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Juvenile bar-tailed godwit (*Limosa lapponica baueri*) settlement at the Avon-Heathcote Estuary/Te Ihutai

Prepared for the Avon-Heathcote Estuary Ihutai Trust

by

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Executive Summary

- Bar-tailed godwits (*Limosa lapponica baueri*) are native shorebirds that migrate between New Zealand and Alaska each year. Juveniles visit different sites in New Zealand before settling at one, which they return to each year following migration.
- This research aimed to study how human disturbance and environmental quality affect the settlement of juvenile godwits at the Avon-Heathcote Estuary/Te Ihutai.
- Primary data on the juveniles' locations and numbers was collected at the estuary. This was supplemented with secondary data from eBird and the Ornithological Society of New Zealand. A graph of juvenile population trends and a density map were created.
- Juvenile godwit numbers appear to be declining at the estuary. Over time, there have been hotspots of sightings around the western side of the estuary and Southshore Spit. A decline in their use of Southshore Spit was detected during 2021. This could be due to disturbance and flow-on effects of low water quality. However, juveniles were observed using Linwood Paddocks. This area appears to be a suitable roost site, with food availability at all tide levels and low disturbance.
- COVID-19 lockdown restrictions and the return of adult godwits limited primary data collection. Secondary data had limitations, including reduced reliability.
- Additional research, including longer duration studies, should be conducted to further investigate factors affecting juvenile godwit settlement.

Introduction

Bar-tailed godwits/kuaka (*Limosa lapponica baueri*) are migratory birds that are native to New Zealand. Each year they migrate 11,000 km between Alaska, where they spend their breeding season, and New Zealand and Australia, where they spend the non-breeding season (Conklin et al., 2016; Woodley, 2017). After initially migrating to New Zealand, juvenile godwits spend 2-4 years here, visiting different locations before choosing one site to settle at (Battley et al., 2020). Adult godwits are site faithful, returning after migration each year to the same location they settled at as juveniles (Battley et al., 2020).

Bar-tailed godwits have a large population at the Avon-Heathcote Estuary/Te Ihutai. This is a site of ecological significance located on the eastern side of Christchurch (Shadbolt, 2015). It has a variety of indigenous vegetation (Shadbolt, 2015) and is an important location for shorebird settlement, including godwits (Sage, 2018). Over time, the land use surrounding the estuary has changed considerably, with the wetland vegetation being reduced to less than 20% of its former extent (Shadbolt, 2015). The estuary is now bordered by farmland, the Bromley Oxidation Ponds, and an increasing number of locations where human activity is prevalent, such as beach access points, boardwalks, and sea walls (Avon-Heathcote Estuary Ihutai Trust, 2020).

The global godwit population is decreasing by 2% each year (Conklin et al., 2016), and their conservation status is at risk of declining (Department of Conservation, n.d). This raises concerns from both conservation and cultural perspectives. Godwits are culturally significant birds to Māori (He Kuaka – Te Mana Kaha O Te Whanua, n.d.). New Zealand is a key overwintering habitat for godwits and is, therefore, a critical conservation location for the future of this species. The effects of environmental quality and human disturbance on godwits at the estuary could have wider implications on the overall health of their population (Battley et al., 2011).

Therefore, it is important to determine what factors are influencing juvenile godwit settlement at the estuary so solutions can be devised to encourage more juveniles to settle there and to support the global population. This Geography-309 project aimed to identify how human disturbance and environmental quality affect the settlement of juvenile godwits at the Avon-Heathcote Estuary.

This report begins with a review of relevant literature focused on factors that may affect juvenile godwit settlement. The methods of the report are then explained, followed by the results and discussion. Limitations, recommendations, and future research focus areas are then identified, followed by a conclusion.

Literature Review

Literature around migration patterns, human disturbance, water and sediment quality, and climate change was reviewed. These findings highlight the importance of assessing the effects of human disturbance and environmental quality, as these are likely key drivers affecting juvenile godwit settlement at the estuary.

Migration Patterns

Adult godwit migration is a key variable that directly influences identification of juvenile godwits at the estuary. As there is no long-term dataset that focuses on the Avon-Heathcote Estuary, understanding how and when adults migrate relies on studies that focus on other estuaries around New Zealand (Battley et al., 2020).

