Waiuku Wind Farm, Waikato, NZ

Interim assessment of cumulative collision risk at the proposed Waiuku Wind Farm and the consented Awhitu Wind Farm

Prepared for LET Capital Number 3 Limited Partnership (LET)

23 February 2023

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Bibliographic reference for citation: Boffa Miskell Limited 2023. Waiuku Wind Farm: Interim assessment of cumulative collision risk at the proposed Waiuku Wind Farm and the consented Awhitu Wind Farm. Report prepared for LET Capital Number 3 Limited Partnership (LET). 111 p.		
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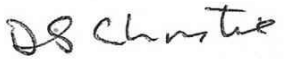
	Derek Christie Biostatistician	
Internal Review	Dr. Leigh Bull Partner, Senior Ecologist Boffa Miskell Ltd.	
Status: FINAL	Revision / version: V.3	Issue date: 23 February 2023

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Template revision: 20210624 0000

File ref: BM220899_20230223_Waiuku Wind Farm_Interim Collision Risk Assessment_V3.docx

Cover photograph: southern end of the site looking across Waiuku Forest toward the Waikato River mouth.

Executive Summary

Project Introduction

In 2022 LET Capital Number 3 Limited Partnership (LET) commissioned Boffa Miskell Ltd and BlueWattle Ecology, to carry out a desktop assessment of the risk to avifauna of a proposed wind farm on the west coast of the North Island, north of the Waikato River. The assessment is to form part of an application under the COVID fast-tracking process consistent with the Environmental Protection Agency (EPA) Referral Process.

The scope of this assessment has been to estimate the likely collision risk for all Threatened or At-Risk avian species known to be present locally and which are likely to be present at this site. The assessment needs to consider the cumulative effects of the proposed windfarm considering the potential effects of a windfarm (Awhitu) to the north which is under construction and to assess the likelihood that those effects will be significant. Finally, the assessment is to consider the scope and scale of necessary offsetting requirements.

Importantly, this assessment relies solely upon information on possible bird presence and activity gathered by a desktop study. No field investigations were carried out to support this analysis. In the absence of data from field investigations we have had to make a range of assumptions regarding each species, and these assumptions are detailed within the report. Given the lack of site verification, we have attempted to provide an analysis that is suitably conservative, using statistical methods to address the uncertainty in the data and provide some confidence in the outputs. Irrespective of this, the modelled results will require validation from proposed comprehensive and standardised field studies. For this reason we consider this assessment to be preliminary and provisional upon field verification of all the assumptions outlined in this report.

Qualifications

The authors of this report have been involved in the study and assessment of wind farm projects in New Zealand over the last 20 years. We understand and have routinely applied the methods for desktop and field study, the tools for bird observation and analysis, and the modelling of collision risk. Between them, the authors have attended Council and Environment Court hearings for wind farm projects as expert witnesses, have authored two publications relating to avifauna at wind farms, and made a number of conference presentations on both best practice EcIA methods, collision risk modelling, and our findings of collision mortality at windfarms. As such, we consider that we are qualified to prepare this study.

Methods

This report considers the site in the context of the habitats within the wider landscape to identify all birds likely to be present locally and potentially within the windfarm footprint (Sections 3, 4 and 5).

The report then considers each species and determines if it is unlikely to be at risk of collision, or if it is a key species requiring further assessment (Section 6).

The report then details a statistical method for identifying the probability of mortalities from turbine collisions (Section 7), presents the key metrics for carrying out this modelling (Section 8), and then

applies the model to each key species, to determine to the extent possible the likelihood of turbine collisions. It carries out this analysis as a cumulative assessment taking into account the likelihood of additional collision mortalities at the nearby Awhitu Windfarm (Section 9).

It then concludes with a discussion of the ability and scope of likely mitigation and/or offsetting and compensation for those losses (Section 10, 11 and 12).

The Local Environment

- In developing this assessment, we have considered the following:
  - Previously identified significant natural areas (SNAs);
  - The identified ecological values of the Waikato River estuary and river mouth habitat;
  - The identified ecological values of the Waikato River delta wetlands;
  - The identified ecological values of the coastal environment;
  - The site itself, based on aerial imagery and photographs provided by the client, and a site visit by one of the authors, is dominated by improved pasture with small drains and stock ponds, small highly modified wetland areas, and hedgerows and shelterbelt plantings scattered within. To the south of the site a large pine plantation pine is present (Waiuku Forest), a coastal dune system is located to the west and several coastal dune lakes in close proximity to the north; and.
  - We have considered potential flight paths of seabirds (e.g. black and cooks petrels from Great and Little Barrier islands), domestic migrants, international migrants, and their destinations (Firth of Thames, Manukau Harbour, Kaipara Harbour).
- We have also considered four other coastal wind farm studies:
  - Taharoa (consented but not built);
  - Hauāuru mā raki Wind Farm (consented but not built);
  - Waipipi Wind Farm (commissioned 2021); and
  - Awhitu Wind Farm (under construction).

Results of Desktop Investigation

- Section 5 begins with the collation of all birds known to occur locally. It identified a total of 75 bird species recorded in the literature for this section of coast. Of these 25 were introduced and were not considered further, leaving 50 native species. Of the native species, 21 were not threatened. These natives were excluded from our consideration of key species. Our focus therefore fell to species with a national conservation status of which there are 29.
- Section 5 also identified and discussed 8 species of seabird, which were not seen within the study area, but which are known to, or are capable of crossing this part of the North Island during night time movements.
- Finally Section 5 considered 6 species of international migrant, which were also not seen within the study area, but which may also cross the site during seasonal movements.

Identification of key species

- Section 6 looks in more detail at the 29 observed native species, recorded within 10km of the site and which have a conservation status (i.e. Threatened or At Risk under the NZ threat

classification ranking). It reviewed each species in terms of its local distribution, abundance, presence of habitat within or near the site, and known flight behaviours such as flight height. We concluded that a further 12 were not at risk from this project.

- From this analysis 17 species are considered to be potentially at risk from the development of a wind farm at this location, and these species were then assessed by way of collision risk modelling.

Total native bird species observed with the study area	Bird species with no conservation status	Bird species with a conservation status but not of concern	Bird species of concern requiring collision modelling
50	21	12	17

- Section 6 also considers the eight additional species of international migrants and oceanic seabirds which may traverse the mainland to forage along the west coast and Tasman Sea. The likelihood of any of these species crossing the site, in sufficient numbers or with sufficient frequency to be at risk is considered low. However, we identify five species with small populations and restricted distribution which we consider require further consideration as part of ongoing investigations. At this stage, the data on these species is insufficient for further analysis by way collision risk modelling.
- Finally Section 6 considers the additional six species of international migrant, which were also not seen within the study area, but which may also cross the site during seasonal movements. We concluded that none of these additional species require further consideration.

Approach to Collision Risk Modelling

Statistical Modelling

- Section 7 starts with a discussion of the general approach to collision risk modelling, which is based largely on the internationally recognised Band Model. It explains the data requirements, and the application of Monte Carlo simulation to provide confidence intervals reflective of data uncertainty.

Cumulative Effects

- The presence of the Awhitu Windfarm to the north of the proposed Waiuku site, requires that this analysis consider potential cumulative effects.
- Each windfarm was modelled separately, then the Awhitu results were added to the Waiuku results to determine the potential cumulative effects of both sites.
- For the Awhitu windfarm, we used many of the same metrics and assumptions that were used for Waiuku but adjusted for differences in windfarm size and turbine metrics.

Magnitude of Effects

- There is currently no standard method for determining the magnitude of effects of a windfarm on avian populations. Attempts have been made to use population modelling to quantify impacts at the population level, however, for most birds being considered there is little to no reliable demographic information for such modelling to be helpful.
- Our alternative is to use the threat status calculations agreed with the Department of Conservation (DOC) for the Waipipi Windfarm. This is simple and transparent.

Modelling Metrics

- Section 8 presents the results of investigations into the metrics required for carrying out the statistical modelling. These include specific mechanical and operational aspects of the turbine, details of the site being assessed, and the size of the at-risk population
- The most challenging data to obtain for the modelling was the size of the threatened and at-risk bird populations. In the absence of standardised data from the site or key surrounding habitats we have relied heavily on data from the eBird database, which is a citizen science project, and which contains a number of opportunistic observations within the wider landscape. We note that this data would not normally be accepted as the sole source for the assessment of a windfarm, however, this interim assessment will be supplemented with further monitoring.

Result of Collision Risk Modelling

- Section 9 presents the results of the Band modelling for both the Waiuku and Awhitu projects combined and the results are summarised on the following table (refer to Section 9, Table 21).
- Looking firstly at the Waiuku Results, we see that the estimated mortalities are given as a "probable" or 20% to 80% range for both birds per year, and years per bird. For example the results can be interpreted as follows:

  "The expected bittern mortality is probably somewhere between one death every 47 years and one death every 121 years. In any event we can be 80% sure that the mortality is rarer than one death every 47 years." or

  "The expected Pied Oystercatcher mortality is probably between 2 and 4 birds per year, and we are 80% sure that it is no more than 4 birds per year."

Key Species	Conservation Status	Birds/year (20% to 80% CI)	Years/bird (20% to 80% CI)
Bittern, Australasian	Nationally Critical	0.01 - 0.02	47 - 121
Tern, Caspian	Nationally Vulnerable	0 - 0.01	197 - 476
Dabchick, New Zealand	Nationally Increasing	0.06 - 0.17	7 - 18
Dotterel, Northern NZ	Nationally Increasing	0 - 0	1534 - 4529
Wrybill	Nationally Increasing	0.2 - 0.4	3 - 5
Crake, Spotless	Declining	0.06 - 0.15	7 - 17
Dotterel, Banded	Declining	0.04 - 0.09	11 - 26
Godwit, Eastern Bar-tailed	Declining	0.24 - 0.47	2 - 4
Gull, Black-billed	Declining	0.01 - 0.02	64 - 155
Gull, Red-billed	Declining	0 - 0.01	98 - 250
Oystercatcher, Pied [1]	Declining	2 to 4	0 - 1
Tern, White-fronted	Declining	0.02 - 0.04	24 - 62
Oystercatcher, Variable	Recovering	0 - 0	377 - 958
Shag, Pied [1]	Recovering	1 to 3	0 - 1
Shag, Little Black	Naturally Uncommon	0.19 - 0.46	2 - 5
Shag, Black	Relict	0.21 - 0.51	2 - 5
Shag, Little [1]	Relict	0.5 to 1	1 - 3

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

- The results for Awhitu were very similar to those for Waiuku but mortalities are reduced by approximately half which reflect differences between the two windfarms the turbines likely to be used.
- The following table presents the combined results (years/bird) for Waiuku and Awhitu.

KEY SPECIES	CONSERVATION STATUS	Waiuku Years/Bird (20% to 80% CI)	Awhitu Years/Bird (20% to 80% CI)	Cumulative Effects Years/Bird (20% to 80% CI)
Bittern, Australasian	Nationally Critical	47 - 121	117 - 292	33 - 88
Tern, Caspian	Nationally Vulnerable	197 - 476	470 - 1108	141 - 345
Dabchick, New Zealand	Nationally Increasing	7 - 18	17 - 42	4 - 13
Dotterel, Northern NZ	Nationally Increasing	1534 - 4529	3768 - 11137	1111 - 3333
Wrybill	Nationally Increasing	3 - 5	6 - 12	2 - 4
Crake, Spotless	Declining	7 - 17	17 - 40	5 - 12
Dotterel, Banded	Declining	11 - 26	27 - 60	8 - 18
Godwit, Eastern Bar-tailed	Declining	2 - 4	5 - 10	2 - 3
Gull, Black-billed	Declining	64 - 155	156 - 384	45 - 116
Gull, Red-billed	Declining	98 - 250	235 - 605	70 - 175
Oystercatcher, Pied [1]	Declining	0 - 1	1 - 1	0 - 0
Tern, White-fronted	Declining	24 - 62	57 - 147	16 - 42
Oystercatcher, Variable	Recovering	377 - 958	765 - 1994	189 - 667
Shag, Pied [1]	Recovering	0 - 1	1 - 2	0 - 1
Shag, Little Black	Naturally Uncommon	2 - 5	4 - 9	1 - 3
Shag, Black	Relict	2 - 5	5 - 13	1 - 4
Shag, Little [1]	Relict	1 - 3	2 - 5	1 - 2

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

- Three species stand out as having a high probability of annual mortalities: the pied oystercatcher (80% likelihood of between 3 to 6 mortalities per annum); the little shag (80% likelihood of between 1 to 2 per annum); and the pied shag (80% likelihood of between 2 to 4 per annum).
- Other species may see a single mortality between 1 and 10 years, and this includes other of the shag species. A majority are unlikely to see a mortality within the life of the windfarm.

Assessment of Magnitude of Adverse Effects

- Section 10 provides an attempt to determine the magnitude of adverse effect. It is highly subjective in line with the data limitations, but it highlights species within the wider group for which the modelling suggest the greatest risk of collision lies, and those where the risk is negligible. The results for all 17 species, and for both the Waiuku and Awhitu windfarms combined, are summarised in the table below (refer to Section 10, Table 22).
- In summary, we consider that, based on the population data available:
    - There will be negligible effects on 7 species where the modelled predictions of collision mortality lie between 1 every 25 years and a period significantly greater than the life of the wind farm (Wind farm life = 40 years).

- There may be a very low level of risk for three species where the modelled predictions of collision lie between 5 and 25 years. They are Caspian tern, dabchick, and banded dotterel.
- There may be a low level of risk for four species where the modelled predications of collision mortality lie between 1 every two years and 1 every five years. They are wrybill, godwit, little black shag, and black shag.
- There are three species where the modelled predications of collision is more than 1 bird per annum. They are pied oystercatcher, pied shag, and little shag.

KEY SPECIES	CONSERVATION STATUS	Modelled result Birds/Year	Modelled result Years/Bird	Annual Mitigation Review Threshold (Waipipi)	Assessed magnitude of effect
Bittern, Australasian	Nationally Critical	0 - 0	33 - 88	0.5	Negligible
Tern, Caspian	Nationally Vulnerable	0 - 0	141 - 345	5	Negligible
Dabchick, New Zealand	Nationally Increasing	0.1 - 0.2	4 - 13	5	Low
Dotterel, Northern NZ	Nationally Increasing	0 - 0	1111 - 3333	5	Negligible
Wrybill	Nationally Increasing	0.3 - 0.6	2 - 4	5	Low
Crake, Spotless	Declining	0.1 - 0.2	5 - 12	2	Very Low
Dotterel, Banded	Declining	0.1 - 0.1	8 - 18	5	Very Low
Godwit, Eastern Bar-tailed	Declining	0.3 - 0.7	2 - 3	5	Low
Gull, Black-billed	Declining	0 - 0	45 - 116	5	Negligible
Gull, Red-billed	Declining	0 - 0	70 - 175	5	Negligible
Oystercatcher, Pied [1]	Declining	3 to 6	0 - 0	10	Moderate
Tern, White-fronted	Declining	0 - 0.1	16 - 42	5	Very Low
Oystercatcher, Variable	Recovering	0 - 0	189 - 667	5	Negligible
Shag, Pied [1]	Recovering	2 to 4	0 - 1	5	Moderate
Shag, Little Black	Naturally Uncommon	0.3 - 0.7	1 - 3	5	Low
Shag, Black	Relict	0.3 - 0.7	1 - 4	5	Low
Shag, Little [1]	Relict	1 to 2	1 - 2	5	Moderate

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

Importantly, the modelled predications of collision fall short of the trigger threshold we have selected and described in Section 7.4. This suggests that, subject to confirmation by additional field data, we can have some confidence that the effects will not be significant, i.e. are unlikely to have a population level effect on a species.

Discussion And Conclusion

Predictive Collision Risk Modelling

This desktop analysis has sought to generate results which are reasonable and conservative and there is a degree of confidence in the results. However, confirmation of the modelling outputs requires further dedicated and systematic data collection from the site and neighboring habitats to test the assumptions and confirm the quantum of effects that may require offsetting.

Identification of Significant Adverse Effects

We modelled the collision risk for 17 species, and we are satisfied at this stage, that effects will not be significantly adverse based on the thresholds used. However, for some species there will be low to moderate levels of adverse effects which need to be confirmed through further site investigation.

International Migrants

Six international migrants which had not been observed within he study area were considered. We concluded that none of these required further consideration at this stage. For some this was due to their very small numbers, or their dispersal into small groups and broad distribution around the New Zealand coastline.

Seabirds

While we suggest that the risk to seabirds is low, we have identified five species, which are known to breed on the Hauraki Gulf islands and forage in the Tasman Sea (traversing the mainland), as requiring further consideration during the ongoing assessments.

Consideration of Offsetting / Mitigation

We have presented a range of methods for offsetting adverse effects. We are confident there are mitigation / offsetting methods for each of the species where modelling has suggested a low to moderate level of adverse effects.

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Maps

1. Introduction

LET Capital Number 3 Limited Partnership (LET) has commissioned Boffa Miskell Ltd and Bluewattle Ecology to identify key project risks by way of a desktop assessment of the key avifauna species potentially most at risk from the construction and operation of a proposed wind farm on the west coast of the North Island, north of the Waikato River – the Waiuku Wind Farm (WWF) (refer to Map 1 and Map 2).

Specifically, we have been asked to carry out a 'Referral Assessment' to support a later, more extensive consent application, to the EPA under the COVID Fast Track Act. Our scope is to carry out a preliminary site assessment containing sufficient analysis to allow an opinion on whether the project will result in significant adverse effects. The assessment must provide information on methods to support the limited quantitative assessments with existing data collected within this region on the avifauna populations, movements, and potential impacts of the wind farm on these.

This document first describes the local landscape, and which may be present within the site (Section 3). It considers the proposed wind farm site and the species that might utilise habitats within it (Section 4). It then compiles a list of all species known to be present within and surrounding the site (Section 5), and then considers whether there are "key" species, where small levels of collision mortality will have a large impact on the local or national populations (Section 6). It then carries out collision risk modelling of these key species to determine the level of risk.

A desktop assessment

While some site investigations have commenced, no data on bird presence, distribution or abundance within the site is yet available to assist in this assessment. It therefore has been carried out in the absence of field data and is reliant on data obtainable from existing reports and databases. The challenge when undertaking a desktop assessment in this way is to develop a method that provides a degree of confidence in the modelling results, while remaining cautious with regard to the limited data available. Addressing this tension has played an important role in the design of this study and the analysis of the data.

Where there are gaps, we have made a range of assumptions regarding population sizes and movements across and within the site, which are based on our experience and understanding of the species involved.

The results of our modelling need to be considered in this context. We have applied Monte Carlo simulations to the modelling to provided confidence intervals that reflect uncertainty, and we believe the modelling is as accurate as it can be given the data limitations. However, the results presented here are unlikely to be identical to results based on comprehensive field investigations. For that reason we consider this assessment to be interim. Data limitations are described in detail in Section 2.4.

Qualifications of the Authors

The authors of this report have been involved in the study and assessment of wind farm projects in New Zealand over the last 20 years.

Mr Fuller has been a practicing ecologist since 1983 and is a Certified Environmental Practitioner with the Environment Institute of Australia and New Zealand (EIANZ). He has carried out assessments of 14

wind farm sites in New Zealand since 2003. This work has included effects' assessments, designing, and conducting pre-construction baseline surveys, construction and post construction monitoring, and design of effects mitigation. Of those 14 sites, seven have been built, and another four consented, with the construction of two about to commence.

Mr. Kessels is an experienced ecologist and independent hearing commissioner. He has undertaken ecological assessments of wind farms since 1998, including Tararua Wind Farm, Te Uku, Hauāuru Mā Raki, Puketoi, Mt Cass, Poutoa, and review of several others, such as the Castle Hill Wind Farm consent application. In 2011, Mr Kessels presented the findings of his research on assessing and predicting avian bird strike risk in New Zealand to the first Wildlife and Wind Farm Conference in Norway on behalf of the NZ Ecological Society. Mr Kessels is currently acting as an independent peer reviewer of the avian monitoring programme on the Waipipi (Waverly) Wind Farm and assisting Main Power with the development of avian monitoring plans for their consented Mt Cass Wind Farm.

Mr Christie is a qualified wildlife statistician with over 25 years teaching and consulting experience in statistics. He has carried out statistical analysis for avifauna and bat assessments and advised on the statistical aspects of monitoring and mitigation for a number of windfarms. His special interest is in nonstandard analyses with unusually distributed data. He has contributed towards several scientific papers related to New Zealand birds, wind farms, and Monte Carlo risk analysis.

On this basis, we consider the authors to be qualified to prepare this study.

Definitions

Project Footprint:	Refers to the extent of physical works; site compounds, laydown areas, roading, turbine platforms, fill sites.
The Site:	Refers to the properties within which the wind farm will be developed.
Study Area:	Refers to the potential receiving environment and the extent of any fauna distribution studies. For avifauna, the study area extends beyond the Project Footprint to include the 200km^2 of land defined in the bird atlas used for this study.
Resident Birds:	A population of non-migratory birds which reside within the site and use it for roosting and nesting.
Local Birds:	A population of non-migratory birds whose home range extends to include all or part of the WWF site but do not roost or nest within the site.
Migrant Birds	Birds which undertake regular seasonal movement, often north and south along a flyway, between breeding and wintering grounds.
Native or Indigenous:	In its broadest sense, a species is defined as native or indigenous if it has originated or occurs in New Zealand as the result of a natural process (without human involvement). A species which is native to NZ may also be native to other countries (e.g. kingfisher, inanga).
Endemic:	This can be considered a subset of native. A species is defined as endemic if it has evolved and occurs and breeds naturally only in New Zealand (e.g. tui, red beech, long tailed bat).
Introduced:	A species that has been introduced accidentally or deliberately by human activity outside its natural range.
CRM	Collision Risk Modelling
MC - Monte Carlo	Monte Carlo Simulation is a computer simulation that seeks to determine the likelihood of various scenarios by running multiple simulations using random variables. The results of the Monte Carlo simulation show the most likely outcomes (thefreedictionary.com).

Map 1 Proposed Waiuku Wind Farm and the Awhitu Wind Farm in relation to the surrounding coastline and harbours.

Map 2 Location of the proposed Waiuku Wind farm and Awhitu Wind Farm in relation to the Waikato River mouth, Waikato River delta wetlands, and the Aka Aka floodplain.

2. Methods

2.1. Desktop Investigations

This assessment commenced with a desktop review of the site and the habitats, ecosystems, and the avifauna within it, as well as looking further afield at significant avifauna habitats which are within range of the site, given most of the species found are highly mobile and capable of flying many kilometres a day to forage or find mates.

The review included scientific literature (published and unpublished), relevant websites, and previous ecological reports prepared for the area and surrounds, including:

- The study area extended 30km (N-S) by 20 km (E-W) with the site nearly central.
    - From North to South, it extended from Cochran's Gap in the north to Tetehe Peak in the south and included most of Karioitahi Beach, the coastal and inland dunes of the west coast, and the Waikato River Mouth and Estuary.
    - From West to East it extends from 10km out to sea to 10km inland at the Aka Aka Township, and included the Waiuku Arm of the Manakau Harbour, the Aka Aka stream and floodplains, and the lower half of the Waikato River wetlands.
- Within the study area local distribution and estimates of local population size were largely based on eBird[1] observations supported by other published data. The extent of the study area is shown in Figure 1.

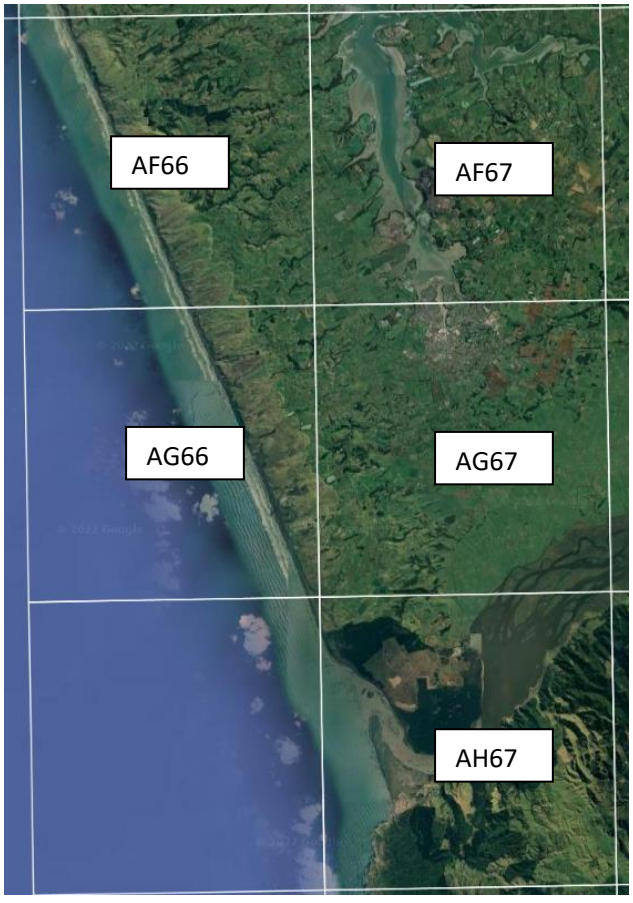


Figure 1: Extent of the study area as defined by the eBird Map Grid.

The 5 grid squares used for this review were:
AF66 = Coast north of site
AF67 = Manukau Harbour
AG66 = Coastline/ foredune below the site
AG67 = Inland including the site
AH67 = Port Waikato, harbour river mouth, sandbar and spit, and lower river wetland systems.

[1] https://ebird.org/hotspots

Additional information on bird behaviour, abundance and distribution has been obtained from:

- iNaturalist[2] data for the Project site and adjacent coastal waters.
- NZ Birds Online[3] and the volumes of the Handbook of Australian and New Zealand Birds (Various authors, 2006) provided data on bird morphology, behaviour, distribution, and populations sizes.
- The conservation status of all avian species was derived from Robertson et al. (2021).
- Review of various regional reports including "Significant Natural Areas of the Waikato District: Terrestrial and Wetland Ecosystems" (Cromarty, P. & Scott, D.A. (eds), 1995)
- Various scientific papers and reports on migrant species and shorebirds (Dowding, 2019; Dowding & Moore, 2006; Riegen & Sagar, 2020; Southey, 2009b, 2009a).
- The published results of two years of observation at the proposed Hauāuru mā raki Wind Farm (Craig, J. L. et al., 2015), and the proposed Taharoa Wind Farm (Fuller et al., 2009).

