AVON-HEATHCOTE ESTUARY IHUTAI TRUST
SUMMER SCHOLAR RESEARCH

EFFECTS OF HUMAN DISTURBANCES ON BIRDS AT THE AVON-HEATHCOTE ESTUARY

15/02/2020

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Abstract

Bird disturbance may be caused by natural (e.g. predators) and human-induced stimuli (e.g. walkers with dogs, boats, automobiles) and is manifested in behavior or in physiological parameters. Human-induced stimuli are known to affect birds' reproductive success, time budgets, spatial and temporal distribution and decrease in population numbers, including in threatened species. This study used Flight Initiation Distance (FID) as a measurement of human-induced stimuli to birds in four areas of the Avon-Heathcote Estuary Ihutai, a wetland of international significance located Christchurch, New Zealand. In addition to FID measurements, observations were conducted during the Christmas Holidays, when recreational activities are conducted more often on the estuary, corresponding with the highest numbers of native and migratory birds in the area. Measurements of FID were taken for 11 species of shorebirds and waterfowl, with a total of 43 disturbances. Overall mean FID was of 62m (±66.29), with maximum FID value of 373.76m and minimum of 3m. Most disturbances (n=14) were caused by shellfish harvesters, followed by dogs off leash (n=13). FID was species-specific and related to the type of disturbance, and habituation to human presence. Observations show that people undertake recreational activities without consideration for the potential disturbances to birds, and signs that limit access to important bird areas are ignored. The creation of a no-disturbance zone (i.e. exclusion zone) is suggested to protect the estuary edge of the Bromley Oxidation Ponds, which is used as refuge from disturbances occurring elsewhere within Te Ihutai.

Key words: Bird Disturbance, FID, shorebirds, waterfowl, urban estuary, management.
Avon-Heathcote Estuary Ihutai

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Introduction

Bird disturbance is defined as the response of a bird to the presence of a stimulus (Weston *et al.* 2012, McLeod *et al.* 2013). Stimuli can be natural (such as predators) and anthropogenic, such as humans walking, jogging, cycling, operating motorized vehicles or recreational activities (i.e. kite-surfing) and accompanied by dogs (Weston *et al*. 2012, McLeod *et al.* 2013, Glover *et al.* 2015). Birds' response is related to several individual or species-specific traits, such as temperament (Møller and Garamszegi 2012) and may be manifested in behavior and physiological ways (Ellenberg *et al.* 2013), with costs to the bird's time budget, changes in parental care, roosting and feeding habits (Gill 2007, Lin *et al.* 2012, Weston *et al*. 2012) and might ultimately result in change of habitat use and population declines (Weston *et al*. 2012, Livezey *et al.* 2016).

To access how several stimuli affect bird behavior, measurements such as the Starting Distance (SD), the Alert Distance (AD) and the Flight Initiation Distance (FID) are made. The starting distance is related to the distance at which a human begins approaching an animal (Blumstein 2003); the alert distance represents the distance at which an individual bird or flock begin a vigilance response to any given stimulus, and therefore it is greater or equal to the Flight Initiation Distance (Weston *et al.* 2012); The FID represents the distance at which scape behavior occurs (Blumstein 2003, Blumstein 2010) and is correlated to habitat and life-history traits, such as age, size, reproductive stage and occurrence in flocks (Weston *et al.* 2012, Dear *et al.* 2015). Additionally, FID may vary regarding the bird's learning experience: By facilitation, when FID increases with increased exposure to humans and by habituation, where FID decreases with increased exposure to humans. Facilitation is usually associated with dangerous, rapid and unpredictable events, such as exposure to dogs (Blumstein 2003, Weston *et al.* 2012, McLeod *et al.* 2013). Habituation, however, is associated with frequent, slow and predictable approximations, such as walking (Weston *et al.* 2012).

Flight Initiation Distance is used as a tool to determine buffer zones between important bird areas and anthropogenic land-use, especially for recreational activities (Blumstein 2003, Gill 2007, Weston *et al.* 2012, McLeod *et al.* 2013). Therefore, in areas where development projects are planned to occupy natural areas, it is of the utmost importance to quantify the effects of anthropogenic disturbance in birds. Wetlands are important habitats that have been severely depleted worldwide (Lotze *et al.* 2006) and increased use of these areas for recreational activities means that anthropogenic disturbances caused by water sports as well as walking and cycling activities in the shoreline will also increase (Glover *et al.* 2015).

In NZ, previous studies regarding human induced disturbances found these influence incubation success (Lord 2001), time budget (Haase 1995), heart rate (Ellenberg *et al.* 2012, Ellenberg *et al.* 2013), and spatial distribution on braided rivers used by jetboats (McKinley and Smale 2001). However, little is known about human disturbances in estuarine species in urban areas. In this study, SD, AD, FID and observations on flock composition and behavior will be made in order to access how activities such as shellfish harvesting, wind-surfing, walking, cycling and dog-walking disturb birds at the Avon-Heathcote Estuary/Ihutai in Christchurch, New Zealand, a wetland of international significance in the East-Asian Australasian Flyway.

Methods

The focal areas of the study were chosen taking into consideration the following aspects: 1) Areas with a historical high number of animals of a given species; 2) High probability of disturbance; 3) Future areas of occupancy by development projects; 4) Areas of shellfish harvesting. The following areas were chosen (nomenclature following Crossland 2013):

1) Spit Tip/Zero Beach (A1): Characterized by high numbers of shorebirds, the area is also commonly visited by locals during weekends;
2) Penguin St. (Southshore; A2): Area with shellfish harvesting;
3) McCormacks Bay/Beachville Road Area (A3): Area with shellfish harvesting;
4) Sandy Point (A4): This area is of major importance to waterfowl during high tide roosting and will be highly affected by the construction of a walkway by the Christchurch City Council.

Figure 1. The study areas at the Avon-Heathcote Estuary. Adapted from NZ Topographic Map.

Surveys were conducted during low tides for investigation of how shellfish harvesting may affect bird behavior and at high tide to investigate how other anthropogenic stimuli affect birds in the Avon-Heathcote Estuary. Tidal variations determined survey hours, and all sampling occurred between one hour before and one hour after the lowest/highest tide. Samplings lasted from December 19th, 2019 to January 19th, 2020 and compared bird behavior and occurrence of stimuli during weekends and on weekdays. Dates were chosen based on the daylight hightide threshold of 2.3 - 2.6m and low tide threshold of 0.3 - 0.5m. Tidal information was taken from *Land Information New Zealand - Lyttelton tides* and a +45m minutes or +1h30min correction gap was made between Lyttleton and the study sites in Avon-Heathcote Estuary.

