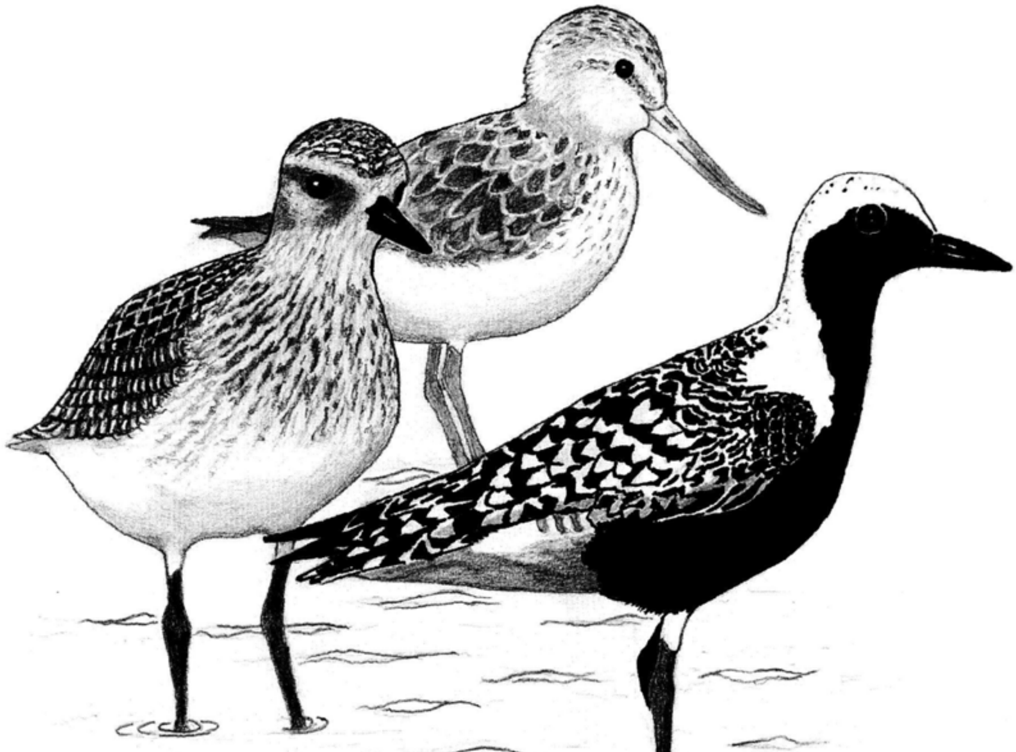
Stilt

The Journal for the East Asian-Australasian Flyway



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Australasian Wader Studies Group

EDITORIAL

Greetings from New Zealand. I hope that whether you are reading this in Australasia or further afield, you are safe and well. In these difficult times, it can be the little things that help us focus on what really matters in our lives. In the southern hemisphere, those include seeing the migratory waders return. Every year, the Bar-tailed godwits (*Limosa lapponica*) arrive and feed voraciously. As they rest and feed and get stronger (and fatter) it gives hope to those of us lucky enough to observe them.

Bar-tailed godwit, *Limosa lapponica,* at Manawatu Estuary, New Zealand, 08/01/2021 (by Imogen Warren)

It is great to see such a variety of articles in this edition of Stilt. We have an interesting combination of species-specific articles and others focusing on shorebird sites. There is a lot of work involved in the manuscript to publication process. Our Editorial Board put in a great deal of effort to work with authors to ensure scientific quality and that the research or report is given an appropriate airing.

I would like to introduce Assistant Professor Chi-Yeung Jimmy Choi, one of our Board members. Jimmy works at the School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen, China. I have asked him to tell us a little about himself:

"I was trained as an ecologist with expertise in animal ecology and conservation biology. I first came to know about shorebirds when studying for my Masters as I investigated the wintering ecology of Dunlin (*Calidris alpina*) in Shanghai. This marked the beginning of my wandering journey, following migratory shorebirds to many coastal wetlands in mainland China, to their breeding grounds in the Arctic tundra in Alaska, wintering coastal wetlands in New Zealand and Australia, studying shorebird ecology, the threats that they are facing and ways to mitigate those threats. Migratory shorebirds also connected me to many shorebird enthusiasts along the flyway that I would otherwise never meet.

Being the same age as *Stilt*, it was my great pleasure to join *Stilt*'s Editorial Board in 2016 November. The journal provides an excellent venue for shorebird enthusiasts, especially amateurs, to share their observations and findings internationally. For example, the results of many important local-scale surveys conducted in the Yellow/Bohai Seas were published in the *Stilt*. This first-hand data helped to identify the important shorebird sites in the Yellow/Bohai Seas and laid the critical baseline for future research, monitoring and management. *Stilt* also published results on shorebird banding expeditions and flag resighting analysis, revealing the oldest shorebird banded, seen, or the migration route of shorebirds. Without Stilt, some of these articles may get buried in local journals in other languages inaccessible to international readers or even not getting published. In short, *Stilt* is an invaluable source of reference that shorebird enthusiasts could turn to, for learning more about the amazing story of shorebirds".

For *Stilt* 76, Jimmy worked on the Point Moore and Separation Point article and for the author Marcus Singor, Birdlife WA osprey observer, the review process was great and Jimmy's constructive and informative feedback improved the quality of their manuscript. Professionalism, enthusiasm and valuable suggestions seem to be the key ingredients to add value to publications. Thanks Jimmy.

Australasian Shorebird Conference 2021 (ASC 2021)

A reminder that the 2021 Australasian Shorebird, jointly organised by The QWSG and AWSG, and under the theme "Global strategies, Local actions", has been postponed to March 2022. For more details, please be in touch with David Edwards, Chair QWSG and Alison Russell-French OAM Chair AWSG.

I would like to thank the Editorial and Production team for their contribution to the journal. Also, a big thanks to our contributors. We are reviewing our processes so that our communication and systems are smoother. We will see you in May 2022 for *Stilt* 77.

Imogen Warren
Editor

A NOTE FROM THE AWSG CHAIR

I took over as Chair of the Australasian Wader Studies Group (AWSG) in 2018 following the appointment of the previous Chair Mr. Doug Watkins to the Chief Executive position in the East Asian – Australasian Flyway Partnership (EAAFP) Secretariat. As a Partner of the EAAFP, we maintain a close and effective working relationship with Doug and the Secretariat in the pursuit of conservation of migratory shorebirds and their habitat.

The AWSG Committee now meets on a quarterly basis rather than biannually to more actively pursue our business. The following matters provide a brief outline of the work that the Committee has been progressing over the last two years.

Australian national migratory shorebird program

The Shorebirds 2020 project (S2020) was a joint initiative established in 2007 by AWSG and Birds Australia. In 1981 AWSG initiated counts of shorebirds at selected sites and has been a major driver for shorebird counting since then. The program has now come to an end and has been replaced by the National Shorebird Monitoring Program. We have a vast network of around 1600 volunteers who have played a crucial role in and contributed significantly to monitoring of shorebirds since inception of the project and their monitoring has been seamlessly transitioned into the National Shorebird Monitoring program. National Shorebird Monitoring continues to be a critical undertaking, providing unique nation-wide information on the state of Australia's shorebirds from 520 shorebird areas.

BirdLife Australia and AWSG are aiming to (re)appoint state coordinators in all Australian states and territories in 2020 to install a decentralised network to coordinate count efforts, close survey gaps and to address the demographic problem of an aging counter population by increased recruitment efforts through events and workshops. Several key publications have been revised and reprinted, such as the Shorebird ID Booklet and a new Wetland Bird ID Booklet (refer to http://birdlife.org.au/sb-monitoring and download access to booklets via http://birdlife.org.au/projects/shorebirds-2020/counter-resources).

AWSG Newsletter Tattler

After a period of production difficulties, a special Edition of the AWSG Newsletter *Tattler* "A Year in Review" was produced late in 2019. Phil Straw, AWSG Flyway Liaison Officer, has taken on the role of editor of *Tattler*. The Newsletter aims to provide articles of interest both within Australia and in the Flyway. Articles for *Tattler* are encouraged from all respective shorebird networks.

Stilt

In July 2020, the AWSG Committee welcomed Imogen Warren as the new *Stilt* editor. Imogen lives in the Manawatu Ramsar site in New Zealand and is involved with Birds NZ. She comes to AWSG with loads of experience in editing and proofreading, and has experience in websites and photography through her own site imogenwarrenphotography.net. Imogen worked with Dr Birgita Hansen, former editor, during a transition into the role and she is assisted by the editorial board with the scientific review process and making decisions about the scientific appropriateness of author contributions. Imogen's editorial work in producing Stilt has continued the high standard of production of AWSG's centrepiece ornithological publication.

Key AWSG Research and Science Directions

In 2020, the AWSG Committee focused on reviewing AWSG's portfolio of research activities across the EAAF. There has been significant discussion about the current AWSG research activities with the main points raised being:

- *Re-appraisal of flyway populations 2016.* Given the rapid declines in some species this project, delivered in 2016, should be undertaken at least every 5 years, which would align it with the lifespan of the Australian Government's Wildlife Conservation Plan for Migratory Shorebirds.
- *Migration/flagging.* It was agreed that a review of the effectiveness of plain leg flags should be conducted, and that contact should be made with Japan, Taiwan and other international bodies regarding the benefits of plain flags on Red-necked Stints.
- *Global Flyway Network.* AWSG is looking to establish a formal agreement with the Global Flyway Network (GFN) given the close cooperation taking place between both organisations.
- *Terns.* It was agreed that Stilt should continue to be the publication for material on Terns and that further efforts should be made to find analysts for the data – perhaps through collaboration with the Australian Seabird Group. It was noted that there will be a Seabird Conference 4-8 October 2021. Further development of AWSG research and science directions is ongoing.

AWSG Communications Plan and Communications Officer position

Led by Committee member Dr Amanda Lilleyman, AWSG has prepared a draft communications plan to guide CEPA activities and identify priority areas for attention including the need for a dedicated AWSG Communications Officer. The communications plan for AWSG includes Facebook, Twitter and other social media platforms, as well as an updated website, closer integration with BirdLife Australia communication streams and renewed development and delivery of traditional communications platforms Stilt and Tattler.

New NT Shorebird Banding Project

The AWSG Committee supported a proposal for an NT Shorebird Banding Project for catching and banding shore birds in the Northern Territory. Dr Amanda Lilleyman, who proposed the project, stated that she would like the project to come under the AWSG banner and would seek the necessary Animal Ethics and ABBBS permits for the project.

Development of database listing all AWSG and VWSG Publications

The AWSG Committee, led by Dr Danny Rogers, is investigating the means to develop a framework for listing all AWSG and VWSG publications on an online accessible platform. A number of possible systems that could be adopted for use have been suggested and additional work is being undertaken to determine which search engine would be most useful for AWSG to be involved with including relevant controls and functionality.

AWSG Scientific Committee

Collaborations with universities and other research organisations led to several publications making use of AWSG data. The scientific committee continued its basic work of overseeing requests for AWSG data. A key activity of the committee has been completing a review of the shorebird banding program in north-western Australia.

Global Flyway Network Update

Due to the COVID-19 pandemic, Global Flyway Network (GFN) researchers from Australia, The Netherlands and the United Kingdom were unable to travel to China. Luckily, GFN colleague Miss Katherine Leung was able to lead the fieldwork. Katherine was ably assisted in the fieldwork by six additional scanners, Mr. Guan Xiangyu, a Beijing bird guide, Miss Gao Chang, a freelance investigator from Beijing and graduate from Beijing Normal University (BNU) under our long-time collaborator Professor Zhang Zhengwang, Miss Wu Entao, Miss Guo Jia and Miss He Ying, research assistants at Beijing Forestry University, and our close colleague Mr Hebo Peng. GFN thanks them all for their efforts in difficult times. The costs this year were covered by the Center for East Asian-Australasian Flyway Studies (CEAAF) at Beijing Forestry University (BFU) under the leadership of Professor Lei Guangchun. The team was in the field from 4 May to 7 June 2019, 34 days (less than a usual spring field season of 56 days).

The main findings from fieldwork showed that on the Luannan Coast in 2020, Red Knot *Calidris canutus* were never present in such large numbers as in 2019. The biggest single count in 2020 was 20,000 on 24 May. This is in stark contrast to the 47,537 counted on 22 May 2019. The numbers of Red Knot using the Luannan Coast varies a lot from year to year. Relatively large numbers were present in 2014, 2015 and 2018. However, relatively low numbers were recorded during 2016 and 2017. Given that food resources usually determine distributions, the benthic food at Luannan and other sites determine the numbers of Red Knot that come to Luannan.

Despite the shorter study period and subsequently lower numbers, as in previous years, these records reflect the vital importance of the area for Red Knots from NWA and throughout the EAAF.

MYSMA Counts 28 November – 3rd December 2020

The AWSG maintained its scientific program in North-western Australia, with banding expeditions in February 2020 and 2021 and continuation of the ongoing collaboration with the Global Flyways Network on studies of survival of north-western Australian Shorebirds. The MYSMA (Monitoring Yellow Sea Migrants in Australia) project continued the series of large-scale repeatable shorebird counts that have been carried out by the AWSG in two of Australia's premier shorebird sites (Roebuck Bay and Eighty Mile Beach) since 2004; MYSMA surveys were carried in June and December 2019. A major report on results from the MYSMA program was completed, reviewing trends in north-western Australia since 2004 and recommending future directions for the monitoring program. The report was published in 2020.In 2018, after consultation with the main funders, the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA), we reduced the program to one winter count and one summer count each year, following an analysis by Danny Rogers et al. (2020) that demonstrated that the reduced program would bring costs down by ~40% with little impact on our capacity to detect change.

The report by Rogers et al. (2020) provides much additional information on shorebird monitoring in North-western Australia; it is available online here.

Toward the end of 2020, the MYSMA team undertook another comprehensive survey of the Broome region and counted 309,591 shorebirds (44 species) during the 5-day survey. Numbers were broadly consistent with those in recent surveys. Once entered and vetted, the data will be included in the AWSG's MYSMA database, and also the database of Birdlife Australia's National Shorebird count program.

Highlights included a Buff-breasted Sandpiper *Calidris subruficollis* – the first record of this South American vagrant in northern Australia and the third record for WA. Still more remarkably, the team found two Nordmann's Greenshank *Tringa guttifer*: one on Eighty Mile Beach, the second at Bush Point. These are the 6th and 7th Australian records of this critically endangered species, which usually spends the non-breeding season in south-east Asia. It is noteworthy that ALL previous Australian records of Nordmann's Greenshank have been found during MYSMA surveys – an indication of how exciting the shorebird populations in north-western Australia are, and of the careful scrutiny that they are given by MYSMA teams. In January 2021, a Nordmann's was finally found in Australia outside NWA, on the Cairns foreshore.

AWSG NWA2020 Shorebird and Tern Expedition – February 2021

This year, 2021, we celebrated the 40th anniversary of the North-West Australia Wader and Tern Expedition. The first expedition to catch waders was in 1981, and members from the AWSG had just discovered the importance of the Roebuck Bay and Eighty Mile Beach region. The early work included counts of how many birds were in the region, where they occurred, what the most appropriate survey methods might be, and to catch and colour mark as many waders as possible. The team caught 1189 waders from 12 species. An impressive first catch for the region and it has gone down in history. The Expedition in 2021 was significantly impacted by COVID 19 and was limited to fewer participants and species caught. A report on the Expedition is currently in preparation.

Banding and Leg-flagging Databases Updates

With financial support from the Wettenhall Small Grants program awarded to the Victorian Wader Studies Group (VWSG) and logistic support from Deakin University, Dr Aaron Spence and Professor Marcel Klaassen (AWSG Committee Member) have completed the process of transferring all VWSG and AWSG banding databases to a web-based platform. This move, including transferring both the metal-band and the flag-sighting databases, has enabled VWSG and AWSG to better interrogate and present over 40 years of data.

The BirdMark portal is specially designed to accept submissions of resightings of colour marked waders along our flyway. It supports multiple different languages, offering the possibility for volunteers and researchers to enter and submit observations both interactively or as a file. It can be accessed here.Videos on the various ways in which this can be done are included in the Help Guides provided on the portal. Feedback on flagged shorebird observations, including a history of the birds that have been observed, will be returned to the observer within a couple of days of submitting data.

With the launch of this site, we hope to further boost the reporting of marked shorebirds, which is crucial for ongoing conservation and scientific research, informing on the birds' population dynamics, movements and site use. The potential for other overviews to be generated and readily shared with the group and the wider public through the internet has now been improved dramatically.

Shorebird Science Meeting in the Republic of Korea

The 1st East Asian-Australasian Flyway (EAAF) Shorebird Science Meeting, which was due to be held at the National Institute of Ecology, Seocheon-gun, Chungcheongnam-do, Republic of Korea (May 5-8th, 2020), was moved online, taking place from 3-6 November 2020 due to the coronavirus situation. A full report of the meeting can be found online with presentations being available on the EAAFSSM Official YouTube Channel. The AWSG was well represented at the meeting and gave a number of presentations at the Meeting. It is expected that outcomes from the meeting will feed into discussion at the East Asian - Australasian Flyway Partnership (EAAFP) Shorebird Working Group which will be held in conjunction with the next EAAFP Meeting of the Partners 2022 or 2023.

Meeting of the Partners (MOP) of the EAAFP

The 11th Meeting of the Partners (MoP) was originally scheduled for mid-March 2020 then 2021 but owing to the COVID 19 pandemic the Australian Government and Secretariat of the EAAFP have resolved to postpone the MoP until March 2022. The date and arrangements for the MoP will continue to be reviewed in light of the COVID pandemic.

Australasian Shorebird Conference (ASC)

The Queensland Wader Studies Group (QWSG) and AWSG are joint organisers of the Australasian Shorebird Conference and plans were to hold the Conference after the EAAFP MoP in March 2021. However, this was postponed owing to the COVID19 pandemic and closure of borders to international travellers in Australia. The QWSG and AWSG Organising Committee will continue to review potential dates and arrangements for the Conference and provide information to update possible timing for the Conference.

I would like to extend my appreciation to the Committee for their efforts and dedication over the last two years in contributing to an extensive program of work on migratory shorebirds both in Australia and in the Flyway. I would also like to acknowledge the tremendous effort from our volunteers who are an integral part of the monitoring and counting of shorebirds and contribute to our knowledge base.

Alison Russell-French OAM
Chair, Australasian Wader Studies Group

OBITUARY KEN ROGERS (1939 – 2021)

The birding world lost a friend when Ken Rogers died on 18th February 2021 aged 81.
Over 50 years Ken made a substantial contribution to ornithology in both the UK and Australia where he arrived in 1980 with his wife Annie and son Danny and daughter Maryam.
Soon after their arrival they met the inimitable Clive Minton who immediately saw a like-minded spirit in Ken and thereby commenced 40 years of contributing to shorebird and other ornithological studies in Australasia and the flyway.

Ken was born in Lancashire, UK, in 1939 and developed a love of the outdoors which remained throughout his life. Although a talented student in the sciences and mathematics at Kings College, he preferred to spend his time in the theatre and the arts and yes, socialising in pubs. As son Danny has pointed out elsewhere, he had an attitude to learning that embraced reading, thinking, and questioning, attributes that stayed with him for his life.

His interest in passerine banding was foremost over the first two decades in Australia and in the 1980's he commenced compiling his observations and findings into a guide to the ageing and sexing of bush birds. This was published as Banders Aid in 1986 and emphasised the two principles so important today; safe banding practices and careful attention to data accuracy and recording. It was around this time that shorebird research was developing, and Ken soon found his niche alongside other workers such as Clive, Brett Lane, Mark Barter and others. With his professional background in operations research and applied statistics, he started analysing field data and contributing to the publishing of papers. While this may not be the priority of many of us, Ken had an ability to make some sense of the data and find ways of demonstrating the often-complex relationships and potential impacts, in an understandable and digestible way. All of this was done with an abundance of humour and a constant willingness to help anyone who would listen.

It wasn't until around the new millennium that I was introduced to Ken and Annie at Ninks Road through Mark Barter. As a relative newcomer to shorebird studies, Mark was one of my mentors and suggested that Ken could provide help in understanding ways of interpreting data. Our irregular meetings at Ninks Road were memorable for the debates and exchange of ideas.Although I was a novice, Ken was a patient teacher and provided enormous encouragement to take a holistic view and try different ways of looking at data as a means to provide a basis for conservation strategies. These meetings not only showed his skill with numbers but also his imaginative approach to data analysis. All of this was accompanied by much storytelling, debate and even quotes from Elizabethan literature which was one of Ken's other passions.

Perhaps one of Ken's greatest contributions to the AWSG was as editor of Stilt 50. This was a milestone edition of 325 pages containing 27 papers, many providing an overview of the status of shorebirds in our flyway. In the words of Mike Newman 'it was probably the apex of amateur publication of AWSG field studies' and is still proving useful today. At that time, it highlighted the contribution being made by the AWSG to international shorebird conservation. Ken had an ability to help and encourage first time authors and non-English speakers, to get their findings into print while at the same time being rigorous in the use of language and presentation. In his editorial to that edition, he states that 'The aim of this issue is to showcase the status of waders throughout the flyway, the problems they face, the ways in which they are addressed, and what has been learned from the studies'. At that same time in 2006 he commented on the 'the size and task facing Australian wader buffs', a challenge that the AWSG took up in the years to follow. He recognised that nearly all monitoring of Australian wader populations by banding and monitoring at that time was, and still is, carried out by amateurs or citizen scientists to use current terminology. He recognised that he could make a significant contribution by developing and encouraging the use of relevant analytical techniques and through assisting workers in their use.

Ken was especially interested in biometrics and moult data as well as looking to make sense of the extensive population data available, much of which had not been analysed up until that time. In regard to the former he developed a useful software package (SHEBA) to analyse bird biometrics. The AWSG managed the PMP (Population Monitoring Program) from the 1980's that demonstrated long term population changes. However, because of the destruction of stopover sites in Asia, a more rapid detection of change in shorebird populations was needed to promote a more responsive conservation management. Through the rigorous advice of Ken (and Danny) the AWSG initiated the Monitoring Yellow Sea Migrants in Australia (MYSMA) project in 2004. Part of the impetus for this project was the need to find a more sensitive way to monitor shorebird populations in Australia. The fact that this program is still being maintained is a tribute to Ken and others for their foresight and ability to implement a program based on good science.

Ken was unable to join a lot of the shorebird field work in later years but in the background, he contributed an enormous amount through his erudite discussions, expert mathematical and statistical skills and constant willingness to help and support the less experienced, all accompanied by a unique sense of humour. Over the years he published at least 50 papers. We value Ken's contribution as a scientist, trainer and mentor and the legacy for future workers that he has left behind.

As important as his passion for birds and numbers, it was his family that was his highest priority throughout his life. He supported Annie following her illness and helped pick the family up after the disastrous bushfires of 2009 destroyed their property at Ninks Road. He was a friend and colleague to so many people throughout the birding world and will be remembered not only for his backroom contributions but his willingness to always be there to help others whatever their need and to do so with humility and a sense of humour. Brett Lane summarised his character succinctly: 'What a brilliant thinker, generous mentor and barrel of fun Ken was'. Our condolences to his son Danny and daughter, Maryam.

Ken Gosbell
July, 2021

GALLINAGO RECORDS FROM UNIVERSITAS ANDALAS' LIMAU MANIS CAMPUS, WEST SUMATRA, INDONESIA

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We report on records of individuals of unidentified *Gallinago* snipe from a grassland site near the faculty buildings within the Universitas Andalas' Limau Manis campus. Due to its secretive habit, which creates difficulties in counting individuals, the flushing technique was used to count the snipe in the area. Up to 16 individuals were counted from surveys between January and March 2020. This record represents the second shorebird species observed in this area, after Greater Painted Snipe *Rostratula bengalensis*, and the first *Gallinago* records from repeat monitoring on the west-Sumatran mainland. This suggests that the campus may support other wetlands birds, warranting further survey and protection of bird habitat inside the campus complex.

INTRODUCTION

In the Greater Sunda of Indonesia, there are three wintering *Gallinago* snipes recorded: Pin-tail Snipe *G. stenura*, Common Snipe *G. gallinago* and Swinhoe's Snipe *G. megala* (Holmes 1996, Robson 2008, MacKinnon et al. 2010). These snipes breed during the boreal spring and summer in the Palaearctic region and migrate at the end of the breeding season to various parts of the globe (Eaton et al. 2018). The Pin-tail Snipe is considered more abundant than the other two snipes in the Malay Peninsula (Gibson-Hill 1949). It is also presumed to be common in Sumatra (Marle and Voous 1988), albeit an observation at Riau Archipelago was questioned (Rajathurai 1996). The population size of Pin-tailed Snipe in the eastern tidal area of North Sumatra Province (400+ ha) is around 160 individuals, although it is possible that Swinhoe's Snipe co-occurs in the same area (Crossland et al. 2009). Common Snipe is more common on mudflats of the eastern coastline of Sumatra, with population counts between 8-37 individuals (Putra et al. 2015, Putra et al. 2017). An observation of an unidentified *Gallinago* snipe from the tidal lowland and floodplain in South Sumatra may indicate the use of inland swamp and rice fields for over-wintering (Verheugt et al. 1993). Swinhoe's Snipe is generally uncommon and a probably overlooked migrant in Sumatra, and is more frequently recorded in Java (Marle and Voous 1988, Menkhorst et al. 2017, Eaton et al. 2018).

Universitas Andalas' Limau Manis campus (Unand LMC) consists of 500 ha of hilly forested terrain, located 15 km from the shores of Padang, the capital city of West Sumatra Province. The township limits border protected forest along the mountainous chain of Bukit Barisan Range, which provides landscape and habitats that are suitable for various tropical birds (Janra 2019a). A long-term birdwatching program in Unand LMC has recorded more than 160 bird species, including Greater Painted-snipe *Rostratula benghalensis* from this area (Janra et al. 2018, Janra 2019b). In this study, we report on recent observations of unidentified *Gallinago* snipe based on observations made within the Unand LMC.

STUDY SITE AND METHODS

The existence of the snipe was firstly brought into attention when the second author (EB) reported that he saw some individuals of 'peculiar' bird during a butterfly survey in Unand LMC in late December 2019 (Figure 1a). The sighting was located at a site in front of the Faculty of Law building (0° 55' 6.024" S, 100° 27' 37.728" E), an 83 x 62.5 m area of wet grassland. On the first survey, these 'peculiar' birds were also found occupying the neighbouring 62.5 x 50 m grassland patch located in front of Faculty of Social and Political Sciences (0° 55' 4.674" S, 100° 27' 39.852" E). These grassland patches are surrounded by faculty buildings on the north side, roads in between and campus main boulevard on south (Figure 1b, Figure 2). Unand LMC contains other similar sites but there were no observations of the birds made in these areas in the same observation period. Photographical documentation was made using Nikon Coolpix P900 set at the highest resolution.

The stationary bird counts were initially followed to survey the snipe (Bibby et al. 2000, Gregory et al. 2004), but failed to clearly spot the skulking birds. The simple

MacKinnon count technique, that sequentially records bird species into predetermined standard-length lists (MacKinnon and Phillipps 1993), was also thought to be ineffective in detecting motionless birds that are well camouflaged among the grass, even when observing at a distance or with the aid of binoculars. Therefore, we used a flushing method to count individuals by consistently walking through the grassland near the Faculty of Law all the way eastward to the grassland near the Faculty of Social and Political Sciences. This method was previously used to count shorebirds in North Sumatra (Crossland et al. 2009). In our study, the flushing survey was initially conducted on consecutive days in early January 2020, but then changed to weekly surveys in March 2020, and eventually to a single observation in February 2020. One observer conducted each survey to minimise disturbance to the birds. Flushed individuals were visually followed to determine their direction of movement within and between grassland patches in order to avoid double-counting. If it was the case, the total count was adjusted accordingly by deducting the suspected double-counted bird from the total count.

RESULTS AND DISCUSSION

Species identification

Although the first snipe record from Unand LMC was the Greater Painted Snipe, these birds observed during our surveys were recognised as belonging to the *Gallinago* genus. The snipe individuals were observed to be more diurnally active during the initial observations in early January 2020, however, they became more secretive for the rest of the observation period, until late March 2020. This was presumably caused by human disturbance, either due to the use of the flushing method or due to the commencement of the new semester in the third week of January 2020, when campus students and residents returned for activities. Some photographs were taken during the early observations when birds were visible (Figure 3), which were used to try to identify the species. We were unable to obtain more photographs during subsequent surveys from 6 January up until 20 March 2020, as the snipe spent most of their time hiding in the grass.

The photographs were mostly about the upper half of the snipes' body. Some features for identification of snipe species, such as pattern of wing covers and shape of tail feather, were obscured by the grass. Morphological details that could be determined from the photographs were: pale coloration and pattern on head, rather high eye-placement on face and on one individual with a rather short bill compared to the head length (Figure 4). Our impression was that these features might be indicative of

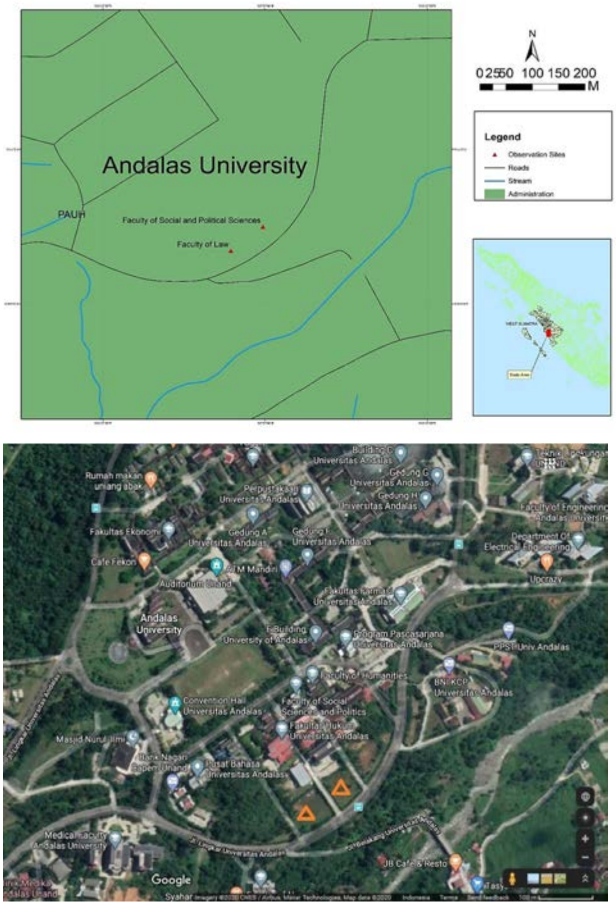

Figure 1. a. Map of study site, b. Observation site (orange triangles) in the campus complex. Satellite imagery source from Google Earth.

