BEFORE COMMISSIONERS APPOINTED BY NORTHLAND REGIONAL COUNCIL

UNDER	the Resource Management Act 1991 (**RMA**)
AND	
IN THE MATTER	of an application for a resource consent to build a replica of the Mangawhai Wharf
BY	**THE MANGAWHAI HISTORIC WHARF TRUST**
	Applicant

STATEMENT OF EVIDENCE OF DR PHILIP MCDERMOTT FOR THE MANGAWHAI HISTORIC WHARF TRUST

(RESEARCH AND ANALYSIS)

Dated: 4 September 2020

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1. INTRODUCTION

1.1. My full name is Dr Philip James McDermott. I live in Mangawhai Heads. I am a retired development planning consultant and a retired Member of the Planning Institute of New Zealand. I became involved in an advisory capacity in the initiative to rebuild the Mangawhai Wharf in November 2019 and became a Trustee of the Mangawhai Historic Wharf Trust in July 2020.

2. CREDENTIALS

2.1. My expertise is not in ornithology. It is in research, modelling, and analysis. I have worked extensively in assessing development and its impacts, mainly from an economic point of view. My qualifications are in Geography, a Masters degree in 1972 (Auckland University), and a PhD in 1977 (Cambridge University).

2.2. Since establishing a consulting business in 1978 and a market research business in 1986 I have provided advice to government agencies in New Zealand, Australia, Singapore and Macau, the Pacific Island nations, and to businesses throughout New Zealand and Australia. This advice has been based on research and analysis many activities and sectors (primary production, manufacturing transport, retailing, housing, tourism, and government). I have expertise in the application of a wide range of techniques, including survey design, inferential statistics, multivariate analysis, demographic analysis, cost-benefit analysis, and impact assessment. I have managed large, multidisciplinary consultancy projects spanning environmental, economic, and operational matters.

2.3. In 1994, I accepted a five year appointment as Professor and Head of the Department of the Resource and Environmental Planning at Massey University where I managed the restructuring of the bachelors and masters planning degrees to develop two distinct but integrated streams comprising natural resource planning and development planning.

3. THIS STATEMENT OF EVIDENCE

3.1. I made a written submission in support of the proposed Mangawhai Historic Wharf but opted not to speak to my submission at this Hearing. However, when I read the submissions I felt it was important to apply my research skills to the information supplied, in particular by Mr Southey and the New Zealand

Fairy Terns Charitable Trust (**NZFTCT**), regarding the survival and vulnerability of the fairy tern. I **attach** as **Appendix A** a report of the research of secondary sources that I undertook. This does not explicitly consider the impact of the wharf on the fairy tern, which I will leave to Dr Craig to address as an expert in animal behaviour and ecology. Instead, I address the wider issue of the survival of the fairy terns and the events and circumstances that threaten their survival which place any possible threat the wharf may impose in context. I summarise my findings and conclusions below.

Code of conduct

3.2. I have read and agree to comply with the Code of Conduct for expert witnesses as set out in the Environment Court Consolidated Practice Note 2014. The opinions expressed in this evidence are based on my experience in research and analysis. I am not aware of any material facts which might alter or detract from the opinions I express based on the material I have considered.

4. SURVIVAL OF THE NEW ZEALAND FAIRY TERN AT MANGAWHAI: FINDINGS

The Numbers

4.1. The NZ fairy tern population has long been at risk, with numbers apparently lower in the 1950s than today's 35 to 40 live birds. Since the 1950s the sub-species has only survived in small numbers between Waipu and Pakiri on the east coast and Papakanui Spit on the Kaipara Harbour. The numbers have been more or less stable for some time, at least since the early 1990s, although subject to year to year fluctuation and sustained by gains at Mangawhai. Data compiled from past publications, and the submissions of Mr Southey and the NZFTCT suggest a small but significant gain over the past decade, rather than a decline. [1]

[1] I use "significant" as a relative term here. Mr Southey refers to "statistical significance". It is not clear why he uses inferential statistical tests, though, as we are dealing with an entire population over a finite period rather than a sample from a much larger population, for which such tests are designed. Although this means sampling error is irrelevant, potential observation error may be a factor for which no test has been applied. This means that the figures must be read at face value.

The Threats

4.2. Given a small population, episodic events are a significant threat. The documentation confirms that the main ones are predation and weather-related. Direct disruption by human activity does not appear to be as significant. This presumably reflects the success of management initiatives to protect nests, eggs, and fledglings.

4.3. Long-term habitat changes could be a greater threat to fairy tern survival than short term disruption. One such change posited is the increasing presence of people around and on the harbour. However, this does not appear to have been detrimental to the survival of the subspecies. From 1991 to 2018, the period for which we have continuous data on the number of fledglings, the resident population in Mangawhai Heads and Village combined has grown by 265% (from 900 to 4,200 people). A large summer holiday population has presumably grown along similar lines. Allowing for year to year variation, production of fairy terns (fledgling numbers) appears to be on the increase over that period (Figures 3 and 8 in my report).

4.4. A shorter timeframe (2009 to 2019) covering the components of the tern population and residents in the wider Mangawhai catchment (Figures 2 and 9) shows the total bird population to have lifted slightly since 2015 (when mangrove clearance commenced), with female and nesting pair numbers more or less constant. Over the same period, the number of people residing permanently in the wider catchment (which includes nearby rural areas as well as the Village and Heads) doubled, to around 5,600.

4.5. This evidence does not support the hypothesis that substantial growth in settlement and related human activity are major threats to fairy tern survival. This may reflect both interventions led by the Department of Conservation focused on the safety of nesting areas and the resilience of the fairy tern, especially in terms of its foraging capacity.

Adaptability

4.6. Considering the second of these two possibilities first, the adaptability of the fairy tern to change is illustrated by its use of the harbour. The maps of Pair Foraging Territories presented in the evidence of the NZFTCT (pages 6 and 7) and Mr Southey (Figure 4) demonstrate this. Mr Southey states that territorial "*lines are clearly drawn and recognised, do not vary within a season and are* *very similar from year to year…*", while the NZFTCT states that "*the foraging territories used by NZFT in the Mangawhai Harbour have remained relatively consistent over the last ten years*". These claims conflict with the evidence. Over the nine years from 2009/10 to 2017/18 the number of territories increased from five to nine (Figure 5 in my report) and the estimated average size diminished from 87ha to 43ha (Table 2, p12). [2]

4.7. During this time mangroves have been removed (Figures 4 and 6), which may well have increased accessibility for foraging, while activity on and around the harbour has greatly increased. The evidence of the numbers documenting the presence of fairy terns throughout this period do not support claims that either the increased presence of people or reduced reduction of mangroves prejudice fairy tern survival.

4.8. To illustrate further the lack of apparent impact of people on foraging, the Mangawhai Boating and Fishing Club membership almost doubled over the five years to 2019. The number of annual ramp passes issued for non-members increased by 127%, and this does not account for the large number of casual users. There could be as many as or more than 200 boat movements in summer weekends in the lower harbour.

4.9. Adjoining the fishing club boat ramp in the same foraging territory is the Mangawhai Heads Holiday Park, where there were 4,200 visitors January 2020, further illustrating the intensity of both harbour and shoreline use.

4.10. Other longer-term habitat changes (associated with sedimentation, mangrove colonisation, and climate change, for example) may be a greater threat than either episodic events or a growing human presence. Despite the many indicators of expanding settlement in the catchment and of increasing, intensive recreational use of the harbour, the fairy tern population has adapted and has continued to reproduce.

4.11. It is noteable that the few (although clearly significant) episodes of disturbance and loss reported are confined to nesting areas and are dominated by weather events and predation. Two instances of likely human interference with nests were reported by DoC, in 2009 and 2011 (Section 3.1 of my report). I assume that more instances of all types of event have occurred and that public

2 These figures are estimates only, based on transcription of territories from the NZFTCT figures on pages 6 and 7 of its submission.

reporting is perhaps not comprehensive. It is clear though, that the human risk to fairy terns is focused on the breeding areas on the Mangawhai Spit and not on the foraging areas of the harbour. That is no doubt why the conservation efforts of DoC and others comprise interventions on the former.

Long-term survival

4.12. The long-term threats are more insidious. The major exogenous threats are those associated with climate change, including changing water conditions (warming, sea level rise), and the increasing frequency of severe weather events (turbidity and inundation).

4.13. Another is the possibility that the fairy tern population has simply reached or exceeded the natural carrying capacity of the Mangawhai habitat. Nine breeding pair foraging territories (or forty live birds) may be around the maximum that the harbour can support, meaning that the fairy tern has been at or close to a reproduction ceiling for some time. Fortunately, there is evidence of foraging further afield which, if associated with new nesting areas, offers some hope for further growth in numbers.

4.14. In-breeding is a major threat to long-term survival, as flagged by the number of infertile males in the flock and infertile eggs, raising the possibility that the best hope for long-term survival may be to increase genetic diversity.

4.15. The best prospects for fairy tern survival, then, appear to lie with sustaining the current management programme focused on the security of nests, and increasing more far-reaching and challenging management initiatives, including continuing egg and chick manipulation; relocating birds to alternative roosting areas (such as new sites at Te Arai, Pakiri and perhaps Waipu/Uretiti in the first instance); and introducing new genetic lines.

5. SURVIVAL OF THE NEW ZEALAND FAIRY TERN AT MANGAWHAI: CONCLUSION

5.1. There is no evidence that the rapid growth of settlement and any associated human disturbance on the harbour is or can be seen as a threat to the survival of the fairy tern by impacting on its capacity to forage. The birds have demonstrated their resilience and adaptability in the face of far-reaching change over many years. At the same time, nesting protection initiatives on Mangawhai spit by DoC and the community appear to have substantially reduced adverse impacts from any human activity there and episodic losses attributable to predation, weather-related events, and deficient nesting (with respect to nest placement) or parenting (with respect to egg nest abandonment) behaviours.