Juvenile godwits reside in New Zealand until they reach adulthood (2 – 4+ years old). After this, they migrate in March – April each year to the Yellow Sea, where they stop to refuel before continuing on to Alaska (Battley et al., 2012; Choi et al., 2015). When adult godwits are not in New Zealand, juveniles can be accurately observed (Battley et al., 2020; Conklin et al., 2010). Therefore, migration timing was a key factor to consider when setting up the project's methodological approach.

Human Disturbance

There has been little research into how human disturbance affects godwits, including in New Zealand. However, overseas research provides insight into how shorebirds in general react to disturbance, and the implications disturbance can have.

Flight initiation distance (FID) refers to the distance at which a bird begins escaping from disturbance (Navedo & Herrera, 2012). Glover et al. (2011) looked at 28 shorebird species in Victoria, Australia, and found they often have increased FIDs when in larger flocks, possibly because disturbance is detected earlier. Heavier shorebirds had greater FIDs (Glover et al., 2011), suggesting godwits may be more readily disturbed than smaller species. Flock composition can also affect FID. Both knots (*Calidris* spp.) and plovers (*Charadrius* spp.) in Darwin, Australia, had greater FIDs in single species flocks compared to mixed species flocks (Lilleyman et al., 2016).

The type of disturbance can also affect how shorebirds respond. Overall, faster forms of disturbance, such as joggers or people with dogs, seem more disruptive, causing shorebirds to flee earlier than pedestrians (Glover et al., 2011; Mayo et al., 2015). There are mixed findings around whether shorebirds habituate to disturbance (Glover et al., 2011; Lilleyman et al., 2016; Martín et al., 2015; Navedo & Herrera, 2012).

Human disturbance can cause shorebirds to increase vigilance and decrease feeding, as Martín et al. (2015) found in Kentish plovers (*Charadrius alexandrinus*) at Los Lances Beach, Spain. Energy costs at highly disturbed sites may be unsustainable. Lilleyman et al. (2016) suggested this was a concern for knots and plovers in Darwin. Ultimately, birds may leave highly disturbed sites and move elsewhere, as seen in shorebirds in Santoña, Victoria and Joyel Marshes Natural Park, Spain (Navedo & Herrera, 2012). This suggests human disturbance is a factor that may affect juvenile godwit settlement. It was, therefore, one aspect considered in this project.

Water and Sediment Quality

The Avon-Heathcote Estuary has many inputs, including the Avon and Heathcote rivers. Additionally, storm water drains and drainage from the surrounding land and oxidation ponds discharge into the estuary, the latter of which provides the largest input (Bolton-Ritchie & Main, 2005). The Pacific Ocean also feeds into the estuary. Decaying plants and animals contained within the estuary cause the water and sediment to be abundant with nutrients (Carlson et al., 2013). Heavy metals and metalloids are naturally found in the environment, but human activity increases their concentration to levels that may be harmful to animals (Bolton-Ritchie, 2010). This is usually caused by run-off from roads, factories, and agricultural land, which all occur near the estuary.

Bolton-Ritchie and Main (2005) concluded that the concentrations of nutrients found in the estuary were comparable to the Australia New Zealand Environment and Conservation Council trigger levels for 'slightly disturbed estuarine water'. The trigger levels indicate where adverse biological effects may begin to occur. For example, macroalgal growth can only occur when certain threshold nutrient levels are observed (Ren et al., 2014). Some sites around the estuary, such as those closer to the river mouths or oxidation ponds, had higher nutrient concentrations than others (Bolton-Ritchie & Main, 2005). However, at all sites, water quality exceeded the trigger values. This study occurred before any of the recent Christchurch earthquakes. The 2011 earthquakes led to the breakdown of Christchurch's wastewater infrastructure, causing untreated sewage to be discharged into the estuary between February and June 2011 (Barr et al., 2020). As a result, eutrophication occurred, but this was reversed once repairs were made (Barr et al., 2020).