Figure 2. The view of grassland site from the faculty building (above) and from campus south boulevard (bottom)

Pin-tail Snipe *Gallinago stenura* (see Menkhorst et al. 2017, Leader & Carey 2003), however, no definitive characters can be pinpointed from neither the photographs, nor the field observation. In addition to these identification challenges, there is also the possibility that the three *Gallinago* snipes may have mixed together within the same congregation (Iqbal et al. 2013). Therefore, we cannot confidently assign a species to these *Gallinago* snipes.

Figure 3. Two photos from early January 2020, two individuals skulking among grasses (top) and an individual rested under tree shading at the corner of grassland site (bottom)

Figure 4. Head- and bill-length comparison of the unidentified snipe

Individual Counting

Our observations made between early January until late March 2020 produced quite variable numbers of snipe (Table 1). Before late January, the campus was on semester vacation so the grassland site was relatively undisturbed. The largest count of 16 snipes was recorded on 17 January 2020. The snipe usually returned to and landed in the same grassland even when repeatedly flushed during surveys. This behaviour continued when the semester commenced in late January, and the snipe continued to return to the same grassland site (although numbers flushed would vary from survey-to-survey). Observations ceased after campus lockdown in late March due to Covid-19 restrictions. This prevented continuing observations into the migration season. Opportunistic visits in July and August 2020 did not record any snipe, and another short visit on 30 December 2020 recorded one snipe, which flushed out from the grassland site (not included in Table 1).

Table 1. The counting on unidentified *Gallinago* snipe at Universitas Andalas' Limau Manis Campus Complex.

Date	Ind. count	Comments
03-Jan-20	1	An individual was seen bathing in open water puddle
04-Jan-20	7	Counting based on seen and flushed individuals
06-Jan-20	1	One snipe seen flew in and out of observation site
06-Jan-20	7	Flushed out in the afternoon
07-Jan-20	10	Flushed out in the morning
07-Jan-20	4	Flushed out in the midday
08-Jan-20	5	Flushed out in the afternoon
17-Jan-20	16	Flushed out in the afternoon
03-Feb-20	1	Flushed out in the afternoon
02-Mar-20	1	Flushed out in the afternoon
07-Mar-20	3	Flushed out in the afternoon
11-Mar-20	2	Flushed out in the afternoon
20-Mar-20	4	Flushed out from their closely sitting point

In Singapore and the Malay Peninsula, all three *Gallinago* snipes have been observed wintering from August to April in the next year (Gibson-Hill 1949), which could also be the case for the individuals in Sumatra. All published observations of the three *Gallinago* snipes in Sumatra, to the best knowledge of the authors, are summarised in Table 2. This summary consisted of many historical records listed in the checklist of Sumatran birds (Marle & Voous 1988), to which more contemporaneous records were added from the 1990s till early 2021. Most of the records, except one on Swinhoe's Snipe from Aceh in May 2021, fall in the non-breeding season of *Gallinago* snipes. In addition, most records come from the eastern of Sumatra, including offshore islands. On the western side, Pin-tail Snipe was only ever recorded offshore, from Nias Island and Mentawai Islands (Marle & Voous 1988, Kemp 2000). Recent avifauna surveys between 2017 and 2019, however, did not record Pin-tail Snipe or other *Gallinago* snipes on the Mentawai Islands (Taufiqurrahman et al. 2019). There are also two Pin-tailed Snipe records on eBird from the western coast (https://ebird.org/map/pitsni; accessed 12 August 2021), but the reliability of these records is unknown. Therefore, our observations represent the first records from repeat monitoring of *Gallinago* snipe on mainland western Sumatra, regardless of the species.

Table 2. Summary of published records of *Gallinago* snipes on Sumatra.

Location	Date	Source	Comments
Pin-tail Snipe *G. stenura*			
Offshore islands of North Sumatra		Marle & Voous (1988)	
Riau Archipelago		Marle & Voous (1988)	
Nias Island, North Sumatra	1854, Nov 1895 - Feb1896	Dymond (1994)	
Deli, North Sumatra	3 Oct 1919	Marle & Voous (1988)	
Siberut, Mentawai, West Sumatra	1926	Chasen & Kloss (1926), Holmes (1994)	Holmes validated the previous record from Chasen & Kloss
Batam, Riau Archipelago	1926	Rajathurai (1996)	A single record
Mt. Leuser, Aceh	1941	Marle & Voous (1988)	Sighting at 3500 m altitude
Lampung	2 May 1980s	Marle & Voous (1988)	
Siberut, Mentawai, West Sumatra	Aug 1997 - Dec 1999	Kemp (2000)	Several individuals occasionally sighted at disturbed vegetated area and riverine habitats
Batu Lima, Asahan, North Sumatra	Mar 2002	Crossland et al. (2009)	50+ individuals of mixed Pin-tail and Swinhoe's Snipes
Swinhoe's Snipe *G. megala*			
Unknown locality		Marle & Voous (1988)	Common in Java, may be overlooked in Sumatra
Batu Lima, Asahan, North Sumatra	Mar 2002	Crossland et al. (2009)	50+ individuals of mixed Pin-tail and Swinhoe's Snipes
Cemara Beach, Jambi	2007-2010	Iqbal et al. (2013)	Three individuals captured with mistnets
Banda Aceh, Aceh	24 May 2021	inaturalist (2021)	Confirmed ID
Common Snipe *G. gallinago*			
Unknown locality	1935	Marle & Voous (1988)	
Bagan Percut, North Sumatra	Feb 2011	Putra et al. (2015), Putra et al. (2017)	Eight individuals were seen at mudflat
Unidentified or unconfirmed Snipe *Gallinago* spp.			
Ketambe, Aceh	1974	Marle & Voous (1988)	Unconfirmed sighting for Common Snipe
Belawan, North Sumatra	1977	Marle & Voous (1988)	Unconfirmed sighting for Common Snipe
Padang Sugihan, South Sumatra	Aug 1984 - Jun 1985	Nash & Nash (1985)	Author hinted this species was possibly Pin-tail Snipe
Musi Banyuasin, South Sumatra	Aug 1988 - Aug 1989	Verheugt et al. (1993)	Unidentified snipes at inland tidal mudflat and ricefield
Bintan, Riau Archipelago	27 Apr 1994	Rajathurai (1996)	Four individuals were sighted flying
Padang, West Sumatra	Jan - Mar 2020	This study	Up to 16 individuals counted

Conservation Implication

The *Gallinago* snipe is the second shorebird species recorded for Unand LMC besides Greater Painted Snipe. The latter was also observed at the grassland site on 17 March 2021. These two shorebirds, along with 11 non-shorebird species, were observed using the grassland site during daylight. Despite its barren appearance, the wet grassland offered useful resources to many bird species for feeding, bathing, preening, mating and other activities. However, the grassland is very exposed to disturbance from humans due to its location in between campus facilities.

So far, the authority of Unand LMC has established regulation that forbids hunting and poaching activities for any wildlife within the campus (Janra 2019a, 2019b), but the focus of these regulations is more directed to the forested part of Unand LMC rather than campus areas. Our observations suggest that all types of habitats within Unand LMC could be considered potentially important for birds. Many university campuses can serve as the sites for research and conservation, as they harbour numerous wildlife species within the campus complex, providing ample opportunities for local ecologists and conservationists (Liu et al. 2021). It also has potential for urban birdwatching, as Unand LMC has more than 160 bird species to date or around 26% of total Sumatran birds (Janra 2019b). The addition of migrant *Gallinago* snipes into Unand LMC bird checklist may provide further interest to birdwatchers for sightseeing this unique and rare bird.

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INTERNATIONALLY SIGNIFICANT COUNTS OF BROAD-BILLED SANDPIPER IN ROEBUCK BAY, WESTERN AUSTRALIA

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INTRODUCTION

Roebuck Bay, a large intertidal wetland adjacent to the town of Broome, is one of the most important sites in Australia for non-breeding migratory shorebirds. Most of these birds feed on benthic invertebrates in the bay's rich and expansive mudflats. Sixteen shorebird species are consistently counted in 'internationally significant' numbers (>1% of the total flyway population): Australian Pied Oystercatcher *Haematopus longirostris*, Red-capped Plover *Charadrius ruficapillus*, Greater Sand Plover *C. leschenaultii*, Oriental Plover *C. veredus*, Whimbrel *Numenius phaeopus*, Far Eastern Curlew *N. madagascariensis*, Bar-tailed Godwit *Limosa lapponica*, Black-tailed Godwit *L. limosa*, Ruddy Turnstone *Arenaria interpres*, Great Knot *Calidris tenuirostris*, Red Knot *C. canutus*, Red-necked Stint *C. ruficollis*, Sanderling *C. alba*, Asian Dowitcher *Limnodromus semipalmatus*, Terek Sandpiper *Xenus cinereus* and Grey-tailed Tattler *Tringa brevipes* (Rogers *et al.* 2011, 2020, Hansen *et al.* 2016). A further four species have also been counted above this threshold with some regularity: Pied Stilt *Himantopus leucocephalus*, Little Curlew *Numenius minutus*, Sharp-tailed Sandpiper *Calidris acuminata* and Curlew Sandpiper *C. ferruginea* (Rogers *et al.* 2003, 2011, 2020, Hansen *et al.* 2016, BBO *unpubl. data*). Having 20 species in such numbers is unparalleled in the country, and has earned Broome the informal title, 'Shorebird Capital of Australia'. The bay is formally recognised as a Ramsar site (no. 479).

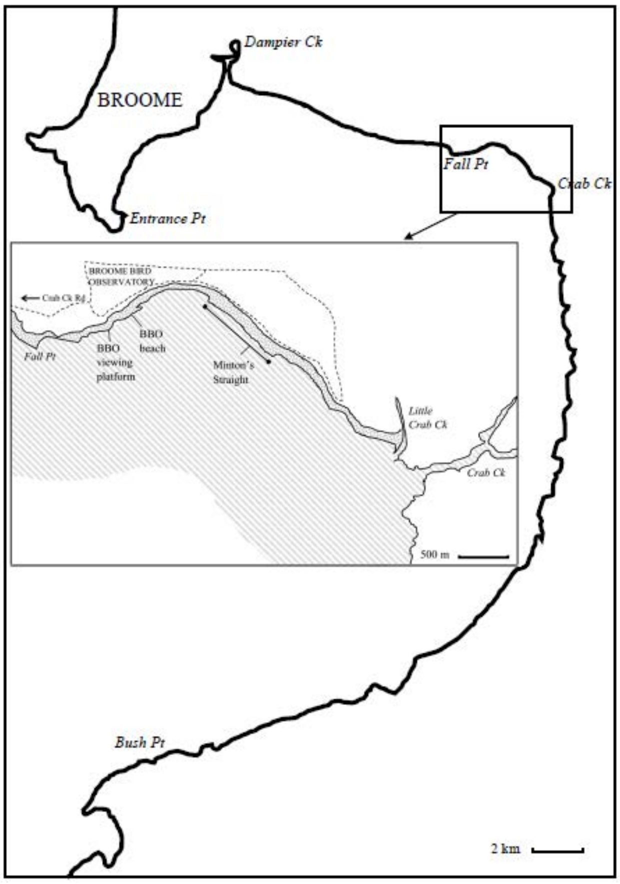

Figure 1. Map of Roebuck Bay, Broome, Australia. It includes Minton's Straight, Broome Bird Observatory (BBO) beach and BBO Viewing Platform (©Mattea Taylor).

Here, I report the highest counts for Roebuck Bay of a 21st species, Broad-billed Sandpiper *Calidris falcinellus*, made in March and April 2020. Broad-billed Sandpipers breed in eastern Siberia during the boreal summer and after breeding, they migrate to the coastlines of south and east Asia and Australasia (Higgins and Davies 1996). Australia is thought to support 10,000 individuals during the species' non-breeding season, more than any other country in the flyway (Department of the Environment 2020).

The total EAAF population of Broad-billed Sandpiper is estimated at 30,000 individuals (Hansen *et al.* 2016). Two previous counts in the bay exceeded 1% of this number and met the criterion for international significance. The first was by a team from the Australasian Wader Studies Group Monitoring Yellow Sea Migrants in Australia (MYSMA) project, who counted 350 birds during a composite high tide count of the entire bay on 16-17 December 2005 (Rogers *et al.* 2006). MYSMA counts of the entire bay have been made each summer since 2001; no other count exceeded 212 Broad-billed Sandpipers (Rogers *et al.* 2020). The second significant count of 302 birds was by John Graff, at a single high tide roost in the northern bay on 1 April 2016 (BBO *unpubl. data*).

METHODS & RESULTS

Early in 2020, along with other Broome Bird Observatory (BBO) staff, I noticed Broad-billed Sandpipers regularly feeding close to the BBO Viewing Platform (Figure 1) on ebbing tides. Counts were modest (e.g. 18 birds on 13-14 February 2020), but noteworthy, as in our experience it was unusual to see so many of them close to the observatory outside the high tide period. From 2 March 2020, every evening between 4-6 pm, BBO staff carried out watches for our long-term Migration Watch study, during which observers overlook the ‘BBO Beach’ (Figure 1) and scan south for migrating shorebird flocks. When this coincided with ebbing tides, we noticed that Broad-billed Sandpipers were often the most numerous species feeding around tidal pools on the freshly exposed mudflats.

I was able to count Broad-billed Sandpipers opportunistically – when conditions were suitable and when not busy counting migrating flocks. As the tide receded, feeding Broad-billed Sandpipers tended to move predictably westwards: starting at Minton’s Straight, where they were too distant to count; arriving in the area in front of Migration Watch observers, where they could be counted, and then moving further towards the BBO Viewing Platform, where they were obscured from view and could no longer be counted (Figure 1, Table 1). This pattern gave me a short window for counting, but the consistent one-way movement reduced the risk of double-counting birds. The circumstances during the high count of 558 on 7 April were different, of a large group remaining away from the tideline at low tide and close to the BBO Beach. This group continued feeding in the same position for some time, making the count easier and probably more accurate.

Table 1. Broad-billed Sandpiper *Calidris falcinellus* counts made from the BBO Beach lookout in March and April 2020. With the exception of the count on 7 April, all counts were made on an ebbing tide, with birds feeding close to the tideline on the beach in front of me.

Date	Time	Count	Notes
2 March	17:40	39	
13 March	16:50	175	
14 March	17:25	422	
15 March	17:45	411	
28 March	16:05	550	Counted individually, but possibly more present
30 March	16:40	550	Approximate count of fast-moving feeding group
1 April	17:40	-	Unable to count properly, but several hundred certainly present
7 April	16:58	558	Feeding group on flats at low tide, just SW of BBO Beach

High counts generally corresponded with spring tides. However, this is likely to have been a result of how these tides were timed relative to the timing of our watches, rather than any quality of the spring tides themselves. During spring tides in Broome, high tide is in the middle of the day or early afternoon, meaning that the tide was ebbing during the 4-6 pm window when the author was regularly observing shorebirds during the Migration Watch period, and making these counts.

At 17:51 on 15 April 2020, one migratory flock of 60 Broad-billed Sandpipers was observed departing northwest from the bay in a line formation.

DISCUSSION

The peak count of 558 Broad-billed Sandpipers in Roebuck Bay reported here is over 50% greater than any count known to us from previous years in the bay (Rogers *et al.* 2020, BBO *unpubl. data*). It includes only birds that were visible together at one time in a small area of the bay, and so is a minimum estimate of the number that were present. Many more could have been feeding in suitable habitat elsewhere in the bay, though it is also possible that these were indeed all of the individuals in the bay at the time, and precautionarily, we should assume this was the case.

This count far exceeds the 135 recorded in a systematic high tide count of the bay earlier in the season, on 26-27 November 2019 (Rogers *et al.* 2020). Broad-billed Sandpipers are often undercounted in surveys, being (1) small and often hidden among larger shorebirds in dense high tide roosts, and (2) uncommon and potentially misidentified as similar more common species (e.g. Red-necked Stint) by observers counting in a hurry or under difficult conditions (Rogers *et al.* 2006). Nevertheless, it is unlikely that experienced shorebird watchers undertaking the MYSMA counts would have missed over 400 Broad-billed Sandpipers. The more probable explanation is that staging birds from further south moved into the bay prior to northward migration. This interpretation is supported by the counts increasing through March (Table 1), although some of this is probably explained by more accurate counting after the author became familiar with the birds’ behaviour. It is also consistent with a previous high count of 302 individuals in the Bay, also occurring in April (in 2016). These birds were all at a single high tide roost site. As other roosts were unsurveyed at the time, it is possible that more were present, perhaps approaching or exceeding the numbers from 2020. Most Broad-billed Sandpipers probably depart from Roebuck Bay on migration later in April, as did the flock observed on 15 April 2020.

Systematic counts of Roebuck Bay are not generally carried out in March and April. This may explain why there are no previous counts as high as 558. However, Migration Watch sessions have run at the same time for over 20 years, carried out by experienced birders familiar with the Bay’s shorebirds. Seeing over 500 of this uncommon species busily feeding at close range is striking and would surely not have been missed by such observers. Therefore, if similar numbers have been present in the bay in previous years, they have probably not all been feeding regularly along the BBO Beach. The reasons for them doing so in 2020 are unknown, and it may reflect a genuinely unusual influx into the bay.

Elsewhere in Western Australia, the species is rare outside a few key sites (Johnstone and Storr 1998). Between 50 and 150 Broad-billed Sandpipers are regularly counted at Eighty-mile Beach, with a high count of 223 in December 2011 (Rogers *et al.* 2020). The Port Hedland Saltworks supported very large numbers in the 1980s, with 1000-2000 counted there regularly and a peak count of 6000 in March 1987 (Minton 1987, 2006). However, shorebird occurrence at the site declined substantially following changes to the saltworks in the 1990s (Minton 2006), and Broad-billed Sandpiper counts in the thousands appear to be a thing of the past: the highest count since 2000 is 537 in October 2013, and just 63 and 44 birds were present in Novembers of 2018 and 2019 respectively (O'Connor 2019). The only other recent large counts the author is aware of are from Urala Creek near Onslow, where John Graff and Stewart Ford recorded 175 Broad-billed Sandpipers on 9 December 2018 and 129 on 7 March 2019 (records accessed via eBird).

In summary, records in March and April 2020 of 550+ Broad-billed Sandpipers feeding in Roebuck Bay, combined with two previous counts of the species above the 1% of total flyway population threshold, illustrate that the bay is an internationally significant site for the species. It is likely to be particularly important in March and April before northward migration, as counts earlier in the season have tended to be lower. Comparisons with numbers elsewhere in Western Australia suggest that Roebuck Bay is currently one of the most significant sites in the state for Broad-billed Sandpiper. Roebuck Bay is now known to support a diversity of 21 shorebird species, highlighting its conservation value as a non-breeding area for migratory and resident shorebirds.

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RED-WATTLED LAPWING (*VANELLUS INDICUS*) RECORDS IN SUMATRA, INDONESIA: BRIEF HISTORY AND POSSIBLE EXPANSION

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INTRODUCTION

Red-wattled lapwing subspecies description

There are four subspecies of Red-wattled Lapwing, with *Vanellus indicus atronuchalis* ranging from north-east India to southern China, South-East Asia and Peninsular Malaysia (Wiersma & Kirwan 2018). Extralimital records extend into northern parts of Sumatra with a single record from West Java (MacKinnon et al. 2010; Eaton *et al.* 2016). The Red-wattled Lapwing has a black head, chest and neck, with a red eye-ring that extends forwards as a slim wattle that stops at the base of the bill, which is red with a black tipped bill. The belly and most of the underparts are white, with a white ring separating the base of the neck from the brown mantle and wing covert feathers. The flight feathers are black and the species possesses a black subterminal tail band that is visible in flight, as are bright yellow legs. Unlike other subspecies, *V. indicus atronuchalis* has a white cheek that does not extend towards its breast (Eaton *et al*. 2016). Where it occurs, the species is usually conspicuous as a large, colourful and noisy shorebird. Within Sumatra, the only potential confusion species is the Grey-headed Lapwing (*V. cinereus*) which has become an increasingly common migrant to the northern part of the island over the last 10 years (Crossland & Sitorus 2011; Putra & Hikamtullah 2020). The two species however are easily separated on head, neck and bill colour. The Red-wattled Lapwing is not considered "Threatened" and is currently listed as "Least Concerned" by the IUCN, although the species' global population trend remains unknown (Birdlife International, 2016).

METHODS

To better understand possible patterns of dispersal, records of Red-wattled Lapwing in Indonesia were compiled from a variety of sources including our own personal sightings of the bird from mainland Sumatra. These sources include eBird reports, personal communications and scientific papers. The compiled data also includes reports that occur after our incidental sighting in 2018 extending the collection window to August 2021.

RESULTS

Previous records

Prior to 2018 there were just four adequately documented records of Red-wattled Lapwing in Sumatra (Iqbal *et al.* 2013). The first observation was of 6–8 birds reported by P. & J. Stewart during winter 1981–82 at Lhokseumawe, Aceh (van Marle and Voous 1988). The next record was of a single individual spotted by M. Iqbal on the 6 November 2008 in the Kampar Peninsular, Riau along a silty river bank close to a log pile (Iqbal & Goenarto 2017), In 2012 K. Baskoro recorded a single individual on Bintan Island, Riau Islands (Iqbal et al. 2013).

Five years elapsed before the next sighting by A. Noviyono at Grand Lagoi Hotel, Bintan, Riau Islands (Noviyono 2017) on 21 May 2017. Interestingly this record falls outside the winter season and is within the breeding season which occurs from February–August (Lok & Subaraj 2009, Ariyasiri *et al*. 2009). Since *V. indicus* are considered territorial breeders, this may explain why only a single individual was recorded. The sighting of the bird near Grand Lagoi Hotel grounds also corroborates known instances of the birds having a higher tolerance of urban areas during the breeding season as evidenced by their nesting habitats on man-made structures (Ali *et al*. 2017, Muralidhar & Barve, 2013).

On 1 August 2018 two lapwings were seen in an open airfield by M. Iqbal. Subsequently on 6 August 2018 at 8:26 four Red-wattled Lapwings (*Vanellus indicus*) were seen in the same airfield (0º29'14.3" N,101º55'24.6" E; at Pangkalan Kerinci subdistrict, Pelalawan Regency, Riau Province, Sumatra) around 3–4 km from a human-created pond and 1–2 km from a hangar. The airfield was covered in short grass with no vegetation higher than one meter growing except towards the edge of the airfield. When first encountered all four individuals were in short grass (Figure 1), however a few moments later two individuals flew over the runway and landed on the opposite side of the road closer towards a forest stand. Although the heat dissipating from the road caused slight visual distortions, the distinctive red on the bill and orbital ring could be seen. The diagnostic white cheeks of the *atronuchalis* subspecies were also visible as well as the black terminal tail feather band when seen in flight (Figure 2).

Subsequent records

Following the 2017 sighting a Red-wattled Lapwing call was heard on 28 July 2018 at the Laguna Golf Bintan golf course, followed by 6 birds spotted on 14 September 2018 in open habitat around Lake Lagoi, Bintan Island (Chan & Chan, 2019). On 17 January 2021 on the adjacent island of Batam, 8 individuals were spotted in open scrub habitat adjacent to a pond (D.A. Budiman pers. *comm.*). Interestingly, the flock represents a sizable number and consisted of various age groups as an immature was photographed in flight (Figure 3). Similar to the 2008 sighting, on 11 April 2021 two individuals were sighted on Kampar Peninsula close to a log pile (Figure 4) (M. Iqbal2). Then on 13 June 2021 a single individual was reported in a similar habitat close to an Acacia plantation this time in Sei Kuat, Pulau Padang (Figure 5) (M. Mulyo). Finally, on 3 July 2021 three individuals were spotted by M. Iqbal on the same airstrip as our original 2018 sighting (eBird, 2021).

Figure 1. Red-wattled Lapwing (*Vanellus indicus atronuchalis*) with the subspecies-specific "white cheeks", on an open airfield in Pangkalan Kerinci, Riau, East Sumatra on 6 August 2018. (by Prayitno Goenarto)

Figure 2. Red-wattled Lapwings (*Vanellus indicus atronuchalis*) in flight, displaying black subterminal band, yellow feet and red facial markings. (by Prayitno Goenarto)

Figure 3. Red-wattled Lapwins(*Vanellus indicus atronuchalis*) in flight seen on 17 January 2021 on Batam Island, Riau Islands, Sumatra. White facial feather patches and non-fully developed black mask suggest this is an immature bird. It was part of a flock consisting of 8 individuals of varying age classes. (by Daniel Arief Budiman)

Figure 4. One of two Red-wattled Lapwings (*Vanellus indicus atronuchalis*) recorded adjacent to a canal in the Kampar Peninsula, Riau, Sumatra on 11 April 2021. (by Muhammad Iqbal2)

Figure 5. Single adult Red-wattled Lapwing (*Vanellus indicus atronuchalis*) found near an Acacia plantation Pulau Padang, Riau, Sumatra on 13 June 2021.

DISCUSSION

Site Selection and Survey Timing

The scarcity of lapwing sightings in Indonesia could arise from sampling bias since most sites covered by the Asian Waterbird Census (AWC) and other shorebird surveys in Sumatra have focused on coastal beach and intertidal areas. The 2016 AWC in Indonesia recorded a total of 7,362 shorebirds in Sumatra from 17 sites, four of which were within North Sumatra (the likely range of Red-wattled Lapwing), but did not record the Red-wattled Lapwing (Noor *et al*. 2016). The 2017 AWC in North Sumatra recorded 7,956 waterbirds (3rd highest region) with 3 of 4 sites surveyed being focused on beach/coastal areas (Noor *et al*. 2017). Although Red-wattled Lapwing are considered habitat generalists and occupy a variety of wetland habitats including coastal sites (Lok & Subaraj 2009), coastal habitats may favour different charadriform community compositions. This could potentially cause shorebird species such as lapwings that favour wetlands or inland habitats to be under-sampled or undetected (Crossland *et al.* 2006, Iqbal *et al.* 2013)This sampling bias also affects other shorebird species including stilts, Pintail Snipe (*Gallinago stenura*), Common Snipe (*G.gallinago*), Swinhoe's Snipe (*G.megala*), Painted Snipe (*Rostratula benghalensis*), Long-toed Stint (*Calidris subminuta*), Wood Sandpiper (*Tringa glareola*), Common Sandpiper (*Actitis hypoleucos*), Ruff (*C.pugnax*), Little Ringed Plover (*Charadrius dubius*), etc. Past extensive surveys of Riau's coasts reveal it as an important area for shorebirds, with 20,000 individuals from over 23 different migratory species surveyed (Silvius 1988). Yet despite multiple surveys along the South Eastern coast of Sumatra in the 1980s (Silvius 1988) no Red-wattled Lapwings were recorded. This could be a result of survey timing as in 1988 most birds would mostly be confined to Peninsular Malaysia with few records in Singapore prior to their range expansion around the early to mid-2000s (Yong 2012). Multiple wader-focused surveys on nearby Bintan and Batam Island spread out across 2000–2012 also did not record Red-wattled Lapwing (Crossland & Sinambela 2005; Crossland & Sinambela 2014). Expansion of lapwings into Singapore from Peninsular Malaysia would have started by early 2000, but perhaps the density in Singapore was not high enough to act as source population for dispersal/vagrancy to the neighboring Indonesian islands.

Future range expansion

The recent sightings from 2021 could be early evidence of a predicted range expansion and colonization of Sumatra following the *V. indicus* population increase in both Malaysia and Singapore (Eaton *et al*. 2016). Neighbouring Singapore and Malaysia have both recorded Red-wattled Lapwing every year during AWC surveys in 2008–2015, with numbers varying from a single record to a peak of 12 individuals in 2010 for Singapore and 10 individuals to 56 in 2015 for Malaysia (Mundkur *et al*. 2017). In less than 60 years the lapwing's status in Singapore has changed from "rare winter visitor" to "locally common resident" (Yong 2008), highlighting its ability to exploit disturbed habitat and disperse. Furthermore, in the past few years the species has been consistently spotted year-round and in high numbers, even reaching 56 individuals from a single location (eBird, 2021). It is likely that the Red-wattled Lapwing colonisation of Sumatra will mirror the historic trend of range expansion from Johor into Singapore (Yong 2012) given the higher numbers in Singapore and the habitat change prerequisites that have already been met. Deforestation and land use changes across the Riau Islands (Yong 2012) and parts of Sumatra (Chan & Chan 2019; Iqbal *et al.* 2013) would benefit lapwing populations through conversion of forest area into favourable open habitat. The growing number of oil palm plantations and land development projects would benefit the lapwings since Malaysian Red-wattled Lapwing populations commonly occur in oil palm plantations (Jambari *et al*. 2012) and deforested areas (Yong 2012).

The sightings on Pulau Padang and Batam Island possibly represent the first documented and published records of the species on the islands. These distribution records provide evidence and support for an expansion from source populations in Singapore and the Malay Peninsula to mainland Sumatra via the Riau Archipelago. This route of species vagrancy into mainland Sumatra has been documented for other species in the past (Subaraj 1996; Crossland & Sinambela 2005, 2014; and Chan & Chan 2019). Dispersal and range expansion across islands should not be a limitation as Red-wattled Lapwing are already known to occur in significant numbers on satellite islands off the Singapore mainland on Pulau Ubin and Pulau Tekong (Yong 2008).

Currently there are no confirmed breeding records of Red-wattled Lapwing in Indonesia and just the eleven known records of vagrancy summarized in this paper, therefore its current status as a winter visitor will likely remain. The lack of sightings and numbers recorded in the Riau and Lingga Archipelagoes could be "effort" based rather than actual absence (Iqbal 2010). However, the increased frequency of Red-wattled Lapwing records in Indonesia and spatial records this past year support the idea of eventual expansion into mainland Sumatra (Eaton *et al*. 2016). Ultimately, establishing an accurate timeline of Red-wattled Lapwing expansion and status change from "rare winter visitor" (Eaton *et al*. 2016) into eventual "resident" in Indonesia will require a concerted effort to document birds across the less-monitored Riau Islands and eastern provinces of Sumatra.

