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

Evidence of Ian Southey on behalf of the New Zealand Fairy Tern Charitable Trust

Date: 11 September 2020

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1. OUTLINE

1.1 This statement of expert evidence addresses a resource consent application to build a wharf at Mangawhai at a site that once had a wharf but has not now for some decades. It specifically looks at potential impacts on New Zealand fairy terns and how they might change if visitor numbers increase as they are intended to do.

1.2 It also covers the recent population status of fairy terns, declining productivity since mangrove removal in 2015, some relevant aspects of fairy tern biology and issues related to human disturbance.

1.3 Appended is a preliminary report showing how both fairy terns and people used the area in the vicinity of the wharf from November 2019 to January 2020 (appendix 1).

2. QUALIFICATIONS

2.1. My name is Ian Southey and I am providing expert evidence on behalf of the New Zealand Fairy Tern Charitable Trust.

2.2. I have read the Code of Conduct for Expert Witnesses produced by the Environment Court (2014) and undertake to follow it for this hearing. I confirm that the issues addressed in this brief of evidence are within my area of expertise unless specifically attributed to others. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2.3. I am an amateur ornithologist with more than 40 years' experience. I am a member of Birds New Zealand where I serve as the regional representative for South Auckland, am on the Records Appraisal Committee and have been heavily involved in organising and running camps to engage youth in study and enjoyment of birds.

2.4. I have an MSC (Hons) from Auckland University. I have had experience working with the Department of Conservation on several species management and wildlife survey and monitoring projects and more recently as a consultant. I have had a strong and active interest in fairy terns, especially since 2012, and have become a member of the New Zealand Charitable Fairy Tern Trust (the Trust or NZFTCT). My particular current interest is in the food and feeding of fairy terns and I have carried field based research, mostly based on Mangawhai Harbour. Some of these projects have been carried out in partnership with the Trust. I am also providing input to the Department of Conservation's newly re-established Fairy Tern Recovery Group.

2.5. Relevant ongoing research which informs this submission includes:

a. Every year since 2014 I have monitored and mapped the feeding territories of fairy terns on Mangawhai harbour so I know how individual fairy terns use different areas of the harbour.
b. I have led a New Zealand Fairy Tern Trust project to monitor the numbers of small fish that fairy terns eat with monthly samples covering three breeding seasons 2017-19 and some sampling through the remainder of the year. This includes a site immediately adjacent to the proposed wharf.
c. From November 2019 to January 2020 members of the NZFTCT and I observed foraging patterns by the pair of fairy terns that occupy the proposed wharf site mapping dive sites, and the physical condition of the environment, the presence of people and the reaction of fairy terns to them, if any was observed. Relevant results from a preliminary analysis of this work is included as appendix 1.

2.6. In addition, I have used information on population dynamics and breeding success and annual monitoring reports compiled by the rangers tasked with protecting fairy terns obtained from the Department of Conservation by an Official Information Act request. The numbers of fairy terns alive were provided by Tony Habraken who maintains a database of fairy tern sightings.

2.7. This submission is based on my wider knowledge of birds and my specific knowledge of fairy terns.

3. **THE POPULATION STATUS OF FAIRY TERNS**

3.1. New Zealand fairy terns are the probably the most threatened endemic New Zealand bird, and certainly the rarest, with a current population of just 36 living individuals (known to be alive in August 2019, Tony Habraken pers. comm.) and last breeding season only nine pairs laid eggs. Six of these pairs fed in Mangawhai Harbour and bred on the sand spit. Department of Conservation records over the last ten years (2010-2019) show an average of 52% of the breeding pairs of fairy terns have nested at Mangawhai showing the extreme importance of this site for the species.

3.2. New Zealand fairy terns have been monitored and managed fairly intensively by the Department of Conservation and volunteers since 1983. The breeding population appears to have been as low as 1-3 pairs before this work began. The initial response was exponential growth subsequent growth has been slower (Ferreira et al 2005).

3.3. In recent years the population has usually been between 35 and 40 birds (figure 1). The apparent stability of this population is actually a balance between periods of loss and recovery and every dip in numbers carries a story.

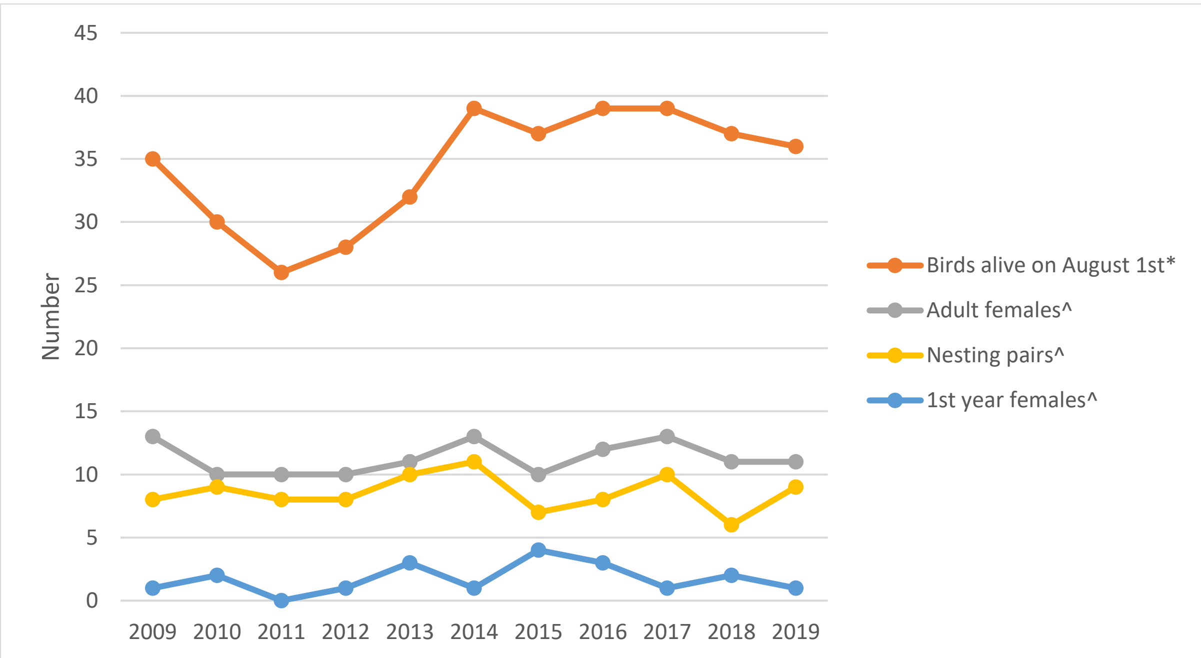

Figure 1. The total numbers of fairy terns alive from 2009 to 2019. The total number of birds alive on August is calculated by Tony Habraken from sightings of individually colour banded birds around the start of the breeding season. The other trends are taken from Department of Conservation ranger's reports and my own fieldwork.

3.4 Department of Conservation rangers' reports show that a difficulty in controlling cats at Waipu during the three breeding seasons starting 2008-10 lead to the deaths of a number of adult females (one confirmed, three suspected) and no chicks being produced there. The replacement of these birds was slow and it was not until 2014 that the population had recovered to its previous level. A severe storm in early 2015 killed two productive adult females and a number of almost fledged chicks but the population recovered in a year.

3.5 There is currently a heavily male biased sex ratio and the only pool of replacement females available are the young birds about to mature. This means that after the January 2015 storm four young females were available to replace losses by 2016 while the Waipu cat incident took six years from the start to the recovery (figure 1) and even now, there are fewer breeding pairs present at Waipu than there were prior to this incident. Recovery from such losses is possible only with good breeding productivity but it does mean that for a time population increase is stalled as such productivity cannot also go into population growth and range expansion.

3.6 Active management by the Department of Conservation and community groups has been improving. Predation by cats, ferrets and stoats is seldom recorded now and it is particularly notable that more nests are successful and result in fledged chicks since a specialist trapper was employed at Mangawhai in 2012 (figure 2). In the 2013-14 breeding season a record 12 chicks fledged with nine of them from Mangawhai. The following year also started very well but the deaths of three chicks within days of fledging in a severe storm meant that only five did fly from Mangawhai that season.

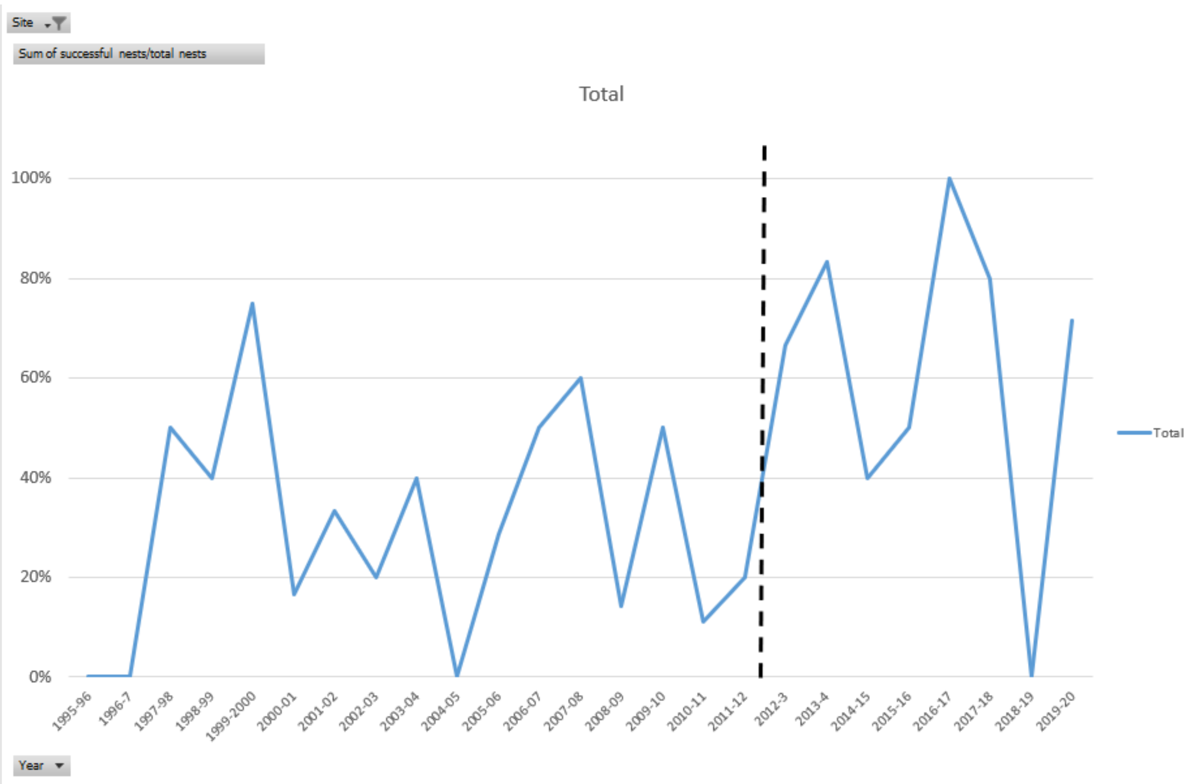

Figure 2. The ratio of successful nests to total nests laid at Mangawhai from 1995 to 2019. Note the higher nest success in most years since a specialised hunter was employed in 2012 (black dotted line). The lack of nest success in the 2018-19 season seems to have been largely due to a very stormy season.

4. The impacts of mangrove removal at Mangawhai on fairy terns.

4.1 Mangroves were cleared from a small part of Mangawhai Harbour in March 2014 and a much larger area from June to August 2015. Immediately after the more extensive mangrove removal on Sand Island and near Insley Street in Mangawhai Harbour in 2015, it had become noticeable to people monitoring Fairy Terns that fewer eggs were being laid and nests, when lost, were seldom replaced as they had been in previous years.

4.2 Breeding data collected by the Department of Conservation as part of their management of New Zealand fairy terns was obtained by an Official Information Act request and it contains comprehensive data back to about 1998 and less complete data extending further back. The information for 25 years was examined here, the five breeding seasons since mangrove removal and 20 before. Suspicious entries were examined and sometimes changed after reference to the contemporary ranger's reports but not all of these were available. Discrepancies were so few, however, that I consider any that were not found would not impact the conclusions drawn from the data.

4.3 The data was divided into four categories – Mangawhai post mangrove removal (2015-19), Mangawhai pre mangrove removal (1997-2014), all other sites combined post mangrove removal at Mangawhai (2015-19) and all other sites pre mangrove removal (1997-2014). The choice of these time periods is justified by the changes shown in figure 3.

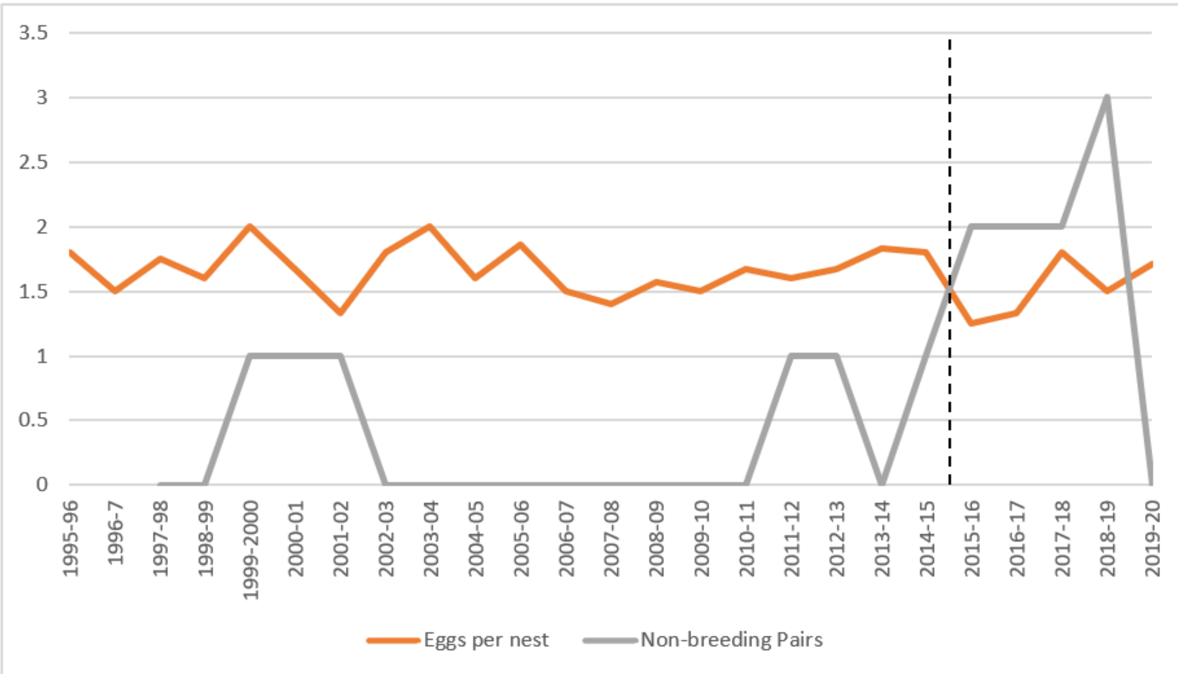

Figure 3. Two indicators of changes in reproductive performance of fairy terns at Mangawhai showing the drop in clutch size from 2015, with an apparent recovery, and the increase in the number of non-breeding pairs that hold feeding territories on the harbour but do not lay. The dotted line shows the timing of the largest areas of mangrove removal.

