Submission in response to the resource consent application to extract sand offshore at Pakiri. Expert evidence on birds.

Ian Southey

Introduction, qualifications and experience

1. My name is Ian Campbell Southey.
2. I am presenting expert evidence on birds in support of Te Whanau O Pakiri regarding the resource consent application for Pakiri offshore sand extraction by Kaipara Ltd.
3. I have an MSc (Hons) in Zoology and have worked on contract for the Department of Conservation on survey, monitoring and species management issues, mainly with birds and lizards from 1985 to 2008 and consulted in the private sector since 2006, mainly carrying out bird survey work.
4. I have a life-long interest in birds and have been a member of Birds New Zealand (the Ornithological Society of New Zealand) since 1978 assisting with a wide variety of the society's projects and birding recreationally. I have been the Regional Representative for the South Auckland branch since 2012, a member of the national Records Appraisal Committee since 2016 and involved in a series of youth camps to teach basic birding skills. I am also a member of the Miranda Naturalist's Trust and have contributed articles on a wide variety of topics to their magazine.
5. I am also a member of the New Zealand Fairy Tern Charitable Trust and have recently given evidence for them at hearings in front of the Kaipara District Council, Northland Regional Council and the Environment Court.
6. Since 2012 I have had a special interest in the New Zealand fairy tern that began with a season of intensive observation at Pakiri Beach and has developed into several research projects mostly carried in Mangawhai and Kaipara Harbours now. During the breeding season I have studied feeding behaviour and patterns of use on Mangawhai Harbour and, with the assistance of the New Zealand Fairy Tern Trust have monitored small fish in Mangawhai Harbour monthly from 2017 to 2020. I have also recently carried out some analysis of fairy tern productivity using the Department of Conservation data base. Since this work is unpublished at present, I include the relevant results within this response.
7. I have not carried any field work specifically for this case but am drawing my own experience birding on this coast, especially over the last ten years, my entire experience with fairy terns, published works and unpublished reports to the Department of Conservation.

Seabird fauna offshore from Pakiri

8. The applicants evidence (Bioresearches 2019) does not deal with the potential impacts of the proposed sand mining on birds. They do note that birds are often seen feeding around the dredge but the only species mentioned is the red-billed gull and there is a picture of twelve of them feeding while the dredge is operating. I have watched channel dredging in Mangawhai Harbour where I have seen red-billed gulls aggregating and feeding in a similar manner but no other species.

9. Between the Bream Tail and Leigh the coastal waters are particular good for seabirds and many species can be seen easily just off the beach including gannets, white-fronted and Caspian terns, fluttering and Buller's shearwaters and sometimes they are present in very large numbers. This includes the area for which resource consent is being sought. The sheer number of birds that can be seen feeding so close inshore at times (many thousands) is unusual and suggests that this area is particularly productive. A number of the species present are listed as threatened or at risk in the national threat rankings (table 1). In addition to these species, little blue penguins (at risk, declining) have bred at Te Arai (Jane Vaughan pers. comm.) and a report of one recently killed in the dunes by a dog there (Sioux Plowman pers. comm.) suggests that they may still do so.

10. There is an important breeding colony of Caspian terns at Mangawhai and another isolated pair breeds at Pakiri. There are also substantial White-fronted Tern and Red-billed Gull colonies on Mangawhai sandspit and Goat Island. The proposed mine site is an area of water that is probably used quite heavily by these birds for feeding while they are tied to their nests and limited in their feeding range.

11. The Caspian tern colony at Mangawhai has declined from 120 pairs in the mid-1980s to 50-60 pairs in 2016-2017 (Harris et al 2019). This corresponds with the period of active fairy tern management (Ferreira et al 2005) which has included a steadily improving, and now very effective, predator control program so issues with food supply while breeding are more likely to be responsible and the timing overlaps with the period of previous sand mining.

Threatened species	
New Zealand fairy tern	Nationally critical
Caspian tern	Nationally vulnerable
Flesh-footed shearwater	Nationally vulnerable
At risk species	
Red-billed Gull	Declining
White-fronted tern	Declining
Pied shag	Recovering
Fluttering shearwater	Relict
Buller's shearwater	Naturally uncommon

Table 1. The threatened and at risk sea bird species that I have seen regularly using the proposed sand mining site off Pakiri Beach and their threat categories (Robertson et al 2017).