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FURTHER NOTES ON POSSIBLE OCCURRENCE OF PIED STILT (*Himantopus leucocephalus* Gould, 1837) IN THE PUNJAB AND RAJASTHAN PROVINCES OF INDIA

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INTRODUCTION

The status of Pied Stilt *Himantopus leucocephalus* in Asia has been debated in recent years (Kotogama and de Silva 2009; Bakewell 2012; Parasharya et al. 2014). Pied Stilt (formerly considered a subspecies of the Black-winged Stilt *Himantopus himantopus*) occurs in Australia, New Zealand, New Guinea and the Greater Sundas (Cramp and Simmons 1983; BirdLife International 2012, Bakewell 2012). However, the species has also been reported in Asia, especially since the 1980s, including the Philippines, Vietnam, Peninsular Malaysia and Sri Lanka (Bakewell 2012). Parasharya *et al.* (2014) reported individuals resembling Pied Stilt at four locations in Gujarat, India. The identity of these Asian sightings is puzzling. Some individuals look very similar to Pied Stilt, with a clean white head, face and throat contrasting with a long black mane on the back of the neck. Others differ from a typical Pied Stilt, with incomplete mane or some dark feathering in the face. Moreover, most sightings have been made during the boreal winter, September to February (Bakewell 2012). This timing suggests that the sightings do not involve non-breeding movements of birds of direct Australian origin, as that the breeding season in Australia occurs at approximately the same time.

Black-winged Stilt is resident in Rajasthan and Punjab, but with a large influx of individuals during the boreal winter, which is the non-breeding season for stilts that breed in the northern hemisphere. The species is easily seen in the region, especially in winter, when large numbers occur near ponds, rivers, marshes, and artificial water sources, such as hand pumps. Most stilts in Western India have plumage typical of the species. This taxon was formerly treated as a subspecies *Himantopus himantopus himantopus* of a complex of black-and-white stilts that are now split into several species by many checklists (e.g. Gill et al. 2021). Other recorded individuals resemble Pied Stilt, which was formerly treated as *H. h. leucocephalus*. Therefore, the distribution and identity of stilts with a black mane in Asia is still somewhat of an enigma. Here, we report the first documented occurrence of these birds in the Punjab and Rajasthan provinces in north-west India.

METHODS

Stilts were identified visually during regular wetland surveys. We accessed the sites by car or motorbikes and we walked through the wetlands in the morning (06:00 to 10:00) or evening (16:00-19:00). We observed the birds with binoculars, identified them using field guides (Grimmet et al. 2011 and Ali & Ripley 1987) and photographed them using Canon SX10 and Canon 1200D cameras.

RESULTS

We observed 10 individuals with plumage characters of Pied Stilts at seven sites (Figure 1, Table 1). Most were recorded during the boreal winter, but the two Punjab records were from April and May.

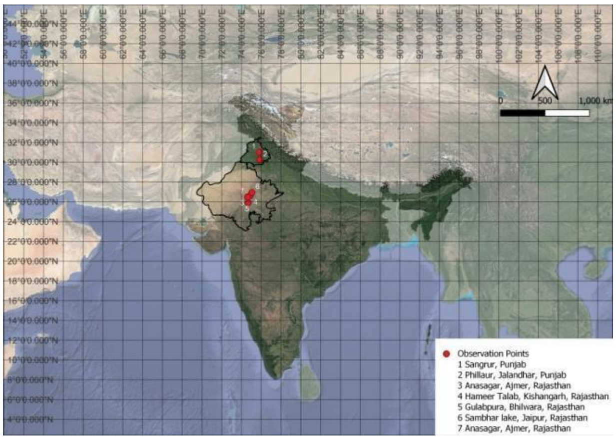

Figure 1: (A) Map of the study area (Indian Subcontinent).

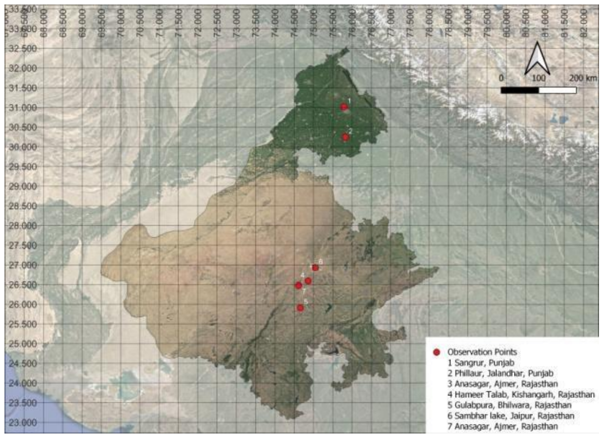

Figure 1: (B) Map of Rajasthan and Punjab showing numbers on the map correspond to the site numbers given in Table 1.

Figure 1: (A) Map of the study area (Indian Subcontinent). (B) Map of Rajasthan and Punjab showing numbers on the map correspond to the site numbers given in Table 1.

Table 1: Observations of apparent Pied Stilts in Punjab and Rajasthan with the characteristics of the site

S. No.	Location	Day of Observation	No of Individuals	Coordinates	Elevation (m)	min-max temperature (ºC).
1	Sangrur, Punjab (Toba)	14 April, 2015	1	30º14'35.51" N 75º49'39.22" E	235	20 - 33
2	Near Punjab Police Academy Campus, Phillaur, Jalandhar District, Punjab	03 May, 2015	1	31º00'26.36" N 75º47'47.74" E	237	20 - 38
3	Anasagar, Ajmer, Rajasthan	11 December, 2015	1	26º28'55.36" N 74º36'53.37" E	490	14 -24
4	Hameer Talab, Kishangarh, Rajasthan	16 January, 2016	2	26º35'25.52" N 74º51'33.51" E	443	10 - 24
5	Gulabpura, Bhilwara District, Rajasthan	17 January, 2016	1	25º54'33.54" N 74º39'25.82" E	402	7 - 21
6	Shakambri Mata" Temple Sambhar lake, Jaipur District, Rajasthan	21 February, 2016	1	26º55'47.50" N 75º02'57.14" E	443	15- 28
7	Anasagar, Ajmer, Rajasthan	13 December, 2020	3	26º28'30" N 74º36'47" E	490	16 - 30

Case 1. Found opportunistically in Sangrur, feeding on small insects.

Case 2. A single bird seen in a pond surrounded by trees behind Phillaur Police Academy. While the back of the bird's neck was black, its plumage differed from a Pied Stilt (Figure 2), having white speckling within the dark hindneck, and the feathers in the hindneck did not appear to be elongated.

Case 3: One individual seen in shallow water on the banks of Anasagar Lake, a long-established artificial wetland in the Aravalli Ranges, used as a reservoir. We noted a black band on the back of the head and neck of this bird, while the upperparts were glossy greenish black, suggesting the individual was male.

Case 4: Two individuals were seen in Hamir Talab, a freshwater pond 29 km northeast of Ajmer. One individual was photographed (Figure 3). Unlike typical Pied Stilts, the black of the hindneck extended onto the nape, crown and forehead, and there was a brown tinge to the upperparts.

Case 5: A single individual was seen in dirty drain water by the road in Gulabpura, Rajasthan. While it had a clearly defined black hindneck (Figure 4), the shape of the marking was not typical of Pied Stilt; the feathering on the hindneck did not appear elongate, the marking was not as broad as is usual in Pied Stilt, and it tapered to a point on the lower nape rather than having a clearly defined 'square' apex.

Case 6: A single individual was found in the "Shakambari mata" area of Sambhar Lake, a saltwater lake about 65 km NE of Ajmer. The black hindneck marking of the bird was mottled with grey and white (Figure 5). It also differed from typical Pied Stilts in having a smudge of dark feathering above the eye.

Figure 2. Case 2, Phillaur (Punjab), 3 May 2015 (by Dinesh Meena).

Figure 3. Hamir Talab, Rajasthan, 16 January 2016 (by Dinesh Meena).

Figure 4. Gulabpura, Rajasthan, 17 January 2016, Individual exhibiting the prominent pattern throughout its backside of neck (by Dinesh Meena).

Figure 5. Near Shakambri mata Temple, Sambhar Lake, Rajasthan, 21 February 2016 (by Dinesh Meena).

Figure 6. Anasagar (Rajasthan), 13 December 2020 (by Dinesh Meena).

Case 7: Three individuals were seen roosting on a small clay pile near Anasagar Lake, along with other bird species including Black-winged Stilt, Ruff (*Calidris pugnax*), Spot-billed Duck (*Anas poecilorhyncha*), Little Cormorant (*Microcarbo niger*) and herons. In the photograph (Figure 6) the black hindneck of all individuals is evident. However, in the two individuals in the foreground, the hindneck marking is incomplete, with white mottling in the mid-line of one individual, grey smudging near the nape of the seconding individual; in both of these individuals, the hindneck marking does not extend as far onto the nape as is typical in Pied Stilt. In the third individual, at the back of the image, it is not possible to assess whether the shape of the black hindneck marking was identical to Pied Stilt.

DISCUSSION

In total, we found ten individual stilts with black hindnecks, spread across seven sites in the states of Punjab and Rajasthan in India. Most were found during winter, but there was one record at Philaur in early May.

The identity of these birds is difficult to confirm. Their general plumage pattern, with an obvious black marking on the hindneck, is similar to Pied Stilt. However, in at least six of the seven individuals that were photographed, some of the fine details of plumage patterning on the head and hindneck were atypical of Pied Stilt. This suggests they were not "pure" Pied Stilts from Australasia, as does their occurrence in the boreal winter (at the peak of the breeding season for Pied Stilts in Australia). It is also possible that black neck markings are a feature occasionally found in Black-winged Stilts – an interpretation supported by the occasional occurrence of these markings in the boreal winter in north-west India (this study), Gujarat (Parasharya et al. 2014), Sri Lanka (de Silva 2000, Kotogama and de Silva 2009), Peninsular Malaysia and the Philippines (Bakewell 2012).

Alternatively, the possibility that these birds were hybrids cannot be discounted. Aside from plumage characters, Pied and Black-winged Stilts differ slightly in structure (relative length of wing lengths, bill length and tarsus; Bakewell 2012) and markedly in call. Unfortunately, none of the individuals we observed were captured or measured, and calls were not recorded. Genetic work may be required to solve the identity of stilts with black hindneck markings in Asia.

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POPULATION SIZE AND DISTRIBUTION OF LESSER SAND PLOVER *CHARADRIUS MONGOLUS* IN BANYUASIN PENINSULA, SOUTH SUMATRA, INDONESIA

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Lesser Sand Plover *Charadrius mongolus* is one of the most common small migratory shorebird in Banyuasin Peninsula, South Sumatra Province, Indonesia. There are at least 32 documented observations of significant counts of Lesser Sand Plover in Banyuasin Peninsula between 1984 to 2020. Based on the single largest record of Lesser Sand Plover at a site, the population in Banyuasin Peninsula is estimated at 20000 birds (15% population in EAAF region). We investigated the population trend over time and show that since the 1980s that population size for Lesser Sand Plover across nine monitored sites in Banyuasin Peninsula has more than halved. The estimated population for the region has been less than 4000 individuals since the late 1980s. We recommend continued monitoring of shorebirds at this site and habitat protection for the conservation of this declining species.

INTRODUCTION

Lesser Sand Plover *Charadrius mongolus* is a small migratory shorebird that breeds discontinuously from Himalayas through Tibet (upto 5500 m) to eastern Asia, and moves to coasts of the southern hemisphere (South Asia, Southeast Asia and Australasia) (Hayman *et al*. 1986, Sonobe & Usui 1993). There are five subspecies of Lesser Sand Plover, including: *Charadrius mongolus pamirensis* (breeds in West Tien Shan, Pamirs, Karakoramto West Kunlun Shan; winters to Africa and India), *C. m. atrifrons* (breeds in Himalaya and South Tibet, winters to India and Sumatra), *C. m. schaeferi* (breeds in East Tibet and Mongolia, winters to Thailand and Greater Sundas), *C. m. mongolus* (breeds in Siberian and Russian Far East; winters to Taiwan to Australasia) and *C. m. stegmanni* (breeds in Kamchatka and Chukotskiy; winters to Ryukyu island and Taiwan to Australasia) (Piersma & Wiersma 1996, del Hoyo & Collar 2004). Two of the four populations in the East Asian-Australasian Flyway (EAAF) (*C. m. mongolus* and *stegmanni*) may qualify for Endangered status at the regional level (criterion A2/3/4 of IUCN), due to substantial documented declines in the flyway, and recognition that further proposed degradation of intertidal staging habitats will perpetuate this decline (Garnett 2011, Conklin *et al.* 2014).

As an extremely large range shorebird species, the global population of Lesser Sand Plover is estimated to be made up of 310,000 to 390,000 individuals (Wetlands International 2006, Birdlife International 2021b). The population in the EAAF is estimated to range between 180,000 to 275,000 individuals, and Indonesia supports the most Lesser Sand Plover in the EAAF during the non-breeding period (Bamford *et al.* 2008, Hansen *et al.* 2016). The global population trend is unknown, but the population is not recognized to be decreasing sufficiently rapidly to approach the thresholds under the population trend criterion (>30% decline over ten years or three generations) (Birdlife International 2021b). In the EAAF, the species is declining (Studds *et al*. 2017) due to habitat loss predominantly in eastern Asia.

Banyuasin Peninsula of South Sumatra province is an important habitat for Lesser Sand Plover in Indonesia during the non-breeding season (Bamford *et al.* 2008). Lesser Sand Plover is one of the nine most common shorebirds in Banyuasin Peninsula, including Black-tailed Godwit *Limosa limosa*, Common Redshank *Tringa totanus*, Bar-tailed Godwit *Limosa lapponica*, Terek Sandpiper *Xenus cinereus*, Eurasian Curlew *Numenius arquata*, Asian Dowitcher *Limnodromus semipalmatus*, Curlew Sandpiper *Calidris ferruginea* and Whimbrel *Numenius phaeopus* (Silvius 1988, Iqbal *et al.* 2020). In this paper, we review the population estimate and distributions of Lesser Sand Plover in Banyuasin Peninsula.

METHODS

We summarize all records and review Lesser Sand Plover in Banyuasin Peninsula, South Sumatra province, Indonesia. Banyuasin Peninsula is one of important wetlands sites in Indonesia (Wibowo& Suyatno 1997, Wibowo & Suyatno 1998). This area is also a Ramsar site, one of international importance, Important Bird Area (IBA) or Key Biodiversity Area (KBA) and UNESCO world heritage site (Authentic Indonesia 2021, Birdlife International 2021a, EAAFP 2021, RSIS 2021). We mapped the maximum count from our monitoring surveys of Lesser Sand Plover, and estimated the population size of Lesser Sand Plover in Banyuasin Peninsula based on the single highest count recorded from the monitoring sites (Figure 1).

DISCUSSION

Lesser Sand Plover were recorded from at least eight monitoring sites along the Banyuasin Peninsula. There are at least 32 internationally significant observations of Lesser Sand Plover in Banyuasin Peninsula between 1984 to 2020 (Table 1). Silvius (1988) reported a total of 10,764 Lesser Sand Plovers in Banyuasin Peninsula during October-November 1984. This record is the highest count of Lesser Sand Plover in this area, including in Sumatra and Indonesia (Bamford *et al.* 2008). Based on the single largest record of Lesser Sand Plover in a site, the population in Banyuasin Peninsula is estimated to be made up of at least 20000 birds.

Table 1. Lesser Sand Plover records in Banyuasin Peninsula between 1984 to 2020.

Date	Sources	Locations								
		1	2	3	4	5	6	7	8	9
Oct-Nov 1984	Silvius 1988									**1076**
Jul-Aug 1985	Silvius 1988									200
24-29 March 1986	Silvius 1987	**600**								
23-29 March 1986	Silvius 1987				**150**					
Aug 1988	Verheugt *et al.* 1990									250
Sep 1988	Verheugt *et al.* 1990									1322
Oct 1988	Verheugt *et al.* 1990									5565
Nov 1988	Verheugt *et al.* 1990									6624
Dec 1988	Verheugt *et al.* 1990									1310
Jan 1989	Verheugt *et al.* 1990									1675
Feb 1989	Verheugt *et al.* 1990									50
Mar 1989	Verheugt *et al.* 1990									2000
Apr 1989	Verheugt *et al.* 1990									715
May 1989	Verheugt *et al.* 1990									35
Jun 1989	Verheugt *et al.* 1990									15
Jul 1989	Verheugt *et al.* 1990									50
Aug 1989	Verheugt *et al.* 1990									200
31 July 2001	Gonner & Hasudungan 2001		*c.*70 0				***c.*70 0**		*c.*700	
Dec 2012	TNS 2016									1000
Nov 2014	TNS 2016									3200
1 Nov 2008	MI *pers.obs*							**3.00 0**		
14 Dec 2008	MI *pers.obs*								**5.000**	
Nov 2008	TNS 2016									1515
Nov 2009	TNS 2016									226

Nov 2010	TNS 2016									1000
Jan 2016	SNP 2016		56						50	
Sep 2017	Iqbal & Martini 2018		10							
Feb 2018	Iqbal & Martini 2018		298		32				100	
Nov 2018	Iqbal & Martini 2018		352		3				28	
Dec 2019	TNBS 2019		426			**2120**				
Oct 2020	MI & DM		150	**3000**		200		50	2000	
Nov 2020	SY *pers.com*		**3600**							

Notes:

1. Bungin and Apung River
2. Barong River
3. Dinding River
4. Jentolo River
5. Between Tengkorak and Palu Gedi River
6. Teluk Galas River
7. Kuala Sapi River
8. Nibung River
9. Total count in Banyuasin Peninsula
10. TNS 2016 (Taman Nasional Sembilang 2016)
11. MI & DM Muhammad Iqbal and Deni Mulyana observations)
12. TNBS 2019 (Taman Nasional Berbak Sembilang 2019)
13. SY *pers.com* (Suyoko personal communication to Muhammad Iqbal)

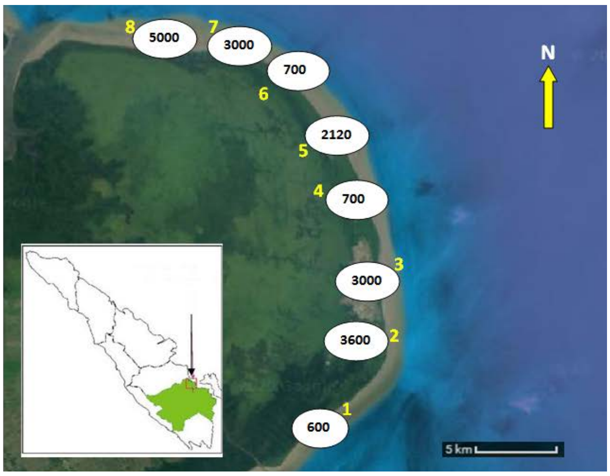

Figure 1. Map showing the Banyuasin Peninsula, South Sumatra, Indonesia. Yellow numbers refer to the number of rivers in Table 1. Numbers in white circles refer to the largest number in a single record of each localities.

The coastal zone of Banyuasin Peninsula is at least 50-60 km long stretching from the south (Bungin and Apung River) to the north (Sembilang River) (Silvius 1986). There are small rivers in this area, namely Bungin River, Apung River, Barong River, Dinding River, Jentolo River, Tengkorak River, Palu Gedi River, Teluk Galas River, Kuala Sapi River and Nibung River. Most of the area is mangrove forest, but in the inner part of Barong to Jentolo River, the mangrove forest has been converted to aquaculture ponds of up to 205,750 ha (Iqbal *et al.* 2019). The single largest record of Lesser Sand Plover in a site is 5000 birds in Bungin River, following 3600 birds in Barong River. Except Barong River, where Lesser Sand Plover is found in aquaculture ponds, all records are observed in mudflats along the coastline (Figure 2 and 3). A record of 3600 birds in Barong River suggests aquacultural ponds can be important non-breeding habitat for Lesser Sand Plover. It is presumed concentration of Lesser Sand Plovers in aquaculture ponds is caused by high tides.

Bamford *et al*. (2008) estimate the number of Lesser Sand Plover in Indonesia during the non-breeding period is around 45,000 birds. Conklin *et al.* (2014) only listed Benoa Bay (Bali Province) as important habitat for Lesser Sand Plover in Indonesia, with a number of 4000 birds in 15 January 1996. Other important habitats for Lesser Sand Plover in Indonesia are Cemara beach of Jambi Province *c.* 3481-3924 birds, Wasur National Park of Papua Province birds c. 3130 birds, and in Bagan Percut of North Sumatra Province *c.* 2180-2222 birds (Silvius 1988, Crossland *et al.* 2012, Putra *et al.* 2015, Conklin*etal.* 2016, Febrianto *et al.* 2019). The results from this study show that the population is estimated to be at least 20,000 birds in Banyuasin Peninsula (15% population in EAAF region) indicating that this area is internationally important for Lesser Sand Plover.

The population trend of Lesser Sand Plover in Banyuasin Peninsula has decreased over time. This assumption based on a total number in October-November 1984 is around *c.* 10,000 birds, and compare to a single largest count of c. 4,000 birds in October and November 2020. No indication about threats to Lesser Sand Plover in Banyuasin Peninsula, including from hunting, aquaculture ponds and fisheries activities. However, the data since the 1980s suggest population size for Lesser Sand Plover across nine monitored sites in Banyuasin Peninsula has more than halved. The estimated population for the region has been less than 4000 individuals since the late 1980s (Figure 4). We have no significant indication of threats to Lesser Sand Plover and other shorebirds in Banyuasin Peninsula. The decline of Lesser Sand Plover in this region could be induced by hunting or loss of habitats outside this area. In the EAAF region, hunting of migratory shorebirds has occurred; there are records of hunting from 14 of the 22 countries (63.6%) within the flyway, from the non-breeding grounds through stopping sites, and also in breeding grounds areas (Gallo-Cajiaoetal. 2020).

The Lesser Sand Plover is recently listed as Least Concern, because of its large number and the global population trend is unknown (Birdlife International 2021b). However, there is a potential to upgrade the species to Near Threatened or Vulnerable based on recent information of declines in some areas in East Asia (MacKinnon *et al.* 2012, Conklin *et al.* 2014). Two subspecies (*C. m. mongolus* and *stegmanni*) are listed as Endangered in EAAF region (Conklin *et al.* 2014), and concern on the population future trend should be pointed out. We need to continue monitoring Lesser Sand Plover in Banyuasin Peninsula to study local population trends.

Figure 2. Lesser Sand Plovers (with mix Terek Sandpiper and Curlew Sandpiper) on 16 October 2020 in Dinding River, Banyuasin Peninsula, South Sumatra, Indonesia (©Muhammad Iqbal).

Figure 3. Group of small shorebirds dominated by Lesser Sand Plovers on 6 December 2020 at an aquaculture pond in Barong River, Banyuasin Peninsula, South Sumatra, Indonesia (©Suyoko).

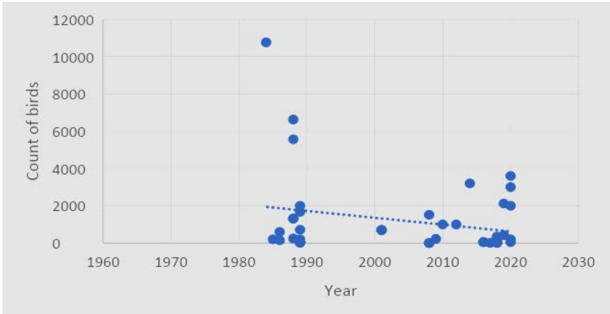

Figure 4. The estimated population of Lesser Sand Plovers in the region from the late 1980s to 2020.

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We are very grateful to Afan Absori (head of Berbak Sembilang National Park of South Sumatra office) for facilitating us to conduct fieldwork in Banyuasin Peninsula. We thank Pak Suyoko and Pak Taher for their help in the field. Finally, we thank the Asian Waterbird Conservation Fund and the World Migratory Bird Day Fund 2020 for their support of our shorebird conservation work in Banyuasin Peninsula.

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AN EXCEPTIONAL NUMBER OF WOOD SANDPIPERS AND PIED AVOCETS IN HAIFENG, SHANWEI, GUANGDONG PROVINCE, CHINA, APRIL 2021

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INTRODUCTION

The coast of the South China Sea harbors many paddies, wetlands, marshes, and intertidal flats, which serve as vital stopover and wintering grounds for migratory shorebirds in the East Asian-Australian Flyway (EAAF)(Bamford *et al.* 2008). Most of the internationally important wetlands that meet the Ramsar 1% population criterion are recorded in the northern part of China in sites such as Yalujiang and Bohai Bay. Relatively few sites in the southern part of mainland China meet the criterion except for Futian National Nature Reserve and Zhanjiang Mangrove National Nature Reserve (Bamford *et al.* 2008).

Waterbird surveys along the coast of China have been carried out mostly on intertidal mudflat, salt works and aquaculture ponds, which may overlook waterbird species that utilize the farmlands away from the intertidal zone (Barter 2002, Choi *et al*. 2021, Kuang *et al*. 2019), despite some studies indicating that shorebirds rely on crop paddies during their spring and autumn migration on the EAAF (Kasahara *et al*. 2014). Therefore, there is a significant lack of information on the use of rice paddies by waterbirds along the coast of China.

The Futian National Nature Reserve in Shenzhen is 175 km away and geographically close to Haifeng, Shanwei and has similar economic development levels. Haifeng County, in Shanwei, located in the east of Guangdong province, China, has relatively few published waterbird survey records historically and its importance in the flyway is not well understood. Local people in Haifeng are involved in the fishery industry and utilize the coastal zone by building fishponds behind the mangroves, which indirectly creates roosting and feeding habitats for shorebirds during high tides (Choi *et al.* 2021).

A survey coordinated by Alashan SEE (Social, Entrepreneur & Ecology) Ecology Association, Shenzhen University, and Southern University of Science and Technology was conducted in April 2021 for a thorough evaluation of waterbird species richness and habitat conditions in Shanwei. Specifically, we focused on Haifeng county in Shanwei for its numerous aquaculture ponds and paddies next to the intertidal wetlands. Understanding habitat usage conditions of shorebirds could offer insights to conservation efforts on shorebird populations in the EAAF and be beneficial for future migratory shorebird habitat protection.

METHODS

Survey Sites

By noting down the geographical location and habitat of Guangdong Neilingding Island-Futian National Nature Reserve in Shenzhen (provide the GPS record), we identified Haifeng as our survey site for its proximity and similarity of landscape which is composed of intertidal zones and marshes. The 2021 Haifeng Survey was conducted along the coastal intertidal zone. Salt marshes surrounded by reeds, fishponds, and paddies are found on the landward side of the seawall while on the seaward side, the mangroves and bare tidal flats. The survey covered different habitats including salt marshes, rice paddies, salt works, drained aquaculture ponds, and tidal flats. The distance of surveyed paddies to the intertidal zone ranged from 1 km to 4 km.

We counted the shorebirds along the survey route and recorded the species and abundance. We also recorded other waterbirds that share the same habitat with the shorebirds. We noted down forest birds that are not commonly seen in Guangzhou Province. "Uncommon" is defined as sighted infrequently in urban habitats. The ponds are found on either side of a trail parallel with the X127 freeway and intersect with the G15 freeway as indicated in Figure 1. Yanqian and Leifengliao are two sub-sites at the beginning and the end of the trails. We separated the survey into two zones: the first half of the roads close to Yanqian, and the second half close to Leifengliao.

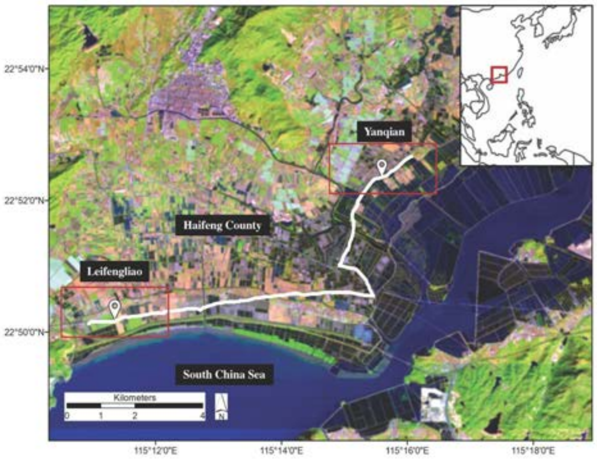

Figure 1. Survey route and location on the EAAF. Base map from Dr Amanda Lilleyman.

The 12-hour duration surveys began on April 11th, 2021, with a visible sky at 8:30 am. We focused on shorebirds in salt ponds and paddies before 3 p.m. in the day because the intertidal wetlands were covered with tides and the birds were ashore. We also recorded forest birds in the marshes where shorebirds were present.

***Yanqian* (岩前22°52' N 115°16' E)**

The distance from Yanqin to the sea ranges up to 4 kilometers. The ponds along Yanqian are mainly used for extracting salt from seawater. Water depth ranges from 3 to 5 centimeters. Surrounding the ponds are farmlands rich with wild plants and insects. The paddies are planted with rice shoots in spring, and the shoots are separated approximately 10 cm apart with a height under 10 cm, leaving adequate room for shorebirds to forage. The paddies were inundated with water depths of around 4 to 6 centimeters. Both salt ponds and farmlands were surveyed for shorebirds.

The overall landscape is flat and covered with vegetation. Gentle hill slopes raise occasionally around the farmlands. We hiked and recorded the species in the ponds.

***Leifengliao* (雷封寮22°50'N 115°10'E)**

Leifengliao is comparatively closer to the coast than Yanqian with up to 2 kilometers distance away from the coast. The surveyed habitats are mostly shallow paddies or aquaculture ponds that have not yet been filled with water. Culturing ponds are separated into grids by the embankments. Human activity is evident in the floats and sheds next to the ponds.

Farmlands near Leifengliao are mostly planted with corn, which is too dense for shorebirds to forage in. The landscape in Leifengliao is flatter than that of Yanqian and the mangroves effectively separated the intertidal zone from the ponds. We drove along the trail and hiked to the mangrove to see the birds presented at each habitat.