2.2. Site Visit

The site was visited by Gerry Kessels on 2 February 2023. The objective of the site visit was to obtain a better understanding of the avifauna habitats present, and potential habitats in the locality, as well as how the site sits within the landscape relating to how both resident and migratory birds may utilise or cross over it (see Section 4).

2.3. Collision Risk Modelling

The method and various metrics required for collision risk modelling are described in detail later in this document (see Sections 7 and 8).

2.4. Data Limitations

For this assessment most of the metrics relating to the turbine geometry and design, the site, and the basic biological metrics of the avifauna species are known with some degree of confidence.

The key data limitation has been the lack of information on the local population size of each species, the proportion of that population that crosses the site, and the key behaviours critical to accurate modelling. In the absence of field data, the only current source we have regarding the local population are eBird records, and the only source for flight behaviours are from other wind farm sites if the birds have also been modelled at those sites.

eBird is a citizen science project, a visual database hosted on a website where any subscriber can upload their observations of birds for others to view. These uploaded observations can, over time, accumulate sufficiently to be helpful in confirming species resident at certain areas, and at some locations the lack of observations, can indicate a lower abundance of a species. For these reasons, eBird is used for the desktop component of most avifauna assessments but unless the contributor is known the data should always be treated with caution.

[2] https://inaturalist.nz/
[3] https://nzbirdsonline.org.nz/

We have reviewed all available eBird data for the study area and most of the observers who have contributed to these observations are skilled birders who are known to the authors. We therefore have no concerns regarding bird identification or counts of birds.

The key limitations of the eBird data is that it has not been gathered for the purpose of assessing the potential effects of a wind farm. The data uploaded to eBird is typically species presence, the numbers of birds seen, and occasionally observations regarding breeding. The observations therefore lack key details needed for wind farm assessments such as descriptions of flight behaviours, breeding behaviours, flight heights, direction of movement, individual flock sizes, and so on.

In addition, the eBird observations, with a few exceptions, are opportunistic and, are strongly biased toward publicly accessible areas (e.g. roads, parks, rivers, beaches), thereby underrepresenting bird abundance and distribution on private land. Also the numbers of visits to each habitat vary from site to site, do not cover the full range of habitats, do not cover all seasons or weather conditions, do not cover differences in bird activity with time of day, and rarely contain night-time activity. They therefore present a series of limited snap shots of bird activity without continuity across seasons.

These limitations mean, if a review is reliant on eBird, these key metrics must be inferred from publicly accessible data from other studies and must assume that the behaviours observed at other sites are representative, with some tempering through expert knowledge of windfarms generally and of the site specifically.

Much of this report has therefore taken this limited data and applied expert opinion to fill in the gaps, and the modelling has been developed to ensure this uncertainty is taken into consideration as much as possible. However, before firm conclusions can be drawn regarding the modelling outputs, further dedicated and systematic data collection is required from the site and neighbouring habitats.

3. Habitats and Ecosystems

3.1. The Proposed Windfarm Site

Based on the site visit and aerial imagery (Google Earth), the environment within the project footprint consists primarily of improved pasture, with some plantation pine, coastal dunes with areas of 'rough' vegetation, a small number of drains and stock ponds, and some small, highly modified wetland areas.

The range of habitats attractive to native species is therefore quite limited in terms of native forest and shrublands, but there are numerous small ponds, dune lakes and wetland areas that provide potential habitat for a range of waterbirds and cryptic wetland species.

3.2. The Surrounding Landscape

The site lies within a mixed landscape of improved and highly productive farmland, as well as a diversity of high value habitats for indigenous fauna. They are:

- The coastal and oceanic environment to the west;
- The Waikato River mouth, sandbar and spit, and Port Waikato;
- The lower Waikato River and delta wetlands;
- The inland dunes running from the Manakau Harbour mouth to the Waikato River mouth, and within which the site lies;
- The Aka Aka floodplains to the east;
- Known and potential flyways for domestic and international migrants.

The following sections summarise current knowledge of these environments.

3.3. Coastal and Oceanic Environment

Forest & Bird Important Birds Areas (IBAs) for seabirds. We have considered the WWF against three IBA reports as follows:

3.3.1. Seabirds Rivers, Estuaries, Lagoons

Forest & Bird (2016): Important areas for New Zealand seabirds: Sites on land, rivers, estuaries, coastal lagoons, and harbours. The Royal Forest & Bird Protection Society of New Zealand, Wellington, New Zealand

The proposed wind farm site falls outside the nearest IBA.

3.3.2. Seabirds on Land

Forest & Bird (2015): Important areas for New Zealand seabirds: Sites on land, coastal sites, and islands. The Royal Forest & Bird Protection Society of New Zealand, Wellington, New Zealand.

The proposed wind farm site falls outside the nearest IBA.

3.3.3. Seabirds Offshore

Forest & Bird (2014a): Important areas for New Zealand seabirds: Sites at sea, seaward extensions, pelagic areas. The Royal Forest & Bird Protection Society of New Zealand, Wellington, New Zealand.

The proposed wind farm site falls within the NZ M003, West Coast North Island IBA site for seabirds.

The extent of the proposed West Coast IBA is shown in Figure 2.

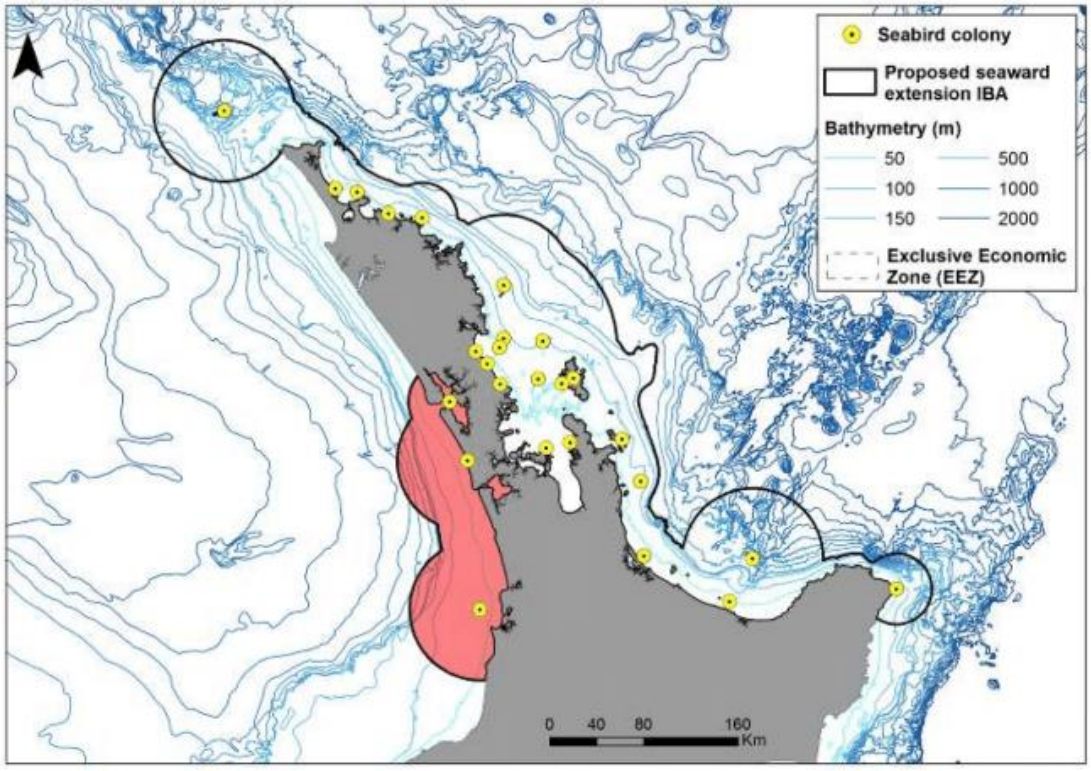


Figure 2: Proposed seaward extension of the west coast IBA (Source: Forest & Bird (2014a)).

3.4. Port Waikato and Waikato River Mouth

A report by Dowding (2019) identifies the Waikato River Mouth and associated beach, spit, and dune habitat as a Priority 2 Site (see page 79). A Priority 2 Site is defined as follows:

> *The site regularly holds one or more Threatened or At-Risk species or subspecies (but not at the 1% level), or values are insufficiently known but type of habitat, older data, and/or other factors suggest that this is very likely.*
>
> *The distal part of the sand spit at Port Waikato (shaded red) is used by variable oystercatchers and New Zealand dotterels for breeding, and by gulls, terns, and flocks of migrant shorebirds for roosting. The vegetated islands and river margins upstream of the mouth (shaded yellow) are likely to be important habitat for bitterns and other waterbirds, but there is little recent information (Dowding, 2019).*

We include the full discussion in Appendix 4 (page 74). Locations shown in Map 3.

Map 3 Coastal, estuarine, and riverine habitats including Karioitahi beach, the Waikato River mouth, sand bars and spit, Port Waikato mudflats, and the Waikato River delta wetlands. The proposed wind farm site top left with turbine locations shown.

3.5. Lower Waikato River and Delta Wetlands

This area has been included by Cromarty et.al. (1995) in their register of the most important wetland sites in New Zealand. The reasons for inclusion of this area within this national register were listed as:

"1a. The Lower Waikato River and Estuary are a particularly good example of a lowland river system with a diverse estuarine delta.

2a. The wetland supports populations of at least four globally threatened species of birds, notably *Poliocephalus rufopectus*, *Botaurus poiciloptilus*, *Charadrius obscurus* and *Anarhynchus frontalis*.

2b. The wetland supports a variety of plant and animal species which are uncommon or rare elsewhere in New Zealand (e.g., *Desmoschoenus spiralis*), and is thus of special value in maintaining the genetic and ecological diversity of the region.

2c. The wetland is of special value as breeding habitat for several uncommon species of birds, notably *Botaurus poiciloptilus*, *Haematopus unicolor*, *Charadrius obscurus* and *Stern caspia"*.

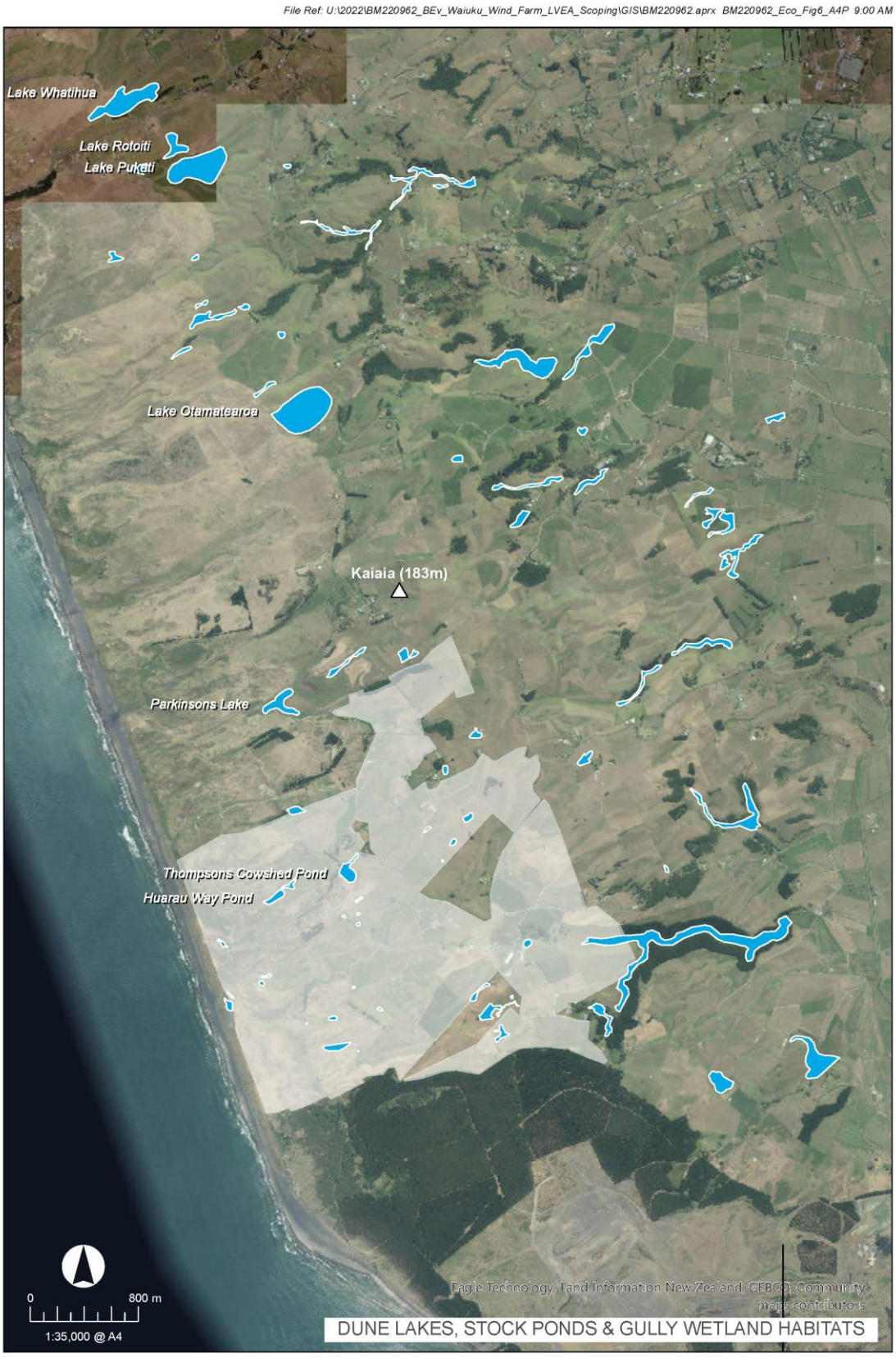
We include the full discussion in Appendix 4 (page 74).

Locations shown in Map 3.

3.6. Wetlands, Stock Ponds, Dune Lakes

The landscape surrounding the site appears to contain a number of linear wetlands in gullies, a number of small stock ponds, dune depressions that will be seasonally flooded, vegetated drains, and a small number of natural dune lakes and wetland slacks inland of the coast. We have attempted to identify these from aerial photographs in order to understand the extent of potential habitat (refer to Map 4).

These features will provide a mix of habitats sufficient to support small populations of waterbirds including shags, and potentially cryptic species such as spotless crake and bittern.



Map 4 Dune lakes, stock ponds and gully wetland habitats within the stable dune landscape surrounding the proposed wind farm site. The seven named lakes and ponds have had waterfowl, including dabchick and several species of shag, recorded. The proposed wind farm site and turbine locations are shown.

3.7. Migrant waders

3.7.1. Predicted migrant flyways nationally

The levels of migrant activity that may cross the WWF site are discussed in Southey (2009a, 2009a) who prepared the following indicative maps (Figure 3) based on observations from ornithologists throughout the country during migration events.

A report by Riegen & Sagar (2020) identified the key wader sites on the coastline of New Zealand, and included Site 21 Port of Waikato, noting that Northern New Zealand dotterel (*Charadrius obscurus*) occur mainly from Bay of Plenty and Port Waikato northwards (Figure 4)

Southey (2009b) does not identify Port Waikato as an important migrant destination but calculates that, based on data collected between 1994 and 2003; however, the Manukau Harbour contained the largest number of overwintering pied oystercatcher of all the northern harbours at up to 29,000 birds (SEM 1,938), which is a third of the national population. This is the number of birds likely to have traversed to and from the South Island along the North Island west coast of the North Island, past and potentially across, the proposed wind farm site. The other two thirds of this species will have continued up the coast to the Northland harbours such as Kaipara and Whangarei or crossed the North Island at some point on the migration to the Firth of Thames and the Tauranga Harbour.

Southey noted that the Manukau Harbour also contained the largest number of overwintering pied stilts (3,980 birds, SEM 376); the second largest number of wrybill (1,925 birds, SEM 239) and a relatively small proportion of banded dotterels (540 birds, SEM 73). With regard to international migrants, Southey calculated 16,859 (SEM 1,674) godwit settle in Manukau Harbour annually.

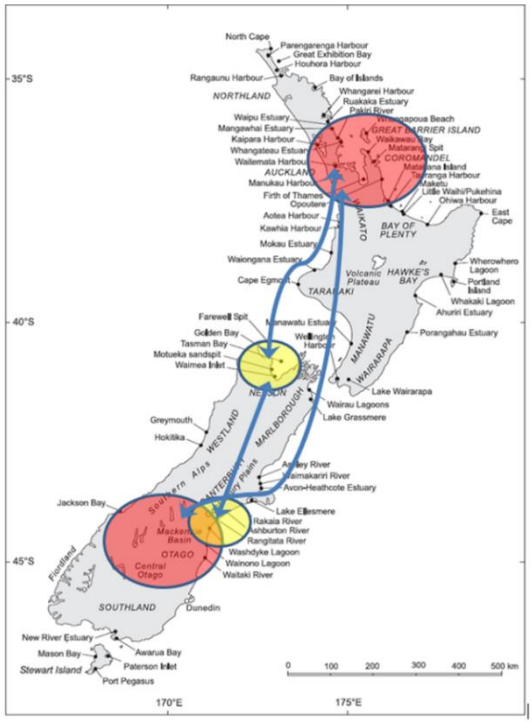


Figure 3: Predicted migration routes for national migrant birds between the North and South Islands (blue lines), showing key habitats (red) and secondary habitats in the South Island (yellow) (adapted from Southey 2009b).

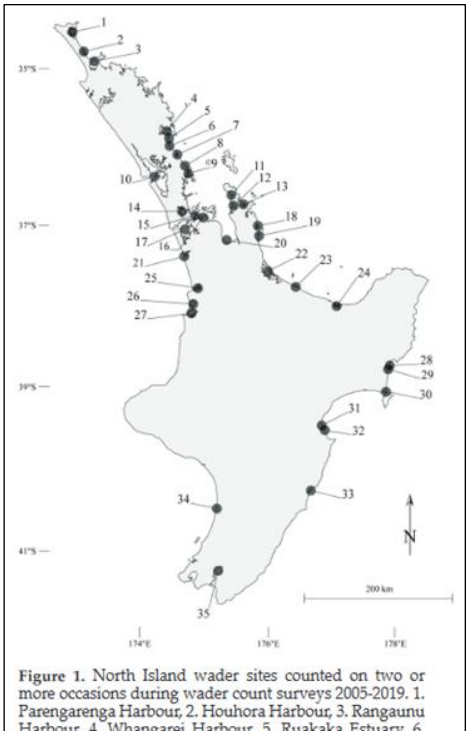


Figure 1. North Island wader sites counted on two or more occasions during wader count surveys 2005-2019. 1. Parengarenga Harbour, 2. Houhora Harbour, 3. Rangaunu Harbour, 4. Whangarei Harbour, 5. Ruakaka Estuary, 6.

Figure 4: North Island harbours utilised by migratory waders and shorebirds. Port of Waikato is Site 21 (Source: Riegen & Sagar 2020)

3.8. Local Knowledge

Local Ornithological Society members note the following key observations of recent bird activity within the Waikato River wetland delta complex and the river mouth beaches and sand dunes.

1. At the sand dunes on the Port there are currently (Spring 2022) two pairs of banded dotterel (*Charadrius bicinctus*), but only one pair has been successful thus far. That pair have two chicks which were banded in mid-October. 2022;
2. There are at least two pairs of NZ dotterel (*Charadrius obscurus*) attempting nesting within the Port Waikato sand dunes each year.;
3. Both NZ dotterel and banded dotterel are attempting to breed on the beaches south of Port Waikato, but there is not data on dotterel activity north of the Port. However, they could also be attempting to breed on these beaches too.
4. Probably the biggest breeding population of Australasian bittern (*Botaurus poiciloptilus*) in north-west Waikato is present in the Waikato River delta wetland complex, especially in the open, native-dominated swamp vegetation. These birds are regularly seen feeding on the edges of the river channels and drains north of the river mouth. About 10 booming males have been heard in recent years. DOC has also tracked a bird flying from Whangamarino over the lower Waikato and on to South Head (Kaipara). Bittern, appear to move around the farmland over winter.
5. There are increasingly isolated small populations of North Island fernbird (*Poodytes punctatus*), and spotless crake (*Zapornia tabuensis*), and banded rail (*Gallirallus philippensis*) in suitable habitat in this locality.
6. There are many shags in the Waikato River delta wetland complex including several large breeding colonies.
7. There is also often a flock of pied oystercatchers (*Haematopus finschi*) feeding on the paddocks at Aka Aka that may come and go from the Port - or the Manukau.
8. Very few petrels are seen offshore, or beach wrecks collected; the water is very shallow and maybe a bit fresh from the Waikato River.
9. There are approximately 100 godwit (*Limosa lapponica*) over summer on the northern spit of the Waikato River mouth.
10. About 40 royal spoonbill (*Platalea regia*) are resident upstream of the river mouth.

4. Waiuku Site Description

The site's environment consists primarily of improved pasture, with some plantation pine, coastal dunes with areas of 'rough' vegetation, a small number of drains and stock ponds, and some small, highly modified wetland areas.

The southern extent of the Awhitu Peninsula is situated in the Awhitu Ecological District and leads into the northern tip of the mouth of the Waikato River, rising some 100-120m above Karioitahi beach to the west and the Aka Aka floodplains to the east. The underlying soils and geology consist of terraced Pliocene and Holocene fixed dune sands which fall away relatively gently to the west of the central plateau watershed. To the east it also falls away into the farmland of the Aka Aka floodplain which, while now in pasture, is divided into numerous creeks and drains flowing into the northern end of the vast wetland complex of the Waikato River mouth.

The sand spit and beach heading north of the Port Waikato Township lies a couple of kilometres to the south of the site. Some 10km to the northeast, the Manukau Harbour can be seen from the high point of the site, while to the south, Mount Karioi can be viewed behind the immediate hills on the southern flank of the Waikato River mouth. These natural areas surrounding the site are key habitats for a variety of bird life, both resident and migratory.

The areas of the site visited are shown in photos below:

Photo 1 *Southern end of the site bounding the Waiuku Forest*

Photo 2 View form the site looking south. A small range (Tetehe 183m) extends westward into the sea in the distance. This indicates the main migratory route for most domestic migratory birds flying between the north-western harbours where they feed, and the South Island braided rivers where they breed.

Photo 3 Sand dune and coastal habitat to the west of the site

Photo 4 *Sand dunes and coastal edges along the west of the site*

Photo 5 *A variety of ponds and dune lakes, such as this are found within, or in close proximity to, of the site*

Photo 6 Parkinson's Lake, directly of the north of the site. Birds utilising habitats in the Port Waikato wetlands and Aka Aka flood plains may cross regularly over the site to utilise dune lakes such as this from time to time

Photo 7 Lake Otamatearoa, approximately 2km north of the Waiuku, and 3km south of Ahipara, where shags, Australasian swans and Canadian geese were observed.

Overall, habitats attractive to native species are quite limited within the site in terms of native forest and shrublands, but there are scattered small stock ponds, dune lakes, wetlands, and seasonally wet pasture that provide potential habitat for foraging and breeding of waterbirds and cryptic wetland species. These are shown in the following map (4Sight wetland survey results). The three waterbodies where shags and dabchick have been observed historically (EBird, n.d.) are named (Huarau Way Pond, Thompsons Cowshed Pond, and Parkinson's Lake) (Map 5). There are no records of avifauna observations at other ponds or wetland areas.

Map 5 Stock ponds, dune lakes, and pastoral wetlands that provide potential habitat for foraging and breeding of waterbirds and cryptic wetland species.

5. Identification of Local Avifauna

The following identification of indigenous birds likely present near or within the project site is based on several National datasets (EBird, n.d.; Miskelly, n.d.; C. J. R. Robertson et al., 2007) and several key publications and observational information.

The Study Area equates to six 10km x 10km grid squares, covering 30km of coastline and extending 10km inland and 10km offshore.

Once a master list of all potentially present species had been compiled it was then filtered to exclude firstly introduced species, and secondly all native Not Threatened species. This produced a preliminary list of key species.

5.1. Coastal, inland and wetland species

A total of 75 species have been identified within the study area; of these 25 are introduced and 50 are native. Of the native species, 21 are classified as Not Threatened under the New Zealand Threat Classification System (H. A. Robertson et al., 2021). The remaining 29 species have a conservation status of Threatened, At Risk or Migrant (protected under international convention).

We do not consider that any of the introduced species require further consideration, however, for a full list of all birds recorded within the study area see Appendix 1.

Table 1 presents the results for the 50 native species observed on site separated into five 10 x 10km areas defined in the eBird Atlas (see Section 2.1). Two areas include the site, AG66 and AG67 (shaded) and the birds found in each can be determined from this table.

Table 1: All native and endemic birds recorded within the Study Area, and which may be present at proposed Waiuku Wind Farm site. Observations are separated into the eBird grid where the observations occurred. National Conservation status shown (Robertson et.al., 2021). Sorted by common name.

