Waikato Regional Council Technical Report 2017/23

Use of mangrove habitat by threatened or at risk birds

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

Prepared by:
Jacqui Bell and Andrew Blayney
Boffa Miskell Limited

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

June 2017

Document #: 10314248

Peer reviewed by:
Hannah Jones, Ben Bunting and
Michelle Lewis Date June 2017

Approved for release by:
Dominique Noiton Date November 2017

Disclaimer

This technical report has been prepared for the use of Waikato Regional Council as a reference document and as such does not constitute Council's policy.

Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

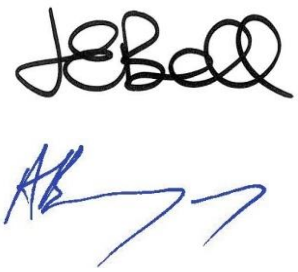
While Waikato Regional Council has exercised all reasonable skill and care in controlling the contents of this report, Council accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Use of mangrove habitat by Threatened or At Risk birds

Literature Review
Prepared for Waikato Regional Council

8 May 2017

Document Quality Assurance

Prepared by:	Jacqui Bell Senior Ecologist Boffa Miskell Limited Andrew Blayney Senior Ecologist Boffa Miskell Limited	
Reviewed by:	Dr Leigh Bull Senior Principal Ecologist Boffa Miskell Limited	
Status: [FINAL]	Revision / version: [1]	Issue date: 8 May 2017

Template revision: 20150331 0000

Cover photograph: Mangrove tree and pneumatophores, © Boffa Miskell, 2004

CONTENTS

Executive Summary

This document reviews the use of mangrove habitat by Threatened or At Risk birds within New Zealand. The report relies on chance observations, theses, technical reports, statements of evidence, resource consent applications and personal communications. Relatively few published studies have been carried out on this topic. The findings reported here should therefore be read with an understanding that they are based on information which is sourced from a variety of sources and have undergone varying levels of formal quality assurance and peer review.

Species identified as those that make use of mangrove habitat include: New Zealand fairy tern (*Sterna nereis davisae*) (Beauchamp, 2015), white heron (*Ardea modesta*), Australasian bittern (*Botaurus poiciloptilus*) (Miller and Miller, 1991), caspian tern (*Hydroprogne caspia*), pied shag, North Island fernbird (*Bowdleria punctata vealeae*), banded rail (*Gallirallus philippensis assimilis*), New Zealand pied oystercatcher (*Haematopus finschi*), pied stilt (*Himantopus himantopus leucocephalus*) and eastern bar-tailed godwit (*Limosa lapponica baueri*). In addition to the information within this report a stand-alone, in detail, review addressing banded rail has been prepared by Bell and Blayney (2017).

For each species a number of parameters have been reported on. These include: the degree of dependency on mangrove habitat, the purpose of use of mangrove habitat, important characteristics of mangroves, seasonal use of mangroves, connectivity of mangrove habitat and habitat patch size.

Our findings showed that New Zealand Fairy Tern (NZFT), white heron, Australasia bittern, pied shag, north island fernbird, pied oyster catcher, pied stilt, eastern bar-tailed godwit, and banded rail all use mangroves or habitat fringing mangroves for foraging. Whilst, pied shag and pied stilt have been observed roosting within or directly adjacent to mangroves and New Zealand pied oyster catcher have been observed using mangroves as refuge.

Banded rail, fernbird and Australasian bittern have been observed using mangrove as habitat within many of the harbours and estuaries along the east coast of the Waikato Region. Whilst, Eastern bar-tailed godwit, New Zealand pied oystercatcher, pied stilt and Caspian tern have been observed using coastal areas where mangroves are present within the Waikato region, these observations did not stipulate use of mangroves. There is however, no evidence that these species would behave any differently in the Waikato compared to other regions of New Zealand where they have been observed in association with mangroves along with other coastal habitats.

There are a number of threats to coastal birds that have been identified within the Waikato Region (Dowding, 2013). These include mammalian predation, human disturbance, sedimentation and exposure to adverse weather conditions. Mangroves have been shown to alleviate these stressors in other systems throughout the north island and are potentially valuable habitat to a larger range of Threatened or At Risk bird species.

The key issue associated with mangrove removal is that it is likely to have a negative impact on Threatened and At Risk birds by causing the direct loss of suitable foraging habitats with the potential to have severe detrimental impacts on bird populations. Mangrove removal is also likely to impact on the ability of many species to move within and between foraging, roosting and/or resting areas as mangroves provide a dispersal corridor seaward to open sand and mud

flats, shellbanks and sand spits, as well as landward to saltmarsh, freshwater wetland and coastal forest.

Additionally mangrove removal (especially mechanical and large scale removal) can cause elevated levels of water turbidity, macroalgal blooms and decreased oxygen levels in the water and sediment. This can have a direct negative impact on the benthic infauna, reduce the ability of wading birds to find food, and impact on the distribution of pelagic communities.

Currently the gaps in our knowledge and outstanding questions on the use of mangroves by Threatened or At Risk birds include:

- What is the distribution of birds in relation to mangroves in the Waikato region and New Zealand?
- What is the abundance of *Threatened and At Risk* birds within mangroves?
- How can we survey and monitor them effectively?
- What are the current limitations on *Threatened and At Risk* bird populations?
- What is the impact of mangrove removal on *Threatened and At Risk* birds?
- If we continue to remove mangroves can we effectively mitigate for the loss of mangrove habitat?

We consider the priority of further research to answer these questions to be:

1. Presence/non-detection inventory of *Threatened and At Risk* bird distribution within mangrove habitat with information on habitat use and use of adjoining habitats throughout the Waikato.
2. Research into modifying existing or developing new monitoring techniques in order to develop a standard protocol for monitoring of *Threatened and At Risk* birds that includes the ability to provide estimates of density within mangroves.
3. Surveys across sites in the Waikato region and New Zealand to determine how density and carrying capacity are impacted by different habitats and their connectivity.
4. Research and monitoring on the effect of mangrove removal on *Threatened and At Risk* bird populations in the short and long term. Including measures of density, survival, fecundity, site occupancy, use of mangrove removal areas, migration. This could be achieved through comparisons between specific mangrove removal study sites and appropriate control sites where mangroves are not removed.
5. Research the effect of changes in oxygen within the sediment and water column after mangrove removal on benthic and pelagic communities.
6. Research into the life history factors that may contribute to the impact of mangrove removal on *Threatened and At Risk* birds such as breeding patterns, parental care and moult regimes (See Bell and Blayney (2017)).
7. Explore and compare the abundance and habitat use distribution patterns of *Threatened and At Risk* birds across New Zealand; what are the different habitats they are using, habitat patch size, predation pressure, connectivity to other habitats, etc.
8. Conduct a research trial: design and implement a trial of habitat enhancement/creation based on the previous priority research findings to provide supplementary and alternative habitat for *Threatened and At Risk* birds that are known to use mangroves.

In order to establish a baseline understanding of the presence, density and distribution of *Threatened and At Risk* birds use of mangrove habitat in the Waikato region and to compare changes over time, the following monitoring techniques are recommended.

- Call counts
- Footprint surveys
- Audio recorders
- Visual surveys

Given that these species are Threatened or At Risk, an understanding of their habitat requirements is critical to their management. A number of recommendations have been made within this report to address the gaps in our understanding of the use of mangroves by threatened birds. We have also provided a prioritised list of research steps to begin answering these questions and enable us to understand this interaction between mangroves and Threatened or At Risk birds, while also enabling the conservation of Threatened or At Risk birds and their habitats into the future in a wider catchment management and ecosystem restoration framework.

1.0 Introduction

Report purpose

This review outlines the use of mangrove habitat by Threatened or At Risk birds throughout New Zealand and within the Waikato region. It provides an overview of the degree of dependency, purpose of use, important characteristics, seasonality and connectivity between habitats required by each species. A separate standalone report has been prepared addressing issues of relevance to banded rail (Bell and Blayney, 2017).

The review has drawn on a range of literature including peer reviewed scientific journal articles, technical reports, evidence, grey literature including data collected for council monitoring and consultant's reports and theses, books and discussions with technical experts.

The report begins with a broad overview of the ecology of mangroves, their distribution and their use by birds (Section 1.0). This is followed by a summary of the dependency, purpose of use, important characteristics, seasonal use and connectivity of mangroves for Threatened or At Risk birds in a National Context (Section 2.0) and in a Waikato Regional context (Section 3.0). Section 4.0 outlines what is known of the impact of mangrove removal on Threatened or At Risk birds. This is followed by recommendations (Section 5.0) including identified knowledge gaps, research recommendations and monitoring recommendations.

This report will be used by Waikato Regional Council (WRC) to inform the review of the Regional Coastal Plan and future science and policy work on mangrove management.