Unlike several studies (Haase 1995, Blumstein 2003, Guay *et al.* 2012, Lin *et al.* 2012, McLeod *et al.* 2013, Dear *et al.* 2015, Glover *et al.* 2015) where researchers mimic a stimulus and therefore can easily measure SD and FID, in this study the actual stimuli presented by recreational activities around the estuary was measured, in order to correctly access how anthropogenic disturbance is affecting shorebirds and waterfowl. This approach, however, presents limitations, such as the occasional lack of data on Starting Distances, as well as the lack of constant pace in the stimuli. Sampling occurred in a 280 to 600m radius in each study area. The researcher reached all study sites by foot or bicycle and kept a minimum distance of 50 meters to the birds whenever possible, to minimize the potential of being considered a threat and therefore trigger flush behavior. Standardized clothing was used in order to minimize bias.

Measurements of SD, AD and FID were accessed with the use of a laser rangefinder and flock numbers and composition were accessed with a Nikon Monarch 8x42 binocular. The type of scape (walking, swimming or flying), the relative direction of scape and the time necessary for the flock to resume the same activities presented before disturbance were accessed. Positions were taken by a sole researcher to avoid bias, avoiding individuals that approach humans (i.e. gulls) willingly (Møller and Garamszegi 2012). To avoid resampling focal birds, after SD, AD and FID were taken the researcher moved to another sampling point in parallel direction to the substrate and proceeded to take measurements until the whole sampling area was accounted for. All distances were taken in meters. Results are presented in maximum, mean and standard deviation values. Raw data is available (Weston *et al.* 2012) in the supplementary material.

Results

From December 19th to January 19th a total of 43 disturbances were measured for SD, AD and FID in all sampling sites, with a total of 34 sampling hours. Additionally, several disturbances were observed and not measured, since they were caused by the researcher, a resampling of a bird that had been previously disturbed or flew occurred too far away to be measured with the range finder. Disturbances were recorded at all sample sites. The following species were part of the FID measurement: White-faced heron (*Egretta novaehollandiae)*, Eastern Bar-tailed godwit (*Limosa laponica baueri*), South Island Pied oystercatcher (*Haematopus finschi*), Variable oystercatcher (*Haematopus unicolor*), Spur-winged plover (*Vanellus miles*), Pied shag (*Phalacrocorax varius*), Little shag (*Phalacrocorax melanoleucos*), Grey duck (*Anas superciliosa*), Black swan (*Cygnus atratus*), Canada goose (*Branta canadensis*).

This research showed that shorebirds and waterfowl are constantly disturbed in Te Ihutai Estuary and that people often undertake recreational activities without consideration for their impacts on bird behavior. The following sections describe the effects of human-related disturbance at each sampling site, provide measurements of flight initiation distances (FID) for several species and discuss how these relate to previous studies in similar environments.

Measurements of Flight Initiation Distance

A total of 43 measurements of Flight Initiation Distance were made for 11 species of shorebirds and waterfowl. The Pied oystercatcher and the Variable oystercatcher had the most measurements (n=9 for each), while the Little shag was the least represented species (n=1). Although values of Starting Distance (SD) and Alert distance (AD) were taken, these values were not accessed in all measurements, and therefore were not included as part of the statistical analysis. For example, SD depends on determining the precise location where a stimulus starts its approach to the birds, a metric not always available in this study due to the large number of stimuli happening at the same time and the existent barriers in some sampling sites (e.g. bushes and trees in A1). As supported by Blumstein (2010), values of Alert Distance are not easily measured, since it's not always clear when birds perceive a stimulus. Considering these issues, only Flight Initiation Distances were used for mean, standard deviation, minimum and maximum values (Table 1). Since only one measurement was made for the Little shag, this species is not included at Table 1.

Table 1. Mean, standard deviation, maximum and minimum FID for ten of the eleven species measured.

Species	Mean FID (m)	Minimum FID (m)	Maximum FID (m)
Spur-winged plover	n=2 29.79 (±0.28)	29.59	30
Eastern Bar-tailed godwit	n=4 74.14 (±36.75)	49.7	128.87
Variable oystercatcher	n=9 34.72 (±22.02)	10	66.74
Pied oystercatcher	n=9 45.03 (±34.34)	3	114
White-faced heron	n=5 32.29 (±11.66)	22.27	51.66
Pied shag	n=2 26.04 (±28.34)	6	46.09
Grey duck	n=3 36.32 (±35.32)	13	76.97
Canada goose	n=6 130.16 (±56.18)	47.27	191.97
Black swan	n=2 229.60 (±203.86)	85.45	373.76

The overall mean FID value was of 62m (±62.29) for all 43 disturbances (Figure 2). The maximum FID value was of 373.76m (Black swan disturbed by vehicle and dog off leash at Sandy Point) and the minimum was of 3 meters (South Island Pied oystercatcher disturbed by shellfish harvester at McCormacks Bay). Regarding the source of disturbances, 14 were caused by shellfish harvesters, 13 by dogs off leash, 10 by people walking, 3 by water recreational activities, 2 by a car, 1 by a cyclist. One stimulus was caused by a car followed by a large dog off leash (On a large flock of Black swans in A4, January 19th) and was counted as caused by car.