12. Many of these seabirds feed near the water's surface but, collectively, they have a range of foraging strategies and can use different depths. With a bathymetry of 25-40m, the bottom is within reach for part of the proposed mining site for Fluttering and Flesh-footed Shearwaters with regular maximum depths of 30-35m and 30 m respectively (Taylor 2008). Little blue penguins are even better divers and may reach depths of more than 50m. Foraging strategies vary between individuals and sites but one hunting strategy is to trap fish against the bottom (Chiaradia et al 2007).

13. This means that even benthic habitats in the proposed sand mining site may be of concern. Biogenic habitats like shellfish beds increase habitat and species diversity on sandy substrates may be important. Horse mussel beds, for instance, are known to be a nursery for juvenile fish including snapper and trevally (Morrison et al 2014) but monitoring shows that previous mining has destroyed the horse mussels that were present (Bioresearches 2019).

14. No assessment of these threatened and at risk species of birds that use the proposed mine site has been given. In particular there has been no effort made to identify the species present or identify any potential threats so it is not clear which species might suffer from the mining and which might not.

15. In particular one of these species, the New Zealand fairy tern is New Zealand's rarest endemic bird and the remainder of this submission discusses its conservation status and potential risks.

Fairy terns in the proposed sand mining area.

16. From the at least the start of the Ornithological Society of New Zealand in 1939 fairy terns were known to breed along the Pakiri coast. In the 1950s Geoff Moon found three pairs in separate sites along the beach but when marram and lupins were planted to stabilise the dunes behind the beach the breeding sites were altered and the birds abandoned these sites although they continued to nest on Mangawhai sandspit (Moon 2005). The last historic breeding record at Pakiri Beach was in 1965 but after a long absence a pair settled and bred in the 2003-04 season (Wilson 2004).

17. Since that time Pakiri Beach has been occupied, usually by a breeding pair, but sometimes just a single male. Their first two breeding seasons were not successful but this pair then became a very reliable producer of chicks rearing one or two every year. The male died during the 2013-14 breeding season (Rathe and Lagnaz 2014) and the female moved to Mangawhai. Subsequently the males that occupied the site have had difficulty attracting mates until the 2017-18 season but the pair that formed then has managed to rear a single chick in every year but one since this time but, unfortunately, the female died during this last breeding season (2020-21).

18. Pakiri Beach has been, and probably is still, a good site for New Zealand fairy terns and there may be scope for increase to the three pairs once found there once the population begins to grow again.

19. As evidence of this in the 2012-13 season a pair of fairy terns laid two unsuccessful nests, one at Te Arai and then another Poutawa Stream. They resumed breeding at Te Arai in 2015 (Stanbury 2016) and continued intermittently until the 2019-20 season when both members of the pair died although one of the chicks was reared by supplementary feeding (Ogle 2020) so the future of this site is not certain.

20. Both of these pairs will have used the proposed sand mining area for feeding during the breeding season as it is immediately adjacent to their nest sites. The majority of fairy terns (six pairs in 2020-21) breed on Mangawhai sandspit. These birds feed both in the harbour

and at sea and while feeding in the harbour has been well observed, much less is known about their behaviour at sea. I have seen birds from the two pairs feeding in Mangawhai Harbour between the pub and Insley St causeway heading overland toward the sea rather than back up the harbour toward the sandspit, so these birds are probably using the northern of the sand mining site. Whether other birds move south along the coast to overlap this area is uncertain but the physical distance is not great.

21. Immediately after the breeding season a roosting flock usually forms at Te Arai (Harris et al 2019) and they are known to use the Tomorata Lakes for feeding and they also appear to fish in coastal waters. Although only one percent of observations were of feeding in coastal waters (Jeffries et al 2016), feeding at sea is by far the most difficult behaviour to observe. Some of them return along the beach from the south giving the impression that they their foraging beat has included the coastal water (pers. obs.).

22. The similar least tern in the U.S. was initially regarded as estuarine but detailed foraging studies have found them to be more of a nearshore feeder with 75% of foraging trips there (Burton and Terill 2012). There could easily be a similar observation bias with New Zealand fairy terns given how few birds there are for the large area of water offshore.

23. The proposed mine site is potentially a very important area for fairy terns – the single pair at Pakiri alone is more than 10% of the entire breeding population but more than half of the entire population could fish there after breeding as up to 23 birds have been recorded on the Te Arai roost (Harris et al 2019).