Sediment is a good integrator and amplifier of metals; thus, heavy metal contamination is concerning in aquatic ecosystems such as the estuary as metals can accumulate and cause adverse effects on the inter-tidal habitats (Lau, 2000). Carnivorous migratory birds like godwits are at greater risk of contamination exposure. This is because benthic invertebrates, the godwits' primary food source, accumulate significant concentrations of contaminants from sediment (Liu et al., 2015). This could potentially lead to biomagnification and impacts on food webs (Cui et al., 2011; Jumbe & Nandini, 2009), a wider issue that must be considered in the environmental quality assessment. These effects are concerning as the highest heavy metal concentrations in the Heathcote catchment are downstream at the Curletts Road Drain and City Outfall Drain. These both directly drain into the eastern part of the estuary (Gadd, 2015). Thus, the health of the Heathcote catchment is closely connected with the estuary.

Following the Christchurch earthquake in February 2011, liquefaction covered 20 – 40% of the estuary bed. The sediment from liquefaction contained lower concentrations of heavy metals compared to pre-existing sediments, as it came from historical pollutant sources. Despite this, the changes in mudflat exposure and liquefaction likely impacted sedimentation patterns and estuary biota (Zeldis et al., 2011). This raises concerns about the impacts on godwits, other organisms, and vegetation in the estuary.

Overall, pollutants and excess nutrients can affect sediment and water quality, negatively impacting ecosystems (Lau, 2000; Ren et al., 2014). Water and sediment quality are relevant to juvenile godwit settlement patterns as they can affect the quality and availability of food sources for godwits. Therefore, they were considered in this project as factors that could affect juvenile godwit settlement.

Climate Change

Global sea levels are rising due to climate change (Nicholls & Cazenave, 2010). Sea level rise changes the morphology of estuaries and is predicted to be the main driver of future habitat loss as roosting sites will be prone to flooding (Austin & Rehfisch, 2003). Sea level rise may also affect sediment quality in the future, which is a major influence on where wading birds settle (Veloz et al., 2013). To protect juvenile godwits, future plans must consider the impacts of sea level rise. For example, restoring wetlands can provide wading birds with new habitat if their previous habitat becomes flooded (Kelly & Condeso, 2017).

Methods

This research occurred at the Avon-Heathcote Estuary (-43.545507, 172.729302), which is separated from the Pacific Ocean by Southshore Spit and is made up of 880 hectares of mudflats and salt marsh (Crossland, 2013). Near the estuary are the 875-hectare Bromley Oxidation Ponds and 100-hectare Linwood Paddocks (Crossland, 2013). There are also 40 hectares of nearby man-made tidal wetlands (Crossland, 2013).

This project combines data from three different sources. The first source is primary data, which was collected by visiting 12 different sites around the estuary throughout August (Figure 1), making a total of 29 site visits. On each visit, counts of godwits were made, although they were only observed on six visits. The godwits' behaviour, any potential human disturbance, and habitat characteristics were also noted.