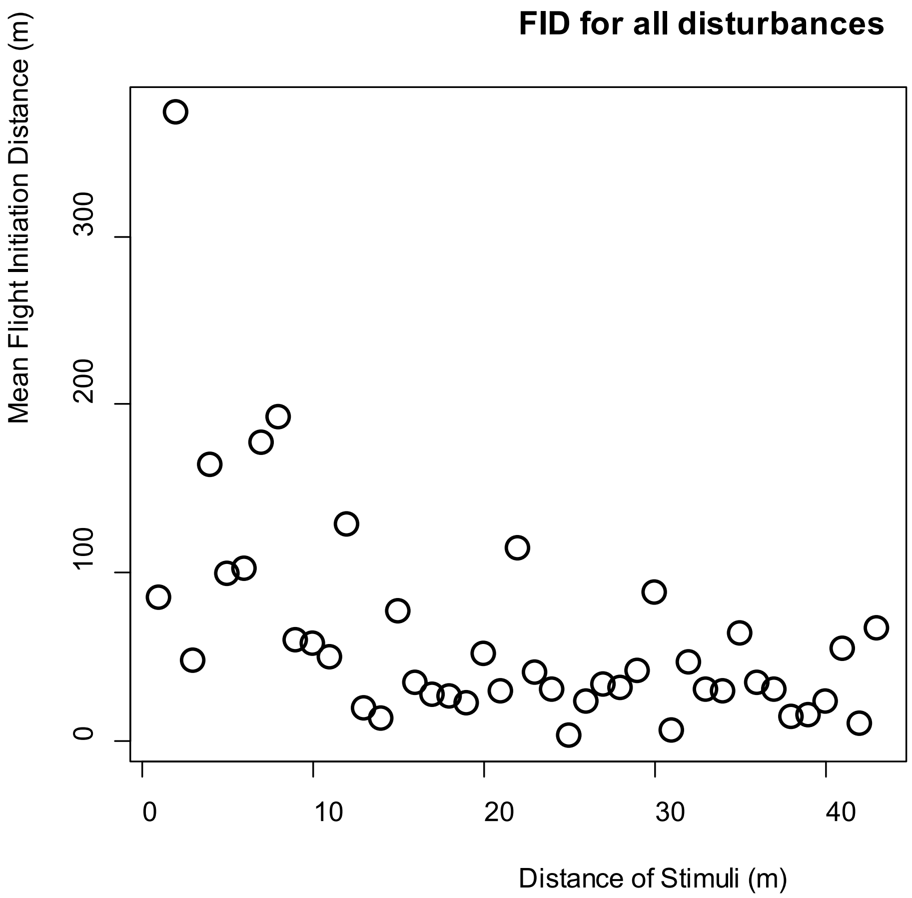

Figure 2. Overall mean values of FID in meters for all 43 disturbances.

The results make clear that dogs off the leash represent a major source of disturbance to shorebirds and waterfowl at the Avon-Heathcote Estuary. In fact, birds tolerate human approach (either by walking, cycling, and engaging on water sports) far more than they tolerate the approach of a dog off leash: Mean FID for dog disturbances was 69.54m (±44.87), while shellfish harvesting had mean FID of 30.51m (±15.31). Since all dogs off leash documented during this study were medium to large-sized, it is impossible to determine if birds' perception of risk to dogs off leash vary according to the size of the dog.

Regarding the disturbances in each site, the McCormacks Bay area (A3) accounted for 23 disturbances, 14 of which were caused by shellfish harvesters; The windsurf car park/Sandy point area (A4) had 13 of disturbances; A1 accounted for 6 and A2 had only 1 disturbance, caused by a dog off leash on a group of Spur-winged plovers. Although the initial experimental design intended to compare the number of disturbances on weekdays and weekends, the fact that part of the study was conducted during the Christmas holidays meant that it is impossible to determine if people's behavior during this season mirrors their availability to engage in recreational activities in the sampling areas year around. Nevertheless, most disturbances occurred on sunny days, from 10 a.m. to 6 p.m.

As explored thoroughly in the following section *(Observations*), each area presented particularities regarding its size, type of disturbances and presence of particular bird species. For the Spit/zero beach area (A1) mean value of FID was 62.24m (±41.13), with minimum of 10m (Variable oystercatcher disturbed by a person walking nearby) and maximum of 128.87m (Eastern Bar-tailed godwit disturbed by dog off leash). The Penguin St. area (A2) accounted for only 1 disturbance (Spur-winged plovers disturbed by a dog off leash), and therefore mean values cannot be calculated. The McCormacks Bay area (A3) had mean FID of 35.31m (±23.89), with minimum of 3m (Pied oystercatcher disturbed by shellfish harvesters) and maximum of 114m (Pied oystercatcher disturbed by two dogs); A4 had mean FID of 111.60m (±97.53), with minimum of 6m (Pied shag disturbed by a dog off leash) and maximum of 373.76 m (flock of Black swans disturbed by a car and dog of leash on the pathway heading to Sandy Point).

Some bird species, such as the Black swan, had high FID values, (229.60m ±203.86) and the Canada goose (130.16m ±56.18) regardless of the type of stimuli presented. These species kept a "buffer zone" of at least 200 meters from shorelines in A2, feeding closer to the water in low tides; Canada geese were seen feeding at the pathway to Sandy Point (A4) at 100 meters from the edge of the car park, but were instantly alert and eventually flew to different areas if a car or person approached the Paddocks/pathway. The Bar-tailed godwit had mean FID of 74.14m (±36.75) and kept a "buffer zone" of at least 32 meters from the edge of the Coastal Pathway in A3 and 90 meters at A2. During the observations it was also clear that this species was highly sensitive to human movement, and birds were aware and behaved differently if people were walking by the Coastal Pathway or sitting on the rocks by its edge, despite the distance to them being virtually the same. Additionally, even though some Godwits use the mudflats next to the Spit to feed (therefore becoming susceptible to disturbances caused by recreational activity in this area), most flocks gather in mudflats and sandbanks further from shore, more protected from human-induced stimuli.

It is interesting to note that despite their different FID values, Pied and Variable oystercatchers, Pied shags, Grey ducks and White-faced herons did not maintain a constant "buffer zone" from people. On several occasions birds from these species were seen approaching people (especially shellfish harvesters) and continued to engage in feeding activity on the shoreline next to the sandbank where harvesting was occurring (A3). Additionally, these species would even approach the researcher (who assumed an initial position 50m away from the closest animal in each sampling site) without presenting any signs of alertness. Grey ducks, Pied shags and White-faced herons, for example, would usually feed within 20 meters from the researcher, and only left when a different stimulus happened (e.g. people walking, approach of dog off leash).

Observations

Area 1

This site was 284m of beach between the Spit (43°33'34.1"S 172°44'46.0"E, estuary lookout) and Zero Beach (43°33'41.4"S 172°44'56.3"E). The Zero Beach area (Sampling Stations 1-3) is not easily accessed by car and that might account for the small number of people during the observations. It contains an important roosting site during spring tides for shorebirds (>600 birds recorded on December 21th), located between sampling stations S2 and S3 (Figure 3) and not accessible by the existing trail at high tide. No disturbance events were observed in this roosting site for Godwits and Oystercatchers, although tyre marks compatible with "land-sailing" were seen in January 12th (Figure 4), evidencing that in low tide this area is visited by people.

Figure 3. Spring-tide roosting site (S2-S3) and sandbank located in front of the Spit in A1 on January 17th, 2020.

Figure 4. Tyre marks compatible with land-sailing at spring tide roosting between Zero beach and the Spit on January 12th, 2020.

The area around the Spit (estuary lookout-S4) is an important feeding and roosting site for Oystercatchers, gulls, cormorants and Godwits during high tide, gathering up to 1.200 birds during sampling in sandbanks within 300m from lookout. The closest sandbank, located directly in front of the lookout (85m), is available during regular high tides but disappears on spring tides, forcing shorebirds to fly to the roosting site at Zero Beach. On average 300 birds, mostly Oystercatchers, were seen roosting in this sandbank before the highest tide, with hundreds of Godwits joining when other sandbanks become unavailable. The distance between high-tide roosting sandbanks and the shoreline at the Spit area means that if people keep on the pathway and dogs are restrained, disturbances are not likely to occur. Additionally, few shorebirds choose the water next to the Spit's shoreline to feed, with most birds preferring the exposed mudflats further from shore.