5.2. My intention in preparing the attached working paper was simply to take stock of the record on the fairy tern and its current status and not to defend the construction of the wharf. However, the results show that the evidence offered in opposition to the wharf and relied upon to inform the planner's recommendation in the Section 42A report does not support the hypothesis that harbour based activities and structures are a threat to the survival of the fairy tern. There are no grounds to suppose that reconstruction of the historic wharf will change this.

Dr Philip McDermott

Appendix A

The Survival of the New Zealand Fairy Tern at Mangawhai

Working Paper

August 2020

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1. INTRODUCTION

1.1 AIM

The NZ fairy tern is a subspecies of fairy tern *Sternula neries.* Other subspecies found in Australia and New Caledonia. The New Zealand population is most at risk, with around ten breeding pairs compared with 100 in New Caledonia in 2002 and 2,000 to 3,000 in Australia (Baling, 2008). Today there are around forty New Zealand fairy terns in total, with the subspecies classed as *Threatened – Nationally Critical* (Robertson et al., 2017, 10).

This paper considers fairy tern survival since the 1950s and threats associated with recent development in its breeding habitat, the harbour, spit, and dunes of Mangawhai. It relates these to longer term issues facing the population, and actions intended to sustain it.

1.2 SUMMARY

The NZ fairy tern population has long been at risk, with numbers lower in the 1950s than today's 35 to 40 live birds. Now confined to Northland, it is thought to have been once widespread, possibly observed on the South Island east coast in the 19th century.

Since the 1950s the sub-species has only survived in small numbers between Waipu and Pakiri on the east coast and Papakanui Spit on the Kaipara Harbour. For much of the time the numbers were more or less stable, although subject to year to year fluctuation. There are signs of a small gain over the past decade. This aligns with increasingly intensive management by the Department of Conservation, supported by community initiatives.

This history of survival and incipient recovery has taken place against a background of transformation in the Mangawhai environment. This includes land use changes in the catchment, expanding coastal settlement, and increasing recreational use of the harbour.

Given a small population, episodic external events are a significant threat. The main ones appear to be predation and weather-related. Disruption by human activity may be an ongoing threat, especially in the vicinity of nesting sites, but does not seem significant given the success of recent management initiatives and the apparent capacity of the fairy tern to adapt to substantial changes in the character and use of the harbour. The persistence of the population in the face of increasing settlement and long-term changes in the harbour itself demonstrate the birds' resilience.

This means substantial long-term habitat changes –associated with land use intensification, sedimentation, mangrove colonisation, and climate change, for example – are more threatening than episodic events. More fundamentally, infertility from limited genetic variability or resulting from the harbour's finite carrying capacity may be limiting local reproduction. This would mean that the population will remain at risk from catastrophic short- or long-term events.

Under these circumstances, the best prospects for fairy tern survival may lie with sustaining the current management programme and moving towards more far-reaching and challenging initiatives, including continuing egg and chick manipulation; relocating some birds to alternative roosting areas (such as new sites at Te Arai, Pakiri and perhaps Waipu/Uretiti in the first instance); and introducing new genetic lines.

2. THE POPULATION

2.1 THE LONG TERM

The NZ fairy tern may have been reasonably widespread in the 19th century, apparently observed in the braided rivers in Marlborough and Canterbury, and in the lower North Island (Parrish and Pulham, 1995a, citing Heather and Robertson, 1996 and Oliver 1955).

However, Beauchamp (2002) considered the estimates of numbers before banding commenced in 1991 to be questionable due to the possibility that early sightings were of Little Terns, a species that is similar to the Fairy Tern:

"*especially in the nondescript non-breeding and immature plumages most often seen in New Zealand. Even museum specimens were misidentified and over-looked. … the little tern is now known to be the commonest small tern in the country over the summer… most of them are northern hemisphere migrants that spend their non-breeding season in New Zealand but a few are from the population breeding in Australia*" (Southey, I. 2013. Little tern. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online* www.nzbirdsonline.org.nz.

This is consistent with a reported sighting on the eastern side of the Kaipara in 1978 (Goffin, 1978) of a flock of 25 small terns, 13 of which were fairy terns, the balance eight of which were little terns. The observer was familiar with both species from observations of Tauranga Harbour "on many occasions". Four others had left the flock at the time of identification.

Parrish and Pulham (1995b, 175) similarly call for caution over historical sightings.

In any case, it is accepted that NZ Fairy Terns have been confined to the northern North Island since the 1940s. Although open to some debate, there is little doubt that the numbers were low at the time. Beauchamp (2002) cited Ferriera et al. (2005) as identifying "a minimum" of eleven birds and just two pairs in the 1940s to 1950s. He also cited Heather and Robertson (1996) who suggested an unsourced estimate of a "population of 18 pairs" – not necessarily nesting pairs – in the 1950s. Parrish and Pulham referenced a

1957 study (McKenzie and Sibson) indicating that "the breeding population may not have exceeded six pairs"; and studies by Falla et al. (1979) and Shaw (1985) indicated there were fewer than 10 pairs.

Parish and Pulham (1995b) cite Classified Summarised Notes from the Ornithological Society of New Zealand (published in Notornis) indicating that while breeding had occurred at Tauranga, Pakiri, Te Arai, Ruakaka, Papakanui Spit (Kaipara Harbour), Mangawhai Spit, and Waipu between 1940 and 1983, since 1984 it had "apparently been confined to Papakanui Spit, Mangawhai and Waipu". They also cited an unpublished DoC report indicating that when protection was initiated by the NZ Wildlife Service in 1983/84 the breeding population was as low as three or four pairs.

Parrish and Pulham suggested that from this possible low there had been an increase tonine in 1993/94 (Table 1), with 39 to 41 chicks "believed to have fledged" in the interim. To the authors' knowledge, all 11 chicks fledged and banded between 1991 and 1993 survived the first year. Despite "the apparent high output and survival of chicks in recent years, … the breeding population has not increased although this might be explained by low survival of adults and/or emigration which has gone unnoticed." (179). They also 28 birds in 1984 as an "accurate assessment … comprising 9 breeding pairs, 7 immatures and 3 chicks that fledged in 1994" (178).

Table 1: Summer and Winter Counts of Breeding Pairs, Parrish and Pulham (1995)

Breeding Season	Waipu	Papakanui	Manga-whai	Total
1991/92	1	1	4	6
1992/93	1	1	4	6
1993/94	2	2	5	9

It can be concluded that:

(1) While the fairy tern may have been observed in central New Zealand before the 20th century, the range and numbers were substantially diminished by the 1940s;
(2) The latter part of the century saw small, fluctuating, and uncertain numbers of birds and breeding pairs limited to the lower Northland (Rodney/Kaipara); and
(3) The observations in the 1950s indicate that the Fairy Tern was already vulnerable. It has remained so for over sixty years.

Despite its Nationally Critical status and occasional claims that the bird is "*on the brink of extinction*"[1], observations since the 1950s suggest that despite its size, the population can be considered to have been stable since then. They are currently considered stable (Robertson et al. 2017)

2.2 THE MEDIUM TERM

The New Zealand Fairy Tern Charitable Trust (NZFTCT , 20202) has compiled population numbers using DoC reports and its own observation programme. With those provided by Parrish and Pulham (op. cit.), these enable assessment of post-1984 trends (Figure 1).[2]

Acknowledging the likelihood of some field error, these figures lead to the following observations:

- Annual fledgling production generally improved after 1984, peaking at eleven in 2000, and averaging 5.5 chicks per year over the 37 breeding seasons.[3] One inference is that introduction of active protection in 1984 has had a positive impact on survival.
- There is still significant year-to-year fluctuation, explained largely by individual events: predation, weather, food availability, or disturbance.
- Reasonably consistent fluctuations between high and low years suggest dynamic equilibrium in the population; i.e., the capacity to recover from setbacks sustaining the long-term average at around five chicks per year.
- Since the 1980s, the figures have been sustained mainly by production at Mangawhai, as the productivity at Waipu and Papakanui Spit has fallen.