4.4 Comparing productivity at Mangawhai before and after mangrove removal (table 1) shows some important changes. There has been an increase in the number of pairs present yet, at the same time, the number of those pairs that did not actually breed more than tripled so the net effect is that numbers of breeding pairs remained similar. Each breeding pair also lays fewer nests each season but a small decline in average clutch size is not statistically significant until the comparison is reduced to first clutches only. When fairy terns replace lost clutches, the final clutches are often smaller than first clutches. The number of chicks fledged by each successful pair has fallen a little, but not significantly.

	Number of pairs	Number of breeding pairs	Proportion of pairs that did not breed	Number of nests per breeding pair	Clutch size - all nests	First clutch size only	Number of chicks fledged per year
Mangawhai 2015-2019	6.4 +/- 1.14 n = 5 (5-8)	4.6 +/- 1.14 n = 5 (3-6)	0.28+/- 0.16 n = 5 0-0.40	1.14 +/- 0.35 n = 22 (1-2)	1.56 +/- 0.51 n = 25 (1-2)	1.50 +/- 0.51 n = 22 (1-2)	2.8 +/- 1.92 n = 5 (0-5)
Other sites 2015-2019	4.8 +/- 0.84 n = 5 (3-5)	4.2 +/- 0.83 n = 5 (3-5)	0.11 +/- 0.18 n = 5 (0-0.4)	1.85 +/- 0.67 n = 19 (1-3)	1.77 +/- 0.43 n = 35 (1-2)	1.83 +/- 0.38 n = 18 (1-2)	2.0 +/- 1.92 n =5 (2-2)
Mangawhai 1997-2014	4.4+/- 1.20 N= 18 (3-8)	4.1 +/- 1.21 n = 18 (3-7)	0.08 +/- 0.11 N= 18 (0-0.25)	1.50 +/- 0.67 n = 78 (1-4)	1.68 +/- 0.47 n = 111 (1-2)	1.72 +/- 0.45 n = 74 (1-2)	3.4 +/- 2.45 n = 18 (0-11)
Other sites 1997-2014	5.4 +/- 1.34 N=18 (3-7)	5.1 +/- 1.21 n = 18 (3-7)	0.06 +/- 0.12 N= 18 (0-0.43)	1.45 +/- 0.65 n = 96 (1-3)	1.75 +/-0.44 n = 139 (1-2)	1.77 +/- 0.43 n = 90 (1-2)	2.7 +/- 1.19 n = 18 (0-4)
Mangawhai c.f. Other sites 2015-19	P = 0.018	P = 0.273	P = 0.080	P < 0.001	P = 0.048	P = 0.012	P = 0.202
Mangawhai 2015-19 c.f. 1997-2014	P = 0.006	P = 0.192	P = 0.023	P = 0.002	P = 0.158	P = 0.041	P = 0.293
Other sites 2105-2019 c.f.1997-2014	P = 0.108	P = 0.051	P = 0.269	P = 0.007	P = 0.405	P = 0.285	P = 0.015
Mangawhai vs Other sites 1997-2014	P = 0.008	P = 0.009	P = 0.325	P = 0.468	P = 0.094	P = 0.234	P = 0.136

Table 1. Numbers of eggs laid by New Zealand Fairy Tern comparing Mangawhai before and after mangrove removal and other sites combined during the same time periods. The numbers given are the average +/- standard deviation, sample size (n) and range in brackets. There is variation in sample sizes because some pairs lay third, even fourth, clutches and occasionally pairs or females move between clutches and breed at two sites.

4.5 Comparing Mangawhai after mangrove removal with the other breeding sites over the same time period (table 1) gives similar results to the before and after comparison for Mangawhai but the differences in the proportion of non-breeding pairs is less marked. The productivity of breeding birds at Mangawhai, however, is clearly lower. Again, fewer nests are laid by each breeding pair and both total clutches and first clutches are statistically smaller. In spite of this fewer chicks are fledged by pairs in other sites largely reflecting the poor productivity at Papakanui, a site exposed to extreme weather causing nest failure where only one chick was reared over the five breeding seasons. At both Pakiri and Waipu, there was a higher success rate.

4.6 Prior to mangrove removal the only significant difference between the sites was the number of pairs present. Breeding performance appears to have been similar.

4.7 It is noticeable that at Mangawhai after mangrove removal there were two years of particularly poor average clutch size followed by an improvement from 2017 (figure 3). This suggests that foraging conditions were particularly harsh for the two seasons immediately following mangrove removal but there appears to have been some subsequent recovery.

4.8 For the first two years after mangrove removal clutch size declined markedly but since the 2017-18 season it has improved (figure 3) so the overall difference is not statistically significant (table 1). This is, however, not actually a recovery as egg fertility has declined. Egg fertility of fairy terns due to an altered environment is difficult to address as in recent years there have been three congenitally infertile males in the population, whole clutches are lost to predators and storms or abandoned. To address this question I have made the assumption that if one egg is able to hatch, the other would have hatched too unless the embryo failed to form or died prior to hatching. I then looked only at the subset of clutches where two eggs were laid. This shows that of 28 clutches laid from 1995 to 2014 88% of eggs hatched while from 2015 to 2019 from 10 clutches, only 60% of eggs hatched and this difference is fairly large and statistically significant ($P = 0.001$).

4.9 Mainly assessed using data collected before mangrove removal, the average annual mortality for the whole fairy tern population has been assessed at 6.4 birds dying per year, 3.1 birds less than two years old and 3.3 adults (Maloney et al 2017). Therefore, this is the minimum necessary number of fledglings required each year, on average, just to maintain a stable adult population and gives conservation managers a clear target to aim for. Since 2015 this target of 6.4 fledglings has been exceeded only once, in the 2019-20 season when seven were produced. The figure has been as low as just two in 2018-19 and averages 4.6 birds, well short of this target. This is why the fairy tern population is now in decline.

4.10 The successful predator control campaign continued throughout the post mangrove removal period although it was only in operation for 3 years of the previous 20 year period and this probably reduces the differences that appear to be due to mangrove removal.

4.11 Monitoring of neither mangrove removal nor fairy terns was designed to assess the effects of one on the other but there has been change with these three notable properties –

i. the timing is exact,
ii. it occurred only at Mangawhai and,
iii. Lundquist et al (2017) note a few years of particularly increased impacts immediately after mangrove removal which appear to coincide with particularly low average clutch sizes for the first two years.

These three factors suggest to me the coincidence may have an element of cause and effect. Any causal mechanism cannot be identified with certainty at present as appropriate work has not been carried out but it is obvious that fairy terns are not entering the mangroves and that the effects are harbour wide so there appears to have been a whole ecosystem impact of some kind.

4.12 In response to Dr McDermott's suggestion that the carrying capacity of Mangawhai Harbour may have been reached or exceeded the 2014-5 season needs also to be considered. Although there was severe storm related mortality the seven breeding pairs present raised eight chicks to banding age, the point from which successful fledging can usually be expected. The previous season five breeding pairs fledged nine chicks. Both of these seasons had the same effective predator control that has been carried out since mangrove removal but the productivity for each pair was greater than it is now simply because more fertile eggs were laid. Current clutch sizes cannot allow these high numbers to be reached even though there have been seasons when every fertile egg laid has resulted in a chick fledging since 2015.

4.13 Achieving carrying capacity without impaired fertility would probably bring about much needed range expansion but that is unlikely while the production of new females can't keep pace with mortality. I don't consider that poor breeding success can be regarded as clear evidence that carrying capacity has been exceeded.

4.14 Dr Craig's speculation that pairs of fairy terns that do not breed might be inexperienced birds is partly true. Of the five different females involved three of them had indeed never bred but two had already raised chicks before skipping a season and this, to my knowledge, is unprecedented. In fact, second year females also may breed successfully, especially when mated to experienced males as some of those birds were.

4.15 In response to points made by Dr Craig I reconsidered the increase in the number of pairs present at Mangawhai between the two time periods and now consider that this is largely a legacy issue rather than a case of attraction to a poor site. By 2014 there were seven breeding pairs present at Mangawhai and another pair that did not breed, a sharp rise that is made less apparent here by the use of averages. Four females have recruited into the Mangawhai population since 2015 to largely maintain the number of pairs present but not all of them breed every year. Last season there were six paired females at Mangawhai and this is a nett loss of only one pair rather than a gain.

A closer examination of potential and actual recruitment in relation to survival suggests that the lower number of breeding pairs at Waipu may also better be related to survival than recruitment.

4.16 From 2015 onward eight new females have entered the population but not at an even rate. In 2015 there was a pair and two single males at Waipu but no breeding age females were available. In 2016, of three recruiting females, one went to Waipu and paired with a young male. They did not breed until the following season but both birds in the pair then appear to have died due to a poisoning incident. In 2017 there was one single male but the one new female available recruited to Mangawhai. That single male was replaced by a younger male in 2018 but again the two recruiting females chose partners at Mangawhai. This young male paired with a second year female in 2019 but did not breed but may in 2020.

4.17 The scarcity of females means that replacement of breeding pairs is not guaranteed or necessarily quick but at Waipu it has occurred about as fast as can reasonably be expected. The potential numbers present are so small that the early death of a breeding female likely due to a pollution incident has prevented effective increase there.

4.18 Similarly, at Papakanui, one breeding recruit did survive the winter after her first breeding season and the two established breeding females died in the 2018 – 19 season. The young female that settled there last season, one of two available, did not breed but may in 2020.

4.19 In contrast all of the four young females that have settled at Mangawhai over this time period have survived and there have been only two deaths of established females, one of them after emigration from the site. Simply counting up pairs does not give sufficient insight into the processes that determine how many there are. The differences between sites are more due to survival than site choice.

5. Food

5.1 In the past the productivity of fairy terns has not been impacted in such an enduring way and their recovery was able to begin as soon as the mortality issue resolved. That is no longer the case.

5.2 The fundamental problem associated with mangrove removal has not been identified but reduced breeding success in similar species small terns overseas shows that similar patterns can be caused by food shortage and productivity can improve when food supply improves. Nesting colonies of Little Terns (*Sternula albifrons*) typically form near good food resources but when the food fails there can be severe nest failure (Perrow et al 2011). When there are poor food supplies for breeding Least Terns (*S. antillarum*) clutch size is reduced, chicks grow to smaller sizes at fledging, eggs are abandoned more often and non-predator related mortality is higher (Atwood and Kelly 1984). Conversely when food supplies and quality are good (Elliot et al 2007 in Burton and Terill 2012, Reinsche et al 2012) clutch sizes increase, hatching success of eggs increases, fledging success improves and generally the breeding season is shorter, presumably because more first clutches are successful.

5.3 The distance between the nest and food constrains the range of any feeding bird and terns are no exception. They are particularly limited by the fact that they usually carry only one fish at a time and cannot regurgitate a bulk load. Looking at similar species of small terns, over a number of studies the mean distance from the nest that Little Terns foraged was 2.1 km, and mean extreme distance was 6.3 km with an absolute maximum of 11 km (Eglinton and Perrow 2014). Most Least Terns (*Sternula antillarum*) forage within 4km of the nest (Atwood and Minsky 1983) but may travel over 10 km for particularly good fishing (Ehrler et al 2006, Sherfy et al 2012). Radio tagged Australian Fairy Terns in one colony were never found more than 100m from their nests and at another did not travel more than 2km (Paton and Rogers 2009). At Mangawhai the greatest distance between an active feeding territory and nest was about 3.5 km so they seem to be a typical small tern in this respect. These records and the regular use of an even more distant feeding territory south of the Riverside Motorcamp show that fairy terns using the proposed wharf site are unlikely to be anywhere near the limits of their range.

5.4 A small effective feeding range requires some care must be taken to select a nesting site close enough to foraging sites that will provide food reliably for the duration of nesting. When the food of breeding small terns has been studied colonies are often positioned near sites with the predictable occurrence of specific fish species which become dietary staples, sometimes only one fish species. There may be a strictly limited seasonal window of opportunity when suitably sized fish are sufficiently available as they often seem tied into spawning events. Little Terns in England nested while juvenile herring (*Clupea harengus*) were present at a discrete spawning sites until they dispersed leaving food more difficult to find for late and re-nesting birds (Perrow et al 2006). Similarly, harbours in California and Mexico are a nursery for young silversides (*Atherina spp.*) and Least Terns hatch their chicks when peak numbers of these fish occur but colonies dispersed rapidly as fish numbers declined (Ehrler et al 2006, Zuria and Mellinck 2005).

5.5 Observations of food fed to fairy tern chicks at Mangawhai (Parrish and Pulham 1995) and stable isotope signatures also from Mangawhai (Ismar et al 2014) showed that gobies (*Favonogobius spp.*) form the bulk of the prey of fairy terns at Mangawhai during the breeding season.

5.6 Samples of fish taken as part of a foraging and habitat study for fairy terns from the mid to lower Mangawhai Harbour during the 2010-11 fairy tern breeding season showed gobies to be the most common species present comprising 92.8% of the catch (Ismar et al 2014). Newly settled gobies were caught only during January and only at mid-harbour sites. Lower harbour sites were characterised by having fewer but larger gobies than upper harbour sites. This was considered consistent with the settlement of gobies in the mid-harbour with some washed down stream before they are large enough to resist the current (Ismar et al 2014).