However, the Spit area is prone to disturbances by dogs. It is easily accessed by trail (<10min from closest car parking area) and the exposed sand during low tide accounts for a popular place for dog walking. Despite signs warning owners to keep dogs under control and "no dogs on estuary" (Figures 5-6), 29 occurrences of dogs off leash were counted, including three situations where dogs were encouraged to get in the water between the roosting sandbank in front of the lookout and the shoreline (Figure 7), with one animal getting 15m away from 530 roosting shorebirds before being called back by the owner. Interestingly, on five occasions dog owners restricted their animals as soon as they perceived the researcher (who had a notebook and binoculars), evidencing that people are aware of the dog-related restrictions but choose not to abide by them when there is no enforcement. The behavior of ignoring dog-related restrictions was also observed at the area to the left of the Zero Beach sampling sites, accessed by trail from Rocking Horse Road (Southshore): Despite the clear sign in the entrance area showing 'dogs prohibited on the beach' (Figure 5), five dogs off leash were counted on the beach in January 18th, in a one-hour period (Figures 8-9).

Figure 5. Sign on Rocking Horse Road access to Zero Beach and The Spit. Photograph taken on January 17th, 2020.

Figure 6. Man walking with dog off leash on sand next to the Spit. Photograph taken on January 12th, 2020.

Figure 7. Large dog in water next to roosting sandbank at the Spit. Photograph taken on December 21th 2019.

Figure 8. Man walking with dog on leash at Zero beach on January 18th, 2020.

Figure 9. Man walking with dog off leash at Zero beach on January 18th, 2020.

Area 2

The Penguin St. area (43°32'46.5"S 172°44'39.7"E) was initially chosen for shellfish harvesting observations but no harvesting activity was seen in the area during the study. The site is close to streets, bus stops and pathways, and therefore is easily accessible. This area presented a high number of birds within sight, with an average of 381.25 waterfowl, 71.5 Eastern Bar-tailed godwits and 105 Oystercatchers feeding within 500m from the observation point (lookout) and thousands of waterfowl and shorebirds scattered in the area between Sandy Point (A4) and the shoreline in front of the Bromley Oxidation Ponds. The pathway is popular for dog walking, and 28 large dogs off leash were observed on the track and on the sand (Figures 10-11). However, only one disturbance was measured in this area. This may be because birds feed on mudflats closer to the water's edge, creating a >80m "buffer zone" from the estuary's edge. Only 4 Spur-winged plovers were observed feeding 55 m from the shoreline, with Godwits, Oystercatchers, Stilts, Royal spoonbills, and waterfowl feeding further from shore and therefore less prone to human disturbances.

Figure 10. Woman with large dog off leash playing catch in estuary (circle in top right corner). Photograph taken on January 12th, 2020.

Figure 11. Man with large dog off leash in estuary on December 21th 2019.

From this sampling point the researcher could observe a large portion of the estuary, including the area in front of the Bromley Oxidation Ponds, where thousands of waterfowl can be observed during the day. On January 12th, the presence of a kayak in the area during low tide accounted for the disturbance of a flock of 120 Black swans that were feeding >500m from the lookout. The kayaker seemed to aim for the flocks of waterfowl and shorebirds feeding in the area between Sandy Point (A4) and Penguin St., and its direct angle of approach to the birds meant that hundreds of animals were potentially disturbed/alarmed by it during low tide feeding. Unfortunately, the distance between the approaching kayak and the flocks could not be accessed with the rangefinder, but the tidal flow put the vessel on a direct angle of approach to the birds.

Despite not documenting any shellfish harvesting activity in Penguin St. during the sampling, the researcher was able to document three occasions where groups of people (presumably collecting shellfish) were on the sandbanks in other parts of Southshore while sampling the Moncks Bay area (A3). In two observations, large dogs off leash were documented running freely between feeding shorebirds (Figure 12), and on the other a child actively disturbed a flock of 75 Oystercatchers by running towards the animals.

Figure 12. Five people and 2 large dogs off leash (red circle) on sandbank accessed by Southshore. Photograph taken on December 27th, 2019 by Lucas Martins.

Area 3

The McCormacks Bay area was chosen for observation and measurements of disturbances caused by shellfish harvesting in Ihutai. The sampling points ranged 760m from The McCormacks Bay bridge (43°33'22.4"S 172°43'43.6"E) (Figure 13) to the edge of Moncks Bay (43°33'23.9"S 172°44'17.2"E), on Beachville Rd. Shellfish harvesting occurs mainly on a sandbank at the tip of McCormacks Bay area (Figure 14), which is close to the Redcliffs School parking lot and is easily accessed by a staircase and by the Coastal Pathway. The shellfish harvesting occurs despite signals warning of water pollution (Figure 15), and groups ranging from 6 to 33 people were observed collecting shellfish at the sandbank during this study. Harvesters usually arrived one and a half hours before the low tide and leave two hours after the low tide. Several harvesters were children from 5 to 10 years old, and some people engaged in the activity with their dog, both on and off leash (Figure 16). Only 4 observations of dogs off leash were made, a small number in comparison to other sampling sites.

Figure 13. Shorebirds feeding at McCormacks Bay bridge and the left tip of sandbank where shellfish harvesters gather. Photograph taken on January 11th, 2020.

Figure 14. Group of shellfish harvesters on sandbank while 2 godwits feed near the water. Photograph taken on December 28th, 2019 by Lucas Martins.

Figure 15. Group of shellfish harvesters on sandbank. In red circle: Sign that reads “Health warning: This coastline is polluted- Collecting seafood is not recommended”. Photograph taken on December 28th, 2019 by Lucas Martins.

Figure 16. Harvesters with two small dogs on leash (one of them inside bucket) at sandbank. Photograph taken on December 28th, 2019 by Lucas Martins.

Harvesters collect Tuangi mainly the tip of the sandbank where it is closest to the Coastal Pathway, and the main disturbance is when they walk from the pathway through the channel to the sandbank (Figure 17). Some birds (notably the White-faced heron and South Island Pied oystercatcher) appeared to tolerate harvesters’ presence and in some cases even approached groups of people. However, they are invariable disturbed by the constant influx of people moving from the sandbank to the Redcliffs School parking lot, and therefore the same birds were disturbed several times while feeding. Some observations showed that birds escaping the disturbances from the shellfish harvesters moved closer to Redcliffs jetty, only to be disturbed by people engaging in water sports or by dogs off leash (Figure 18).

Figure 17. Shellfish harvesters on sandbank while White-faced heron flushes after being disturbed by harvesters walking from shoreline to sandbank. Photograph taken on December 28th, 2019 by Lucas Martins.

Figure 18. Woman with dog off leash next to Redcliffs jetty. Photograph taken on January 14th, 2020.