Report limitations

Very little scientific or peer reviewed information exists on the use of mangroves by Threatened or At Risk bird in New Zealand. As a result, this review heavily relies on individual statements of evidence, and anecdotal one off observations. The results of this review should therefore be read with a level of caution. One of the outcomes of this review is the recommendation for future research and monitoring (section 6.0), which have been made in order to address the significant gaps in our understanding of the role of mangroves for Threatened or At Risk birds within New Zealand.

What are mangroves?

Mangroves are specialist woody trees or shrubs, adapted for growth within the intertidal zone of low energy coastal and estuarine environments (Morrisey *et al.*, 2007). Typically, mangroves prefer to inhabit a soft muddy substratum and the gradual infilling of estuaries (concurrent with changes in land use) provides a suitable habitat for their establishment and growth (Morrisey *et al.*, 2007). These fringing habitats form a buffer to the land from natural hazards such as storm surge, while their dense root system form mats that stabilise sediment and protect the coastline from erosion (Thrush *et al.* 2013; Nicholls and Ellis, 2002). In New Zealand, mangrove habitat is indigenous to the northern coastlines of the North Island. Comprising a single species (*Avicennia marina* var. *australasica*) it has been present for over 19 million years (Morrisey *et al.*, 2007).

Distribution

The latitudinal range of mangrove habitat is limited by a number of factors, including microclimate, currents and suitable coastlines (de Lange and de Lange, 1994). Presently the southernmost limit of mangrove habitat in New Zealand is Ohiwa Harbour (38º 03'S) on the east coast and Kawhia Harbour (38º 05'S) on the west coast (Morrisey *et al.*, 2007).

Ecology

Mangroves form an important link in the coastal vegetation sequence between seagrass and saltmarsh habitat (Harty, 2009; Saintilan *et al.*, 2007). They are one of the most productive forest types in New Zealand and provide a key source of organic material and nutrients to the estuarine food web (Gladstone-Gallagher, 2014; De Luca, 2013; Woodroffe, 1982). Use of mangroves by an array of species contributes to the complexity and biodiversity of the coastal environment (Hutchings and Recher, 1982). Branches and roots provide protection from predation for native fish and birds, as well as a substrate with which both mobile and sessile invertebrates and plants can directly or indirectly inhabit (De Luca *et al.,* 2012; Beauchamp, 2012; Green *et al.*, 2003; Hutchings and Recher, 1974). These benthic invertebrates in turn provide an important food source for the fish and in turn birds that also inhabit mangroves (De Luca, 2015a, b; Morrisey *et al.*, 2010; Morrisey et al, 2007; Green *et al.*, 2003; Cox, 1977; Ritchie, 1976). Mangroves also provide important habitat corridors, maintaining native species distribution and connectivity between wider forest remnants (Baird, 2015).

Mangrove use by birds

As many as 48 different bird species, both native and introduced, have been observed using mangrove habitat (O'Donnell, 2011; Morrisey *et al.*, 2010; Whelan *et al.*, 2003; Crisp, 1990). Whilst not all species of birds that use mangrove habitat appear to be mangrove specialists, this type of habitat provides an important environment for many of the species that reside within them (Morrisey *et al.*, 2010). Common bird species (both native and introduced) that are regularly observed within mangroves in New Zealand include white-faced heron (*Egretta novaehollandiae*), harrier (*Circus approximans*), chaffinch (*Fringilla coelebs*), grey warbler (*Gerygone igata*), Australian magpie (*Gymnorhina tibicen*), kingfisher (*Halcyon sancta*), welcome swallow (*Hirundo tahitica neoxena*), house sparrow (*Passer domesticus*), pukeko (*Porphyrio porphyrio*), blackbird (*Turdus merula*), silvereye (*Zosterops lateralis*), song thrushes (*Turdus philomelos*), dunnock (*Prunella modularis*) and fantails (*Rhipidura fuliginosa*) (Morrisey *et al.*, 2010; Beauchamp and Parrish,1999; Cox, 1997). Observations of species breeding in the mangroves include the grey warbler, silvereye, fantail, house sparrow, shining cuckoo (*Chrysococcyx lucidus*) and New Zealand kingfisher (*Halycon sancta vagans*) (Morrisey *et al.*, 2010; Cox, 1977). Species that have been observed roosting within mangroves include little black shag (*Phalacrocorax sulcirostris*), pied shag (*P. varius*), white-faced heron, royal spoonbill (*Platalea regia*), starling (*Sturnus vulgaris*), house sparrow and chaffinch (*Fringilla coelabs*) (Beauchamp and Parish, 1999).

In addition to the common bird species that use mangroves, a number of At Risk or Threatened species have been observed using mangrove habitat (Table 1) (Robertson *et al.*, 2017; Moon, 1996). Such species include the New Zealand fairy tern (*Sterna nereis davisae*) (Beauchamp, 2015), white heron (*Ardea modesta*), Australasian bittern (*Botaurus poiciloptilus*) (Miller and Miller, 1991), caspian tern (*Hydroprogne caspia*), pied shag, North Island fernbird (*Bowdleria punctata vealeae*), banded rail (*Gallirallus philippensis assimilis*), New Zealand pied

oystercatcher (*Haematopus finschi*), pied stilt (*Himantopus leucocephalus*) and eastern bar-tailed godwit (*Limosa lapponica baueri*). An understanding of the value of mangrove habitat for these species is necessary for their effective conservation and management.

Table 1: Threatened or At Risk species of birds that use mangroves[1]

Threat Classification (Robertson *et al.* 2017)		Common Name	Scientific Name
THREATENED	**Nationally Critical**	New Zealand fairy tern	*Sterna nereis davisae*
		White heron	*Ardea modesta*
	Nationally Endangered	Australasian bittern	*Botaurus poiciloptilus*
	Nationally Vulnerable	Lesser knot	*Calidris canutus rogersi*
		Caspian tern	*Hydroprogne caspia*
AT RISK		Pied shag	*Phalacrocorax varius*
		Banded rail	*Gallirallus philippensis assimilis*
		New Zealand pied oystercatcher	*Haematopus finschi*
		Pied stilt	*Himantopus leucocephalus*
		Eastern bar-tailed godwit	*Limosa lapponica baueri*

2.0 National Context

Assessment of significance of mangrove habitat for Threatened or At Risk birds

There are relatively few published studies on the use of mangroves by *Threatened and At Risk* birds in New Zealand. Some of what is available consist of a chance observation (Miller and Miller, 1991), a MSc thesis (Cox, 1977), as well as a range of technical reports, evidence, resource consent applications and personal observations. This section of the report outlines what is known of the importance of mangrove habitat for *Threatened* and *At Risk* bird species throughout New Zealand. A number of parameters will be reported on in this section and include:

- Degree of dependency. To what degree are the birds' dependent on mangrove habitat?
    - low dependency – rarely seen using mangrove habitat
    - moderately dependent – occasionally seen using mangrove habitat

[1] Addendum to Evidence of Dr Sharon De Luca (requested by the Hearing committee) – 16 April 2015, from Dr Leigh Bull personal observation.

* A stand-alone report addressing Banded Rail has been prepared (Bell and Blayney, 2017).

    - highly dependent –frequently seen using mangrove habitat
- Purpose of use. For what purpose are the birds using the mangrove habitat?
- Important characteristics. Is the use of mangroves by the birds related to specific characteristics of mangroves, for example, age or height of mangroves, density or size of the mangrove patch?
- Seasonal use. Is there a seasonal component to the use of mangroves by Threatened or At Risk birds?
- Connectivity and habitat patch size. Consideration of the importance of connectivity between mangroves and surrounding habitat (e.g. saltmarsh, intertidal flats), and of the importance of habitat patch size to supporting populations of threatened or at risk birds.

New Zealand fairy tern

New Zealand fairy tern (NZFT) is a small endemic bird with a relic population of less than a dozen pairs (Pulham, 2013). It is New Zealand's rarest breeding bird (Ismar *et al.*, 2014) and the sub-species is classified as *Threatened - Nationally Critical* due in part to its very small population and limited distribution (Robertson *et al.*, 2017). Previous records show populations within the Kaipara (Tauhoa River and Waikiri Creek) on the west coast and small populations at Pakiri, Te Arai, Mangawhai, Waipu on the east coast (Beauchamp, 2012; Baird, 2015) and breeding sites include Waipu sandspit, Mangawhai sandspit, Pakiri River mount and Papakanui sandspit (Pulham and Wilson, 2013).