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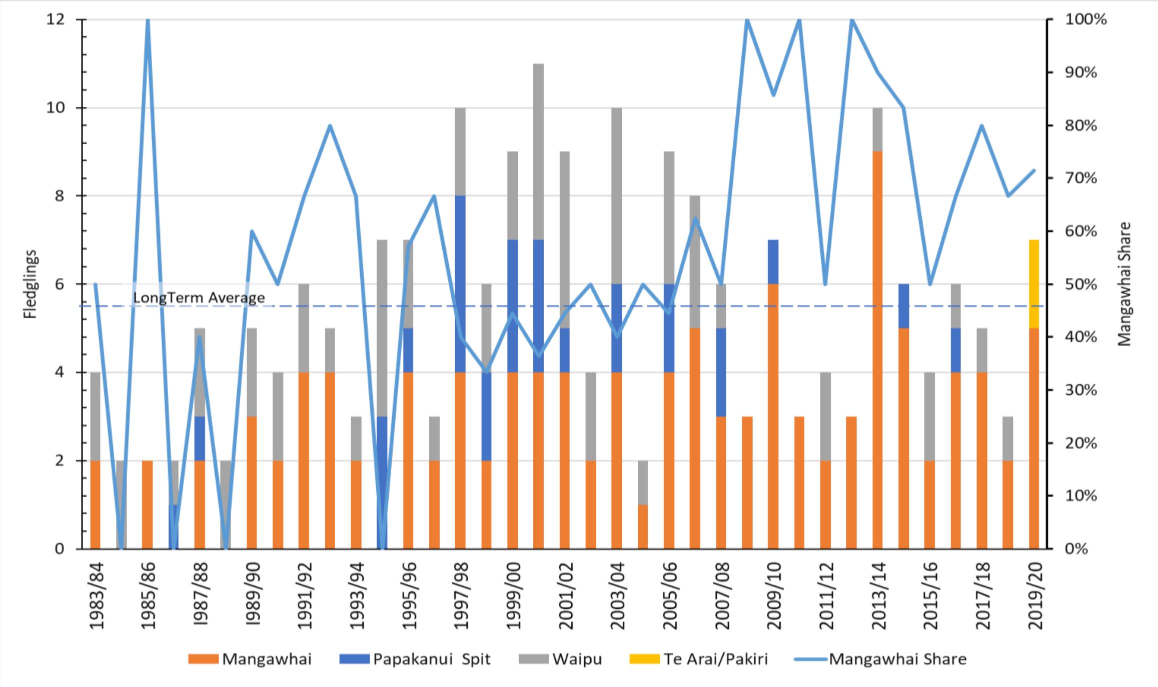
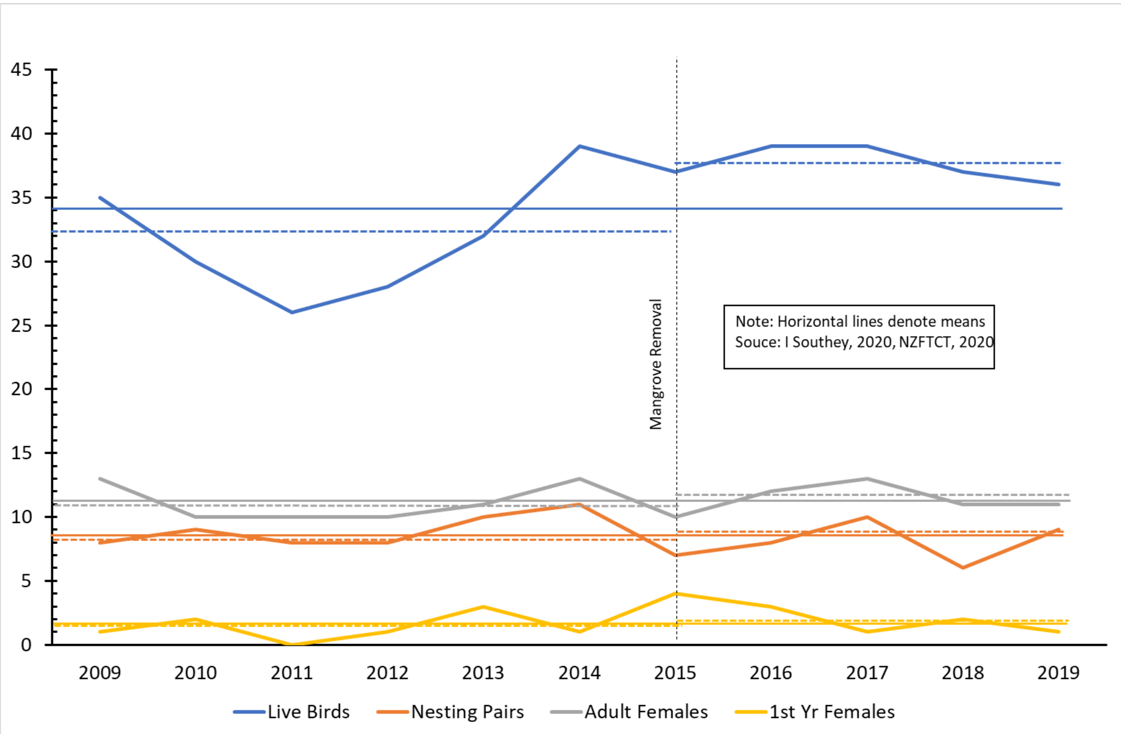
1 E.g., Newsroom, January 2019 "New Zealand's rarest bird on the brink
2 http://www.fairytern.org.nz/html/trust.htm; the figure for 2020 was accessed from DoC
3 Baling (2008, p.88) noted the lowest record of three breeding pairs in 1983.

Figure 1: Total Fairy Tern Fledglings, 1984-2020



The NZFTCT (2020) presents more detailed data on the population from 2009 to 2019. This reveals a period of relative stability in numbers (Figure 3). Live bird numbers fluctuated between 26 (2011) and 39 (2014, 2016, and 2017) for an average of 34. Interestingly. the average for the six years since 2013, at 38 live birds, is ahead of the average of 30 live birds observed over the previous five years. The proportion of birds from Mangawhai (blue line above) has remained above 50% since 2005/06.

Figure 2: Fairy Tern Population, 2009-2019

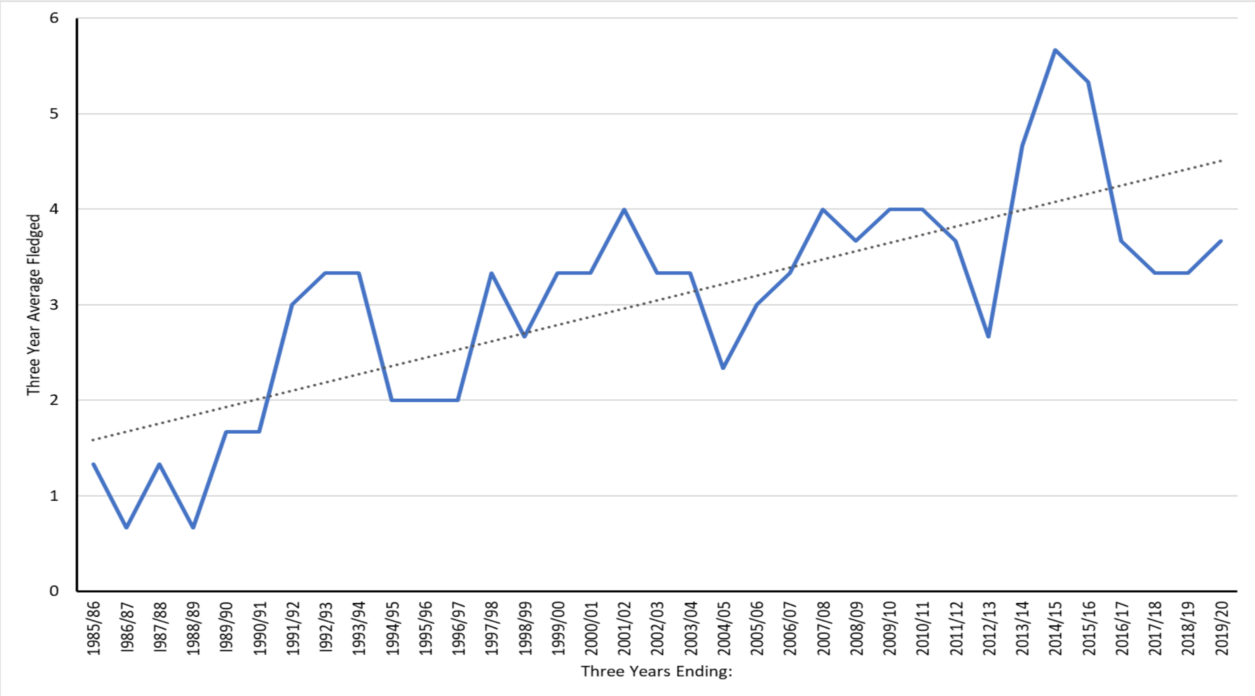


Note: Evans and Robinson (2020) recorded 36 adult birds in early 2020

2.3 THE MANGAWHAI FAIRY TERN POPULATION

The increasing importance of the Mangawhai breeding site appears to be underpinned by increasing productivity there. The three year rolling average dampens the impact of individual events revealing a reasonably consistent medium-term gain (Figure 2).

Figure 3: Fledgling Numbers at Mangawhai, Three year Rolling Average (1986-2019)



A growing Mangawhai population is consistent with Preddy and Pulhams' (2017) post- breeding observations of birds foraging at Spectacle and Slipper lakes, via the Te Arai Stream mouth, an important post-fledgling roosting site. Some variability in numbers observed foraging in the lakes (Harris et al., 2019), however, suggests their use may depend on variations in conditions at Mangawhai and Te Arai Stream mouth (as a post- fledgling roosting and foraging site), as well as the total chicks successfully fledged. Poor feeding conditions at Te Arai were seen as a reason why the birds returned to the Kaipara earlier than usual in 2017.

3. UNDERSTANDING THE DYNAMICS

The available data shows the bulk of the small NZ fairy tern population breeding at Mangawhai where it has survived and even increased in numbers over the past decade. Much has been written about the threats facing the Fairy Tern population in Mangawhai, mostly in “grey literature”[4]. This includes media releases and reports by the Department of Conservation (DoC), statements by representatives and experts providing evidence under the Resource Management Act, observations in Notornis, the quarterly journal of the New Zealand Ornithological Society, and the newsletters of the interest groups including the NZFTCT and the NZ Forest and Bird Protection Society (F&B). This material identifies a number of threats to the continuing survival of New Zealand Fairy Tern.

The threats are listed on the NZFTCT site as:

- Predation by introduced predators (rats, dogs, cats, hedgehogs, and mustelids - weasels, ferrets and stoats) which prey upon eggs, chicks, and adult birds.
- Environmental events such as high tides, storms, and strong winds which destroy nests or chicks.
- Strong winds and persistent rain can impede the adults' ability to forage, sometimes causing them to desert their nests.
- Disturbance from peoples' activities on beaches and in NZFT estuarine foraging areas during the breeding season.
- Modification and /or loss of foraging, breeding, and roosting habitat.[5]

This section first reviews these episodic factors and then considers longer-term issues: habitat modification, the impact of human settlement, and limits on carrying capacity.