It is interesting to note that only a few birds occupy this sampling area at any given time, with the largest flock being recorded in January 14th (33 South Island Pied oystercatchers, 2 Variable oystercatchers, 6 Eastern Bar-tailed godwits, 1 White-faced

Heron, 1 Pied shag, 1 Little shag) on the left side of the sandbank that is used by harvesters. Few birds feed within 35 meters from the right tip of this sandbank and on the water between the sandbank and the Coastal Pathway. The sandbank located 270m away from the harvesting area had less than 20 birds feeding on it at any given time.

It might be that the construction of the causeway and the Coastal Pathway has affected the spatial distribution of feeding shorebirds around McCormacks Bay. Eastern Bar-tailed godwits, for example, do not appear to feed within 32m from the Pathway regardless of the presence of any stimuli other than the traffic nearby. Prey availability and species-specific feeding niches may also account for the small number of animals in this area. Godwits prefer feeding on fine sediment away from the estuary mouth while South Island Pied oystercatchers search for food even in the middle of the sandbank occupied by harvesters. These species-specific differences might account for the current pattern of distribution in the area. Future construction around Ihutai should consider the possibility that disturbances resulting from infrastructure built near feeding and roosting sites may have ongoing effects on birds, effectively diminishing their occupancy of the available feeding grounds.

Area 4

This sampling site is 978.36m between the windsurf car park (43°32'58.3"S 172°42'15.2"E) and Sandy point (43°32'48.9"S 172°42'57.0"E) and was the area where there were the most different types of disturbance, including water sports (kite and windsurfing), dogs off leash, boats, vehicles and people walking on the trail. The windsurf car park is a popular area for sightseeing (Figure 19), with dozens of cars parked in the area during lunch time and late afternoon (maximum of 27 cars observed at the same time). Interestingly, drivers rarely leave their vehicles, and the ones who do are usually accompanied by dogs or engaging in recreational activities such as kite and windsurfing. Only on one occasion a person seemed to approach the area to observe the roosting birds: On January 15th a single woman trying to take pictures of the birds (Figure 20) walked in the pathway and disturbed 262 animals (Pied shags, Canada goose and White-faced heron), evidencing that even when people are interested in wildlife, they do not necessarily know how to approach it without interfering with its behavior.

Figure 19. Windsurf car park at 8:30 January 15th. Despite the absence of cars in the parking lot, only 8 Black Swans roost in the area. Photograph taken on January 15th, 2020.

Figure 20. Woman walking on path and disturbing large flock of waterfowl. Photograph taken on January 15th, 2020.

This area is used mostly by Canada geese, Black swans, cormorants and ducks. Flock numbers of waterfowl, particularly at Sandy Point, were high, with an average of 224.8 birds (Figure 21). Waterfowl typically form large flocks (> 250 animals) in water in parallel position to the Bromley Oxidation Ponds/windsurf car park when the tides are rising, but this behavior is not present when recreational activities are being conducted on the water. On one occasion, a kayak approached a flock of 400 Canada geese that were roosting in parallel direction to the car park. The animals flew to Sandy Point, but another kayak was inshore, with a small dog off leash running next to the water. The animals then flew away, presumably to the Bromley Oxidation Ponds. The approach of windsurfers (Figure 22) at high speed also disturbe roosting animals, with continuous vocalization, flush by walking to the bushes next to the shoreline/Linwood Paddocks or flying to another area.

Figure 21: A multi-species flock of 122 individuals roosting at Sandy Point. on December 22th, 2019 by Lucas Martins.

Figure 22: The flock from figure 21 is disturbed by approaching windsurfer. on December 22th, 2019 by Lucas Martins.

Eight dogs off leash were documented in this study area. Dogs were unrestricted, even more so than in the Spit area, despite signs of restricted dog access (Figure 23). The relative isolation of the pathway between the car park and the Linwood Paddocks/Sandy Point might be an incentive for dog owners to let their animals roam freely and even actively pursue birds, as documented on several occasions. On December 19th, for example, a medium size dog was observed walking without leash in the area. After a few minutes of playing catch with a toy, the owner encouraged the dog to chase 7 Pied shags and 1 Spotted shag that were roosting on “Cormorant beach”. Birds flew to the water and the dog chased them for 30m before returning to shore. On January 11th a single Alaskan malamute (Figure 24) disturbed 5 Grey ducks, 7 Pied shags, 3 Canada geese and 78 Black swans on a ten-minutes’ walk on the pathway. Animals disturbed by dogs were less likely to quickly return to feeding or roosting activities, and in most cases took up to 20 minutes to return to their previous state or left the area altogether.

Figure 23. Sign in gate of access to Linwood Paddocks. Despite the “no dog” signal, several dogs off leash were observed past this point. Photograph taken on January 11th, 2020.

Figure 24. Man with dog off leash passing sign from figure 22 on January 11th, 2020.

During highest tides waterfowl congregate on the shorelines of Sandy point (mostly Black swans) and "Cormorant beach" (Canada geese that were previously feeding on the pathway) and human activity on the pathway, including dog walking, is responsible for major disturbances in these roosting flocks, that often escape by flying to the water and therefore become susceptible to disturbances by recreational activities. In many cases boats, paddlers and kite/windsurfers approached flocks at high speed and on a direct angle, causing the animals to disperse. In this scenario, waterfowl in Ihutai have little time to roost and feed in between disturbances.

The area presents a constant "buffer zone" between the shoreline adjacent to the car park and the roosting/feeding waterfowl that gather alongside Humphreys Drive to the right (90m from edge of car park), and at Sandy Point to the left (490m from edge of car park), as well as a 200m exclusion zone directly in front of the car park area. Only on one occasion a group of eight Black swans was seen within 100 m from the shoreline of the car park (Figure 19), in the early morning of January 15^{th}. The birds were disturbed by the arrival of the researcher by bike (FID= 85.45m) and left the area to join a large flock at Sandy Point. The shoreline along the car park is only constantly occupied by feeding cormorants, that tolerate human presence within 6 meters from them (Figure 25) and by gulls, that scavenge food from the empty containers left by people in the car park. Due to the lack of previous research for comparison, it is impossible to determine if the construction of the car park and the high human presence is effectively preventing waterfowl from using this otherwise favorable shoreline to roost. The lack of birds from highly disturbance-sensitive species within this "buffer zone" is, however, an indicator that it might be so.

Figure 25. A Pied shag roosts at ("Cormorant beach"). Groups of 3-10 Pied and Little shags use these wood structures for preening and roosting behavior and tolerate close human approach. on December 22th, 2019 by Lucas Martins.

The observations and the measurements of disturbance conducted in this area show that birds gather at Sandy Point and in the adjacent shoreline in front of the Bromley Oxidation Ponds to roost and to escape disturbances faced in other parts of the estuary. Constant human presence in this shoreline would therefore create the absence of undisturbed areas for waterfowl in the estuary.