NZFT nest in open sand flats and shallow estuarine environments and feed on gobies, elvers and flounder (Ismar *et al.*, 2014; Parrish and Pulham, 1995; Pulham and Wilson, 2013; Higgins and Davies, 1996). Changes in land use has meant that breeding, foraging and roosting no longer occur in many of the areas where previous records were made (Beauchamp, 2012). Beauchamp (2012) and Baird (2015) have identified Mangawhai as important breeding habitat and Kaipara Harbour as important year round habitat for NZFT.

Degree of dependency

NZFT forage within areas fringing mangrove habitat at low and high tide (Beauchamp, 2012; Ismar *et al.*, 2014). Productive foraging grounds such as mangroves, located near breeding sites are important for the survival of adults and chick rearing for this species (Ismar *et al.*, 2014). This species is not directly associated with mangroves and appears to have a low-moderate degree of dependency on this type of habitat (Ismar *et al.,* 2014; Beauchamp, 2012).

Purpose of use

NZFT forage within the pneumatophores of fringing mangrove habitat (Ismar *et al.*, 2014). Gobies (*Favonigobius sp*.) were found to be the most important prey species for chick rearing (Ismar *et al.,* 2014; Hindell and Jenkins, 2005). Mangroves are an important nursery grounds for gobies and harbour an abundance prey species, such as shrimp and copepods for this species (Ismar *et al.*, 2014), making them productive foraging habitat for NZFT.

Mangroves also provide water clarity by trapping sediment and reducing turbidity. This may also benefit NZFT by allowing for successful foraging during high tides (Beauchamp, 2012; Alongi and McKinnon, 2005).

Whilst NZFT tern most often roost within open sand flats, Ferreira *et al.* (2004) identifies mangroves as additional suitable roosting habitat for this species. There are however, no other published observations of roosting in mangrove habitat.

In addition, mangroves fringing suitable areas for foraging, breeding and roosting may provide an effective barrier to disturbance for this species (Beauchamp, 2012; Wildland Consultants, 2012; Ismar *et al.*, 2014).

Important characteristics

The important characteristics of mangroves for NZFT (such as age, height, density and size) have not been identified within scientific literature.

Seasonal use

This species is more likely to be using habitat adjacent to mangroves during the winter months, than throughout summer, when shelter from storm fronts is necessary more frequently (Beauchamp, 2012).

Connectivity and habitat patch size

NZFT forage along mangrove lined tidal flats, tidal pools, mud and sandflats, mid estuary and lower harbour, as well as stream mouths and freshwater lakes (Parrish and Pulham, 1995; Ismar *et al.*, 2014; Jeffries *et al.*,2016). Mangrove habitat that is well connected to this sequence of coastal habitats is likely to be beneficial to the survival of this species (Ismar *et al.*, 2014), however, no studies have tested this specifically.

White heron

White heron is a native wading bird that inhabits harbours, estuaries and freshwater wetlands throughout New Zealand (Adams, 2013a). It is a rarely seen during the non-breeding season (Adams, 2013a). This species is classified as *Threatened - Nationally Critical,* with less than 250 mature individuals (Robertson *et al.*, 2017).

Degree of dependency

Whilst this species has been observed using mangrove habitat (Beauchamp, 2012), it does not appear to depend on it alone, and takes advantage of a range of other coastal and freshwater habitats (Moon, 1996). Based on observations, it is likely to have a very low degree of dependency on mangrove as habitat if any at all.

Purpose of use

This species is known to use the seaward margin of mangrove habitat for foraging (Beauchamp, 2012), however few observations have been made and there is a scarcity of data on the specific uses of mangroves by white heron.

Important characteristics

Observations have been made of white heron within the pneumatophores or low standing young seedlings, fringing mangrove stands. Unlike specialist mangrove-dwelling species, white heron do not appear to require dense, well established mangrove coverage for protection from predation or disturbance (Beauchamp, 2012).

Seasonal use

White heron use mangroves in the North Island during the non-breeding season, when they migrate up from their Westland breeding grounds (Miller, 2001; Adams a, 2013; Beauchamp 2012; Moon, 1996).

Connectivity and habitat patch size

This species uses a wide range of habitats from tidal lagoons to wetlands and streams (Moon, 1996). It is not dependent on mangrove habitat alone, and is likely to benefit from its ability to use a diversity of habitats, including mangroves. It is therefore likely that this species requires connectivity to terrestrial and freshwater habitats, through vegetation sequences, of which mangroves often form part. There have, however, been no studies carried out on the potential benefits of mangrove connectivity and patch size for this species.

Australasian bittern

Australasian bittern is a cryptic native species that commonly inhabit wetlands (Williams, 2013). They are extremely sensitive to disturbance, making them difficult to study or count (Williams, 2013). This species is listed as *Threatened* (Nationally Endangered) due to their apparent declining population, currently thought to be less than 1000 mature individuals (Robertson et al, 2017).

Miller and Miller (1991) recorded Australasian bittern using mangrove habitat in Pataua Estuary on the east coast north of Whangarei. Mangroves within Mangawhai Estuary (Gaskin, 2013) and Whangarei Harbour (Pierce, 2005), Hokianga Harbour (Pierce, 2002) and Tairua Harbour (Shaw *et al.*, 2012) have also been identified as important habitat for Australasian bittern. It is believed that this species may use mangrove habitat adjacent to coastal wetlands and swamps, where they are more commonly observed (Moon, 1996).

Degree of dependency

This species is commonly observed within coastal wetlands and does not appear to be highly dependent on mangrove habitat. However, few observations have been made of this species, such that little is known of their complete distribution and population dynamics (O'Donnell and Robertson, 2017; Williams 2013).

Purpose of use

Beauchamp (2012) describes mangroves as suitable foraging habitat for bittern. Mangroves provide water clarity by trapping sediment and reducing turbidity. This function may also benefit this species by allowing for successful foraging during high tides (Beauchamp, 2012).

Important characteristics

Due to the sparsity of data on this species, little is known of the important characteristics of mangroves with which the Australasian bittern take advantage of.

Seasonal use

Australasian bittern have not been observed using mangrove habitat during the breeding season between August and December. During this time, they tend to utilise dense wetland (Williams, 2013).

Connectivity and habitat patch size

This species is most commonly observed using wetlands (O'Donnell and Robertson, 2017; Williams, 2013). It is therefore likely that good connectivity between mangroves and adjacent coastal wetlands and swamps, will be beneficial to this species. No studies have been carried out on the benefits of mangrove connectivity and patch size for this species.

Caspian tern

The Caspian tern is the largest of all terns, often inhabiting sheltered coastal waters as well as lakes and rivers (Fitzgerald, 2013). This species is classified as *Threatened - Nationally Vulnerable* due to its moderate New Zealand population size of less than 1400 breeding pairs and a predicted declining population (Robertson *et al.*, 2017). The Caspian tern breeds mainly on the open coast, on shellbanks or sand spits (Fitzgerald, 2013). It is susceptible to disturbance by people, dogs and vehicles, as well as predation by mammals or other birds (Fitzgerald, 2013).

Degree of dependency

Caspian tern have a moderate dependency on mangrove as foraging habitat. They benefit from the prey species that are commonly found within the tidal channels of mangroves. However, this species is commonly observed in a range of habitats including sheltered bays and harbours as well as inland lakes and rivers (Fitzgerald, 2013).

Purpose of use

This species uses the deep channels within mangroves for foraging (Baird, 2015) and mostly feeds on small surface swimming fish as well as marine worms within soft mud. Mangroves provide a nursery ground for juvenile fish and harbour an abundance of marine worms within their soft sediment substrate.

Caspian tern are known to prefer to forage in clear water (Pierce, 1980). Mangroves trap sediment from terrestrial runoff, reducing turbidity allowing for more successful foraging during high tides (Beauchamp, 2012).

Mangroves provide a barrier from recreational use and adverse weather conditions to adjacent open sand and mud flat habitats (Beauchamp, 2012).

Important characteristics

The Caspian tern utilise the channels within mangroves for foraging and likely benefit from the prey species that mangroves provide (Baird, 2015; De Luca, 2015a, b).

Seasonal use

This species inhabits coastal inlets throughout the year and there are no records of a seasonal association with mangroves.

Connectivity and habitat patch size

Caspian tern inhabit a wide variety of coastal habitats including harbours, lagoons, inlets, bays, estuaries and river deltas, usually with sandy or muddy margins (Higgins and Davies, 1996). Mangroves with good connectivity to other foraging habitat (open wetlands including lakes and rivers, and open coast) as well as nesting and roosting habitat (shellbanks and sand spits) is likely to be beneficial to this species (Higgins and Davies, 1996). There have been no studies carried out on the potential benefits of mangrove connectivity and patch size for this species.

Pied shag

Pied shag often inhabits rocky shores, coastal trees and artificial structures (Powlesland, 2013). The species is classified as *Threatened - Nationally Vulnerable* due to its moderate population size of less than 5000 mature individuals and predicted declining populations (Robertson *et al.*, 2017).