5.7 With the help of other NZFTCT members small bottom dwelling fish were monitored in Mangawhai Harbour from October 2017 to January 2020. We fished at four sites (figure 4) to cover most of the range where fairy terns fed. Sites D, E and G are the same sites fished by Ismar et al 2014 and have the same names but site K is new. We sampled three breeding seasons and covered most of the winter months as well. Samples were taken with a 5m small meshed beach seine net that was good for sampling bottom dwelling fish like gobies and small flounders but free-swimming fish were seldom caught.

Figure 4. Sites where fish were sampled at Mangawhai Harbour.

5.8 We caught 23 fish species overall but many of them just once or a few times. The majority of fish sampled are gobies (48,603, 97.5% of all fish caught). They were almost entirely Estuarine Goby (*Favonogobius lentiginosus)* with small numbers of Exquisite Gobies (*F. exquisitus*). We did not distinguish the species but measured 32,307 gobies. The next most common group, flounders (*Rhombosolea spp.*), were much less frequent (648, 1.3% of all fish caught).

5.9 This analysis focuses on gobies which are the staple in the fairy tern diet over the breeding season (Ismar et al 2014). There is one size class of gobies present except for December when the young fish first begin to settle to February when the last large gobies are present. The two size classes were separated out by size and analysed as year cohorts over the 15 months they were sampled beginning with month 0 being previous December when the first newly settled gobies were caught and months 13 and 14 representing the large gobies in the following January and February.

5.10 In summer and autumn there was a tendency for more fish to be caught in the upper harbour sites but numbers fell rapidly during early winter and by spring until they are very roughly similar in abundance and size at all sites but one (figures 5 & 6). Site G in the lower harbour has fewer but larger fish in most months and particularly stands out with much smaller numbers through spring and summer, the fairy tern breeding season.

Figure 5. The average number of gobies caught each month for cohorts in a. 2018 and b.2019. The x axis is for cohort months (see text, paragraph 5.10). Corrected data used here are for July and August 2018 when a new and less efficient net was used for sampling. A correction factor was calculated from paired hauls, the data adjusted and the old net repaired and used for the remainder of the project.

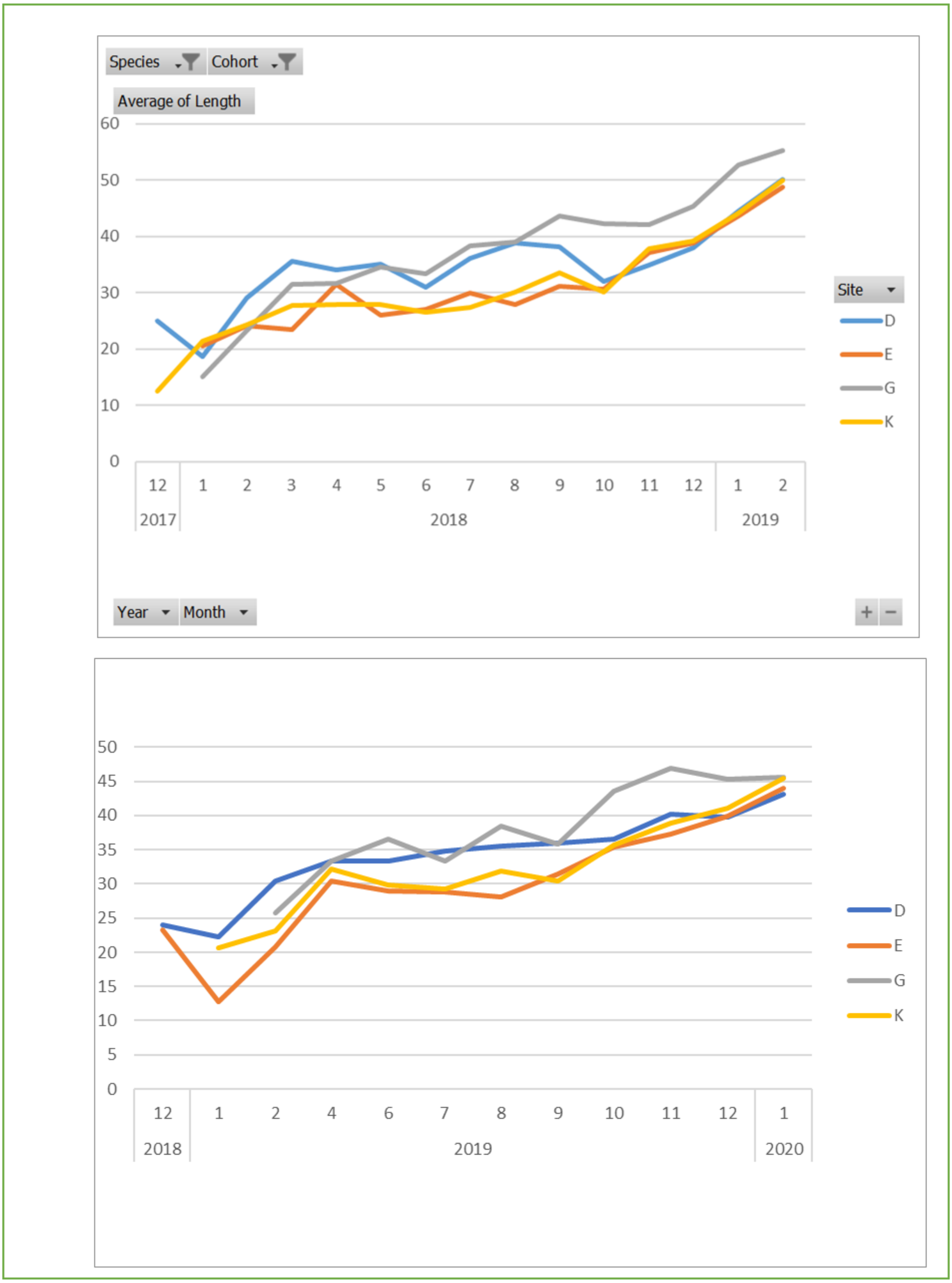

Figure 6. Average fish sizes at four sites in Mangawhai Harbour for cohorts from 2018 (upper) and 2019 (lower). Site E is less than 100m from the proposed wharf site. The x axis is calendar months and note that two months are skipped in the 2019 cohort.

5.11 Seasonal changes in the sizes of gobies shows that New Zealand fairy terns are no different to other small terns in that the life cycle of their main prey seems tailored tightly to their breeding season. As fairy terns begin to return to the harbour in June or July gobies are already well grown. By the time fairy terns are forming eggs and feeding chicks these fish have reached adult size and are coming into spawning condition. Adult gobies usually die after spawning and numbers are starting to fall away by mid-December. This is a good fit for fairy terns rearing eggs from their first clutches but it is not clear what good food sources, if any, are available for late nesting birds.

5.12 While breeding, fairy terns feed mainly on gobies which are bottom dwelling fish. The problem with being very small terns is that plunge diving cannot take them to any great depth but this becomes a virtue making it easier to fish in very shallow water. In Mangawhai Harbour the feeding methods more commonly seen are technically referred to as "dipping" where the head, or just the bill is immersed or, most commonly, "contact dipping" where the body of the bird splashes onto the surface of the water and barely disappears below the surface. At five dive sites measured in December 2019 water depths varied from 8-28 cm and averaged 17.6 cm but this limited sample probably does not give a good idea of the full range of habitats they use. Dive sites are usually close to the water's edge but sometimes over submerged sand banks. Fishing in shallow water is likely to make fairy terns particularly vulnerable to impacts from boat wakes and disturbance by people.

5.13 Fairy terns do not collect all their food from shallow water in the harbour but are also capable of taking pelagic fish from deep water. Pelagic fish from the ocean are generally better food nutritionally with a higher fat content than estuarine fish and this is presumed to be true at Mangawhai too. My limited observations of feeding chicks in the nest suggest that when fish are available at sea, fairy terns fish there fairly intensively and return frequently from the sea to the nest with food. In Mangawhai Harbour, especially at low tide the fish are available and usually there is somewhere sheltered so they are able to catch them on all but the with windiest days. Gobies are by far the most common fish fed to chicks with a minor component of flounder and even fewer other species. Shrimps are sometimes said to be eaten but I cannot personally confirm that at present.

6. Feeding territories

6.1 Fairy terns divide Mangawhai Harbour into feeding territories in the same way that people divide a town into sections. There may be no fences but the lines are clearly drawn and recognised, do not vary within a season and are very similar from year to year.

6.2 Major change has only been seen when a male holding a territory dies. Under these circumstances a territory may be split between two males, sometimes both are new and the territory number increases and sometimes adjacent males enlarge their territories. Once I saw a territory boundary across an obviously favoured fishing site and there was increased chasing there and some trespassing but the actual boundary was fiercely defended and did not change.

6.3 The one time I did see a boundary change during the breeding season a young male carved off a very small territory (about 50m long) from an incumbent territory holder after the chicks of that pair had hatched and more time was required to gather food. In this case the change was not permanent and the boundaries returned to normal the following season.

Each particular territory is defended in low key ways with birds sometimes fishing and roosting conspicuously near the boundary or calling loudly while they fish elsewhere. More energetic defence involves quite a lot of chasing, some of it involving ritualised display components, until the intruder leaves the area. Chasing is usually brief but sometimes there are aerial fights that last for tens of minutes.

6.2 When members of pairs fish in the harbour their fishing activity is almost entirely confined to their feeding territory. Occasionally there is trespassing, but when spotted, the resident males respond immediately to expel the intruder with intense chasing. Within a feeding territory there are often one or a few preferred feeding sites, often at channel confluences, shallow bays and channels. When chicks are able to fly well enough, they move to the food sources to reduce the time and effort their parents spend commuting. Newly flying chicks often come to the harbour, sit in the feeding territory and get fed but also begin to practise fishing by picking up twigs and weed from the water's surface there.

6.3 Feeding territories also serve another important purpose. Fairy terns roost on the sandbanks not only to rest and preen but an important part of their mating activity takes place there too. The currency of mating fairy terns is fish. Although females seem to judge the quality of their mates in other ways, the ability of a male to provide food is clearly important.

6.4 At the start of the breeding season, usually by June or July, birds start appearing on the harbours and estuaries adjacent to their breeding sites. Unpaired males do their best to claim and defend a feeding territory and unpaired females come to check them out. Males may try to attract females down with ritualised display flights, either a "low flight" carrying a fish, or a more ritualised (and spectacular) "high flight". Females are allowed to fish in the male's territory and, as the relationship develops, he will begin to bring her fish and feed her, again with a ritualised element that tests the male's ability to provide. This is courtship feeding and is often called "fish feeding" by local observers.

6.5 As the eggs develop inside the female, she stops fishing for herself, presumably losing the agility required as the load increases. At this time the male supplies all of her food until the eggs are laid so the ability for him to fish well is important. Especially when hungry, she may follow the male as he fishes but at this time but her chosen spots to wait are usually close to good sources of food. The female that was observed near the propose wharf site (appendix 1, paragraph 20) did not fish for 4-7 days before laying and it is not clear how frequent or effectively she fished in the days before this.

6.4 All of Mangawhai Harbour up to the causeways and a distance above the Insley Street causeway is divided into feeding territories (figure 7). If any part of the harbour is made unavailable for feeding or roosting, the impact will fall solely on the particular fairy terns that use that part of the harbour. Other fairy terns will not adjust their territory boundaries to compensate.

6.5 When fairy terns are forced into a neighbouring territory I expect to see prolonged intensive chasing. On 20/12/16 I saw this happen when a pair was displaced by people vigorously exercising horses in the area they normally roosted. I recorded a long intense aerial chase followed by the males sitting about 20m apart flying off in opposite directions. This behaviour could escalate further. On 17/1/1998 after aerial chasing, two fairy terns were observed fighting on the ground. One birds had wrestled the other onto its back and they were "knocking beaks" before they broke apart and one flew off (Hansen 1998). I suspect these incidents may be lethal at times.

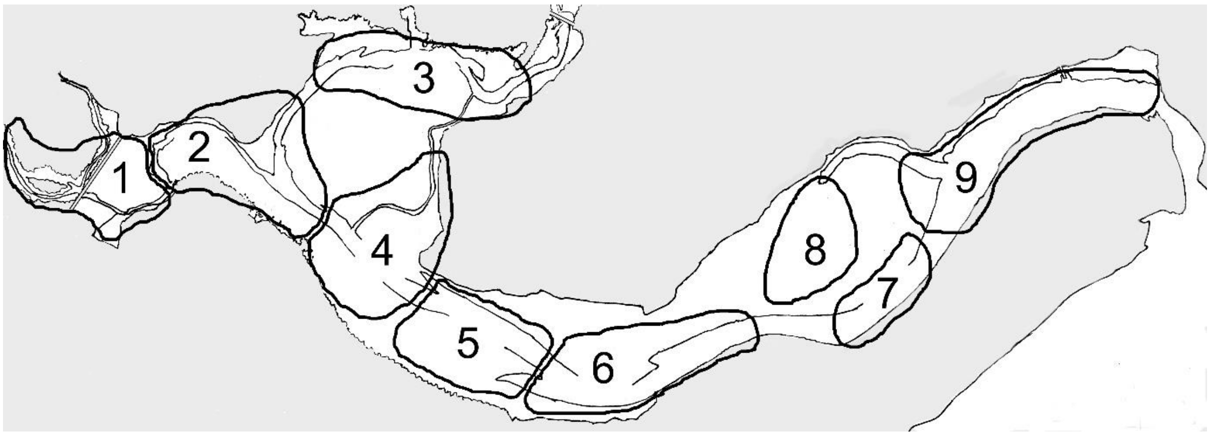

Figure 7. A map of the feeding territories of fairy terns in Mangawhai Harbour for the 2018-19 breeding season. Most territories were held by pairs but territory 4 was held by a single male and the male in territory 7 was seldom seen so this may have been a marginal territory, as the fishing seems to be poor. The proposed wharf site is within territory 2.