3.1 EPISODIC THREATS

The Department of Conservation web site lists five “most likely causes of population decline”[6]. Four of these are episodic in nature:

- Predation – Introduced predators such as rats, dogs, cats, hedgehogs, and mustelids preying upon eggs and chicks.
- Environmental events – High tides, floods, and storms destroying and washing away nests.
- Death of embryos – Nesting birds are eaten or chased away by predators, and the embryos die from exposure.
- Recreational activities – Beach activities disturb nests and scare birds away from their nests.

The fourth listed cause of population decline is habitat change is considered below.

[4] According to Wikipedia, grey literature comprises research produced by organisations outside traditional commercial or academic publishing channels. It includes reports, working papers, government white papers, and documents. To this can be added expert statements before planning and Environment Court hearings, and the newsletters of interest groups.

5 http://www.fairytern.org.nz/html/technical.htm#readbands

6 https://dxcprod.doc.govt.nz/nature/native-animals/birds/birds-a-z/nz-fairy-tern-tara-iti/

Episodic events threaten the survival of a population when it is small and confined to a limited habitat. While there are occasional reports of destructive episodes, these do not appear to have been collated or published in any systematic way. Consequently, it is difficult to rank categories of event in terms of severity of impact, assess how this might be changing, or prioritise actions to offset them.

However, action can be taken to limit the likelihood of such events, or to protect the population from the worst outcomes. The gains since 1984 and particularly over the past five years suggest that intervention is effective. These range from the passive (fencing and signage to limit human disturbance), though active (such as predator control), to intrusive. Intrusive intervention includes uplifting eggs at risk from nest abandonment for transport to Auckland Zoo for incubation, transferring eggs between nests for fostering, egg relocation from vulnerable nests (scrapes), or creating new nesting environments.

The key events are discussed below, with examples where reported.

3.1.1 Weather Events

Craig (2009) said that "*the greatest known loss of fairy terns results from weather events*", followed by predation, including by domestic and farm animals. Weather-related events reflect the vulnerability of shallow nests on unstable dunes at close to sea level. For

example, "*a severe storm in early 2015 killed two productive adult females and a number of almost fledged chicks*" (Beauchamp, 2015, para 3.3.b). Southey (2020, para. 3.5) indicated five out of eleven fledged chicks died as a result of the storm early in the season.

Ideally, artificial nest shelter, nest relocation, or habitat modification are responses that may reduce these threats.

3.1.2 Predation

"Predation by cats, ferrets, and stoats during the breeding season has worsened their population outlook, and although many of the sites have pest control, its people that remain their biggest threat" (Forest & Bird Society)[7]

Mustelids, rats, and hedgehogs are a particular threat to ground-nesting birds, while domestic pets – dogs and cats – are a problem when nesting is close to settlement.[8] Dogs may not only attack directly but may chase adult birds, increasing the prospect for predation by other species.

Dr Beauchamp notes (2020, para 3.3.a) that between 2008 and 2011 cats were responsible for the deaths of "a number of adult females" at Waipu. Other documented events include:

Waipu 2009/10	Six eggs and two chicks thought to be taken by cats; one by a variable oystercatcher,
Waipu 2010/11	Four eggs thought to be taken by cats

7 https://www.forestandbird.org.nz/projects/new-zealand-fairy-tern-tara-iti-project

8 Suburban domestic cats with outdoor access may range around 150m from home, free-tanging suburban cats up to 360m; and free-ranging rural cats as far as 1.3km: D Robertson (https://docs.google.com/document/d/1x06uP7fEurVLCo7wqmycoGl0JIk0j1cGhAnPvnlINjA/edit?hl=en&authkey=CI2Gv7YN)

Predation can be limited by pest eradication, banning domestic cats and dogs from areas in or close to important wildlife habitats, prohibition of dogs from nesting and foraging areas, and dog control on open beaches. Southey notes that active management by the Department of Conservation and community groups means that predation "*by cats, ferrets and stoats is seldom recorded now*" and that "*more nests are successful and result in fledged chicks*" following employment of a specialist trapper in 2012 (para 3.5).

3.1.3 Human Activity

There is a concern that human activity directly disturbs fairy tern foraging and breeding. The impact of beachgoers and harbour users may be to increase predation by introduced and native species (such as black backed gulls and variable oystercatchers) when their presence causes adult birds to abandon their nests. Direct disturbance of nests by visitors to the spit may be another risk.

Southey (2020) suggests that human (or dog) proximity may disrupt feeding and so reduce fairy terns' ability to harvest enough food for their needs. While human activity is not normally an issue for the fairy tern, he expresses concern over the Christmas/New Year period (para 7.2). He also suggests that wave action associated with boat wakes will reduce fishing effectiveness by temporarily reducing water clarity on the channel edges where fairy tern normally fish.

Possible incidents of direct disturbance include:

Waipu 2010/11	Nest damaged and egg disappeared
Mangawhai 2009/10	One egg possible human interference

The risk of disturbance can be minimised by such measures as controls on entry to nesting areas, control on boat speeds, and positive engagement with the community at large. The latter may include educational initiatives, recruitment of volunteers to supporting activities, and the provision of interpretative signage in public spaces.

3.1.4 Overview

While the quality of the record is variable, it is significant that press releases from DoC[9] and media coverage today generally reflect the success of intervention more than losses from episodic events. Losses from predators recorded 10 years ago till tend to dominate commentaries, while the 2014/15 storm appears to have been the last weather-related event of great significance. It appears – and is affirmed in the commentaries – that intervention has become more effective as it has become more intensive, underpinning the recovery of total population numbers and the continuing breeding success.

3.2 LONG-TERM THREATS

Long-term threats involve sustained shifts in the character of the habitat. This may lead to changes in foraging, roosting, and breeding behaviours or reduced environmental carrying capacity, or both, potentially increasing the severity of any disruption by episodic events. Structural changes in the environment call for adaptation by the fairy tern population to offset any increased risk. In addition, interventions that reduce the impact of habitat change will reduce the potential threat of individual episodic events. Given the apparent success of management programmes to date, it is timely to address structural changes.

[9] See www.doc.govt.nz/news/media-releases

3.2.1 Habitat Modification

Both natural processes and human resource use modify the coastal environment. Given a demonstrated capacity to minimise the impact of episodic events, the more significant risks to endangered species may lie with long-term changes in habitat.

For example, while storms are short term events that are particularly threatening during the Fairy Tern nesting season, climate change generally heightens the risk they impose with more extreme and greater frequency of such events. It will also bring about long-term changes in circulation patterns and in air and water temperature. Consequent changes in the flora and fauna within ecosystems may reduce (or increase) food supply, increase competition within the food chain, or lift losses to predation from changes in the distribution of species. More intensive catchment rainfall may accelerate aggradation, impacting on breeding territories and reducing the prey population available within them.

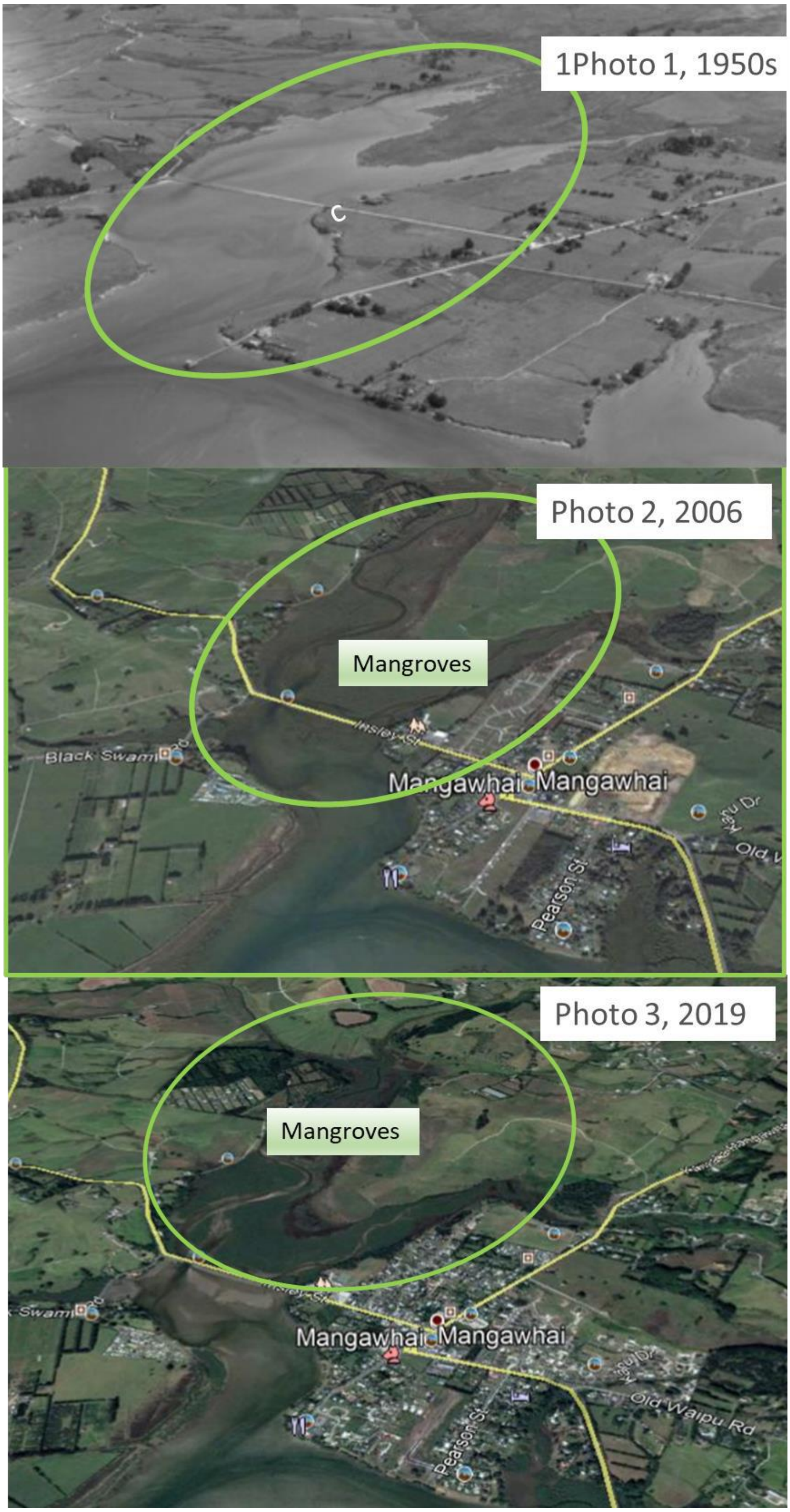
3.2.2 Loss of Habitat

Loss of water surface takes place gradually under "natural" conditions through catchment erosion and downstream aggradation. This can be accelerated from direct or indirect reclamation. Planned reclamation has been limited to causeway development in Mangawhai. However, land use change in the wider catchment accelerates aggradation through increased sedimentation, leading in turn to the reduction of foraging capacity of the harbour. Foraging by the fairy tern is based on:

"*the water edges, shallow channels, and pools of tidal flats of mangrove lined ... parts of the estuary; tidal pools on mud- and sandflats in the lower estuary and lower harbour; the shallow margins of the dredged main channel in the lower harbour; the oxbow lagoons on the sand spit; and coastal shallows*" (Ismar et al., 2014, 72)

The increased sediment load in Mangawhai has promoted the extension of mangroves from the estuary fringes (Photo 1, Figure 4) to occupy the bulk of upper channels (Photo 2), to the point at which they colonised the sand- and mud-flats of the upper and middle harbour. The result will have been to impede water flow and reduce the length of shoreline and channels available for shallow water fishing. Some of shallows have since been restored through post-2015 mangrove removal (Photo 3).

Figure 4: Mangrove Expansion, 1950s-2019



3.2.3 The Question of Mangroves

There is some controversy over the role and value of mangroves in New Zealand estuaries.

While internationally the ecological productivity of mangroves is considered high, the bulk of the literature underlying this is based on tropical mangrove forests. The productivity of New Zealand mangroves tends to be lower than those in tropical and subtropical areas, with less evidence of their value to fish production (Morrisey et al., 2007).

The rapid expansion of mangroves is considered a New Zealand phenomenon (Schwarz, 2003), further reducing comparability with productive tropical or subtropical mangroves. It is based on sediment accumulation from the wider catchment (Nicholls and Ellis, 2002) and the nutrient loads associated with the shift to cultivated and urbanised land uses (Lovelock et. al., 2007).

While the expansion of mangrove forests within New Zealand estuaries and harbours is contentious and their management proving challenging (Lundqvist et al, 2014), they lead to two types of habitat change that may pose a threat to fairy terns. The first is the reduction of foraging areas as described by Ismar et.al. (op. cit.). The second is a possible reduction in prey fish resulting from the trapping of sediment, loss of inter- tidal flats, and channel reduction.

LaBonté suggested that, in some instances, lack of mangrove management could lead to "*complete closure of tidal inlets and total loss of intertidal habitats in harbours, thereby reducing biodiversity*" (2004) While mangrove reduction in Mangawhai and elsewhere is a relatively recent initiative, and the impacts depend somewhat on the regime adopted since it commenced in 2015 there has been a gain in fairy tern numbers.

3.3 Carrying Capacity and Foraging Territories

According to NZFTCT 2005 Dr Beauchamp suggested that the harbour carrying capacity could be limiting the breeding pairs of fairy terns (NFTCT, 2020). It provided maps of 2008/09, 2009/10 and 2017/18 foraging territories (NZFTCT, 2020, pp.6-7), and concluded that foraging territories "*have remained relatively constant over the last ten years*".

That is hardly the case. The 2017/18 map identifies nine foraging areas, supported by Southey's (2020) map for 2019, compared with only five in the earlier two maps. This is a significant increase, most likely a sign of an increase in the carrying capacity of the harbour. The gain appears to lie in the greater subdivision of territories in the mid- and upper harbour which, among other things, coincides with mangrove clearances in those areas. [10]

The 2010 and 2018 maps have been replicated to estimate the relative size of foraging areas (Figure 5). This has meant aligning the ellipses used in 2010 with the relevant shoreline divisions. While the method can only be considered to approximate foraging territories (as no doubt is also the case with the boundaries observed), the comparison demonstrates major changes in territories over the nine years.[11]

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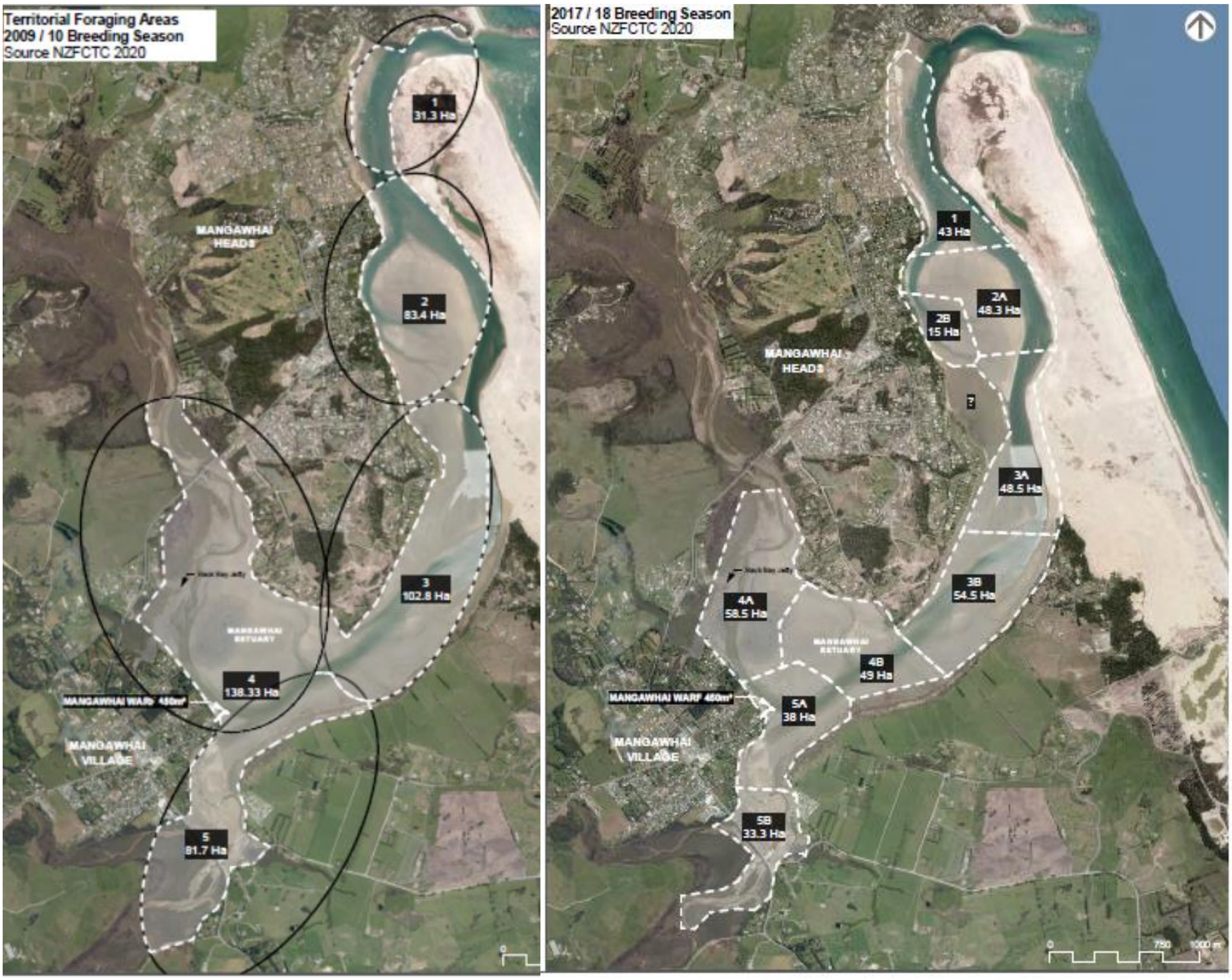
[10] Southey (2020) notes some possible indicators of reduced breeding success following removal of the mangroves (prior to the result for 2020). This may simply be that a reflection of increased competition for a finite resource through the proliferation of foraging territories, which would be consistent with the lift in total population since 2011.

[11] Replication and estimation of areas were undertake by Dream Planning Ltd

Figure 5: Territorial Foraging Areas



Acknowledging the approximate nature of the territories, the areas of each have been estimated (Table 2).

Table 2: Changing Fairy Tern Territorial Foraging Areas

2009/10		2017/18	
Id.	Ha	Id.	Ha.
1	31	1	43
2	83	2A	48
		2B	15
3	103	3A	48
		3B	55
4	138	4A	59
		4B	49
5	82	5A	38
		5B	33
Area (ha)	437		388
Average ha	87		43

They indicate

- A halving in the average territory area between years;
- A substantial range between the largest and smallest area in each of the years, smallest in both being a little more than 30ha, the largest close to 140ha in 2010 but down to around 60ha in 2018;
- A possible reduction in the total area of the harbour utilised (by around 10%).

These figures strongly suggest that there have been gains in the productivity of the harbour, with the capacity to support more birds, although this may only be reflected in total numbers so far and not yet in fledgling production.