Degree of dependency

Pied shag inhabit a range of coastal habitats (Powlesland, 2013) and whilst they are known to make use of mangrove habitat for roosting and feeding, they do not appear to be highly dependent on this habitat type.

Purpose of use

Roosting colonies of pied shag (*Phalacrocorax carbo novaehollandiae*) have been recorded in mangroves at Parengarenga, Hatea, Kaipara, Manukau, Waitemata, and Ohiwa Harbours (Morrisey *et al.*, 2007; Cox, 1977).

This species is also known to feed along the tidal channels and adjacent to mangrove habitat (Wildland Consultants, 2013a, b). Mangroves provide water clarity by trapping sediment and reducing turbidity. This function may also benefit this species by allowing for successful foraging during high tides (Beauchamp, 2012).

Important characteristics

Observations of pied shag have been within adult mangroves, where they roost within the canopy of mangrove trees (Robertson *et al.*, 2017).

Seasonal use

This species is observed in coastal estuaries throughout the year (Powlesland, 2013). There have been no studies carried out on the use of mangroves by pied shag on a seasonal basis.

Connectivity and habitat patch size

Adult pied shag do not disperse widely, sometime roosting or foraging on open undisturbed beaches, coastal trees or artificial structures during the day, and returning to their nesting colonies or roosts within coastal trees (including mangroves) at night (Powlesland, 2013). Connectivity between these types of habitat is likely to be important when considering the management of this species. No studies to date have addressed the potential benefits of mangrove connectivity and patch size for this species.

Banded Rail

Banded rail are medium-sized rail which are found in Northland, Auckland, Waikato and Bay of Plenty regions (including the Three Kings, Poor Knights and Great Barrier islands) (Beauchamp, 2015; Botha, 2011; Bouma, 2016). In the South Island, banded rail are limited to the coastal regions of Nelson-Golden Bay, Marlborough Sounds and offshore Islands around Stewart Island (Botha, 2011; Wildland Consultants, 2012). Banded rail inhabit the estuaries and harbours of the North Island (Bellingham, 2013), generally restricted to mixed patches of saltmarsh and mangrove habitat (Beauchamp, 2015; Botha, 2011). In the South Island, banded rail are confined to unmodified saltmarshes (Beauchamp, 2015; Wildland Consultants, 2012). On offshore islands, banded rail are recorded as being more terrestrial in their habitat use (Baird, 2015; Beauchamp, 2015; Bellingham, 2013). This species is classified as At Risk due to a lack of data and a restricted range (Robertson *et al.*, 2017).
An in-depth review of the use of mangrove habitats by banded rail is provided by Bell and Blayney (2017).

Degree of dependency

In the North Island due to a combination of habitat loss and introduction of mammalian pests banded rail are dependent on mangrove habitat for their continued survival (Baird, 2015; Beauchamp, 2012), requiring mangroves to provide cover from aerial predators while foraging close to their preferred saltmarsh roosting and breeding habitats (Beauchamp, 2012; Bellingham, 2013; Botha, 2011).

Purpose of use

Mangrove habitats have been identified as providing preferred foraging habitat for banded rail (Baird, 2015; Botha, 2011; Bouma, 2016; Giles, 2014; Wildland Consultants, 2012, 2014, 2015a, 2015d, 2015b, 2015c, 2016a, 2016b; Bellingham, 2013; Beauchamp, 2012, 2015; Boffa Miskell Ltd, 2015; Brian T. Coffey and Associates Ltd, 2012). Mangroves may also provide dispersal corridors for banded rail in areas lacking indigenous vegetation landward of mangroves (Giles, 2014; Wildland Consultants, 2012).

Important characteristics

Connectivity of mangroves to saltmarsh habitats appears to be the key characteristic influencing the use of mangroves by banded rail, as they require saltmarsh habitats for roosting and nesting (Beauchamp, 2012, 2015; Botha, 2011; Giles, 2014). Additionally, the reason for banded rail preferring to forage in mangrove habitats appears to be related to their need for protection from aerial predators, which mangroves provide (Botha, 2011; Wildland Consultants, 2012).

Seasonal use

Within the several monitoring reports and studies reviewed banded rail were observed using mangroves throughout the year (Beauchamp, 2012, 2015, Wildland Consultants, 2014, 2014, 2015a, 2015b, 2015d, 2016a, 2016b). While there has been no direct research on this topic these observations suggest there is no seasonal association of banded rail and mangroves.

Connectivity and habitat patch size

As noted above, connectivity of mangroves to saltmarsh habitats appears to be the key characteristic influencing the use of mangroves by banded rail. Banded rail have been recorded in saltmarsh sites of 0.01ha in size which are connected to mangrove habitat indicating that saltmarsh habitat patch size is not a limiting factor (Beauchamp, 2015). There is little information in the literature on the effect of mangrove habitat patch size on banded rail

utilization, but banded rail have been observed using scattered, spatially separated mangroves (Botha, 2011).

North Island fernbird

The North Island fernbird is a small, well camouflaged bird that mainly inhabits low, dense wetland vegetation throughout New Zealand (Heather and Robertson, 1996). The distribution of this species has reduced and many local populations have been lost due to loss of habitat and predation (Miskelly *et al.*, 2013). This species is classified as *At Risk – Declining* due to its declining population (Robertson *et al.*, 2017).

Degree of dependency

North Island fernbird uses a range of habitats from mangrove, saltmarsh, freshwater wetland through to montane scrub (Stewart, 2017). Mangroves within Mangawhai Estuary (Gaskin, 2013), Whangarei Harbour (Pierce, 2005), Hokianga Harbour (Pierce, 2002), Tairua harbour (Wildland Consultants, 2012) and Whangamata Harbour (Wildland Consultants, 2015 a,b 2016a) have been identified as habitat for fernbird. This species is likely to have a moderate degree of dependency on mangroves as habitat.

Purpose of use

This species forages on terrestrial invertebrates associated with mangroves.

Important characteristics

Fernbird preferentially inhabit low dense vegetation (Miskelly *et al.*, 2013). Well established, low mangrove habitat is likely to be an important characteristic to this species, however no studies have been carried out to date that identify the important characteristics of mangroves for this species.

Seasonal use

North Island fernbird are known to nest in low dense wetland vegetation throughout spring and summer and breeding pairs are unlikely to move far from their nest during this time (Miskelly, 2013). It is therefore less likely that this species will be using mangrove habitat during the breeding season.

Connectivity and habitat patch size

North Island fernbird utilise a coastal vegetation sequence comprising mangrove, salt meadow/marsh and freshwater wetland habitat. They are poor flyers and typically have a small home range, occupying habitat patches of no more than 800m width (Miskelly, 2013). For this reason, connectivity between this coastal habitat sequence is likely to be beneficial to this species. To date, no studies have been carried out on the potential benefits of mangrove connectivity and patch size for this species.

New Zealand pied oystercatcher

The New Zealand pied oystercatcher is the most common oystercatcher in New Zealand, occurring in most estuaries and harbours throughout New Zealand (Southey, 2009; Owen *et al.*, 2006; Sagar, 2013). This species is a New Zealand endemic and classified as *At Risk – Declining* due to its predicted population decline (Robertson *et al.*, 2017).

Degree of dependency

The New Zealand pied oystercatcher utilises a diversity of habitats (Sagar, 2013), occasionally inhabiting mangroves or areas adjacent (Thrush *et al.*, 2013). Observations indicate that it is likely to have a low degree of dependency on mangroves.

Purpose of use

This species migrates from its South Island breeding grounds during the non-breeding season to the northern harbours, where it utilises mangrove habitat as a refuge (Thrush *et al.*, 2013). It is also known to forage on the coastal fringe of mangroves at low tide (De Luca, 2015a, b). Mangroves trap sediment and reduce turbidity. This function is likely to allow for more successful foraging during high tides (Beauchamp, 2012).

Important characteristics

There have been no studies carried out to date, that identify the important characteristics of mangroves for this species.

Seasonal use

This species migrates to inland parts of the South Island to breed during spring and summer and is not commonly associated with mangrove habitat throughout this time of the year (Sagar, 2013).

Connectivity and habitat patch size

New Zealand pied oystercatcher use mangrove habitat along with a diversity of intertidal and coastal habitats, such as shell banks and grass flats (Thrush, 2013, Sagar, 2013). They are highly mobile and do not require small scale connectivity between habitat types in order to benefit from use of mangrove habitat. There have, however, been no studies carried out on the potential benefits of connectivity and habitat patch sizes for this species.

Pied stilt

The pied stilt is a native wading bird inhabiting wetlands and coastal areas throughout New Zealand (Adams, 2013b). It is classified as *At Risk - Declining* in New Zealand due to its predicted ongoing decline (Robertson *et al.*, 2017).