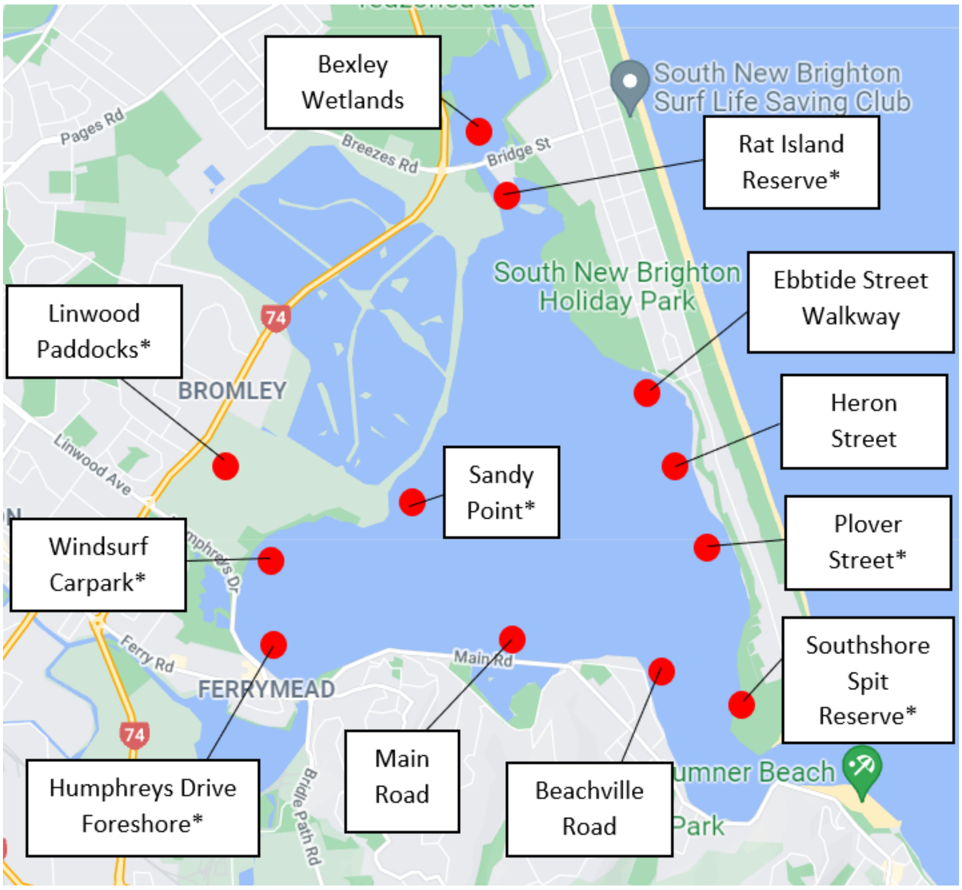

Figure 1: A map of the Avon-Heathcote Estuary. Each primary data collection site, indicated by a labelled red circle, was visited between one and five times in August 2021. Sites with secondary observations of godwits from eBird are indicated with asterisks (*) beside the site names.

The next source of data is secondary data of godwit numbers at different sites around the estuary (Figure 1). This comes from eBird, a citizen science website where members of the public can log their bird sightings (eBird, n.d.). The eBird data included observations between 1997-2019 and from June-August 2021. As this project is focused on juveniles, data between September and March was excluded, as this is when adult godwits are in New Zealand (Battley et al., 2011). This left 29 separate godwit observations to use alongside our primary data.

The final source of data is secondary data from winter wader counts conducted between 2000-2021 by the Ornithological Society of New Zealand. This survey involved counts of waders present at different sites around the country, including the total numbers of godwits present at the Avon-Heathcote Estuary. The survey only includes juveniles as it is conducted in winter when the adults are overseas (Battley et al., 2011).

The wader count data from the Ornithological Society of New Zealand was used to show trends in juvenile godwit numbers at the estuary over time. Combining the primary data with secondary data from eBird, a density analysis of flock counts was run in ArcMap using the kernel density (spatial analyst) tool (ArcGIS, n.d.) to show juvenile site use around the estuary. A significance weighting of 2 was applied to areas that had flock sizes of greater than 50 and for areas with flock sizes below 50 a significance weighting of 1 was applied.

Using this data, themes in the sites that juveniles prefer, and changes in their site use over time, were identified. Based on observations and previous literature, possible factors were suggested that could affect the settlement patterns of juvenile godwits.

Results and Discussion

Overview of Godwit Numbers and Site Use

While the number of juvenile godwits at the estuary fluctuates over time, there appears to be an overall slowly declining trend (Figure 2). This could be explained by the 2% yearly decline in godwit numbers worldwide (Murray et al., 2018). The decrease in juvenile godwit numbers at the estuary around 2011 and 2012 could also be related to the February 2011 Canterbury earthquake. This caused untreated sewage to flow into the estuary from February-July that year, temporarily decreasing water quality (Barr et al., 2020). Liquefaction also occurred, covering up to 40% of the estuary (Potter et al., 2015). By smothering macroinvertebrates and bivalves (Bolton-Ritchie, 2015), which godwits feed on (Ross, 2019), liquefaction could have decreased the godwits' food source. These factors could have caused some godwits to move elsewhere.