RESULTS

A combination of 3568 shorebirds (table 1), 929 other species of waterbirds (table 2), and 86 uncommon forest birds were recorded (table 3). In total, 4,583 birds were recorded. The species habitat ranged from intertidal zones to farmlands.

Overall, 41.59% of total abundance of birds were found in rice paddies, 32.95% of total abundance were found in intertidal zones, 21.86% of total abundance were found in drained aquaculture ponds and 3.6% of total abundance were found in salt marshes. There were no waders in the cornfield.

The abundance of Wood Sandpipers (*Tringa glareola*) stands out with a total of 1048. It was well over the Ramsar 1% threshold of 1,000. Wood Sandpipers were mainly sighted in the farmlands. Pied Avocets (*Recurvirostra avosetta*) were also found to be over the 1% threshold of 250, which were found on the intertidal zones. In addition to shorebirds, Haifeng served as a sanctuary for many other species of waterbirds, including the terns that share the intertidal zone with shorebirds when the tide is low. Egrets and gallinule share salt marshes with the shorebirds when the tide was high.

Table 1. Survey results of shorebirds

Common Name	Scientific Name	Habitat	Count
Common Redshank	*Tringa totanus*	Drained aquaponds	200
Common Sandpiper	*Actitis hypoleucos*	Drained aquaponds	2
Kentish Plover	*Charadrius alexandrinus*	Drained aquaponds	24
Lesser Sand Plover	*Charadrius mongolus*	Drained aquaponds	55
Pacific Golden Plover	*Pluvialis fulva*	Drained aquaponds	181
Red-necked Stint	*Calidris ruficollis*	Drained aquaponds	367
Black-tailed Godwit	*Limosa limosa*	Intertidal area	2
Curlew Sandpiper	*Calidris ferruginea*	Intertidal area	438
Eurasian Whimbrel	*Numenius phaeopus*	Intertidal area	1
Greater Sand Plover	*Charadrius leschenaultii*	Intertidal area	112
Pied Avocet	***Recurvirostra avosetta***	Intertidal area	**795**
Terek Sandpiper	*Xenus cinereus*	Intertidal area	1
Black-winged Stilt	*Himantopus himantopus*	Rice paddies	136
Broad-billed Sandpiper	*Limicola falcinellus*	Rice paddies	1
Common Greenshank	*Tringa nebularia*	Rice paddies	37
Common Snipe	*Gallinago gallinago*	Rice paddies	1
Great Knot	*Calidris tenuirostris*	Rice paddies	2
Greater Painted-snipe	*Rostratula benghalensis*	Rice paddies	4
Grey Plover	*Pluvialis squatarola*	Rice paddies	1
Sharp-tailed Sandpiper	*Calidris acuminata*	Rice paddies	1
Spotted Redshank	*Tringa erythropus*	Rice paddies	8
Wood Sandpiper	***Tringa glareola***	Rice paddies	**1048**
Marsh Sandpiper	*Tringa stagnatilis*	Salt marsh and salt works	145
Temminck's Stint	*Calidris temminckii*	Salt marsh and salt works	6
TOTALS			**3568**

Table 2. Survey results of other waterbirds

Common Name	Scientific Name	Habitat	Count
Black-faced Spoonbill	*Platalea minor*	Drained aquaponds	17
Black-crowned night heron	*Nycticorax nycticorax*	Drained aquaponds	4
Cattle Egret	*Bubulcus ibis*	Drained aquaponds	79
Black-headed Gull	*Chroicocephalus ridibundus*	Intertidal area	21
Gull-billed Tern	*Gelochelidon nilotica*	Intertidal area	140
Brown-cheeked Rail	*Rallus indicus*	Rice paddies	1
Chinese Pond Heron	*Ardeola bacchus*	Rice paddies	42
Common Moorhen	*Gallinula chloropus*	Rice paddies	9
Eastern Spot-billed Duck	*Anas zonorhyncha*	Rice paddies	25
Great Egret	*Ardea alba*	Rice paddies	185
Grey Heron	*Ardea cinerea*	Rice paddies	6
Intermediate Egret	*Ardea intermedia*	Rice paddies	5
Little Egret	*Egretta garzetta*	Rice paddies	373
Little Grebe	*Tachybaptus ruficollis*	Rice paddies	4
Northern Shoveler	*Spatula clypeata*	Rice paddies	2
Purple swamphen	*Porphyrio porphyrio*	Rice paddies	3
Ruddy-breasted Crake	*Zapornia fusca*	Rice paddies	2
Slaty-breasted Banded Rail	*Gallirallus striatus*	Rice paddies	2
Tufted Duck	*Aythya fuligula*	Rice paddies	8
TOTALS			**929**

Table 3. Survey of uncommon local forest birds next to the ponds

Common Name	Scientific Name	Habitat	Count
Chinese Penduline Tit	*Remiz consobrinus*	Drained aquaponds	30
Yellow wagtail	*Motacilla flava*	Drained aquaponds	43
Black-winged Kite	*Elanus caeruleus*	Salt marsh and salt works	1
Eastern Buzzard	*Buteo japonicus*	Salt marsh and salt works	1
Red-Throated Pipit	*Anthus cervinus*	Salt marsh and salt works	10
Richard's Pipit	*Anthus richardi*	Salt marsh and salt works	1
TOTALS			**86**

DISCUSSION

Previously, important Wood Sandpiper non-breeding sites along the EAAF have only been found in Thailand, Brunei, Malaysia, and northern China (Barter *et al.* 2004, Bamford *et al*. 2008). Recorded Pied Avocet sites in southern China only included Mai Po and Futian National Nature Reserve. Our surveys indicated that there are important sites in lower latitudes of China during the stopover periods for Wood Sandpipers and Pied Avocets.

By comparing Haifeng County with Futian Reserve, we located regions that are likely to be good habitats for migratory shorebirds. Future surveys could be carried out in places with similar geographical locations and economical levels with recorded sites to search for more key sites of shorebird species. Thus, wildlife reserves could be effectively identified, thus making conservation more effective.

Wood Sandpipers were found to use rice paddies extensively during stopover stages (Choi *et al*. 2021). They are frequently sighted next to freshwater habitats during migration (Hayman *et al*. 1986). During spring when the height of the crops was short, the paddies provided enough space for the shorebirds during the stopover. However, due to the reliance on rice paddies by Wood Sandpipers and the emphasis on tidal wetland and aquaculture ponds in waterbird surveys along the east coast, Wood Sandpiper was recorded in relatively few sites in the southern part of China. Previous surveys were heavily focused on intertidal wetlands and fishponds while largely ignoring paddies (Melville *et al*. 2016). Through expanding the possible habitats like farmland and rice paddies during shorebird surveys, a more accurate population count could be revealed.

In addition to reporting shorebird species in Haifeng Country, we recorded other waterbirds and not commonly sighted forest birds (as in Guangzhou Province, China) in this study. Previous literature stressed the importance of preserving residential avian species in Haifeng (Hu *et al.* 2011) and earlier surveys indicated Haifeng County was an important habitat for the endangered Black-faced Spoonbill (Chan *et al*. 2010). In the present study Black-faced Spoonbill (*Platalea minor*) was sighted. The subtropical monsoon climate in Haifeng County is warm during the spring. The high numbers and the diversity of avian species demonstrate that with the abundant vegetation, Haifeng provides abundant food for migratory shorebirds in addition to support a wide range of local species (Gao *et al.* 2014). Haifeng County is found to be critical for migrants on EAAF and ecologically significant to many other avian species.

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NEW RECORDS OF BROAD-BILLED SANDPIPER *CALIDRIS FALCINELLUS* IN BANYUASIN PENINSULA (SOUTH SUMATRA, INDONESIA) AFTER 32 YEARS

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Broad-billed Sandpiper *Calidris falcinellus* is an uncommon migrant to northern Sumatra but a rare visitor in the rest of the Greater Sundas (central and southern Sumatra, Borneo, Java and Bali). Until 2018 this species had been recorded just once (on 1 December 1988) in the Banyuasin Peninsula, South Sumatra Province, Indonesia. Three records of Broad-billed Sandpiper on 16 March 2018, 15 October and 7 December 2020 in Barong River are recent records for Banyuasin Peninsula after 32 years (1988-2018) of no observations.

INTRODUCTION

Wetlands in Sumatra, Indonesia, particularly in the east coast of the island, provide habitat for more than 35 species of migratory shorebirds (Iqbal *et al.* 2013). Since the summary provided by Bamford *et al.* (2008) in which they identified eight important sites for migratory shorebirds in Indonesia, dozens more sites have been identified by observers across the archipelago, and there 47 migratory shorebird species have now been recorded (Crossland *et al.* 2006, Putra *et al.* 2020). Banyuasin Peninsula is one of the most important sites that confirmed more 78,000 migratory shorebirds use the site, supporting at least seven populations at 1% level or supported in internationally important numbers (Verheugt *et al*. 1990, Conklin *et al.* 2014).

Banyuasin Peninsula comprises the largest mangrove area within the Indo-Malayan region and the only mangrove area that still has an intact natural transition into adjacent freshwater and peat swamp forest (Silvius *et al.* 2016). There are 28 shorebird species reported in Banyuasin Peninsula with Broad-billed Sandpiper *Calidris falcinellus considered a* locally vagrant species (Verheugt *et al.* 1990, Verheugt *et al.* 1993, Iqbal *et al.* 2020). During 13 months of surveys on the Banyuasin Peninsula from August 1988 to August 1989, Verheught *et al.* (1990) counted a total of 280,519 waders of 25 species with monthly totals ranging from 2146 in May 1989 to 78,561 in October 1988. Broad-billed Sandpiper was only recorded on one occasion –15 birds in December 1988. In this paper, we report two recent observations of Broad-billed Sandpiper in the Barong River sector of Banyuasin Peninsula in 2020, representing the first records of this species in 32 years.

SURVEY SITE

Barong River geographically lies at 02°09'S, 104°53'E. This area is part of Banyuasin Peninsula, Banyuasin Dua subdistrict, Banyuasin district, South Sumatra Province, Indonesia. In terms of conservation area management, the area is under Berbak Sembilang National Park. The habitat is a coastal zone of mangrove forest, and many areas have been converted to aquaculture ponds. The substrate is extremely soft and muddy, providing excellent roosting and feeding ground for numerous waterbirds and shorebirds (Figure 1).

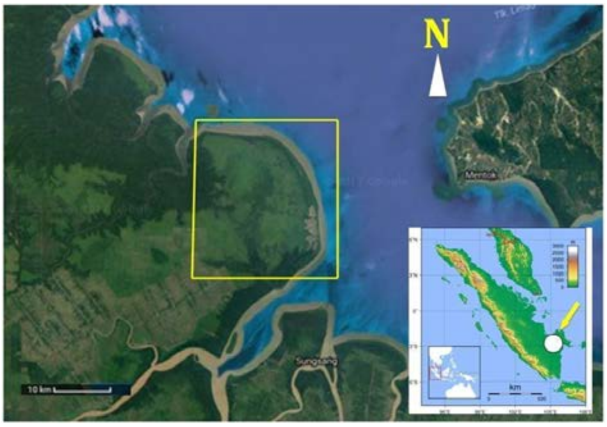

Figure. 1. Map showing the Banyuasin Peninsula, South Sumatra, Indonesia.

BROAD-BILLED SANDPIPER RECORDS

Broad-billed Sandpiper were observed three times in 2018 and 2020 at Barong River, Banyuasin Peninsula, South Sumatra Province, Indonesia.Four Broad-billed Sandpipers were sighted on 16 March 2018 and six on 15

October 2020, on the aquaculture ponds of Barong River. The birds have small size body, short necked, slightly decurved bill and kinked downwards at the tip, short dark-grey legs, double supercilium that joins at forehead, greyish or bownish crown, whitish double supercilium, upperparts are dull grey or brown with diffuse pale fringes (Figure 2 and 3).

Figure 2. An individual Broad-billed Sandpipers *Calidris falcinellus* with Lesser Sandplover *Charadrius mongolus,* on the 16 March 2018 at the aquaculture ponds in Barong River, Banyuasin Peninsula, South Sumatra, Indonesia (©Muhamad Iqbal).

Figure 3. Broad-billed Sandpiper *Calidris falcinellus,* on the 15 October 2020 at the aquaculture ponds in Barong River, Banyuasin Peninsula, South Sumatra, Indonesia (©Deni Mulyana).

The third observation was of at least 40 Broad-billed Sandpipers on 7 December 2020 in the same area. The birds were small shorebirds, when feeding and standing they seemed to be of a similar size to Mongolian Plover *Charadrius mongolus* and Curlew Sandpiper *Calidris ferruginea* , which are two common shorebirds occuring in the coastal zone of Banyuasin Peninsula. After examination with various guides (Sonobe & Usui 1993, Hayman *et al.* 1986, Chandler 2009, Robson 2011), the characters were confirmed to be adult non-breeding Broad-billed Sandpiper.

DISCUSSION

Broad-billed Sandpiper has two subspecies: *Calidris falcinellus falcinellus*, which breeds in Scandinavia and Northeast Russia, and spends the non-breeding period from East Africa (rarely to South Africa) through Red Sea and Arabia to West India and Sri Lanka; and *Calidris falcinellus sibirica*, which breeds in Northeast Siberia and spends the non-breeding period from Northeast India through Asia, Indonesia to Australia (del Hoyo & Collar 2004). The subspecies *sibirica* has brighter, more rufous fringes to the upperpart and a cinnamon wash to breast in breeding plumage, the upper supercilium is less well defined (Haymen *et al.* 1986). This subspecies is uncommon to fairly common coastal winter visitor and passage migrant in Southeast Asia, (Robson 2011).

Table 1. Shorebirds monitoring in Banyuasin peninsula between 1988 to 2020, and Broad-billed Sandpiper records.

No.	Date	No. Species of waders	Total No. of waders	Number of Broad-bille d Sandpiper	References/ Observers
1	1 December 1988	20	18,600	15	Verheugt *et al.* 1990
2	January to August 1989	30	82,736	0	Verheugt *et al.* 1990
3	31 July 2001	10	7,100	0	*Unpublished data*
4	10 November 2001	11	18,500	0	*Unpublished data*
5	26 February 2002	6	4,025	0	*Unpublished data*
6	17 June 2002	>1	160	0	*Unpublished data*
7	9 Oktober 2002	11	9,500	0	*Unpublished data*
8	31 Juli 2003	7	2,500	0	*Unpublished data*
9	21 October 2003	7	10,000	0	*Unpublished data*
10	24 Februari 2004	>10	20,000	0	*Unpublished data*
11	May 2010 (undated)	7	4,421	0	*Unpublished data*
12	December 2011 (undated)	15	10,985	0	*Unpublished data*
13	14 September 2012	>1	50	0	*Unpublished data*
14	December 2012 (undated)	>1	2	0	*Unpublished data*
15	November 2014 (undated)	17	49,309	0	*Unpublished data*
16	8 September 2017	>1	374	0	Iqbal *et al.* 2019
17	24 February 2018	>1	200	0	Iqbal *et al.* 2019
18	16 March 2018	>5	1,000	4	*Unpublished data.*
19	24 March 2018	>1	500	0	Iqbal *et al.* 2019
20	12 May 2018	>1	150	0	Iqbal *et al.* 2019
21	24 November 2018	>1	363	0	Iqbal *et al.* 2019
22	20-24 December 2019	25	8,812	0	*Unpublished data*
23	15 October 2020	25	69,819	6	Our survey
24	7 December 2020	13	5,000	40	Our survey

Both Marle & Voous (1988) and MacKinnon & Phillipps (1993) considered Broad-billed Sandpiper as a rare visitor to the Greater Sundas (Sumatra, Borneo, Java and Bali), while Eaton *et al.* (2016) considered it an uncommon migrant throughout the Indonesian archipelago. The species has only been recorded once in Indonesian Borneo, and is a rare coastal visitor in Java and Bali (MacKinnon 1988, Mann 2008). Records of Broad-billed Sandpiper in most of Sumatra are very limited, but in northern Sumatra Crossland *et al.* (2006) noted that the species is a locally common migrant in the north-east with flocks of up to 100 observed, and multiple records from Bagan Percut, Deli-Serdang District with max 200 on 30 December 1995 (Crossland *et al.* 2012). Further north in Aceh, a survey along parts of the east coast from October 2019 to January 2020 recorded a total 342 Broad-billed Sandpipers (Putra *et al.* 2020). Further south, up to 20 birds were recorded in April 1988 on the east coast of Jambi province (Silvius 1986) but there have been no recent records (Tirtaningtyas & Febrianto 2013, Febrianto *et al.* 2019).

Broad-billed Sandpiper has only been recorded once in Banyuasin peninsula, with 15 birds observed on 1 December 1988 (Verheugt *et al.* 1990, Verheugt *et al.* 1993). Three observations of Broad-billed Sandpiper in Banyuasin peninsula occured in 2018-2020, which are new recent records for this wetland after 30 years (1988-2018). Survey and monitoring of shorebirds in Banyuasin Peninsula were conducted between 1989 to 2017 (see Table 1), but no Broad-billed Sandpiper were reported. Marle & Voous (1988) stated that Broad-billed Sandpiper is a possibly overlooked winter visitor in Sumatra. Our observations of Broad-billed Sandpiper in Banyuasin peninsula suggest that this shorebird is very similar to the Curlew Sandpiper. The increasing number of birdwatchers and local researchers with long lens cameras will lead to better identification and documentation in the Banyuasin peninsula and elsewhere in Sumatra. In this case, there are some new and interesting records of shorebirds in Sumatra during a last decade (eg. Abdillah & Iqbal 2015, Imansyah & Iqbal 2015, Iqbal *et al.* 2014, Putra *et al.* 2018, Muzika *et al.* 2020). Essentially though, the species has no doubt been overlooked but the numbers are so low that it does seem likely that southern Sumatra does not lie below a major migration route for Broad-billed Sandpiper. In contrast, as it is similar to other species (like Great Knot, Red Knot, Red-necked Stint, etc), the main migration route seems to cross Northern Sumatra. Not only have much larger numbers of Broad-billed Sandpiper been recorded in northern Sumatra compared to the southern provinces, but despite the potential to be overlooked amongst large numbers of Curlew sandpipers, Broad-billed sandpipers have been observed at many sites, on many occasions in northern Sumatra. Further monitoring is needed to better understand the abundance and distribution of Broad-billed Sandpiper in Banyuasin peninsula and Sumatra.

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SHOREBIRD DEPENDENCE ON BEACH WRACK HABITAT IN WESTERN AUSTRALIA

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Sites with a relatively small number of shorebirds are often overlooked and undervalued. We monitored three small shorebird sites along the coastline of Western Australia between January 2018 and August 2021 to illustrate their conservation value. One site was south of the Two Rocks Marina located about 60 km north of Perth, Western Australia. The beaches at Point Moore and Separation Point were located 3 km from the city centre of Geraldton, a town on the mid-Western Australian coast. The large accumulation of beach wrack on these beaches made them attractive to shorebirds especially over the austral summer and early autumn. The three sites combined recorded 18 migratory shorebirds and eight Australian breeding shorebirds. The results from the surveys make Two Rocks a site of national importance for Sanderling *Calidris alba* (138 individuals) while Point Moore and Separation Point sites of national importance for Sanderling (139) and Ruddy Turnstone *Arenaria interpres* (70). The data collected over these three years confirmed three new sites of national importance for Ruddy Turnstone and/or Sanderling.

INTRODUCTION

Sites with relatively small numbers of shorebirds are often unrecognised, especially when they do not meet the criteria of a nationally or internationally important site or fall outside dedicated reserves. We gathered baseline data to determine the value of these smaller sites. Our three survey sites all had a sandy coastal beach, were adjacent to an urban area, were subject to recreational pressures, were unprotected and seasonally accumulated large volumes of beach wrack. The importance of beach wrack deposits along the Western Australian are important as they provide migrating shorebirds with an important foraging habitat before shorebirds' northward migration (Campbell 2018, Singor 2018). Beach wrack deposits along the mid-western coastline of Western Australia are used as a staging site prior to northward migration by Ruddy Turnstone *Arenaria interpres* and Sanderling *Calidris alba*.

METHODS

Two Rocks

The beach at Two Rocks (31˚ 29' 58 S, 115˚ 35' 01 E) (Figure 1) was surveyed daily during the peak migration (December to April) and fortnightly during the quieter winter periods. Surveys were carried out around 7 a.m., before disturbance affected shorebird behaviour and took about one hour to complete. Outside the austral winter there is little difference between high and low tides at Two Rocks, except at low tide the base of the limestone stacks is more exposed and at high tide the beach wrack banks get flooded and pools of water are left behind. In winter, the storm surges push the tides up to the primary dune system, which erodes and narrows the beach.

We conducted 271 surveys between January 2018 to August 2021 along a fixed transect, starting at the limestone stack near the inner harbour and continuing along the beach to the second limestone stack at Wreck Point (Figure 1). We followed the same route back, allowing counts to be double checked. The survey continued along the sea facing harbour groyne and returned back to the original starting point. February 2018 and September 2018 were not covered.

Point Moore and Separation Point

At Point Moore (28˚ 46' 51 S, 114˚ 34' 38 E) and Separation Point (28˚ 47' 32 S, 114˚ 35' 56 E) (Figure 2) the same transects were followed along the beach. In summer, most surveys were conducted in the morning and in winter between midday and afternoon. Tidal conditions varied between surveys. At spring low tides, in the austral summer, shorebirds were spread out feeding on the exposed reefs at Separation Point and could not be counted due to the distance and amount of wrack on the reefs hiding shorebirds from view. At Point Moore 116 shorebird surveys were carried out between November 2017 and June 2021, except for June 2018 and May 2021. At Separation Point 86 shorebird surveys were conducted between April 2018 and June 2021, except for June, August and September in 2018 and May 2021 (Bishop *et al*. 2020). Surveys at Point Moore and Separation Point (Figure 2) were conducted more or less weekly during the peak migratory season of December to April and monthly otherwise. As these sites are adjacent to each other, shorebirds move between the locations. Surveys at the sites were conducted in succession to avoid double counts and most often within a two-hour period. During the counts a spotter was placed between the two sites to monitor any shorebird movements between the sites.

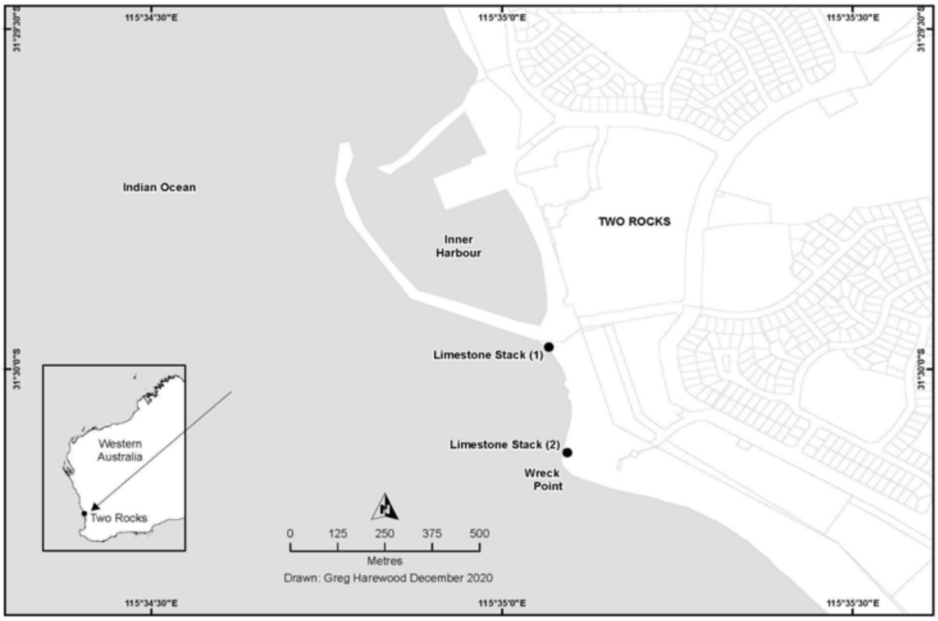

Figure 1. Map shows the Two Rocks research area. Two Rocks Marina, the limestone stacks and Wreck Point are highlighted.

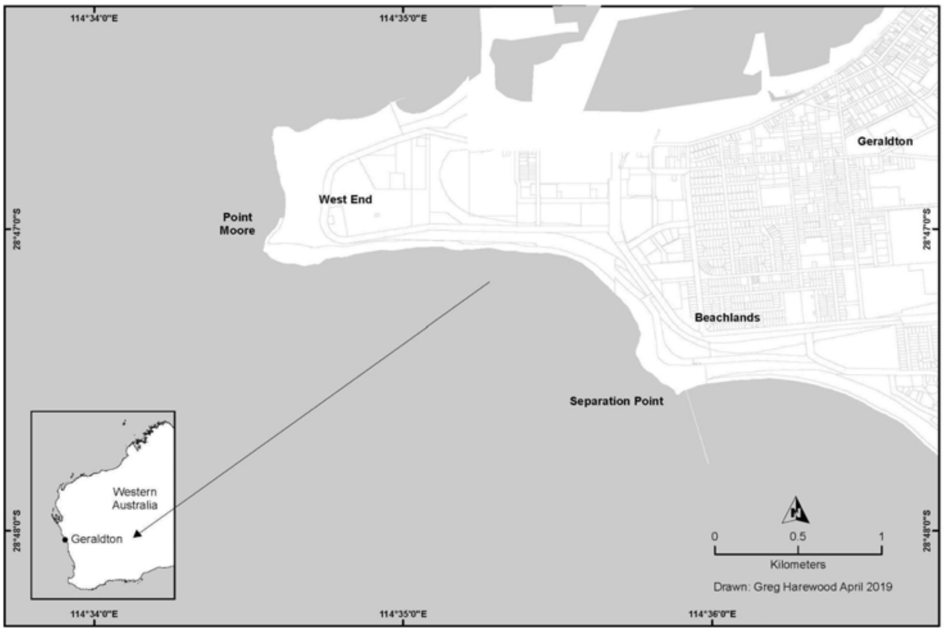

Figure 2. Map showing the Point Moore and Separation Point research areas in Western Australia.

Figure 3. View of the Two Rocks beach, looking south from the first limestone stack. (by Marcus Singor).

Figure 4. Separation Point beach covered in beach wrack. (by Alice Bishop).

The Port reclamation area is located to the north of Point Moore and next to Pages Beach. Shorebirds moved between the landfill reclamation area and Point Moore beach. Shorebirds observed at the landfill area were included in the Point Moore count data.

RESULTS

In total, 18 migratory shorebird species and eight Australian breeding shorebird species were sighted (Table 1). Shorebirds were largely absent at Two Rocks, Point Moore and Separation Point during the Austral winter months June to August.

Two Rocks

At Two Rocks we recorded 15 migratory and six resident shorebird species (See supplementary data). Silver Gulls, *Larus novaehollandiae*, were breeding in all three years on the limestone stack, close to the marina (Figure 1). On 17 November 2019, two large Silver Gull chicks, still downy though partly feathered, were sighted. Silver Gulls commenced breeding in mid-June in 2020 and the colony expanded to 18 breeding pairs. There were seven pairs breeding on 7 June 2021. By 19 September 2021, there were 18 pairs.

Point Moore and Separation Point

At Point Moore we recorded 12 migratory and five resident shorebird species and at Separation Point 14 migratory five resident species (Supplementary Data).

Species

Nationally important habitats for migratory shorebirds have been defined as sites that regularly support 0.1% of a single species of migratory shorebird of the East Asian-Australasian Flyway population. In the case of both Sanderling and Ruddy Turnstone this equals 30 individuals.

Two Rocks is a site of national importance for Sanderling (0.5%) and Point Moore and Separation Point are sites of national importance for Sanderling (0.5%) and Ruddy Turnstone (0.2%) (Table 1).

Migratory shorebirds that visit Australia are protected as a matter of National Environmental Significance under the Australian Government Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). We observed some nationally threatened (EPBC Act 2015 and 2016) transient shorebirds at Two Rocks, Point Moore and Separation Point: Critically Endangered Far Eastern Curlew *Numenius madagascarensis* and Great Knot *Calidris tenuirostris*, Endangered Red Knot *Calidris canutus* and Lesser Sand Plover *Charadrius mongolus* and Vulnerable Bar-tailed Godwit *Limosa lapponica* and Greater Sand Plover *Charadrius leschanaultii* (Weller *et al*. 2020).

Ruddy Turnstone *Arenaria interpres*

At Point Moore and Separation Point the peak transit period for Ruddy Turnstones was from mid-March to mid-April (Figure 6). The highest count was 70 birds at Separation Point.

Whilst Two Rocks had large banks of beach wrack, sightings of Ruddy Turnstones were scarce at this location. They were only seen a few times a year and in low numbers. The reason for this is not clear. In contrast, at Lancelin, 31˚ 01' 39 S, 115˚ 19' 35 E, a beach wrack site about 60 km to the north of Two Rocks, we recorded up to 200 Ruddy Turnstones (0.7% of the flyway population), making it a site of National significance. Further sightings from Lancelin were 200 individuals on 14 January 2017 and 150 on 3 March 2013 and on 5 April 2014, each.

Red-necked Stint *Calidris ruficollis*

At Two Rocks, Red-necked Stint were present from October to June usually in small numbers (5). Sightings of Red-necked Stint at Point Moore commence later in the year (December to April) with one winter sighting in June.

Sanderling *Calidris alba*

The peak transit period for Sanderling seemed to run from February to April at Two Rocks (Figure 5) and was similar at Separation Point. Disturbance levels at Point Moore likely influenced these numbers. Sanderling frequented the large beach wrack deposits at Two Rocks, Point Moore and Separation Point with up to 139 individuals present.

Common Sandpiper *Actitis hypoleucos*

Common Sandpiper is the first migratory shorebird species to arrive at Two Rocks. They were frequently observed from August to April at Two Rocks in small numbers, up to ten. The sheltered harbour environment at Two Rocks provides a favoured habitat for Common Sandpiper. This species was a scarce visitor at Point Moore and Separation Point with few sightings

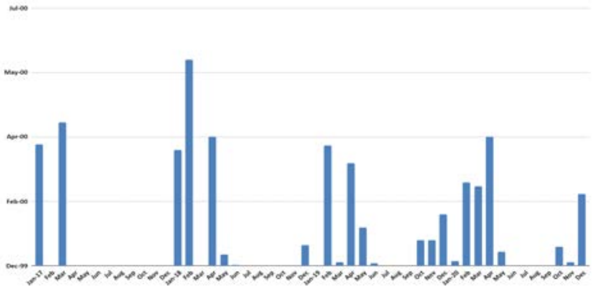

Figure 5. Highest monthly counts of Sanderling at Two Rocks 2017 - 2021.

