, chest, back, wings, and other parts of its body. (The behavioral identification was based on what was described in Brown and King, 2005 and Delfino and Caio. 2021).
	American oystercatcher (*Haematopus palliatus*)
Feeding	Indicates behaviors related to the acquisition, location, detection and consumption of food. Specific behaviors were defined according to the two categories identified in this study (i) "feeding without displacement": In the feeding phase, the American oystercatcher is observed locating and detecting the prey, it makes a head movement looking at a fixed point without moving. Gives pecks that penetrate the substrate in various phases at a superficial level or also evidencing depth (see Hulsher. 1996); (ii) "feeding with displacement": The American Oystercatcher walks parallel to the coastline, straight or in zig-zag looking for prey by sight or touch while walking (see Bachmann and Martinez. 1999). Behaviors that are associated with prey handling were linked to either of these two behaviors when the bird was with or without movement (descriptive details are identified in Hulsher. 1996; Garcia *et al.* 2010).
Maintenance	Maintenance behaviors include grooming, resting, among other behavioral aspects important to the bird's health (Bush and Clayton 2018). (iv) "Sleeping" behavior was observed: The bill is identified under the scapulars and sitting on the ground. (v) "Resting" behavior it also included: The American Oystercatcher is standing or lying in a place without movement. Head and bill can be resting in feathers. One or two exposed legs (Nol. 1985; Timmis *et al*. 2022). Finally, (vi) "Preening" behavior is included: the

bird is evidenced manipulating the feathers with its beak to clean various parts of its body (Nol. 1985).

Appendix 4. Alert distances (AD) (m) and flight Initiation Distance (FID) (m) of two model birds in response to four types of anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil.

Species	Type of stimulus	AD			FID		
		N	Mean	SD	N	Mean	SD
Haematopus palliatus	Single Walker	58	68.3	16.9	48	50.8	15.9
	Group of walkers	50	79.6	10	50	56.2	13.6
	Car	46	64.9	15.9	51	43.9	18.1
Phoenicopterus chilensis	Single walker	29	215.2	39.6	32	155.4	45.5
	Kayak	29	147.8	51.4	28	88.6	48.1

Appendix 5. Mean, median, minimum and maximum values of group size for the two model birds in all approach event - Lagoa do Peixe National Park, South Brazil.

Species	Mean	Median	Min	Max
Haematopus palliatus	3	2	1	23
Phoenicopterus chilensis	14	11	2	48

Appendix 6 Minimum approach distances (m) of the Chilean flamingo and the American Oystercatcher exposed to different types of anthropogenic stimuli in the Lagoa do Peixe National Park, South Brazil.

Species	**Antrhopogenic stimulus**	**Formulas**					
		MAD1	**MAD2**		**MAD3**		**MAD4**
		Based on AD and FID data	AD	FID	AD	FID	Based on AD data
Chilean flamingo (*Phoenicopterus chilensis*)	**Kayak**	363	307	234	230	164	153
	Single walker	488	367	312	286	230	204
American oystercatcher (*Haematopus palliatus*)	**Group of walkers**	176	127	106	102	83	77
	Car	150	103	94	84	70	65

CONSIDERAÇÕES FINAIS

Nossos resultados indicam como a exposição a diferentes estímulos antropogênicos afeta as respostas de alerta e fuga de duas espécies de pássaros modelo, o Flamingo chileno (*Phoenicopterus chilensis*) e o Piru Piru, (*Haematopus palliatus*) às aproximações típicas de turistas em um importante local de parada no Parque Nacional da Lagoa do Peixe. Foi evidenciado que as aves permitem maiores abordagens de caiaques e carros do que caminhantes individuais e em grupo, sendo o flamingo-chileno o mais sensível à perturbação. Adicionalmente identificamos que fatores potenciais biológicos da espécie e ambientais influenciaram as respostas das aves. Com base nas respostas estimadas, sugerimos distâncias mínimas de aproximação conservadoras para reduzir a perturbação de aves limícolas nesta área reconhecida como um sítio Ramsar. A este respeito, é enfatizado e recomendado implementar na área um esquema de monitoramento em conjunto com as distâncias mínimas de aproximação para avaliar sua eficiência, a socialização conjunta com as partes interessadas, particularmente com operadores turísticos, bem como observadores de pássaros, auxiliados com estratégias para minimizar potenciais conflitos sociais. Considerando o aumento do turismo em áreas perto de áreas costeiras e a necessidade de fazer um bom planejamento, este estudo fornece informações para estratégias de conservação de aves e manejo de diferentes estímulos antrópicos com foco na redução de impactos humanos em um local de parada que permite que pássaros e humanos coexistam de forma sustentável.