Degree of dependency

This species lives in a diverse range of habitats from estuaries and saltmarshes to freshwater lakes, swamps and rivers (Adams, 2013b). It is unlikely to be highly dependent on mangroves, due to its known habitat distribution.

Purpose of use

This species forages on the fringe of mangroves in muddy habitats at low tide and roost in shallow water or on shell banks adjacent to mangroves (De Luca, 2013; Adams, 2013b).

Important characteristics

There have been no studies carried out to date that identify the important characteristics of mangroves for pied stilt.

Seasonal use

Breeding occurs inland throughout June and October each year. After the breeding season, birds migrate from inland locations towards more northerly coastal locations (Adams, 2013b). Pied Stilt are unlikely to be seen using mangrove habitat during the breeding period (Adams, 2013b).

Connectivity and habitat patch size

The pied stilt only occasionally uses mangrove habitat and is more often associated with a range of coastal and wetland habitats. Connectivity between these types of habitats is unlikely to be beneficial to this species, however, there have been no studies carried out on the potential benefits of connectivity and habitat patch sizes for this species.

Eastern bar-tailed godwit

Eastern bar-tailed godwit is an international migratory species that commonly inhabits intertidal mudflats throughout New Zealand during its non-breeding season (Woodley, 2013). This species migrates non-stop from the arctic, arriving in New Zealand from early September (Woodley, 2013). Observations are regularly made in the Parengarenga, Kaipara Harbour, Manukau Harbour, Firth of Thames, Farewell spit, Tauranga Harbour, Rangaunu, Whangarei, Tauranga, Ohiwa, Kawhia, Porongahau, Foxton Beach, Tasman and Golden Bays, Avon-Heathcote, Blueskin Bay, and Invercargill Estuary/Awarua Bay (Woodley, 2013; Southey, 2009; Owen *et al.*, 2006). Whilst this species is commonly seen, it is classified as A*t Risk - Declining* due to its predicted declining population (Robertson *et al.*, 2017).

Degree of dependency

This species inhabits a wide range of habitats from intertidal mudflats, to sandy and shelly beaches, reefs, atolls, and wetlands (Higgins and Davies, 1996; Woodley, 2013). It does not appear to be highly dependent on mangroves, but does however, benefit from the ecosystem services that the mangroves provide, such as provision of food (Thrush *et al.*, 2013).

Purpose of use

The eastern bar-tailed godwit is known to utilise mangrove habitat (Thrush *et al.*, 2013). This species feeds on benthic invertebrates found within mangroves such as polychaetes worms, small bivalves and crustaceans, but also feeds on terrestrial invertebrates (De Luca, 2015a, b; Hutchings and Recher, 1974; Ewart, 1973). Mangroves provide water clarity by trapping sediment and reducing turbidity. This may also benefit this species by allowing for successful foraging during high tides (Beauchamp, 2012).

Important characteristics

There is a sparsity of information of the characteristics of mangroves that are important to eastern bar-tailed godwit. Mangroves are known to provide foraging habitat for this species and as such, this species is therefore likely to rely on a sufficient supply of macroinvertebrates associated with an established mangrove habitat (De Luca, 2015a, b; Hutchings and Recher, 1974; Ewart, 1973).

This species has been recorded on the fringes on mangroves and is also likely to forage within the seedlings and pneumatophores of this type of habitat.

Seasonal use

Eastern bar-tailed godwits depart New Zealand in March each year to head to their Arctic breeding grounds, returning to New Zealand around September (Woodley, 2013). Non-breeding individuals remain in New Zealand and are common in estuaries (Woodley, 2013).

Connectivity and habitat patch size

There have been no studies carried out on the potential benefits of mangrove connectivity and patch size for this species.

3.0 Waikato Regional Context

Assessment of significance of mangrove habitat for *Threatened* or *At Risk* birds

Within the Waikato region, mangroves are the predominant coastal vegetation community in the southern firth of Thames, Manaia, Purangi, Te Kouma, Whangamata, Whangapoua and Whitianga estuaries on the east coast (Graeme and Beard, 2015). Mangroves are relatively uncommon on the west coast of the Waikato region, occurring only within the sheltered arms of Raglan Harbour (Graeme and Beard, 2015). This habitat provides important feeding grounds, as well as shelter and breeding habitat for fish, invertebrates and birds (; De Luca, 2015a, b; Baird, 2015; Woodley, 2013; Adams, 2013b; De Luca, 2013; Thrush *et al.*, 2013 Beauchamp, 2012; Brian T. Coffey and Associates Ltd, 2009)

A number of coastal birds classified as *Threatened* or *At Risk* are known to be associated with mangrove habitat have been identified within the Waikato Region (Dowding, 2013).

Banded rail[2], North Island fernbird and Australasian bittern have been observed using mangroves as habitat in Whangamata and Tairua Harbours (Wildland Consultants, 2014, 2015b, c, 2016 a, b). Fernbird were found within mangroves and in fringing saltmarsh vegetation, whilst bittern was observed foraging under the canopy of mangroves (Wildland Consultants Ltd, 2014, 2015ba, b, 2016a; Brian T. Coffey and Associates Ltd, 2012).

Eastern bar-tailed godwit, New Zealand pied oystercatcher, pied stilt and Caspian tern have been observed using coastal areas where mangroves are present within the Waikato region (Dowding, 2013). These observations did not stipulate use of mangroves. There is however, no evidence that these species would behave any differently in the Waikato compared to other regions of New Zealand where they have been observed in association with mangroves along with other coastal habitats (Section 2.0).

Mangroves are known to be used as foraging habitat for eastern bar-tailed godwit, pied stilt, South Island pied oystercatcher, fernbird, caspian tern and Australasian bittern (De Luca, 2015a, b; Baird, 2015; Woodley, 2013; Adams b, 2013; De Luca, 2013; Thrush *et al.*, 2013 Beauchamp, 2012). Pied stilt and fernbird are also known to breed in areas directly adjacent to mangrove habitat (Adams, 2013b; Miskelly, 2013).

There are a number of threats to coastal birds that have been identified within the Waikato Region (Dowding, 2013). These include mammalian predation, human disturbance, sedimentation and exposure to adverse weather conditions. Mangroves alleviate these threats by providing shelter to a number of species including New Zealand pied oystercatcher and Caspian tern (Thrush *et al.*, 2013; Beauchamp, 2012). They also trap sediment within their root system, reducing the impact on adjacent open tidal flats (Alongi and McKinnon, 2005).

Whilst observations of direct use of mangroves within the Waikato have only been made for banded rail, fernbird and Australasian bittern, it is likely that mangroves are providing habitat to a larger range of *Threatened* or *At Risk* species as observed in other parts of New Zealand. By providing habitat to a range of *Threatened* or *At Risk* species and alleviating existing threats to birds in a number of areas within the Waikato Region, mangroves should therefore be assessed as high value habitat and managed accordingly.

[2] A standalone report has been prepared addressing issues of relevance to banded rail (Bell and Blayney, 2017).

4.0 Impact of Mangrove Removal

Mangroves provide shelter and protection from predators for a range of birds, supporting foraging, nesting and roosting success. Removal of mangrove habitat exposes previously sheltered areas or areas bounded by mangroves, increasing the amount of recreational use and therefore disturbance to birds. Species that require shelter from disturbance will therefore migrate to sheltered areas, sometime this requires long distances of travel (Beauchamp, 2012).

For species such as the NZFT, with less than 50 individuals remaining, mangrove removal could result in adverse effects (Beauchamp, 2012). Removal of mangrove habitat on which banded rail depend may also have adverse effects and should be assessed in the context of other factors such as population density and habitat fragmentation (Baird, 2015).

A diversity of habitats within an estuary is likely to support more diverse avifauna assemblages (Wheelan *et al.,* 2003). Mangrove provides a link seaward to open sand and mud flats, shellbanks and sand spits, as well as landward to saltmarsh, freshwater wetland and coastal forest. Mangrove removal is likely to impact on the ability of many species to move within and between foraging, roosting and/or resting areas (Giles, 2014). This coupled with declining areas of connecting saltmarsh and coastal forest, and/or the poor habitat quality within these areas due to predator abundance and fragmentation, is likely to further hinder the ability of a species to successfully adapt to new habitat, after mangrove removal.

Mangrove removal suspends muddy sediments causing high levels of turbidity and re-suspension of fine sediment in to the water column, particularly during wind generated waves. This will have a direct effect on the mortality of benthic infauna, especially filter feeding organisms on adjacent sand flat, as well as an indirect effect on wading birds by affecting their ability to find food (Beauchamp, 2012).