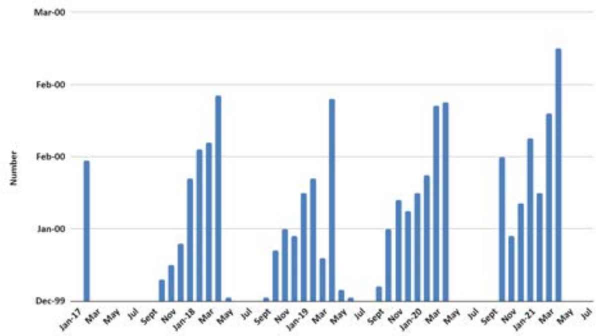

Figure 6. Highest monthly counts of Ruddy Turnstone at Point Moore 2017 - 2021.

Common name	Species name	Maximum counts (TR)	Maximum counts (PM)	Maximum counts (SP)	Status EPBC Act.*	Threshold 0.1% of EAAF**
Australian Pied Oystercatcher	*Haematopus longirostris*	4	3	5		
Sooty Oystercatcher	*Haematopus fuliginosus*	8	1	3		
Banded Stilt	*Cladorhynchus leucocephalus*	1	0	0		
Pied Stilt	*Himantopus himantopus*	4	3	1		
Grey Plover	*Pluvialis squatarola*	1	1	5		80
Pacific Golden Plover	*Pluvialis fulva*	0	0	1		120
Red-capped Plover	*Charadrius ruficapillus*	50	53	59		
Double-banded Plover	*Charadrius bicinctus*	1	0	0		19
Lesser Sand Plover	*Charadrius mongolus*	1	1	1	E	180
Greater Sand Plover	*Charadrius leschanaultii*	1	1	4	V	200
Hooded Plover	*Thinornis cucullatus*	0	0	1		
Black-fronted Dotterel	*Elseyornis melanops*	2	0	0		
Inland Dotterel	*Peltohyas australis*	0	1	0		
Whimbrel	*Numenius phaeopus*	1	0	0		65
Far Eastern Curlew	*Numenius madagascarensis*	1	1	0	CR	35
Bar-tailed Godwit	*Limosa lapponica*	0	1	1	V	325
Ruddy Turnstone	*Arenaria interpres*	4	57	70		30
Great Knot	*Calidris tenuirostris*	1	2	2	CR	425
Red Knot	*Calidris canutus*	6	0	9	E	110
Sharp-tailed Sandpiper	*Calidris acuminata*	3	2	0		85
Red-necked Stint	*Calidris ruficollis*	17	71	50		475
Sanderling	*Calidris alba*	138	88	139		30
Pectoral Sandpiper	*Calidris melanotos*	1	0	1		1220
Terek Sandpiper	*Xenus cinereus*	0	0	1		50
Common Sandpiper	*Actitis hypoleucos*	10	4	2		190
Grey-tailed Tattler	*Heteroscelus brevipes*	7	2	3		70

Table 1. Highest species counts at Two Rocks (TR), Point Moore (PM) and Separation Point (SP) 2018 – 2021.
*Migratory shorebirds listed as threatened under the Environment Protection and Biodiversity Conservation Act (1999) (EPBC Act) (Weller *et al*. 2020). CR = Critically Endangered; E = Endangered; V = Vulnerable.
** A Nationally important habitat for migratory shorebirds regularly supports 0.1 per cent of the East Asian - Australasian Flyway (EAAF) population of a single species of migratory shorebird (Weller *et al*. 2020).

Double-banded Plover *Charadrius bicinctus*

One observation made at Two Rocks from 16 May 2018 to 3 June 2018

Sooty Oystercatcher *Haematopus fuliginosus*

At Two Rocks the Sooty Oystercatcher was observed in small numbers (2-8) for most of the year and was absent in November. Sooty Oystercatchers were only recorded twice at Point Moore over the three years and at Separation Point just once in April.

Red-capped Plover *Charadrius ruficapillus*.

Red-capped Plover was the most common Australian breeding shorebird recorded at the three sites. At Two Rocks they were most often seen at Wreck Point, where the beach is wider. Their numbers peaked over the Austral summer and autumn at all sites, likely due to ephemeral lakes drying out and pushing Red-capped Plover towards the coast.

Red-capped Plover were generally absent from June to September at Two Rocks, Point Moore and Separation Point. Red-capped Plover breed north of Point Moore next to Pages Beach in the Port reclamation area. The Port landfill site falls just outside the areas surveyed and is behind Fisherman's Harbour. At least four breeding pairs of Red-capped Plover were confirmed at this location. Red-capped Plover breed here nearly year-round and newly hatched chicks have been observed from July to January and in March and April in 2020-2021. This area is fenced and provides some respite for Red-necked Stint (10 individuals) and Red-capped Plover (53).

DISCUSSION

Beach wrack tends to accumulate in response to local currents and swells, which in turn are affected by numerous factors, such as the position and size of nearby reef systems, the shape of the coastline and the presence of man-made structures, such as groynes and marinas (Payne & Hyndes 2015). Beach wrack banks support shorebird populations at several sites along the mid-western Australian coast, such as at Lancelin 31° 01' 39 S, 115° 19' 35 E, Wedge Point 30° 49' 22 S, 115° 11' 31 E, Cervantes 30° 31' 10 S, 115° 04' 34 E and Jurien Bay 30° 13' 51 S, 114° 59' 56 E. They have off-shore islands, headlands and bays. There is limited shorebird data available for these sites and they require closer attention, as they form a chain of small coastal shorebird sites between Perth and Geraldton. The best time to monitor these sites is from January to April.

Site 1. Two Rocks, highest monthly count for the years 2018 to 2021

Two Rocks (Site 1)		2018												2019												2020												2021							
Common name	***Scientific name***	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Australian Pied Oystercatcher	*Haematopus longirostris*																												4	1	1						2				2	1	2	2	
Sooty Oystercatcher	*Haematopus fuliginosus*													1					2	2		2	1		3	1			8	6	4		1				1		1	2	3	5	3	2	
Banded Stilt	*Cladorhynchus leucocephalus*						1																																						
Pied Stilt	*Himantopus himantopus*																							3											4			2		1					
Grey Plover	*Pluvialis squatarola*																								1	1											1								
Red-capped Plover	*Charadrius ruficapillus*	1		2	6	40	14				2	4	1		20	30	30	25					6	3	30	15	3	20	50	27					9	5	5	28	13	6	11	27			
Double-banded Plover	*Charadrius bicinctus*					1	1																																						
Lesser Sand Plover	*Charadrius mongolus*																																		1										
Greater Sand Plover	*Charadrius leschanaultii*																						1																						
Black-fronted Dotterel	*Elseyornis melanops*																																				2								
Whimbrel	*Numenius phaeopus*			1		1	1																1		1	1	1										1								
Far Eastern Curlew	*Numenius madagascarensis*																								1																				
Ruddy Turnstone	*Arenaria interpres*					3					1													2			1		4							1					1				
Great Knot	*Calidris tenuirostris*																																			1									
Red Knot	*Calidris canutus*																							6																					
Sharp-tailed Sandpiper	*Calidris acuminata*																								2											2	3								
Pectoral Sandpiper	*Calidris melanotus*																																				1								
Red-necked Stint	*Calidris ruficollis*				P		1								3	5							9		2			8	5	2					17	11	4	2	4	5	17	2			
Sanderling	*Calidris alba*	90			100	9	1						16		93	3	80	2	2				20	20	40	4	58	62	100	11					15	3	56	132	123	92	138	27			
Common Sandpiper	*Actitis hypoleucos*				1						1	1	2									3	1		3	2	1	3					3	5	5	7	7	7	10	4					4
Grey-tailed Tattler	*Heteroscelus brevipes*																						2	1	7	2	3	3	1						4	3	2	2	1						
Number of species		2	n/s	2	4	5	6	0	0	n/s	3	2	3	1	3	3	2	2	2	1	0	2	8	6	10	7	6	5	7	5	2	0	2	1	7	8	12	6	6	6	6	5	2	2	1

P=Present not counted

n/s = month not surveyed

Site 2. Point Moore, highest monthly count for the years 2017 to 2021.

Point Moore (Site 2)		2017		2018												2019												2020												2021					
Common name	**Scientific name**	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Australian Pied Oystercatcher	*Haematopus longirostris*																3		2		1																		1	2		3			
Sooty Oystercatcher	*Haematopus fuliginosus*				1												1																												
Pied Stilt	*Himantopus himantopus*																																										3		
Grey Plover	*Pluvialis squatarola*				1												1		1	1							1	1												1					
Red-capped Plover	*Charadrius ruficapillus*			23	30	20	4	2					1		20	17	44	22	25	12	26	1			11	1	17	30	25	4	9	3				2		9	11	53	23	15	24		4
Lesser Sand Plover	*Charadrius mongolus*																													1										1					
Greater Sand Plover	*Charadrius leschanaultii*																										1		1											1					
Inland Dotterel	*Charadrius australis*																	1																											
Far Eastern Curlew	*Numenius madagascarensis*					1																																							
Bar-tailed Godwit	*Limosa lapponica*																																						1	1					
Ruddy Turnstone	*Arenaria interpres*	10	16	34	42	44	57	1				1				12	34	9	16		1			4		15	25	20	35	9								2	27	45	20	12	4		
Great Knot	*Calidris tenuirostris*						2											1																											
Sharp-tailed Sandpiper	*Calidris acuminata*																1												2																
Red-necked Stint	*Calidris ruficollis*		4		8	15	14										19	12	10	5	1						1	2	10	7									9	14	71	60	52		
Sanderling	*Calidris alba*		1		8	55	88					4				3	13	12	14								3	5	7	12									10	40	72		1		
Common Sandpiper	*Actitis hypoleucos*																4										1		1	1															
Grey-tailed Tattler	*Heteroscelus brevipes*		1																1							1			1										2	1					
Number of species		1	4	2	6	5	5	2	n/s	0	0	2	1	0	1	3	9	6	7	3	4	1	0	1	1	3	7	5	8	6	1	1	0	0	0	1	0	2	7	10	4	4	5	n/s	1

P=Present not counted
n/s =month not surveyed

Site 3. Separation Point, highest monthly count for the years 2018 to 2021.

Separation Point (Site 3)		2018									2019												2020												2021							
Common name	***Scientific name***	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Australian Pied Oystercatcher	*Haematopus longirostris*													4		1									2	4						2	3		2	4	3	5				
Sooty Oystercatcher	*Haematopus fuliginosus*																																					3				
Pied Stilt	*Himantopus himantopus*														1																											
Grey Plover	*Pluvialis squatarola*										1	2	1	1	1						6	1	1	2	2									1	2	2	4	1				
Pacific Golden Plover	*Pluvialis fulva*								1														1																			
Red-capped Plover	*Charadrius ruficapillus*		42						17	23	30	45	19	20	30	26				2	10	20	59	20	19	11	3					4		11	21	4	6	2				
Lesser Sand Plover	*Charadrius mongolus*																								1																	
Greater Sand Plover	*Charadrius leschanaultii*																				3			1	4									1								
Hooded Plover	*Thinornis rubricollis*															1																										
Bar-tailed Godwit	*Limosa lapponica*																								1											1		1				
Ruddy Turnstone	*Arenaria interpres*	P						14	20	18	30	11	2	56	3					20	28	11	30	35	54	55						40	18	22		30	52	70				
Great Knot	*Calidris tenuirostris*	2																																1								
Red Knot	*Calidris canutus*														1						9																					
Red-necked Stint	*Calidris ruficollis*		2						1	5	5	13	7	42	10	3				6	20		2	10	47	20						50	6	2	4	8	40	50				
Sanderling	*Calidris alba*	P	1						3	12	11	9	9	60	11	1					1	3	6	50	139	104						20		10	9	18	136	80				
Pectoral Sandpiper	*Calidris melanotus*																																					1				
Terek Sandpiper	*Xenus cinereus*																															1										
Common Sandpiper	*Actitis hypoleucos*							1		2											2	1										1	1									
Grey-tailed Tattler	*Heteroscelus brevipes*													1						1	3											1	1	1								
Number of species		3	3	n/s	0	n/s	n/s	2	5	5	5	5	5	7	7	5	0	0	0	4	9	5	6	6	9	5	1	0	0	0	0	8	5	8	5	7	6	9	n/s	0	0	0

P=Present not counted
n/s =month not surveyed

Geolocator data from Ruddy Turnstones showed that birds departing from King Island commenced their northward migration 16 days before the Ruddy Turnstones in South Australia (Gosbell 2017, 2018). Individuals from South Australia generally left between 19 and 26 April and flew 7000 km non-stop to Taiwan or Hainan (Christie 2017). The departure dates in Western Australia match those in South Australia (Figure 6) and if the same migratory pattern is confirmed for Western Australia, then the beach wrack-covered beaches of mid-western Australia could prove to be an important fuelling site prior to their northward departure. Ruddy Turnstones departed Point Moore and Separation Point at the end of April (Figure 6). Sanderling showed a similar pattern over March, April at the three sites.

Sites where wrack had built up on the gentle slope adjacent to the beach reefs were the locations preferred by shorebirds. At Point Moore and Separation Point both locations have offshore reefs. At the Two Rocks Marina the preferred shorebird habitats were the beach wrack banks, an exposed reef around the first limestone stack, the harbour breakwaters and the beach (Figure 3). There were two limestone stacks (Two Rocks) on the shoreline, one next to the southern harbour groyne and the other further down at Wreck Point (Figure 1 & 3). The beach was quite wide at the second limestone stack. Large volumes of seagrass accumulated in the corner where the first limestone stack meets the southern harbour groyne. The marina breakwaters consist of large limestone boulders that are weathered along the water's edge.

At low tides, pools of seawater are left behind in the beach wrack beds and around the first stack and these are locations favoured by shorebirds (Figure 3). The high limestone groynes surrounding the marina provide the inner harbour with a sheltered environment, an area frequented by Common Sandpiper and Grey-tailed Tattler often in preference to the beach wrack covered main beach. Common Sandpiper and Grey-tailed Tattler remain at Two Rocks throughout the migratory season.

The accretion of beach wrack at the survey sites followed an annual cycle. There was no beach wrack on the beaches in June to August, as during the winter the beach erodes down to a narrow strip close to the base of the primary dunes. There was a gradual build-up of beach wrack on the beach over spring as the beach accreted. The beach wrack banks seemed more mobile early in the season. On some days the beach was completely covered in wrack and the next day clear (Figure 4). We noticed sparse patches of weed in early September and good size weed banks built up over the following months. Large decaying seaweed banks were available during peak northward shorebird migration. At Separation Point the seaweed banks seemed to amass earlier in the season and remain longer than at Point Moore, possibly due to sea currents and wind direction. The banks of beach wrack at Separation Point (Figure 4) can become quite large and completely cover the beach. For example, in November 2019 one bank measured 1.2 m high near the ocean, was 3 m wide and 80 m long and in December 2020 a bank was 1.9 m high near the ocean and 40 m long.

The large volume of beach wrack found along the central-west coast of Western Australia is due to the ideal growing conditions for seagrass and seaweed near the shore. Large sandy lagoons provide calm waters that give seagrasses the opportunity to flourish protected from the swells by reefs aligning north-south just off the coastline. These reefs also provide a rocky surface seagrass need to attach to (Payne & Hyndes 2015). The beach wracks at our study sites consisted mainly of macroalgae *Amphibolis* and *Posidonia* seagrass species, which washed up in large volumes onto the beach (Wells 2002).

Organic matter from the wrack is broken down and disintegrates, becoming food for sandhoppers and other amphipods, copepods, worms and fly larvae. These all provide food sources and may explain the presence of large numbers of feeding shorebirds around seaweed banks (Payne & Hyndes 2015).

Conservation issues

The area around Two Rocks is undergoing rapid urbanisation, evident on the beaches around Two Rocks Marina. The beach south of the marina is a designated dog beach with high disturbance to shorebirds from unleashed dogs. Two Rocks Marina is also earmarked for substantial redevelopment that will extend the existing marina boundaries. The new marina's design is intended to reduce erosion and seagrass build up (Department of Transport, 2019). Elimination of seagrass accumulations may decrease the importance of the site to shorebirds, particularly impacting migrating Sanderling.

The level of human disturbance at all sites increases during holiday periods and weekends. Point Moore and Separation Point are subject to large numbers of four-wheel drive vehicles driving on the beach as well as people with dogs, kite surfers, windsurfers and reef fishermen (Bishop *et al.* 2020). The level of disturbance could reach a level that these beach areas may become incompatible with the needs of shorebirds. During our surveys we recorded high levels of disturbance. For instance, 10 April 2020, during the Easter holiday period, we counted 62 vehicles on Point Moore beach and 16 unleashed dogs during a one-hour long survey. On the same day, we counted 25 vehicles and 20 off-leash dogs at Separation Point. We observed dogs chasing shorebirds and vehicles driving straight through feeding flocks of Sanderling and Red-necked Stint at both beaches. At these sites, shorebirds would benefit from restrictions for vehicles and pets as a protected seasonal reserve.

There are a number of threats to beach wrack that forms the basis of the food supply for shorebirds. There is public pressure on Local Government Agencies and developers to remove beach wrack from beaches, as it releases hydrogen sulphide during decomposition. The public also removes beach wrack to use as garden mulch. Beach wrack are often removed to control erosion and stabilise sand dunes. The discharge of nutrients affects living seagrass fields and dredging can also destroy these fields (Payne & Hyndes 2015).

An unexpected benefit of the beach wrack banks is that they can act as barriers for vehicles and dogs and stop them from accessing some parts of the beach. In addition, beach wrack banks provide shorebirds with shelter from bad weather conditions and roost sites in the inaccessible parts of the beach.

CONCLUSION

This study showed that sites with a relatively small number of shorebirds can collectively provide an important resource to migratory shorebirds. These sites provide opportunities for shorebirds to refuel, rest and can act as a diversion site when other sites are affected by drought or flooding. They cater for particular shorebird species at specific times and are deserving of more consideration and protection. Two Rocks beach was important during the northward migration of Sanderling, and Point Moore and Separation Point beaches provided resources for Ruddy Turnstone and Sanderling. In addition, several threatened shorebird species used them as stopover sites.

The comprehensive data collected during the three years provides evidence that even these sites with relatively small numbers of shorebirds can be nationally important for Ruddy Turnstone and Sanderling. These smaller shorebird sites deserve protection and provide opportunity for further in-depth studies on shorebird ecology in this overlooked habitat and region. The preservation of beach wrack-covered beaches is critical in this context.

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SHOREBIRD SURVEYS IN THE HUNTER ESTUARY OF NEW SOUTH WALES 1999-2021

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The Hunter Estuary in New South Wales, Australia, was surveyed monthly from April 1999 to March 2021. In this time, 46 shorebird species were recorded in the estuary including 33 species that migrate within the East Asian-Australasian Flyway (EAAF). Fifteen migratory species and eight non-migratory ones were recorded regularly; the other species were uncommon visitors or vagrants. Although the estuary continues to qualify for listing as an internationally significant site within the EAAF, the populations of most of the visiting migratory shorebirds have declined substantially. We compared the numbers present in the non-breeding and breeding seasons for three approximately equal time periods spanning the 22 years of surveys and found statistically significant differences. Although six species were formerly present in internationally significant numbers, currently only Sharp-tailed Sandpiper *Calidris acuminata* and the non-migratory Red-necked Avocet *Recurvirostra novaehollandiae* meet the criteria. Species in significant decline in the estuary include Far Eastern Curlew *Numenius madagascariensis*, Whimbrel *N. phaeopus*, Bar-tailed Godwit *Limosa lapponica*, Black-tailed Godwit *L. limosa*, Red Knot *Calidris canutus*, Curlew Sandpiper *C. ferruginea*, Marsh Sandpiper *Tringa stagnatilis*, and Common Greenshank *T. nebularia*. The populations of three migratory species have increased: Pacific Golden Plover *Pluvialis fulva*, Sharp-tailed Sandpiper and Grey-tailed Tattler *T. brevipes*. The Hunter Estuary now is an internationally significant site for Sharp-tailed Sandpiper, with at times more than 6% of the total population present. The populations of most of the regularly recorded non-migratory shorebird species were stable or had increased over 1999-2021. For example, the numbers of Masked Lapwing *Vanellus miles* have approximately doubled since around 2010. The estuary is very important for Red-necked Avocet, with 4-6% of the total population often present. There sometimes were nationally significant numbers of Pied Stilt *Himantopus leucocephalus* in the estuary. The possible reasons for population changes are discussed. Inland rainfall patterns (droughts and heavy rain) may have affected some species. Recent rehabilitation projects in the estuary have reinstated tidal flushing at former estuarine wetlands that has increased the amount of habitat for shorebirds. Targeted control of Grey Mangrove *Avicennia marina* incursions in the rehabilitated areas has helped create and maintain expanses of salt marsh habitat for foraging and roosting generalist species. Many of the EAAF migratory shorebirds with declining populations in the Hunter Estuary rely on Yellow Sea tidal mudflats during migration. Much of that ecosystem has been destroyed in recent decades, hence significantly affecting the populations of Yellow Sea-dependent species. However, the declines of those species in the Hunter Estuary seem to be larger, which suggests some local factors may also be involved. The main feeding area for those species is in Fullerton Cove, which has become contaminated with PFAS/PFOS, fire-fighting chemicals used for decades at the nearby Williamtown airport. It is speculated that chronic toxicity effects from the chemical contamination may be affecting the numbers and diversity of benthic organisms in Fullerton Cove, to the detriment of the populations of many coastal obligate shorebirds.

INTRODUCTION

In April 1999, members of the Hunter Bird Observers Club Inc. (HBOC) commenced monthly surveys of waterbirds in the Hunter Estuary of New South Wales (NSW). This report details the results and trends for shorebirds from 22 continuous years of monitoring up to and including March 2021.

Figure 1 shows the main roosting or foraging sites for shorebirds in the estuary (centred at 32º51' S 151º46' E). The single-most important area is Fullerton Cove, a large shallow embayment with a maximum depth of 2-3m at its centre and where, at low tide, large areas of mudflats are exposed (Weller *et al*. 2020). Many shorebirds feed in Fullerton Cove at low tide. As the tide rises most of those birds depart to roost at either the Kooragang Dykes or in the Stockton Sandspit/Fern Bay area. Some remain and roost on a narrow beach within the Cove. The three other important areas for shorebirds in the estuary are Ash Island, Hexham Swamp and Tomago Wetland. All three areas provide foraging and roosting habitat for shorebirds. The extent to which birds move from these sites to elsewhere, to forage or roost, is unknown.

The Hunter Estuary is recognised as the most important shorebird site in NSW. It regularly hosts many migratory species, involving thousands of individuals at times, and thus is considered both an internationally and nationally significant site in the East Asian-Australasian Flyway ("the Flyway", EAAF) (Weller *et al*. 2020). The estuary is considered internationally significant for Far Eastern Curlew *Numenius madagascariensis*, Red Knot *Calidris* *canutus* and Sharp-tailed Sandpiper *C. acuminata*, and nationally significant for Bar-tailed Godwit *Limosa lapponica*, Curlew Sandpiper *C. ferruginea*, Pacific Golden Plover *Pluvialis fulva*, Black-tailed Godwit *L. limosa*, Marsh Sandpiper *Tringa stagnatilis*, Common Greenshank *T. nebularia*, Whimbrel *N. phaeopus*, Latham's Snipe *Gallinago hardwickii* and Double-banded Plover *Charadrius bicinctus* (Weller *et al*. 2020). It also frequently hosts thousands of Red-necked Avocets *Recurvirostra novaehollandiae* (Stuart 2017), as well as seven other non-migratory shorebirds.

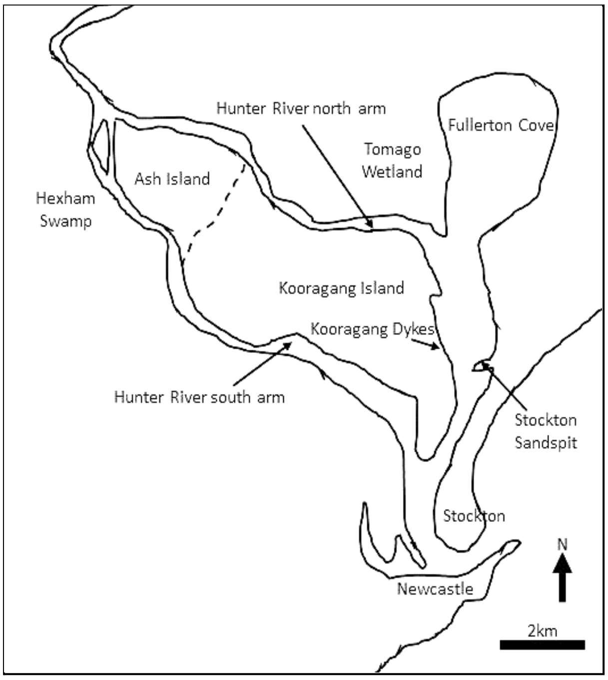


Figure 1. The Hunter Estuary in NSW with main shorebird foraging and roosting sites shown.

Recognition of the importance of the estuary to shorebirds and waterbirds led to the Kooragang Nature Reserve being gazetted in 1983 and designated as a Ramsar site in 1984. The Ramsar site was expanded in November 2002 to include the wetlands at Shortland (Brereton & Taylor-Wood 2010), now known as Hunter Wetlands Centre Australia. However, Ash Island (the name Ash Island is commonly used for the western section of Kooragang Island) and Hexham Swamp were not included in the Ramsar designation despite meeting Ramsar criteria.

In 2011, Kooragang Nature Reserve, Hexham Swamp and Ash Island were combined to form Hunter Wetlands National Park (Lindsey 2021; Hunter Wetlands National Park Plan of Management 2020). However, the most important shorebird sites on Ash Island were excluded from the National Park. Under NSW State Environmental Planning Policy (State Significant Precincts 2005), the site has been earmarked for an infrastructure corridor, which would bisect Ash Island. Currently, this land does not form part of the reserved area of park but is retained as Crown land and is held and managed by NPWS under Part 11 of the National Parks and Wildlife Act (Hunter Wetlands National Park Plan of Management 2020).

The estuary was also designated an Important Bird Area ("Hunter Estuary IBA") in 2010 (Dutson *et al.* 2009). IBAs have since been redesignated as Key Biodiversity Areas (KBAs) in order to extend the concept to non-avian threatened species (BirdLife Australia 2017).

Pre-1999 shorebird counts in the Hunter Estuary

The first documented systematic surveys for shorebirds in the Hunter Estuary occurred in 1967-1970 (Holmes 1970) and there were frequent surveys between 1969 and 1977 (Kendall & van Gessel 1972; van Gessel & Kendall 1972a; 1972b; 1974; 2015; Gosper 1981). The 1967-1977 surveys led to the initial recognition of the estuary's importance for shorebirds. Lane (1987) named the Hunter Estuary as a top-20 site Australia-wide for 14 shorebird species including twelve migratory ones. Smith (1991) nominated the Hunter Estuary as by far the most important shorebird site in NSW, based upon the maximum recorded counts.

After 1977, there were no further regular surveys of the estuary until 1982 when twice-yearly Australasian Wader Study Group (AWSG) counts began, spanning four years locally. However, there also were many opportunistic visits by birdwatchers to key shorebird sites in the estuary, particularly Stockton Sandspit, and it seems clear that high numbers of shorebirds persisted during those intervening years. That inference was confirmed from the annual summer and winter AWSG counts conducted between 1982 and 1985 (Stuart 2014a; 2014b).

After 1985 the survey effort in the Hunter Estuary became infrequent, except for the period 1994 -1997 when 6-10 surveys were carried out each year at key sites (Kingsford *et al*. 1998).

From the intermittent survey effort over 1982-1997, the estuary was rated as internationally important for six migratory shorebird species (Bamford *et al*. 2008 p 213).

History of shorebird habitat changes in the Hunter Estuary

Since European settlement, numerous changes have occurred to shorebird habitat in the estuary. Initially, most of the changes were detrimental for shorebirds. However, more recently various positive developments have partially restored some of the formerly lost habitat.

Lower estuary

Between 1801 and 1994, roosting and feeding sites were lost in the lower estuary, as a result of dredging and the amalgamation of islands aimed at improving passage for container ships and fishing vessels. The number of islands had been reduced from 20 to four, and shorelines where shorebirds could forage were more than halved, from 118 to 51 km. Eventually one large island was created, which became known as Kooragang Island (Kingsford & Ferster Levy 1997). The southern section of this island continues to be known as Kooragang Island. By 1928, 363.3 ha of river mudflats to the south of Fullerton Cove had been removed. As a result, Fullerton Cove became the main feeding area (Kingsford & Ferster Levy 1997). On the positive side, between 1966 and 1969, a breakwater, the Kooragang Dykes, was built (Kingsford & Ferster Levy 1997), using slag from the Newcastle steelworks. The site is now an important artificial roost for shorebirds. Over the decades the breakwater has gradually deteriorated; however, the damage is being addressed by NSW National Parks and Wildlife Service and Hunter Local Land Services through an ongoing maintenance program.

Kooragang Island

Despite ongoing industrial development, for several decades two sites on Kooragang Island continued to be important habitat for shorebirds particularly for small to medium-sized species. The Big Pond, a shallow, brackish wetland of approximately 45 ha was an important foraging site for Curlew Sandpiper, Marsh Sandpiper and Red-necked Stint *Calidris ruficollis* (Straw 1999). In 1993, a section of the wetland was reclaimed in order to extend a coal-loading terminal. This was followed by the suspension of tidal influence in 1996. The destruction of The Big Pond was completed in 2008, when the remaining vacant land became the site for a new coal-loading terminal. Altogether 16 species of migratory shorebirds had been recorded there (Straw 1999). The second site was Deep Pond, a shallow, non-tidal, largely freshwater pond where mudflats formed during drying periods. Eleven migratory shorebird species have been recorded there (Lindsey 2008). Deep Pond was bisected by a railway line constructed to service two coal-loading facilities during the mid-2000s creating Deep Pond North and Deep Pond South. Shorebirds still occur on Deep Pond North (Roderick 2015).