Discussion

The Avon-Heathcote Estuary in Christchurch is an estuarine area surrounded by New Zealand's third largest city and faces several anthropogenic threats. Amongst them, human disturbance to the native and migrant species that use the wetland to nest, feed and roost is of considerable importance. Several studies have discussed bird disturbance worldwide, especially in Australia (Blumstein 2003, Glover *et al.* 2011, Guay *et al.* 2012, Weston *et al.* 2012, Guay *et al.* 2013). In New Zealand, however, the literature on bird disturbance focuses on seabirds, and little is known about bird disturbance in urban areas (Haase 1995, Lord *et al.* 2001) and its implications for landscape planning and conservation (but see Wallace 2016 for the challenges in considering disturbances in coastal management).

The use of wetlands by recreational activities worldwide has brought a new pressure to birds that occupy these areas (Guay *et al.* 2012, Glover *et al.* 2015). According to Miller (2001), even in areas where recreational activities are spatially predictable (such as trails) wildlife presents a threshold of tolerance to stimuli based on distance from a disturbance. Additionally, reproductive success and abundance of some species is positively related to distance from frequently disturbed areas, reducing fitness and displacing wildlife from historically available areas (Miller 1998, Miller 2001). Considering these factors, studying how animals react to human disturbances in an estuarine area where several recreational activities occur (and the construction of new pathways is being proposed) is valuable.

This study was conducted during the Christmas Holidays, in which several factors contributed to the large number of people engaging in recreational activities: Children were not in school, adults were on work leave and the temperatures were favorable for outdoor activities. This creates a spatial and temporal overlap with native and migratory species (Glover *et al.* 2011) that occupy Te Ihutai in maximum numbers at the same period (Crossland 2013). Differences in types of disturbance and values of FID among sampling sites seem to be related to factors such as the distance of the sampling site to pathways and carparks, bird species more common in the area, preferable roosting and feeding sites, frequency and spatial predictability of disturbance. The sampling site that was closest to access points to the estuary (i.e. the Coastal Pathway) and is most frequently used by people in recreational activities is McCormacks Bay (A3), and this site presented mean FID value of 35.31m (±23.89), being the location with smaller Flight Initiation Distances in this study. Conversely, the windsurf carpark/Sandy point area (A4) and its pathway is not as frequently accessed by people as A3, and mean FID value was the largest for all sampling sites (111.60m ±97.53). The most frequent source of disturbance was shellfish harvesting (n=14), followed closely by dog off leash (n=13) and people walking on pathways (n=10). Tuangi harvesting occurs in the estuary mainly close to McCormacks Bay area and disturbances take place when people walk between the shoreline and the sandbank where harvesting happens.

Despite FID being a species-specific trait (Glover *et al.* 2011), several studies show the role of habituation, perception of risk and individual experience in the decision to flush when a stimulus is presented (Lord *et al.* 2001, Miller 2001, Blumstein 2003, Taylor and Knight 2003, Ellenberg *et al.* 2012, Guay *et al.* 2012). The present study corroborates the notion that spatially predictable and frequent stimuli are associated with less flushing behavior (Miller 2001) in some bird species at the Avon-Heathcote Estuary. Pied and Variable oystercatchers, Pied and Little shags, Grey ducks and White-faced herons not only did not present buffer zones from areas frequently used by people but effectively approached people while feeding. These animals are probably habituated to human presence since their feeding grounds are close to the Coastal Pathway (A3) and to the pathways along Southshore and the Spit (A1 and A2). It is important to note, however, that these species had smaller FID values but still presented flushing behavior, suggesting they are susceptible to human disturbance.

Conversely, the Eastern Bar-tailed godwit had larger mean FID (74.14m) and its "buffer zone" was 32 meters from the edge of the pathways in A3 and 90 meters at A2. Godwits may be more sensitive to human presence since only part of their annual cycle is spent in the Avon-Heathcote Estuary, with their breeding ground in the Arctic being far less disturbed by constant human stimuli. Additionally, stimuli that occur off-trails and pathways are associated with unpredictability and therefore increase in flush behavior (Miller 2001). In this sense, activities that are conducted without a clear spatial delimitation, such as water recreational activities and dogs off leash roaming free on areas that are not part of trails may account for high disturbance when compared to predictable stimuli.

Particularly regarding dogs, the disturbances documented in this study are valuable. In fact, most studies that investigate dog-related stimuli on birds happen with dogs that are under control, whether it is by keeping them restrained on leash (Lord *et al.* 2001, Miller 2001, Glover *et al.* 2011) or by only using well-trained dogs that ignore birds (Haase 1995). Less than ten dogs on leash were documented in this research, with all but one being of small breeds. All dog-related disturbances were caused by medium to large dogs off leash, indicating that the effects of unrestrained dogs on bird behavior is underestimated in the literature. The flushing behavior of birds exposed to dogs vary between species, particularly considering that not all habitats present dog-like predators (e.g. foxes, coyotes), and that birds may adopt different strategies to respond to the dog threat: Birds may flush as soon as the dog reaches a distance threshold or may wait until the last minute in order to not be detected by the dog (Miller 2001). In New Zealand there are no native mammal predators, and therefore one can assume that the high FID values related to dog stimuli (mean of 69.54m ±44.87) derive from either a previous experience with this stimulus or the unpredictable nature of it.

Haase (1995) studied the effects of human disturbance to the time-budget of foraging South Island Pied oystercatchers and the Eastern Bar-tailed godwits in the Avon-Heathcote Estuary. In that study, stimuli ranged from people running or walking towards the birds from variable distances, a dog running towards the birds from 30m and a kayak approaching from a 30m distance. The mean FID for Pied oystercatchers was of 75.1m (± 15.73) for humans walking and 57.2m (± 12.4) for a dog running. The present study found mean FID of 26.08m (±14.36) for people (shellfish harvesters) and 77.68m (±42.46) for dogs off leash, presenting therefore a contrary trend. Haase's (1995) results show that vigilant (walk and stand head up) and foraging behaviors altered when stimuli were applied, and in stimuli related to people walking and running the proportion of time spent in vigilant behavior increased and foraging decreased after the disturbances. The kayak disturbance had minimal effects while the ones imposed by people were the most disruptive, even when compared to dogs. These results are somewhat contrary to the present study's finding that dogs represented a major disruption (and presented higher FID values than shellfish harvesters).

The methods used by Haase (1995) regarding dog-control might explain the differences found in the effect of dogs as stimuli: The researcher used a well-trained dog to catch tennis balls that were thrown close to the birds. In all cases the dog returned to the researcher immediately after collecting the ball, and therefore it can be assumed that it moved on a straight line and did not wander closer to the birds, not imposing a threat similar to the dog-related disturbances observed in the present study. In fact, the present results agree with Glover *et al.* (2011) who found that people walking dogs presented a higher threat (higher FID values) than walkers and predicted that FID values would be even longer for dogs off leash. Lord *et al.* (2001) studied the response of New Zealand dotterels (*Charadrius obscurus aquilonius*) in the North Island and found that birds flushed at higher distances when the disturbance was caused by a walker accompanied by a leash dog. The authors also stressed that unrestrained dogs may behave as if hunting, and therefore be perceived as an even higher threat.