Conservation history of the New Zealand fairy tern

24. Historic records of the current population show that only very small numbers of fairy terns have ever been known with 1-3 pairs prior to the early 1970s and 2-5 pairs after. Numbers of birds in the total population have fluctuated more and there was a decline from a maximum population of 30 birds in 1970 to about 10 in 1990 (Ferreira et al 2005).

25. Management and monitoring by the Department of Conservation and volunteers began in the 1983-4 season and intensified from 1991. This has resulted in a steady, if slow, population increase (Ferreira et al 2005, Maloney et al 2017) and the pair of fairy terns that settled at Pakiri Beach are the result of that population growth translating into range expansion rather than filling up existing breeding sites. An apparent plateau in numbers is the result of periods of larger than usual mortality and slow recovery (figure 1). The large dip from 2009 to 2011 is the result of uncontrolled cat predation at Waipu and a smaller one in 2015 was caused by storm mortality.

26. Fairy terns are dependent on active management to survive in the wild. They have had the capacity to increase but the time required for recovery from adverse events has cost years of potential population growth.

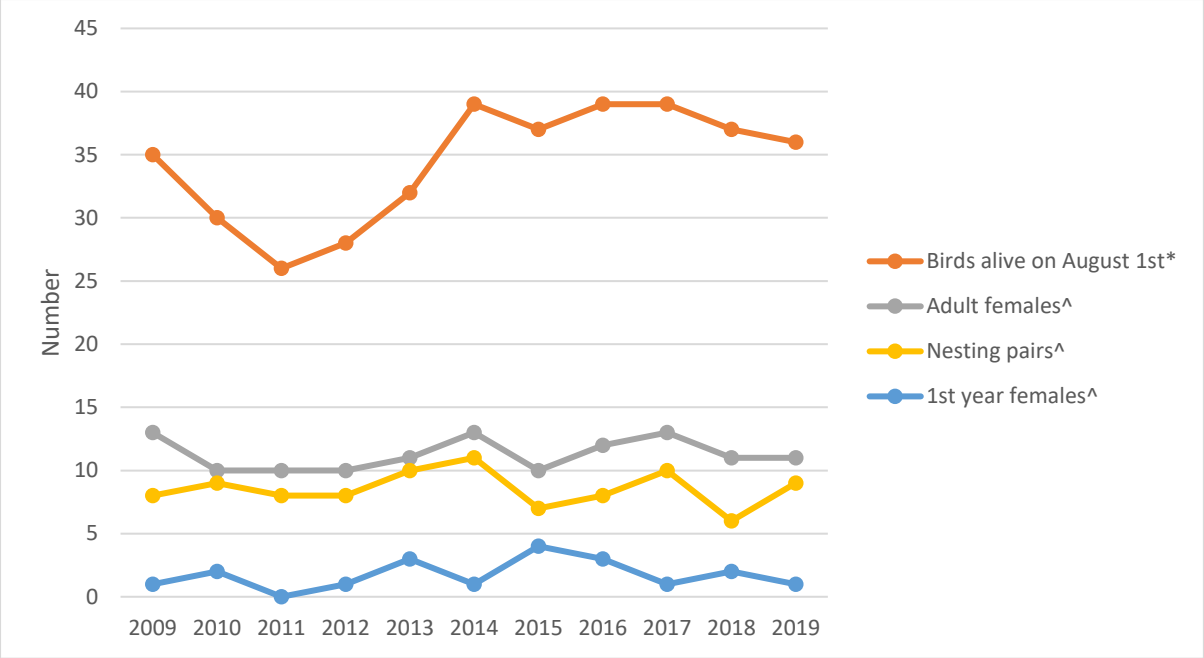

Figure 1. The total numbers of fairy terns alive from 2009 to 2019. The total number of birds alive on August is calculated by Tony Habraken from sightings of individually colour banded birds around the start of the breeding season. The other trends are taken from Department of Conservation ranger's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

27. Since 2015 the productivity of fairy terns at Mangawhai has declined and population growth has changed from an increase to a decline (figure 1, appendix 1). The pair that breeds at Pakiri should not be affected by the changes at Mangawhai so they could become disproportionately important to the fairy tern recovery.

28. Recently there have been a number of adult deaths during the breeding season not obviously related to predation. One was related to a health issue and others to severe storms but the losses of two adult males (2013-14, 2017-18) and one female (2020-21) from Pakiri and both members of the pair from Te Arai in the 2019-20 season cannot be explained by normal mortality factors.