HUMAN DISTURBANCE ISSUES

7.1 The elephant in the fairy tern management room is the issue of human disturbance. To feed in Mangawhai Harbour fairy terns need to find their way around people, sometimes many people. Disturbance issues have not been studied for this species at all but the principle of the issue is simple. When they get too close, people chase birds away (e.g. figure 8), even before this happens birds are forced to stop what they are doing to focus on the threat. When they can quickly find a site to resume that activity there is probably no real impact at all but to some extent it takes up time and energy. Potentially the time taken for birds to settle down and resume feeding, perhaps in sub-optimal sites, can impose a large energetic cost. In essence disturbance can be a form of habitat degradation or loss that can occur even when the habitat seems ideal as it can prevent access to key resources.

7.2 The human disturbance issue is well studied, especially in Europe and North America but not so well known in New Zealand. Fairy terns are fairly tolerant of disturbance. Like some other New Zealand native species they seem relatively comfortable around people and this is probably important in understanding why there are still any left in Northland at all.

Figure 8. Even sedate behaviour chases feeding birds away. Godwits fleeing a walker, Variable Oystercatchers standing their ground but on alert. Out from Lincoln Street 12/1/18.

7.3 The problem will be the density of people. If a person is standing still fairy terns might fish up to about 10 or 15 m away at which point they move away or divert around them and resume fishing. Other work suggests that if people are moving or loud the exclusion distance will become greater and the presence of dogs, especially unleashed dogs will make it greater again. The issue of concern is that many people could lock fairy terns out of significant areas of habitat for long periods of time.

8. BOAT WAKES

8.1 Having observed boat wakes on Mangawhai Harbour I have noticed that they differ from those waves naturally generated by wind. As they reach the shore boat wakes, although small, curl and dump with some force on the shoreline (figure 9). They are capable of stirring sediment and muddying the water. This happens two ways: before the waves break they seem to lift sediment off the bottom in shallow water and as they break they definitely stir up any sediment on the shore line.

8.2 A few observations of boat wakes made near the site of the proposed wharf show how this might happen. On 13/11/19 I watched a small boat travelling slowly to the dredge. The wake, 2-3mm high arrived on the shore a few minutes after the boat passed and stirred up sediment at the water's edge. A minute later there was discolouration of the water out to 4m from shore and 6m out two minutes later but it diffused and settled two more minutes later. 9/1/20 a faster jet ski 100m offshore raised waves of 60mm high that lifted a cloud of sediment drifting about 5m out and lasting for 5 minutes before beginning to dissipate. The same day a very slow runabout travelling at walking speed raised no wake and disturbed no sediment at all.

8.3 One concern here is that fairy terns may not be able to see their prey after boats pass and if the number of boats increases beyond a point, the problem may become adverse. When boats travel very slowly such waves do not form and there is a speed limit of five knots in the harbour. I am not able to judge boat speed but some of these wakes were generated by boats in the vicinity of the proposed wharf site and they may well have been travelling within the speed limit although others clearly were not.

Figure 9. These small but powerful dumping waves are the wake from a speed boat towing a water skier in the ski lane on Mangawhai Harbour on January 12th 2018.

8.4 The impact of wakes on gobies and juvenile flounders is not known to me but they cause a severe disturbance in the very shallow water where fairy terns catch them. It is possible that boat wakes may cause these fish to move to deeper water, or even elsewhere in the harbour and that this would make them unavailable to fairy terns. I have seen natural waves pushed by strong winds that have overturned numbers of starfish at the water's edge so it seems reasonable to expect some impact on shallow water fauna from the more turbulent boat wakes.

8.5 The only real example of a site with increased boat traffic available to study is the ski lane where there is frequent passage of boats but fairy terns seldom feed there (figure 10). This site is also severely compromised by the dredging that takes place there and this may actually be an even bigger issue but the potential ecological problems for fairy terns at Mangawhai that could be caused by boat wakes need to be understood.

Figure 10. Individual dive sites of fairy terns in Mangawhai Harbour (taken from Ismar et al 2014) with blue circle added to show the ski lane.

9.0 Particular impacts near the site of the proposed wharf.

9.1 Being aware that a resource consent application would be forthcoming coming for the proposed wharf the New Zealand Fairy Tern Charitable Trust collected information on how the pair of fairy terns that defended the site used the area around it. I carried out the majority of the field work and also a preliminary analysis of the data. This discussion is based on appendix 1.

9.2 The particular male fairy tern that has controlled territory 2 (figure 7) recently is known as Metal - Red from the coloured leg bands we use to identify him. Metal – Red has been one of the more productive males on Mangawhai Harbour since mangrove removal in 2015 rearing three chicks to independence in those five seasons. It may not seem much but it is 20% of the production from the entire harbour over that time period and only one other male has exceeded this. He has managed to control this area since the 2015-6 breeding season apart from a slight shrinkage at the southern end. A common roosting spot is on the delta where channels from the two arms of the harbour meet and also just across the channel to the north. This places them within 150m of the proposed wharf. Most of their courtship and mating takes place there too.

9.3 The activities of people are not expected to be confined to the wharf. As it is intended to be functional it seems reasonable to expect an increase in boat traffic that may extend all the way to the main boat ramp near the entrance and also for more people to walk on the sandflats adjacent to the site and probably also to wade across the shallow channel to the east at low tide. The northern shore is also accessible by wading but boats will make that more feasible. This whole area is considered to be at risk if the wharf development goes ahead.

9.4 We found that the requirements of fairy terns from their feeding territory changed markedly during the part of the breeding we observed. Before the eggs were laid both birds were present and roosting behaviour was often recorded. The female became increasingly dependent on the male to provide food and it was also a venue for courtship and mating behaviour. Sites where courtship feeding took place were mapped and appear to show that the area most used by people for recreational activity was surprisingly seldom used for this purpose.

9.5 While the eggs were being incubated less time was spent at roost and fishing was particularly active as the tide fell and, to a lesser extent, as it rose. During the chick rearing phase fairy terns were even less often present on their territory but fished with increased intensity over all parts of the tide suggesting that demand for food was higher.

9.6 About 15% of all fishing dives took place in the channel to either side of the proposed wharf. The shallow channel to the east was much more important accounting for 49% of all dives, a further 19.5% of dives took place at the southern end, and the remaining 16% in the north-eastern channel. The channel near the wharf became most important near mid-tide with 26% of recorded dives and the channel to the east at low tide with 65%.

9.7 Wind direction had little effect at slow wind speeds but became important as it increased with fairy terns obviously avoiding the turbulent water where ripples and waves broke. The area immediately around the wharf was particularly heavily fished during south-westerly winds. Of all dives recorded during stronger south-westerlies 27% of dives were made there. Shelter from the escarpment and trees probably were important in allowing fairy terns to fish under those conditions. Mangroves appear to have provided good shelter from south east winds in the channel to the east of the delta and the loss of mangroves from the southern end of this feeding territory may have reduced foraging options in some weather conditions.

9.8 Observers recorded 101 potential disturbance events involving people and another that was a stray dog. Mostly the site was used for walking near low tide, with or without dogs or horses. Most events involved dogs (42 incidents). Five times (12%) dogs obviously disturbed fairy tern behaviour. There were 24 incidents involving various boats and twice fairy terns were disturbed by kayakers (20% of kayak observations). The only other disturbance event was from one of two aircraft that flew overhead.

9.9 When disturbed fairy terns typically moved to another part of their territory and resumed their activity so these disturbance events could not be considered more than minor. When we compared the amount of time people and fairy terns were on the harbour separately and together there was no evidence of any interaction, positive or negative and this fits with the behavioural observations.

9.9 For one brief time period there may have been a negative interaction between the recreational use of this feeding territory by people and the fairy terns that defended it leading to a 50% reduction in the time spent fishing and no roosting compared to the time periods immediately before and after.

9.10 The study does bring up some important points but it is complex and multi stranded so many questions can be raised as plausible but not answered with certainty by quick simple analyses like this one.

i. We can show that use of the feeding territory varies with tide, wind speed and direction and a range of sites across it are required for food security during adverse weather. Most wind speeds and directions are not well covered in the data set so far.
ii. Although based on few data the disturbance impacts of boats, possibly especially kayaks, and dogs need to be clarified as they may be large enough to have a negative impact.

iii. Normal recreational behaviour does not appear to create a disturbance issue but intense recreational use may. One incident suggests that a plausible increase in recreational use could compromise the ability of fairy terns to feed and this may be most important during December and January when they are feeding chicks.

9.11 Birds can accommodate human disturbance in several ways.

i. With fairy terns the obvious one is increased habituation to people. Dr Craig has suggested that this allow fairy terns to adjust to any adverse impacts that may be caused by the wharf. Fairy terns are already much more tolerant of people than many other birds are. We encourage this by making careful approaches to birds during monitoring and avoiding flushing the birds whenever possible. I do not question whether or not habituation takes place but whether there is any scope left for it to increase much further.
ii. Another obvious one is to time their activity to times when people are not present. There were fewer potential disturbance events near mid-tide when most fishing activity took place. This may not be a specific response people but it means that there is less scope for flexibility in future.
iii. They can also move their activity to parts of their feeding territory where people are not present and this was also observed during this study. This assumes that there is no impact from the forced move.

9.12 I think it important to realise that at most times fairy terns routinely accommodate human disturbance. There may be scope for more tolerance in several ways but the mechanisms available to do this are already in use so that scope is probably limited.

9.13 There is a suggestion that the bounds of this tolerance may already be exceeded at times so I recommend further work to understand the relationship between fairy terns and people that is capable of modelling the impact of further increases in recreational use of this part of the harbour. On fairy terns. I recognise that my own work does not do this but I note that some of Dr Craig's comments suggest that he might be able to do better.

10.0 Commentary on Dr Craig's evidence.

10.1 My evidence was not initially put forward as expert evidence so some of the points raised have already seen comment. I have included those parts of my withdrawn submissions to keep a record of the evidence which appears no longer to be in dispute.

10.2 It is good to see that the submitters are now better informed and argument has moved on from their initial dismissal of the importance of the site for fairy terns as being too far from the sand spit, without enough food and being poor habitat. It also seems to be accepted that fairy terns defend feeding territories

10.3 The plans for the pontoon at the end of the wharf show that it is intended to physically cover part of the channel where fairy terns have actually been observed to dive so this matter should not be under dispute.

10.4 We also disagree on whether or not feeding territory boundaries will adjust readily to permanent displacement of birds. He seems to expect a degree of flexibility in territory boundaries that I find unlikely based on my field experience.

10.5 The important points of dispute with Dr Craig that are relevant to building the proposed wharf now seem to be mainly about human disturbance impacts and this is a much more appropriate subject.

10.6 Dr Craig and I seem to have different expectations about the degree that activities of people, attracted to the wharf as intended, will be confined to the wharf or spread into the surrounding channels and sand flats.

10.7 Dr Craig's main thesis seems to be that fairy terns will habituate to disturbance and accommodate the change without adverse effects - "most animals do habituate to nonthreatening stimuli so it appears their "evidence" is just an expression of a concern which lacks support." I too am aware of native birds, including threatened species, living in a human environment, close to roads, paths and on built structures. I think, however, that it is not reasonable to expect a working wharf to be built where there is no wharf at present and not to have it used by boats, nor do I expect the extra people that the wharf is intended to attract would not spill on to the sand flats to some degree.

10.8 Using the ski lane as an example of fairy terns accommodating human activities is, however, just plain wrong. If anything, on available evidence, it seems to be a case of fairy terns being displaced by human activities.

10.9 I am well aware of the habituation response to non-escalating stimuli in fairy terns. Not only are fairy terns tolerant of people, their habituation is encouraged by the people that monitor them by approaching closely enough to read their leg bands but trying to avoid coming so close as to flush the birds. My concern is that I don't believe that fairy terns can become much more tolerant than they are now are – that the habituation response has been pretty much used up. The statement I made was not that fairy terns have survived in Northland because there are fewer people there but that they survived because they were tolerant of people. This statement was made in recognition of the tremendous potential for human – animal conflict given the overlap in habitat preferences of breeding fairy terns and coastally recreating people in Northland.

10.10 There appears to be some confusion about the disturbance impacts of dogs. In the application it was suggested that workers building the wharf should not bring dogs on site to avoid disturbing birds. In this latest round of evidence Dr Craig suggests that birds will become habituated to dogs as well. I would also point out that the distances quoted by him in this paragraph (3.13) are not in part of any evidence I have submitted in relation to this resource consent.

10.11 At present I am agnostic on the subject of boat wakes. I note their differences from wind generated waves, that they can lift sediment off the bottom and suspend sediment from the shoreline. There is potential to reduce the feeding efficiency of fairy terns and even impact on the organisms near the waterline. I have not seen any evidence of it being an issue but as a potential adverse impact from increased boat use in the channel requires due consideration rather than dismissal, especially because it might impact most of the fairy tern feeding territories in the harbour.

10.12 The reason I regard human disturbance impacts as "the elephant in the room" is precisely because they have not been studied, they may already be occurring without our knowledge, and, given the increasing number of people that Mangawhai Harbour attracts, may become acute in the future.

10.13 The responses of fairy terns to mangrove removal are probably a secondary issue here but relevant because, if the issues involved with the wharf are not important enough to refuse this consent application they need to be considered in light of already existing impacts.

10.14 I am not an expert in statistics which is why my arguments are verbal. The statistics I do use are to give some guidance as to which numbers are worth further consideration and which are not and I think this is necessary.

10.15 That Dr Craig is purely reliant on my evidence at this point is shown by his suggestion that fairy terns feeding near mangrove removal sites should show larger effects than pairs further away. This is because I did not cover the issue in full in my earlier, and now withdrawn, submission. The interesting thing here is that the effects of mangrove removal are felt throughout the harbour and I have now provided more evidence here to clarify what has happened and why I consider mangrove removal to be the most likely cause.

10.16 A comparison I did not make is disputed. Specifically, that New Zealand Fairy Tern Trust data do not show that there are more fish at site E than elsewhere. The data were presented to outline overall seasonal changes in fish and as a response to the initial submission that suggested the area was unproductive in terms of food and show that the area is similar to three of the other four sites we monitored that also support breeding fairy terns. My earlier discussion was intended to highlight the selective use of data from Ismar et al (2014) placing weight on a small difference in fish size and ignoring large difference in fish abundance.

10.17 In his response to the Council Officer's report Dr Craig discusses the times available for construction (5.9). He notes the variations and attributes one of the dates to my evidence. I did not make such a claim, the date in question is only present in my withdrawn report as part of a quote attributed to the Bioresearches report in the original application. My own experience is that the site has been occupied by fairy terns during June and that an even more restricted time period than that proposed by the council would be appropriate. If this matter remains in dispute it seems best settled by field observations and it would be easy to do so.