3.4 A DYNAMIC ENVIRONMENT

Although the Fairy Tern population supported at Mangawhai may be at or close to its ceiling based on harbour carrying capacity, posing a fundamental long-term threat, the sorts of medium-term variations identified in Figure 5 will have significant impacts on-year to-year production. This is quite simply because of the naturally dynamic nature of the harbour environment. Shifts in currents, channels, and estuary edges associated with medium-term variation in the weather and long-term climate change could play a significant role in the availability of prey fish and carrying capacity.

Ismar et al. (2014) describe fairy tern foraging behaviour by as follows:

"*We recorded 405 foraging dives that show NZFT foraging habitat includes the water edges, shallow channels, and pools on the tidal flats of mangrove-lined (Avicennia marina var. resinifera) parts of the estuary; tidal pools on mud- and sandflats in the mid-estuary and lower harbour; the shallow margins of the dredged main channel in the lower harbour; the oxbow lagoons on the sand spit; and coastal shallows*."

Clearly, by reducing water surface colonisation by mangrove forest reduces the available pools in mid estuary and on the tidal flats of the mangrove-lined upper estuary, and the tidal pools in the mud- and sand-flats of the mid-estuary, thereby reducing foraging capacity. The evidence suggests that this threat to foraging can be reversed by harvesting mangroves that have occupied such areas, reducing one of the sources of concern associated with increased settlement in the Mangawhai catchment.

Extensive mangrove colonisation has been a feature of the last 50 years or so of development. Figure 7, preproduced courtesy of the National library Collection, is a White's Aviation photo of the harbour in 1963 looking east from west of the Insley Rd causeway. The primary school is at the northern end of the causeway, the tavern and historic wharf site in the middle ground, and Moir point beyond that.

There is evidence of fringing mangroves west of the school, north of the causeway towards the site of the tavern, and perhaps on the southern shore adjoining what appears to be salt marsh grading into pasture. This contrasts strongly with the 2006 Google Earth image below, which shows mangroves dominating the estuary west of the school and occupying the bulk of the shallows north of the tavern and through to (and beyond) the Molesworth Bridge, demonstrating a substantial reduction in water surface and consequently low tide exposure of shallows, pools, and channels The mangrove clearance programme since2015 has largely recovered the situation east of the Insley St Causeway but not beyond the Molesworth St bridge.

Figure 6: The Extension of Mangroves, 1963 to 2006

The natural dynamism of the foraging environment even in the short term is clearly illustrated by variations in the ox-bow lake on the Mangawhai sand spit (Figure 7), considered a significant foraging area in its own right. There appears to be significant variation in foraging potential both within a single season (2017/18) and between seasons. February 2018 clearly offers much more foraging area than February 2019.

Figure 7: The Changing Mangawhai Spit Lake

An obvious feature of the upper harbour foraging areas is the incorporation of the Insley St causeway and bridge in both years and the Molesworth Drive bridge in the earlier year. These are both areas of intensifying human activity. Between 2005 and 2019, for example, Average Daily Traffic Counts on Insley Rd (territories 5 and 5B) increased by around 170% (to 4,850 ADT). Traffic on Molesworth Bridge appears to have increased by 225% over the same period (to 8,170 ADT)1212. Molesworth Drive in the vicinity is also well-used by pedestrians and cyclists. Nearby Back Bay, in the centre of PFT7 Northern Causeway, has a 150m jetty reaching out into the channel.

Consideration of total bird numbers, fledgling production, and foraging territories over the past decade or so does not support the proposition that human intrusion has adversely impacted on the survival of the fairy tern.

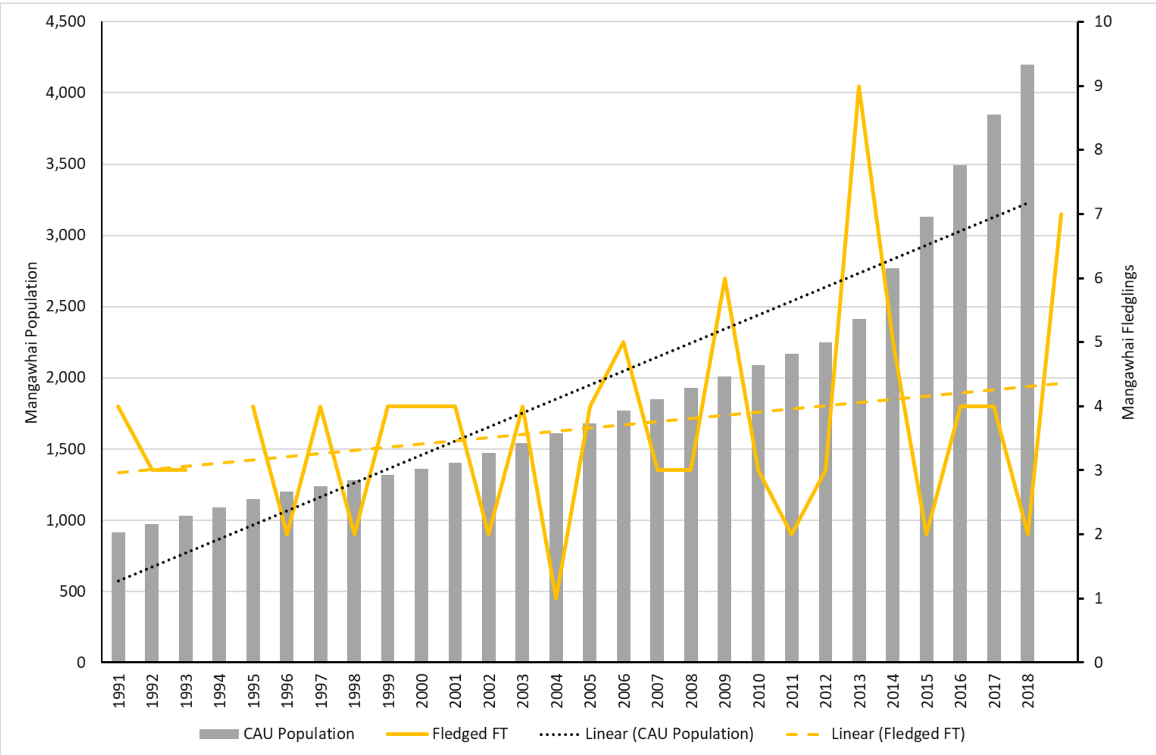
To examine this in terms of structural change rather than disruptive episodes, it is worth considering the relationship between the bird and human populations in the area.

3.4.1 Population Growth

This section addresses the establishment and expansion of settlement in general terms. Two sets of Statistics New Zealand (SNZ) residential population estimates are available.

First, data for Mangawhai Village and Mangawhai Heads Census Area Units enables comparison with 28 years of fledgling observations. Based on SNZ mid-year estimates from 1991 and 2018, the Mangawhai resident population grew by around 265% (Figure 8).

Figure 8: People and Fairy Terns at Mangawhai, 2009-2019



Despite this sustained residential growth, especially since 2013, there is no evidence of a negative response in fledglings produced. There has, in fact, been a medium-term gain.

Second, the recently implemented Statistical Area 2 units (SA2) introduced in the 2018 Census can be used for the comparison with total bird numbers since 2009. These figures include the rural area in

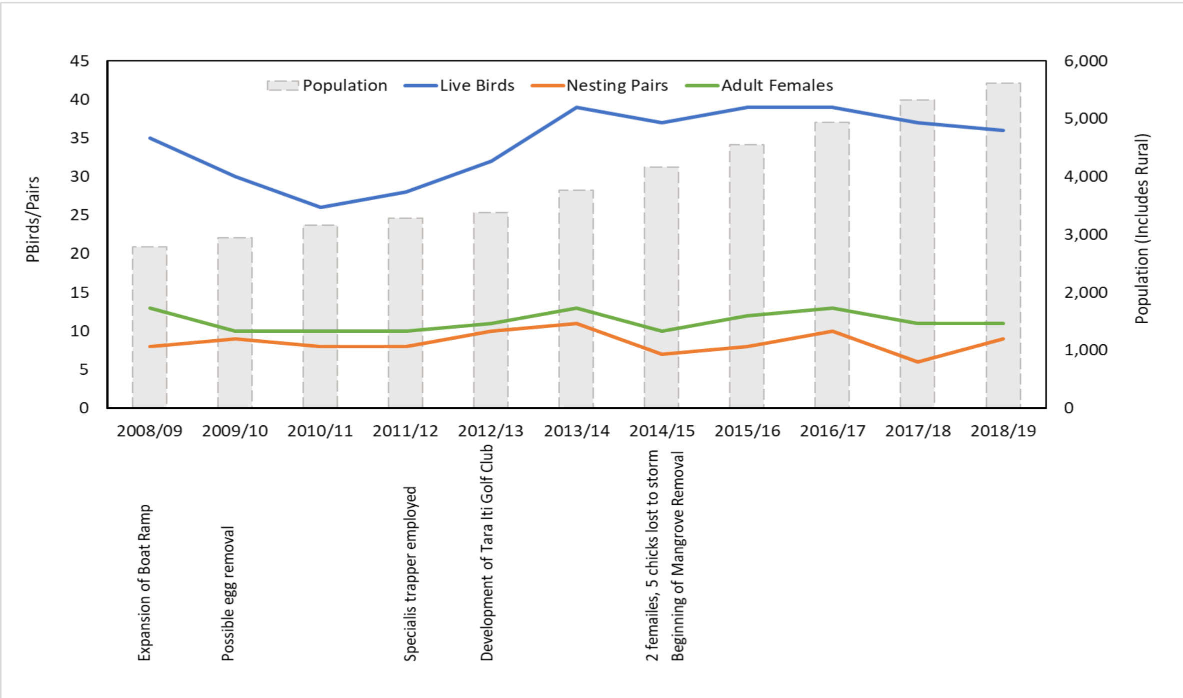
[12] The comparisons were between counts in March 2003 and estimates in July 2019 so are approximate only. Seasonally aligned gains (e.g., March to March) are likely to be higher.

the vicinity of the Mangawhai coastal settlement, which accounts for a significant share of population growth in the immediate Mangawhai catchment.