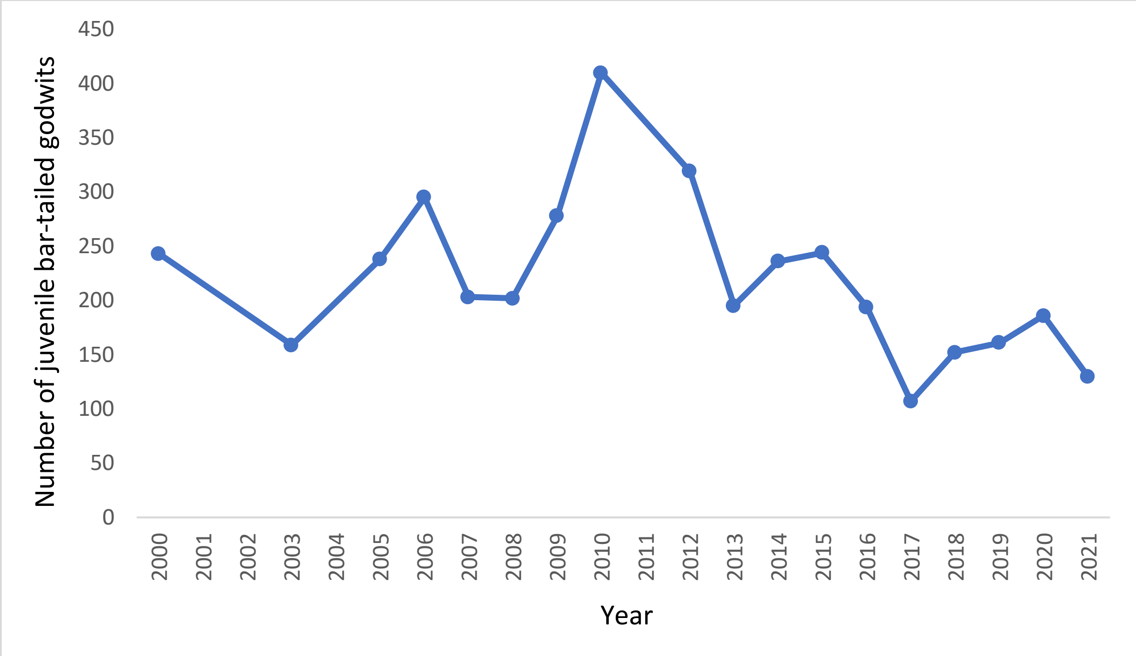

Figure 2: Trends in juvenile bar-tailed godwit numbers over winter at the Avon-Heathcote Estuary between 2000-2021. Data obtained from the Ornithological Society of New Zealand.

Figure 3 shows the different locations of juvenile godwits sightings at the estuary between 1997-2019 and in June-August 2021. Sightings have a higher density around three broad areas of the estuary. One cluster is located to the south-east of the estuary, at the tip of Southshore Spit (Figure 3). A second cluster is found at the north of the estuary, around Bexley Wetlands and Rat Island Reserve (Figure 3). The final cluster is located around the western side by the Windsurf Carpark, Sandy Point, the Humphreys Drive Foreshore, and Main Road (Figure 3). In particular, the areas around the south-east and west of the estuary have been frequently used by juveniles over time, with greater densities in these sites (Figure 3).