		Coast north of Site	Manukau Harbour	The Site Coastline & dunes	The Site Inland farm	Port Waikato, harbour
Name	National Conservation Status	AF66	AF67	AG66	AG67	AH67
Arctic Skua	Migrant (non-resident native)					y
Australasian Bittern	Nationally critical	y			y	y
Australasian Gannet	*Not threatened*	y	y	y		y
Australasian Harrier	*Not threatened*	y	y	y	y	y
Australasian Shoveler	*Not threatened*		y		y	y
Banded Dotterel	At Risk - Declining					y
Banded Rail	At Risk - Declining	y				
Bar-tailed Godwit	At Risk - Declining		y			y
Black-backed Gull	*Not threatened*	y	y	y	y	y
Black Petrel	Nationally Vulnerable					
Black Shag	At Risk Relict		y	y	y	y
Black Swan	*Not threatened*	y	y	y	y	y
Black-billed Gull	At Risk Declining		y	y	y	y
Caspian Tern	Nationally vulnerable	y	y	y	y	y

		Coast north of Site	Manukau Harbour	The Site Coastline & dunes	The Site Inland farm	Port Waikato, harbour
Name	National Conservation Status	AF66	AF67	AG66	AG67	AH67
Cattle Egret	Migrant (non-resident native)		y		y	
Fluttering Shearwater	At Risk - Relict			y		
Grey Duck	Nationally vulnerable				y	y
Grey Teal	*Not threatened*		y		y	y
Grey-faced Petrel	*Not threatened*					
Grey Warbler	*Not threatened*	y	y	y	y	y
Little Black Shag	At Risk - Naturally Uncommon	y	y	y	y	y
Little Shag	At Risk - Relict	y	y	y	y	y
Long-tailed Cuckoo	Nationally vulnerable				y	
Morepork	*Not threatened*	y	y	y	y	y
New Zealand Dabchick	Nationally increasing	y	y	y	y	
New Zealand Dotterel	Nationally increasing		y			y
New Zealand Kingfisher	*Not threatened*	y	y	y	y	y
New Zealand Pigeon	*Not threatened*	y	y	y	y	y
New Zealand Pipit	At Risk - Declining	y		y	y	y
North Island Fantail	*Not threatened*	y	y	y	y	y
North Island Fernbird	At Risk - Declining				y	
North Island Kaka	At Risk - Recovering	y				
Paradise Shelduck	*Not threatened*	y	y	y	y	y
Pied Oystercatcher	At Risk - Declining	y	y		y	y
Pied Shag	At Risk - Recovering	y	y	y	y	y
Pied Stilt	*Not threatened*		y	y	y	y
Pukeko	*Not threatened*	y	y	y	y	y
Red-billed Gull	At Risk Declining	y	y	y	y	y
Reef Heron	Nationally endangered		y			
Royal Spoonbill	At Risk - Naturally uncommon		y		y	y
Shining Cuckoo	*Not threatened*	y	y	y	y	y
Silvereye	*Not threatened*	y	y	y	y	y
Spotless Crake	At Risk - Declining				y	
Spur-winged Plover	*Not threatened*	y	y	y	y	y
Tui	*Not threatened*	y	y	y	y	y
Variable Oystercatcher	At Risk - Recovering	y	y	y		y
Welcome Swallow	*Not threatened*	y	y	y	y	y
White-faced Heron	*Not threatened*	y	y	y	y	y
White-fronted Tern	At Risk - Declining	y	y	y		y
Wrybill	Nationally increasing					y

Table 2 presents the 29 native and endemic birds identified in Table 1, which have a national threat classification of Threatened or At Risk, or which are international migrants. They are presented with the known habitat preferences of each.

Table 2: Native and endemic birds recorded withing the study area which may be present at the proposed Waiuku Wind Farm site. National conservation status shown (Robertson et al., 2021). Sorted by preferred habitat (Heather & Robertson, 2015).

Species Name	National Conservation Status	Oceanic	Coastal / Estuary	Freshwater / wetlands	Scrub / shrubland	Farmland / open country	Native forest	Exotic Forest	Urban/Residential
Black Petrel	Threatened - Nationally vulnerable	■							
Fluttering Shearwater	At Risk - Relict	■							
Arctic Skua	Migrant (non-resident native)	■	■						
White-fronted Tern	At Risk - Declining		■						
New Zealand Dotterel	Threatened - Nationally Increasing		■						
Reef Heron	Threatened - Nationally Endangered		■						
Royal Spoonbill	At Risk - Naturally Uncommon		■						
Bar-tailed Godwit	At Risk - Declining		■						
Caspian Tern	Threatened - Nationally Vulnerable		■	■					
Wrybill	Threatened - Nationally Increasing		■	■					
Black-billed Gull	At Risk - Declining		■	■		■			
Red-billed Gull	At Risk - Declining		■	■		■			
Variable Oystercatcher	At Risk - Recovering		■	■		■			
Banded Dotterel	At Risk - Declining		■			■			
Australasian Bittern	Threatened - Nationally Critical		■	■					
Banded Rail	At Risk - Declining		■	■					
Black Shag	At Risk - Relict		■	■					
Little Black Shag	At Risk - Naturally Uncommon		■	■					
Little Shag	At Risk - Relict		■	■					
Pied Oystercatcher	At Risk - Declining		■	■		■			
North Island Fernbird	At Risk - Declining		■	■					
Pied Shag	At Risk - Recovering		■	■					
Spotless Crake	At Risk - Declining		■	■					
New Zealand Dabchick	Threatened - Nationally Increasing			■					
Grey Duck	Threatened - Nationally Vulnerable			■		■			
New Zealand Pipit	At Risk - Declining		■	■		■			
Cattle Egret	Migrant (non-resident native)					■			
North Island Kaka	At Risk - Recovering						■		
Long-tailed Cuckoo	Threatened - Nationally vulnerable						■		

5.2. International Migrants & Vagrants

In addition to the four migrants that have been observed within the study area (bar tailed godwit, cattle egret, long-tailed cuckoo, and arctic skua) as listed in Table 1, there are six additional international migrants not seen within the study area, but which are present within the northern harbours and may traverse near or across the site. They are:

Table 3: International migrants, not seen within the study area but which may travers the site. National Conservation status shown (Robertson et.al., 2021). Sorted by common name.

Species Name	National Conservation Status	Oceanic	Coastal / Estuary	Freshwater / wetlands	Scrub / shrubland	Farmland / open country	Native forest	Exotic Forest	Urban/Residential
Red knot	At Risk - Declining								
Pacific golden plover	Migrant								
Red-necked stint	Migrant								
Ruddy turnstone	Migrant								
Little whimbrel	Vagrant								
Oriental plover	Vagrant								

5.3. Seabirds

Four native seabird[4] species have been observed within the study area as listed in Table 1 (black petrel, fluttering shearwater, Australasian gannet, and grey-faced petrel). However, ongoing tracking studies that are being carried out by a number of researchers (https://data.seabirdtracking.org/) have shown that a number of seabird species make regular movements between the Hauraki Gulf, across the New Zealand mainland, to the west to forage in the Tasman Sea[5].

Post construction avifauna monitoring has also confirmed records of turbine collisions (Appendix 10) with two seabird species, one a fairy prion (At Risk – Relict) at West Wind Wind Farm (Wellington), and one a broad-billed prion (At Risk – Relict) at Waipipi Wind Farm (South Taranaki). Both of these species have very large populations and the observed losses at these two sites would not have resulted in an adverse effect on their populations. It does, however, highlight that seabird species flight paths do cross land and at RSA height, and are therefore at risk of turbine collision.

The Hauraki Gulf supports twenty species of seabirds (about a third) of New Zealand's seabird species as described in New Zealand Seabirds: Important Bird Areas and Conservation (2014b). Of these twenty species, the group we suggest require further discussion are those which have a limited population, and either only breed in the Hauraki Gulf or the Hauraki Gulf is a stronghold for that species. We suggest that this includes the following 8 additional species.

[4] Defined as a bird that lives near the sea and gets is food primarily from the ocean (beyond the intertidal or surf zone)

[5] https://data.seabirdtracking.org/dataset

Table 4: Key seabird species which have not been recorded within the study area, but which may traverse the proposed Waiuku Wind Farm site. National conservation status shown (Robertson et al., 2021). Sorted by preferred habitat (Heather & Robertson, 2015).

Species Name	National Conservation Status	Oceanic	Coastal / Estuary	Freshwater / wetlands	Scrub / shrubland	Farmland / open country	Native forest	Exotic Forest	Urban/Residential
NZ storm petrel	Threatened - Nationally vulnerable								
Sooty shearwater	At Risk - Declining								
Little shearwater	At Risk - Recovering								
Pycroft's' petrel	At Risk - Recovering								
Common diving petrel	At Risk - Relict								
Cook's petrel	At Risk - Relict								
Flesh-footed shearwater	At Risk - Relict								
White-faced storm petrel	At Risk - Relict								

6. Identification of Key Species

6.1. Coastal, inland and wetland species

In Table 5 all birds identified in Section 5 (Table 2) are assessed based on information available on local distribution, habitat preferences, key behaviours, and level of knowledge with a focus on data poor species. Appendix 11 contains supporting eBird records for each species.

From this we attempt to confirm whether each species should be considered at risk of adverse effects of the wind farm, and which should therefore be considered key species for this assessment.

Table 5: Analysis of likely risk to Threatened and At Risk species by the proposed Waiuku Wind Farm area; shorebirds, domestic migrants, water birds, and terrestrial species (Sorted by threat status)

Species	Analysis of available data and risk profile
Australasian Bittern *Botaurus poiciloptilus* (Threatened – Nationally critical)	The Waikato River wetland delta is known to be a stronghold for this species. Bittern can also range widely within the local landscape to forage and is known to traverse long distances between wetlands seasonally. eBird shows most bittern observations are on accessible margins of the delta wetlands or on low lying pasture between Otaua and Aka Aka, up to 1.5k from the wetlands. There is also one observation in a small dune lake 18km north of the Waiuku site. **A species of concern**
Reef heron *Egretta sacra* (Threatened – Nationally endangered)	This species has not been recorded along this section of coastline or within the Waikato River estuary. It has been frequently observed on the margins of the Manukau Harbour and birds will be occasionally traversing along this section of coast during seasonal movements between harbours. However we do not consider that these movements will be occurring with sufficient frequency that this species will be at risk of turbine collision. **Not a species of concern**
Caspian Tern *Hydroprogne caspia* (Threatened – Nationally vulnerable)	Caspian tern have been recorded on the coast near the site, along the lower Waikato River, and at the river mouth. There is little habitat to attract this species within the site but these terns range widely, especially following breeding and it is likely they will traverse the site from time to time. **A species of concern**
Grey Duck *Anas s. superciliosa* (Threatened – Nationally vulnerable)	The placement of pārera / grey duck (*Anas superciliosa*) in the national threat classification is problematic because of ongoing extensive hybridisation with mallards (*Anas platyrhynchos*) For most observers it is extremely difficult to distinguish pure birds from hybrids, the hybrids between the two are not threatened (H. A. Robertson et al., 2021). For these reasons we have chosen not to assess this species. **Not a species of concern**
New Zealand Dabchick *Poliocephalus rufopectus* (Threatened – Nationally increasing)	This species has been recorded at most large ponds and dune lakes along this section of coastline, including observations at three locations within or immediately adjacent to the site. **A species of concern**
New Zealand Dotterel *Poliocephalus rufopectus* (Threatened – Nationally increasing)	Known to be present on the sandspit at the Waikato River mouth and to breed there. Not recorded on Karioitahi beach in front of site. Do fly inland to forage in pasture on occasion. **A species of concern**

Species	Analysis of available data and risk profile
Wrybill *Anarhynchus frontalis* (Threatened – Nationally increasing)	Domestic migrant to and from Manukau Harbour and other northern harbours. Will be crossing over and near the site. Known to roost in small numbers in the Waikato River mouth and estuary. eBird observations are all at the river mouth and spit. Four observations of between 1 and 5 birds. No observations inland or along the beaches to north or south. May move between costal sites during winter stopover. **A species of concern**
Banded Dotterel *Charadrius bicinctus* (At Risk - Declining)	Domestic migrant but Manukau Harbour not a key destination. Known to be present and breed on the sandspit at the Waikato River mouth. Not recorded on Karioitahi beach in front of site. Do fly inland to forage in pasture on occasion. Like pied oystercatcher and wrybill it will be traversing. **A species of concern**
Banded Rail *Gallirallus philippensis* (At Risk - Declining)	Banded rail is a largely estuarine and coastal scrub dwelling species, which could be present within the locality. However, none have been observed by local ornithologists in the vicinity of the site. Habitat within the site does not appear to be sufficient for this species to be resident. **Not a species of concern**
Black-billed Gull *Chroicocephalus bulleri* (At Risk - Declining)	Recorded on coast near site, Waikato River, and river mouth. May traverse site from time to time. **A species of concern**
Pied oystercatcher *Haematopus finschi* (At Risk - Declining)	Domestic Migrant. Manukau Harbour is a nationally significant overwintering site. Has been observed along coastline, at the spit and inland utilising farmland to shelter / roost. The line of habitat connecting Port Waikato and the southern arm of Manukau Harbour is obvious. A proportion of birds will cross this site during each migration with an expectation of ongoing mortalities. **A species of concern**
New Zealand Pipit *Anthus novaeseelandiae* (At Risk - Declining)	This native species is almost always present at rural wind farm sites, however, post construction monitoring has so far not recorded a single collision mortality. Our observations from other wind farm sites are that this species typically stays close to the ground and is rarely seen flying up to turbine height. **Not a species of concern**
North Island Fernbird *Poodytes punctatus* (At Risk - Declining)	Fernbird are present in many lower Waikato wetlands. There is no appropriate habitat within the site, but it may be in scrubby habitat and back dune wetlands s adjacent to the site but likely only in low numbers. Our observations of fernbird in Whangamarino are that it flies close to the ground and unlikely to fly to turbine height. **Not a species of concern**
Red-billed Gull *Larus novaehollandiae* (At Risk Declining)	Recorded on coast near site, Waikato River, and river mouth. May traverse site from time to time. **A species of concern**
Spotless Crake *Porzana tabuensis* (At Risk - Declining)	This species has not been observed locally. However it is highly secretive, and habitat is limited to densely vegetated wetlands and lake margins. While habitat within site does not appear to be sufficient for this species to be resident, there are wetlands and dune lakes in proximity with suitable habitat, and kit is likely to be found in relatively high numbers within the Waikato River delta wetlands. Regional research indicates that this species moves between wetlands on the west coast of the Waikato region and so may traverse site on occasion.

Species	Analysis of available data and risk profile
	There is likely to be a population at the Waikato River delta wetlands which could also utilise wetlands, dune lakes, ponds within and adjacent to the site. **A species of concern**
White-fronted Tern *Sterna striata* (At Risk – Declining)	eBird observations are along coast below the site and at the Waikato River mouth and spit which are considered a hotspot. Numbers vary from small groups of up to 700 along the coast, to some very large gatherings of up to 2,200 birds on the spit. Do fly inland to open pasture to rest, shelter. **A species of concern**
North Island Kaka *Nestor meridionalis* (At Risk -Recovering)	Community from Little Barrier, utilising urban parks and northern forests of the Waitakere Ranges. Not common on the west coast but has been observed in Raglan. Habitat limited to forested landscapes which do not exist within the project footprint. **Not a species of concern**
Pied Shag *Phalacrocorax varius* (At Risk - Recovering)	Widely present on Waikato River and river mouth, and in ponds and dune lakes within coastal environment and the river wetland delta. A species that traverses daily from roost to feeding areas. Cormorants known to be At Risk species. **A species of concern**
Variable Oystercatcher *Haematopus unicolor* (At Risk – Recovering)	Seen along coast below site and Waikato River mouth considered hotspot. Often seen in coastal farmland. **A species of concern**
Little Black Shag *Phalacrocorax sulcirostris* (At Risk - Naturally Uncommon)	Widely present on Waikato River and river mouth, and in ponds and dune lakes within coastal environment and the river wetland delta. A species that traverses daily from roost to feeding areas. Cormorants known to be At Risk species. **A species of concern**
Royal Spoonbill *Platalea regia* (At Risk - Naturally Uncommon)	Adult royal spoonbills undertake repeated seasonal inter-island migration, moving north to wintering sites (mainly Parengarenga, Rangaunu and Whangarei), then relocating to the south again in summer to breeding sites, mostly in the South Island. The species may traverse across the site on migration flights. However, spoonbill are a species exclusively adapted for estuarine feeding, the number of birds in New Zealand is low and the possible migration flight path broad. Thus it is considered that this species is only rarely likely to fly over the site. **Not a species of concern**
Black Shag *Phalacrocorax novaehollandiae* (At Risk – Relict)	Widely present on Waikato River and river mouth, and in ponds and dune lakes within coastal environment and the river wetland delta. A species that traverses daily from roost to feeding areas. Cormorants known to be At Risk species. **A species of concern**
Little Shag *Microcarbo melanoleucos* (At Risk – Relict)	Widely present on Waikato River and river mouth, and in ponds and dune lakes within coastal environment and the river wetland delta. A species that traverses daily from roost to feeding areas. Cormorants known to be At Risk species. **A species of concern**
Game birds	The Waikato River delta wetlands provides a vast network of habitat for many exotic and native waterfowl and other gamebirds (such as Canada geese). There are a number of ponds and wetlands within and adjacent to the site which will be regularly utilised by a range of waterfowl species. While an important resource for gamebird hunting, none of the waterfowl and/or gamebird species found in this locality are At Risk or Threatened species. **Group not investigated further**

6.2. International Migrants and Vagrants

Table 6 provides an analysis of the likely risk to 10 migrants and vagrants to New Zealand.

Four of these species have been seen within the study area (bar-tailed godwit, long-tailed cuckoo, cattle egret, and Arctic skua). The remaining six species, while not seen within the study area, are present within the northern harbours and may occasionally traverse the site. Appendix 11 contains supporting eBird records for each species.

Our analysis of risk to this group follow.

Table 6: Analysis of likely risk to international migrant species by the proposed Waiuku Wind Farm area (Sorted by threat status)

Species	Analysis of available data and risk profile
Long-tailed Cuckoo *Eudynamys taitensis* (Threatened – Nationally vulnerable)	Migrates from the pacific but often travels at night so unlikely to be observed. May be a very rare visitor, but no appropriate habitat. eBird shows only two observations in the area, both at some distance from the site. The site does not contain habitat that would attract this species. **Not a species of concern**
Bar-tailed Godwit *Limosa lapponica baueri* (At Risk - Declining)	Local NZ Bird observers report up to 100 godwits on the Waikato River estuary Port Waikato mudflats over summer months. eBird also shows a number of observations at the Waikato River Mouth and Port Waikato mudflats, and this species overwinters in large numbers in the Manakau Harbour. This species was observed at both HMR. It was estimated that of the national population of up to 80,000, a worst case would be for 10,000 to traverse HMR (Caucus statement, 2010). **A species of concern**
Red Knot *Calidris canutus* (At Risk – Declining)	The global population is around 900,000 birds across six breeding regions. The NZ population is estimated at 30,000. Found widely around the large harbours and estuaries of the North Island, but only a few are seen in the Waikato. eBird has no records within the study area but birds are seen regularly within Manakau Harbour. Three were seen during migration surveys at HMR. **Not a species of concern**
Arctic Skua *Stercorarius parasiticus* (Migrant)	Secure overseas and does not breed in New Zealand. Seen in small groups or individually along the New Zealand coastline. The New Zealand population size is unknown. eBird has a single arctic skua observation at the Waikato River Spit. The majority of local observations have been near Manakau Harbour mouth, and within the Hauraki Gulf. **Not a species of concern**
Pacific golden plover *Pluvialis fulva* (Migrant)	The total global population of Pacific golden plover is estimated to be 190,000 - 250,000 individuals with 300-1200 birds migrating to New Zealand. They are widespread and usually occur as small flocks of 10-50 birds at harbours and estuaries, plus some lowland lakes. eBird has no records within the study area but several observations within the Manakau Harbour. Not seen during the migration monitoring at HMR or Taharoa. **Not a species of concern**
Red-necked stint *Calidris ruficollis* (Migrant)	World population about 325,000 birds, about 270,000 reaching Australia annually, and 50-200 reaching New Zealand. Found at scattered, coastal sites throughout New Zealand,

	eBird has no records within the study area but several observations within the Manakau Harbour. Not seen during the migration monitoring at HMR or Taharoa. **Not a species of concern**
Ruddy Turnstone *Arenaria interpres* (Migrant)	The total global population of the ruddy turnstone is estimated to number 460,000 - 730,000 individuals, with 1,000 - 3,000 birds reaching New Zealand annually. eBird has no records within the study area but several observations within the Manakau Harbour. Not seen during the migration monitoring at HMR or Taharoa. **Not a species of concern**
Cattle Egret *Bubulcus ibis* (non-resident native)	First recorded in NZ in 1963 and increased in numbers since. A species that is predominantly found in damp pasture, and associate with cattle and, occasionally sheep. Occasionally observed along the Waikato River and in the Aka Aka floodplain. Little habitat within the site to attract it. **Not a species of concern**
Little whimbrel *Numenius minutus* (Vagrant)	Little whimbrels usually a single bird occur in New Zealand every year or two. eBird has no records within the study area or the Manakau harbour. Not seen during the migration monitoring at HMR or Taharoa. **Not a species of concern**
Oriental plover *Charadrius veredus* (Vagrant)	There have been about 19 accepted sightings of oriental dotterels in New Zealand since the first sighting of 3 birds in the Kermadec Islands in April 1908. eBird has no records within the study area or the Manakau harbour. Not seen during the migration monitoring at HMR or Taharoa. **Not a species of concern**

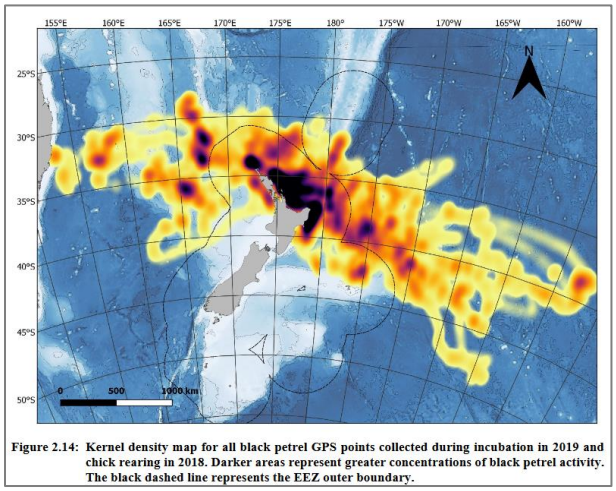
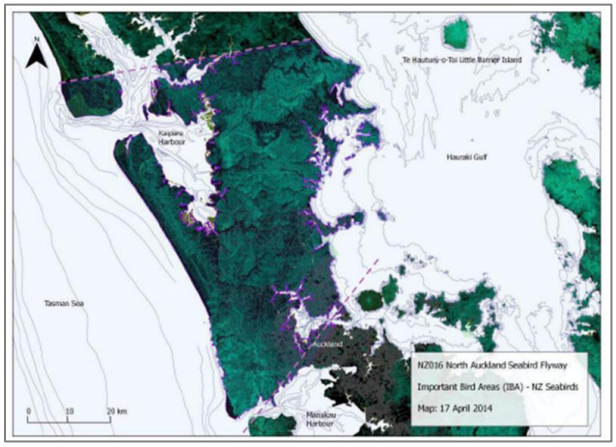
6.3. Seabird species

Table 7 lists 12 seabird species, two of which were observed within the study area, and the other ten being species which are abundant within the Hauraki Gulf which are of high ecological value based on value criteria of Roper-Lindsay et al. (2018). There is a possibility some of these species will cross the site.

The table draws on data from several sources (Bell et al., 2020; EBird, n.d.; Gaskin & Rayner, 2017; Miskelly, n.d.; Royal Forest and Bird Protection Society of New Zealand, 2014b) to understand their flight movements, known breeding locations, observed coastal distribution, estimates of population size (for most this is not known), and any other matters that may put them at risk of collision.

Table 7: Analysis of likely risk to Threatened and At Risk seabird species by the proposed Waiuku Wind Farm area (Sorted by threat status)

Species	Analysis of available data and risk profile
NZ storm petrel *Fregetta maoriana* (Nationally Vulnerable)	A NZ and regional endemic species. Once thought extinct and rediscovered in 2003 at sea in the Hauraki Gulf. This endemic species only breeds under tall forest in the interior on Little Barrier Island. It is believed that the national population is around 2,000 birds. All eBird observations of this species are north of Little Barrier Island, but observations over sea are limited.
Black petrel *Procellaria parkinsoni* (Nationally Vulnerable)	This NZ endemic only breeds on Great Barrier and Little Barrier Islands, and the population sits at 5,000 breeding pairs. It is known to cross the North Island mainland to feed in the Tasman Sea.

	The following figure shows distribution of black petrel activity during breeding. During breeding the majority of foraging occurs on the east coast but some birds traverse to the west coast, either by passing north cape or by traversing the North Island (Bell et al., 2020).  **Figure 2.14: Kernel density map for all black petrel GPS points collected during incubation in 2019 and chick rearing in 2018. Darker areas represent greater concentrations of black petrel activity. The black dashed line represents the EEZ outer boundary.**  Finally, a black petrel flyway across Auckland City and Kaipara Harbour has been identified by Forest and Bird (2014). This map suggests a peak of activity over this zone, although petrel will be crossing over a wider zone than is shown.
Sooty shearwater *Puinus griseus* At Risk - Declining	The NZ native species is one of the most widely distributed seabirds in the world. In addition to breeding in New Zealand, it also breeds on islands off Australia, Chile, and the Falklands. Known to traverse the North Island mainland (https://data.seabirdtracking.org/). It is estimated that the world population exceeds 20 million birds.
Little shearwater *Puffinus assimilis haurakiensis* At Risk - Recovering	*Puffinus assimilis haurakiensis is one of four subspecies of little shearwater and a regional endemic.* In addition to the Kermadec Islands, the breeding islands are scattered off the north-eastern coast of the North Island south to the northern Bay of Plenty (Taylor 2000). Known to traverse the North Island mainland (https://data.seabirdtracking.org/). The population size for this regional subspecies is thought to be in the order of 10,000 pairs
Pycroft's petrel *P. pycrofti* (At Risk – Recovering)	This NZ and regional endemic species breeds on several island groups from the Coromandel (Mercury), north of Hauraki (Hen and Chicken and Poor Knights) up to northern Northland (Ririwha Island group). The national population is estimated at 10,000 pairs or greater. Known to traverse the North Island mainland (https://data.seabirdtracking.org/). All coastal observations on eBird are from the east coast extending from Coromandel and to the Poor Knights Islands to the north. The nearest observation is from Motuora Island in the Hauraki Gulf.