The conclusion is much the same (Figure 9): there is no evidence that a doubling of the human population has adversely influenced the fairy tern population or reproduction.

While increasing the number of people in the habitat raises the possibility of adverse impacts, this does not appear to be the case, with no adverse events apparently reported since 2009. Although the record may well be incomplete, it does suggest that human activity is not impacting on the fairy tern's long-term survival. Before considering why this might be the case, and what the real threats may be, some consideration is given to the nature and intensity of activity in and around the harbour.

Figure 9: Components of the Fairy Tern Population, Increasing Resident Numbers, and Reported Events 2009 to 2019



3.4.2 People on and around the harbour

Alongside the growth in resident population, it can be assumed that there has been strong growth in the summer holiday population. In the 2018 Census, 30% of Mangawhai's houses were recorded as "empty". These are mainly holiday homes which could easily boost the mid-summer population by 50% or more given their high levels of short-term occupancy.

In addition, a large number of people stay in the three harbour-edge camping grounds, particularly in summer – Mangawhai Heads Holiday Park, Riverside Holiday Park, and Moir Point Camp. A 63% increase in annual visitors from 2012 to 2020 (June years) is reported by the Heads Holiday Park alone. The smaller Riverside Holiday Park reports around 75% growth in just three years. The three could receive as many as 25,000 guests a year between them, the bulk over the summer fairy tern breeding season.

A rapidly increasing permanent and holiday settlement in Mangawhai is evident in a range of indicators including significant increases in:

- Vehicle traffic on Insley Rd and Molesworth Drive causeways;

- Use of the harbour by powered (dinghies and runabouts for water-skiing and fishing and jet skis) and non-powered craft (yachts, canoes, paddleboards, skiffs, and thelike);
- Intensive use of the lower harbour for boat launching, swimming, estuary fishing, and paddleboard and surfboard activity;
- Beach and dune visits, including activity in and around ocean beach foraging areas (including the canal stream mouth used for roosting and foraging at Te Arai), peaking in the middle of the breeding season;
- Pedestrian activity on the harbour edge.

The distribution of harbour-focused activities is shown in Figure 10. The most intensively used areas are in the lower and middle harbours in summer, despite which there now appear to be five foraging territories (numbers 1 to 3B in Figure 5), where ten years earlier there were only three (1 to 3).

The boat ramps are located foraging area 1, where the Mangawhai Boating and Fishing Club (MBFC) has seen a continuing rise in memberships over the past 6 years. At the end of 2019 the club had over 350 members, almost double the figure of five years earlier. Over a third of the growth comprised children, indicating the changing composition of the community and the growing importance of family activities around the harbour.[13]

While record keeping has been mixed in the past year or so, the number of annual ramp passes issued for non-club members has also increased markedly, from around 200 in 2014 to 450 in 2018 (127%), indicating a growing number of regular users. Ramp purchasers are estimated to account for around a third of all non-club users, which could amount to another 900.[14]

Assuming:

(1) there is one active boat for every two adult members of the fishing club (110 boats), land 1,350 boats associated with non-club members (as above);
(2) club members and pass holders take 6 trips each per year on average and casual users 4 trips per year, each trip comprising two movements (in and out); and
(3) weekends account for two thirds of all trips (although week-day use is growing as the local population increases), then

there would around 180 boat movements at the MBFC boat ramp each weekend, obviously more in summer than winter, and significantly more in fine summer weekends or on the four or so weekend when fishing competitions are held. It is common for more than 100 boat to enter competitions to (each carrying an average of perhaps three people), leading to significant queueing and potentially generating 400 movements over the two days.[13] While only indicative, these figures suggest that there will be many days of intense activity on the harbour, intermixed with more moderate ones.

Smaller powered and non-powered craft also use the sand ramp 350m south of the boat club to access the harbour (rather than the sea), although in smaller numbers. Associated with this, fForaging areas 2A, 3A, and 3B (Figure 5) are subject to intensive summer use for water skiing and jet boating.

Adjoining the boat ramp, Mangawhai Heads Holiday Park reported 4,200 visitors in January 2020 (up 20% on two years earlier), further adding to the intensity of both harbour and shoreline use in the breeding foraging territory labelled 1 in Figure 5 (2017/18).

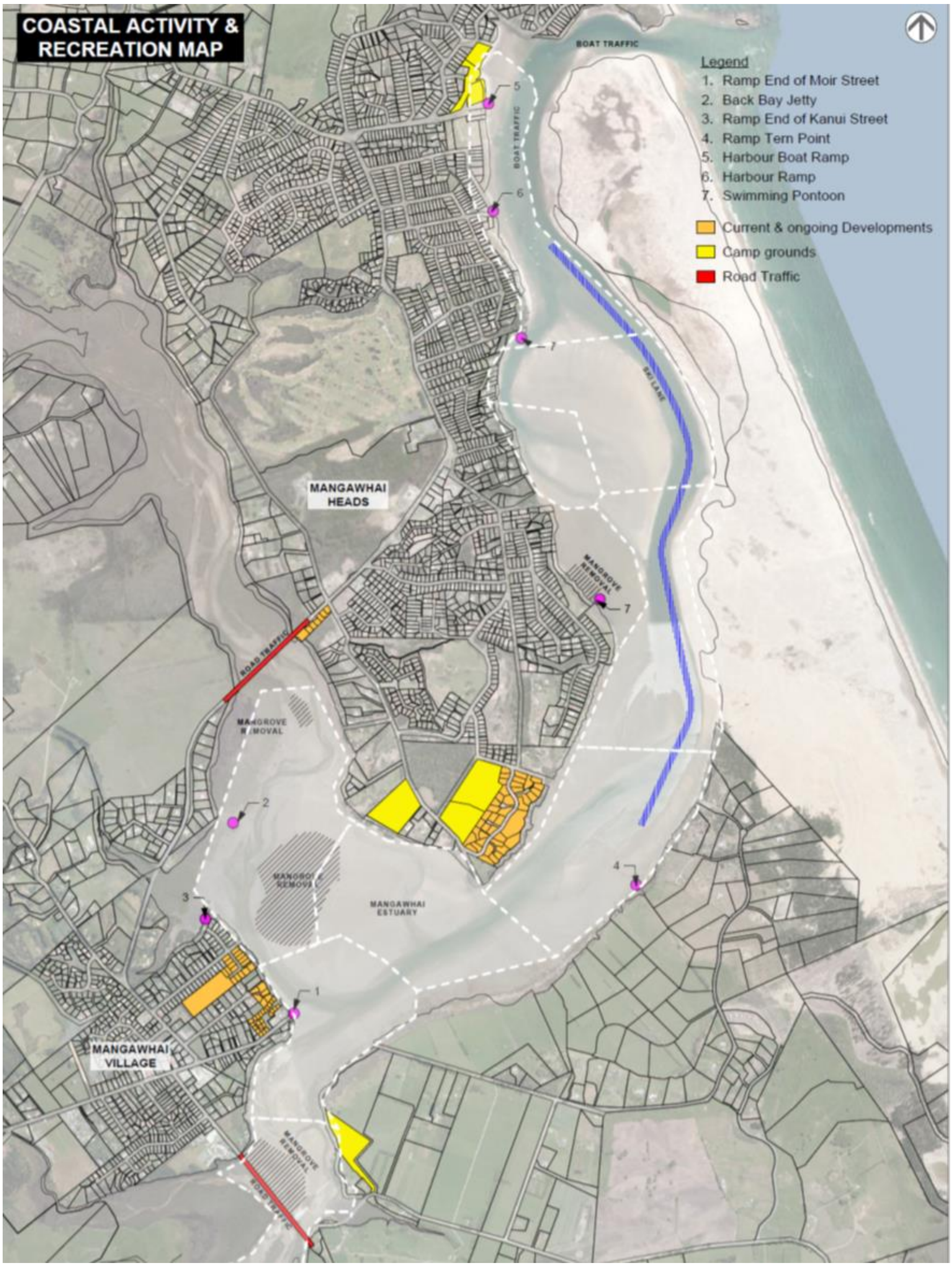
13 The information and opinions regarding fishing activity have been supplied ed by the Club Secretary, Kerry May, and Past President Darryl Reardon

14 Although built and maintained by the MBFC the ramp is treated as a public facility without compulsion to pay fees.

These activities will have increased in keeping with the growth recorded by the camping ground and boat ramp users. At the same time, the entire harbour is popular among canoeists and stand up paddleboard users, while swimming takes on the beaches and bays of the lower and middle harbour.

Recreational activity is not confined to the lower harbour as indicated in Figure 10, which also shows how foraging territories abut areas of intensive residential development and traffic movement.

Figure 10: Recreation Activity, Mangawhai Harbour[14]



[14] Map prepared by Dream Planning

3.5 INTERVENTION

The persistence of the fairy tern population in the face of settlement growth and more intensive activity on and around the harbour may be attributable to a concurrent increase in intervention aimed at preserving it, as outlined in DoC media releases. Indeed, settlement itself may be a positive force, encouraging participation in activities intended to enhance the prospects of survival and residents choosing to play a custodial role.

It could be argued that the ultimate disturbance to fairy tern nesting areas, a least, comes from deliberate intervention: the erection of fences, the construction of hides, the movement and manipulation of eggs and chicks, and most recently the creation of totally new nesting areas by the deposition of tonnes of shell in selected localities. The apparent success of such intrusive initiatives may itself be a reflection of the resilience of the birds.

3.5.1 Community Groups

The proposition that settlement has a positive impact on the fairy tern population goes further than this, demonstrated by the emergence of settlement-based and development- funded local constituency committed to fairy tern protection over the past two decades.