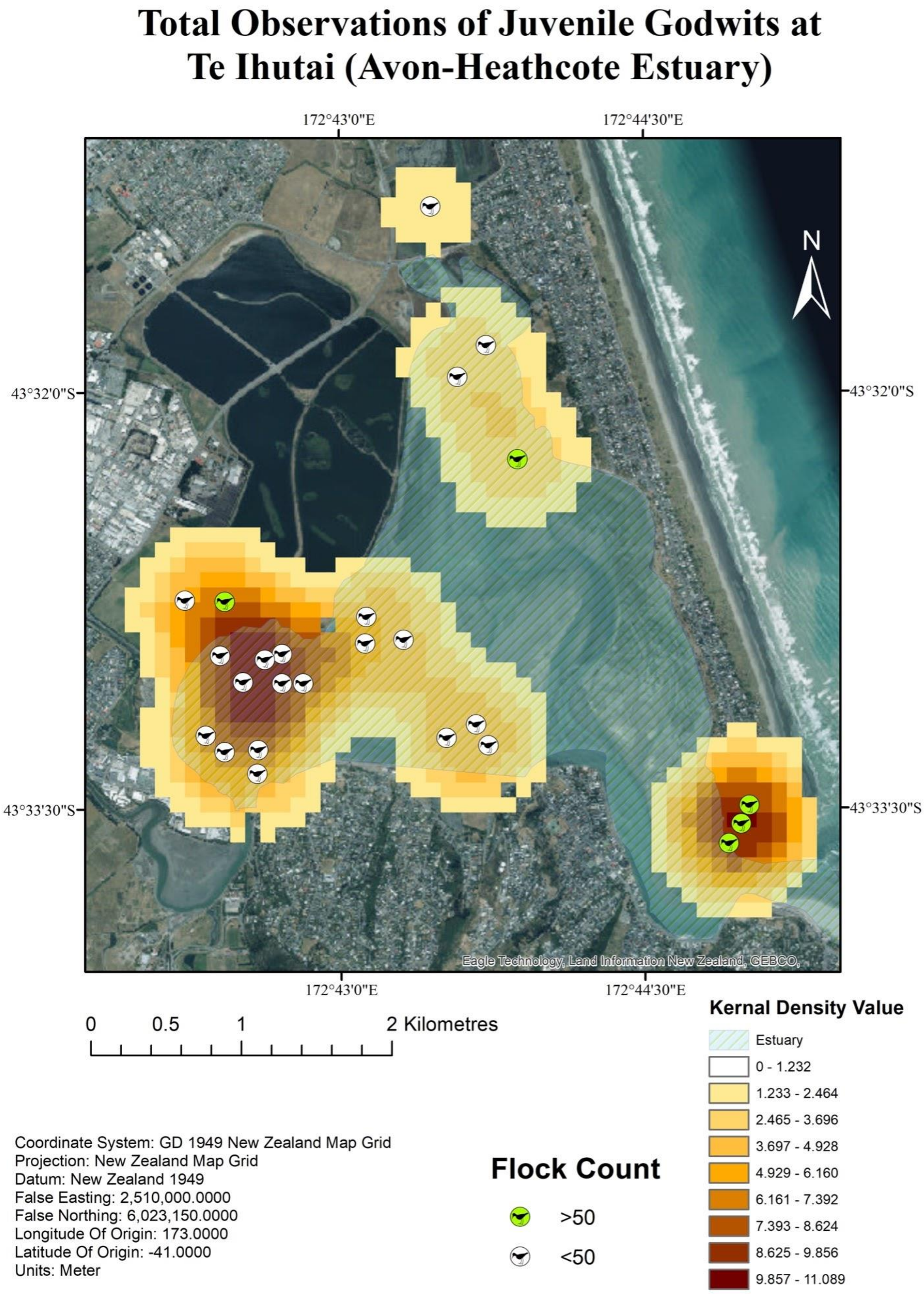

Figure 3: A kernel density map of juvenile bar-tailed godwit observations at the Avon-Heathcote Estuary, based on primary observations and secondary data obtained from eBird.

Site Use on the Western Side

The western side of the estuary around the Windsurf Carpark, Sandy Point, and the Humphreys Drive Foreshore seems to be regularly utilised by godwits. The water quality in this area is lower than other sites around the estuary, likely due to inputs from the Heathcote River and drains nearby (Gadd et al., 2020). It is unclear why godwits may prefer these sites to others at the estuary with better water quality. However, one possible explanation could relate to human disturbance.

Overall, human disturbance in these locations seems to be lower than in other parts of the estuary. Sandy Point should have minimal disturbance, as it cannot be publicly accessed. Based on our observations, there seems to be low human activity around the Humphreys Drive Foreshore. This could be because there is little parking and no footpath beside the estuary. Around the Windsurf Carpark, we observed some disturbance, largely from windsurfers. The impacts of windsurfing on shorebirds are unclear due to a lack of prior research. However, we only observed windsurfers at high tide. Based on our observations, there seems to be a lack of suitable high tide roosting habitat in this area. Therefore, there may be temporal separation in the use of the area by godwits and windsurfers, meaning the windsurfing may have limited impacts on godwits.

Southshore Spit

Another pattern in this data relates to juvenile godwit numbers at Southshore Spit. From 1997-2018, juveniles were reported on eBird at the spit, including in larger flocks than in many other areas (Figure 3). However, no juvenile godwits were seen at Southshore Spit from June-August this year.