Mangrove removal can sometimes lead to macroalgae blooms (Lundquist *et al.*, 2014). This is likely a result of nutrient release from decomposing mangrove mulch left after removal (Lundquist *et al.,* 2014). Significant decreases in oxygen within the sediment and water column have also been recorded after mangrove removal. This increases the likelihood of mortality of infauna within the sediment column, reducing the amount of food available for wading birds and is also likely to impact on the distribution of pelagic communities (Lundquist *et al.,* 2014).

5.0 Recommendations

Knowledge gaps

There has been research carried out and several reports that have identified significant gaps in information on use of mangroves by threatened birds. Additional research recommendations outlined within these reports include the following[3]:

Dowding (2013):

[3] These recommendations are in line with recommendations made for banded rail (Bell and Blayney, 2017).

- An inventory of threatened birds and their distribution within the Waikato - several areas on the east coast of the Waikato noted lack of data on the distribution and presence of species within mangroves.

Giles (2014) also referenced and expanded on within Bouma (2016):

- Investigate bird behaviour (quantify movement and feeding patterns in saltmarsh and mangrove habitats);
- Territory sizes and whether certain species are territorial;
- Carrying capacity of habitats and suitability of habitats post mangrove removal;
- The role of predation in population dynamics;
- Lag effects/ long term effects on threatened bird fecundity and survival following mangrove removal.

Botha (2011):

- Investigate the influence that mangroves have on the reproductive success of threatened birds;
- Evaluate the value of mangroves as ecological corridors for threatened birds around harbour edges.

Further to the research gaps identified by previous authors, we have found additional gaps or incomplete information within the literature:

- Variation in habitat preference (size, extent and composition) of threatened birds between the North and South Islands;
- Variation in the level of disturbance, exposure to adverse weather, food availability, predation and abundance of *Threatened* and *At Risk* bird species within and adjacent to mangrove habitat;
- Potential mitigation strategies of mangrove removal and their effectiveness in providing suitable habitat for threatened birds;
- The distribution of *Threatened* and *At Risk* birds on the west coast of the Waikato region.

Research recommendations

This review highlights the sparsity of information on the use of mangroves by *Threatene*d and *At Risk* birds. To progress from here, a prioritised approach to further research is needed in order to begin answering outstanding questions and to inform future policy decisions and documents relating to mangroves and threatened birds.

We consider the outstanding questions to be:

- What is the distribution of birds in relation to mangroves in the Waikato region and New Zealand?
- What is the abundance of *Threatened* and *At Risk* birds within mangroves?
- How can we survey and monitor them effectively?

- What are the current limitations on *Threatened* and *At Risk* bird populations?
- What is the impact of mangrove removal on *Threatened* and *At Risk* birds?
- If we continue to remove mangroves can we effectively mitigate for the loss of mangrove habitat?

We consider the priority of further research to answer these questions and the justification of this priority to be[4]:

1. Presence/non-detection inventory of *Threatened* and *At Risk* bird distribution within mangrove habitat with information on habitat use and use of adjoining habitats throughout the Waikato.
    - Justification: A clear picture of *Threatened* and *At Risk* bird habitat use in the Waikato is needed to further determine the importance of mangroves to these species.
2. Research into modifying existing or developing new monitoring techniques in order to develop a standard protocol for monitoring of *Threatened* and *At Risk* birds that includes the ability to provide estimates of density within mangroves.
    - Justification: Currently a lack of density evaluating monitoring techniques limits our ability to determine abundance patterns across New Zealand and the Waikato region (which may point to what factors that might limit populations). Importantly without these techniques the impact of the modification of their habitats by mangrove removal or other disturbance cannot be quantified.
3. Surveys across sites in the Waikato region and New Zealand to determine how density and carrying capacity are impacted by different habitats and their connectivity.
    - Justification: First requiring suitable monitoring techniques; without density information at sites we are unable to determine potential impacts of mangrove removal on threatened birds. This information can also begin to further inform the level of dependence on mangrove habitats, habitat requirements and increase our predictive power on what effects mangrove removal will have.
4. Research and monitoring on the effect of mangrove removal on *Threatened* and *At Risk* bird populations in the short and long term. Including measures of density, survival, fecundity, site occupancy, use of mangrove removal areas, migration. This could be achieved through comparisons between specific mangrove removal study sites and appropriate control sites where mangroves are not removed.
    - Justification: Current monitoring represents only a relatively short term continuation of bird presence post mangrove removal with acknowledgement this does not indicate lack of effect. Without this information effects of mangrove removal on threatened birds are largely based on likelihood given the accepted literature on habitat usage and known foraging behaviours.
5. Research the effect of changes in oxygen within the sediment and water column after mangrove removal on benthic and pelagic communities.

[4] These recommendations are in order of priority and are in line with recommendations made for banded rail (Bell and Blayney, 2017).

- Justification: Mortality of prey species within the benthic and pelagic communities is likely to have cascading effects on higher trophic species such as birds.

6. Research into the life history factors that may contribute to the impact of mangrove removal on *Threatened* and *At Risk* birds such as breeding patterns, parental care and moult regimes (Bell and Blayney, 2017).
    - Justification: We need to understand whether there are times of the year when *Threatened* and *At Risk* birds rely on mangroves more to survive and reproduce, so that policy and mitigation strategies can attempt to provide for these requirements.
7. Explore and compare the abundance and habitat use distribution patterns of *Threatened* and *At Risk* birds across New Zealand; what are the different habitats they are using, habitat patch size, predation pressure, connectivity to other habitats, etc.
    - Justification: To determine why certain threatened birds use and depend on mangroves in the North Island we must first find out how they survive and what pressures they face where they do not inhabit mangrove habitats compared to when they do. With this information we can begin to determine what pressures drive the requirement for mangroves use in the North Island.
8. Conduct a research trial: design and implement a trial of habitat enhancement/creation based on the previous priority research findings to provide supplementary and alternative habitat for *Threatened* and *At Risk* birds that are known to use mangroves.
    - Justification: For some *Threatened* and *At Risk* bird species the relationship with mangrove appears to be a recent phenomenon driven by anthropogenic pressures on populations. The ultimate long term goal of research should be to enable the conservation of threatened birds by providing a greater suite and extent of suitable habitats. This last stage would be an aspirational goal and would likely benefit a wider range of native species than those that are threatened and should be conducted as part of wider catchment management and ecosystem restoration.

Monitoring recommendations

In order to establish a baseline understanding of the presence, density and distribution of *Threatened* and *At Risk* birds use of mangrove habitat in the Waikato region and to compare changes over time, the following monitoring techniques are recommended[5][6].

- Call counts: call surveys should be done in spring and in the period of 0.5 to 1 hour before sunset when birds call more frequently. This should be carried out at a time of year where the full array of threatened birds (known to use mangroves) are likely to be present.
- Footprint surveys: ensure survey planning takes into consideration the ability of the substrate to hold footprints. In sand and dense pneumatophores of mangroves there may be little trace of banded rail footprints, or where substrates remain shallowly submerged by the tide (Wildlands, 2015d). Consider using print stations or alternative survey methodology

[5] These recommendations are in line with recommendations made for banded rail (Bell and Blayney, 2017).

[6] Appropriate methods should be selected on a species specific basis (See Introduction to bird monitoring, Department of Conservation, by John Dowding, 2012).

where substrates are unsuitable. Surveys should be timed when low tide occurs in the morning, during which most birds exhibit a peak of activity (Beauchamp, 2015).

- Audio recorders: ensure that audio recorders are placed close to preferred estuarine margin habitats and at a high enough density to effectively detect targeted species (Stewart, 2016).
- Visual surveys: consider all points above mentioned for footprint and call surveys to increase likelihood of encounter.

As reviewed in previous sections, there is currently no accepted effective monitoring techniques that have the ability to provide information on density. There have been surveys that use a combination of calls and footprints and spatial separation of greater than 100m to provide estimates of density (Davis & Bellingham, 1984 cited in Beauchamp, 2015) but this methodology needs research to determine the validity of results, as little is known about home ranges.

Research required on the effective monitoring of *Threatened* and *At Risk* birds to support the #2 research priority identified in the Research Recommendations section should include:

- Exploring the use of satellite or radio transmitters to determine home ranges, survival, and habitat use patterns to provide information towards the calibration of call frequency and absolute density of threatened birds within mangroves;
- Continue to develop and refine methodology for the use of electronic audio recorders to monitor for *Threatened* and *At Risk* birds and attempt to calibrate these methods with density. Electronic recorders have been used for monitoring in Tairua harbour by Wildlands (2016a) but further development of protocols and methodology to assess densities with automatic recorders is required. UAV placement of audio recorders at study sites could also be explored to avoid disturbance and tracking into habitats (Stewart, 2016);
- Explore the use of remote sensor operated cameras to gather information on habitat use and behaviour and as a monitoring tool to determine density indices.