11.0 Commentary on Dr McDermott's evidence.

11.1 Much of Dr McDermott's evidence is not directly relevant to the proposed wharf construction either but he does provide discussion about human pressure and boat traffic.

11.2 He suggests that there is a positive relationship the production of fledged fairy tern chicks and numbers of people. Much of the apparent increase in the fairy tern population in his graph is simply recovery from a long period of severe cat predation at Waipu. Matching patterns in short segments of data sets does not add clarity to the argument unless there is a good reason to tie them together.

11.3 He also points to an increase in boat traffic over this same period but again, we don't know where these boats go. Many will head outside the harbour and others will use the ski lane which is seldom used by fairy terns anyway. We don't yet know what the actual level of interference is and can only guess the impacts. More basic work needs to be done just to work out how important this issue really is.

11.4 In general, this kind of correlative approach will not identify any problems until some time after they have happened. Given the extreme importance of this particular fairy tern population I do not think it prudent to place them at risk on the basis of this kind of information when there is an opportunity to do better.

11.5 Using a three-year rolling mean to dampen individual events has the effect of confusing the five-year period of reduced productivity after mangrove removal with the very high productivity immediately beforehand. The rising trend line that has been fitted to the data is not at all consistent with the very few young birds available for recruitment into the breeding population. I am certainly not confident that the capacity to recover from setbacks has been maintained over the last five years.

11.6 I sympathise with Dr McDermott's comments about finding consistent data for fairy terns but I am also aware that he lacks key data required to gain understanding of the situation. This considerably reduces the value of the work he has done. He seemed also to regard undocumented phenomena as unimportant and has ignored the possibility of impacts that happen on the harbour when food is so vital for wild animals. So little research has been done on fairy terns, especially on the harbour, that I find out new things every year. At some point actual data needs to be gathered to cast light on some of these key questions rather than shrouding them in speculation.

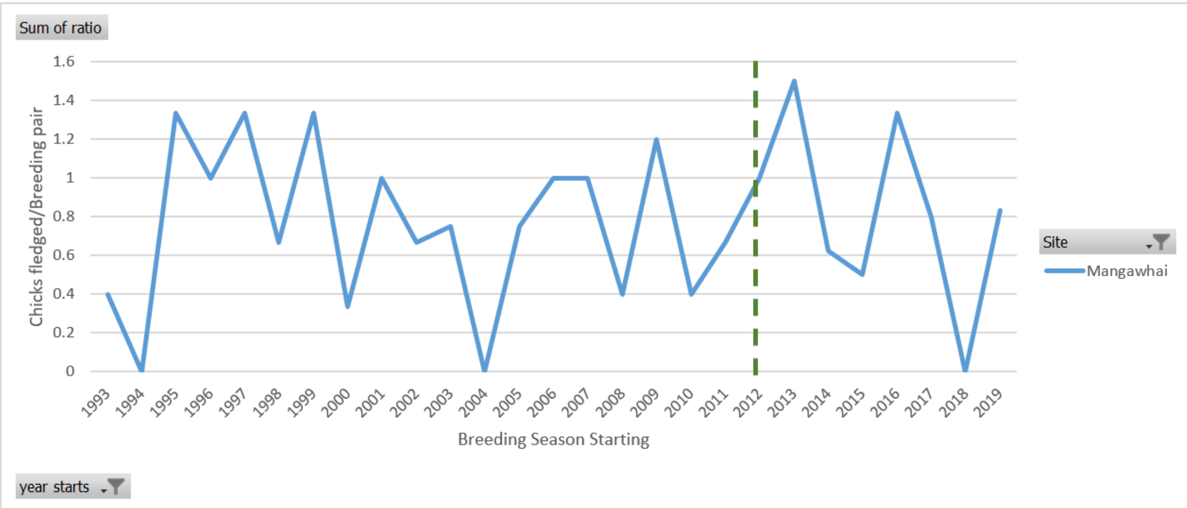

Figure 11. The number of chicks fledged at Mangawhai per breeding pair from 1993 to 2019. The dotted line at 2012 shows when the more intensive predator control began.

11.7 One key variable missing from Dr McDermott's data set was simply the number of breeding pairs. Productivity per pair (figure 11) was initially boosted after increased predator control (2013) and then reduced by storm mortality (2014). Apart from severe storm related mortality in 2018 the breeding seasons have actually been very good in terms of adverse weather and predator pressure so that most fertile eggs have resulted in chicks fledging. There is actually a declining trend in per pair productivity, however, which stems from pairs not laying eggs and fertile pairs not usually laying two fertile eggs and seldom replacing lost clutches which is a change from the period up to 2014.

11.8 This is also why the slight decline in the whole population in the last two years is concerning to me. Rather than seeing it as a small deviation from a long-term average I see it as the longer-term impact of not producing enough chicks to replace deaths in the population and expect it to continue to follow a downward trend.

11.9 I do not think this kind of analysis is helpful without a better fairy tern data set and without making some effort to gather data to ground in truth some of the connections that have been suggested but this could be done.

12. Summary

12.1 Amongst all this quibbling it is easy to lose sight of just how important the fairy terns at Mangawhai are.

12.2 As a species in New Zealand once reduced to no more than three breeding pairs, only the black robin has dipped to lower numbers and the recovery to the present level has been a long hard slog by Department of Conservation staff and members of the public.

12.3 For perspective, a well known critically threatened species in New Zealand is the kakapo. They currently have a population of 209 birds. That's about six kakapo for every fairy tern and this should perhaps give a realistic perspective of how fairy terns should be regarded.

12.4 With the largest area of breeding habitat and more than half of the breeding pairs at present Mangawhai Harbour and the sandspit are the beating heart of this species. The recent breeding statistics there show that this population is not in good health and I do not consider that the risk of further impacts should be taken lightly or allowed without evidence showing that adverse impacts will actually be avoided.

12.5 There are few similar situations on mainland New Zealand where such a concentration of such a rare species is so accessible to people. The natural breeding populations of white herons or takahe could be considered similarly restricted but both species are in sanctuaries with very restricted access. The human component in fairy tern management is a new issue for such a rare species.

12.6 My concerns are not just with harm that can reasonably expected but with risk of unknown impacts as well. If we make a mess of Mangawhai we can't shrug it off and start again somewhere else. Last year there were just two fertile breeding pairs at sites other than Mangawhai and one of these is already known to have died.

12.7 My personal opinion is that if it is a genuinely good idea to build the wharf it will still be a good idea when the appropriate work has been done but it will not be so easy to remove the wharf if it proves to be a mistake.

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Appendix 1. Fairy terns near the proposed wharf site on Mangawhai Harbour – feeding behaviour and potential human disturbance.

Ian Southey

Main conclusions

Fairy terns do use the area around the proposed wharf site for feeding, roosting, courtship and mating.

Although not particularly heavily fished in lighter winds it still accounts for 15% of fishing activity but becomes much more important (27%) in strong south west winds due to the shelter provided by the escarpment and trees on shore.

Human disturbance does affect fairy tern behaviour but it may not usually be detrimental at current levels. Observations made over a period of heavy recreational use suggest that it could, however, become a serious problem at a level that is sometimes already reached if it becomes more prevalent at this higher intensity.

Introduction

1. The New Zealand fairy tern is New Zealand's rarest bird and found nowhere else. In recent years the population has fluctuated between 35 and 40 birds and there have been about 10 breeding pairs. At their lowest ebb there were only two breeding pairs and, of all the rare birds in New Zealand, only black robins have dipped to a lower population and still recovered.
2. Other bird species restricted to such small areas at this level of threat live in protected sites and most of them have very restricted public access. Mangawhai Harbour is an exception – as well as supporting at least half of all the breeding fairy terns it is the recreational hub for a rapidly growing town and we expect there to be growing conflicts between the needs of these birds and the needs of people.
3. The esplanade by the Mangawhai Tavern and the boat ramp has long been known to be a good place to see fairy terns as they are often roosting or feeding nearby.
4. Knowing that a resource consent application to build a wharf on the site of the old wharf would be forthcoming the New Zealand Fairy Tern Charitable Trust was concerned that habitat modification and increased levels of human disturbance would be detrimental to the particular pair of fairy terns that used that area. A decision was made to collect information to show that the area was regularly used by fairy terns.

Field methods

5. From earlier territory mapping of fairy terns on Mangawhai Harbour we knew that the proposed site for the new wharf was defended by a particular fairy tern pair identified by the combination of their coloured leg bands. The male was Metal – Red (M-R) and the female Red-Black over Red (M-KR) and their territory boundaries were also known.
6. We made a detailed site map traced from a google earth image and for further precision added GPS points of small existing features such as rocks and pegs that were placed to aid more accurate mapping.
7. On copies of this map we plotted the position of every dive made by a fairy tern that broke the surface of the water and sites on the ground where courtship feeding took

place. This was to give an idea of which parts of the feeding territory were most important for the fairy terns.

8. The time of each arrival and departure from the feeding territory was noted and when changes from one of three activity types occurred. Three classes of behaviour were recorded but they did not necessarily serve a single function. The categories were “sitting” which included sleeping, preening and washing, courtship and copulation, and also territory defence when the male sat at the boundary and the neighbouring male sat nearby. “Flying” almost always meant foraging but can also be defensive as neighbouring males will fish close to each other at their boundaries. “Chasing” was unequivocal territory defence. This generated a simple activity budget showing the time the birds spent on the harbour and how activities were prioritised.
9. Notes were taken of weather conditions that might affect feeding. We developed simple semi-quantitative scales for water clarity, wave height on the harbour, the strength of waves breaking on the shore, wind speed and wind direction. Sometimes an anemometer was used to measure wind speed.
10. For most sheets the wind directions were divided into sectors centred on the eight cardinal and intercardinal compass points. In addition, on four sheets, wind was recorded as calm and no direction given. These were given a separate category.
11. Wind strength was measured with an anemometer when available, the maximum and minimum wind speed was recorded over one minute or else it was ranked by the observer. Semi-objective categories applied to waves on the harbour and wave break on the shore were also used to classify condition into strong, moderate or calm. Strong wind had a minimum wind speed greater than 15 km/h, or was described as strong, brisk or gusty, there were ripples 10-20 cm on the harbour and small waves breaking on the shore. Calm conditions were when the minimum wind speed was less than 10 km/hr, wind direction could not be determined, when the harbour surface was still or lightly rippled, up to 5cm, and when no waves were seen at the shore to small waves, not breaking. Moderate winds fell in between these categories.
12. In addition, we recorded the number of potential disturbance incidents without spatial information, just noting groups of people, their number and whether they were accompanied by dogs or horses, and air and watercraft. Times of their arrival and departure from the study site were recorded and whether there was any noticeable change in fairy tern behaviour from their presence or not.
13. For analysis the sites of dives that showed where fairy terns fish were divided into eight zones that reflect different patterns of use (figure 1). These sites are of different sizes so the length of the main channel was measured on google earth and used to standardise the number of dives.
14. Zone 1 (300m channel length) had a raised sandbank along the edge of the channel that appears as a sandspit as the tide falls. Initially there was a series of wide shallow pools and drainage channels starting above the anchored dredge and moving toward the northern groyne as the tide receded and they dry out. At dead low tide there was a small embayment near the north groyne and a pool around the groyne.
15. Zone 2 (250m) had a straight edge, and lacked puddles, channels or sandbanks. The bottom was mostly a hard sandstone pan.
16. Zone 3 (200) started at an oyster bed just west of the south groyne and ran to the tip of the delta. Apart from pools around the south groyne it was a fairly simple shore line with no major pools or channels.
17. Zone 4 (300m) had a high sand bank on the shore at low tide and no pools or channels.

18. Zone 5 (230m) had a mangrove lined shore with an even gradient and a simple edge

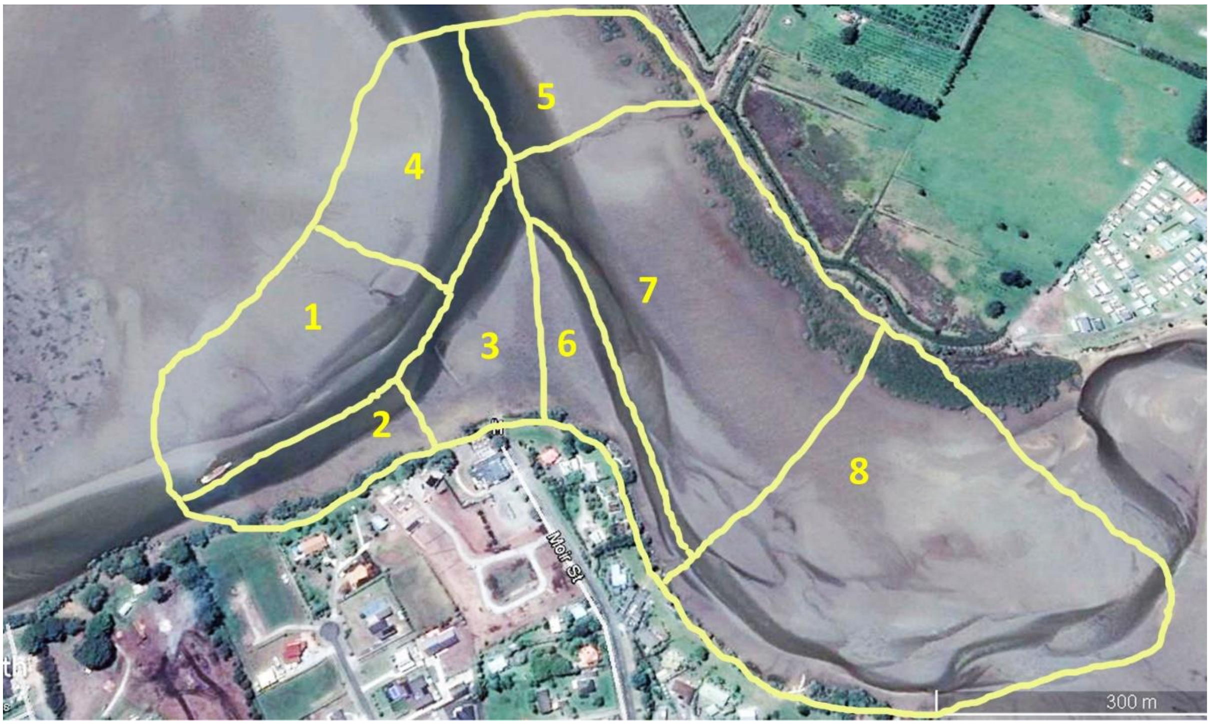

Figure 5. The feeding territory of the fairy tern pair M-R and RM-K divided into the eight feeding zones compared in the text.