Ash Island, Hexham and Tomago

Flood mitigation schemes between the 1950s and 1970s and mosquito control initiatives, led to the installation of floodgates at creeks at Ash Island, Hexham Swamp and Tomago Wetland. The floodgates prevented tidal flushing and estuarine wetlands reverted to freshwater wetlands which were no longer able to support shorebirds in any substantial numbers. The planning and main initial rehabilitation activities for those three sites were driven by Hunter-Central Rivers Catchment Management Authority (now Hunter Local Land Services). Their Kooragang Wetland Rehabilitation Project (KWRP) commenced in the 1990s and initially was focussed mainly on Ash Island (one of the three sites targeted for rehabilitation). Reinstatement of tidal flushing was accomplished at Hexham Swamp between 2008-2013 and at Tomago Wetland between 2012-2015 (Lindsey 2021). A fourth project at Fish Fry Flats on Ash Island, the Newcastle Coal and Infrastructure Group (NCIG) Shorebird Compensatory Habitat Construction, commenced in 2016. Among the aims for these four projects was the restoration of estuarine wetland for the benefit of shorebirds through the reintroduction of tidal flow or partial tidal flow (Kooragang Wetland Rehabilitation Project 2010; Local Land Services Hunter 2016; Lindsey 2021; Reid 2019).

One way of achieving estuarine wetland was to promote the growth of salt marsh, often favoured by shorebirds, over that of Grey Mangrove *Avicennia marina*, a species which had been increasing throughout the estuary to the detriment of the former (Brereton & Taylor-Wood 2010; Clarke 2010; 2011; Straw 1999). Central to the NCIG project for example, was the removal of 17 ha of juvenile mangroves (Reid 2019). The control of weeds and mangrove incursion into salt marsh habitat has been an important local focus and has included an annual program to remove mangrove seedlings and weeds (Clarke 2020).

Stockton

Serious losses of shorebird habitat occurred as a consequence of the closure in 2001 of a primary sewage treatment plant at Stockton which destroyed an important roost site for Curlew Sandpiper, and changed conditions at a roost site near Stockton Bridge, which resulted in birds abandoning that site (Straw 1999).

A second component of KWRP was restoration work at Stockton Sandspit designed to bring shorebirds back to the site. Between 1966 and 1969 a sandspit had formed from dredge spoil deposited on the eastern shore of the river in preparation for the construction of the Stockton Bridge (Kingsford & Ferster Levy 1997). During the 1970s, thousands of shorebirds used the bare, shelly sand as a roost, but by the 1980s the site had become hemmed in by Grey Mangrove (Brereton & Taylor-Wood 2010) and overgrown with introduced weeds greatly reducing its value to shorebirds. The construction of a lagoon, the removal of weeds and mangroves fringing the site saw a significant increase in numbers of shorebirds returning to the Sandspit (Svoboda 2017).

Major environmental incidents

Two major environmental incidents have occurred in the estuary. On 25 August 2010, 72,000 litres of fuel oil was accidentally discharged with ballast water into Newcastle Harbour from a coal ship. Although booms were placed in the South Channel of the Hunter River, oil was discovered on Stockton Sandspit two days later. Invertebrate animals on mudflats, in saltmarsh and mangroves and several Australian Pelicans *Pelecanus conspicillatus* were affected. Fortunately, there apparently were no long-term impacts (Rule of Law Education Centre 2021). A potentially more significant incident has resulted from the long-term use (over several decades) of firefighting foams at Williamtown airport to the north of Newcastle. That has resulted in substantial contamination of Fullerton Cove (Australian Department of Defence 2018). The fire-fighting group of chemicals includes a large variety of similarly-behaving products, such as per- and poly-fluoroalkyl substances (PFAS) and per- and poly-fluorooctyl sulphonates (PFOS). PFAS/PFOS chemicals have been shown to accumulate in the food chain (Taylor *et al*. 2018) and to have acute toxicity to benthic organisms (Simpson *et al*. 2021).

METHODS

Survey methodology

The estuary is divided into nine shorebird areas (BirdLife Australia 2021). Data were obtained from structured surveys, which commenced in April 1999. They were carried out monthly at high tide using a standard procedure involving multiple teams visiting high tide roost sites at Stockton Sandspit/Fern Bay/Stockton Channel, Fullerton Cove and Ash Island (Stuart *et al.* 2013). Simultaneous surveys at Hexham Swamp and Tomago Wetland commenced in 2013 and 2014 respectively, when those sites first began to host shorebirds (Stuart *et al*. 2013; Lindsey 2021). Simultaneous surveys at some other sites on Kooragang Island, the main one being the Deep Pond complex, commenced in September 2000. However, from 2014 these surveys took place the day before the other estuary surveys, because of access restrictions at what had become industrial sites (Roderick 2015). A document with detailed descriptions of the survey methodology is available (BirdLife Australia 2021).

Data management and data analysis

The data for each individually surveyed site from every survey were entered into BirdLife Australia's Birdata database (www.birdata.birdlife.org.au). Between 1999-2017, we also recorded the data in an MS Excel spreadsheet, updated monthly.

In March 2021 we downloaded the 1999-2021 Birdata records for the Hunter Estuary. However, it soon became apparent that the 1999-2017 records in the database had many errors. Primarily these involved duplicate records for the same site/s on the same day. From 2018 onwards, when it became easy for survey team leaders to enter data directly into Birdata, there appeared to be no more issues about data quality.

Accordingly, we expanded our original MS Excel spreadsheet by adding the downloaded 2018-2021 data to it. Where possible, we cross-checked the records against those published in other forums (e.g. the Hunter Region annual bird report series).

We used standard MS Excel graphing tools for our core analyses. We calculated annual rates of change of species abundance by analysing the slope of the linear trend line for that species. We divided the data into three-time intervals for closer analysis of any changes:

- Non-breeding season: data for the November to March period, spanning November 1999 to March 2006, November 2006 to March 2013, and November 2013 to March 2021.
- Breeding season: data for the May to August period, spanning May 1999 to August 2005, May 2006 to August 2013, and May 2014 to August 2020.

The three time periods we used to analyse the non-breeding and breeding season records were arbitrarily selected. However, they divided the data set into three approximately equal time intervals, each spanning 7-8 years of data.

To assess population changes over time, we compared the data sets for the above three time periods (NB comparing the non-breeding season data separately to the breeding season data). We compared time periods 1 and 2, and then separately compared time periods 2 and 3. We calculated p-values using two-tailed t-tests assuming unequal variance. With $p < 0.05$ we rated the differences in the two data sets as being statistically significant, and as highly significant with $p < 0.01$.

We excluded all data collected in surveys carried out in April, September and October from our general analyses, as we found that shorebird numbers had fluctuated markedly in these months. In particular, it was the time when migratory shorebirds were moving through on passage, and not necessarily staying for long in the estuary. However, we used the data for all months when considering the number of records and the maximum counts. For the Red Knot, which mainly was present on passage in spring, we also analysed the September-November records.

Table 1. Summary of the shorebirds recorded in the Hunter Estuary between April 1999 and March 2021

Species	Visitation status	Preferred habitat[@]	Number of records	Max.count	Population trend
Migratory shorebirds					
South Island Pied Oystercatcher[#] *Haematopus finschi*	Irregular	Coastal	1	1	Unknown
Grey Plover *Pluvialis squatarola*	Irregular	Coastal	6	1	Unknown
Pacific Golden Plover *Pluvialis fulva*	Regular	Generalist	191	522	Increasing
Double-banded Plover *Charadrius bicinctus*	Irregular	Generalist	22	60	Unknown
Lesser Sand Plover *Charadrius mongolus*	Irregular	Coastal	16	4	Unknown
Greater Sand Plover *Charadrius leschenaultii*	Irregular	Coastal	4[*]	2	Unknown
Oriental Plover[#] *Charadrius veredus*	Irregular	Generalist	1	10	Unknown
Whimbrel *Numenius phaeopus*	Regular	Coastal	227	185	Decreasing
Little Curlew[#] *Numenius minutus*	Irregular	Generalist	3	6	Unknown
Far Eastern Curlew *Numenius madagascariensis*	Regular	Coastal	260	617	Decreasing
Bar-tailed Godwit *Limosa lapponica*	Regular	Coastal	259	2019	Decreasing
Black-tailed Godwit *Limosa limosa*	Regular	Generalist	225	425	Decreasing
Ruddy Turnstone *Arenaria interpres*	Irregular	Coastal	35	6	Unknown
Great Knot *Calidris tenuirostris*	Regular	Coastal	108	90	Decreasing
Red Knot *Calidris canutus*	Regular	Coastal	150	1472	Decreasing
Ruff *Calidris pugnax*	Irregular	Generalist	1	1	Unknown
Broad-billed Sandpiper *Calidris falcinellus*	Irregular	Coastal	2[*]	1	Unknown
Sharp-tailed Sandpiper *Calidris acuminata*	Regular	Generalist	157	6408	Increasing
Curlew Sandpiper *Calidris ferruginea*	Regular	Generalist	180	812	Decreasing
Long-toed Stint *Calidris subminuta*	Irregular	Generalist	2[*]	1	Unknown
Red-necked Stint *Calidris ruficollis*	Regular	Generalist	148	144	Decreasing
Buff-breasted Sandpiper *Calidris subruficollis*	Irregular	–	1	1	Unknown
Pectoral Sandpiper *Calidris melanotos*	Irregular	–	6+[*]	1	Unknown
Latham's Snipe *Gallinago hardwickii*	Irregular	Generalist	32	22	Unknown
Terek Sandpiper *Xenus cinereus*	Regular	Coastal	133	68	Decreasing
Common Sandpiper *Actitis hypoleucos*	Regular	Generalist	87	6	Decreasing
Grey-tailed Tattler *Tringa brevipes*	Regular	Coastal	214	52	Increasing
Wandering Tattler *Tringa incana*	Irregular	Coastal	1	1	Unknown
Lesser Yellowlegs[#] *Tringa flavipes*	Irregular	–	2[*]	1	Unknown
Common Greenshank *Tringa nebularia*	Regular	Generalist	238	333	Decreasing
Wood Sandpiper *Tringa glareola*	Irregular	Generalist	3	1	Unknown
Marsh Sandpiper *Tringa stagnatilis*	Regular	Generalist	163	324	Decreasing
Oriental Pratincole[#] *Glareola maldivarum*	Irregular	Generalist	1	1	Unknown
Australian shorebirds					
Beach Stone-curlew *Esacus magnirostris*	Irregular	Coastal	1	1	Unknown
Australian Pied Oystercatcher *Haematopus longirostris*	Regular	Coastal	243	43	Prob. stable
Sooty Oystercatcher *Haematopus fuliginosa*	Regular	Coastal	127	22	Prob. stable
Banded Stilt *Cladorhynchus leucocephalus*	Irregular	Coastal	7	2	Unknown
Red-necked Avocet *Recurvirostra novaehollandiae*	Regular	Generalist	238	6753	Prob. stable
Pied Stilt *Himantopus leucocephalus*	Regular	Generalist	249	1576	Increasing
Red-capped Plover *Charadrius ruficapillus*	Regular	Coastal	208	158	Prob. stable
Black-fronted Dotterel *Elseyornis melanops*	Regular	Generalist	226	80	Increasing
Banded Lapwing *Vanellus tricolor*	Irregular	Generalist	1	1	Unknown
Masked Lapwing *Vanellus miles*	Regular	Generalist	263	364	Increasing
Red-kneed Dotterel *Erythrogonys cinctus*	Regular	Generalist	106	222	Increasing
Australian Painted-snipe *Rostratula australis*	Irregular	Generalist	1	1	Unknown
Australian Pratincole *Stiltia isabella*	Irregular	Generalist	1	1	Unknown

[#]Not recorded during a scheduled survey [*]Includes some records from non-survey days [@]Habitat preference assignments are based on Jackson *et al*. (2020)

Table 2. Data for shorebirds regularly present in the Hunter Estuary – the mean counts for November-March and May-August for three-time intervals and the linear trends (i.e. the average % change per annum over 22 years). Count data shown in **Bold** indicate where there is a statistically significant or highly significant difference to the data from the preceding time interval.

	November-March				**May-August**			
Species	1999-2006 mean	2006-2013 mean	2013-2021 mean	Linear trend 1999-2021	1999-2005 mean	2006-2013 mean	2014-2020 mean	Linear trend 1999-2020
Migratory shorebirds								
Pacific Golden Plover	69	**157**	**230**	+11.7%	0	1	5	-
Whimbrel	47	**22**	**32**	-1.3%	16	12	5	-3.8%
Far Eastern Curlew	383	**244**	**144**	-3.7%	110	**69**	**35**	-3.9%
Bar-tailed Godwit	1127	**859**	**579**	-2.9%	214	228	**125**	-2.5%
Black-tailed Godwit	179	**116**	**50**	-4.1%	8	**2**	1	-4.5%
Great Knot	8	3	1	-4.4%	1	0	0	-
Red Knot	38	15	10	-4.4%	3	1	0	-
Sharp-tailed Sandpiper	274	210	**1934**	>30%	0	0	9	-
Curlew Sandpiper	261	**125**	**87**	-4.5%	3	3	5	+2.0%
Red-necked Stint	44	**14**	29	-3.7%	5	2	1	-3.7%
Terek Sandpiper	23	9	3	-4.5%	0	0	0	-
Common Sandpiper	2	1	1	-	0	0	0	-
Grey-tailed Tattler	17	22	21	+1.5%	2	3	4	+4.5%
Common Greenshank	147	**82**	72	-3.4%	8	7	11	+1.9%
Marsh Sandpiper	85	**38**	31	-3.8%	9	**1**	**4**	-2.0%
Australian shorebirds								
Australian Pied Oystercatcher	8	8	7	0%	7	8	7	-
Sooty Oystercatcher	1	**5**	4	+4.5%	1	**4**	2	-
Red-necked Avocet	1471	993	1473	-0.1%	1918	1487	2245	+0.1%
Pied Stilt	374	**194**	**642**	+3.3%	395	**234**	**489**	+0.6%
Red-capped Plover	18	**10**	7	-2.5%	14	20	21	+5.3%
Black-fronted Dotterel	4	5	5	+2.3%	16	12	**29**	+8.2%
Masked Lapwing	77	80	**157**	+3.3%	43	47	**95**	+3.1%
Red-kneed Dotterel	2	8	17	+13.6%	17	5	25	+2.3%

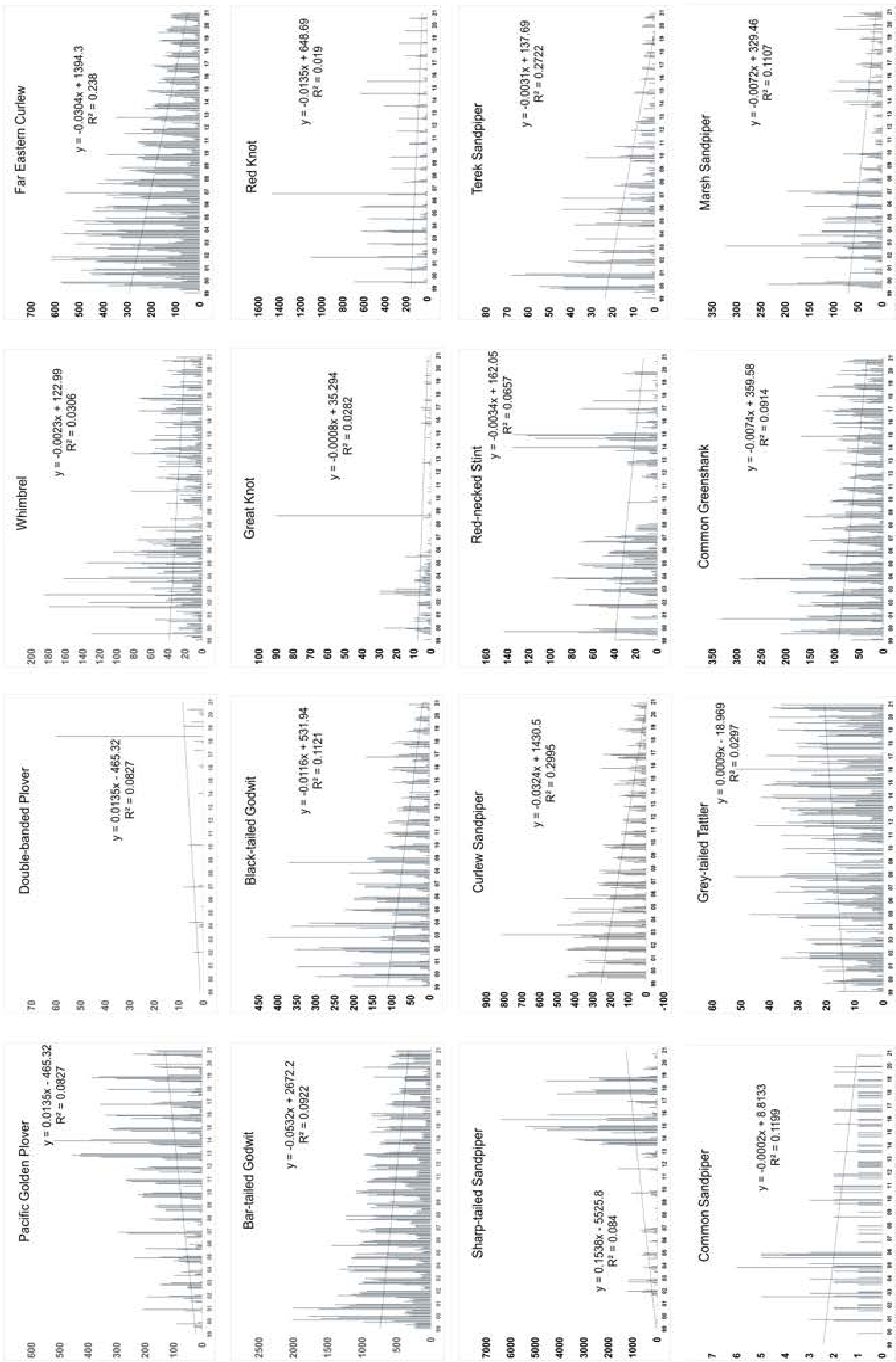


Figure 2. Monthly counts for the 16 most-frequently recorded migratory shorebirds in the Hunter Estuary, for April 1999 to March 2021 with trend lines and the related regression equation data, based on linear regression of all counts

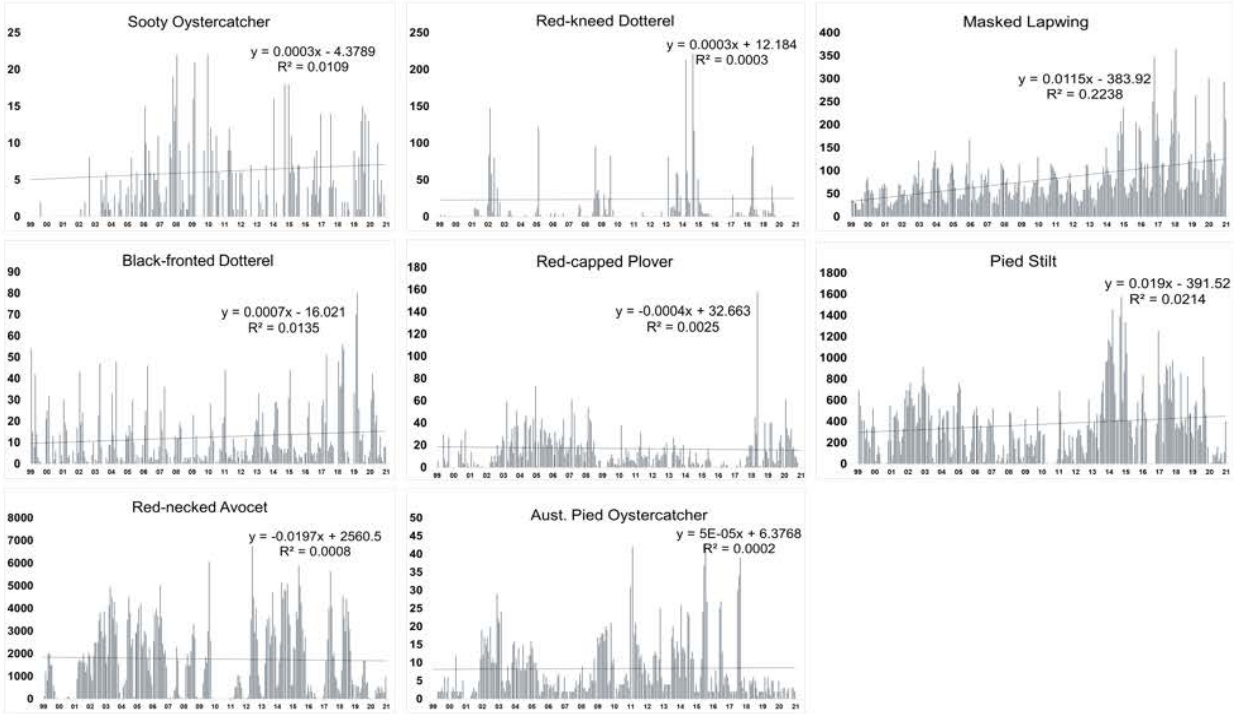


Figure 3. Monthly counts for the eight most-frequently recorded non-migratory shorebirds in the Hunter Estuary, for the period April 1999 to March 2021. Trend lines and the related regression equation data, based on linear regression of all counts, are presented to help guide the eye.

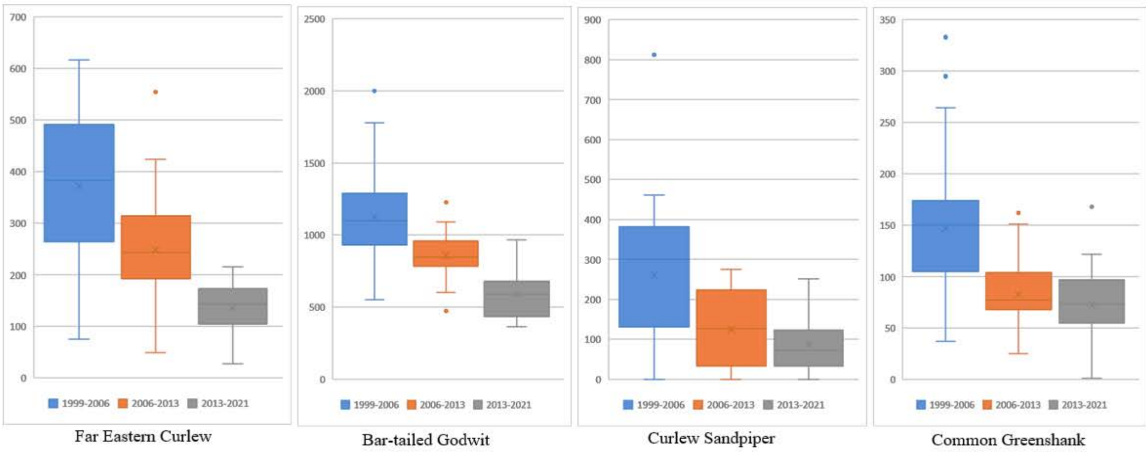


Figure 4. November-March survey results for four migratory shorebirds with declining numbers in the Hunter River Estuary. Means are represented as X and medians as horizontal lines, between the interquartile ranges (boxes), and 1.5*interquartile ranges (whiskers). Outlier values are presented individually (•).

RESULTS

Overview

Of the 264 possible surveys, the only one which did not take place was in June 2007 when none of the survey sites could be accessed after a series of East Coast Lows caused major local flooding and storm damage. In 10 other surveys, the Kooragang Dykes were not able to be surveyed because of mechanical or other operability problems with the boat (e.g. unsuitable weather, COVID-related access issues). In one survey, the Stockton Sandspit could not be accessed. On nine other occasions there were access problems at some other sites, mostly at the Tomago Wetland site.

For the 20 surveys that potentially resulted in an incomplete total count of shorebirds in the estuary, we mostly have still used the results in the analyses reported below. The exceptions involved the analyses of species, which were known to prefer to roost at the site that was not surveyed.

Fifteen migratory and eight non-migratory shorebirds were regularly recorded in the surveys (Table 1). The most commonly recorded species was Masked Lapwing *Vanellus miles*, which was present in every survey, while Common Sandpiper *Actitis hypoleucos* was the least common of the regular shorebirds, with 87 records.

In addition to the Masked Lapwing, five other species were each recorded in more than 90% of the surveys: Far Eastern Curlew, Bar-tailed Godwit, Australian Pied Oystercatcher *Haematopus longirostris,* Red-necked Avocet, Pied Stilt *Himantopus leucocephalus.* An additional 23 species were recorded as vagrants or were only occasionally present (Table 1). Three species were only briefly in the estuary and were not recorded on a scheduled survey date: South Island Pied Oystercatcher *H. finschi*, Oriental Plover *Charadrius veredus* and Little Curlew *N. minutus*. Most of the 23 species had only a small number of records; however Double-banded Plover *C. bicinctus*, Lesser Sand Plover *C. mongolus*, Ruddy Turnstone *Arenaria interpres* and Latham's Snipe each were recorded 16-35 times.

Thus, 46 shorebird species were recorded in the Hunter Estuary over 1999-2021 including 23 regular visitors (with 15 of those being migratory species) and 23 uncommon or vagrant species (with 18 being migratory species). Figures 2 and 3 illustrate monthly counts for the main migratory species and non-migratory species, respectively. Figure 2 also includes the results for Double-banded Plover, which had only 22 records but with a maximum count of 60 birds.

In Table 2 we summarise the trends for the 23 species which were regularly recorded in the estuary. Of the migratory shorebirds, 11 species have undergone declines in their non-breeding season populations while the numbers for three other species have increased. These trends were largely mirrored in the breeding season counts, although for Curlew Sandpiper and Common Greenshank there were modest increases. For the eight non-migratory shorebirds that were regularly present, many had increasing trends, while others had fluctuating, but overall stable or increasing populations. Red-capped Plover *Charadrius ruficapillus* was the only species with a decreasing population, with the mean counts dropping from 18 to 7 birds from November to March. However, their numbers increased in the May-August surveys.

Migratory shorebirds with declining populations

November-March counts for four of the species with declining populations illustrate the changes that have occurred for all 12 species (Figure 4). The plots for the other eight species in decline followed similar patterns. The differences in the two counts for any two time periods for ten of the species were found to be statistically significant ($p < 0.05$) and in many cases, highly significant ($p < 0.01$). The differences were not significant for the Common Sandpiper, which was only ever recorded in low numbers (the maximum count was of six birds, most counts were of one or two individuals). The differences for Red-necked Stint between 1999-2006 and 2006-2013 were highly significant. In general, its numbers further declined during 2013-2021; however, in 2014-2015 there was an influx, with 100+ birds often present and a peak count of 135 birds in March 2015. In the previous season, there also were 136 birds in March 2014. The influx raised the mean count for the overall period to 29 birds. If those records from the influx were excluded, the mean count for Red-necked Stint for 2013-2021 would have been 13 birds. That was not a statistically significant change from the 2006-2013 results.

Most migratory shorebirds were absent in the May-August period or present only in low numbers (Table 2). The exceptions were Whimbrel, Far Eastern Curlew and Bar-tailed Godwit. Although both of the latter species continued to be recorded regularly, there was clear evidence of their decline. The changes when comparing any two time periods were highly significant ($p < 0.01$). No statistically valid conclusions could be drawn from the Whimbrel data.

Small numbers of Red Knot spend their non-breeding season in the Hunter Estuary and very few in the breeding season. However, in spring there is a migration passage of birds primarily bound for New Zealand (Crawford & Herbert 2017). Thus, the peak counts for Red Knot in the Hunter Estuary occur in the period September to November (Figure 5). There has been a substantial decline in Red Knot numbers; however, the magnitude of the decline is exaggerated by unusually high counts occurring in September 2001 (1,100 birds) and October 2006 (1,472 birds).

Migratory shorebirds with rising populations

Three species had increasing populations over 1999-2021: Pacific Golden Plover, Sharp-tailed Sandpiper and Grey-tailed Tattler *Tringa brevipes*. The changes for Grey-tailed Tattler were not statistically significant. The changes for the other two species are summarised as box and whisker plots in Figure 6. They were found to be statistically highly significant. The Pacific Golden Plover population has been increasing steadily since regular monitoring began. However, the pattern for Sharp-tailed Sandpiper was different (Figure 2). Its numbers rose sharply in the 2013-2014 non-breeding season and remained high for the six years, up to and including the 2018-2019 non-breeding season.