29. One of these birds was described as having worn out plumage immediately before disappearing (Lagnaz 2018). The wear and tear of the breeding season takes quite a toll on the birds and there is an obvious loss of body condition, especially when it is successful (figure 2). This suggests that food intake is not sufficient to compensate for the energy expended in parental care and defence of the feeding territory and nest. When this mortality occurs, it takes place as the chicks become large and need the greatest amount of food.

30. Since 2012 all five deaths like this have taken place in the one or two breeding pairs at Pakiri and Te Arai but none elsewhere. These are the breeding pairs are most dependent on the area affected by sand mining. This mortality has fallen on both males and females and may be one of the issues limiting population growth. If sand mining has affected food supplies enough to play a role in this mortality it would be a major concern.

a. The adult male fairy tern Y-M at the start of the breeding season. Pakiri 9-10-12

b. The adult male fairy tern Y-M at the end of the breeding season. Pakiri 28-1-13.

Figure 2. A fairy tern at the start and end of one breeding season (2012-13) showing the physical changes that take place. Note the loss of body condition so that the belly has shrunk and a much greater length of leg is exposed. The plumage is very worn and the darkening bill is the start of the transition into breeding plumage. The bill tip has also become blunted from catching fish from the sand surface. This bird survived this season but died in the next.

Feeding of fairy terns at Pakiri

31. During the 2012-3 breeding season, I observed the pair of fairy terns breeding at Pakiri Beach quite intensively through the breeding season and I saw them feeding both in the river and at sea. On subsequent visits I have seen similar behaviour.

32. Some fish from the river fed to the female during courtship and to chicks were identified. Frequently seen throughout the season were estuarine gobies (*Favonogobius lentiginosus*) and estuarine triplefins (*Forsterygion nigripenne*) with some flounder (*Pleuronectes sp.*) and soles (*Peltorhamphus latus*) before they became too large to swallow. Vey small grey mullet (*Mugil cephalus*) are also taken later in the season when they enter the estuary.

33. At sea fairy terns were sometimes be seen working the wash of breakers, especially around the creek mouth, or the area just beyond where the waves form. Most often, however, they wander well out to sea where they seem to particularly follow the slicks that form when the wind is not too strong. Judging from birds seen at known distances on Mangawhai Harbour I estimate that these birds are fishing out to at least 2 km offshore and suspect they go even further. I am not familiar with marine fish species and have had none of those brought back to the nesting territory identified but suspect that some of them may be the larval forms which means that even bottom dwelling species could be involved.

34. While monitoring nests at Mangawhai and Pakiri I have noticed that when other species of seabirds (especially white-fronted terns, Buller's and fluttering shearwaters) are feeding in numbers immediately offshore fairy terns mostly bring food to chicks from the sea and often return quite rapidly. When other seabirds are not seen offshore fairy terns may still forage at sea but most of the food brought to chicks comes from the estuary or harbour. This suggests that marine food is not always available.

35. From analysis of stable isotope signatures in fairy tern feathers Ismar et al (2014) were able to show that sites within Mangawhai Harbour were heavily used but also noted that in some years the isotope ratios indicated that more of their food came from another habitat and they suggested that it was offshore.

36. Ranger's reports from Pakiri record the source of the food, from the sea or the river, that is exchanged during courtship feeding for three breeding seasons (Table 2 a) and when fed to chicks for seven breeding seasons (table 2b). It can be seen that most of the food for the chicks comes from the river rather than the sea but the proportions vary considerably from 14% to 47% and averaging 29%. A similar proportion of marine food (average 22%) is exchanged during courtship feeding. Food from the sea is an important dietary component in all years and very important in some.

37. The variability in importance of marine food in different years is consistent with Ismar et al's (2014) inference from different stable isotope signatures, that marine food was more important in some years than others. If there are differences in food availability in the two different habitats, to some degree they may be complementary so that reduced food availability in one can be compensated for by the other in most years.

	River observations	River percentage	Sea observations	Sea percentage	Unknown source	Total observations
2017-18	117	88	16	12	8	141
2018-19	44	80	11	20	3	58
2019-20	23	64	12	34	2	37

a. The source of food passed by the male to the female during courtship feeding at Pakiri over three breeding seasons

	River observations	River percentage	Sea observations	Sea percentage	Unknown source	Total observations
2010-11	136	75	46	25	45	227
2011-12	228	66	119	44	29	376
2012-13	125	63	75	47	29	229
2013-14	145	86	24	14	27	196
2017-18*	55	15	157	85	6	218
2018-19	178	73	65	27	29	272
2019-20	141	84	26	16	31	198

b. The source of food fed by the parents to chicks at Pakiri over seven breeding seasons.