This change in site use could be due to the flow-on effects water quality. Overall, water quality measurements have improved at the estuary in recent years. This is because wastewater has been discharged out to sea since 2010 (Gadd et al., 2020), excluding the temporary entry of raw sewage caused by the 2011 earthquake (Barr et al., 2020). However, nutrients still enter the estuary through other sources, including the Avon and Heathcote rivers (Gadd et al., 2020; Potter et al., 2015). Nitrogen inputs are leading to macroalgal growth (Gadd et al., 2020). Because the nitrogen is being quickly taken up by the algae, especially during summer, it may not be picked up in high levels during monitoring (Gadd et al., 2020). However, it can still affect the habitat. Decomposing macroalgae can reduce the amount of oxygen available in sediments, making the habitat less suitable for macroinvertebrates (Gadd et al., 2020). This affects the godwits' food source. Macroalgal blooms occur throughout the estuary. However, on the eastern site of the estuary, where Southshore Spit is located, blooms of the sea lettuce *Ulva* have detrimentally affected beds of the seagrass *Zostera muelleri* (Gadd et al., 2020). *Z. muelleri* is an important component of the estuarine ecosystem. It provides habitat for invertebrates and other species, stabilises sediment and affects its deposition (Siciliano et al., 2019). Therefore, the decline in *Z. muelleri* resulting from nutrient inputs and algal blooms may affect the use of this area by juvenile godwits.

Another possible explanation for the lack of juvenile godwits observed on Southshore Spit is human disturbance. Southshore Spit is a popular recreation site and human activity was observed there during this research. This included cyclists, pedestrians, and people with dogs on and off leash. Off leash dogs were observed in restricted areas on multiple occasions. This is of particular concern, given dogs disturb shorebirds from a greater distance than pedestrians (Glover et al., 2011; Mayo et al., 2015). Ultimately, disturbance can cause shorebirds to leave roost sites and move elsewhere (Navedo & Herrera, 2012). If human disturbance has increased on Southshore Spit over time, or if humans are using the area differently, this may have reduced the suitability of this habitat for juvenile godwits.

Linwood Paddocks

While eBird had no previous observations of juvenile godwits in the Linwood Paddocks, pictured in Figure 4, a flock of 161 juveniles were observed there on one visit during high tide. If other sites around the estuary, such as Southshore Spit, are decreasing in suitability for godwits, godwits may be using different sites than they did previously.

There are multiple reasons why the Linwood Paddocks may be a suitable location for godwits. One of these is the lack of disturbance, as there is no public access to these paddocks. On later visits, cows were seen in the paddocks. It is unclear if they affect godwits using the habitat. While they could be a potential source of disturbance (Jackson & Straw, 2021), they could also keep the grass short. Generally, shorebirds prefer roosting in areas with good visibility (Jackson & Straw, 2021), so this may benefit the godwits.

At high tide, suitable feeding habitat on the estuary itself may be underwater. However, in the Linwood Paddocks, godwits can feed even at high tide, as was observed. Godwits are known to feed on terrestrial invertebrates in wet paddocks such as this (Woodley, 2017). Additionally, godwits do not need to travel far from the estuary to reach this habitat, as the paddocks are directly beside the estuary. These factors both increase the suitability of high-tide roosts for shorebirds (Jackson & Straw, 2021).

Figure 4: The Linwood Paddocks, located on the western side of the Avon-Heathcote Estuary.

Limitations

Several limitations were identified as part of this research. The first of these involved the inconsistent timing of field observations. Due to this, the lack of repeatability in this study would not meet the assumptions attributed to scientific analysis (Cassey & Blackburn, 2006; Gregory et al., 2004). For the analysis to be repeatable, it would require a stronger, consistent methodological design that aims to control for variables such as time of observation, weather conditions and time spent at each site. This follows the requirements set out by Gomez and Jones (2010) for sample design.

The next limitation was the time lost during the nationwide COVID-19 lockdown. This created a large gap in the dataset, as no observations could be conducted from the 17^{th} of August until the 1^{st} of September 2021 (New Zealand Government, 2021). Additionally, the end of lockdown coincided with the migration of adult godwits returning to the estuary from Alaska (Conklin et al., 2010). This meant observations could not resume after lockdown ended, due to the difficulty separating adults and juveniles.

The scale of the estuary itself posed an issue when making observations. Using equipment such as binoculars or spotting scopes was crucial for identifying species with high accuracy and precision. As only one member of the group owned such equipment, the remainder of the group struggled to identify species that were situated, at times, more than 500 metres from the edge of the estuary access points.