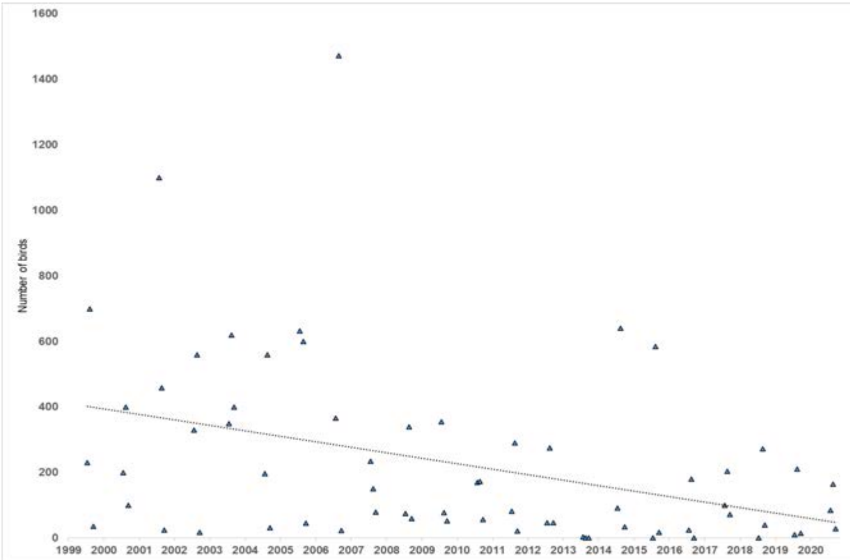


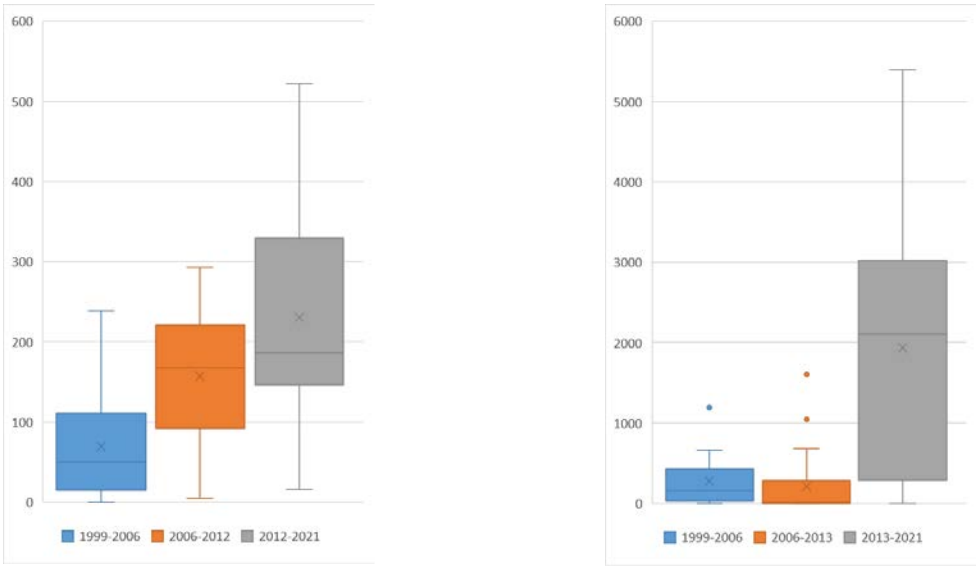
Figure 5. Annual monthly counts and linear trend line for Red Knot in September-November.

Non-migratory shorebirds

Large numbers of Red-necked Avocets often were present in the estuary. The peak count was of 6,753 birds in August 2012 and the mean counts mostly were of more than 1,000 birds. However, there also were many absences, for periods of several months and usually occurring in late summer and autumn although not in every year. Avocet behaviour in the estuary has changed somewhat. In the first *c* 15 years of surveying, and prior to that, the entire flock appeared to feed in Fullerton Cove each day and then roost at high tide on the Kooragang Dykes or at Stockton Sandspit. Since then, up to 1,000 birds have regularly been at Ash Island and appear to forage and roost there; also, there sometimes are birds (in fewer numbers) at Hexham Swamp and Tomago Wetland.

The numbers of Pied Stilt also fluctuated considerably, ranging from a peak count of 1,576 birds in December 2014 to several times there being none found in the estuary. The absences of Red-necked Avocet and Pied Stilt did not correlate – sometimes both species were absent, but it was just as likely that only one of the species had left the estuary.

The most reliable site for Red-capped Plover was Stockton Sandspit, where 20+ birds often were recorded and there were many breeding records and attempts (in spring and summer). However, for the peak count of 158 birds in August 2018, 155 of those birds were at Tomago Wetland, where generally they were uncommon. In recent years there have been fewer Red-capped Plovers at Stockton Sandspit in the breeding season, and very few breeding attempts. In the non-breeding season, birds have begun to be distributed more widely in the estuary, for example on Ash Island.



Pacific Golden Plover Sharp-tailed Sandpiper

Figure 6. November-March survey results for Pacific Golden Plover and Sharp-tailed Sandpiper.

The Masked Lapwing population initially was stable, albeit with seasonal changes. However, in recent years the population has approximately doubled. There were similar changes for Red-kneed Dotterel *Erythrogonys cinctus* and Black-fronted Dotterel *Elseyornis melanops* (for the latter, only in the May-August period). The trend for Red-kneed Dotterel was overshadowed by some large influxes, with counts of 100+ birds in May 2002, May 2005, June and November 2014 (the 2014 counts were of 200+ birds). All four of those counts were considerably above the mean. The 2002 and 2005 influxes occurred at Ash Island, and the 2014 events at Hexham Swamp.

DISCUSSION

International and national significance of the Hunter Estuary for shorebirds

The estuary's designation as a Ramsar site in 1984 was because it met the following criteria:

- Regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.
- Supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal.
- Is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its fauna and flora.
- Is a particularly good example of a specific type of wetland community characteristic of its region.

The decline in populations of migratory shorebirds in the Hunter Estuary in general mirrors the trends observed elsewhere (e.g. Studds *et al*. 2017; Hansen 2011). However, some of the local declines have been steeper, such that the estuary is no longer internationally significant for several species, which previously it had been (based on Bamford *et al*. 2008). The estuary is no longer internationally significant for Latham's Snipe, Black-tailed Godwit, Bar-tailed Godwit or Curlew Sandpiper. It continues to be a nationally significant site for those species.

In a recent report, the estuary was listed as internationally significant for Far Eastern Curlew and Red Knot, based on 406 birds in February 2007 and 2,172 birds in October 2006, respectively (Weller *et al*. 2020). In 1999-2007, HBOC's surveys often recorded 500+ Far Eastern Curlew, but with substantial declines from then onwards. Surveys in the non-breeding season in 2020-2021 have recorded 100-150 birds i.e. around 0.3-0.5% of the total population. The 2006 Red Knot record of 2,172 birds (Spencer 2009; Weller *et al*. 2020) was not from an HBOC survey, but 1,472 birds had been present during a scheduled survey only a few days before and it is well-known that there is a transient population in spring when birds are on migration passage. However, since 2014 the peak count has been of 640 birds (in October 2014) and all of the counts since October 2015 have been of fewer than 300 birds. Those numbers represent around 0.3-0.5% of the total population. It has been 14-15 years since the Hunter Estuary hosted more than 1% of the populations of either Far Eastern Curlew or Red Knot.

Weller *et al*. (2020) also listed the estuary as internationally significant for Sharp-tailed Sandpiper. This is also the case based on our data, the peak counts of the 2013-2019 HBOC surveys often were of 3,000-5,000 birds, equivalent to 4-6% of the total population. The high numbers persisted for eight consecutive non-breeding seasons, from 2011/12 to 2018/19, with 1000+ birds being recorded each season (Stuart 2016; 2019).

The Hunter Estuary's importance for Red-necked Avocet is very clear. Since 1985 there have been records of more than 1% of the total population (estimated at 107,000 birds: Wetlands International 2021) in almost every year (Stuart 2017). There have only been three periods with prolonged absences of all or most birds: December 1999 – April 2001, January 2010 – May 2011 and February 2016 – March 2017. The peak count in August 2012 was approximately 6.5% of the total population. Also, for the Pied Stilt, there were several records of more than 1,000 birds over 2014-2019 with the peak count of 1,573 birds in December 2014. These records were 0.1-0.15% of the estimated total population (Wetlands International 2021).

The estuary's IBA nomination in 2010 included three shorebirds (Far Eastern Curlew, Sharp-tailed Sandpiper and Red-necked Avocet) and one waterfowl (Chestnut Teal *Anas castanea*) that were regularly present at more than 1% of their total populations. That is no longer the case for Far Eastern Curlew but the IBA continues to support significant numbers of all three other species.

Ramsar criteria continue to be met for the estuary although there have been changes in which species are present at levels of 1% or more of their total population. However, some of the Limits of Acceptable Change for the Ramsar site (Brereton & Taylor-Wood 2010) have been exceeded:

- *For any five consecutive years there will be no instance of all years recording a maximum summer annual count of migratory shorebirds of less than 5,000 birds*. 5,000+ migratory shorebirds were not recorded in any survey between April 1999 (when the surveys started) and October 2014 i.e. for more than 15 years. Between November 2014 and October 2018, there were several instances of more than 5,000 birds being recorded. However, there have been no further instances. It has been only when there have been substantial numbers of Sharp-tailed Sandpiper in the estuary that the target of 5,000+ birds has been met. If Sharp-tailed Sandpiper numbers are excluded from the reckoning, the highest total count of migratory shorebirds was 3,589 birds in December 1999. Since 2008, there have been only four instances where more than 2,000 migratory shorebirds were present (excluding Sharp-tailed Sandpipers).
- *For any five-year period, there will be no instance of all years recording a maximum summer annual count of eastern curlew* (sic) *for the Hunter River Estuary of less than 600 birds*. In 22 years of monthly surveys, there have been two records of 600+ Far Eastern Curlew. Both occurred in the 2001/02 non-breeding season and involved counts of 614-617 birds.

Winners and losers

The populations of seven species, including three migratory shorebird species, have increased over 1999-2021. For Pacific Golden Plover and Sharp-tailed Sandpiper the changes have been substantial. However, the populations of all twelve of the other regularly-visiting migratory shorebirds have decreased. In most cases the declines have been substantial and the differences in counts for three successive 7-8year periods were statistically significant or highly significant. For the most part, those declines have been a continuation of trends from the late 1980s onwards (Herbert 2007; Spencer 2009; Stuart 2014a; 2014b). For example, Lane (1987) reported 490 Far Eastern Curlew, 470 Black-tailed Godwit, 1,300 Bar-tailed Godwit; 560 Common Greenshank; 280 Marsh Sandpiper and 570 Curlew Sandpiper as average counts in the estuary for 1981-1985. Spencer (2009) showed that the declines for many of these species had been occurring since the 1980s. Between 1993 and 2009, the number of migratory shorebird species present in the estuary at >1% of their Australian populations decreased from 11 to five species and the number of migratory species present at >1% of their Flyway population decreased from five to two species (Spencer 2009). In 2009 the estuary was considered internationally significant for Far Eastern Curlew and Sharp-tailed Sandpiper (Spencer 2009).

Spencer (2009) assessed Pacific Golden Plover and Grey-tailed Tattler as in decline, however the evidence for Grey-tailed Tattler was not definitive. For Pacific Golden Plover, the average count was 410 birds in the 1980s (Lane 1987), similar to recent surveys. There also were many records of 500-800 birds in the 1970s and 1980s. However, in the 1990s the counts dwindled to 100-200 birds. This species has been making an encouraging local recovery in recent years, particularly given that the overall Australian population has decreased by 2.8% (Clemens *et al*. 2016). Grey-tailed Tattler has made a modest recovery in the Hunter Estuary in recent years (the mean counts have risen from 17 to 21-22 individuals). Importantly, it is no longer experiencing a continued decline in numbers.

Sharp-tailed Sandpiper was mainly only recorded in low numbers in the estuary until recently, although prior to that there were occasional brief influxes of more than 1% of the total population (Stuart 2016). The regular presence recently of many thousands of birds, over 2013-2019 in particular, is a significant change.

For migratory shorebirds with declining local populations, a crucial question is whether the local declines mirror the overall EAAF trends or whether there might be some local factors involved. Many migratory EAAF shorebirds have declining populations (e.g. Studds *et al*. 2017; Hansen 2011). However, the available evidence suggests that local declines for many species exceed their trends for the overall Flyway. Some indirect evidence is that the estuary no longer hosts internationally significant numbers of shorebirds, such as Bar-tailed Godwit, Black-tailed Godwit, Curlew Sandpiper Marsh Sandpiper and Common Greenshank. This change indicates that the local declines have exceeded the overall declines (i.e. if the population changes were uniform across the Flyway, the estuary would still be hosting internationally significant numbers of each of those species).

More direct evidence comes from a recent analysis of total Flyway populations (Clemens *et al*. 2016). The numbers of Bar-tailed Godwit, Black-tailed Godwit, Whimbrel and Curlew Sandpiper in the estuary have declined far more than in southern Australia, and the estuary had the highest decline of migratory shorebirds of all sites in Australia (Clemens *et al*. 2016). Again, this points to some local factors being involved.

Several non-migratory shorebirds have experienced population changes in the estuary. For Black-fronted Dotterel (in May-August) and Masked Lapwing there were statistically significant population increases, as discussed in the section *Effects of rehabilitation projects and inland conditions*.

Yellow-Sea dependency

Most of the migratory shorebirds that have undergone significant population declines in the Hunter Estuary have a high reliance on Yellow Sea tidal mudflats when they are on migration in the Flyway (Studds *et al*. 2017). Although Black-tailed Godwit was not mentioned as being Yellow Sea-dependent by Studds *et al*. (2017), we are assuming it to be, as more than 1% of the flyway population use Bohai Bay, north-western Yellow Sea as a staging area (Yang *et al.* 2011; Zhu *et al.* 2020). The area of tidal mudflats in the Yellow Sea has shrunk by more than 65% in recent decades and continues to shrink by more than 1% per year (Studds *et al*. 2017). Species with high reliance on the Yellow Sea during migration have declined at rates of up to 8% per year.

Yellow Sea habitat losses possibly account for the bulk of the population declines for migratory shorebirds in the Hunter Estuary. However, as discussed earlier the declines locally, in many cases, appear to have been larger.

Although some Sharp-tailed Sandpiper use Yellow Sea mudflats on migration, many of them do not (http://www.nzbirdsonline.org.nz/). According to geolocator data, Pacific Golden Plover migrate mainly through Japan and Pacific Islands (Johnson *et al*. 2012). This pattern was further confirmed when in 2016 a Pacific Golden Plover fitted with a Platform Terminal Transmitter (PTT) spent 13 days in Japan before flying to Alaska (Coleman & Bush 2020). Grey-tailed Tattlers mainly go via Japan and Taiwan (Branson *et al*. 2010). Thus, the three regularly visiting migratory species with increasing populations all have relatively low Yellow-Sea dependency.

Coastal specialist versus inland specialist/generalist species

Weller & Lee (2017) classified migratory shorebirds as being either coastal obligates, generalists, inland species or snipes, with generalists being species routinely found in both marine and freshwater habitats. Jackson *et al*. (2020) used a simpler classification scheme, categorising shorebirds as either coastal specialists or as inland specialists/generalists. Because Jackson *et al*. (2020) dealt with both non-migratory and migratory shorebird species we adopted their approach (Table 1). Three species which were recorded in the estuary over 1999-2021 were not categorised by Jackson *et al*.(2020): the locally uncommon Pectoral Sandpiper and two vagrants to the estuary – Lesser Yellowlegs and Buff-breasted Sandpiper.

In the Hunter Estuary, the majority of the coastal specialist shorebirds feed in Fullerton Cove at low tide and roost at high tide either at the Kooragang Dykes or at Stockton Sandspit.

The populations of most of the regularly recorded coastal specialist species are in decline in the Hunter Estuary. The exceptions are Red-capped Plover, Grey-tailed Tattler and the two oystercatchers. Those four species rarely forage in Fullerton Cove, preferring beaches and mangrove-dominated shorelines. To some extent the Red-capped Plover behaves as a generalist in the estuary as it also occurs regularly at Hexham Swamp and Ash Island. Red-capped Plover numbers in the estuary in the November-March have decreased, but their numbers in May-August have increased. These changes reflect improved management of the beaches in the Worimi Conservation Lands on Newcastle Bight, immediately to the north of Stockton (and stretching to Port Stephens). This has been to the advantage of beach-nesting shorebirds, such as Red-capped Plover and

Australian Pied Oystercatcher (Russell & George 2012; Newman & Lindsey 2014; Fraser & Lindsey 2018). It appears that the plovers now prefer to breed on the beaches rather than at Stockton Sandspit, hence are recorded in lower numbers in the estuary, while the increased numbers in the non-breeding season are an indicator of the improved breeding success.

In contrast to the coastal specialists, the populations of most generalist species have been stable or increasing. The main exceptions were Black-tailed Godwit, Red-necked Stint, Common Sandpiper, Common Greenshank (but which had an increasing population in the non-breeding season) and Marsh Sandpiper. Notably, they all are migratory species.

Common Sandpiper was classified in both articles as a generalist, but it behaves as a coastal specialist in the estuary, not ever having been recorded at Hexham Swamp or Tomago Wetland and only occasionally at Ash Island (at a roost site, not foraging). The behaviour of the Black-tailed Godwit is complex. Both Weller and Lee (2017) and Jackson *et al*. (2020) classified it as a generalist or inland specialist, but in the estuary, it forages in Fullerton Cove and roosts at the Kooragang Dykes or Stockton Sandspit from October to February, behaving like the coastal specialists. However, from late March until it departs to the breeding grounds in April, it moves to more brackish wetlands, primarily those on Ash/Kooragang Islands, where it both forages and roosts.

The inland / generalist species with increased populations in the estuary include two migratory species: Pacific Golden Plover and Sharp-tailed Sandpiper, and four non-migratory ones: Pied Stilt, Black-fronted Dotterel, Masked Lapwing and Red-kneed Dotterel. Pacific Golden Plovers seem to prefer to forage on mudflats around Stockton rather than in Fullerton Cove (Crawford & Herbert 2009). In recent years, a sub-population of them (involving up to 80 birds) have been foraging and roosting on Ash Island during the non-breeding season (AS pers. obs.). Sharp-tailed Sandpiper mainly were recorded at Hexham Swamp and Tomago Wetland, at times as many thousands of birds (Stuart 2016; 2019).

Effects of rehabilitation projects and inland conditions

The effects of rehabilitation projects are complex and outcomes will become clearer only in the long term. For some species there was a rapid response to wetlands with reinstated tidal flushing. The arrival of increased numbers of a species may however, also be linked to the condition of inland wetlands. Coastal annual bird abundance is generally higher when inland Australia is relatively hot and dry (Clemens *et al*. 2021).

Resident shorebirds

The rehabilitation projects at Tomago, Hexham Swamp and Ash Island resulted in positive outcomes for some shorebird species in providing an expansion in estuarine habitat. In Victoria and South Australia coastal wetland management was found to help mitigate shorebird declines (Clemens *et al*. 2016). Average numbers for Masked Lapwing, Pied Stilt and Red-kneed Dotterel for November-March almost doubled for 2013-2021 compared to the two previous time periods and there was also an increase over the winter period, May to August, though less substantial.

The effects of long-term inland droughts, such as the Millennium drought in 1996-2010 and the 2017-2019 drought Previous droughts - Climate may also have played a role in forcing shorebird species to the coast. For instance, the highest recorded number of Red-kneed Dotterel was 222 birds in 2014, which was then the warmest year on record in NSW with record-breaking temperatures inland and below average rainfall (New South Wales in 2014). During spring/summer 2013, 2014 and 2015 Red-kneed Dotterel bred successfully (Lindsey 2021) among the Samphire *Sarcornia quinqueflora* raising at least 10 chicks (more than one clutch) in one season at Tomago Wetland. Since February 2020, however, when widespread rain in the interior of the state again prevailed, there was only one record of 52 birds in the estuary in a freshwater wetland in March 2021 on a non-survey day (www.birdata.birdlife.org.au).

The overall population of Red-capped Plover is probably stable, but habitat preferences have changed according to local conditions. In the 2000s, Red-capped Plover became a common breeding species on Stockton Sandspit. As a result of ongoing maintenance work, it successfully bred every year from 2003 to 2010 on sandy, shelly ground with negligible vegetation. Vegetation increased gradually despite efforts to contain it. Breeding decreased and the last successful breeding event was 2015 and the last attempt was in 2017 (Clarke 2017). Since December 2017, Red-capped Plover has been breeding at Fish Fry Flats on Ash Island after extensive rehabilitation works were completed in December 2016. Before this date, there were no recorded sightings (Reid 2019). The maximum count of 54 in December 2019 (Birdata portal) at Fish Fry Flats was outside HBOC surveys. Overall numbers in the estuary decreased in the summer period perhaps because some birds flew to other areas such as Worimi Conservation Lands to breed. Vehicular access to dunes behind the beach front, where Red-capped Plover has been observed breeding has been curtailed and disturbance reduced accordingly (Worimi Conservation Lands Plan of Management 2015).

In 2002, Red-necked Avocet responded almost immediately to the removal of mangroves and other vegetation at Stockton Sandspit by choosing that site in preference to the hitherto-favoured Kooragang Dykes site, a kilometre away across the Hunter River. In response to disturbance at the Sandspit, the birds fly back across the river to the Dykes to roost. Differences between the two roost sites include proximity to tall vegetation, surface structure and microclimate. We speculate that Stockton Sandspit is preferred as it offers clear line of sight and cool, wet substrates. Cool, wet substrates have been found to be associated with diurnal roost choice (Rogers *et al.* 2006). During the diurnal low tide period, avocets fly from these roost sites to Fullerton Cove where they forage. Distance between these roost sites and foraging sites in Fullerton Cove does not seem to be a factor in the preferred choice of Stockton Sandspit as it is approximately one kilometre further from foraging sites than Kooragang Dykes. It has been found that foraging to roost distances often vary more than a kilometre in some migratory shorebird species (Jackson *et al*. 2017).

Migratory shorebirds

Although 14 migratory species initially visited rehabilitated sites after tidal flow was reintroduced, Sharp-tailed Sandpiper and Common Greenshank were the only species to return regularly in significant numbers to Tomago (Lindsey 2021). A similar pattern was noted at Hexham Swamp, the numbers of Sharp-tailed Sandpiper increased dramatically after reinstatement of tidal flows at Hexham Swamp and Tomago Wetland, with more than 5% of the population often present (Stuart 2016). Conversely, constant interruptions to tidal flow at Tomago combined with a long drought period led to their disappearance after 2018 (Lindsey 2021; Stuart 2016). Clemens *et al*. (2021) discuss the effects of changing wetland dynamics on migratory shorebirds. Temporary departures of Sharp-tailed Sandpiper were associated with heavy rainfall inland (Stuart 2016). This was reflected in the 2020/2021 non-breeding period when the maximum number observed was only 189 birds. Presumably this species was taking advantage of the temporary expansions of suitable habitat inland (Clemens *et al*. 2021). Salt marsh sites in the estuary are becoming well established which may also play a role in the decrease in numbers of Sharp-tailed Sandpiper, as this species seems to show a preference for salt marsh in transition rather than when it has been established for some time (Stuart 2016).

Tomago Wetland may be important as a winter site for Common Greenshank as some have been present there every winter since 2013 with a peak number of 38 in 2016 (Lindsey 2021). There is a small increase in the linear trend for the winter period May to August.

The significant increase in Pacific Golden Plover may be explained not only by the increase in salt marsh habitat but also by this species' use of a greater number of sites in the estuary compared with other species e.g. Kooragang Dykes, Stockton Sandspit, Stockton Channel and Ash Island. Roost sites may have been missed, as not all the available areas are monitored, e.g. at Tomago Wetland and Hexham Swamp. Also, Pacific Golden Plover are known to roost behind the dunes on Worimi Conservation Lands (Crawford & Herbert 2009).

Is the contamination of Fullerton Cove affecting its ability to provide prime feeding habitat?

The main reason for the Hunter Estuary to have hosted shorebirds in such high numbers for so many decades has been the rich feeding habitat available in Fullerton Cove. Nine migratory species have been recorded foraging in Fullerton Cove, the most numerous being larger-sized species, Bar-tailed Godwit, Black-tailed Godwit, Eastern Curlew and Whimbrel (Spencer 2009). The other five species occurred in small numbers. Red-necked Avocets also forage at Fullerton Cove (Spencer 2009) but, unlike the larger-sized migratory shorebirds, they do not probe into the mud to feed.

For several decades Fullerton Cove became increasingly contaminated by chemicals used in fire-fighting programs at the nearby Williamtown airport (Australian Department of Defence 2018). The fire-fighting group of chemicals includes a large variety of similarly behaving products, such as per- and poly-fluoroalkyl substances and per- and poly-fluorooctyl sulphonates. These two chemicals have been shown to be present in Fullerton Cove sediments (Australian Department of Defence 2018) and to accumulate in the food chain (Taylor *et al*. 2018).

The measured PFAS/PFOS levels in Fullerton Cove were found to be below the levels causing acute toxicity to benthic organisms (Simpson *et al*. 2021). However, in light of the magnitudes of the population declines for all the shorebirds that preferentially forage in Fullerton Cove, the possibility of chronic toxicity effects needs to be considered. There have been no studies about the potential chronic toxicity effects of PFAS/PFOS to benthic organisms and how the long-term PFAS/PFOS background concentrations might have affected benthic life and thus, the creatures that feed upon that benthic life. It seems telling that the most numerous migratory species that forage in Fullerton Cove are in decline, whereas the species that do not, mostly have been prospering. There is an urgent need for a comprehensive study of PFAS/PFOS distribution in Fullerton Cove and how the contamination of Fullerton Cove by toxic chemicals is affecting benthic life and thus impacting on shorebird populations.

It could be argued that the population declines for the species that prefer to forage in Fullerton Cove are related to rising sea levels. A consequence of rising sea levels would be that less of the mudflats in Fullerton Cove were exposed and for shorter periods of time. However, rising sea levels are a global phenomenon and do not readily account for the more substantial declines that are occurring in Fullerton Cove.

CONCLUSIONS

For at least 50 years, the Hunter Estuary has been an important site for resident shorebirds and a significant international staging and destination site for migratory shorebirds. It has become an internationally significant site for Sharp-tailed Sandpiper, with many recent records of several thousand birds, representing 4-6% of the total population at times. However, with the exception of Pacific Golden Plover and Grey-tailed Tattler, the number of migratory shorebirds has decreased substantially in the past two decades, continuing the trends first established in the 1980s. In the non-breeding season fewer than 2,000 migratory shorebirds are now usually present, except when there are visiting Sharp-tailed Sandpipers. The estuary is no longer internationally significant for Latham's Snipe, Black-tailed Godwit, Bar-tailed Godwit or Curlew Sandpiper, although it continues to be nationally significant for those species. Also, it has been at least 14 years since the estuary has hosted more than 1% of the total populations of Far Eastern Curlew or Red Knot.

The estuary is important for Red-necked Avocet, with thousands of birds usually present, except when conditions inland are favourable for breeding. The peak count was almost 6.5% of the total population. There were also several records of more than 1,000 Pied Stilt.

For much of the 20th century, there were considerable losses of shorebird foraging and roosting habitat in the estuary because of industrial and agricultural development initiatives or for mosquito control. However, since the 1990s several positive developments have partially restored lost shorebird habitat. Those developments have favoured generalist shorebirds in particular, most species of which have experienced population growth in the past two decades.

The majority of migratory shorebird species with declining numbers in the Hunter Estuary rely on Yellow Sea tidal mudflats and adjacent saltpans during migration. Thus, local declines reflect overall Flyway trends of decreasing populations. However, for many species local declines exceed the overall Flyway declines. Those declining species mainly forage in Fullerton Cove, which has become contaminated by the fire-fighting chemicals used for decades at the nearby Williamtown Airport. There is an urgent need for a comprehensive study of chemical contamination in Fullerton Cove to assess whether benthic life has been affected thus impacting shorebird populations.

The local populations of Pacific Golden Plover and Sharp-tailed Sandpiper have increased significantly, and the Grey-tailed Tattler population also has risen. These three species have a lower dependency on the Yellow Sea during migration and, locally, a lower dependency on Fullerton Cove for foraging. Both of those points may be important factors for explaining the observed population rises.

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TWELVE YEARS OF MONITORING SHOREBIRD USE OF A TIDAL FLAT AT BRISBANE AIRPORT IN MORETON BAY, QUEENSLAND

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Spatial and temporal variation in shorebird use of tidal flat feeding habitats has been subject to limited monitoring, including in Moreton Bay, one of the most important shorebird areas in Australia. We present the results of 12 years of monitoring over a 17-year period (2004 to 2021) of shorebird use of an extensive and important area of tidal flats on the mainland shoreline of Moreton Bay at Brisbane Airport. The overall migratory shorebird population increased from September to peak in November and declined thereafter. The maximum count of migratory shorebirds feeding on the 96.5 ha of tidal flats each year ranged between 1,340 and 2,546. There was no significant trend in the average total count for any migratory shorebird species during the austral summer months (October to February) over the 11-year period 2009/10 to 2020/21 besides Pacific Golden Plover *Pluvialis fulva*, which showed a significant increase in average abundance. The relative importance of the Brisbane Airport foreshore tidal flats to a species' Moreton Bay population was greatest for Curlew Sandpiper *Calidris ferruginea*, supporting 16% of the Moreton Bay population on average but up to a maximum of 43%. While the Brisbane Airport tidal flats comprise just 1% of the tidal flat area in Moreton Bay, they support approximately 3.8% to 7.3% of the estimated total Moreton Bay population of migratory shorebirds.

INTRODUCTION

Moreton Bay in south-eastern Queensland is one of the most important areas for migratory shorebirds on the east Australian coastline, supporting around 35,000 birds during their non-breeding season in the austral summer (Fuller *et al.* 2019). The Moreton Bay shorebird area stretches 130 km from Caloundra in the north to Southport in the south and incorporates approximately 10,000 ha of tidal flats at low tide within one of the largest estuarine bays in Australia (Fuller *et al.* 2019).

On their non-breeding grounds, migratory shorebirds inhabiting coastal shorelines depend on two critical habitat features: (1) feeding habitat on tidal flats exposed during the low-tide phase of the tidal cycle; and (2) nearby roost sites where they can rest undisturbed during the high tide phase of the tide cycle when their feeding habitats are inundated (Colwell 2010). Since 1992, the Queensland Wader Study Group (QWSG), a non-government organisation, has been conducting co-ordinated monthly counts of shorebirds at a network of roost sites that includes most of the major roost sites throughout Moreton Bay (Milton and Driscoll 2006). This monitoring has identified issues associated with the loss or disturbance of roost sites (Milton *et al.* 2011, Fuller *et al.* 2019), has provided the basis for estimating total species population sizes in Moreton Bay each year and has been invaluable in monitoring temporal change in the population sizes of migratory shorebirds using the East Asian-Australasian Flyway (Wilson *et al.* 2011, Clemens *et al.* 2016, Studds *et al.* 2017). Feeding habitats in Moreton Bay have been subject to much less monitoring attention. Several studies have examined migratory shorebird use of a variety of intertidal feeding habitat areas around Moreton Bay (Thompson 1990a, Stigner *et al.* 2016), including species-specific studies of spatial variation in feeding bird densities (Thompson 1990b, Finn *et al.* 2001, Zharikov and Skilleter 2002). However, all these studies have been short-term, monitoring over timescales of less than one year.