Table 2. The origin of food collected by a single pair of fairy terns at Pakiri. The percentages only include the items of known origin as I have assumed that the proportions of food deliveries from unknown sources would have been similar to those of identified items but they are included to show the potential for error. (Data from Lagnaz (2020) and pers. comm., percentages recalculated.)

38. The result for 2017-18 has been left out because of the particularly high proportion of food from the sea. In this year the male died when the chick was 18 days old and the chick was raised by the female. The contributions of male and female were quite different. The female delivered less food to the chicks than the males, 20% of all recorded feeds in 2018-19 and 28% in 2019-20 but a high percentage of the food items are marine, 54% in 2018-19 and 37% in 2019-20. The male tended to bring food from the river so instead so only 11% of prey items came from the sea in 2018-19 and 5% in 2019-20. Although she brought in much less food the female consistently provided a greater amount of food items from the sea than the male. Males are the predominant defenders of the estuarine or harbour feeding territories while females spend more time guarding the chicks so the amount and origin of the food that they deliver is probably influenced by these duties.

Feeding at sea

39. When monitoring fairy terns on Mangawhai Harbour on fine, calm mornings I have often noticed that some to many of the normally resident birds often cannot be found. I suspect that these birds are feeding at sea as these are the conditions when the pair at Pakiri was most likely to be feeding at sea with well-defined slicks extending well offshore. This

occurred at times when suitable fish in the harbour were abundant and even during the short, about four-hour, time window around low tide when harvesting gobies there is possible and efficient. I suggest that this indicates a preference for offshore food whenever it is available.

40. Other studies on similar small terns suggest that pelagic marine species are often oil rich and favoured food. Such fish species were preferentially fed to little tern chicks even when they were not common in net captures (Perrow et al 2011), to the point where there are clear differences in the composition of adult and chick diets (Catry et al 2006). A surprisingly marked benefit has been reported for a small difference in the quantity of northern anchovies fed to least terns - an increase from 1% to 5% of anchovies in the diet was reported to increase the fledging success of least terns from 0.16 to 0.67 chicks per year (Elliot et al 2007, in Burton and Terill 2012). Another study of least terns indicates that the more anchovies in the diet of least terns the bigger the clutch, the greater the hatching success of eggs and the shorter the nesting season (Reinsche et al 2012). In poorer years when fewer anchovies were available clutch size was smaller, asymptotic chick weights lower, eggs were abandoned more often and non-predator related mortality was higher (Atwood and Kelly 1984). There were also bigger colonies of little terns and higher reproductive success in a year when pilchards were more abundant (Paiva et al 2006). These studies indicate that many pelagic fish species are a particularly high quality food.

41. At present I don't know what species of fish are available or used as food by the fairy terns adjacent to the sand mining site but pelagic fish generally seem to have a high oil content. For this reason it seems likely that even small quantities of pelagic fish might also be important for the nutrition of fairy terns.

42. There are limits to the distance a breeding tern can go from its nest. Unlike many species of seabirds, terns do not regurgitate food for their chicks but bring in whole fish, usually one at a time. The commuting time that this entails determines the rate at which they can provide food and it may become limiting when the distance is too great. Over a number of studies of similar species of terns 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 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).

43. At Mangawhai the greatest distance between an active feeding territory and nest was about 3.5 km but most are within 1km so they seem to be a typical small tern in this respect with a similar limit to how far they can forage and still breed effectively.

44. If the affects of sand mining reduce the numbers of small pelagic fish in and around the area to be mined it will change the cost effectiveness of foraging at sea. It is uncertain just how big an area will be affected by the operations and whether or not fairy terns can reasonably be expected to fly beyond it if the impact is severe. If the quantity or quality of the food supply close to the nest is reduced then the energetic cost of harvesting fish relative to the gain in energy will also increase, perhaps to the point where productivity is impacted or adult survival is reduced.