19. Zone 6 (340m) was the south eastern edge of the delta running south west to just past some private wharves/walls. It is adjacent to a channel with a very complex bottom which is mostly excluded as the boundary was only about 2m off the shore.
20. Zone 7 (440m) had a mangrove lined shore with an even gradient and simple structure until the low tide. The low tide channel was very complex with many sand banks and small channels.
21. Zone 8 (500m) included both sides of the channel and had a short stretch of mangroves on the eastern shore, the end of the patch behind zone 7. Initially the shoreline had an even gradient and a simple edge but at intermediate levels sandbanks emerged and there was a complex of pools and drainage channels. In the low tide channel there were some sandbanks but it was not as complex as zone 7.
22. Observations of fairy tern activity and the presence of potential disturbance events were broken down into minutes and standardised as time from low tide to allow characterisation and comparison. During each minute of the tidal cycle the frequency that each event occurred was calculated from the observations made during that minute period.

Results

Bird activity

23. Between November 5th 2019 and January 17th 2020 we carried out 64.7 hours (4045 minutes) of observations in the feeding territory of this fairy tern pair.
24. Observations of the territory were made over the full tidal cycle. Although there were a few brief visits beforehand fairy terns usually arrived on the harbour for prolonged periods of time from about three hours before low tide and are present on and off until about 2 ½ hours after.
25. By the time observations started on November 5th the breeding season was well underway and feeding territories had been set up for some time. During territory mapping I first saw fairy terns occupying this area on June 26th involved in a chase and identified them as this pair of birds on the next visit, July 17th, and almost every visit after that. Although boundaries seemed settled there was a small degree of chasing (3-5%) throughout the observation period (table 1).
26. Birds could appear from as early as five hours before low tide but these visits were fly bys and feeding was not observed. They were occasionally present as the first bare sand began to appear low tide and they were most often present from about 3 to 1 ½ hours before low tide as roosting options improved and intermittently until about three hours after.
27. There was considerable variation in how that time was spent over different stages of the breeding cycle (table 1) so the three periods before the eggs were laid, during incubation and chick rearing are discussed separately.

Time period	Sitting	Flying	Chasing	Observation time with fairy terns present	Total observation time
Total	841 37%	1256 59%	79 4%	2176	4045
Pre-laying 5/11-20/11	528 52%	455 45%	26 3%	1009	1710
Incubation 21/11-14/12	179 29%	420 67%	26 4%	625	1039
Chick rearing 15/12-17/1	134 25%	381 70%	27 5%	542	1296

Table 1. The basic activity budget of a pair of fairy terns at different stages of the breeding cycle. Time spent is given in minutes and as a percentage of the total time fairy terns were present and the total observation time for each period is also shown.

28. Before the eggs were laid both birds spent a substantial amount of time on the feeding territory, both sitting and flying (table 1). The last date that the female was observed to make a dive was on November 13th but, by this stage she did not appear to be fishing intensively on her own. In observations from November 17th until the eggs were laid the only fish she was seen to eat were fed to her by the male.

29. With the female waiting for the male to bring food, particularly long periods of sitting were observed in this period and they were closely correlated with long periods of flying activity (figure 2). This shows the male was fishing for the female as well as himself. Overall, in fact, the time spent at roost (52%) exceeded that spent flying (45%) during this time (table 1).

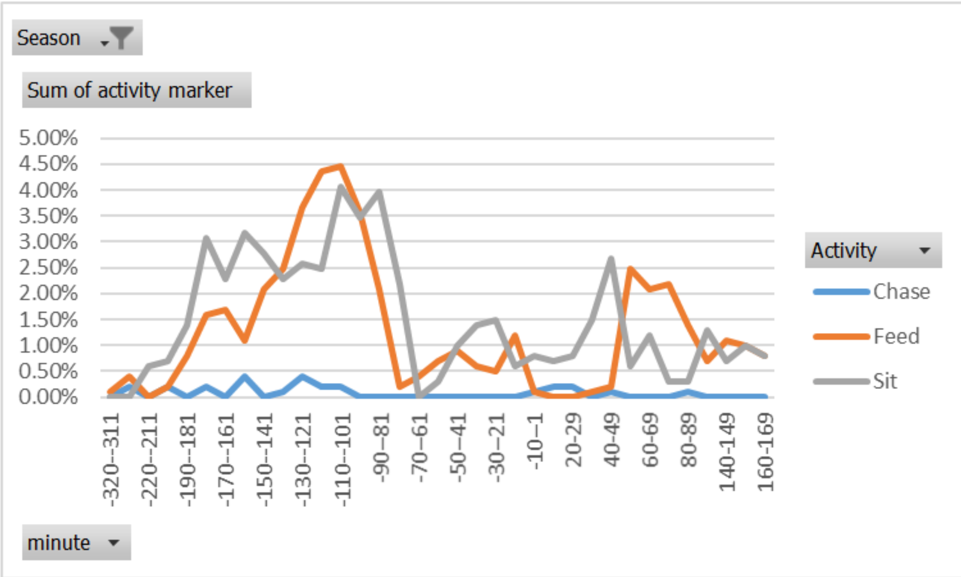

Figure 2. The percentage of total observation time when fairy terns were present that they engaged in the chasing, flying and sitting behaviour before their eggs were laid.

30. With the female waiting for the male to bring food, particularly long periods of sitting were observed in this period and they were closely correlated with long periods of flying activity (figure 2). This shows the male was fishing for the female as well as himself. Overall, in fact, the time spent at roost (52%) exceeded that spent flying (45%) during this time (table 1).
31. Fairy terns were less often present after an hour before low tide and presumably returned to their nesting territory periodically.
32. After the eggs are laid the proportion of time spent sitting (29%) declined markedly and most time was spent flying (67%) (table 1).
33. During the incubation period fairy terns arrived about three hours before low tide and fished intensively for about the next hour and a half. From an hour and a half before low tide to about an hour after more time was spent sitting and fairy terns were more likely to be absent but there was another peak of flying activity from one to two hours after low tide before the birds left the territory at the end of the tidal cycle (figure 3).
34. Although there was less sitting, the flying periods were similar both before laying (figure 2) and during incubation (figure 3) with a big peak from mid-tide to 1 ½ hours before low, a lull and then second peak from one to two hours after low tide. Movement of fish as the water is receding from, or just starting to cover, the flats may allow for better fishing.
35. During the chick rearing period there was a slight increase in the amount of time spent flying (70%) and a little less time was spent sitting (25%) but over all time spent was similar to time allocation over the incubation period (table 1).

36. It was, however, notable that while the proportion of the total observations when fairy terns were present had been 59% before laying and 60% during incubation it declined to 42% while chicks were being fed. Fish monitoring by the New Zealand Fairy Tern Charitable Trust (unpublished data) shows that the numbers of large gobies decline rapidly during January and this may mean that more food was sought elsewhere as the chicks grew, presumably at sea. Equally, this period coincided with the Christmas – New Year holiday period when human activity on Mangawhai Harbour increases markedly and this may also have led to a reduction in activity there.

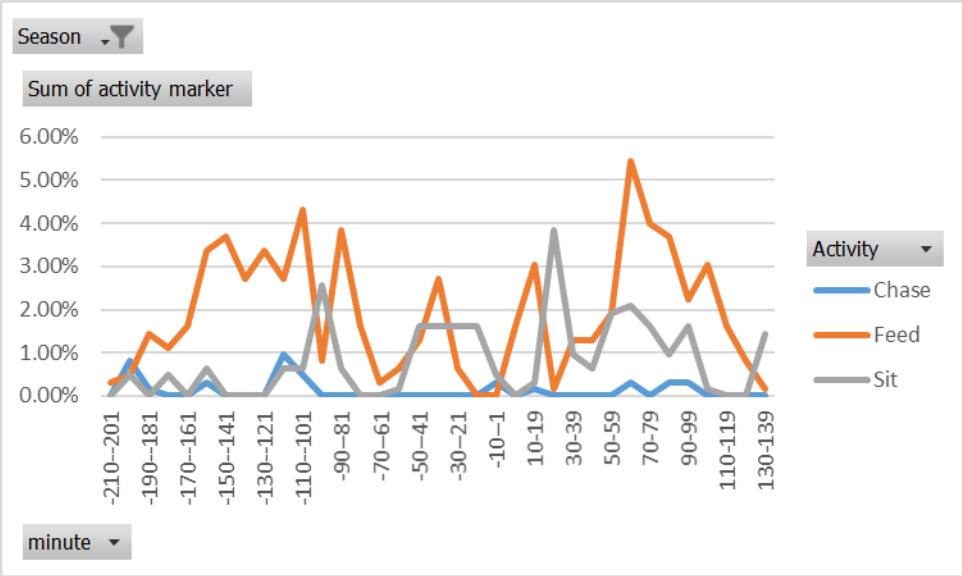

Figure 3. Fairy tern activity during incubation, showing the percentage of observation time spent in the three main activities that were recorded aggregated into ten minute segments centred on low tide.

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39. Chick rearing also differed from the two earlier periods in the spread of behaviour. Fishing was spread erratically over the whole time period with a general declining trend and does not slacken off over low tide (figure 4).
40. Unlike the previous stages there was a 30 or 40 minute period of intense feeding before any roosting was observed (figure 4). This had always been a period of more intense fishing but the initial lack of roosting time is different.

41. Both of these changes may reflect an increased demand to supply food to growing chicks.

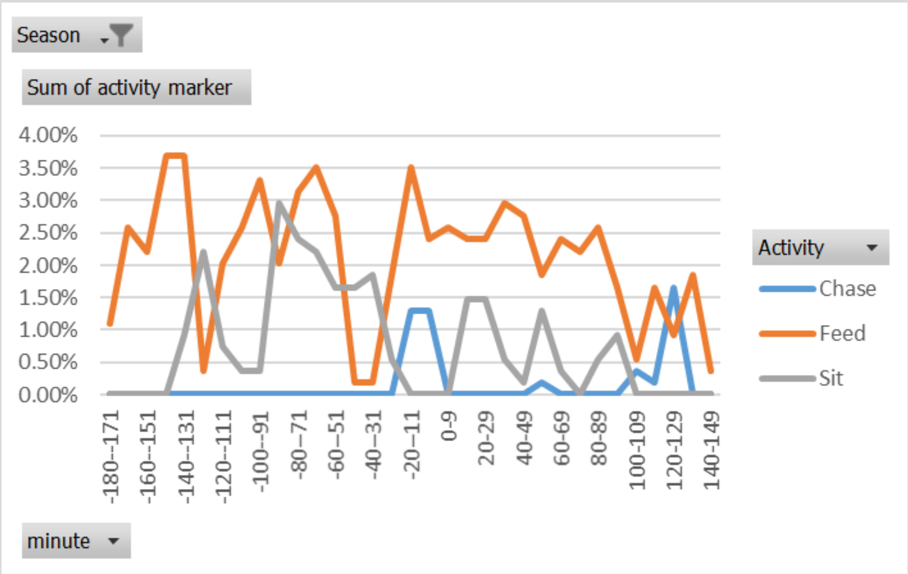


Figure 4. Fairy tern activity while rearing chicks, showing the percentage of observation time spent in the three main activities that were recorded during ten-minute intervals centred on low tide.

Roosting sites

42. The start of the main activity period appeared to follow the availability of suitable roost sites within the feeding territory. These were flat open sandy areas, often a little elevated.
43. The first available site was just out from the end of Raymond Bull Road and was well exposed from between 3 hours 20 minutes and 3 hours before low tide and remaining available until 2 to 2hours 20 minutes after low tide but this was not the most favoured roost. The big flat to the north and the delta in front of the pub was more favoured and become available from about 3 hours before low tide or shortly after and last until about 2 hours after low.
44. Other fairy terns using Back Bay and near the Insley Street causeway appeared earlier in the tidal cycle but the sand banks in their territories emerged earlier too.
45. Prior to egg laying male fairy terns feed fish to their mates. During courtship it appears to be a test of his ability to provide. Before the eggs are laid the female does not fish at all but is entirely dependent on food provided by the male, presumably because she becomes too awkward and/or fragile to dive for herself as the eggs develop.
46. We did not record all roost sites but did map places where courtship feeding (also known as fish feeding) took place (figure 5) and this does highlight the main sites although, when the female is hungry, she may position herself close to the male as he forages.
47. The 46 courtship feeding sites mapped are well distributed along the wider sand flats at low tide (figure 5). Few sites were mapped in the southern-most part of the territory and this may be due to the distance from the observers making accurate placement difficult there. The other area where very few courtship feeding events were recorded is on the eastern side of the channel opposite the delta in most of zone 7. This area was close to observers and a productive feeding area so the scarcity here is genuine and surprising.