Common diving petrel *Pelecanoides urinatrix* (At Risk – Relict)	NZ and regional endemic subspecies A species with large colonies in the Hauraki Gulf, but also breeds on other islands around the NZ coast. Current estimate is of > 1,000,000 pairs nationally. It is known to traverse the North Island mainland (https://data.seabirdtracking.org/), although the majority of activity available for the monitoring period shown is over the ocean east of the North Island.
Cook's petrel *Pterodroma cookii* (At Risk – Relict)	This NZ endemic species only breeds on Little Barrier and Great Barrier Islands. The national population is estimated at 300,000 breeding pairs. It is known to traverse the North Island mainland (https://data.seabirdtracking.org/) with tracks near this site with abundant activity both east and west of the North Island.
Flesh-footed shearwater *Puffinus carneipes* (At Risk – Relict)	This NZ native species nests on 15 islands around northern New Zealand and in Cook Strait, with the largest colonies on the Chickens and Mercury groups plus Ohinau and Karewa Islands. It also has colonies on Lord Howe Island, islands off Western Australia and on Ile St Paul in the Indian Ocean. It is known to traverse the North Island (https://data.seabirdtracking.org/). The total New Zealand population is unknown but may be in the order of 12,000 pairs (Baker et.al. 2010), with a global population in the order of 74,000 breeding pairs (Lavers 2015).
Fluttering shearwater *Puffinus gavia* (At Risk – Relict)	A NZ endemic species with at least 10 breeding populations in the Hauraki Gulf is breeds on islands within the Haruaki Gulf, but also breeds on other offshore islands around the New Zealand coastline. No firm population estimate but may be in the range of > 100,000 breeding pairs. It is known to traverse the North Island mainland (https://data.seabirdtracking.org/). This species has been observed once on Karioitahi beach north of the site. Breeds in many locations around the NZ coastline so is not restricted for breeding to this area.
White-faced storm petrel *Pelagodroma marina maoriana* (At Risk – Relict)	NZ endemic subspecies In New Zealand they are tied to their breeding colonies and often seen much closer to shore. on many small offshore islands all around the New Zealand coast, and on the Chatham and Auckland Islands. At least a million breeding pairs breed in the New Zealand region with at least six breeding populations in the Hauraki Gulf.
Australasian Gannet *Morus serrator* (Not Threatened)	The NZ native nests in dense breeding colonies on the New Zealand mainland and coastal rocks and islands, as well as off south-east Australia and Tasmania. At least six breeding colonies in the Hauraki Gulf. The New Zealand population was about 46,000 pairs in 1980-81 and has been increasing
Grey-faced petrel *Pterodroma (macroptera) gouldi* (Not Threatened)	This NZ native species has a world population estimated to be between 200,000 to 300,000 pairs. The largest colonies are on Moutohora Island and Hongiora Island in the Bay of Plenty with smaller colonies elsewhere. Importantly this species is one of the few burrowing petrels to still survive on the New Zealand mainland with small colonies scattered around the coasts of the upper North Island. On eBird it is recorded widely along both coastlines. This species is one that is likely to fly along this coastline and may come into contact with windfarms along this coast. We consider it unlikely to be breeding in the dunes between the site and Karioitahi beach which are too modified by grazing and associated farm activities for this species to be nesting (SeePhoto 3, page 16).

We note that this site constitutes a very small area relative to the total area of the upper North Island being traversed by these seabird species.

Based on our experience at other sites we can say with confidence there will be seabird mortalities from time to time at this project. The question is; will any of these species cross the site in numbers sufficient for there to not only to be occasional mortalities, but for there to be sufficient number of collisions to result in a population level effect. For those seabirds with very large populations (100,000+) and based on collision risk modelling for other coastal species, there would need to be a large number of ongoing traverses of the site, at the height of the rotor, to result in mortalities sufficient for there to be a population effect. For those species we consider the risk to be low. For species of smaller population size, the level of risk requires data which is not available for an assessment.

Overall, for this assessment, we suggest that seven species the size of the local populations, exceeding 50,000 pairs, make it unlikely for there to be a population effects. For these species we consider that collisions may occur, but the risk of significant effects are low. The seven species are;

- Sooty shearwater (At Risk – Declining);
- Common diving petrel (At Risk – Relict);
- Cook's petrel (At Risk – Relict);
- Fluttering shearwater (At Risk - Relict);
- White faced storm petrel (At Risk – Relict);
- Australasian gannet (Not threatened), and
- Grey-faced petrel (Not Threatened).

One species, the Arctic Skua is not considered to be at risk, being a migrant which is secure internationally, and which only occurs in low numbers around the NZ coastline.

Five species, however, have small populations (between 1,000 pairs and 12,000 pairs) have a restricted breeding range, and if they experience collisions are more likely to experience an adverse effect. They are:

- NZ storm petrel (Nationally Vulnerable);
- Black petrel (Nationally Vulnerable);
- Little shearwater sub species haurakiensis (At Risk - Recovering);
- Pycroft’s petrel (At Risk – Recovering), and
- Flesh-footed shearwater (At Risk – Relict).

We suggest these species, and seabirds generally, be given further consideration as part of the ongoing investigations for this application.

No further analysis is provided as there is insufficient data for collision risk modelling.

6.4. Confirmation of Key Species

Coastal, inland and wetland species

Based on the preceding analysis of Threatened and At Risk species we conclude that the key species which will be potentially affected, and which can be subject to collision risk modelling, are as follows:

Table 8: Final list of key species requiring further investigation at the proposed Waiuku Wind Farm area (sorted by Threat Status).

Name	National Conservation Status
Australasian Bittern	Threatened - Nationally critical
Caspian Tern	Threatened - Nationally vulnerable
New Zealand Dabchick	Threatened - Nationally increasing
Northern NZ Dotterel	Threatened - Nationally increasing
Wrybill	Threatened - Nationally increasing
Banded Dotterel	At Risk - Declining
Bar-tailed Godwit	At Risk - Declining
Black-billed Gull	At Risk - Declining
Pied Oystercatcher	At Risk - Declining
Red-billed Gull	At Risk - Declining
Spotless Crake	At Risk - Declining
White-fronted Tern	At Risk - Declining
Pied Shag	At Risk - Recovering
Variable Oystercatcher	At Risk - Recovering
Little Black Shag	At Risk - Naturally uncommon
Black Shag	At Risk - Relict
Little Shag	At Risk - Relict

In summary, and based solely on the desktop review carried out, we would summarise the results as follows:

- We do not think any of the species in this list are at risk of displacement, as there is very little indigenous habitat within the site to sustain populations of these species.
- However, the information suggests that approximately 17 native species could traverse or utilise habitat within the site sufficiently frequently for them to be at risk of collision.
- Of these 17, five have a conservation status of Threatened. The remainder are At-Risk.
- Twelve have a conservation status of At Risk, suggesting the impact of mortalities would be more able to be addressed, but mitigation would be required.

Seabird species

Based on the preceding analysis of Threatened and At Risk seabird species we conclude that the key species which will be potentially affected, and for which there is insufficient data for collision risk modelling, are as follows.

Table 9: Final list of key species requiring further investigation at the proposed Waiuku Wind Farm area (sorted by Threat Status).

Name	National Conservation Status
NZ storm petrel	Threatened - Nationally vulnerable
Black petrel	Threatened - Nationally vulnerable
Pycroft's' petrel	At Risk - Recovering
Little shearwater (ssp. haurakiensis)	At Risk - Recovering
Flesh-footed shearwater	At Risk - Relict

National Coastal Policy Statement

- The NZCPS (Department of Conservation, 2010), Policy 11, requires us to avoid adverse effects of activities on:
  - (i) indigenous taxa that are listed as threatened or at risk in the New Zealand Threat Classification System lists (DOC 2021);
  - (ii) taxa that are listed by the International Union for Conservation of Nature and Natural Resources as threatened (IUCN, n.d.);
- Looking at the species recorded in the study area, the IUCN red list identifies 3 species known to be present locally, and a further 4 species of seabird which may traverse the site, as being Threatened (Appendix 9, page 83).
- Of the key species listed in Table 8, three meet this requirement as shown in Table 10.

Table 10: Key native species identified as threatened in the IUCN Red List.

Common Name	New Zealand Conservation Status	IUCN Red List
Australasian bittern	Threatened - Nationally Critical	Vulnerable VU
Northern NZ dotterel	Threatened - Nationally Increasing	Critically endangered
Wrybill	Threatened - Nationally Increasing	Vulnerable
New Zealand storm petrel	Nationally Vulnerable	Critically Endangered
Black petrel	Nationally Vulnerable	Vulnerable
Pycroft's petrel	At risk - recovering	Vulnerable
Cook's petrel	At risk - relict	Vulnerable

7. Collision Risk Modelling Method (CRM)

7.1. Overview

Avian collision risk models are valuable tools used in the impact assessment of wind farms. In the UK, the most frequently used avian collision risk model is commonly known as 'the Band model' developed for onshore wind turbines (Band et al., 2007) and promoted as guidance by Scottish Natural Heritage (Scottish Natural Heritage, 2005). While all models have their limitations, the Band model has been trialed and improved over time and is generally considered to be statistically sound (Chamberlain et al., 2005; Masden & Cook, 2016). Avian collision risk models are a valuable tools used in the impact assessment of windfarms.

The model used for this strike risk analysis is a refined version of the Band model, tested through peer review (Christie & Urquhart, 2015) and technical expert review for the Hauāuru mā raki Wind Farm (HMR) wind farm consent application (Craig, J. L. et al., 2015).

7.1.1. Modelling Metrics

To run the model a range of metrics are required relating to each species of bird, to the turbines, and to the wind farm site and layout. They are:

Turbines

To determine the level of risk the wind farm would pose to resident, local, and migratory species, the following turbine metrics are required for the Band model:

- Number of turbines
- Number of blades
- Maximum chord (width of the blade) (m)
- Pitch (degrees)
- Rotor diameter (m)
- Rotation period (sec)
- Height to nacelle, and the upper and lower blade tip height (m)

Avifauna

The following information is required for each avifauna species for the modelling:

- Bird metrics (length, wingspan, speed of flight) of each species of concern;
- The size of each bird population at risk;
- The percent of birds within each population likely to cross the wind farm footprint;
- The percent of birds crossing the footprint which flies within the RSA (rotor swept area), and
- A turbine avoidance rate.

Other Metrics

- Turbine downtime; when wind velocity is too low or too high for generation and blades drift.
- Windfarm dimensions (width and area).

7.2. General approach to assessing vulnerable species mortality

The overall aim of the modelling is to assess the risk that the Waiuku Wind Farm poses to key bird species of concern, including those both resident and migrating through the Waikato flyway as identified in section 8.2. This has been undertaken by comparing the likely mortality of each species with mitigation review thresholds.

While available data is sparse and uncertainties can be large for some species, technical information is available from the developers, relevant physical data about the species has been gathered from the literature, information about bird behaviour, such as flight patterns and flight heights, has been gathered from published reports from other wind farms (notably the HMR site close by), there are recorded notes from local birders and eBird, and expert advice has been sought from professional ornithologists familiar with the area.

This background data used to populate the strike risk models is summarised in Sections 3 to 6 above.

The general application of this refined Band model uses the trail density calculated within the site based on available data and expert opinion on utilisation of the site based on this data. The strike risk analysis addresses with the uncertainties underlying the lack of on-site data using a Monte Carlo Risk Analysis (MCRA).

7.2.1. Trail density

The trail density concept was first developed for the HMR wind farm to deal with species with many short or erratic flights (Christie & Urquhart, 2015). The idea was subsequently adopted by the Scottish Natural Heritage as one of its Band model techniques (Scottish Natural Heritage, 2018). The idea works just as well with other flight patterns. The trail density concept was first developed for the HMR wind farm to deal with species with many short or erratic flights. The idea was subsequently adopted by the Scottish Natural Heritage as one of its Band model techniques (Scottish Natural Heritage, 2018). The idea works just as well with other flight patterns.

In its most straightforward form, it assumes that each bird of a species of interest leaves a permanent radar trail on a map as it flies round the general area for a year. The total length of the trails averaged over each 1 km^2 over one year is the trail density measured in total km of trail left per km^2 per year. Trail density has three attractive features:

- The trail density in the rotor zone can be used to calculate the number of birds flying through a turbine of given size each year. Assuming no avoidance we use Rotor zone flights per year flying through a turbine of diameter D = Trail density x $\pi/4$ x D
- If the flights are purposeful (crossing the farm to go from one place to another rather than, say, the looping patrol path of a harrier) then the trail density in km of trails over a km square is exactly the same as the linear trail density expressed as trails/km/yr. or flights/km/yr. over any front.
- Trail density relates to the general area round the farm and so it can provide a context in which decision making may be easier. For this exercise, we will consider the “general area” to be a 10 km2 block surrounding the farm, but in fact conditions in this area will be similar further up and down the coast.

Review of existing data and literature has allowed expert opinion to determine trail densities over the site for each key bird species.

The direct relationship between trail density and mortality helps us estimate a particular species' mortality and compare it with the Mitigation Review Threshold (MRT) set for Waipipi.

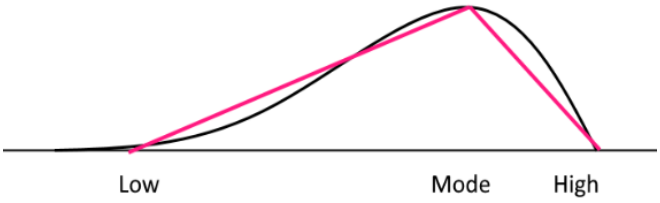
7.2.2. Monte Carlo Risk Analysis (MCRA)

All the mortality calculations have a degree of uncertainty. The underlying concept of a MCRA analysis is that uncertain model inputs are given a distribution of plausible values from which a random but plausible input is taken. A set of random inputs give a plausible scenario. The range of plausible scenarios gives a distribution of plausible mortalities. Statistical inferences about mortality can thus be made from this distribution.

The four important MCRA principles are: -

1. All randomly generated inputs must be plausible.
2. All plausible inputs must have some chance of being generated.
3. The likelihood of any particular input value being generated must reflect the likelihood of that value occurring in real life.
4. A 'worst case or precautionary analysis' is only undertaken once and at the end of the process.

MCRA inputs reflect a range of estimations because of a lack of on-site robust data, which would allow determination of the true values. Typically, there is a most likely value, and the likelihood drops off as we move away from this modal value. For what follows, we will use the triangular distribution. This approach can handle asymmetric distributions. The figure shows a curved distribution approximating a triangle. In the MC sheet we use here, a user defined Excel function is given by =Tri (low, mode, high). In this case, because of the absence of on-site quantitative data, the three numbers are determined by collaborative expert opinion utilising relevant available data and literature data, reference, or expertise.



7.2.3. Model Approach

The MCRA requires determination of the following inputs:

1. Estimation of key species trail density within the site. Robust data is from HMR is available for the migratory species. For resident species local data is used to estimate the number of flights over the site. A Monte Carlo input for the trail density is needed. Determination of trail density in the rotor swept area (RSA). An MCRA distribution for the percentage of flights in the rotor zone is needed.
2. Calculation of the number of turbine transits through 18 turbines per year using the formula above. (The distribution of turbines is not needed for this.) The MC input used is Tri (estimate/2, estimate, estimatex2).

3. Multiply by corrections for the avoidance rate, turbine risk, and turbine downtime. MC distributions are needed for each of these three inputs.
4. Record the generated mortality for, say, 2000 plausible scenarios.
5. Find the likely range of the mortality for the species. The middle 60% of the range gives a general idea, while we can be 80% sure that the mortality is less than the top of this range.

7.2.4. Model inputs

Monte Carlo inputs for resident species are as follows:

1. **Traverse rate:** The number of flights of the species over the 10 km^2 farm block per year. This is not always easy. Local birders notes and expert opinions can give a round figure.
2. **Combined trail length:** The total trail length can now be calculated from the number of transits through block x √10 km. (√10 is the average path length over the 10 km^2 block). The trail density can is found by dividing the total trail length by 10 km^2, the area of the block. Any migrant trail density is added at this stage. No MC distribution needed here.
3. **Rotor Swept Area (RSA):** The percentage of the trail density within the RSA. Data is available from five wind farms for some species. Where estimates are not available, we use the default Tri (25%, 50%, 75%) which reflects the range of all the reliable estimates for all species. If the species has a reliable range recorded, we use that.
4. **Individual Collision Risk:** Turbine strike risk is calculated from the bird and turbine metrics through the Band spreadsheet. The part of the model is described as only being accurate to 10%. We therefore use the calculated value plus or minus 1 percentage point.
5. **Determination of the avoidance rate (AR).** No species or group of birds published in the Band model recommendations has an AR less than 99% and some go as high as 99.8%. This is why the default rate can be safely set at 98% as a very precautionary figure. A more realistic value would be about the 99% mark. In fact we use Tri (98%, 99%, 99.8%) as a plausible input range. (Published lists of ARs do include the occasional 95% but these are not because 5% of preconstruction flights remain over the farm. The published notes for these numbers make it clear that these few species are at increased risk due to flight behaviour near the turbines (hovering is given as an example), not because there are more birds. The Band spreadsheet for these species gives a turbine risk which is unrealistically low. Rather than try to adapt the spreadsheet to increase the turbine risk to the correct levels for these species, it is easier to use the lower (wrong) spreadsheet risk as calculated, and artificially increase the number of birds in the area by using an inflated AR. We have no species of concern of this type).
6. **Turbine downtime.** We use the HMR figures with a suitable uncertainty band. Tri (11%,15%,19%).

For migratory species we have, in addition to the resident trail density, the migration trail density. Estimates are based on the trail density found at HMR from radar and extensive observer records with a suitable uncertainty. We now add this trail density to the local trail density at step 5 above.

7.2.5. Summary of Band Model Process

Table 11 provides a step-by-step explanation of the application of the Band Model to this site using the data for the pied shag.

Table 11: Explanation of the Band Model process used for this assessment.

Explanation	Example
Estimate of Traverse Rate	**Inputs**
Step 1: Estimate local population	51
Step 2: Estimate of proportion of population traversing the wind farm footprint	20%
Step 3: Calculation of birds at risk	10
Step 4: Estimate of frequency of traverses (day, month, season) e.g., daily return.	730 per bird / year
Step 5: Sum of traverses (This input undergoes a Monte Carlo simulation using a low, expected, and high estimation of the mean)	7,446 / yr.
Estimate of Trail Density	
Step 6: Length of full traverse	3.16 km
Step 5: Area of footprint	10.0 km2
Step 6: Combined trail length	23,529 km/yr.
Step 7: Trail density	2,356 km/km2/year
Collision Mortality Calculation	
Step 8: % flights at RSA (This input undergoes a Monte Carlo simulation using a low, likely, and high estimation of the mean with a spread which considers the sampling variability, e.g., 30%, 50%, & 65%)	50%
Step 9: Number of turbines	18
Step 10: Diameter of turbine blade	0.136 km
Step 11: Flights @ RSA per annum	2,265 / yr.
Step 12: Allow for individual collision risk without avoidance. This input undergoes a Monte Carlo simulation using a low, calculated, and high estimation of the mean, e.g., 5.6%, 6.6%, & 7.6%.	6.6
Step 13: Mortality with 99% avoidance. This input undergoes a Monte Carlo simulation using a low, likely, and high estimation of the mean. For this project we have used 98%, 99% and 99.8% for all birds.	99.0
Step 14: Allow for turbine downtime	15%
Step 15: Probability of mortality. The result of the Monte Carlo simulation process is to provide confidence intervals for this result. In this example the result is 80% confidence that mortalities will lie between 1 bird per annum and 2 birds per annum.	1.27 birds per annum.

7.2.6. Example - Pied Oystercatcher. An internal migratory species

Pied Oystercatcher is an important migratory species and large numbers will be traversing the site twice a year, arriving in the northern harbours in January/February post breeding, and returning to the breeding grounds in the South Island in July/August.

While in the northern harbours, which include the Waikato River mouth, they will be foraging locally and moving between roost sites, and so the analysis needs to consider movements of the local population, so we will also need a local analysis and combine the two.

We have good pied oystercatcher data from HMR in quite similar conditions nearby. At HMR, the average trail density totalled over the two migrations and averaged over all the clusters was about 7000 flights/km/yr. There are strong indications from the HMR radar data that some portion of the pied oystercatcher stream splits off before the Waikato River mouth (refer to section 8.2.1), so we use Tri (5000, 6000, 7000) as our trail density input.

For the local population, local data suggests about there will be about 90 pied oystercatcher flights over the farm block per year. The MCRA gives a probable mortality for the migrant pied oystercatcher in the range 2 to 4 deaths per year total combining both the resident and migrant movements.

Mortalities are given within a 20% to 80% range. Use of this band provides a "probable" range and indicates the general level of risk without giving the extreme possibilities.

7.3. Cumulative Effects

This assessment is a cumulative effects assessment, modelling both the proposed Waiuku site and the Awhitu Wind Farm separately, and then combining the results.

Awhitu Wind Farm lies to the north of Waiuku. To date 1 of 18 turbines has been installed at this site. Awhitu lies on the same landform as Waiuku, rolling coastal duneland. The boundaries of the two sites lie 5.3 km apart. Awhitu also sits between Waiuku and the mouth of the Manukau Harbour.

We note that the ecological impact assessment for Awhitu (Bioresearches, 2004) did not consider the site to present a risk to local birds, national or international migrants, however no collision risk modelling was carried out which could be used to support this assessment.

We have modelled a scenario that assumes both Waiuku and Awhitu are built, and which assumes both sites will have 18 turbines. We note that the Awhitu turbines are much smaller than those for Waiuku resulting in a higher collision risk due to closer spacing and faster blade speeds. However, the windfarm is also smaller (25%) than Waiuku reducing the number of traverses.

We have modelled the collision risk for the Awhitu Wind Farm, adjusting for differences in wind farm size and turbine metrics. Awhitu is a quarter the size of Waiuku and so we have also adjusted both individual collision risk and traverse rates to allow for this.

7.4. Assessing Magnitude of Effect

We have considered several options to assess the magnitude of adverse effects relating to varying rates of modelled collision mortality. All typically rely on an understanding of the local and national population size of each species, as well as their demographics (reproduction, survival etc.) none of which are available for most species at this site.

For simplicity, we chose to apply the mitigation review thresholds agreed with DOC experts at the Waipipi Wind Farm hearings. These thresholds relied on the threat status of each species as a surrogate for population estimates, applying an arbitrary quantum of mortalities against each species that would trigger a review of mitigation. We suggest that this list should not be considered definitive but should be considered a placeholder to be updated for each species when better data becomes available. This

is the reason pied oystercatcher, with a threshold of 10, differs from all other At Risk species which have a threshold of 5. For pied oystercatcher the risk to the national population was modelled and 10 or more annual mortalities was considered to result in a measurable effect to the national population over the life of the wind farm.

The mortality numbers chosen were conservative in the absence of data and applied to the group, not the individual, and so are likely to overstate the impact for some species. However, we consider use of this list the simplest approach to this assessment. The review thresholds are provided in Table 12.

Table 12: Thresholds used for the Waipipi Wind Farm for determining mitigation requirements (Condition 82).

CONSERVATION STATUS	Mitigation Review Threshold Mortalities / year
Nationally Critical	0.5
Nationally Endangered	0.5
Nationally Vulnerable	2
Nationally Increasing	5
Declining	5
Pied oystercatcher (Declining) [1]	10
Recovering	5
Relict	5
Naturally Uncommon	5

[1] Pied oystercatcher differs from all other At Risk species with a threshold of 10.

8. Collision Risk Modelling Metrics - Results

8.1. Modelling Metrics

8.1.1. Turbine metrics

We were asked to consider two potential wind turbines, a Vesta V136 and a Vesta V117 (Table 13). We ran simulations with both and determined that the V136 presented a higher risk to birds due to its greater swept area within the same footprint (136m blade as opposed to a 117m blade), and because the longer blades will extend higher and lower in areas of bird activity. We have therefore modelled the V136.

Table 13: Turbine parameters required for collision risk modelling, comparing the generic design modelled in 2016, and the turbine selected by TWPL for the wind farm design.

Turbine Parameters	Vesta V117 – 3.3 MW Option 1		Vesta V136-4.5MW Option 2	
Number of turbines	18	-	18	-
Number of blades	3	-	3	-
Maximum chord	4.0	m	4.1	m
Pitch (Variable)	7.5	degrees	6.5	degrees
Rotor diameter	117	m	136	m
Rotation period (Variable)	5	sec	4.8	sec
Rotor Swept Area	10,568	m^2	14,526	m^2

In addition, we have modelled a generic turbine for the Awhitu Wind farm as part of a cumulative effects assessment. (Table 14) The turbine being used at Awhitu is not known; however, the rotor diameter appears to be in the order of 62m m. The nearest turbine we have previously modelled is the GE1.5 with a blade length of 68m and we have used this as a surrogate. We note that the GE1.5 blade is half the length of the V136 and has one quarter the rotor swept area.

Table 14: Turbine parameters required for collision risk modelling, comparing the Waiuku Vesta V136 turbine, and an analogue for the Awhitu Wind Farm, the GE 1.5.

Turbine Parameters	Waiuku Wind Farm Vesta V136-4.5MW		Awhitu Wind Farm GE 1.5sle	
Number of turbines	18	-	18	-
Number of blades	3	-	3	-
Maximum chord	4.1	m	3.5	m
Pitch (Variable)	6.5	degrees	15	degrees
Rotor diameter	136	m	68	m
Rotation period (Variable)	4.8	sec	3.3	sec
Rotor Swept Area	14,526	m^2	3,631	m^2

8.1.2. Windfarm Metrics

The area and dimensions of the wind farms are required to calculate traverse rates. In terms of width and depth of the wind farms the Awhitu site is approximately half the size of the Waiuku site. (Table 15) In terms of area, the Awhitu wind farm is a quarter of the size of Waiuku. For simplicity the area which defines the wind farm is calculated as the maximum width multiplied by the maximum length of the wind farm layout.

Table 15: Dimensions of both the Waiuku site and the Awhitu site for calculation of flight density.