In this paper we present the results of 12 years of monitoring over a 17-year period (2004 to 2021) of shorebird use of an extensive and important area of tidal flat feeding habitat on the mainland shoreline of Moreton Bay at Brisbane Airport, close to the mouth of the Brisbane River. This monitoring was undertaken between December 2004 and April 2021 to inform the management of migratory shorebirds under the Brisbane Airport Biodiversity Management Strategy that was developed to meet conditions of approval by the Commonwealth and State Governments for the Brisbane Airport New Parallel Runway and Northern Access Road projects. Construction of the new runway on the western flank of the airport commenced in 2012, the major stages of construction were completed in mid-2020 and the runway became operational in July 2020. The development project included the construction of a high intensity approach lighting system (HIAL) that extended on a narrow, raised platform on piles for a distance of 375 m over the tidal flats into Moreton Bay as well as the reconstruction of a rock seawall along a 1.75 km length of the shoreline. The seawall was reconstructed during the austral winter of 2018 and the HIAL was constructed during the austral winter of 2019, during periods when most migratory shorebirds are absent during their northern hemisphere breeding season.

METHODS

Study area

The study area covered a 3 km length of tidal flats extending from the southern bank of Kedron Brook mouth in the north to Serpentine Creek Inlet in the south (Figure 1). Situated in the shallow waters of Bramble Bay, the tidal flats become exposed to a width of between 150 m and 650 m and cover a total area of 96.5 ha on a spring low tide. The tidal flats have a gentle gradient with a substrate consisting of fine sands nearshore but becoming progressively muddier with distance offshore (Stephenson *et al*. 1977). The movement of water across the tidal flats creates sand ripples in the intertidal and shallow subtidal zone, and no seagrass is present (BMT WBM 2013). The survey area was split into two portions: a 27.0 ha western portion from the mouth of Kedron Brook; and a 69.5 ha eastern portion closer to the mouth of the Brisbane River. The study area is located along the eastern boundary of Brisbane Airport, which means that access to the shoreline from land is restricted and strictly controlled. Consequently, there is generally very limited human disturbance to shorebirds feeding in this area besides the regular overflight of jet airplanes during take-off and landing, to which the birds have habituated and are therefore rarely disturbed.

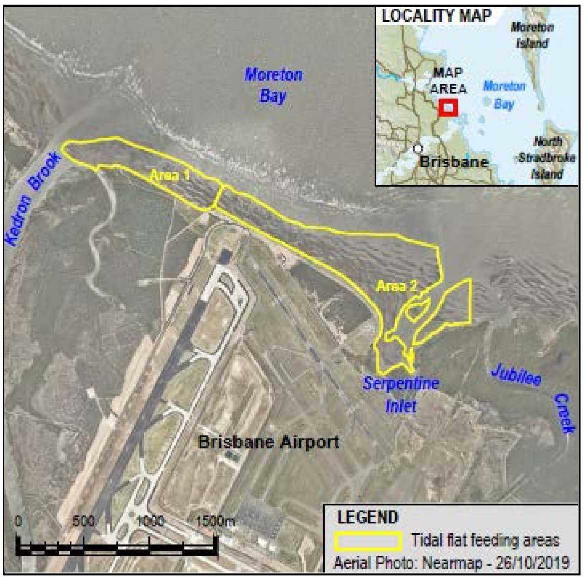

Figure 1. Location of the study area.

Survey approach

Surveys were done within the 4-hour time window between two hours before low tide and two hours after low tide. A total count of all individuals of each waterbird species present on the tidal flat within the two survey areas (Figure 1) was obtained using a Swarovski HD 25-60 spotting telescope mounted on a sturdy tripod from sequential vantage points along the elevated rock-wall shoreline. Six surveys were conducted by members of the QWSG in 2004/5, two each in the months December 2004 and February and April 2005. Thereafter, a survey was conducted by the authors (two observers per survey) once a month from September to April inclusive each season from 2010/11 to 2020/21. Any sources of potential anthropogenic disturbance or actual natural or anthropogenic disturbance were recorded during each survey.

Data analysis

Temporal trends in the annual average austral summer count (October to February inclusive, the months that migratory shorebird numbers were most stable within the study area) of individual species or groups of species over the 11-year period 2010/11 to 2020/21 were tested using a non-parametric Mann-Kendall trend test in R (R Core Team 2021) to statistically assess if there is a monotonic upward or downward trend in shorebird numbers over time. A monotonic upward (or downward) trend means that the variable consistently increases (or decreases) through time, but the trend may or may not be linear.

To assess the relative importance for migratory shorebirds within Moreton Bay of the 96.5 ha of tidal flat along Brisbane Airport foreshore, the average October to February summer count and maximum count of each species was compared to the corresponding maximum count of each species recorded within Moreton Bay since 2008, as summarised in Fuller *et al*. (2019). The seasonal composition and abundance of the benthic macroinvertebrate community infauna in the tidal flats within the Brisbane Airport foreshore study area was summarised based on an unpublished study conducted within the study area (BMT WBM 2013). This study sampled the macroinvertebrate community using Veen grab samples (gape area approximately 0.028 m^2) sieved through a 0.5 mm sieve on four occasions: in January and March 2006 at four sites within Serpentine Inlet and adjacent tidal flats (Area 2) (WBM Oceanics Australia 2006, reported in BMT WBM 2013); and in December/January 2012/13 and March 2013 on each of four transects (two in Area 1 and two in Area 2) at four sampling points along each transect: 50 m, 150 m, 200 m and 300 m (BMT WBM 2013). Avian nomenclature follows Gill *et al.* (2021).

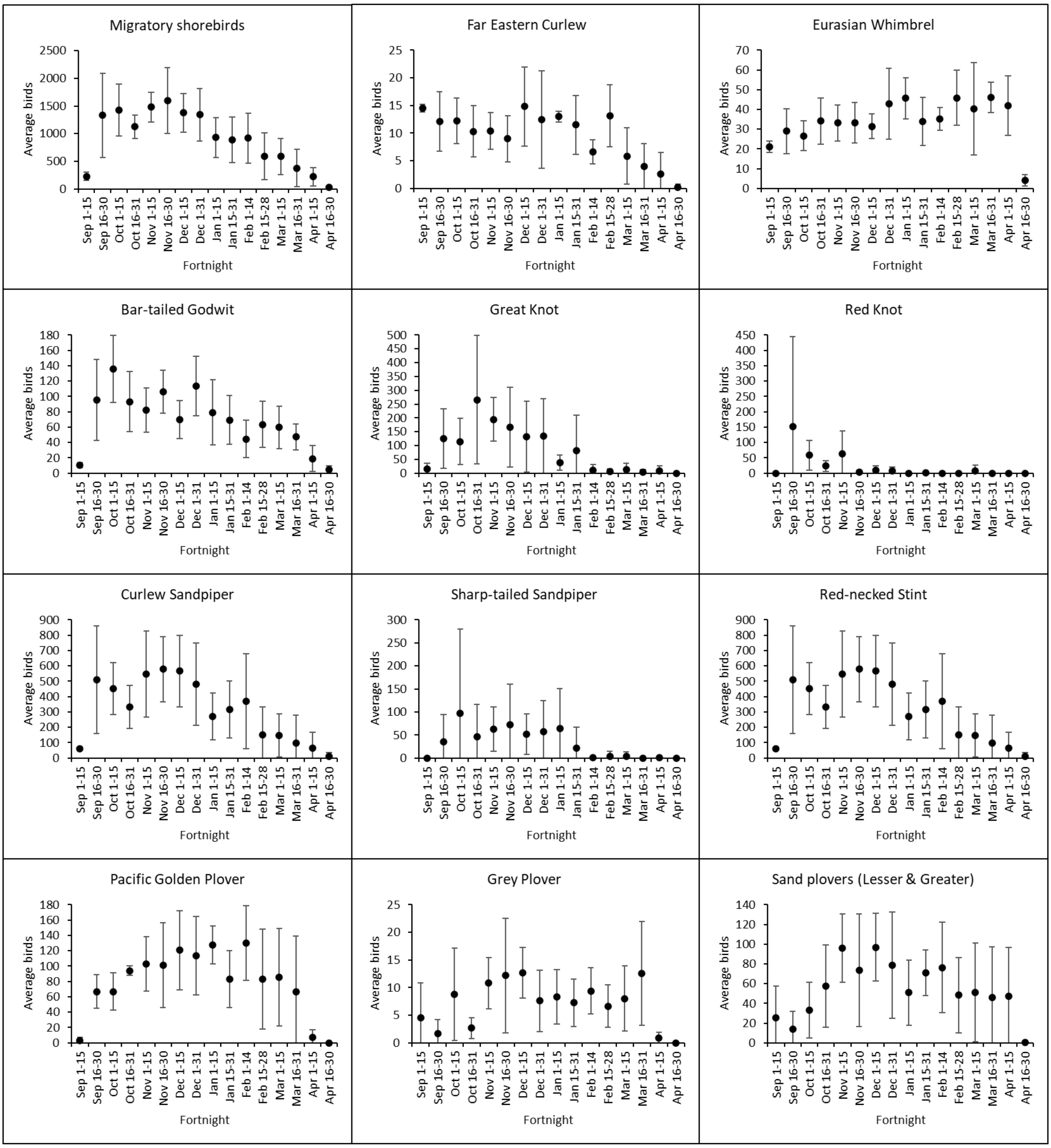

Figure 2. Average (±1 standard deviation) total counts of birds feeding on the tidal flats each fortnight from September to April over the 11-year period 2009/10 to 2020/21.

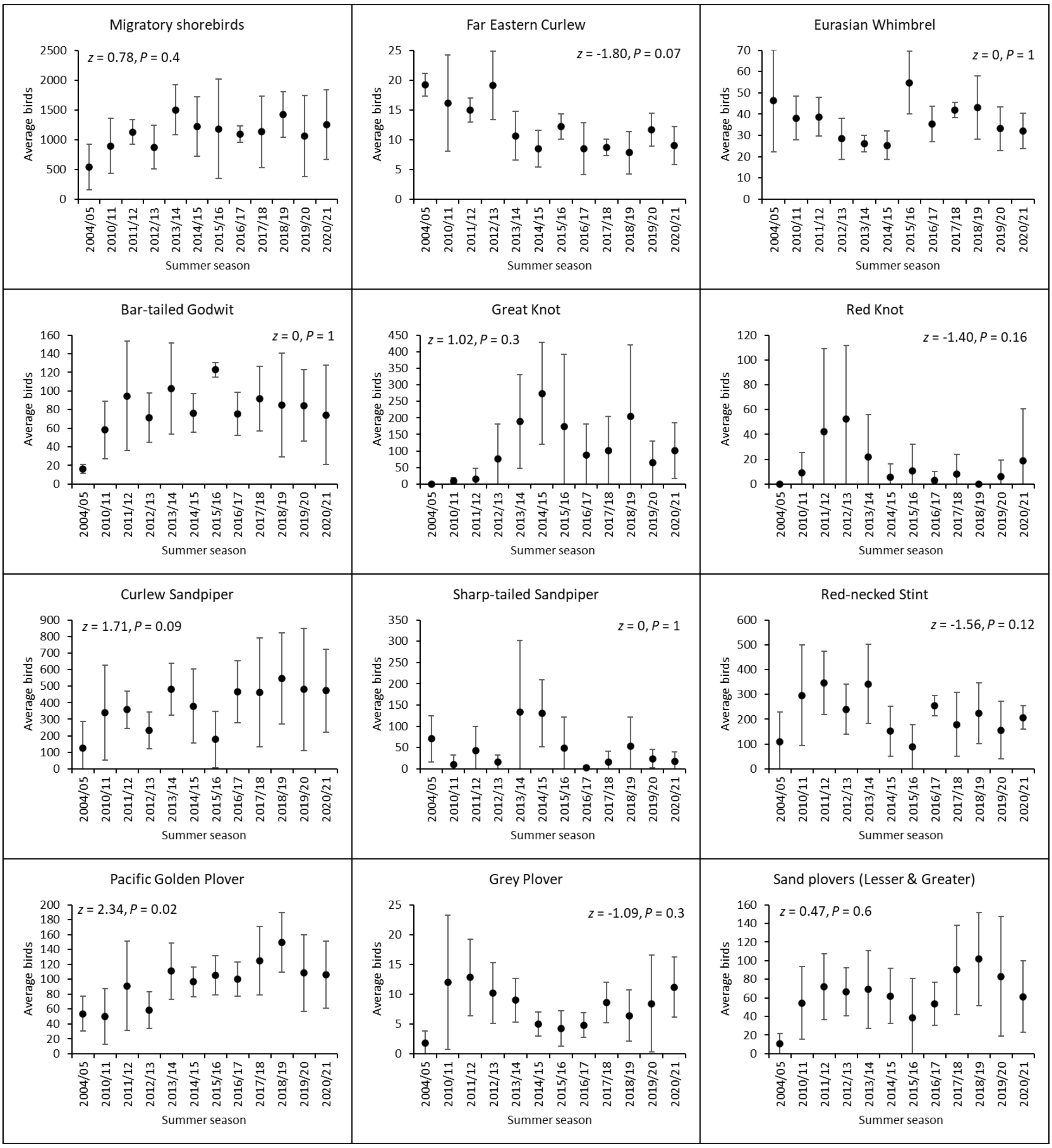

Figure 3. Average (±1 standard deviation) total counts of birds feeding on the tidal flats each month from October to February from 2004/05 to 2020/21. Mann-Kendall trend test statistics restricted to trend analysis over the 11-year period 2009/10 to 2020/21.

Table 1. Low tide feeding densities (birds per 10 hectares ± 1 standard deviation) of individual species of migratory shorebirds (average of 52 surveys in the months October to February, 2010 to 2021) or resident shorebirds and other waterbird species (average of 86 surveys in the months September to April, 2010 to 2021) that feed on tidal flat Area 1 and Area 2 along the Brisbane Airport foreshore.

Species	Common name	EPBC*	NCA*	Area 1	Area 2
Tidal flat area (ha) at lowest astronomical tide				27.0 ha	69.5 ha
Calidris ferruginea	Curlew Sandpiper	M, CE	E	11.7±19.4	53.3±32.3
Calidris ruficollis	Red-necked Stint	M	S	7.8±15.9	29.3±17.5
Pluvialis fulva	Pacific Golden Plover	M	S	7.7±4.9	11.7±5.6
Calidris tenuirostris	Great Knot	M, CE	E	2.5±7.6	15.6±17.0
Limosa lapponica baueri	Bar-tailed Godwit (Western Alaskan)	M, V	V	7.2±5.9	9.4±5.2
Charadrius mongolus	Lesser Sand Plover	M, E	E	1.6±2.7	8.9±5.8
Calidris acuminata	Sharp-tailed Sandpiper	M	S	0.8±3.2	6.3±10.7
Numenius phaeopus	Eurasian Whimbrel	M	S	2.7±1.4	4.1±1.6
Calidris canutus	Red Knot	M, E	E	0.1±0.4	3.1±7.1
Numenius madagascariensis	Far Eastern Curlew	M, CE	E	1.2±0.6	1.1±0.7
Pluvialis squatarola	Grey Plover	M	S	0.1±0.2	1.1±0.7
Charadrius leschenaultii	Greater Sand Plover	M, V	V	0.05±0.2	0.7±1.2
Tringa nebularia	Common Greenshank	M	S	0.02±0.1	0.1±0.1
Arenaria interpres	Ruddy Turnstone	M	S	0.02±0.1	0.03±0.1
Tringa brevipes	Grey-tailed Tattler	M	S	0.01±0.1	0.02±0.1
Total migratory shorebirds				43.3±39.3	151.0±67.8
Himantopus leucocephalus	Pied Stilt		LC	1.7±5.2	2.5±7.1
Charadrius ruficapillus	Red-capped Plover		LC	1.5±3.5	1.7±3.9
Haematopus longirostris	Australian Pied Oystercatcher		LC	0.9±0.7	0.6±0.3
Vanellus miles	Masked Lapwing		LC	0.1±0.5	0.4±0.7
Esacus magnirostris	Beach Stone-curlew		V	0.03±0.1	0.02±0.1
Total resident shorebirds				4.2±6.5	5.2±8.3
Chroicocephalus novaehollandiae	Silver Gull		LC	12.6±11.5	12.8±11.1
Threskiornis molucca	Australian White Ibis		LC	1.4±3.7	1.4±2.8
Gelochelidon macrotarsa	Australian (Gull-billed) Tern		LC	0.4±1.1	0.5±0.8
Egretta novaehollandiae	White-faced Heron		LC	0.1±0.2	0.2±0.2
Egretta garzetta	Little Egret		LC	0.1±0.1	0.2±0.3
Butorides striatus	Striated Heron		LC	0.03±0.1	0.1±0.1
Ardea alba modesta	Great Egret		LC	0.01±0.1	0.1±0.1
Platalea regia	Royal Spoonbill		LC	0.01±0.1	0.01±0.0
Ardea intermedia	Intermediate Egret		LC	<0.01±0.0	0.01±0.0

* Conservation status under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) or Queensland *Nature Conservation Act 1992* (NCA): CE = critically endangered; E = endangered; LC = least concern; M = migratory; S = special least concern (migratory); V = vulnerable.

Table 2. Summary of the maximum count of each species recorded within Moreton Bay (MB max) since 2008 (from Fuller *et al*. 2019), the maximum count recorded on the Brisbane Airport (BA max) tidal flats since 2010, the average count recorded at Brisbane Airport (BA avg) within the months September to April since 2010, and Brisbane Airport maximum and average counts as a percentage of the Moreton Bay maximum count.

Common name	MB max	BA max	BA avg	BA max %	BA avg %
Curlew Sandpiper	2443	1051	400	43	16
Pacific Golden Plover	827	206	100	25	12
Great Knot	1433	544	118	38	8
Grey Plover	119	30	8	25	7
Red-necked Stint	5412	947	226	17	4
Lesser Sand Plover	1929	152	64	8	3
Sharp-tailed Sandpiper	1550	422	45	27	3
Eurasian Whimbrel	1364	87	36	6	3
Red Knot	992	810	16	82	2
Greater Sand Plover	336	48	5	14	1
Bar-tailed Godwit (Western Alaskan)	11650	187	85	2	1
Far Eastern Curlew	3651	29	12	1	<0.5
Common Greenshank	170	5	<1	3	<0.5
Ruddy Turnstone	213	3	<1	1	<0.5
Grey-tailed Tattler	2430	4	<1	<0.5	<0.5

Table 3. Average abundance of benthic macroinvertebrate infauna (individuals/m^2) in tidal flats along the Brisbane Airport foreshore. Source BMT WBM (2013).

Phylum/Class	Jan 2006 [a]	Mar 2006 [a]	Dec/Jan 2012/13 [b]	Mar 2013 [b]
Oligochaeta	0	0	0	2
Polychaeta	457	211	281	84
Nemertea	0	0	68	9
Crustacea/Amphipoda	114	16	2867	169
Crustacea/Cumacea	0	0	63	2
Crustacea/Mysidacea	0	0	6	2
Crustacea/Decapoda	0	0	6	11
Bivalvia	493	176	81	26
Gastropoda	77	202	26	4
Cnidaria	0	0	4	1
Echinodermata	0	0	2	0
Phoronida	0	0	3	1

[a] Restricted to the ten most abundant species from Veen grab samples (gape area approximately 0.028m^2) from four sites within Serpentine Inlet and adjacent tidal flats (Area 2), sieved through a 0.5 mm sieve (WBM Oceanics Australia 2006, reported in BMT WBM 2013).

[b] Including all taxa from four replicate Veen grab samples (gape area approximately 0.028m^2) on each of four transects (two in Area 1 and two in Area 2) at four sampling points along each transect: 50 m, 150 m, 200 m and 300 m, sieved through a 0.5 mm sieve (BMT WBM 2013).

RESULTS

The overall migratory shorebird population feeding on the Brisbane Airport tidal flats increased from September to peak in November and declined thereafter (Figure 2). The total migratory shorebird counts in the second half of September were the most variable, evidenced by a larger standard deviation, with early September counts during the early in-migration period being substantially smaller than late September counts during the peak in-migration period. The seasonal pattern of abundance differed among species: Far Eastern Curlew *Numenius madagascariensis* and Eurasian Whimbrel *Numenius phaeopus* arrived earlier, and Far Eastern Curlew declined in abundance through March and early April. Some species, including Far Eastern Curlew, Eurasian Whimbrel and four species of plover showed no change in abundance through the summer months October to February, whereas the remaining species showed evidence of a decline in abundance after November-December (Figure 2). Red Knots *Calidris canutus* were more commonly recorded during the in-migration period (mid-September to mid-November, Figure 2), including maximum counts of 810 in September 2014 and 482 in September 2015, with the species generally absent through mid- to late-summer.

The maximum count of migratory shorebirds feeding on the Brisbane Airport tidal flats each year ranged between 1,340 and 2,546. There was no significant trend in the average total migratory shorebird count during the austral summer months (October to February) over the 11-year period 2009/10 to 2020/21 ($z = 0.78$, $P = 0.4$, Figure 3). Similarly, there was no significant trend in the average abundance of any individual species besides Pacific Golden Plover *Pluvialis fulva*, which showed a significant increase in average abundance over the same period ($z = 2.34$, $P = 0.02$, Figure 3). The average abundance of Great Knot *Calidris tenuirostris* appeared to increase between 2010/11 and 2014/15 before decreasing again; the low abundance in 2010/11 was also observed in 2004/5 when no Great Knot were present on four summer surveys in December 2004 and February 2005. Area 2 closer to the mouth of the Brisbane River supported particularly high densities of migratory shorebirds, with an average density of 151 birds/10 ha during the summer months (Table 1). Curlew Sandpiper *Calidris ferruginea* was the most abundant species on average, followed by Red-necked Stint *Calidris ruficollis* (Table 1). The relative importance of the Brisbane Airport foreshore tidal flats to a species' Moreton Bay population was greatest for Curlew Sandpiper, supporting 16% of the Moreton Bay population on average but up to a maximum of 43% (Table 2). Other species for which the tidal flats are particularly important are Pacific Golden Plover, Great Knot and Grey Plover *Pluvialis squatarola* (Table 2).

In 2012/13, the tidal flats supported a relatively diverse and abundant benthic macroinvertebrate infauna dominated by polychaete worms, ribbon worms, amphipod crustaceans and bivalve molluscs (Table 3). In both the 2006/7 and 2012/2013 seasons, the abundance of most benthic macroinvertebrate taxa declined substantially between December/January and March (Table 3).

The most frequent source of disturbance to foraging shorebirds observed during the surveys was overflight by raptors including White-bellied Sea Eagle *Haliaeetus leucogaster* and Peregrine Falcon *Falco peregrinus*. Anthropogenic disturbance was restricted to occasional short-lived disturbance by aircraft passing overhead and, during the construction period, occasional disturbance from vehicular noise and movement behind the seawall and the presence of workers on the HIAL structure. No disturbance to foraging shorebirds by aircraft using the new runway was observed during the 2020/21 season after the runway became operational. Shorebirds were observed foraging within 20 m of the raised HIAL platform post-construction.

DISCUSSION

Tidal flats adjacent to the Brisbane River mouth have historically supported high densities of migratory shorebirds due to localised nutrient enrichment associated with the discharge of treated sewage effluent into the mouth of the Brisbane River at Luggage Point, approximately 3 km south-east of the study area; this nutrient enrichment is thought to have facilitated high benthic invertebrate biomass, particularly polychaete worms in the tidal flats immediately west of the Brisbane River mouth (Thompson 1990b, Driscoll 1993). The relatively diverse and abundant benthic macroinvertebrate infauna that was dominated by polychaete worms, ribbon worms, amphipod crustaceans and bivalve molluscs in both 2006/7 and 2012/13 (Table 2) provides an abundant food supply for shorebirds foraging on this habitat at low tide. Soldier Crabs *Mictyris longicarpus* were also a common component of the relatively sparse epifauna (BMT WBM 2013). The apparent strong seasonal decrease in most benthic macroinvertebrate infauna taxa between December/January and March (Table 2) may explain the seasonal decline in the abundance in many migratory shorebird species between November/December and February (Figure 2). Since migratory shorebird numbers in Moreton Bay more broadly do not decline over this period (Driscoll 2021), birds may be preferentially feeding in this area earlier in the season and depleting benthic invertebrate food availability before some move to other feeding areas later in the season.

Migratory shorebird foraging densities are strongly influenced by spatial variation in the density and availability of their preferred prey (Goss-Custard *et al.* 1977, Ribeiro *et al*. 2004, Finn *et al.* 2008, VanDusen *et al*. 2012). The Brisbane Airport tidal flats were relatively more important for species that include polychaete worms and/or bivalves as dominant components of their diet, such as Curlew Sandpiper (Kalejta 1993, Dann 2000, Lourenço *et al.* 2017), Pacific Golden Plover (Kato *et al.* 2000), Great Knot (Piersma 1985, Tulp and Degoeij 1994) and Grey Plover (Pienkowski 1982), and relatively less important for species whose diet is often dominated by crabs, such as Far Eastern Curlew (Piersma 1985, Finn *et al*. 2008), Eurasian Whimbrel (Piersma 1985), Bar-tailed Godwit *Limosa lapponica baueri* (Zharikov and Skilleter 2002), Terek Sandpiper *Xenus cinereus* (Piersma 1985) and Grey-tailed Tattler *Tringa brevipes* (Stuart *et al*. 2015). Polychaete worms are an abundant component of the benthic macroinvertebrate community in tidal flats between the Brisbane River mouth and Nudgee Beach, whereas crabs are a relatively minor component (BMT WBM 2013, Fuller *et al*. 2019). The Brisbane Airport tidal flats are particularly important for the critically endangered Curlew Sandpiper; while these tidal flats account for approximately 1% of the 100 km^2 tidal flat area within Moreton Bay (Fuller *et al*. 2019), they supported 16% of the population on average and up to a maximum of 43% of the population, at an average density of up to 53 birds per 10 ha of tidal flat. By contrast, the observed average densities of Bar-tailed Godwit of 7.2 and 9.4 birds per 10 ha in the two areas were substantially less than the densities of 52.9 and 105.2 birds/10 ha recorded in sandy and seagrass flats respectively along the western shores of North Stradbroke Island on the eastern side of Moreton Bay (Zharikov and Skilleter 2002). Similarly, the observed average densities of Far Eastern Curlew of 1.1 and 1.2 birds/10 ha were towards the lower end of the range of feeding densities of 0.1 to 13.5 birds/10 ha recorded from tidal flats throughout Moreton Bay (Finn *et al.* 2001).

There was no evidence of a decline in the abundance of migratory shorebirds overall or in the abundance of any single species over the 11-year period of monitoring from 2009 to 2021, despite species including Far Eastern Curlew, Curlew Sandpiper and Lesser Sand Plover *Charadrius mongolus* known to have undergone significant declines in abundance across Moreton Bay over the period 1992 to 2008 (Wilson *et al.* 2011) and the period 1992 to 2012 (Dhanjal‑Adams *et al*. 2019). For example, the Eastern Curlew population using Moreton Bay declined by an estimated 2.4% per year over the period 1992-2008 (Wilson *et al*. 2011), and the population across northern Australia declined by an estimated 2.91% per year over the period 1996-2014 (Clemens *et al.* 2016). Yet, the average summer density within the Brisbane Airport study area was 1.2 birds/10 ha in 1998/99 (Finn *et al.* 2001), the same as the average density recorded in this study 11-22 years later (Table 1). The declines in most migratory shorebird populations are attributed to factors outside of Australia, particularly habitat loss at key migration stopover sites in the Yellow Sea region (Murray *et al.* 2014, Moores *et al.* 2016, Studds *et al.* 2017) and changing temperatures across their northern hemisphere breeding grounds (Van Gils *et al.* 2016, Murray *et al*. 2018), possibly exacerbated by hunting pressure (Gallo-Cajiao *et al.* 2020). The failure to detect a significant decline over the more recent period since 2010/11 may be partly explained by evidence of a flattening out of declining trends in species such as Great Knot and Lesser Sand Plover since 2009 (Dhanjal‑Adams *et al*. 2019) and/or the proximity of the tidal flats to two major roost sites at Luggage Point (2 km distant) and the Port of Brisbane (5 km distant), both well protected from human disturbance. The Port of Brisbane alone has supported between 44% and 52% of the roosting migratory shorebirds in Moreton Bay during the austral summer over the past five years and has become an increasingly important roost site, possibly due to increasing disturbance and loss of roost sites elsewhere in Moreton Bay (Driscoll 2021). Since energy expended flying between feeding and roosting sites reduces a birds' ability to store fat for migration (Rogers 2003), migratory shorebirds may preferentially feed on tidal flats closer to available roost sites (Rogers *et al*. 2006). There was no evidence that construction of the new runway at Brisbane Airport through the period 2012-2020 or operation of the new runway through the 2020/21 season affected shorebird use of the tidal flats for foraging at low tide during the survey period, with no significant decline in shorebird abundance observed for any species (Figure 3). The activities that had the greatest potential to disturb shorebirds were those that took place on or adjacent to the tidal flats, namely the construction of the HIAL platform over the tidal flats at the western end of Area 2 and the reconstruction of the seawall along much of the shoreline edge of Area 2 (Figure 1). The scheduling of the major works for HIAL and seawall construction to the austral winter months when most migratory shorebirds are absent during their northern hemisphere breeding season may have avoided disturbance impacts.

Given the evidence of significant declines in the populations of migratory shorebirds in Moreton Bay (Wilson *et al*. 2011, Dhanjal‑Adams *et al*. 2019), the stable trend in total migratory shorebird numbers using the Brisbane Airport foreshore suggests that this area remains a particularly important feeding habitat.

While the Brisbane Airport tidal flats comprise just 1% of the tidal flat area in Moreton Bay, the range in annual peak count of between 1,340 and 2,546 migratory shorebirds feeding on these tidal flats represents approximately 3.8% to 7.3% of the estimated total Moreton Bay population of 35,000 birds (Fuller *et al*. 2019). The Brisbane Airport foreshore is particularly important in supporting relatively large numbers of several threatened migratory shorebird species, including the critically endangered Curlew Sandpiper (average October-February monthly abundance of 400, representing 16% of the Moreton Bay population), the critically endangered Great Knot (average October-February monthly abundance of 118, representing 8% of the Moreton Bay population), the endangered Lesser Sand Plover (average October-February monthly abundance of 64, representing 3% of the Moreton Bay population) and the vulnerable Bar-tailed Godwit (average October-February monthly abundance of 85, representing 1% of the Moreton Bay population).

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Stilt 76 November 2021

Table of Contents