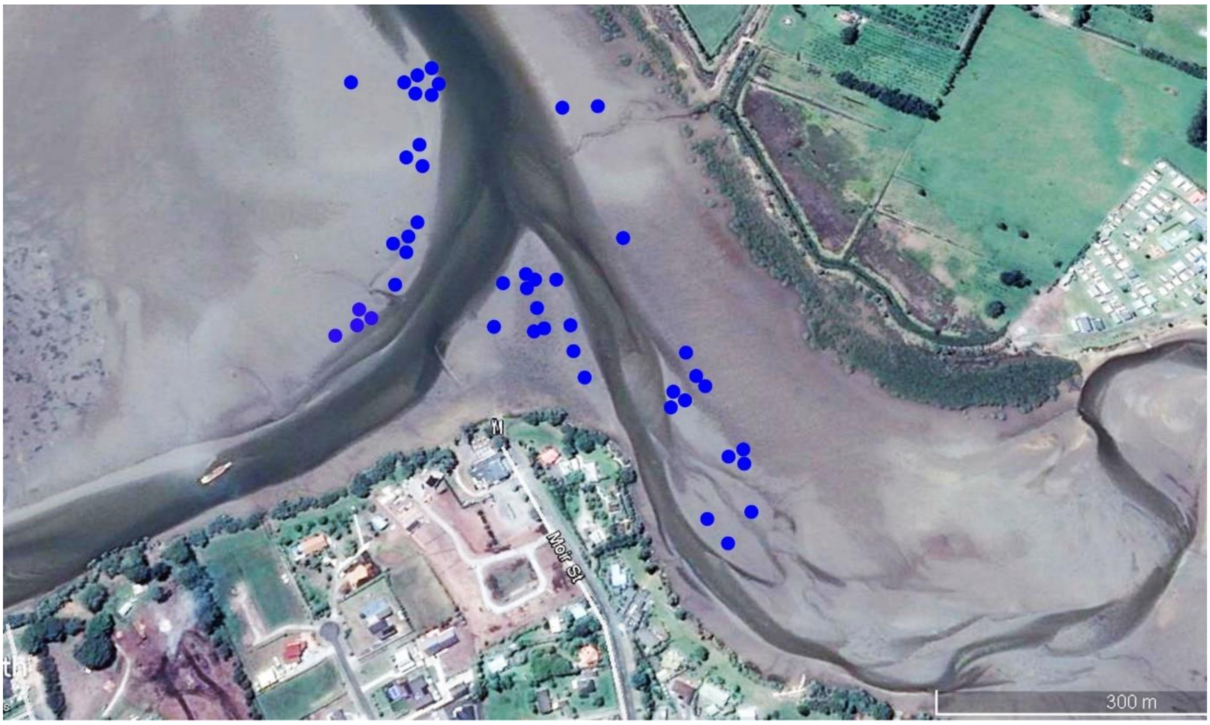


Figure 5. The courtship feeding sites for the pair of fairy terns using the proposed wharf site. Each spot represents a separate event.

48. This was an area frequently used recreationally by people and all of the recorded instances when fairy terns reacted obviously to disturbance occurred here so it may reflect active avoidance.
49. From these observations 12 courtship feeding events (26%) took place on the delta that is immediately accessible from the current boat ramp and a further 9 (20%) took place immediately across channel from the footprint of the proposed wharf.
50. These sites may also be a reasonable representation of the main roosting sites too. At all of these sites there is a risk that human activity may disrupt the ability of the birds to carry out their normal behaviours and possibly this could be, or become, an adverse effect.

Feeding sites

51. When fairy terns were flying we presumed that the it was mostly feeding activity. Feeding birds seemed to switch between two modes. Sometimes they would arrive, cover a large portion of the territory fairly quickly and make relatively few dives. This may have been exploratory behaviour and good food patches may not have been found. At other times birds would go to particular places and fish intensively there.
52. Relating dives to the state of tide was difficult as individual dive times were not recorded. Data sheets sometimes covered long periods, up to three hours but this usually also meant that the birds were absent from the territory for long periods of time. For this purpose, the time period on each from the activity records was truncated by starting the analysis at the first appearance of the bird and ending it at the last. This cut out most of the extremes and left only five time periods longer than one hour.

53. For analysis of tidal state the time when fairy terns were usually present was divided into three periods depending on tide height - mid tide to one hour after on the falling tide and from one hour before on the rising tide, one hour either side of low tide and an intermediate period. Each set of observations was allocated to the time period in which the mid point of the truncated observations fell. This division was not as precise as the observation periods do overlap but did show differences.
54. There were clear differences in the number of dives made in each feeding zone and some variation with tide height (table 2).

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Total dives	116 (10.9%) 3.4	11 (0.9%) 0.4	43 (3.6%) 1.83	71 (6.2%) 2.2	109 (9.5%) 4.0	160 (14.2%) 4.2	405 (35.1%) 8.3	224 (19.5%) 3.8
1	75 (23.0%) 0.25	3 (0.9%) 0.01	7 (2.2%) 0.04	30 (9.2%) 0.10	33 (10.2%) 0.14	45 (13.8%) 0.13	80 (24.6%) 0.18	52 (16.0%) 0.10
2	32 (7.4%) 0.11	8 (1.8%) 0.03	30 (6.9%) 0.15	20 (4.6%) 0.07	48 (11.1%) 0.21	46 (10.6%) 0.14	147 (33.9%) 0.33	102 (23.6%) 0.20
3	9 (2.4%) 0.03	0 (0%) 0	6 (1.6%) 0.03	21 (5.5%) 0.07	28 (7.3%) 0.12	69 (18.1%) 0.47	178 (46.7%) 0.40	70 (18.3%) 0.14

Table 2. The number of dives by a pair of fairy terns in different parts of their feeding territory by zone and time period. The numbers presented are total number of dives, percentage of dives made in that time period, and number of dives per metre of channel. Time periods are 1. mid tide to an hour after and from then to a hour before on the rising tide, 2. One to two hours after and before mid tide, 3. one hour either side of low tide.

55. Zone 7 stood out as the most intensively fished site even on a per metre basis. It was heavily used through all of the stages of tide when fairy terns were present and was increasingly used as the tide fell and 46.7% of all dives were made there.
56. Zone 2 was the other area that stood out for having very few dives at all, just 0.9% of the total dives on site.
57. Zone 3, which included the proposed wharf, also had few recorded dives and even when corrected for the small size it was at the lower end of the scale but similar to zone 4.
58. Zones 1, 5, 6 and 8 all had similar intermediate dive intensity, especially when corrected for size. Zone 1 was heavily used just after and before mid-tide and zone 8 in the intermediate tide period.
59. At low tide most fishing was carried out in zones with complex bottom topography. This was primarily in the channel in zone 7 and, to a lesser degree, zones 6 and 8. This kind of habitat is not present in the Tara Creek channel and the two groynes placed to keep the channel open for shipping may be the reason for this difference.
60. On a falling tide uneven substrate where spits and pools form at sites 1 and 8 also provided better feeding opportunities.

Wind direction

61. On most data sheets the wind came from the south west (n=26 sheets, 480 dives) or the south (n=11, 251 dives). Fewer observations were made in calm conditions (n=4, 150 dives) or wind from the west (n=2, 69 dives), north (n= 3, 43 dives), north-east (n=4, 81 dives) and south-east (n=3, 62 dives) but enough dives were recorded to suggest a pattern. The data is just too limited from the east (n=1, 3) and north-west (n=1, 0) to be useful.

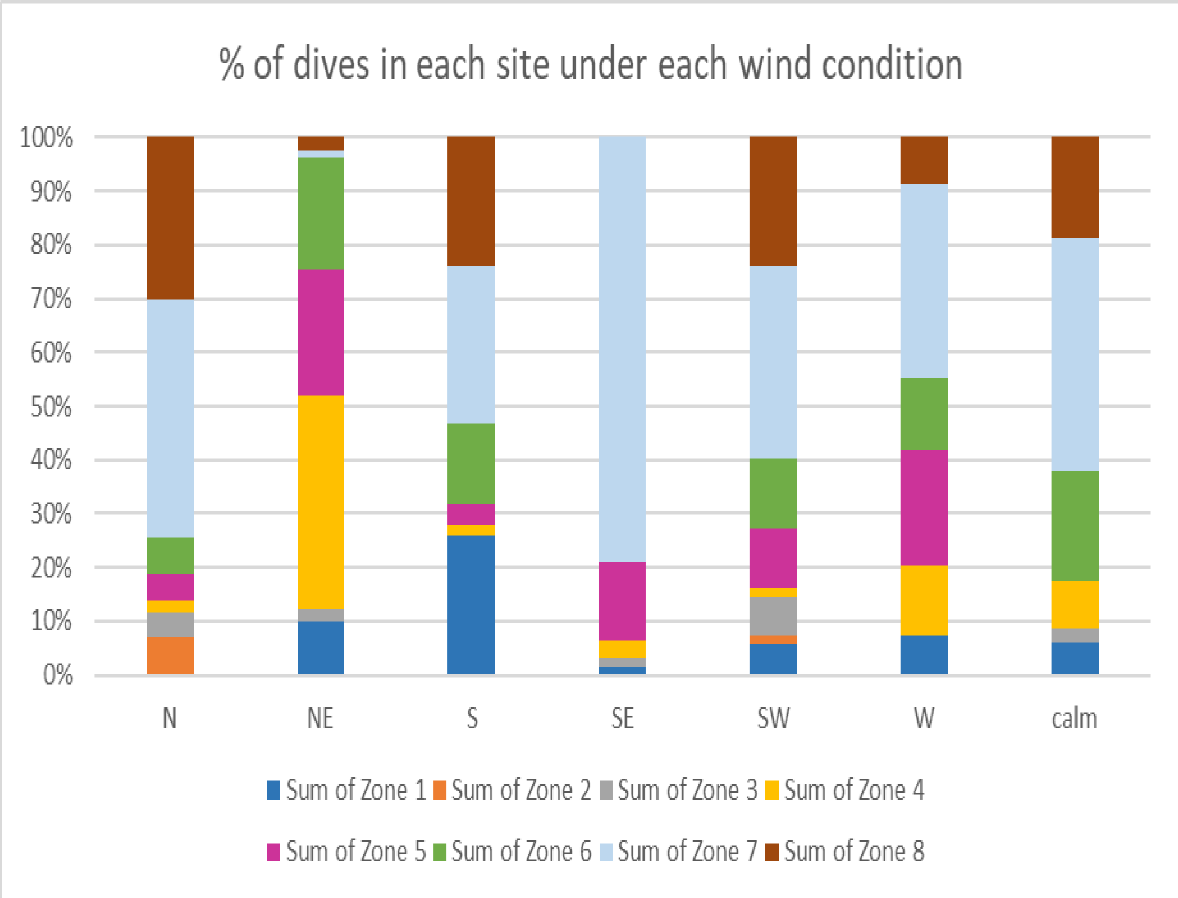


Figure 6. The use of different feeding zones in different wind directions. Easterly and north-west west winds are omitted due to a lack of data.

62. Compared to calm conditions the zones where fairy terns dived in westerly winds were similar but with more dives in zone 5.
63. In northerlies there was an increase in dives made in zones 8 and 2 but fewer in 5 and 6 and none from zone 1.
64. In north-east winds there were almost no dives recorded from zones 7 or 8 but more from 4, 5 and 6.
65. There was a marked increase in dives in zone 7 but none from 6 or 8 in south easterlies.
66. In southerlies there was a marked increase in dives in zone 1.
67. In south-west winds there was an increase in dives in zones 2 and 3.

68. There are observable differences in the use of most zones with wind direction and they are often striking. Zones 6 and 7, for instance had an almost opposite pattern of use. In north-easterlies zone 6 was favoured but no dives were recorded from zone 7 and the opposite pattern occurred south-easterlies. This probably reflects shelter from the waves pushed up by the wind. In zone 6 the shoreline angles away from north-easterlies and provides some protection but faces the south-easterlies directly.
69. Zone 7 was heavily used during south easterlies unlike zone 8 which was adjacent on the same shore but not used at all. This is probably due to the lack of mangroves along the shore providing shelter there. Zone 8 was most often used in northerlies (30%), southerlies and south-westerlies (both 24%) when there was some shelter provided by the escarpment and trees.
70. In the vicinity of the proposed wharf site there was enhanced use of zone 1 in southerly winds and zones 2 and 3 during sou'westers.

Wind strength

71. It is only possible to consider wind strength for south-west winds as there were 26 data sheets with 480 dives covering a range of wind strengths (table 3).

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Number of dives
Calm	9 6.0%	0 0%	4 2.7%	13 8.7%	0 0%	31 20.7%	65 43.3%	28 18.7%	150
Light	6 3.1%	0 0%	9 4.7%	6 3.1%	23 11.9%	25 12.8%	95 49.2%	29 15.0%	193
Moderate	0 0%	0 0%	0 0%	2 2.3%	7 8.0%	25 28.4%	4.8 27.3%	24 34.1%	88
Strong	22 11.1%	7 3.5%	25 12.6%	0 0%	24 12.1%	12 6.0%	53 26.6%	56 28.1%	199

Table 3. Differences in site use with different wind strengths during south west winds. The number of dives and their percentage for each category are shown.

72. The proportion of the total dives in each zone was similar in calm conditions and light winds but differences appeared in most sites as the wind strengthened but zone five was fished at a similar rate in most wind strengths.
73. In light wind and calm almost half of all dives occur in zone 7 but in moderate to strong wind it decreases to a little over a quarter and the effort is allocated elsewhere.
74. In zone 8 the highest use is during moderate and strong winds and it has an escarpment and trees protecting it from this direction.
75. In zone 6 there appears to be a drop off in dive rate in strong wind. The edge of the channel there runs in approximately the same direction as the wind so it appears that initially there is some shelter here from irregularities in the shoreline and perhaps the edge of the escarpment and trees but this is overwhelmed as the wind builds.

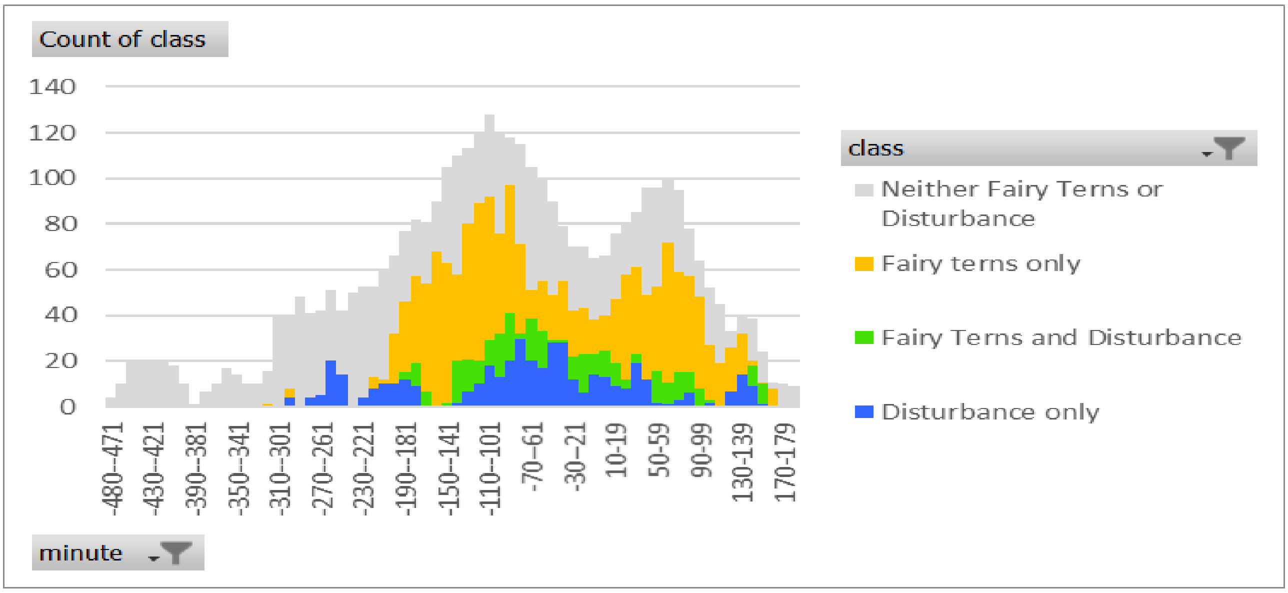
76. Use of zone 4 also seems to decline as wind strength builds but it seems to be affected almost immediately.
77. Zones 2 and 3 are fished much more heavily during strong and gusty south-westerlies than they are in light winds and calm conditions.
78. The tendency for fairy terns to fish in sheltered water is enhanced as wind strength grows. The number of dives in the favoured site, zone 7, decreases markedly in winds categorised as moderate or strong and the effort is allocated elsewhere, particularly zones 5, 6 and 8. In strong wind it is adjusted further and particularly favours zones 1,2,and 3 as well as 5 and 8.