Turbine Parameters	Waiuku Wind Farm		Awhitu Wind Farm	
Length (north to south)	2.8	km	1.35	km
Depth (west to east)	2.3	km	1.25	km
Area (footprint surrounding turbines)	6.44	km2	1.69	km2

8.1.3. Avifauna metrics

Bird size and speed

Three flight metrics are required for the Band Model. They are body length, wingspan, and flight speed.

A full breakdown of the metrics of the 17 modelled species is provided in Appendix 6 (page 79). The metrics for body length and wingspan are derived predominantly from the *Handbook of Australian, New Zealand and Antarctic birds* (Various authors, 2006). For four bird's wingspan was not provided, nor could it be found by an internet search, and in these cases an analogue species was used.

Flight speed is only available for a small number of native birds. We have therefore relied on a variety of international sources selecting analogue species based on similarity (body weight, size, family-genus), to native birds.

For modelling, the range obtained for body length and wingspan are averaged. In doing so we note that minor variances in these three metrics have a relatively insignificant effect on the modelling outcome.

Flight height

One of the most important metrics required by the Band Model is the proportion of activity for each species which occurs at the height of the blade rotors. This varies widely between species from zero or close to zero for some species (NZ Pipit, NZ dotterel) to a value of 50% or greater.

A full breakdown of the metrics of the 17 modelled species is provided in Appendix 7 (page 81). In this appendix we have collated the flight height data from the reports of five windfarm projects which are West Wind (Bull et al., 2013), Taharoa (Fuller et al., 2009), HMR (Kessels & Associates Ltd, 2009), Waipipi (Boffa Miskell Ltd, 2019, p. 20), and Kaiwaikawe (Boffa Miskell Ltd, 2020).

In these reports we note the quality of data available for each species and provide a range of values for the modelling.

There is no data or very poor data for 4 of the 17 key species. Data for the remaining birds is adequate for several and good for the remainder. For all birds, we provide a range from low to high for the modelling. The range is based on the data where possible, or our knowledge of these species.

Individual Collision Risk

Using a combination of the turbine and bird flight metrics, the individual collision risk can be determined using the Band Model (see Appendix 5, page 76). This is a calculation which assumes the probability that a bird of a certain size and flight speed, flying through the rotor swept area will be struck by the blade. The calculation assumes that there is no avoidance behaviour. This calculation feeds into the Band Model.

Table 16: Individual Collision Risk for birds passing through a Vesta V136 and a GE1.5. Sorted by conservation status.

Key Species	Conservation Status	Vesta V136 – 4.5 MW Individual Collision Risk (%)	GE 1.5 Individual Collision Risk (%)
Bittern, Australasian	Nationally Critical	8.2	13.2
Tern, Caspian	Nationally Vulnerable	6.5	10.8
Dotterel, Northern New Zealand	Nationally Increasing	4.6	7.5
Wrybill	Nationally Increasing	5.1	8.4
Crake, Spotless	Declining	4.5	7.3
Dotterel, Banded	Declining	4.5	7.3
Godwit	Declining	4.7	7.9
Gull, Black-billed	Declining	5.1	8.3
Gull, Red-billed	Declining	5.8	9.7
Pied oystercatcher	Declining	6.0	10.0
Tern, White-fronted	Declining	5.7	9.3
Oystercatcher, Variable	Recovering	5.8	9.6
Shag, Pied	Recovering	5.9	9.5
Shag, Little Black	Naturally Uncommon	6.6	10.6
Shag, Black	Relict	6.2	10.0
Shag, Little	Relict	6.9	11.1

8.1.4. Avoidance Rates

The first stage of the CRM assumes that birds approaching a turbine do not attempt to avoid it. However, it is known that all birds have a significant avoidance behaviour. The CRM accounts for this by applying an avoidance rate.

The NatureScot guidance for use of the Band CRM provides recommended avoidance rates for a number of key species. The guidance is updated when robust new information becomes available. The 2018 version, referenced here, replaces previous 2010 and 2016 versions and is the most current available (NatureScot, 2018).

In this guidance an avoidance rate of 98% has been recommended for species where existing data is not available, however, for those where data is available avoidance lies between 98% and 100%. For this study we have chosen to do a Monte Carlo simulation of risk using low 98%, mode 99% and high 99.9%.

8.2. Population Estimates & Calculation of Traverse Rates

The key metric for the Band Analysis is the number of flights through the wind farm. However, there is poor to no data on the sizes of the local populations. We have therefore drawn on a range of sources to provide estimates of these values.

8.2.1. Use of HMR avifauna research to support inputs into the Waiuku models

Unless otherwise noted the following discussion draws on data obtained from the HMR avifauna research where publicly available (Craig, J. L. et al., 2015). This assisted with populating the models for collision strike at Waiuku. Use of this data was considered appropriate due to the proximity and similarity of the HMR site in terms of its elevated *topography* and its location in relation to Port Waikato. The HMR data was also reviewed to confirm that the subjective inputs into the Waiuku models were supported by flight behaviour.

Four seasons of radar and observer field monitoring of the migration patterns of internal New Zealand migrants were completed for the HMR wind farm proposal –- two summer periods and two winter periods of radar monitoring, using three marine radar and up to 19 observer stations. In addition, hundreds of hours of surveys were undertaken for bush and other land bird species as well as coastal surveys. The study design and development of the collision risk analysis technique were undertaken in consultation with DOC and Council experts. As well as studying the movements of domestic migrants, international migrants, resident shorebirds, and bush birds were intensively surveyed and collision strike modelled based on these studies. The following sections summarise findings of these studies relevant to this preliminary collision risk assessment for Waiuku Wind Farm.

Resident Internal migrant shorebirds

Twenty-three species of coastal and wader birds (resident shorebirds) were recorded within and offshore of the HMR study area. Behaviour of key species of resident shorebird (NZ dotterel, variable oystercatcher, Caspian tern, white-fronted tern, pied stilt, and black shag) were observed on numerous occasions. The vast majority of observations of all resident shorebird species were made over sea and beach habitats, with relatively few observations over land.

Three pairs of NZ dotterel are thought to be present on the beaches below the HMR site (of a population of only 5-7 pairs between Marokopa and Port Waikato) and the population along the Waikato coastline is thought to be in decline (Dowding, 2009). One pair of NZ dotterel was confirmed as resident in the area of Kaawa beach and this pair is also thought to use the beach north of Opura. NZ Dotterel *were* recorded crossing land on just a few occasions at Opura where they were presumed to have been passing between beaches. On these occasions they were recorded to have passed over at a very low height (2 m or less) and did not pass far enough inland to be at risk of colliding with the proposed turbines. While dispersal of juveniles elsewhere has been recorded overland, for example, between sites in North Auckland and the Kaipara Harbour (Dowding, 2001) and adults may move irregularly between the Firth of Thames and the Waikato coastline; a route that potentially takes them through the path of the wind farm*, in* caucusing*,* the expert group agreed that monitoring of NZ dotterel was impractical. Thus, although the risk to this species was agreed to probably be low.

Beach transects indicated that pairs of breeding variable oystercatchers were found on most of the beaches along the HMR site. Observers during the winter migratory shorebird surveys recorded

infrequent movements over land, mostly from within valleys or over the coastal cliffs away from where the turbines were proposed to be located on the ridge tops. Observations of flying variable oystercatchers were generally of a short duration flights at a low height (less than 10 m) above the beach or the sea. Small numbers of variable oystercatchers (1 to 2 birds) were occasionally seen in mixed flocks of migratory pied oystercatcher crossing the wind farm site.

Caspian tern were seen predominantly feeding along the coastline and roosting on the beaches (80% of observations were recorded over the sea). Most over land observations were within 1 km of the coast or of birds following valleys. Caspian tern are known to have a breeding colony on the Waikato River therefore some of the birds observed flying up valleys (e.g. along Kaawa Stream) may have been travelling between the Waikato River and the coast. Powlesland (2009) notes that when Caspian tern are seen inland they are generally seen flying along river courses. At times they were observed crossing over land; occasionally at a height which could place them at risk of collision mortality. This data was used to model collision risk.

Like Caspian tern, the majority of white-fronted terns observed during the HMR studies were out to sea (e.g., 95% of observations in the summer 2010 migratory shorebird surveys) or along the shoreline. White-fronted terns are partially migratory (large numbers migrate to winter in Australia each year) (Heather & Robertson, 2015) with numbers being greatest during summer. Although high mortality of terns has been recorded at three wind farms overseas this was only recorded when turbines were located in close proximity to large breeding colonies and when birds were regularly observed crossing through the site (Everaert, 2003; Everaert & Stienen, 2007). Very few observations were made of white-fronted terns crossing over land at HMR indicating that high collision rates were highly unlikely to eventuate in this case.

Gulls have generally been noted to have suffered a low rate of windfarm mortality overseas (Powlesland, 2009) and because black-backed gull and red-billed gulls were recorded as spending very little of their time over land at HMR, the likelihood of significant mortality due to turbine collision was considered to be very low for the HMR site. Eight observations of red billed gulls were made during winter 2009 and 64 in the summer 2010 during the HMR surveys. Flocks of up to 30 red-billed gulls were often observed feeding off the coast. While flocks of red-bill gulls were observed flying over ridges on several occasions, only one flock of 11 birds was observed entering the RSA during these surveys.

Pied shag were commonly recorded during the HMR shorebird surveys. The majority of pied shag were observed flying over the coastal cliffs up to about 100 m inland, along the beach or offshore. Around 50% of the birds recorded over land were observed flying at RSA. Black shag were also commonly recorded during shorebird surveys and a black shag breeding colony was located on the rock stack at Kaawa Stream. A large number of black shags were observed flying up stream valleys (e.g. Kaawa Stream valley and Waikawau Stream) which may be the main route to the Waikato Lakes and Waikato River. The majority of observed flights were along the coast, offshore or up to 100 m inland but a number were also observed flying over land. When they were observed flying over land they sometimes did so across ridges where turbines were proposed and within the RSA. Little black and little shags were not commonly observed at HMR with most birds observed flying offshore, or along stream mouths.

8.2.2. Resident and local birds, and Migrants during winter stopovers

Table 17 draws together the available information from eBird, HMR observations from the coastline to the south (section 8.2.1), other reports and papers, and experience from other sites to:

- Estimate the size of the local populations;
- Estimate the proportion of that local population that may traverse the wind farm site, and
- Estimate the frequency of those traverses (daily, weekly, monthly, seasonally).
- Calculate the annual traverse rate for each species.

There were sufficient eBird records from local sites that we divided them into six discrete sub-populations:

- Waikato River Mouth and Spit;
- Port Waikato mud flats;
- Southern Karioitahi Beach (adjacent to the project site);
- Northern Karioitahi Beach (north of the project site);
- Dune lakes within or immediately adjacent to the site;
    - Huarau Way farm pond,
    - Thompson cow shed pond,
    - Parkinson's lake).
- Dune lakes between the Waiuku Site and Awhitu Wind Farm;
    - Lake Otamatearoa,
    - Lake Whatihua,
    - Lake Puketi.

We have chosen to treat the birds recorded within each of these six areas as discrete populations, even though there is likely to be movement between them, and therefore some double counting is possible. Field work is needed to accurately determine seasonal populations of these species.

For bittern and spotless crake there was no information on the potential population size. For bittern we sought to obtain a density estimate from Ogle (1981), Stewart (2016) and Fuller (Fuller, 2021), and for spotless crake we referenced Stewart (2016), and Onley (1982).

For all other species eBird and the HMR investigations were the primary sources for numbers.

Table 17: Estimations of At Risk populations including resident, and overwintering birds only (excludes migration movements). Sorted by threat status.

Key Species	Discussion
Bittern, Australasian Threatened - Nationally Critical	We were unable to locate any data on local populations. At other sites, Stewart (2016) estimated one bird every 12ha (123 birds), Ogle (1981) estimated an average of 1 bird every 49ha in the Whangamarino Wetlands with a peak of 1 bird every 8.3ha (179 birds), Fuller (2021) estimated in the order of 10 bittern in the 205 ha Omamari and Maitahi wetlands or 1 bird per 17ha (87 birds). We have used 1 bird every 20ha as the average of 8.3ha, 12ha, 17ha, and 49ha. The Waikato River wetlands (not including open water) has an area of approximately 1,485 ha. This gives an estimate of 74 birds.

Key Species	Discussion
	On the basis that extensive areas of floodable pasture, drains and wetlands in the Aka Aka floodplain are available to bittern within the river wetlands, and there is limited habitat at the study site, we assumed no more than 5% of the total population will cross the site in any one year. The estimates used to determine traverse rate for this species are: • Assume 74 birds in local population. • Assume 5% of this population traverse to this site (4 birds). • Assume each bird traverses seasonally, once a week for 6 months. • 100 traverses / p.a.
Crake, Spotless At Risk - Declining	We were unable to locate any data on local populations. Two sources were considered. Onley (1982) estimated 4 birds per ha on Aorangi Island, however, Aorangi is a predator free island so not representative. Stewart (2016) estimated one crake per km of wetland margin in the Waikato. We have estimated the Waikato River wetlands have 112 km of riverine margin; we have doubled to allow for internal ponds and drains to 224 km = 224 birds. The estimates used to determine traverse rate for this species are: • Assume 224 birds in the local population. • Assume 5% of this population traverses to or locally resident (11 birds) • Assume each bird traverses the site once a week for 12 months. • 582 traverses / p.a.
Dabchick, New Zealand Threatened - Nationally Increasing	This species is seen in all six ponds and lakes along the dune ridgeline extending from Waiuku to Awhitu; 1 to 2 birds each plus occasional chicks. We are assuming each lake has a discrete population, but that there is movement between. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 1.8 birds in each lake, = 11 birds over six lakes. • Assume 100% of birds traverse regularly between lakes and ponds. • Assume traverse once a week for 12 months. • 552 traverses / p.a.
Dotterel, Banded At Risk - Declining	This estimate for activity of banded dotterel is for the winter stopover and any resident birds. The traverse rate of this species during each migration event is calculated in Section 8.2.3. Local observations are limited to the Spit and Port Waikato mudflats. No observations inland or along the Karioitahi Beach. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 10 birds at the Waikato River mouth. • Assume 10% of birds traverse the site. • Assume monthly return flight during stopover, six months (Jan to July). • 12 traverses / p.a.
Dotterel, Northern NZ Threatened - Nationally Increasing	Local observations are limited to the Spit and Port Waikato mudflats. No observations inland or along the Karioitahi Beach. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 6 birds at the Waikato River mouth. • Assume 5% of birds traverse the site. • Assume traverse once a week for 12 months.

Key Species	Discussion
	• 15 traverses / p.a.
Godwit, Eastern Bar-tailed At Risk - Declining	This estimate for activity of godwit is for the winter stopover and any resident birds. The traverse rate of this species during each migration event is calculated in Section 8.2.3. Only recorded on the Spit and Port Waikato mudflats; none inland or along the Karioitahi Beach. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 23 birds at the Waikato River mouth. • Assume 10% of birds traverse the site. • Assume monthly return flight during stopover, six months (Oct to Mar). • 28 traverses / p.a.
Gull, Black-billed At Risk - Declining	Predominantly seen on the Spit and the Port of Waikato mudflats, but also occasionally seen on the Karioitahi Beach and near the Waikato River wetlands. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 9 birds at the estuary and Karioitahi beach. • Assume 10% of birds traverse the site. • Assume traverse once a week for 12 months. • 48 traverses / p.a.
Gull, Red-billed At Risk - Declining	Predominantly seen on the Spit and the Port of Waikato mudflats, but also occasionally seen in larger numbers than black-billed gulls on Karioitahi Beach. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 13 birds at the estuary and Karioitahi beach • Assume 10% of birds traverse the site. • Assume traverse once a week for 12 months. • 67 traverses / p.a.
Oystercatcher, Pied At Risk - Declining	This estimate for activity of pied oystercatcher is for the winter stopover and any resident birds. The traverse rate of this species during each migration event is calculated in Section 8.2.3. Most observations are within the spit and Port of Waikato mud flats, with 4 observations in farmland in the Aka Aka floodplain, and several observations on Karioitahi Beach to the north. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 99 birds at the Waikato River mouth. • Assume 10% of birds traverse the site. • Assume monthly return flight during stopover, six months (Jan to July). • 118 traverses / p.a.
Oystercatcher, Variable At Risk - Recovering	Local observations are restricted to the Waikato estuary and spit and along the Karioitahi Beach in front of the site. No observations from the site on the dune ridgeline, the Waikato River wetlands, or the Aka Aka floodplain. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 17 birds at the Waikato River mouth. • Assume 5% of birds traverse to or across the site. • Assume monthly return flight for 12 months. • 21 traverses / p.a.

Key Species	Discussion
Shag, Black At Risk - Relict	Scattered observations as singles or up to 4 birds at the river, spit, river wetlands, on the Karioitahi Beach, and in three of the six dune lakes along the dune ridgeline extending from Waiuku to Awhitu. Maximum of 3 birds in one group. We are assuming each lake has a discrete population, and black shag arrive and depart at each lake daily. The estimates used to determine traverse rate for this species are: • Based on EBird we obtain an average of 2 birds over six lakes. • Assume 100% of birds traverse the site daily (return). • 1,182 traverses / p.a.
Shag, Little At Risk - Relict	Scattered observations as singles upriver, wetlands, dune lakes. None seen on Karioitahi beach below the site. Largest group was of 90 on the spit. Also seen in five of the six ponds and lakes along the dune ridgeline extending from Waiuku to Awhitu. We are assuming each lake has a discrete population, and little shags arrive and depart each lake daily. The estimates used to determine traverse rate for this species are: • Based on EBird we obtain an average of 5 birds over six lakes. • Assume 100% of birds traverse the site daily (return). • 3,441 traverses / p.a.
Shag, Little Black At Risk – Naturally Uncommon	Scattered observations as singles upriver, wetlands, dune lakes. None seen on Karioitahi beach below the site. Largest group was 89 on the spit. Also seen in five of the six ponds and lakes along the dune ridgeline extending from Waiuku to Awhitu. Largest group of 2 birds on these waterbodies. We are assuming each lake has a discrete population, and little black shags arrive and depart at each lake daily. The estimates used to determine traverse rate for this species are: • Based on EBird we obtain an average of 3 birds over six lakes. • Assume 100% of birds traverse the site daily (return). • 1,968 traverses / p.a.
Shag, Pied At Risk - Recovering	Significant number of observations along Karioitahi Beach in front of site, dune lakes, Waikato harbour mouth, Port of Waikato and upriver on both banks. Also an observation at a dune lake on the dune ridgeline between the Waiuku and Awhitu sites. Parkinson's Lake. The estimates used to determine traverse rate for this species are: • Based on EBird estimate local population of 51 averaged across all sites seen. • Assume 20% traverse the site • Assume traverse rate of daily return • 7,473 traverses / p.a.
Tern, Caspian Threatened - Nationally Vulnerable	Local observations are widespread and include the Waikato estuary and spit, up the Waikato River to the Aka Aka floodplain, and along the Karioitahi Beach. No observations from the site on the dune ridgeline. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 16 birds at the Waikato River mouth. • Assume 5% of birds traverse the site. • Assume traverse once a week for 12 months.

Key Species	Discussion
	• 42 traverses / p.a.
Tern, White-fronted At Risk - Declining	Local observations are restricted to the Waikato estuary and spit and along the Karioitahi Beach. No observations from the project site, the Waikato River wetlands, or the Aka Aka floodplain. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 218 birds at the Waikato River mouth. • Assume 5% of birds traverse the site. • Assume traverse once a week for 12 months. • 567 traverses / p.a.
Wrybill Threatened - Nationally Increasing	This estimate for activity of wrybill is for the winter stopover and any resident birds. The traverse rate of this species during each migration event is calculated in Section 8.2.3. All local observations on the Waikato estuary and spit. No observations on the Aka Aka floodplain, Waikato River, Karioitahi Beach, or the site. The estimates used to determine traverse rate for this species are: • Based on EBird obtain an average of 2 birds at the Waikato River mouth. • Assume 10% of birds traverse the site. • Assume monthly return flight during stopover, six months (Jan to July). • 2 traverses / p.a.

8.2.3. Domestic and International Shorebird Migrations

In the absence of data on migrant bird traverses we have also looked to the data from HMR Wind Farm. The species considered are pied oystercatcher, wrybill, banded dotterel, and pied stilt. Table 18 shows the number potentially passing through the HMR site as predicted by the HMR experts at caucusing in 2010. It was agreed amongst the HMR experts that due to difficulty in detecting smaller shorebird species (e.g., wrybill and banded dotterel), monitoring of pied oystercatcher should be concentrated on, and that the migratory movements of this species would be used as a proxy for the movements of all other shorebirds (including international migrants).

Table 18: A summary of the species of internal migratory shorebirds recorded as migrating along the Waikato coastline, the estimated population size and the number potentially passing through or past the proposed HMR Wind Farm (outlined in the HMR Caucus Statement dated 27 April 2010).

Species	Population estimate (2010)	Number through HMR
Pied oystercatcher	111,085	70,000
Wrybill	5,274	5,000
Pied stilt	30,000	9,000 – 13,000 (resident and migratory)
Banded dotterel	20,000	6,000

Three main attributes of migratory trails were established as shown as heat density trail maps (Figure 5 and Figure 6):

- On the northbound migration (summer) birds travelled in a north, north-west, or north-easterly direction, with the majority of birds traveling at sea or along the coastline and less overland;

- On their southbound migration (winter) birds travelled in a west, south-west, south or south-easterly direction on a broad front, but still largely concentrated flying along the coastline or out to sea; and
- Migratory birds typically travelled in a broadly straight line, however, many birds on the northern migration were observed changing direction from a northerly flight path to a distinct north-east flight path over the mouth of Kaawa Stream. This was either whole flocks or several birds splitting from larger flocks.

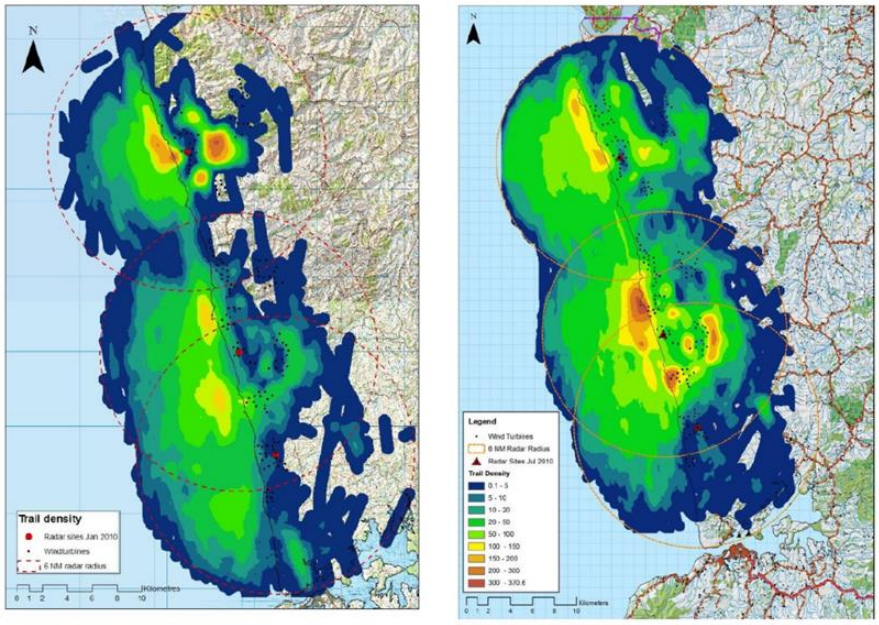


Figure 5: Density of trails (trails/km2) for the HMR winter (left) and Winter 2010 (right) surveys (southern migrations)

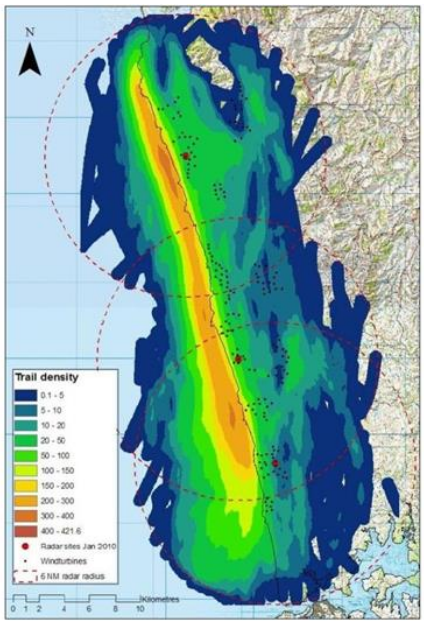


Figure 6: Density of trails (trails/km2) for the HMR summer 2010 survey (north migrations). International migrant shorebirds that were observed at or passing through the proposed HMR Wind Farm were: eastern bar-tailed godwit (godwit) and red knot (knot). Turnstone may also migrate through this area yet far less is known about the migratory patterns of this species. The expert group agreed that avoidance rates for godwit and knot should be the same as those developed for pied oystercatcher.

9. Predicted Collision Risk - Results

This section presents the results of the Band modelling for the Waiuku and Awhitu projects separately and then combined.

9.1. Waiuku Results

Table 19 presents the results of collision risk modelling for the Waiuku Site. Predicted mortalities are given as a "probable" or 20% to 80% range for both birds per year, and years per bird. By way of example the data can be interpreted as:

- *"The expected bittern mortality is probably somewhere between one death every 47 years and one death every 121 years. In any event we can be 80% sure that the mortality is rarer than one death every 47 years."*
- *"The expected Pied Oystercatcher* mortality is probably between 2 and 4 birds per year, and we are 80% sure that it is no more than 4 birds per year."

Table 19: Predicted collision rates for the proposed Waiuku Wind Farm, presented as both birds per year and as years per bird (20%, 80% confidence intervals). Sorted by conservation status.