There has been significant research on the development of monitoring techniques for cryptic bird species by Williams (2016) with a focus on Australasian bittern using electronic recording devices. There have also been successful trials within the Waikato region using audio recorders to detect cryptic avifauna (Stewart, 2016). This work should provide an effective research and knowledge base to develop these techniques. These techniques are also described within O'Donnell & Williams (2015) with further information on a decision framework for when to use differing monitoring techniques.

6.0 Conclusion

Mangroves provide suitable habitat to a range of *Threatened* or At Risk birds. However, a sparsity of data means that there are significant gaps in our understanding of the way in which many species use mangroves, the benefits of associating with mangroves as opposed to other habitats, the degree of dependency on mangroves and the limitations of mangrove habitat for. Banded rail, North Island fernbird and Australasian bittern have been observed directly using mangrove habitat for foraging throughout the North Island, including the Waikato region. In addition, a number of other Threatened or At Risk bird species, more commonly associated with

open tidal flats, saltmarsh, and wetland habitat (including eastern bar-tailed godwit, New Zealand pied oystercatcher, pied stilt, Caspian tern, white heron, NZFT, pied shag and lesser knot) have been observed in association with mangrove habitat throughout the North Island for foraging, refuge and breeding. Whilst these birds have not been observed using mangrove habitat within the Waikato Region, they have been observed inhabiting areas where mangrove habitat is also present and are likely to exhibit the same behavioural characteristics of mangrove use within the Waikato region, as observed elsewhere throughout New Zealand.

Given that these species are Threatened or At Risk, an understanding of their habitat requirements is critical to their management. A number of recommendations have been made within this report to address the gaps in our understanding of the use of mangroves by threatened birds. We have also provided a prioritised list of research steps to begin answering these questions and enable us to understand this interaction between mangroves and Threatened or At Risk birds, while also enabling the conservation of Threatened or At Risk birds and their habitats into the future in a wider catchment management and ecosystem restoration framework.

7.0 References

Adams, R. (2013a). Pied stilt. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/pied-stilt

Adams, R. (2013b). White heron. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/white-heron

Alongi, D. M., & McKinnon, A. D. (2005). The cycling and fate of terrestrially-derived sediments and nutrients in the coastal zone of the Great Barrier Reef shelf. *Marine Pollution Bulletin*, *51*(1), 239–252.

Baird, K. (2015). Statement of Evidence in reply of Karen Baird on behalf of The Environmental defence Society Incorporated and Royal Forest and Bird Protection Society of New Zealand Submission numbers 4735 and 4848. Hearing Topic 33 - General Coastal Marine Zone and Activities.

Battley, P. F. (2013). Lesser knot. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/lesser-knot

Beauchamp, A. J. (2012). Statement of Evidence prepared for Environment Court hearing, Mangawhai Harbour Restoration Society Incorporated, Northland Regional Council, and Royal Forest and Bird Protection Society Incorporated, Topic ENV-2011-AKL-000110

"Mangawhai Mangrove Removal."

Beauchamp, A. J. (2015). Banded rail (*Gallirallus philippensis*) occupancy and detection in saltmarsh mangrove systems at Onerahi, Whangarei Harbour. *Notornis*, *62*(1), 14–20.

Beauchamp, A. J., & Parrish, G. R. (1999). Bird use of the sediment settlement ponds and roost areas at Port Whangarei. *Notornis*, *46*(4).

Bell, J. & Blayney A. (2017) Use of mangrove habitat by banded rail (*Gallirallus philippensis assimilis*). Waikato Regional Council Technical Report 2017/24.

Bellingham, M. (2013). Banded rail. In C. M. Miskelly (Ed.), New Zealand Birds Online. Retrieved from http://www.nzbirdsonline.org.nz/species/banded-rail

Boffa Miskell Ltd. (2012). *Baseline ecological monitoring (Marine Reserves Act), Waterview Connection Causeway Project*. Prepared by Boffa Miskell Ltd for New Zealand Transport Agency.

Boffa Miskell Ltd. (2015). Review of Coromandel Mangrove Removal: Whangamata and Tairua. Prepared by Boffa Miskell Limited for Waikato Regional Council.

Botha, A. (2011). Foraging distances and habitat preferences of Banded Rail in the Ohiwa Harbour (Bay of Plenty Regional Council Environmental Publication No. 2010/06). Whakatane: Bay of Plenty Regional Council.

Bouma, S. (2016). Marine biodiversity stocktake of the Waikato region 2015. Waikato Regional Council Technical Report 2015/48.

Brian T. Coffey and Associates Ltd. (2009). *Mangrove clearance scenarios for Whangamata Harbour: Peer review of Ecological Assessment*. Prepared by Brian T. Coffey and Associates Ltd for Waikato Regional Council.

Brian T. Coffey and Associates Ltd. (2012). *Ecological assessment for proposed mangrove removal activities in Tairua Harbour*. Prepared by Brian T. Coffey and Associates Ltd for Waikato Regional Council.

Cox, G. J. (1977). *Utilization of New Zealand mangrove swamps by birds* (MSc). University of Auckland, Auckland.

Crisp, P., Daniel, L. J., Tortell, P., Wagemaker, P., & Nature Conservation Council. (1990). *Mangroves in New Zealand : trees in the tide*. Wellington: GP Books.

de Lange, W. P., & de Lange, P. J. (1994). An appraisal of factors controlling the latitudinal distribution of mangrove (*Avicannia marina* var. resinifera) in New Zealand. *Journal of Coastal Research*, 539–548.

De Luca, S. B. (2013). Statement of Rebuttal evidence prepared for Environment Court hearing, Royal Forest and Bird Protection Society of New Zealand and Bay of Plenty Regional Council, Topic ENV 2013 348 000003 “Mangrove Management’.

De Luca, S. B. (2015a). Mangroves in NZ: Misunderstandings and management. In *Coasts & Ports Conference 2015*. Auckland.

De Luca, S. B. (2015b). Statement of evidence prepared for the Bay of Plenty Regional Council Hearing Panel, Mangrove Protection Society, in the matter of policies and rules for mangrove management in the proposed Bay of Plenty Regional Council Coastal Environment Plan.

Dowding, J. E. (2008). *Monitoring of shorebirds in the Firth of Thames Ramsar site* (DM Consultants Contract Report No. 79). Christchurch: Unpublished report to Waikato Conservancy, Department of Conservation.

Dowding, J. E. (2013). *Sites of importance to coastal and estuarine birds on the east coast of the Waikato region* (Waikato Regional Council Technical Report No. 2013/15). Prepared by DM Consultants for Waikato Regional Council.

Ewart, A. (1973). Bird observations at the Plantation Creek estuary, Ayr, North Queensland. *The Sunbird: Journal of the Queensland Ornithological Society*, *4*(3), 58–61.

Ferreira, S. M., Hansen, K. M., Parrish, G. R., Pierce, R. J., Pulham, G. A., & Taylor, S. (2005). Conservation of the endangered New Zealand fairy tern. *Biological Conservation*, *125*(3), 345–354. https://doi.org/10.1016/j.biocon.2005.04.015

Fitzgerald, N. (2013). Caspian tern. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/caspian-tern

Gaskin, C. (2013). *Important areas for New Zealand seabirds, Part 1 – North Island*. Forest & Bird / BirdLife International.

Giles, H. (2014). Mangroves removal effects on banded rail (*Gallirallus philippensis assimilis*). Memo to Vaugh Payne & Tony Petch. Waikato Regional Council Internal Memo - File

Number 47 05 25.

Gladstone-Gallagher, R. V., Lundquist, C. J., & Pilditch, C. A. (2014). Mangrove (*Avicennia marina* subsp. *australasica*) litter production and decomposition in a temperate estuary. *New Zealand Journal of Marine and Freshwater Research*, *48*(1), 24–37.

Graeme, M., & Beard, C. (2015). *Review of the Waikato Estuarine Vegetation Project* (Waikato Regional Council Internal Series 2015/47). Waikato Regional Council.

Green, M., Ellis, J., Schwarz, A.-M., Green, N., Lind, D., & Bluck, B. (2003). *For and against mangrove control* (NIWA Information Series No. 31). NIWA.

Harty, C. (2009). Mangrove planning and management in New Zealand and South East Australia: A reflection on approaches. *Ocean & Coastal Management*, *52*(5), 278–286.

Heather, B. D., Robertson, H. A., & Onley, D. J. (1996). *The field guide to the birds of New Zealand*. Auckland: Viking.

Higgins, P. J., & Davies, S. J. J. F. (Eds.). (1996). *Handbook of Australian, New Zealand and Antarctic birds: Volume 3, snipe to pigeons*. Auckland: Oxford University Press.