Wind conclusions

79. Watching fairy terns fish it is easy to see them avoiding the rougher water. It was not so easy to show the full degree to which they do this because they often target the protection provided by small irregularities in the shoreline and sand banks which do not show at the scale we recorded data.
80. It is clear that light wind has little impact on site use but in moderate wind there is a switch to the windward shore, where waves originate and the water is smoother rather than the shore where the waves break. It is common to see fairy terns fishing just one side of a channel as the wind rises, especially when the wind blows straight across emphasising the differences between the banks.
81. The most effective shelter was provided by shoreline features. The escarpment and trees to the south are probably why zones 2 and 3 were most heavily used during strong south-westerlies. The mangroves along the shore of zone 7 appear to have provided good shelter from south-easterlies and 79% of mapped dives, the most intensive use of the site, occurred there then. Most of the channel in the adjacent zone 8 has the same orientation but there are no mangroves providing effective shelter from this direction and no dives were observed there during south-easterlies.
82. A full understanding of where fairy terns fish in relation to wind requires more observations in a wider range of conditions as lighter winds prevailed during most observation periods in this study. As wind strength increases the value of different parts of the feeding territory changes in importance and it is important to understand what is required to allow fairy terns to fish in the most difficult weather conditions.

Human disturbance

83. In total there were 101 disturbance events involving people on the study site and one that did not, a stray dog. There were 723 minutes during the observation period when there was at least one potential disturbance on the study area and together they totalled 1233 minutes.
84. People on foot, with and without dogs or horses, were the frequent event (79 cases) and most occurred between 2 hours, 20 minutes before low tide to about an hour and a half after.
85. In 28 cases there were only people in groups of one to five, averaging two, without pets or boats and there was at least one group present for 484 minutes. Usually they walked and did not enter the water - three groups fished, two swam and four paddled as they walked. There were no obvious negative interactions with fairy terns.



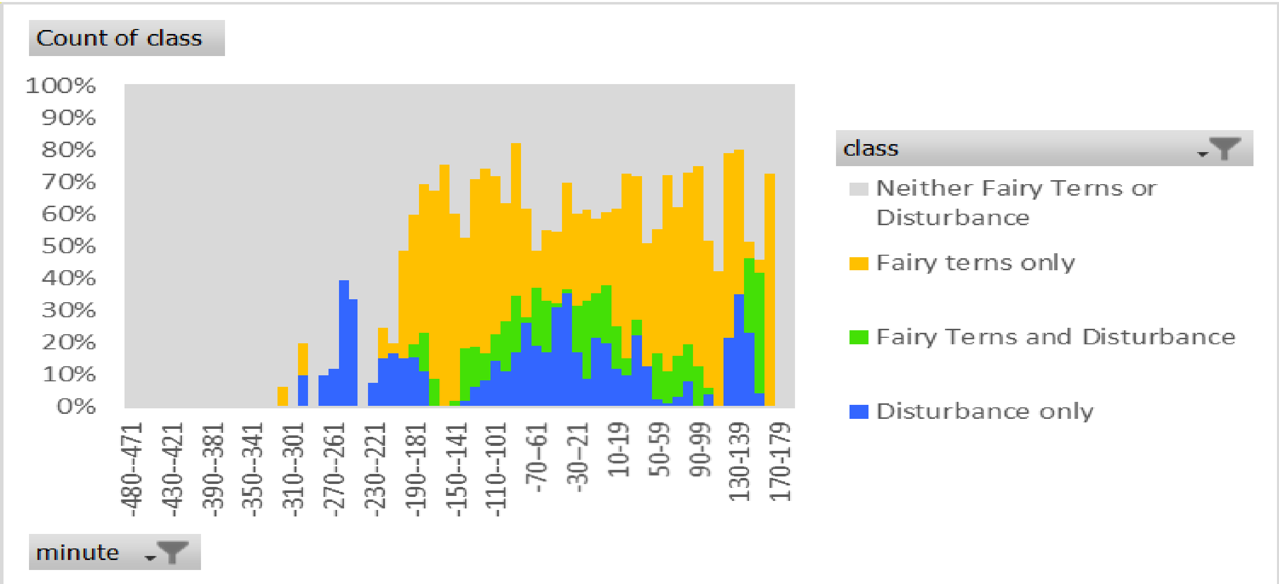


Figure 7. The overlap between potential disturbance events and fairy terns. The first graph shows the number of observations and the second the percentage of observation time. In both cases the data are presence or absence of at least one event during a single minute, indexed from low tide and added into 10 minute blocks.

86. Most of the potential disturbance events (42 incidents, 41%) involved dogs (1-5, average 1.4 dogs) and at least one dog was recorded on the harbour for a total of 529 minutes suggesting that one of the main recreational purposes of this part of the harbour is to exercise dogs. Most of them were on the eastern side entering from Raymond Bull Road or further south, maybe the motor camp.
87. One stray dog was seen but the others were accompanied by people. Only twice were dogs walked on a lead although once a lead was obviously carried but not used suggesting

the harbour was regarded as a place for dogs to run free. Fifteen times the dogs entered the water (36%), mostly this was spontaneous, but one dog chased sticks. Mostly the dogs stayed within 10 or 20 m of their walkers but some ranged much further and eight times free running dogs chased birds, at least three times it appeared to be deliberate, the others may have been inadvertent. Five times (12%) dogs obviously disturbed fairy terns and they reacted from distances of 10-80m (average 52.5m) but none of these dogs appeared to be purposefully chasing birds.

88. Seven events involved horses, mostly a single rider but once there were two and, in total they were present on the harbour for 54 minutes. Mostly they walked but twice trotted. Horses often entered the water (four times), and four times were accompanied by dogs off lead and once by a pet sheep as well. None of them obviously disturbed fairy terns but a horse trotting in shallow water flushed many godwits.
89. There were 24 groups of people with varied water craft, one stand-up paddleboard, ten with kayaks, one windsurfer, eight with jet skis, and four with small motorboats. These boats were present for 217 minutes, jet skis and motorboats for 49 of those minutes.
90. They were present right across the low tide period but more common near to mid tide (n=14, 58%). Of all disturbance events taking place more than 2 ¾ hours before low tide all were boats except for a single person that walked onto the boat ramp. After this walkers began to appear and they were the main users of the harbour until the last event was observed 2 ½ hours after low tide.
91. At higher water levels boats and fairy terns interacted little. Fairy terns were on their territory less often at this time and fished elsewhere when present.
92. Three vehicles came onto the harbour, two simply parked on the boat ramp by the pub but the third was a tractor that went to retrieve a stuck boat trailer and spent 35 minutes on the harbour. None of them interacted with fairy terns.
93. The two aircraft that flew over the harbour put up all of the birds on the sand flats. Once they returned fairly quickly and the other time they circled for a few minutes first. In one case a pair of fairy terns was present and flushed with the other birds. This is also potentially a problem but fortunately they were a rare event.

Disturbance discussion

94. The most frequently observed fairy tern disturbance events were reactions to dogs, 12% of dogs that were exercised on the harbour resulted in some response from fairy terns. They reacted from 10-80m from dogs (average 38m) which is a greater distance than they react to walking people (pers. obs.). Some dogs appeared to deliberately run at and flush birds but there none of the observed fairy tern disturbance events was of this nature, most are likely to be inadvertent. On one occasion a fishing bird came to about 10m then stopped fishing, veered around the people and dogs and resumed fishing 50 m later.
95. Given that kayaks were observed only ten times in the study site, the two observations of them disturbing fairy terns also seems high (20%), especially given that four of the ten kayak records were made at higher water levels when fairy terns were absent or fishing elsewhere. The fairy terns reacted from 50 and 80m (average 65m) away. The fact that these boats were both kayaks being paddled fairly sedately indicates that speed is not the issue, merely the presence of boats and this could be important but it needs to be reliably quantified.

96. The scarcity of courtship feeding events in zone 7 has already been noted as a possible impact of human disturbance as it is the area that was most often used recreationally by people. It is possible that fairy terns prefer not to sit in this area due to an expectation of disturbance.
97. An intriguing possibility is that as well as birds being scared of people, people may also spoil the fishing by disturbing the water. I saw two mobbing events by fairy terns, once of two dogs that ran into the water where a tern was fishing and the other of a little shag fishing very shallow water also in the path of a fishing fairy tern. On one further occasion a fairy tern ceased fishing (i.e. looked up) and moved to another part of the harbour at a distance of 50m from a kayaker, a greater distance than I would have expected for this kind of incident.
98. The presence of people and potential disturbance events can be directly compared with the presence of fairy terns (figure 7). It is noticeable that there was a period of relatively high and sustained presence by fairy terns from about three and a half hours before low tide, peaking at two hours before low tide when potential disturbance levels were low or just beginning to rise. For about an hour either side of low tide the presence of fairy terns was reduced while potential disturbance events were most frequent. This may not be cause and effect however, because this pattern may also reflect improved fishing opportunities as the water moves into and out of the channels.
99. Adverse effects of disturbance on fairy terns are not, however, clear from this data and this is not surprising as there are usually other places to fish so the birds can, and do, move within the territory rather than being forced to leave entirely but whether or not food intake or energy expenditure are impaired is difficult to know.
100. When periods of increased recreational use over the Christmas-New Year period are combined with a high demand to supply food to large chicks, there is clearly potential for problems to arise maintaining a sufficient food supply.
101. From one particular period of high use by people on one day there is an indication that that human disturbance could, at some level, exceed the tolerances of fairy terns and impact on their ability to harvest food and defend their territories.
102. On January 10th the weather started overcast with a moderate southerly. Feeding areas became available from about 12:30 (sheets 46-47) and the first fairy terns arrived soon after. About 14:00 the wind dropped, the sun came out and the day became warmer. There was a marked influx of people onto the harbour from 14:20 until about 16:00. Shortly after the people began to appear (c.13:35) there were no fairy terns present for about 30 minutes and over the following hour there were three brief visits by fishing fairy terns, all fishing or chasing but none sitting. The visitation rate of people dropped off markedly after 16:00 and fairy terns spent more time fishing and sitting as they had before (table 4).
103. Looking only at the data on these sheets there is statistically significant reduction in time spent feeding (almost 50%) and birds ceased to sit on the sand flats during the two time periods of intense disturbance compared to the periods immediately before and after.
104. It is not a general or strong conclusion but it validates the impression gained in the field of shorter visits by the fairy terns and more time absent from the harbour during this period of intense disturbance. Further observations during similar periods of high disturbance are required to clarify this issue as it appears that fairy terns could suffer significant adverse effects from human disturbance at plausibly increased disturbance levels.
105. Understanding that the productivity of fairy terns now appears to be food limited, this reduction in feeding time is a concern. Although it was only brief in this instance, it does

give an indication of the kinds of changes that might be caused by increased human disturbance if more people are attracted to the area.

Data sheet number	Observation time (minutes)	Feeding	Sitting	Chasing	Fairy terns absent	Number of disturbance events
46	80	0	0	0	80 100%	3
47	60	19 41.4%	12 20.0%	0 0%	29 48.3%	2
48	30	13 31.7%	7 23.3%	0 0%	10 33.3%	2
49	60	10 16.7%	0 0%	0 0%	50 83.3%	9
50	64	16 25.0%	0 0%	13 20.3%	35 54.7%	17
51	116	48 41.4%	14 12.1%	4 3.4%	50 43.1%	4
Normal	124	26 21%	0 0%	13 10%	85 69%	
Disturbed (sheets 49 &50)	206	80 39%	33 16%	4 2%	89 43%	
T test		P=0.03	P=0.02	P=0.27	P=0.14	P= 0.11

Table 4. A summary of data sheets recording fairy tern activity on the study site before fairy terns arrived (sheet 46) and their activity before (sheets 47 and 48), during (Sheets 49 and 50), and after (sheet 51) an intense period of potential disturbance events. For each data sheet the total number of observation minutes is recorded and for each major fairy tern activity class the number of minutes and the percentage of total observation time is given. T tests were performed on percentages comparing sheets 49 and 50 with the other time periods.

106. There are several ways that birds can accommodate the impacts of disturbance and fairy terns illustrate them well. Firstly, they are remarkably tolerant of people and will roost and feed closer to them than many other bird species might allow. Secondly, they can move their activity to less disturbed areas and fairy terns do this within the constraints of their territories. Finally, they can feed utilising time periods when fewer people are present and we can see this too with their earlier arrival onto their feeding territory. All of these adjustments are used by fairy terns to some extent already and make coexistence with people possible under the current conditions at Mangawhai. The fact they are all currently operating suggests that much of their resilience has also been used up.
107. Although a considerable period of field work was carried out not all of the questions surrounding the impacts of wind and human disturbance on where and how well fairy terns were able to forage and carry out their normal behaviours could be answered. Some worthwhile conclusions can be drawn from this study and it could be used to make future field work more focussed and efficient.