Key Species	Conservation Status	Birds/year (20% to 80% CI)	Years/bird (20% to 80% CI)
Bittern, Australasian	Nationally Critical	0.01 - 0.02	47 - 121
Tern, Caspian	Nationally Vulnerable	0 - 0.01	197 - 476
Dabchick, New Zealand	Nationally Increasing	0.06 - 0.17	7 - 18
Dotterel, Northern NZ	Nationally Increasing	0 - 0	1534 - 4529
Wrybill	Nationally Increasing	0.2 - 0.4	3 - 5
Crake, Spotless	Declining	0.06 - 0.15	7 - 17
Dotterel, Banded	Declining	0.04 - 0.09	11 - 26
Godwit, Eastern Bar-tailed	Declining	0.24 - 0.47	2 - 4
Gull, Black-billed	Declining	0.01 - 0.02	64 - 155
Gull, Red-billed	Declining	0 - 0.01	98 - 250
Oystercatcher, Pied [1]	Declining	2 to 4	0 - 1
Tern, White-fronted	Declining	0.02 - 0.04	24 - 62
Oystercatcher, Variable	Recovering	0 - 0	377 - 958
Shag, Pied [1]	Recovering	1 to 3	0 - 1
Shag, Little Black	Naturally Uncommon	0.19 - 0.46	2 - 5
Shag, Black	Relict	0.21 - 0.51	2 - 5
Shag, Little [1]	Relict	0.5 to 1	1 - 3

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

Summary

The modelled results suggests the potential for three species to suffering 1 or more collision events per annum. They are pied oystercatcher, pied shag, and little shag.

Four species could experience collisions every 2 to 5 years (wrybill, godwit, little black shag, and black shag). Ongoing monitoring is recommended to test the population numbers used for this group.

All other birds may experience a collision every one to two decades or longer.

9.2. Awhitu Results

Table 20 presents the results of collision risk modelling for the Awhitu Site. Predicted mortalities are given as a "probable" or 20% to 80% range for both birds per year, and years per bird. This is interpreted as for example

As discussed above, for this modelling we have used the Waiuku model framework and only changed those metrics that are known; the turbine size and design, the size of the windfarm site, and the number of traverses which are likely to be a quarter of those used for Waiuku.

All other metrics including bird population sizes and proportion of populations traversing the site are untouched. It is unlikely they will mirror Waiuku, Awhitu being much further away from the Waikato River the estuary, spit, and delta wetlands, and having fewer nearby ponds, but equally it is also much closer to the Manukau Harbour and the harbour mouth. Without data to clarify the effects of these location changes we have chosen to retain the risk rates used for Waiuku.

Table 20: Predicted collision rates for the proposed Awhitu Wind Farm, presented as both birds per year and years per bird (20%, 80% confidence intervals). Sorted by conservation status.

Key Species	Conservation Status	Birds/year (20% to 80% CI)	Years/bird (20% to 80% CI)
Bittern, Australasian	Nationally Critical	0 - 0.01	117 - 292
Tern, Caspian	Nationally Vulnerable	0 - 0	470 - 1108
Dabchick, New Zealand	Nationally Increasing	0.02 - 0.06	17 - 42
Dotterel, Northern NZ	Nationally Increasing	0 - 0	3768 - 11137
Wrybill	Nationally Increasing	0.09 - 0.17	6 - 12
Crake, Spotless	Declining	0.02 - 0.06	17 - 40
Dotterel, Banded	Declining	0.02 - 0.04	27 - 60
Godwit, Eastern Bar-tailed	Declining	0.1 - 0.19	5 - 10
Gull, Black-billed	Declining	0 - 0.01	156 - 384
Gull, Red-billed	Declining	0 - 0	235 - 605
Oystercatcher, Pied [1]	Declining	1 to 2	1 - 1
Tern, White-fronted	Declining	0.01 - 0.02	57 - 147
Oystercatcher, Variable	Recovering	0 - 0	765 - 1994
Shag, Pied [1]	Recovering	0.5 to 1	1 - 2
Shag, Little Black	Naturally Uncommon	0.11 - 0.27	4 - 9
Shag, Black	Relict	0.08 - 0.19	5 - 13
Shag, Little [1]	Relict	0.19 - 0.47	2 - 5

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

Summary

Generally the Awhitu site adds 50% to the Waiuku results. This is despite the windfarm being one quarter the size of the Waiuku site, and is because the turbines are smaller, their blades rotate more quickly, and the turbines are located at a higher density than at Waiuku.

The modelling for this site suggests that two species could suffer 1 or more collision events per annum; pied oystercatcher and pied shag. Two species could experience collisions every 2 to 5 years (little shag and little black shag), five species every 5 to 25 (dabchick, wrybill, spotless crake, godwit, and black shag). All other birds may experience a collision every two decades or longer.

9.3. Cumulative Effects

Table 21 combines the predicted collision mortality from Waiuku and Awhitu to provide and cumulative collision risk. Adding the collision risk from the Awhitu site to the proposed Waiuku site does not significantly alter the outcome for any bird species.

Table 21: Predicted cumulative collision rates for the proposed Waiuku Wind Farm and the consented Awhitu Wind Farm. Presented as both presented as both birds per year and years per bird (20%, 80% confidence intervals). Sorted by conservation status.

KEY SPECIES	CONSERVATION STATUS	Cumulative Effects Birds/Year (20% to 80% CI)	Cumulative Effects Years/Bird (20% to 80% CI)
Bittern, Australasian	Nationally Critical	0 - 0	33 - 88
Tern, Caspian	Nationally Vulnerable	0 - 0	141 - 345
Dabchick, New Zealand	Nationally Increasing	0.1 - 0.2	4 - 13
Dotterel, Northern NZ	Nationally Increasing	0 - 0	1111 - 3333
Wrybill	Nationally Increasing	0.3 - 0.6	2 - 4
Crake, Spotless	Declining	0.1 - 0.2	5 - 12
Dotterel, Banded	Declining	0.1 - 0.1	8 - 18
Godwit, Eastern Bar-tailed	Declining	0.3 - 0.7	2 - 3
Gull, Black-billed	Declining	0 - 0	45 - 116
Gull, Red-billed	Declining	0 - 0	70 - 175
Oystercatcher, Pied [1]	Declining	3 to 6	0 - 0
Tern, White-fronted	Declining	0 - 0.1	16 - 42
Oystercatcher, Variable	Recovering	0 - 0	189 - 667
Shag, Pied [1]	Recovering	2 to 4	0.5 - 1
Shag, Little Black	Naturally Uncommon	0.3 - 0.7	1 - 3
Shag, Black	Relict	0.3 - 0.7	1 - 4
Shag, Little [1]	Relict	1 to 2	1 - 2

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

Summary

- The cumulative results once again focuses on three species as having a high probability of annual mortalities; pied oystercatcher (80% likelihood of between 3 to 6 collisions per annum), little shag (80% likelihood of between 1 to 2 collisions per annum), and pied shag (80% likelihood of between 2 to 4 collisions per annum),
- Similarly, the cumulative assessment identify dabchick, wrybill, godwit, little black shag, and black shag as potentially suffering a collision mortality every 2 to 5 years, requiring confirmation of the modelling data by site investigation.

10. Assessment of Magnitude of Effect

As a guide to our analysis of the magnitude of effects, we have assessed the likely magnitude of effects using the following criteria:

Negligible:	80% confident the modelled predications of collision mortality lie between 1 every 25 years and a period significantly greater than the life of the windfarm (Windfarm life = 40 years).
Very Low:	80% confident the modelled predictions of collision mortality lie between 5 and 25 years, subject to confirmation of local populations.
Low:	80% confident the modelled predications of collision mortality lie between 1 every two years and 1 every five years, subject to confirmation of local populations.
Moderate:	80% confident the modelled prediction of collision mortality is more than one per annum but does not exceed the threshold value for that species. Requires field data to confirm this magnitude. If confirmed mitigation a likely requirement.
High (Significant):	80% confident that annual mortalities will exceed the Threshold Value for the species.

The results for all 17 species, and for both the Waiuku and Awhitu windfarms combined, are summarised in Table 22.

Table 22: Analysis of magnitude of cumulative effects based on Thresholds established for Waipipi Windfarm. Sorted by conservation status.

KEY SPECIES	CONSERVATION STATUS	Modelled result Birds/Year	Modelled result Years/Bird	Annual Mitigation Review Threshold (Waipipi)	Assessed magnitude of effect
Bittern, Australasian	Nationally Critical	0 - 0	33 - 88	0.5	Negligible
Tern, Caspian	Nationally Vulnerable	0 - 0	141 - 345	5	Negligible
Dabchick, New Zealand	Nationally Increasing	0.1 - 0.2	4 - 13	5	Low
Dotterel, Northern NZ	Nationally Increasing	0 - 0	1111 - 3333	5	Negligible
Wrybill	Nationally Increasing	0.3 - 0.6	2 - 4	5	Low
Crake, Spotless	Declining	0.1 - 0.2	5 - 12	2	Very Low
Dotterel, Banded	Declining	0.1 - 0.1	8 - 18	5	Very Low
Godwit, Eastern Bar-tailed	Declining	0.3 - 0.7	2 - 3	5	Low
Gull, Black-billed	Declining	0 - 0	45 - 116	5	Negligible
Gull, Red-billed	Declining	0 - 0	70 - 175	5	Negligible
Oystercatcher, Pied [1]	Declining	3 to 6	0 - 0	10	Moderate
Tern, White-fronted	Declining	0 - 0.1	16 - 42	5	Very Low
Oystercatcher, Variable	Recovering	0 - 0	189 - 667	5	Negligible
Shag, Pied [1]	Recovering	2 to 4	0 - 1	5	Moderate
Shag, Little Black	Naturally Uncommon	0.3 - 0.7	1 - 3	5	Low
Shag, Black	Relict	0.3 - 0.7	1 - 4	5	Low
Shag, Little [1]	Relict	1 to 2	1 - 2	5	Moderate

[1] The highlighted birds have been predicted to have a collision risk greater than 1 bird per annum.

Summary

- We acknowledge that the five criteria used for determining magnitude of effect are highly subjective, however, we are confident that it highlights species within the wider group for which the greatest risk of collision lies, those where the risk is uncertain and will rely on further study, and those where the risk is negligible.
- In summary, we consider that, based on the population data available:
    - There will be negligible effects on 6 species where the modelled predications of collision mortality lies between 1 every 25 years and a period significantly greater than the life of the windfarm (Windfarm life = 40 years). They are Australasian bittern, Caspian tern, New Zealand dotterel, black-billed gull, red-billed gull, and variable oystercatcher.
    - There may be a very low level of risk for three species where the modelled predictions of collision lie between 5 and 25 years. They are spotless crake, banded dotterel, and white-fronted tern.
    - There may be a low level of risk for 5 species where the modelled predications of collision mortality lie between 1 every two years and 1 every five years. They are New Zealand dabchick, wrybill, bar-tailed godwit, little black shag, and black shag.
    - There are three species where the modelled predications of collision is more than one per annum. They are pied oystercatcher, pied shag, and little shag.
- Importantly, the modelled predications of collision fall short of the trigger threshold for all species. This suggests that, subject to confirmation by additional field data, there is confidence that the effects will not be significant, i.e. are unlikely to have a population level effect on a species based on the trigger values used.

11. Offsetting Adverse Effects

It is premature to design offsetting or mitigation for the modelling impacts of this site. Such a discussion requires confirmation of the modelled scale of impact. However, a number of mitigation methods have been debated and agreed for other windfarm projects. The following presents a number of these, which may be relevant to this site.

11.1. Hauāuru mā raki Wind Farm (HMR)

The following examples are derived from HMR windfarm, which is the closest to this site, however, similar agreements have been reached for Taharoa Wind Farm and Waipipi Windfarm, with site specific variations.

Pest Control

Targeted animal pest control at the breeding ground of the key species was the primary method for mitigating collision strike presented to the HMR Board of Inquiry hearings by the applicant's ecological experts and was largely supported by the DOC and Council experts.

Post-construction carcass monitoring was considered essential to address any uncertainty in the collision risk modelling results and to ensure that any effects are fully mitigated.

If higher collision rates occur than collision risk modelling predicted, the level of mitigation would be increased through proposed review processes.

The review process included an adaptive management approach. For example, for domestic shorebirds should monitoring have shown that the predator control programme was not sufficient, then the conditions required that the area of predator control would have to be increased until it could have been reliably demonstrated that there was no net loss for pied oystercatcher, and a net gain to wrybill, banded dotterel and pied stilt accrued.

Domestic Migrants

For pied oystercatcher this would require predator control at the nesting sites of this species in Southern Canterbury, the goal being to increase productivity to offset predicted losses due to bird strike. The following factors were required to be determined to achieve this:

- The scale of predator control required to increase productivity above the baseline productivity rate; and
- The proportion of fledglings currently surviving to become breeding adults; the intent being to produce breeding adults as most of the birds suffering collision mortality will be breeding adults, and
- The additional protection required to produce 25 breeding adult pied oystercatcher above baseline.

A BACI (Before After Control Impact) monitoring design would be employed to achieve confidence in the results.

Generally, the other domestic migrants used the same breeding areas as pied oystercatcher and so control of predators to enhance breeding productivity for pied oystercatcher would also

benefit these other species. This dual benefit was agreed to by the experts at the time, the Commissioners and subsequently became part of the consented condition set for HMR.

International migrants

The experts at HMR agreed that when put in the context of population size, and the extent of the impacts that are currently affecting these species overseas, the level of mortality associated with HMR would not have an effect of concern on the population of any international migrant species. Nevertheless, it was the opinion of the experts that it was appropriate to compensate for these losses.

Given the greatest impacts on global populations of these species occur overseas and during migration, Contact agreed to support the creation of a research grant with the specific aim providing the funds to allow New Zealand researchers to investigate the migration pathways and international conservation of international migrant shorebirds (including godwits and knots).

One of the experts for DOC at the time also suggested that the protection and improvement of high tide roosting options for Arctic waders may be an option to aid the mitigation of any effects of the proposed wind farm.

Resident shorebirds:

The experts agreed to several offsetting tools in relation to NZ dotterel and other resident breeding shorebirds. They included predator control, reduction of disturbance, advocacy, and avoiding losses to flooding.

In the case of NZ dotterel, the offsetting package sought to raise productivity to 0.75 chicks per pair per season, averaged over a three-year period or longer.

Mitigation of collision risk for resident wetland birds at HMR was not specifically required as the predicted strike rate was very low. However, when turbine collisions were combined with estimates of potential transmission strikes, the experts recommended mitigation would be appropriate with a focus on habitat enhancement in the Pungapunga wetland which has a known breeding population of bittern.

11.2. Waipipi Wind Farm

Water birds including Shags

At this windfarm, in addition to offsetting for migrants, consideration was given to the impact on local shag populations. Numbers of three species of shag visited this windfarm daily to forage in a large lagoon in the center of the site.

It was proposed to remove this lagoon (infill) and deliberately displace shags from the site. This displacement effect would be offset by enhancement of an appropriate wetland further along the coast where numbers would be sustained or increased. This approach was acceptable and has been implemented.

12. Summary of Results

12.1. This Assessment

This assessment is a desktop study and is not based on any observations within the project site, other than some opportunistic observations by local ornithologists. We have relied on published information to derive the required metrics for the analysis, and where data was lacking have made assumptions based on our knowledge of windfarms and our observations of the species being considered.

We have relied on a range or sources:

- In term of bird metrics, we are confident the data on bird size and flight speed are of sufficient accuracy for this analysis. Where data on NZ birds has not been available, we have used analogue species from international studies, i.e., closely related species of similar size and behaviours.
- In terms of flight height, we have drawn on the limited data that is available publicly from other windfarm sites. For some species this data is very good, for others the data is poor or missing. Again, we have considered analogues, and Monte-Carlo ranges around the means to account for this variability.
- Estimates of local population sizes has been the most difficult data to obtain. The only recent data available which spanned the site and surrounding landscape was the eBird website where any observations of birds can be uploaded. Some of these observations can be quite comprehensive and many are made by experienced birders, however, they are not a replacement for methodically obtained site data and have a number of limited. However, they were the only data available for most species. Again, we ran Monte-Carlo simulations of estimated ranges around the estimated traverse rate for each population to account for the quality of the data.
- For migrant species we eventually decided to use the flight density rates calculated for the HMR project which lies 10.8 km to the south of the site. We did not consider any other data to be as comprehensive or accurate. We recognise this data may over-estimate migrant movements across the site, but without site observations we have no way of calculating the number that avoid or bypass the site. Again, we have run Monte-Carlo simulations for ranges around the means traverse rates to account for this variability.

Finally, this assessment is by necessity a cumulative effects assessment which also considers the Awhitu Wind Farm which is under construction adjacent to the Waiuku Site was also modelled, and the collision rates for the two sites were combined.

12.2. The Site

The site was visited part way through the gathering of data for modelling to confirm the presence or absence of key habitats, and the likely bird movements across the site. This was to assist the development of location population numbers and traverse rates being considered. After this visit, some numbers were revised.

From this visit we confirmed that the project site has very limited and low-quality habitat and very few indigenous species of concern would be resident within this habitat. The exceptions

are a six small dune lakes / large farm ponds where at least three shag species forage daily, where the NZ dabchick is known to breed, and which may provide some limited habitat for cryptic water birds such as bittern and crake.

Otherwise, potential interactions with the windfarm are most likely to occur by way of traverses through the site while moving from one destination to another. This includes:

- Domestic migrants (pied oystercatcher, banded dotterel, wrybill) which will be crossing the site twice a year to overwinter at harbours to the north and return to breed in braided rivers to the south.
- International migrants (godwit) which will be crossing the site twice a year as they arrive from the northern hemisphere to overwinter, and then return to breed.
- Pied shag that will be traversing the site daily or seasonally from inland roosts to the western coastline to forage.
- Various unpredictable movements of coastal species (gulls, terns, oystercatchers) moving inland to forage or traversing along the inland dunes as they move seasonally between harbours or inland in response to weather patterns.
- Turbine metrics were provided by LET Capital Number 3 LP. Some information was not able to be obtained on pitch rate and variations in RPM, but we have filled these gaps with information from other turbines we have modelled in the past that are of similar size and engineering.

12.3. Species of Concern

Prior to modelling we had identified 75 species of which 50 were native and known to be active locally. After a review of each species this number was reduced to 17 native species where we considered they could be at risk of turbine collision, and which had a national conservation status of Threatened or At Risk. The process of arriving at the final list of key species (Species of concern) is detailed. All 17 species were subject to a collision risk model.

We also considered fourteen species which have not been previously recorded in the study area but could be traversing the site at sufficient height they would not be observed or could be traversing the site at night. We concluded that five seabird species could potentially be at risk which will require some additional consideration. There was insufficient data on these five species to allow collision risk modelling.

12.4. Collision Risk Modelling

CRM modelling is a standard tool used nationally and internationally since the early 2000's. The base model used fixed data. We have used a modified form of the model which applies Monte Carlo simulations to predict the probability of an outcome where there is significant uncertainty in inputs. It does this by randomly generating a probability distribution from which confidence intervals can be obtained around a probable outcome.

Variables which were randomized were the local population size and associated flights per year, the proportion of flights within the rotor swept area (RSA), the individual turbine collision risk for each species, turbine downtime and avoidance rate.

12.5. Cumulative Effects

Both the proposed Waiuku Wind Farm and the consented Awhitu Wind Farm have been modelled and the results combined.

We have reviewed the Awhitu turbines and wind farm layout and concluded that the turbines are about twice as dangerous due to the closer spacing of the turbines, and the faster rotation speed of the blades. This increases individual collision risk for each species. However, this increased collision risk is balanced by the swept area of the turbines being only 25% that of the of the Waiuku ones.

The results from both wind farms have been combined.

12.6. Results

The modelling that has been carried out suggests that three birds are likely to have annual mortalities, the pied oystercatcher, pied shag, and little shag. Potential pied oystercatcher mortalities will relate to a combination of bi-annual migrations through the site, and movements along the coast and inland during their winter stop-over. For little shags potential mortalities will relate to regular movements to stock ponds and dune lakes within and adjacent to the site. For pied shags potential mortalities will relate to daily traverses from inland roosts, across the site to forage along the west coast.

The other three shag species may experience a mortality every 1 to 6 years, depending on the species. We do not know the regional populations of these birds and so it is difficult to determine whether these will have a regional or local effect.

Both the bar-tailed godwit and the wrybill are predicted to have a mortality every 2 to 5 years.

The modelling for all other birds considered by this review suggest that mortalities are unlikely to occur or will be at a rate of tens of years. This includes Australasian bittern, NZ dabchick, northern dotterel, Caspian tern, spotless crake, banded dotterel, black-billed gull, red-billed gull, white-fronted tern, and variable oystercatcher.

Overall, we conclude that the four shag species, pied oystercatcher, godwit, and wrybill are the species of greatest concern, but the modelling suggests that the effects will not be significant. Further data collection is needed to test the assumptions used for this modelling.

12.7. Mitigation and Offsetting

While it is premature to design offsetting or mitigation for this site, we describe below a number of mitigation methods developed for other wind farm projects, and which cover all the key species of concern at Waiuku.

We consider that methods, which have been debated and agreed for other wind farm projects, are available to offset impacts on each of the potentially affected species.

13. Conclusions

In conclusion, this study has sought to achieve three things:

Predictive Collision Risk Modelling

It has been challenging to obtain sufficient data to carry out the collision risk modelling in the absence of site-specific data. We have relied heavily on data from previous studies and data bases and where gaps have existed, we have made assumptions that we feel are conservative, and have applied statistical analysis to improve confidence.

However, while we have been able to populate our collision risk models and have results that appear to be reasonable and conservative, confirmation of the modelling outputs requires further dedicated and systematic data collection from the site and neighboring habitats to test the assumptions and confirm the quantum of effects.

Identification of Significant Adverse Effects

We are satisfied at this stage, that effects will not be significantly adverse based on the thresholds used. However, for some species there will be low to moderate levels of adverse effects which need to be confirmed through further site investigation.

We note that an ecological impact assessment is primarily concerned with population level effects at the scale of the study (either nationally or regionally). Individual mortalities that do not have a population level effect, are generally not treated as adverse. From our analysis we remain cautious regarding the population effects on some local species, particularly shags, such that the local population may be reduced through the life of the wind farm. This should be a focus for ongoing sampling.

Seabirds

We suggest that the risk to seabirds of population level effects is low, however, this risk will increase as more wind farms are built along the coastline of the upper North Island and cumulative effects begin to come into play.

The issue of risk to seabirds will remain unclear until there has been national research which would assist in collision assessments. However, for this assessment the data needed to understand the risk profile for any one species is missing and we have not carried out collision risk modelling for these species.

We have identified four species, which are known or likely to traverse the North Island from the east to west coast to forage, as requiring further consideration during the ongoing assessments.

Consideration of Offsetting / Mitigation

We have presented a range of methods used for offsetting adverse effects other New Zealand wind farm projects. Given the range of species with a modelled risk, we are confident there are mitigation / offsetting methods for each.

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Appendix 1: All species within the study area

All native and introduced species, recorded within the study area (EBird, n.d.; C. J. R. Robertson et al., 2007). Their national conservation status is provided. Sorted by NZ Conservation Status.

Common Name	Scientific Name	New Zealand Conservation Status
Australasian bittern	*Botaurus poiciloptilus*	Threatened - Nationally critical
Reef heron	*Egretta sacra*	Threatened - Nationally endangered
Black petrel	*Procellaria parkinsoni*	Threatened - Nationally vulnerable
Caspian tern	*Hydroprogne caspia*	Threatened - Nationally vulnerable
Grey duck	*Anas s. superciliosa*	Threatened - Nationally vulnerable
Long-tailed cuckoo	*Eudynamys taitensis*	Threatened - Nationally vulnerable
New Zealand dabchick	*Poliocephalus rufopectus*	Threatened - Nationally increasing
New Zealand dotterel	*Charadrius obscurus*	Threatened - Nationally increasing
Wrybill	*Anarhynchus frontalis*	Threatened - Nationally increasing
Banded dotterel	*Charadrius bicinctus*	At Risk - Declining
Banded rail	*Gallirallus philippensis*	At Risk - Declining
Bar-tailed godwit	*Limosa lapponica baueri*	At Risk - Declining
Black-billed gull	*Chroicocephalus bulleri*	At Risk - Declining
New Zealand pipit	*Anthus novaeseelandiae*	At Risk - Declining
North Island fernbird	*Poodytes punctatus*	At Risk - Declining
Pied oystercatcher	*Haematopus finschi*	At Risk - Declining
Red-billed gull	*Larus novaehollandiae*	At Risk - Declining
Sooty shearwater	*Ardenna grisea*	At Risk - Declining
Spotless crake	*Porzana tabuensis*	At Risk - Declining
White-fronted tern	*Sterna striata*	At Risk - Declining
North Island kaka	*Nestor meridionalis*	At Risk - Recovering
Pied shag	*Phalacrocorax varius*	At Risk - Recovering
Variable oystercatcher	*Haematopus unicolor*	At Risk - Recovering
Little black shag	*Phalacrocorax sulcirostris*	At Risk - Naturally Uncommon
Royal spoonbill	*Platalea regia*	At Risk - Naturally Uncommon
Black shag	*Phalacrocorax novaehollandiae*	At Risk - Relict
Little shag	*Microcarbo melanoleucos*	At Risk - Relict
Arctic skua	*Stercorarius parasiticus*	Migrant (non-resident native)
Cattle egret	*Bubulcus ibis*	Migrant (non-resident native)
Australasian gannet	*Morus serrator*	Not Threatened
Australasian harrier	*Circus approximans*	Not Threatened
Australasian shoveler	*Spatula rhynchotis*	Not Threatened
Black swan	*Cygnus atratus*	Not Threatened
Grey teal	*Anas gracilis*	Not Threatened
Grey warbler	*Gerygone igata*	Not Threatened
Morepork	*Ninox novaeseelandiae*	Not Threatened
New Zealand kingfisher	*Todiramphus sanctus*	Not Threatened
New Zealand pigeon	*Hemiphaga novaeseelandiae*	Not Threatened
North Island fantail	*Rhipidura fuliginosa*	Not Threatened

Common Name	Scientific Name	New Zealand Conservation Status
Paradise shelduck	*Tadorna variegata*	Not Threatened
Pied stilt	*Himantopus himantopus*	Not Threatened
Pukeko	*Porphyrio porphyrio*	Not Threatened
Shining cuckoo	*Chalcites lucidus*	Not Threatened
Silvereye	*Zosterops lateralis*	Not Threatened
Spur-winged plover	*Vanellus miles*	Not Threatened
Black-backed gull	*Larus dominicanus*	Not Threatened
Tui	*Prosthemadera novaeseelandiae*	Not Threatened
Welcome swallow	*Hirundo neoxena*	Not Threatened
White-faced heron	*Egretta novaehollandiae*	Not Threatened
Australian magpie	*Gymnorhina tibicen*	Introduced
Barbary dove	*Streptopelia risoria*	Introduced
California quail	*Callipepla californica*	Introduced
Canada goose	*Branta canadensis*	Introduced
Common chaffinch	*Fringilla coelebs*	Introduced
Common myna	*Acridotheres tristis*	Introduced
Dunnock	*Prunella modularis*	Introduced
Eastern rosella	*Platycercus eximius*	Introduced
Eurasian blackbird	*Turdus merula*	Introduced
Eurasian skylark	*Alauda arvensis*	Introduced
European goldfinch	*Carduelis carduelis*	Introduced
European greenfinch	*Chloris chloris*	Introduced
European starling	*Sturnus vulgaris*	Introduced
Graylag goose	*Anser anser*	Introduced
House sparrow	*Passer domesticus*	Introduced
Indian peafowl	*Pavo cristatus*	Introduced
Lesser redpoll	*Acanthis flammea*	Introduced
Mallard	*Anas platyrhynchos*	Introduced
Red junglefowl	Gallus gallus	Introduced
Ring-necked pheasant	*Phasianus colchicus*	Introduced
Rock pigeon	*Columba livia*	Introduced
Song thrush	*Turdus philomelos*	Introduced
Spotted dove	*Streptopelia chinensis*	Introduced
Wild turkey	*Meleagris gallopavo*	Introduced
Yellowhammer	*Emberiza citrinella*	Introduced

Appendix 2: Additional species considered

The additional 14 species of migrant and seabird were not recorded within the study area but have been considered due to their proximity or rarity. Their national conservation status is provided as well as the IUCN Red List Status. Sorted by NZ Conservation Status.