For example:

Tern Point:

Tern Point was established in 2000 as a gated residential community of 41 lots adjacent to the upper harbour at the base of the spit and approximately 1,500m from the nesting areas. Twelve lots are currently permanently occupied and many others used extensively. Residents are active in preserving the estuary boundary, planting on the spit, predator control, and track development in common areas.

The Mangawhai Harbour Restoration Society:

Established in 1994 following restoration of the Mangawhai Harbour mouth after a storm induced breach of the sandspit, the Mangawhai Harbour Restoration Society aims to protect and restore the spit and the harbour. It undertakes planting, fencing, and rabbit control as part of a longer-term programme aimed at completely revegetating the spit. Planting is undertaken by members of the Society and volunteers from the wider community using native spinifex and *pingao* plants grown in a nursery established for the purpose.

The New Zealand Fairy Tern Charitable Trust

The NZFTCT was established in 2008 with the aim of ensuring the survival of the fairy tern by supporting and participating in the DOC New Zealand Fairy Tern Recovery Project. It provides funding and volunteer support as well as acting as an advocacy agency for the sub-species. It provides practical support by members recording the detail of bird sightings and observing nesting, roosting, and foraging behaviour.

It listed its activities (2018) as public education, community involvement, advocacy, assistance with bird and habitat management, predator control, and research (a recently launched study of the Mangawhai Harbour fish population).

Tara Iti

Tara Iti Golf Club and associated housing (with provision for 46 dwellings) commenced development in 2012 and opened in 2015. Environmental initiatives include direct predator control and replacement of radiata forest with native grasses and shrubs intended to improve dune stability. This reduces habitat for the predators that are a particular threat to ground nesting shorebirds. Plans for the development of two further links courses south of Te Arai Point will see intensive predator control extended through and to the south of the existing Te Arai South Forest.

The Shorebirds Trust

Established by Tara Iti Golf and supported through its Annual Charitable Golf Tournament, formed a partnership with DoC in 2017, and undertakes a variety of measures. These include funding shell enhancement of nesting areas in Waipu (2019) and Mangawhai (2020), providing material support to the Department of Conservation Fairy Tern Recovery Programme, and sponsoring research into fairy tern genetics at the University of Canterbury.[15]

Among other things, in 2002 the Trust received funding from Auckland Council and Foundation North to develop a plan for a predator-free buffer zone from Mangawhai to Pakiri north, with the aim of managing invasive pests to very low densities within a Buffer Zone within the public and private land along the coastline to Pakiri north.

3.5.2 The Department of Conservation

The commitment of residents and volunteer groups to protection of the fairy tern is directed at supporting the role of the Department of Conservation in the area. This commenced when in 1983/84 the New Zealand Wildlife Service initiated protection. It is suggested that the subsequent population turnaround (from decline to growth) was associated with the fencing of nest sites and the use of wardens during the breeding season (DoC, 1997, p.11). Management techniques used over the following years also involved movement of eggs and chicks to avoid loss to storms, remote incubation (at Auckland Zoo) and some fostering. Colour banding of chicks was introduced in 1991/92.

The 1997-2002 DoC Fairy Tern Recovery Plan sought, first, to prevent extinction and, second, to increase the breeding population by 25%. It was based on:

(1) A commitment to site protection for breeding pairs;
(2) Maximising productivity by manipulation of chicks and eggs;
(3) Monitoring the population and its dynamics;
(4) Improving the legal status of breeding and flocking habitat protection;
(5) Raising public awareness of the need for conservation; and
(6) Formalising a Fairy Tern Recovery Group; The Plan also set out areas for research.

The 2005-2015 recovery plan noted that while active management had halted the decline it was still required "to secure the population" (p.7). Its management goals were extended to include research

15 https://www.shorebirdstrust.org.nz/projects

into how the lack of genetic variation may be depressing breeding, considering fledgling traits, post-fledgling behaviour, and techniques for captive rearing.

Raising public awareness remains an important goal. It includes media coverage of the recovery programme and fairy tern management; improved signage "*that advocates protection and provides information*"; identifying opportunities for community and iwi management; and following up funding and sponsorship opportunities. The Plan also includes a commitment to encouraging increased volunteer support of wardens for monitoring, surveys, and assistance with incubation/rearing programmes.

3.5.3 The Tara Iti Recovery Project

The Tara Iti Recovery Group was established in 2019 to formalise collaboration among various community interests and DoC. It include includes Ngāti Whatua O Kaipara, Patuharakeke Te Iwi and Te Uri o Hau, community stakeholders, Forest and Bird, Boffa Miskell, and the Shorebird Trust. The initiative is intended to bring "Structured Decision Making" to identifying and prioritising management strategies to achieve the most positive impact on recovery efforts.[16]

3.6 Fairy Tern Fertility and Breeding Behaviour

The big unknown in considering the survival prospects for the NZ fairy tern is the possibility that limited genetic diversification will permanently constrain reproduction. Breeding and parenting failures often appear to undermine reproduction. Those documented in various DoC media releases include the influence of infertile males in the population, infertile eggs and eggs failing to hatch, nest abandonment by one or both adult birds, and Interference of nesting pairs by a third adult bird. To these "endogenous" failures can be added a tendency to nest in areas open to inundation by the sea or wind-blow sand.

While behavioural shortcomings can be offset by direct intervention (such as shelling potential nesting areas, egg movement between nests, and artificial incubation) infertility raises a more entrenched risk of extinction.

In 2005 DoC (2005, 7) reported the following parameters:

- Proportion of population attempting to breed: 63%
- Proportion of eggs hatching: 38%
- Chick survival to fledgling: 63%
- Fledgling recruitment into breeding population: 33%
- Adult survival: 95%
- Average lifespan: 6 years

These observations point to particular weaknesses in the low level of eggs hatching and the recruitment of fledglings into the breeding population. While no later performance figures have been found, it was suggested that

> "*The population could be suffering from inbreeding depression and this may be the cause of the high levels of egg infertility (p17), justifying the breeding site separation and egg or chick manipulation between sites*."

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16 https://www.doc.govt.nz/news/media-releases/2019/stepping-up-to-save-new-zealands-most-endangered-bird--the-tara-iti-fairy-tern/

In 2018 the Department of Conservation and University of Canterbury committed to a three-year research programme, funded by the Mangawhai Shorebirds Trust, into fairy tern genetics. Scheduled for completion in March 2021 it aims to:

- Determine causes and patterns of loss of fertile eggs during the incubation stage.
- Make recommendations on how to maximize productivity from genetically robust pairs based on pedigree information.
- Collect blood samples from tara iti (NZ Fairy Tern) and undertake genomic level analysis of fairy tern to underpin management.
- Establish pedigrees for breeding pairs to aid decisions about pair management.
- Undertake a reassessment of the classification status of tara iti.[17]

It is to be expected that insights into the genetic diversity or otherwise of the bird will enhance management intervention intended to lift reproduction and raise the prospect for a sustained increase in population. The question is likely to remain, though, whether the Mangawhai spit and harbour have the capacity to sustain a significant increase in successful breeding and the total population that gains in fertility might bring about.

4. CONCLUSION

There is no evidence that the rapid growth of settlement and associated human disturbance is or need be a significant threat to the survival of the fairy tern. The nesting protection initiatives by DoC and the community, and, more recently, increasing sponsorship providing additional resources for management and research, appear to have more than offset possible adverse impacts from increasing human activity. The commitment to active management means that has accompanied settlement growth appears to have been effective in terms of limiting the effects of human disruption on the fairy tern population and is reflected in effective predator control and some success in egg manipulation. The best hope for fairy tern survival in the short term appears to lie not in limiting human activity, but in continuing to protect and, indeed, enhance nesting areas.

The long-term threats are more insidious. The major exogenous threats are those associated with climate change, including changing water conditions (warming, sea level rise), and the increasing frequency of severe weather events (turbidity and inundation).

Another is the possibility that the population has reached or exceeded the natural carrying capacity of the Mangawhai habitat. Nine breeding pair foraging territories may be at or close to the maximum that the harbour can support. The fairy tern may have already encountered a reproduction ceiling. If production continues in the long-term at around the recent average of four to five fledged chicks a year, it is unlikely that the population will ever exceed 40 live birds or thereabouts. This means that survival of the sub-species, as long as it depends on Mangawhai as its breeding hub, will continue to be under threat even if the threat from human disturbance is, as the evidence suggests, very low and, where it occurs, focused on nesting rather than foraging activity.

It may also be that pressure from recent gains in bird numbers has led to an excess of territories, and that just five or six may achieve better breeding performance than nine or ten. If the harbour is at its full carrying capacity to support breeding pairs, the best response may be to promote nesting at alternative sites such as Te Arai stream, Pakiri near Tomorata lakes, the Pakiri stream locality, or on the Kaipara (where they currently winter). That chicks were produced at Te Arai and Pakiri in 2020 and foraging occurs at Te Arai and Spectacle Lake lend weight to this possibility.

Although the research has not been undertaken, it is possible that further gains in harbour productivity from improved catchment management and restoration of water surface may sustain nine or more territories without prejudicing the nutrition requirements of breeding pairs. However, if, as the record suggests, the population is approaching its limit and it is not possible to manage recovery elsewhere (or in captivity), the fairy tern will remain critically endangered in New Zealand until lack of genetic diversity eventually leads to its extinction.

The best prospects for its long-term survival, then, appears to lie with sustaining the current nest-focused management programme <u>and</u> moving towards more far-reaching and challenging management initiatives, including continuing egg and chick manipulation; relocating birds to alternative roosting areas (such as new sites at Te Arai, Pakiri and perhaps Waipu/Uretiti in the first instance); and introducing new genetic lines.

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