As seen in Figure 3, large numbers of godwit observations were identified to the southwest of the estuary, including around the Linwood Paddocks. Private land is owned north of this area, preventing access and the gathering of observational data there. Due to this, we were unable to investigate juvenile settlement behaviour in all the areas directly linked to the estuary.

A final limitation that affected our findings was the incorporation of secondary data sources. As the data used was based on citizen science observational counts, there is an intrinsic element of error in the form of both overestimation and underestimation (Randler, 2021). This means there is likely low accuracy associated with this data, but not necessarily low precision (Gregory et al., 2004). The data is also skewed into areas that are easily accessible to the public and away from areas that involve a more active search.

By affecting the amount and accuracy of data, the above limitations prevented the research question from being fully addressed. They also decreased the applicability of this research. However, this study still partly addressed the research question by suggesting some broad factors relating to environmental quality and human disturbance that may affect juvenile godwit settlement.

Recommendations

Similar studies have longer data collection periods, such as eight years (Miller et al., 2003). If this project were to continue over a longer timeframe, more definitive results could be collected. This would allow for a better understanding of juvenile godwit settlement patterns at the estuary. A longer study could involve individually colour-banding juveniles. Colour-banding has been used to study godwit movement in general around New Zealand (Battley et al., 2020). Tracking juveniles using GPS transmitters could also occur. This has been used to follow the movement of godwits in their overwintering grounds on the French coast (Jourdan et al., 2021). These tools could help provide a better understanding of juvenile settlement patterns.

In the 2021 winter, juvenile godwits were sighted in the Linwood Paddocks, which has not been recorded on eBird before. This would be useful to investigate further. Why are they using this area now, rather than in the past? How might cows in the paddocks affect the godwits' use of it? If godwits continue to use the paddocks, it is important to consider how the site could change through time. Will these paddocks be farmed in the same way they are now, or will they eventually be converted into land for developments? Also, what effects will climate change have on them? Their proximity to the estuary means they are at risk of submergence due to sea level rise.

Originally, this study aimed to monitor environmental factors, such as the water and sediment quality of the estuary, through field research. This would hopefully have allowed information about the quality and availability of the godwits' food to be deduced. A comparison of this data to the same features at other sites that juvenile godwits visit, such as the Miranda Coast in the Firth of Thames, would help better understand their preferences.

A deeper investigation into the impacts of human behaviours and godwit settlement patterns would be useful moving forward. Field observations from this project suggest that godwits prefer sites with lower disturbance, supporting findings relating to shorebirds in general overseas (Navedo & Herrera, 2012). However, gaining more information around godwit responses to human disturbance at the estuary would be useful. As previously mentioned, the estuary is a popular windsurfing site. Godwits and windsurfers seem to be using areas at different tide levels, but more research around this would be useful.

Based on field observations, further signage and education around human access to areas of the estuary is recommended. Increased signage around Southshore Spit and its reserve would be useful, as this area is popular for recreation. There are beach access routes that did not clearly state the restrictions on dogs, and not all access points had signage. On several visits, dogs were seen off the leash and in areas where they are not permitted. While balancing recreational use and the protection of the area for wildlife is important, more education and awareness should be encouraged.

Conclusions

This report aimed to evaluate factors that influence the settlement of juvenile godwits on the Avon-Heathcote Estuary. Juvenile godwit numbers at the estuary appear to be slowly declining. Whilst Southshore Spit had previously higher numbers of juvenile godwits, during the winter of 2021 there were no sightings of juveniles at the spit. Instead, they were observed feeding in the Linwood Paddocks, which was not previously reported in eBird data. This indicates there may be a shift in juvenile site use around the estuary. Potential factors causing this change could include human disturbance, including disturbance caused by dogs, and flow-on effects of water quality. To encourage juvenile godwit settlement within the estuary, it is recommended that increased signage and education occur in areas of high juvenile density to try to mitigate human disturbance. Due to the limitations discussed, these conclusions surrounding the settlement of juvenile godwits may lack reliability. Future research, including longer duration studies, should be conducted to investigate juvenile godwit settlement and the factors that may affect it in more detail.

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