Hindell, J. S., & Jenkins, G. P. (2005). Assessing patterns of fish zonation in temperate mangroves, with emphasis on evaluating sampling artefacts. *Marine Ecology Progress Series*, *290*, 193–205.

Hutchings, P. A., & Recher, H. F. (1974). The fauna of Careel Bay with comments on the ecology of mangrove and sea-grass communities. *Australian Journal of Zoology*, *18*(2), 99–128.

Hutchings, P. A., & Recher, H. F. (1982). The fauna of Australian mangroves. *Proceedings of the Linnean Society of New South Wales*, *106*, 83–121.

Ismar, S. M. H., Trnski, T., Beauchamp, T., Bury, S. J., Wilson, D., Kannemeyer, R., … Baird, K. (2014). Foraging ecology and choice of feeding habitat in the New Zealand Fairy Tern *Sternula nereis davisae*. *Bird Conservation International*, *24*(01), 72–87.

Jeffries, D.S.; Bull, L.S.; Lagnaz, E.G.; Pulham, G.A.; Wilson, D.S.; Wilson, P.; Zimmerman, R.L. (2016) New Zealand fairy tern (*Sternula nereis davisae*) foraging behaviour at Te Arai Stream. *Notornis 63:* 42-45.

Lundquist, C. J., Morrisey, D. J., Gladstone-Gallagher, R. V., & Swales, A. (2014). Managing

mangrove habitat expansion in New Zealand. In *Mangrove Ecosystems of Asia* (pp. 415–438). New York: Springer.

Miller, C. (2001). Long-term monitoring of a breeding colony of white herons (Egretta alba) on the Waitangiroto River, South Westland, New Zealand. *Notornis*, *48*(3).

Miller, P., & Miller, K. (1991). Bitterns using mangroves. *Notornis*, *38*(1).

Miskelly, C. M. (2013). Fernbird. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/fernbird

Moon, G. (1996). *The Reed field guide to New Zealand birds*. Auckland: Reed.

Morrisey, D., Beard, C., Morrison, M., Craggs, R., & Lowe, M. (2007). *The New Zealand mangrove: Review of the current state of knowledge* (Auckland Regional Council Technical Publication No. TP325). Auckland: Prepared for Auckland Regional Council by National Institute of Water & Atmospheric Research.

Morrisey, D., Swales, A., Dittmann, S., Morrison, M. A., Lovelock, C. E., Beard, C. M., & Gibson, R. N. (2010). The ecology and management of temperate mangroves. *Oceanography and Marine Biology: An Annual Review*, *48*, 43–160.

Nicholls, P., & Ellis, J. (2002). Fringing habitats in estuaries: The sediment–mangrove connection. *Water & Atmosphere*, *10*(4), 24–25.

O'Donnell, C. F. J., & Robertson, H. A. (2016). Changes in the status and distribution of Australasian bittern (*Botaurus poiciloptilus*) in New Zealand, 1800s−2011. *Notornis*, *63*(3–4).

O'Donnell, C. F. J., & Williams, E. M. (2015). *Protocols for the inventory and monitoring of populations of the endangered Australasian bittern (*Botaurus poiciloptilus*) in New Zealand* (Department of Conservation Technical Series No. 38). Wellington: Department of Conservation.

O'Donnell, E. (2011). *Tairua Harbour and catchment management plan* (Waikato Regional Council Technical Report No. 2011/40). Waikato Regional Council.

Parrish, G.R.; Pulham, G.A. (1995a) Population size, productivity and post breeding movements of the New Zealand fairy tern. *Tane 35*: 175-181.

Parrish, G. R., & Pulham, G. A. (1995b). Observations on the breeding of the New Zealand

Fairy Tern. *Tane*, *35*, 161–173.

Pierce, R. J. (1980). Seasonal and long-term changes in bird numbers at Lake Wainono. *Notornis*, *27*(1), 21–44.

Pierce, R. J. (2002). *Assessment of ecological effects of proposed bridges and associated roadworks at Hokianga Harbour, Northland* (Wildlands Consultants Report No. 575). Prepared by Wildland Consultants Ltd for Northland Regional Council.

Pierce, R. J. (2005). *General patterns of bird use of Whangarei Harbour, March 2005* (Wildland Consultants Report No. 1047). Whangarei: Prepared by Wildland Consultants Ltd for Northland Regional Council.

Powlesland, R. G. (2013). Pied shag. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/pied-shag

Pulham, G., & Wilson, D. (2013). Fairy tern. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/fairy-tern

Ritchie, L. D. (1976). Fish and fisheries. In *Proceedings of a Symposium Organised by Nature Conservation Council*. Whangarei.

Robertson, H. A., Baird, K., Dowding, J. E., Elliott, G. P., Hitchmough, R. A., Miskelly, C. M., McArthur, N., O'Donnell, C. F. J, Sagar, P. M., Scofield, R. P. and Taylor, G. A. (2017). *Conservation status of New Zealand birds, 2016* (New Zealand Threat Classification Series 19.) Wellington: Department of Conservation. 27p.

Sagar, P. M. (2013). South Island pied oystercatcher. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/south-island-pied-oystercatcher

Saintilan, N., Hossain, K., & Mazumder, D. (2007). Linkages between seagrass, mangrove and saltmarsh as fish habitat in the Botany Bay estuary, New South Wales. *Wetlands Ecology and Management*, *15*(4), 277–286.

Southey, I. (2009). *Numbers of waders in New Zealand 1994-2003* (DOC Research & Development Series No. 308). Wellington: Department of Conservation.

Stewart, P. (2016). *Acoustic recorders for detection of cryptic avifauna: A trial of two coastal wetlands in the Waikato Region* (Waikato Regional Council Technical Report No.

2016/06). Waikato Regional Council.

Stewart, P. (2017). *Eastern Coromandel cryptic avifauna inventory of the Waikato Region wetlands*. Prepared by Red Admiral Ecology for Waikato Regional Council.

Thrush, S. F., Townsend, M., Hewitt, J. E., Davies, K., Lohrer, A. M., Lundquist, C., & Cartner, K. (2013). The many uses and values of estuarine ecosystems. In *Ecosystem services in New Zealand - conditions and trends*. Lincoln: Manaaki Whenua Press.

Wildland Consultants. (2012). *Management of estuarine vegetation in Tairua Harbour* (Contract Report No. 2892a). Prepared for Waikato Regional Council.

Wildland Consultants. (2013a). *Avifauna monitoring in mangroves at Whangamata Harbour in March 2013* (Contract Report No. 3120a). Prepared for Waikato Regional Council.

Wildland Consultants. (2013b). *Surveys of high tide roosts and lichens on mangroves in Tairua Harbour* (Contract Report No. 2898d). Prepared for Waikato Regional Council.

Wildland Consultants. (2014). *Monitoring of Banded Rail and other avifauna before and after mangrove clearance at Whangamata Harbour: Annual Report (March 2013 - March 2014)* (Contract Report No. 3120b). Prepared for Waikato Regional Council.

Wildland Consultants. (2015a). *Ecological effects of non-consented Mangrove removal in the Pepe Inlet, Tairua Harbour* (Contract Report No. 3508). Prepared for Waikato Regional Council.

Wildland Consultants. (2015b). *Monitoring of avifauna before and after mangrove clearance at Whangamata: Annual Report March 2014 - April 2015* (Contract Report No. 3120c). Prepared for Waikato Regional Council.

Wildland Consultants. (2015c). *Monitoring of avifauna before and after mangrove clearance at Whangamata: Annual Report March 2016* (Contract Report No. 3120e). Prepared for Waikato Regional Council.

Wildland Consultants. (2015d). *Monitoring of Banded Rail before and after mangrove clearance at Whangamata Harbour: Annual Report (March 2013 - July 2015)* (Contract Report No. 3120d). Prepared for Waikato Regional Council.

Wildland Consultants. (2016a). *Monitoring of Banded Rail before and after mangrove clearance at Whangamata Harbour: Annual Report March 2016* (Contract Report No. 3120f).

Prepared for Waikato Regional Council.

Wildland Consultants. (2016b). Monitoring of mangrove removal areas at Tairua Harbour, Coromandel, December 2014 - March 2016 (Contract Report No. 2898h). Prepared for Waikato Regional Council.

Williams, E. (2013). Australasian bittern. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/australasian-bittern

Woodley, K. (2013). Bar-tailed godwit. In C. M. Miskelly (Ed.), *New Zealand Birds Online*. Retrieved from http://www.nzbirdsonline.org.nz/species/bar-tailed-godwit

Woodroffe, C. D. (1982). Litter production and decomposition in the New Zealand mangrove, *Avicennia marina* var. resinifera. *New Zealand Journal of Marine and Freshwater Research*, *16*(2), 179–188.