Black swans and Canada goose presented high mean FID values (229.60m and 130.16m, respectively) and kept a "buffer zone" of at least 200 meters from shorelines in A2, as well as in A4. These results corroborate previous studies with a positive relationship between body size and FID (Guay *et al.* 2012). Blumstein (2010) proposes that "animals will flee approaching predators soon after they detect and identify them as a threat to reduce or minimize ongoing attentional costs of monitoring the approaching predators.'' This hypothesis implies that species that detect threats at greater distance (due to body size, for example) than birds which are unable to detect threats will monitor the approach of disturbances and this behavior comes with important energy costs and trade-offs between an early flush without maximum velocity and a late energetically-costly flush as a predator approaches (Blumstein 2003).

Additionally, large prey may initiate flush behavior earlier than smaller ones to counteract their high detectability (Guay *et al.* 2012) and smaller species have time-budgets specifically related to high energy requirements, and therefore will risk predator proximity and disturbances to maximize food intake (Blumstein 2010). Waterfowl use water as refuge, and higher distance from their feeding sites to water and the angle of approach of a disturbance in relation to refuge position may affect FID (Guay *et al.* 2013). Although some species in the Avon-Heathcote estuary community may present habituation to human presence and therefore present shorter FID, such as the Oystercatchers and cormorants, previous studies have shown that bird species are not equally susceptible to habituation (Glover *et al.* 2011). In this sense, it might be that waterfowl populations in this area will not adapt to human disturbances. Considering that disturbances affect physiological conditions, reproductive success and population sizes (Gill 2007, Lin *et al.* 2012, Weston *et al.* 2012, Livezey *et al.* 2016), it is important to include waterfowl as focal species when discussing the recreational use of this estuary. Additionally, these characteristics and the spatial segregation between small shorebirds and large waterfowl at Te Ihutai, make it possible to adapt signs and restrictions in each of the study areas to account for these inter-species differences.

Values of mean FID for several species were similar between this study and others conducted in Australia with walkers (Blumstein 2003, Glover *et al.* 2011): 26.04m (±28.34) in this study and 31.2m (±18) in Blumstein (2003) for the Pied shag; 32.29 m

(±11.66) in this study and 30.8m (±20.2) in Blumstein (2003) for the White-faced heron; 36.32m (±35.32) in this study and 38.9m (±29) in Blumstein (2003) for the Grey duck. Conversely, mean FID values for the Eastern Bar-tailed godwit (74.14m ±36.75) were considerably higher at the Avon-Heathcote Estuary. Blumstein (2003) found mean FID of 22.1m (±14.8) and Glover (2011) found 59.50m (±5.25). It might be that sampling sizes affected the possibility of comparison, but since the present study also accounted for dog-related disturbance, the higher mean FID may account for the influence of dogs in the species-specific flush distance. During the observations, Eastern Bar-tailed godwits were affected differently by the presence of a stimulus and the movement associated with it, i.e. a person standing on the edge of the Coastal Pathway versus a person climbing on the rocks, sitting down and moving constantly to write and use binoculars. This sensitivity to movement was also observed in Ellenberg *et al.* (2013), who studied heart rates of the Yellow-eyed penguin (*Megadyptes antipodes*) and represents important data for conservation purposes and buffer zone delimitations.

Interestingly, the two cases of disturbances in the Spur-winged plovers were caused by dogs but presented smaller mean FID (29.79m ±0.28) than in Blumstein (2003), who found 46.8m (±30.5) and Glover *et al.* (2011), who found 62.62m (±5.81). This difference might be related to sampling size but is more likely to be a result of habituation, since all three measurements were made next to pathways. Lord *et al.* (2001), for example, found that incubating New Zealand dotterels would allow closer approximation and return to nests sooner on beaches constantly used by people in comparison to more isolated breeding sites.

Short FID distances were recorded for Black Swans in Guay *et al.* (2013): 6.5m (± 5.9) while this species presented the highest mean FID values in the present study: 229.60m (±203.86). As discussed earlier, frequency and spatial predictability of disturbances, risk perception and habituation are directly related to flush responses (Miller 2001, Blumstein 2003, Taylor and Knight 2003, Guay *et al.* 2012), and the high values of FID for waterfowl (Canada goose also presented the high mean FID value of 130.16m ±56.18) in A4 can be explained by these factors.

This study showed more disturbances from shore based recreational activities in the Avon-Heathcote Estuary than those caused by water sports. In fact, only three of the 43 measured disturbances were caused by water recreational sports. However, observations confirmed that on sunny days birds may be caught between escaping people and dogs off leash on the pathways and being disturbed by motorized or non-motorized boats and kite/windsurfing activities (such as in A4). Kayaks and kitesurfing can access shallower intertidal areas, as evidenced previously in Glover *et al.* (2015). By comparing FID values for aquatic birds (including *P. varius,* also accessed in this study), the authors discovered that Flight Initiation Distance for canoes' approaches were shorter than the ones for walkers, and an 89.5m aquatic exclusion zone was proposed by taking into consideration the different species measured and the types of recreational vessels. Notably, people engaging in water recreational activities at the Avon-Heathcote Estuary approached birds at direct angles, high speed and did not avoid large flocks of birds. Taylor and Knight (2003) argued that the behavior of recreationists on public lands is influenced by how they perceive their effects on wildlife. In this scenario, water recreationists at the Avon-Heathcote Estuary seem not to perceive themselves as threats to bird behavior, especially considering the case of waterfowl that use water as a refuge (Guay *et al.* 2013).

In New Zealand, the access to coastal zones is protected under the RMA and its use for recreational activities is firmly engrained in public perception (Wallace 2016). In addition, despite a general positive attitude towards bird conservation measurements, including the creation of buffer zones to limit disturbances, the limitation of access to walkers is not well received, probably due to self-interest (Glover *et al.* 2011). Activities such as wildlife photography and ecotourism are constantly perceived as benign to birds but can impose long-lasting disturbances to animals as well (Ellenberg *et al.* 2012, Ellenberg *et al.* 2013). The present study highlights that people would often consider themselves as champions for wildlife conservation and complain about recreational activities that they perceived as harmful to the birds (e.g. walkers with dogs off leash complained about shellfish harvesting), while conducting activities that caused considerable disturbance (as seen in Taylor and Knight 2003).