Common Name	Scientific Name	New Zealand Conservation Status	IUCN Red List
Migrant and Vagrant Species			
Red knot	*Calidris canutus*	At Risk - Declining	Near threatened NT
Pacific golden plover	*Pluvialis fulva*	Migrant	Least Concern
Red-necked stint	*Calidris ruficollis*	Migrant	Near threatened NT
Ruddy turnstone	*Arenaria interpres*	Migrant	Least Concern
Little whimbrel	*Numenius minutus*	Vagrant	Least Concern
Oriental plover	*Charadrius veredus*	Vagrant	Least Concern
Endemic seabirds			
NZ storm petrel	*Fregetta maoriana*	Threatened - Nationally vulnerable	Critically Endangered
Sooty shearwater	*Ardenna grisea*	At Risk - Declining	Near Threatened
Little shearwater	*Puffinus assimilis haurakiensis*	At Risk - Recovering	Least Concern
Pycroft's petrel	*Pterodroma pycrofti*	At Risk - Recovering	Vulnerable
Common diving petrel	*Pelecanoides urinatrix*	At Risk - Relict	Least Concern
Cook's petrel	*Pterodroma cookii*	At Risk - Relict	Vulnerable
Flesh-footed shearwater	*Ardenna carneipes*	At Risk - Relict	Near Threatened
White-faced storm petrel	*Pelagodroma marina*	At Risk - Relict	Least Concern

Appendix 3: Habitat Preferences

All native, endemic, migrant and vagrant species, from all sources, that have been considered by this assessment are presented in this table comprises five squares (See Figure 1, page 5) which encompass the proposed wind farm site. The conservation status and habitat type/s each species use is indicated. Primary[6] habitat is in dark green and secondary habitat is in light green.

Species Name (OSNZ)	National Conservation Status	Oceanic	Coastal / Estuary	Freshwater / wetlands	Scrub / shrubland	Farmland / open country	Native forest	Exotic Forest	Urban / Residential
Black petrel	Threatened - Nationally Vulnerable								
NZ storm petrel	Threatened - Nationally vulnerable								
Arctic skua	Migrant (non-residential native)								
Sooty shearwater	At Risk - Declining								
Little shearwater	At Risk - Recovering								
Pycroft's' petrel	At Risk - Recovering								
Common diving petrel	At Risk - Relict								
Cook's petrel	At Risk - Relict								
Flesh-footed shearwater	At Risk - Relict								
Fluttering shearwater	At Risk - Relict								
White-faced storm petrel	At Risk - Relict								
Grey-faced petrel	Not Threatened								
Australasian gannet	Not Threatened								
Bar-tailed godwit	At Risk – Declining								
Reef heron	Threatened - Nationally Endangered								
Red knots	Threatened - Nationally vulnerable								
New Zealand dotterel	Threatened - Nationally Increasing								
Pacific golden plover	At Risk - Declining								
White-fronted tern	At Risk - Declining								
Red-necked stint	At Risk - Recovering								
Ruddy Turnstone	At Risk - Recovering								
Royal spoonbill	At Risk - Naturally Uncommon								
Little whimbrel	At Risk - Relict								
Oriental plover	At Risk - Relict								
Caspian tern	Threatened - Nationally Vulnerable								
Wrybill	Threatened - Nationally Increasing								
Black-billed gull	At Risk - Declining								
Red-billed gull	At Risk - Declining								
Variable oystercatcher	At Risk - Recovering								
White-faced heron	Not Threatened								
Banded dotterel	At Risk - Declining								

[6] For the purpose of this report, primary habitat refers to the habitat in which the species spends most of its time. Secondary habitats are other habitat types which the species may also utilise.

Species Name (OSNZ)	National Conservation Status	Oceanic	Coastal / Estuary	Freshwater / wetlands	Scrub / shrubland	Farmland / open country	Native forest	Exotic Forest	Urban / Residential
Black-backed gull	Not Threatened								
New Zealand kingfisher	Not Threatened								
Australasian bittern	Threatened - Nationally Critical								
Australasian shoveler	Not Threatened								
Banded rail	At Risk - Declining								
Black shag	At Risk - Relict								
Black swan	Not Threatened								
Grey teal	Not Threatened								
Little black shag	At Risk - Naturally Uncommon								
Little shag	At Risk - Relict								
Pied oystercatcher	At Risk - Declining								
North Island fernbird	At Risk - Declining								
Pied shag	At Risk - Recovering								
Pied stilt	Not Threatened								
Pukeko	Not Threatened								
Spotless crake	At Risk - Declining								
Paradise shelduck	Not Threatened								
New Zealand dabchick	Threatened - Nationally Increasing								
Grey duck	Threatened - Nationally Vulnerable								
Grey warbler	Not Threatened								
Silvereye	Not Threatened								
Australasian harrier	Not Threatened								
New Zealand pipit	At Risk - Declining								
Spur-winged plover	Not Threatened								
Welcome swallow	Not Threatened								
Cattle egret	Migrant (non-residential native)								
Morepork	Not Threatened								
North Island fantail	Not Threatened								
Shining cuckoo	Not Threatened								
Tui	Not Threatened								
Long-tailed cuckoo	Threatened - Nationally vulnerable								
New Zealand pigeon	Not Threatened								
North Island kaka	At Risk - Recovering								

Appendix 4: References relating to Waikato River

DOWDING

This table from Dowding (2019) describes values at the Waikato River estuary, harbour mouth, sand spit and adjacent dune land habitat. As of 2019. We are aware that some of the abundances of key species have changed since this report.

Site W11	Port Waikato (including lower reach of river)
Priority	2† ASCV-8
Assets	• **Australasian bittern – individuals occasionally sighted near river mouth and further upstream, numbers currently at site unknown. • *Variable oystercatcher – post-breeding flock site for 60-80 birds (~1%) • *Northern New Zealand dotterel – 1-3 pairs breeding in recent years. • *Pied shag – 25 recorded in 2017 (<1%). • *Royal spoonbill – 11 in 2018 (<1%).
Threats	For non-breeding birds, predation, and disturbance at HW roosts by human recreational activities. For breeding birds, predation of eggs, chicks, adults during breeding, disturbance during breeding (reducing productivity), natural factors, e.g., loss of nests/chicks to extreme weather, large tides, floods.
Detailed spatial information available	Map W11. Breeding sites of oystercatchers and dotterels on spit recorded annually.
Additional information	Apparently suitable habitat for wetland birds upstream from the mouth, but little information available. If number of bitterns exceeds 4-5, site may be Priority 1. Large Caspian tern colony at mouth in previous years now absent. Overlap with Waikato Region ASCV 8. Regular presence of Threatened or At-Risk taxa makes the site significant habitat of indigenous fauna (EW 2016). Listed as a wetland of international importance under Ramsar criteria by Cromarty & Scott (1996).
Information gaps	Sand spit visited frequently, but much less information from wetland areas in the lower river.
References and sources	Cromarty & Scott (1996), Dowding & Moore (2006), DOC bittern database, K. Opie (pers. comm.)

CROMARTY

This table from Cromarty et al. (1995) describes values of the Waikato River Delta Wetlands and surrounding estuarine habitat as of 1995. We are aware that some of the abundances of key species have changed since this report. This table from Cromarty et al. (1995) describes values of the Waikato River Delta Wetlands and surrounding estuarine habitat as of 1995. We are aware that some of the abundances of key species have changed since this report.

Noteworthy fauna:

The estuarine habitat near Port Waikato is used by a wide variety of bird species and supports both estuarine and wetland species. The sandspit and tidal flat the mouth of the Waikato River are important for migratory shorebirds, notably Banded Dotterel (*Charadrius bicinctus*), Wrybill (*Anarhynchus*), and Bar-tailed Godwit (*Limosa lapponica*) (ref. New Zealand Wildlife Service, 1981a). The islands are used as high tide roosts. Other notable species occurring in this area include Banded Rail (*Rallus philippensis assimilis*). The North Island Fernbird (*Bowdleria punctata vealeae*) occurs along the estuarine margins.

Some 31 species of birds have been recorded as inhabiting the river, associated swamps and shore vegetation. These include White-faced Heron (*Egretta novaehollandiae*), Pacific Reef Egret (*E. sacra*), Black Swan (*Cygn atratus*), Mallard (*Anas platyrhy*), Grey Duck (*A. superciliosa*), New Zealand Shoveler (*Arhynchotis variegate*), Spotless Crake (*Porzana tabuensis plumbea*), Pied Stilt (*Himantopus leucocephalus*) and White-fronted Tern (*Sterna striata*), as well as shags (*Phalacrocorax* spp.) and some gulls (*Larus* spp.). The New Zealand Dabchick (*Poliocephalus rufopectus*) and New Zealand Scaup (*Aythya novaeseelandiae*) occur in very low numbers, and the Brown Teal (*Anas aucklandica chlorotis*) has been recorded as a very occasional visitor.

The Australasian Bittern (*Botaurus poiciloptilus*) breeds in the thick Typha and Scirpus swamps. Other species reported to breed in the area include Variable Oystercatcher (*Haematopus unicolor*), New Zealand Dotterel (*Charadrius obscurus*) and Caspian Tern (*Sterna caspia*).

Reasons for inclusion:

1a. The Lower Waikato River and Estuary are a particularly good example of a lowland river system with a diverse estuarine delta.

2a. The wetland supports populations of at least for globally threatened species of birds, notably *Poliocephalus rufopectus*, *Botaurus poiciloptilus*, *Charadrius obscurus* and *Anarhynchus frontalis*.

2b. The wetland supports a variety of plant and animal species which are uncommon or rare elsewhere in New Zealand (e.g., *Desmoschoenus spiralis*), and is thus of special value in maintaining the genetic and ecological diversity of the region.

2c. The wetland is of special value as breeding habitat for several uncommon and the species of birds, notably *Botaurus poiciloptilus*, *Haematopus unicolor*, *Charadrius obscurus* and *Stern caspia*.

Appendix 5: The Band Collision Risk Model (CRM)

The Band collision risk model (Band et al., 2007) is, at its simplest, a deterministic model which uses two straightforward spreadsheets to carry out a range of calculations to determine a probability of a collision when a population of birds traverses through a wind farm for one year. The Band collision risk model is, at its simplest, a deterministic model which uses two straightforward spreadsheets to carry out a range of calculations to determine a probability of a collision when a population of birds traverses through a wind farm for one year.

This model has been expanded on for this project, as it was for both the Taharoa and HMR windfarm projects, by the addition of Monte Carlo simulations for those aspects of the data which had low confidence (traverses of the site, turbine downtime) or which had the greatest influence on the final result (flight height and avoidance rates). In this way we can also calculate confidence intervals.

It also, like the new iteration of the model for use in offshore windfarms (Band 2012) uses traverse rates (Density of birds in flight) to calculate the probability of a bird traversing the site and interacting with a turbine.

The following two pages are taken from the publicly available spreadsheets which form the basis of the Band model.

- The first page calculates the risk of collision for a single bird passing through a rotating turbine without avoidance.
- The second page uses a range of inputs on the windfarm layout and size, on the at-risk population, regarding the operation of the turbines, and including the collision risk from the first page to calculate a predicted collision rate for the species.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Only enter input parameters in blue											W Band	11/02/2023
K: [1D or [3D] (0 or 1)	1		x	Calculation of alpha and p(collision) as a function of radius								
NoBlades	3		x				Upwind:			Downwind:		
MaxChord	2.8	m	x	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		=B8*PI()/180	radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.9	m	x	0.025	0.575	12.46	42.23	1.00	0.00125	41.40	1.00	0.00125
Wingspan	1.8	m	x	0.075	0.575	4.15	14.35	0.67	0.00500	13.52	0.63	0.00471
F: Flapping (0) or gliding (+1)	0		=IF(B12,2/PI(),1)	0.125	0.702	2.49	9.72	0.45	0.00564	8.71	0.40	0.00505
				0.175	0.860	1.78	7.97	0.37	0.00648	6.72	0.31	0.00546
Bird speed	17	m/sec	x	0.225	0.994	1.38	6.94	0.32	0.00725	5.50	0.26	0.00574
RotorDiam	66	m	x	0.275	0.947	1.13	5.63	0.26	0.00718	4.25	0.20	0.00543
RotationPeriod	3.80	sec	x	0.325	0.899	0.96	4.71	0.22	0.00711	3.40	0.16	0.00514
				0.375	0.851	0.83	4.03	0.19	0.00701	2.79	0.13	0.00486
				0.425	0.804	0.73	3.50	0.16	0.00690	2.33	0.11	0.00460
				0.475	0.756	0.66	3.07	0.14	0.00677	1.97	0.09	0.00435
Bird aspect ratioo: β	0.50		=B10/B11	0.525	0.708	0.59	2.72	0.13	0.00663	1.69	0.08	0.00412
				0.575	0.660	0.54	2.42	0.11	0.00647	1.46	0.07	0.00391
				0.625	0.613	0.50	2.17	0.10	0.00630	1.28	0.06	0.00372
				0.675	0.565	0.46	2.01	0.09	0.00632	1.20	0.06	0.00375
				0.725	0.517	0.43	1.88	0.09	0.00632	1.13	0.05	0.00379
				0.775	0.470	0.40	1.75	0.08	0.00630	1.07	0.05	0.00385
				0.825	0.422	0.38	1.64	0.08	0.00627	1.03	0.05	0.00393
				0.875	0.374	0.36	1.53	0.07	0.00622	0.99	0.05	0.00402
				0.925	0.327	0.34	1.43	0.07	0.00616	0.96	0.04	0.00413
				0.975	0.279	0.32	1.34	0.06	0.00608	0.94	0.04	0.00425
				Overall p(collision) =				**Upwind**	**12.4%**		**Downwind**	**8.6%**
									Average	**10.5%**		

BAND ET AL 2007 COLLISION MODEL					
EXAMPLE FROM PAPER FOR PREDICTABLE FLIGHTS (GREYLAG GOOSE)					W Band 11/02/2023
	Input	Units	Formulae		
Collision risk height	90	m			highlighted cells are those that require input values
Risk corridor Width	1,560	m			
Risk corridor Area	140,400	m^2	=B5*B4		
Mean bird movements/hr	**3.21**				
Annual flight hours	2,906	hrs			Total hours annual 8,760. Average of 2906 hours of sunlight per year (Scotland)
Annual number flying through risk window	9,328		=B9*B8		
No turbines	27				
Rotor diameter	66	m			
Rotor swept area	3,421	m^2	=(B14/2)^2*PI()		
Allowance for overlap	0%				If multiple rows mean Rotor Swept Area approach Risk Corridor Area
Proportion of risk window occupied by rotors	66%		=B13*B15*(1-B17)/(B5*B4)		
Annual no bird rotor passes	6,137		=B12*B20		
Band individual collision risk	12.3%				from Band-1 CollisionRisk (Stage 2 in paper)
Turbine downtime	15%				Value based on cut in and switch off wind speeds
Non-avoidance collisions	642		=B22*B24*(1-B26)		
Avoidance rate	98%				Derived from research. Specific to each species.
Predicted collisions	**12.8**		=B29*(1-B31)		

Appendix 6: Key Species – Flight Metrics & Assumptions

Three flight metrics are required for the Band Model. They are body length, wingspan, and flight speed.

In the following table the metrics for body length and wingspan are derived predominantly from the seven-volume *Handbook of Australian, New Zealand and Antarctic birds* (or HANZAB). For four birds wingspan was not provided, nor could it be found by an internet search, and in these cases an analogue species was used. See below.

Flight speed is only available for a small number of native birds. We have therefore relied on a variety of international sources selecting analogue species based on similarity (body weight, size, family-genus), to native birds.

For modelling purposes the ranges obtained for body length and wingspan are averaged. In doing so we note that minor variances in these three metrics have a relatively insignificant effect on the modelling outcome.

Key Species	Body Length (cm)	Wingspan (cm)	Flight Speed (m/s)	Flight Speed Source
Bittern, Australasian	0.72	1.10	10.10	Based on GPS telemetry, Kaiwaikawe Wind Farm (Fuller, 2021)
Crake, Spotless	0.19	0.28	13.90	From Alerstam et.al. (2007), using '*Porzana porzana*' as analogue.
Dabchick, New Zealand	0.27	0.46	19.00	From Alerstam et.al. (2007), using 'ducks' as analogue.
Dotterel, Banded	0.20	0.40	12.00	Based on radar observations, Taharoa Wind Farm (Fuller et al., 2009).
Dotterel, Northern	0.27	0.48	12.00	Based on observations, Taharoa Wind Farm (Fuller et al., 2009).
Godwit, Eastern Bar-tailed	0.37	0.66	17.00	Based on Phil Battley pers.com. Taharoa Wind Farm (Fuller et al., 2009).
Gull, Black-billed	0.37	0.90	11.20	From Pennycuick (1997) using *Larus ridibundus* analogue.
Gull, Red-billed	0.40	0.93	11.20	From Pennycuick (1997) using *Larus ridibundus* analogue.
Oystercatcher, Pied	0.46	0.83	14.40	Based on Taharoa radar tracking.
Oystercatcher, Variable	0.48	0.85	14.20	Based on Taharoa measure for pied oystercatcher as analogue. (Fuller, 2021).
Shag, Black	0.82	1.40	16.70	From Bruderer & Boldt (2001) using *P. carbo* analogue.
Shag, Little	0.60	0.87	15.40	From Pennycuick (1997) using *P. aristotelis* analogue
Shag, Little Black	0.60	1.00	15.40	From Pennycuick (1997) using *P. aristotelis* analogue
Shag, Pied	0.75	1.20	16.70	From Bruderer & Boldt (2001) using *P. carbo* analogue
Tern, Caspian	0.50	1.40	12.00	From Tucker & Schmidt-Koenig (1971)
Tern, White-fronted	3.90	0.81	11.60	From Bruderer & Boldt (2001) using *Sterna hirundo* analogue
Wrybill	0.21	0.38	16.40	From Bruderer & Boldt (2001) using ringed plover analogue

Analogues for wingspan

- Dabchick wingspan is not given. Instead from HANZAB for hoary crested grebe which has same size and weight.
- Banded dotterel wingspan is not given. Used agreed metric for Taharoa Windfarm (Fuller et al., 2009).
- Fernbird wingspan is not given. Based on NZ pipit which has same body length and body weight 13-18cm, 33g.
- Wrybill wingspan is not given. Used agreed metric for Taharoa Windfarm (Fuller et al., 2009).

Appendix 7: Key Species – RSA Assumptions

One of the most important metrics required by the Band Model is the proportion of activity for each species which occurs at the height of the blade rotors. This varies widely between species from zero or close to zero for some species (NZ Pipit, NZ dotterel) to a value of 50% or greater).

In the following table we have collated all flight height data from the reports of five windfarm projects which are West Wind (Bull et al., 2013), Taharoa (Fuller et al., 2009), HMR (Kessels & Associates Ltd, 2009), Waipipi (Boffa Miskell Ltd, 2019), and Kaiwaikawe (Boffa Miskell Ltd, 2020).

In these reports there is data for 19 of the 23 key species. For each bird where there is data, we also list the number of birds observed which suggests that the data is very poor (less than 20 observations) for four species and the RSA % is discussed and in some cases not used. There is no data for 7 birds and for these we suggest an appropriate analogue based on our knowledge of these species.

KEY SPECIES	Confidence in data	Low	Mode	High
Bittern, Australasian	Adequate data, 3 birds, GPS flight multiple months.	10	20	40
Crake, spotless	No data. Have used 25, 50, 75	25	50	75
Dabchick, New Zealand	Very poor data, 1 site, 8 obs, Use 25, 50, 75	25	50	75
Dotterel, banded	Good data, 3 sites, 633 obs	5	14	20
Dotterel, New Zealand	Adequate data, 2 sites, 48 obs	2	5	15
Godwit	Adequate data, 1 site, 219 obs.	60	80	90
Gull, black-billed	Very poor data, 1 site, 1 obs, Use 25, 50, 75.	25	50	75
Gull, red-billed	Good data, 2 sites, 689 obs	10	22	35
Oystercatcher, pied	Good data, 3 sites, 100,000 obs +	25	50	65
Oystercatcher, variable	Good data, 2 sites, 301 obs	10	20	40
Shag, black	Good data, 4 sites, 713 obs	25	60	80
Shag, little	Good data, 5 sites, 183 obs	15	40	70
Shag, little black	Good data, 4 sites, 150 obs	25	35	65
Shag, pied	Good data, 4 sites, 276 obs	30	50	65
Tern, Caspian	Good data, 2 sites, 356 obs	10	15	25
Tern, white-fronted	Good data, 2 sites, 766 obs	5	10	20
Wrybill	Poor data, one site, 47 obs.	60	80	90

Appendix 8: Key Species – At Risk Population eBird

A total of 66 bird counts have been uploaded into eBird (EBird, n.d.) which cover key habitats within and surrounding the site. We have separated these into ten locations, treating Waikato River mouth and spit as one population, the Port Waikato mudflats as a second population, and each of the six lakes and ponds which are found along the dune landscape within the site sits each as a separate population.

Karioitahi Beach South is the portion of beach that runs below the site. Karioitahi Beach North extends past the Awhitu Wind Farm to the Manukau heads.

Spit / Estuary	17 counts, 1 Dec 20 to 13 Aug 22
Port Waikato	11 counts, 30 Jan 20 to 30 Jul 22
Karioitahi Beach South	5 counts, 19 Dec 2019 to 23 Jun 22
Karioitahi Beach North	4 counts, 14 May 2020 to 26 Jul 22
Huarau Pond	7 counts, 24 Jun 2021 to 19 Oct 2022
Thompsons pond	1 count. 20 Jul 21.
Parkinson's Lake	7 counts, 20 Jun 2019 to 27 Apr 2022
Lake Otamatearoa	5 counts, 26 Nov 2022 t0 27 Apr 2022
Lake Whatihua	2 counts, 26 Mar 2021 to 20 Nov 2021
Lake Puketi	7 counts, 28 Aug 2020 to 18 May 2022

Mean abundance of species at each site	Spit / Estuary	Port Waikato	Karioitahi Beach South	Karioitahi Beach North	Huarau Pond	Thompsons pond	Parkinson's Lake	Lake Otamatearoa	Lake Whatihua	Lake Puketi
Bittern, Australasian										
Crake, spotless										
Dabchick, New Zealand					1.1	1.0	1.9	1.8	2.0	2.9
Dotterel, banded	6.5	3.2								
Dotterel, New Zealand	4.3	1.5								
Godwit	5.9	17.3								
Gull, black-billed	3.9	5.4		1.3						
Gull, red-billed	3.5	9.3	7.0	23.0						
Oystercatcher, pied	54.8	43.8								
Oystercatcher, variable	13.7	3.7	1.0	4.0						
Shag, black	0.3	0.5		0.5	0.3			0.3	0.5	
Shag, little	0.5	0.2			0.6		0.3	1.0	2.0	0.9
Shag, little black	14.9	8.5			0.1	2.0	0.1	0.1		0.3
Shag, pied	21.8	29.4	0.6	0.3						
Tern, Caspian	10.2	5.9	0.8	21.5						
Tern, white-fronted	216.6	1.4	3.6	226.3						
Wrybill	0.6	1.0								

Appendix 9: IUCN Red List

The New Zealand Coastal Policy Statement, in addition to directing you to the New Conservation Status of our species also directs us to the IUCN Red List of Threatened species (IUCN, n.d.).

Established in 1964, the International Union for Conservation of Nature's Red List of Threatened Species is a comprehensive information source on the global extinction risk status of animal, fungus, and plant species. The threat status of Native and Indigenous species will differ between New Zealand's conservation status and the red list which are assessing conservation status against different criteria. For this site the species with a Conservation Status and their comparable Red List entry are as follows:

Common Name	Scientific Name	New Zealand Conservation Status	IUCN Red List
Coastal, estuarine, riverine, wetland and inland species			
Bittern, Australasian	*Botaurus poiciloptilus*	Threatened - Nationally critical	Vulnerable VU
Heron, Reef	*Egretta sacra*	Threatened - Nationally endangered	Least Concern
Tern, Caspian	*Hydroprogne caspia*	Threatened - Nationally vulnerable	Least Concern
Duck, Grey	*Anas s. superciliosa*	Threatened - Nationally vulnerable	Least Concern
Dabchick, New Zealand	*Poliocephalus rufopectus*	Threatened - Nationally increasing	Least Concern
Dotterel, New Zealand	*Charadrius obscurus*	Threatened - Nationally increasing	Critically endangered
Wrybill	*Anarhynchus frontalis*	Threatened - Nationally increasing	Vulnerable VU
Dotterel, Banded	*Charadrius bicinctus*	At Risk - Declining	Near threatened
Rail, Banded	*Gallirallus philippensis*	At Risk - Declining	Least Concern
Gull, Black-billed	*Chroicocephalus bulleri*	At Risk - Declining	Near threatened
Pipit, New Zealand	*Anthus novaeseelandiae*	At Risk - Declining	Least Concern
Fernbird, North Island	*Poodytes punctatus*	At Risk - Declining	Least Concern
Oystercatcher, Pied	*Haematopus finschi*	At Risk - Declining	Least Concern
Gull, Red-billed	*Larus novaehollandiae scopulinus*	At Risk - Declining	Least Concern
Crake, Spotless	*Porzana tabuensis*	At Risk - Declining	Least Concern
Tern, White-fronted	*Sterna striata*	At Risk - Declining	Near threatened
Kaka, North Island	*Nestor meridionalis*	At Risk - Recovering	Vulnerable
Shag, Pied	*Phalacrocorax varius*	At Risk - Recovering	Least Concern
Oystercatcher, Variable	*Haematopus unicolor*	At Risk - Recovering	Least Concern
Shag, Little Black	*Phalacrocorax sulcirostris*	At Risk - Naturally Uncommon	Least Concern
Spoonbill, Royal	*Platalea regia*	At Risk - Naturally Uncommon	Least Concern
Shag, Black	*Phalacrocorax carbo novaehollandiae*	At Risk - Relict	Least Concern
Shag, Little	*Microcarbo melanoleucos*	At Risk - Relict	Least Concern
International Migrants and Vagrants			
Long-tailed cuckoo	*Eudynamys taitensis*	Threatened - Nationally vulnerable	Least Concern
Bar-tailed Godwit	*Limosa lapponica baueri*	At Risk - Declining	Near threatened

Common Name	Scientific Name	New Zealand Conservation Status	IUCN Red List
Red knots	*Calidris canutus*	At Risk - Declining	Near threatened
Arctic Skua	*Stercorarius parasiticus*	Migrant	Least Concern
Cattle Egret	*Bubulcus ibis*	Migrant	Least Concern
Pacific golden plover	*Pluvialis fulva*	Migrant	Least Concern
Red-necked stint	*Calidris ruficollis*	Migrant	Near threatened
Ruddy Turnstone	*Arenaria interpres*	Migrant	Least Concern
Little whimbrel	*Numenius minutus*	Vagrant	Least Concern
Oriental plover	*Charadrius veredus*	Vagrant	Least Concern
Long-tailed cuckoo	*Eudynamys taitensis*	Threatened - Nationally vulnerable	Least Concern
Shorebirds			
Black petrel	*Procellaria parkinsoni*	Threatened - Nationally vulnerable	Vulnerable VU
NZ storm petrel	*Fregetta maoriana*	Threatened - Nationally vulnerable	Critically Endangered
Sooty shearwater	*Ardenna grisea*	At Risk - Declining	Near Threatened
Little shearwater	*Puffinus assimilis*	At Risk - Recovering	Least Concern
Pycroft's' petrel	*Pterodroma pycrofti*	At Risk - Recovering	Vulnerable
Common diving petrel	*Pelecanoides urinatrix*	At Risk - Relict	Least Concern
Cook's petrel	*Pterodroma cookii*	At Risk - Relict	Vulnerable
Flesh-footed shearwater	*Ardenna carneipes*	At Risk - Relict	Near Threatened
Fluttering shearwater	*Puffinus gavia*	At Risk - Relict	Least Concern
White-faced storm petrel	*Pelagodroma marina*	At Risk - Relict	Least Concern
Gannet	*Morus serrator*	Not Threatened	Least Concern
Grey-faced petrel	*Pterodroma gouldi*	Not Threatened	Least Concern

Appendix 10: Avian Mortalities at Windfarms in NZ

Avian mortalities recorded during post-construction collision monitoring at 4 windfarms in New Zealand (Fuller, 2021). (Sorted by combined count)

Common Name	Threat status	West Wind[7]	Mahinerangi[8]	Te Apiti[9]	Te Uku[10]	Combined
Australasian Harrier	Native - Not Threatened	12	1	1	6	20
Magpie	Introduced		6	2	11	19
Skylark	Introduced	2	4		9	15
Mallard	Introduced	4	1	2	1	8
Chaffinch	Introduced	6		1		7
Paradise shelduck	Native - Not Threatened	5	1			6
Southern black-backed gull	Native - Not Threatened	4	1		1	6
Finch sp.	Introduced	3				3
Redpoll	Introduced	4				4
Waxeye	Native - Not Threatened		1	2	1	4
Yellowhammer	Introduced	3				3
Goldfinch	Introduced	1		1		2
Tui	Native - Not Threatened	2				2
Blackbird	Introduced	1			1	2
Dunnock	Introduced	1				1
Eastern rosella	Introduced	1				1
Fairy prion	Native - At Risk	1				1
Feral turkey	Introduced				1	1
Greenfinch	Introduced	1				1
Rock Pigeon	Introduced		1			1
Song thrush	Introduced	1				1
Spur-wing plover	Native - Not Threatened	1				1
TOTAL		**53**	**16**	**9**	**31**	**109**

[7] (Bull et al., 2013) Bull, L. S., Fuller, S. A., & Sim, D. (2013). Post-construction avian mortality monitoring at Project West Wind. New Zealand Journal of Zoology, 40(1), 28–46.

[8] (Golder Associates, 2013) Golder Associates 2013. *Mahinerangi Wind Farm State 1, 2 years post-construction bird strike monitoring, 2011-2013*. Prepared for TrustPower Limited. Report 1278405717-002-R-Rev0. 37 pages.

[9] Meridian Energy 2020.

[10] (Boffa Miskell Ltd, 2014) Boffa Miskell Limited 2014. *Project Te Uku Post-construction Avifauna & Bat Monitoring: Year 3 Annual Report.* Report prepared by Boffa Miskell Limited for Meridian Energy Limited. A10203. 35 pages.

Appendix 11: eBird Maps

The following table lists the seabird species identified in Section 5.1, Table 2. It is followed by eBird maps for each species.

We note that the data presented in these eBird maps is not based on comprehensive surveys using standardised methodology. Rather they have grown from citizen science where enthusiasts as well as record observations to a website. It is strongly biased toward publicly accessible areas, roads, parks, rivers, beaches, and generally is poorly representative of birds on private land. It also does not collect data on bird movement. This source of data, can however, over time accumulate enough observations to be helpful in confirming residence at key areas, or through the lack of observations over a large area indicate a low abundance of a species. These factors need to be considered when considering the data.

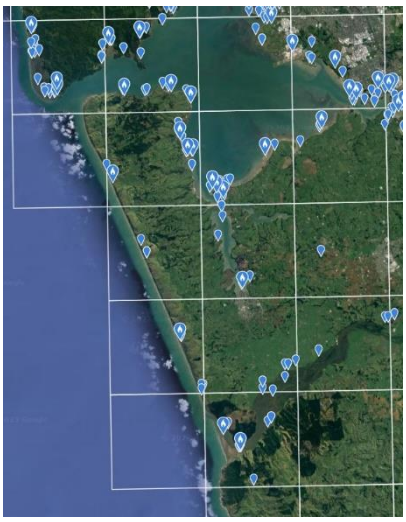
Maps are presented for the following species.

Coastal, inland and wetland species

Name	National Conservation Status
1. Australasian Bittern	Threatened - Nationally critical
2. Reef heron	Threatened - Nationally endangered
3. Caspian Tern	Threatened - Nationally vulnerable
4. Grey duck	Threatened - Nationally vulnerable
5. New Zealand Dabchick	Threatened - Nationally increasing
6. New Zealand dotterel	Threatened - Nationally increasing
7. Wrybill	Threatened - Nationally increasing
8. Banded dotterel	At Risk - Declining
9. Banded rail	At Risk - Declining
10. Black-billed Gull	At Risk - Declining
11. New Zealand Pipit	At Risk - Declining
12. North Island Fernbird	At Risk - Declining
13. Pied Oystercatcher	At Risk - Declining
14. Red-billed gull	At Risk - Declining
15. Spotless Crake	At Risk - Declining
16. White-fronted Tern	At Risk - Declining
17. North Island Kaka	At Risk - Recovering
18. Pied shag	At Risk - Recovering
19. Variable Oystercatcher	At Risk - Recovering
20. Little Black shag	At Risk - Naturally Uncommon
21. Royal Spoonbill	At Risk - Naturally Uncommon
22. Black shag	At Risk - Relict
23. Little shag	At Risk - Relict

1. Australasian Bittern

2. Reef Heron



3. Caspian Tern

4. Grey Duck

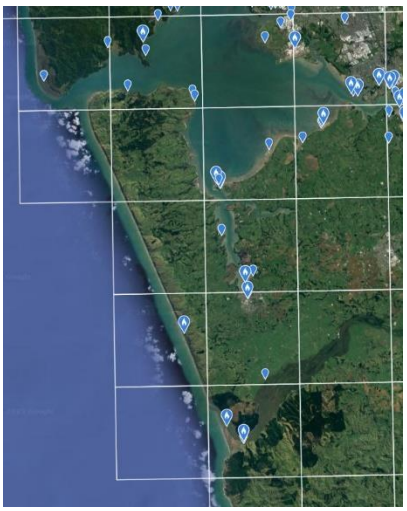
5. New Zealand dabchick

6. New Zealand dotterel

7. Wrybill

8. Banded dotterel

9. Banded rail



10. Black-billed gull

11. New Zealand pipit

12. North Island fernbird

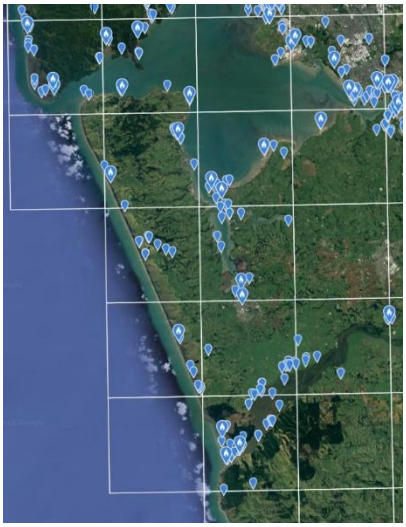
13. Pied oystercatcher

14. Red-billed gull

15. Spotless crake

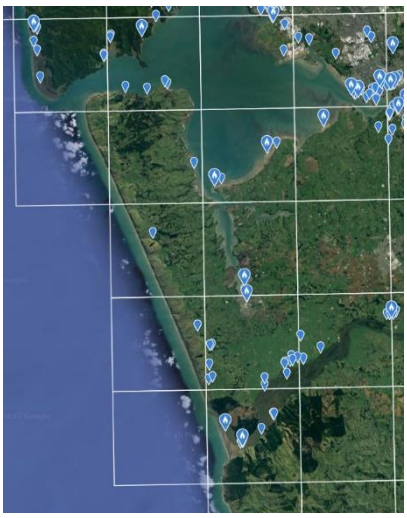
16. White fronted tern

17. North Island kaka



18. Pied shag

19. Variable oystercatcher



20. Little black shag

21. Royal spoonbill

22. Black shag

23. Little black shag

International Migrants

The following table lists the international migrants and vagrants identified in Section5.2, Table 3 It is followed by eBird maps for each species.

We note that eBird observations are often limited to beach or harbour observations and do not represent activity further out to sea.

Name	National Conservation Status
1. Long-tailed cuckoo	Threatened - Nationally vulnerable
2. Bar-tailed Godwit	At Risk - Declining
3. Red knots	At Risk - Declining
4. Arctic Skua	Migrant
5. Cattle Egret	Migrant
6. Pacific golden plover	Migrant
7. Red-necked stint	Migrant
8. Ruddy Turnstone	Migrant
9. Little whimbrel	Vagrant
10. Oriental plover	Vagrant

1. Long-tailed cuckoo

2. Bar-tailed godwit

3. Red knot

4. Arctic skua

5. Cattle egret

6. Pacific golden plover

7. Red-necked stint

8. Ruddy turnstone

9. Little whimbrel

10. Oriental plover

Appendix 12: Other Coastal Wind Farm Projects

Proposed Taharoa C Wind Farm

Taharoa Wind Farm (TWF) was the first wind farm in NZ to use radar for the study of migrant activity, shortly followed by Hauāuru mā raki Wind Farm (HMR). TWF was consented but not built due to financial issues. The assessment for this site was carried out jointly with the Department of Conservation and two other independent ornithologists acting for Council (Fuller et al., 2009). The group jointly hoped that TWF would provide a test site for both the effectiveness of using collision mortality modelling based on radar, to shape a wind farm and minimise effects; and as a test site for the observation by radar of migrants moving through an operational wind farm.

During summer 2008 1,588 Pied Oystercatcher flocks were recorded. During winter 1,395 flocks were recorded. Adjusted numbers predict between 60% and 90% of the national population were observed at this site. The preliminary assessment predicted between 24 and 60 pied oystercatcher would be killed during each migration.

This site was of particular interest as during the northern movement, migrants split with 49% flying along the beach, 26% flying overland south of the wind farm direct to Kawhia Harbour, and 25% crossing the TWF site. The split for the winter movement was slightly different, a key learning from the study.

Using this radar data collision risk modelling was carried out to test several wind farm layouts, moving and removing turbines from high use areas to eventually reduce predicted mortalities by 40%.

It is possible a similar effect may occur at Waiuku, a proportion of migrants continuing along the coast, many of the remainder heading inland at Port Waikato and traversing across directly to the south arm of the Manukau Harbour at Waiuku. This would need to be confirmed by radar observation.

Photo 8: Taharoa looking south along the coastline from Paparoa Point, 2008.

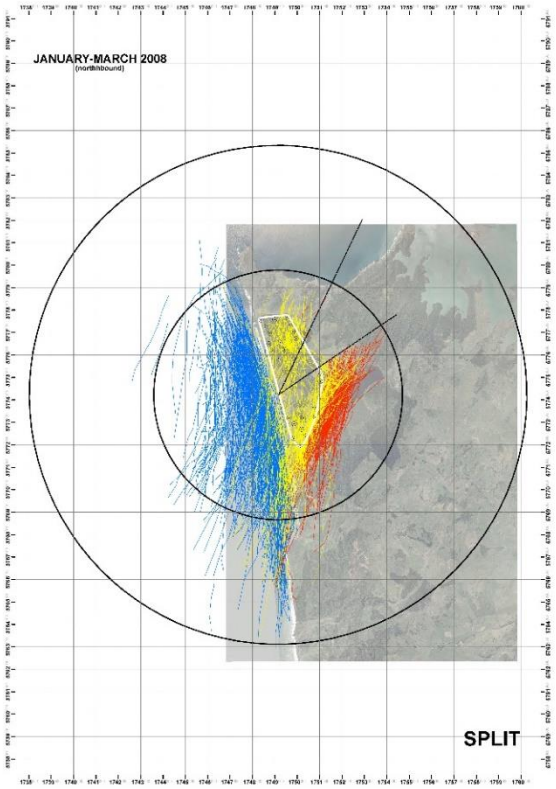


Figure 7: Northward migration 2008. Offshore trails in blue, inland trails in red, traverses across the wind farm in yellow.

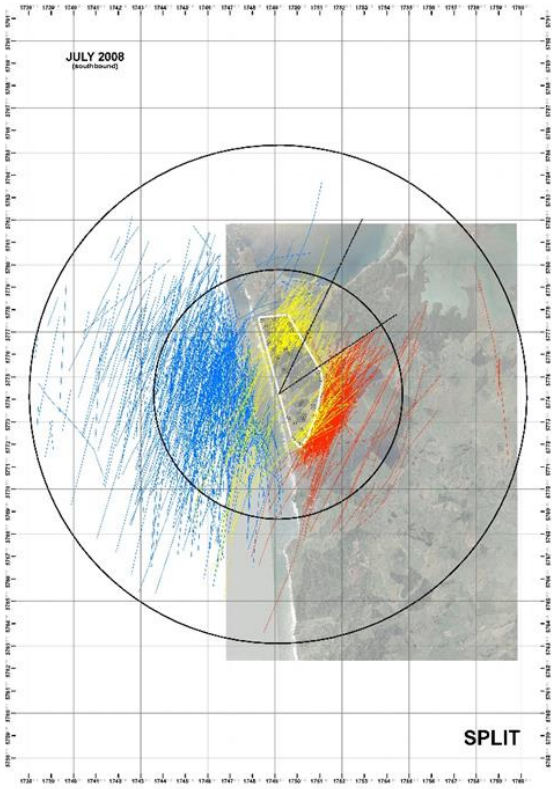


Figure 8: Southward migration 2008. Offshore trails in blue, inland trails in red, traverses across the wind farm in yellow.

The Taharoa study identified behaviours of migrants regarding offshore and onshore movements, the effect of terrain, and a significant variation between seasons. One concern raised by the authors was that only one summer and one winter season was studied, and it was likely there would be some variations in flights between years, as well as between seasons.

The key to the study was the use of radar. Without radar it would have been impossible to carry out these investigations.

Hauāuru mā raki Wind Farm (HMR)

The HMR Wind Farm was not constructed but was consented in February 2011. The site was to be located along approximately 34km of coastline on the west coast of the North Island of New Zealand, four kilometres south of Port Waikato, south to Te Akau, some eight kilometres north of Raglan. Its northern extent was some 12km south of the Waiuku site (Kessels & Associates Ltd, 2009).

Monitoring at the site of HMR's proposed 168 turbines was carried out by an "Expert Shorebird Group" formed by the councils, Contact Wind and DOC. Their brief was to determine strike risk of key bird species.

Pied oystercatcher, wrybill, banded dotterel, and pied stilt were identified by the Expert Shorebird Group as the internal migrant species of most concern and for which collision risk modelling was necessary. It was also agreed amongst the experts that due to difficulty in detecting smaller, faster moving shorebird species (e.g., wrybill and banded dotterel), monitoring of pied oystercatcher should be the focus, and that the migratory movements of this species would be used as a proxy for the movements of all other migrating shorebirds (including international migrants). Resident shorebirds and other bird species were dealt with separately in terms of modelling strike risk through data obtained from surveys combined with the internal migrating shorebird surveys and other separate line transect and point count surveys

A detailed description of the specific routes that each species takes on migration was deemed necessary to determine the risk that the proposed HMR wind farm posed to migrant shorebirds.

Monitoring was conducted using a combination of up to three radars and a number of observers during five seasons: July-August 2008 (6 observer sites only); January-February 2009 (2 radars and 6 observer sites); July-August 2009 (3 radars and 14 observer sites); January-February 2010 (3 radar and 19 observer sites); and July-August 2010 (3 radar and no observer sites).

The surveys showed that a significant proportion of the national populations of the domestic migrant species were flying adjacent to the HMR site (for example see Figure 7). This figure shows radar trails which were verified by field observer data to be internal migrant shorebird movements, as well as initially unidentified radar trails which were determined to be internal shorebird movements based on flight trail characteristics.

The HMR study used a revised version of the Scottish Natural Heritage (SNA) "Band" model (Band et al., 2007) to estimate the mortality of migratory shorebirds at HMR. The following inputs were required to populate the model: The HMR study used a revised version of the Scottish Natural Heritage (SNA) "Band" model (Band et al., 2007) to estimate the mortality of migratory shorebirds at HMR. The following inputs were required to populate the model:

- Total number of birds flying through the general area;
- Percentage of birds flying over the wind farm;
- Percentage of birds flying at rotor swept height (RSH – set between 50 and 150m);
- Wind farm and turbine parameters and the average number of turbines met by a bird at risk;
- The turbine collision risk probability for a bird flying through a rotor; and
- Avoidance rates

The resulting predicted mortalities for the key bird species was determined through the agreed strike risk model. The modelling predicted mean yearly turbine collision mortalities rates for pied oystercatcher ranging from 29 to 43; for wrybill from 2 to 4; and for godwit 2.

It is important not to extrapolate these strike risk rates to the WWF, as strike risk is highly contextual. For example, at the HMR site a significant proportion of pied oystercatcher were flying offshore, whereas that may not be the case at the WWF site.

The Expert Shorebird Group agreed that it was appropriate for Contact Wind to mitigate predicted effects on a No Net Loss basis. The key element to achieve this was a Contact Wind proposal to support a predator control programme at breeding grounds in the Upper Rangitata River in the South Island. This was considered a suitable way to increase the breeding success of each of these species to a level that at least matches the predicted losses even allowing for expected mortality until the additional birds became breeding adults.

In addition, it was agreed by all parties that there would be extensive and long-term post construction monitoring of carcasses under turbines to calculate an actual death rate, given that there was no agreement from the modelling on the likely mortality rate. The decision makers of both sides agreed to a set of conditions which were accepted by the Board of Inquiry and built into the decision.

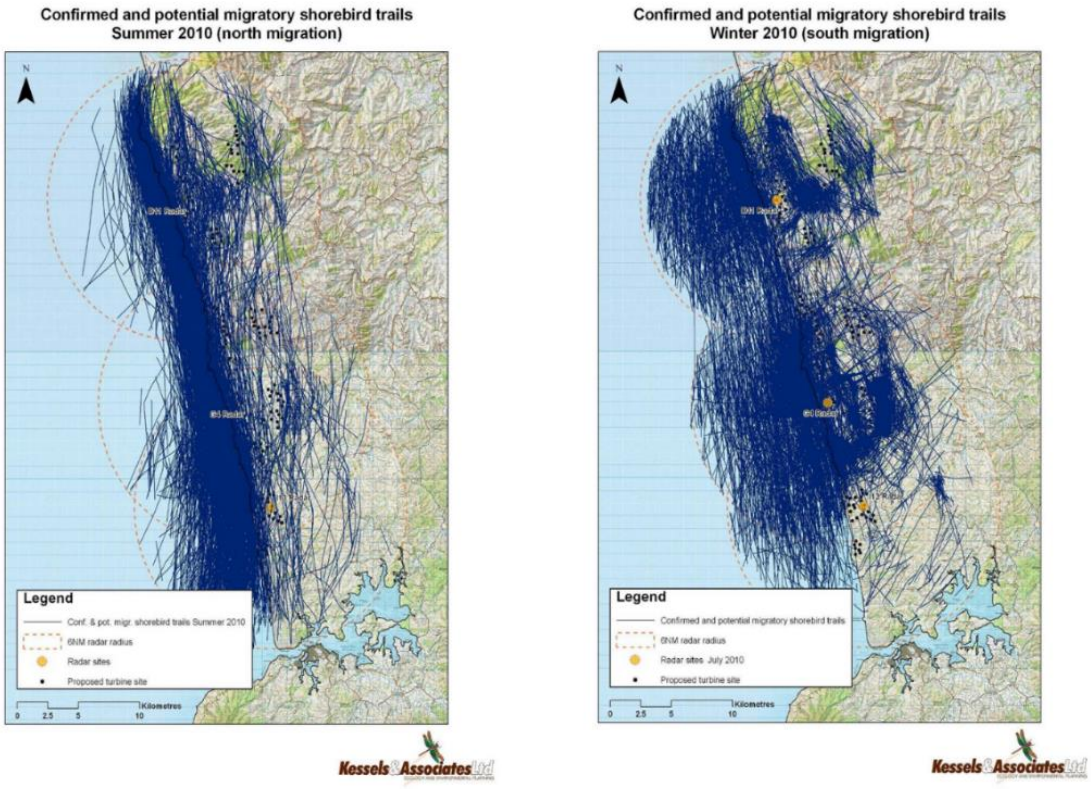


Figure 9: Northward (Summer 2010) and southward (Winter 2010) migration of domestic migrants on the west coast, immediately south of the proposed Waiuku Wind Farm site. Craig et.al. (2015).: Northward (Summer 2010) and southward (Winter 2010) migration of domestic migrants on the west coast, immediately south of the proposed Waiuku Wind Farm site. Craig et.al. (2015).

Waipipi (coastal and constructed)

Waipipi Wind Farm is the first coastal wind farm to be consented and built in New Zealand. The decision was made not to use radar at this site after preliminary surveys confirmed that this site was not on a main migratory flyway. Migrants were crossing the site but orders of magnitude fewer than at either Taharoa or HMR, in the order of 1,000 birds per season (adjusted). This was expected based on the little data we had on migrant movements around the South Taranaki Bight (as seen in Figure 3, page 13).

Our investigations supported the conclusion that migration movements on this section of coastline would be divided over a number of potential migration routes between the North and South Islands, most birds avoiding this section of coastline entirely, and where they were present, likely to be dispersed across a wide front, not constrained within a narrow flyway by topography as seen at Taharoa.

We do not believe this will be case at Waiuku, given its proximity to the west coast flyway and the Manukau Harbour.

We note that mortality modelling predicated collision mortalities in the order of 0.6%, or 1 collision approximately every two years. For the purpose of agreement on conditions, a lower avoidance rate was used giving up to 3 mortalities per annum with review thresholds of 10 mortalities per annum. To date Post Construction monitoring has not resulted in an observed mortality of a migrant.

Photo 9: Waipipi Wind Farm, Waverley NZ. An old iron sand mine area explaining the levelling of sand dunes at this coastal site.

(Baker et al., 2010)

(Taylor, 2000)

Flight Speed Source

Based on GPS telemetry, Kaiwaikawe Wind Farm (Boffa Miskell Ltd, 2020)(Fuller, 2021)

From (Alerstam, T. et al., 2007), using ‘’ as analogue

Based on Phil Battley pers.com. Taharoa Wind Farm (Fuller et al., 2009)

From (Pennycuick, 1997) using Larus ridibundus analogue.

From (Bruderer & Boldt, 2001) using P. carbo analogue

From (Tucker & Schmidt-Koenig, 1971) using analogue

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