Despite efforts taken by the international community, there is a worldwide struggle in biodiversity conservation, and humans are currently held responsible for an ongoing mass extinction event (Kim *et al.* 2011). Wetlands are particularly threatened, and have been occupied by human developments for centuries, especially for agriculture and urban expansion, with consequent loss of habitat and biodiversity (Lotze *et al.* 2006, Kim *et al.*

2011, Ausseil *et al.* 2011, Clarkson *et al.* 2013, Hassall 2014). Wetlands provide ecosystem services, socio-cultural benefits and habitat for wildlife (Kim *et* al 2011, Hassall 2014). Regardless of their importance, in New Zealand wetlands are the most severely impacted ecosystem, with only 10% of the original area remaining (Ausseil *et al.* 2011). Considerations about land-use regarding wetlands are complex: Historical occupation by early human settlements, expensive and time-consuming restoration projects, resistance by the community in avoiding developments in the area and the belief in the resilience of aquatic communities in urban habitats (Lotze *et al.* 2006, Kim *et* al 2011, Hassall 2014), mean that quite often wetlands have continued encroachment and land-use changes.

In this sense, the conservation of biodiversity in wetlands surrounded by urban areas becomes a pressing issue, and requires profound knowledge on the biological community, ecosystem functions and human perspective (Angold *et al.* 2006, Hassall 2014). The literature has shown that urban landscape planning can be compatible with maintenance and enhancement of biodiversity, by promoting connectivity for species through green corridors, fragments of preserved natural vegetation (i.e. "urban greenways") and the creation of artificial habitats (Angold *et al.* 2006, Sandstrom *et al.* 2006, Fontana *et al.* 2011, Hassall 2014). Additionally, the presence of natural sites can enhance life quality for citizens on urban areas (Sandstrom *et al.* 2006).

Discussions about the creation of exclusion and buffer zones are important in landscape planning and conservation efforts worldwide, especially since recreational activities have increasingly encroached on more natural areas that can be occupied by threatened species (Lord *et al.* 2001). Among the strategies used to create buffer zones and exclusion areas, managers can prohibit human access to breeding sites of threatened species or establish a compromise by determining which recreational activities are more disruptive than others and limiting their occurrence to a few hours per day (Lord *et al.* 2001, McKinlay and Smale 2001). Additionally, managers can protect refuge areas, making sure that animals will have a safe site to escape to if disturbed elsewhere (Guay *et al.* 2013). However, this strategy can be particularly tricky in estuarine or coastal areas, since a plethora of recreational activities are conducted both on shore and in water (Glover *et al.* 2015). Assumptions regarding angle of approach and duration of stimuli can also be taken into consideration (Fernández-Juricic *et al.* 2005, Ellenberg *et al.* 2013).

In some cases, buffer zones are determined by specialist-consultation (Ruddock and Whitfield 2007) due to a shortage in empirical field studies. The effects of such decisions can be detrimental, since only empirical data on local context and/or species-specific measurements can provide robust information for each area (Ruddock and Whitfield 2007). The use of previous studies in bird disturbance conducted worldwide (Livezey *et al.* 2016) to several stimuli can be helpful to determine buffer zones, especially considering that flush behavior is species-specific (Blumstein 2003). However, site-specific studies are the most valuable tools for determining buffer zones and exclusion areas. By understanding the effects of human disturbance on the bird community at the Avon-Heathcote Estuary and engaging in discussions and educational activities with different stakeholders, managers of this important site can protect wildlife while respecting its human dimension (Glover *et al.* 2011).

Conclusion

This study showed how waterfowl and shorebird species react to human-induced disturbances in an urban environment, and therefore represents an important tool for managing and conservation of the Avon-Heathcote Estuary Ihutai in Christchurch, a wetland of international significance in the East-Asian Australasian Flyway. The data presented here show that recreational activities around the estuary are often undertaken without consideration for the birdlife that feeds and roosts in the area. Despite warning about no-dog zones and other signs that limit access to the estuary, people do not perceive their recreational activities as detrimental to birds. Interestingly, no Law Enforcement agents were observed in the study area during the busiest time of the year, the Christmas Holidays (except one park ranger at A4 on December 19th). This may be perceived by people as an encouragement to conduct certain behaviors, such as entering no-dog zones with dogs off leash or entering restricted areas with cars (Figure 26).

Figure 26. Car driven by windsurfer with large dog off leash running by its side on pathway leading to Sandy Point. This disturbance documented in January 19th caused all birds roosting in the Sandy Point area to leave it.

Data collected here confirm the notion that waterfowl and some shorebird species (notably the Eastern bar-tailed godwit) are highly sensitive to stimuli resulting from human disturbances and avoid areas with highest probability of human encounter. Conversely, other species appear more tolerant to disturbances, such as the Variable oystercatcher and the South Island pied oystercatcher, and that may be due to habituation. Further studies are needed in these species to determine the distinction between species-specific thresholds and habituation. The habituation to human presence in these animals may be related to previous construction of the Coastal Pathway and the car park next to Sandy Point, as well as the pathways next to Penguin St. and the Spit. The lack of previous studies on bird disturbances in these areas before the constructions, however, means that no comparable studies can be made to thoroughly understand how these alterations in the environment might have changed bird behavior.

Not all species are as tolerant and desensitised to spatial-predictable use of areas by humans, and the fact that waterfowl keep a constant distance from the windsurf carpark evidences that. All species sampled showed flushing behavior when exposed to some degree of disturbances, and the literature clearly shows the detrimental effects of disturbances in bird biology, even when habituation is present. Therefore, considerations on angle of approach, activity, duration of stimuli and distance from feeding and roosting birds should always be taken when engaging in recreational activities at the Avon-Heathcote Estuary Ihutai.

Most importantly, this study shows the need for a no-disturbance zone along the estuary margin of the Bromley Oxidation Ponds. This may be the last haven for wildlife in the estuary due to its distance from pathways and other areas where recreational activities occur year-around. Lastly, it is important to emphasize the need for careful consideration of bird sensitivity to human induced disturbances when planning constructions and development of recreational sites in estuarine areas. Regular studies should be conducted in Te Ihutai to understand how native and migratory species are affected by human presence in the area. Among these studies, qualitative research should be made to investigate how people engaging in recreational activities in this habitat perceive their effects on wildlife. This comprehension would be valuable in the design of activities to educate the community about human disturbance, bird populations, and their role in the maintenance of the estuary as a much-needed wildlife refuge in an urban area.

Acknowledgements

I would like to thank Andrew Crossland for the valuable information regarding the Avon-Heathcote Estuary's wildlife. I would also like to thank Dr Cynthia Roberts, Professors Philippa Mein-Smith and Islay Marsden for the commentaries on this manuscript. Lastly, thank you Tanya Jenkins for supervising the field activities. This research was sponsored by the Avon-Heathcote Estuary/Ihutai Trust via the Summer Scholarship grant.

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