The relationship of harbour or estuarine and marine food sources

45. For New Zealand fairy terns at Mangawhai, at least, offshore foraging may be important in two other ways.

46. The impacts of human disturbance on the ability of fairy terns to feed have not yet been properly studied. They are remarkably tolerant of people but there are limits. They will feed up to 10 or 12m from a person standing still near the water's edge but are less tolerant of dogs, active people and boats. For much of the breeding season Mangawhai Harbour is relatively available to them but over holidays, especially the Christmas/New Year period there are very large numbers of people using all parts of the harbour. At these times fairy terns seem to have difficulty finding room to feed and appear to be actively dodging people when they are present but they also seem to be present on the harbour less often. Pakiri Beach is similarly attractive to people and I expect similar issues to arise there. At these times alternative feeding sites such as inshore along the coast and toward Waipu and Pakiri would be particularly valuable although I am not sure if they are actually used for this reason.

47. The main food fed to fairy tern chicks at Mangawhai is gobies (Parrish and Pulham 1995, Ismar et al 2014) but monthly monitoring of gobies in Mangawhai Harbour (New Zealand Fairy Tern Charitable Trust unpublished data) shows that gobies are mostly spawning in November, into December but during December, many of the fish are spent and of lower food value while, during January, almost all of them die off and the available food supply diminishes rapidly. When chicks hatch from early clutches they may already be mobile enough to follow the food before this happens and they often move from the nesting area to be closer to a site where the adults can find food. Later chicks are still tied to the nest and alternative food sources nearby become more valuable when this food source declines.

48. Formerly the fledged chicks at Mangawhai were often taken to the harbour to be fed but now, since the mangrove removal, they are more likely to go to the beach. Offshore feeding seems to have become more important recently.

Summary

49. The main problem I see with the applicant's evidence is that it does not include any consideration of the threatened and at risk bird species that use the proposed mine site to gather food. The site appears to be particularly productive and important as a number of these species breed in colonies nearby.

50. Every one of these species requires consideration and, while most of them use the surface layers of water, some species are capable of reaching the bottom throughout the proposed sand mining area and feeding there so benthic habitats are also of concern.

51. Two particular points of concern have been identified that need to be addressed as they concern the existing sand mine operation but there may be others not recognised yet.

52. There has been a notable number of deaths of breeding adult fairy terns late in the nesting period and they have occurred in pairs that feed in the waters affected by sand mining and not those breeding in other sites.

53. The Caspian tern colony breeding on Mangawhai sandspit has halved since the 1980s and these birds also depend to some extent on feeding in the water affected by the sand mine.

54. I have focussed on the New Zealand fairy tern as I have a more detailed knowledge of that species, they are already critically rare, their population is declining at present and no further negative impacts can be tolerated as there is no fat left in the system. Further negative impacts will simply hasten the inevitable extinction and reduce the time available to come up with a viable management solution.

55. Every breeding pair of fairy terns is now significant. Last breeding season there were just nine breeding pairs so the single pair at Pakiri constituted more than 10% of the effective population (14%, if pairs with infertile males are excluded) and the single chick reared is 20% of that season's productivity. Any steps that could be taken to improve productivity or reduce mortality would be extremely beneficial at this stage as extinction is inevitable unless current circumstances change.

56. It is uncertain, at present, whether or not sand mining has actually caused adverse effects on fairy terns, or any other species, but it may have. Further information obtained before the licence is renewed could either remove or underscore the potential threats discussed here and might highlight new ones.

57. We already know that food from harbours and estuaries is important because fairy terns defend feeding territories there and males require a feeding territory to retain a mate and breed. Food from the sea also appears to be important for a number of reasons outlined. It would be interesting to test, as a hypothesis, whether or not the quantity of marine food available determines the degree of breeding success as it does with least terns in the U.S.

58. I would prefer that a decision to be to grant this consent is made from more certain information base than exists at present.

59. The applicants have submitted an Environmental Monitoring Management Plan to assess whether or not significant biological or physical change has taken place from their operations. Because the potential risks to threatened and at risk bird species have not been outlined, any factors that might specifically impact birds are unlikely to be covered by this monitoring.

60. Also, any remedial action cannot be undertaken until after the damage has occurred so any impact on the very fragile population of New Zealand fairy terns will have already occurred and there is no guarantee that such damage could quickly be rectified. Data presented suggests that up to now the time interval between monitoring periods has varied between three and six years (Bioresearches 2019) and this is not a suitable time period to identify and attempt to remedy any problems impacting fairy terns.

61. I consider that prevention of further problems would be less expensive than any corrective management response and is more likely to be successful. For this reason, I urge that a cautious approach be taken and the resource consent be declined until the effects of dredging on fairy terns and other bird species can be properly assessed.

Appendix1.

Evidence of food limitation at Mangawhai

1. Since 2015 the productivity of fairy terns at Mangawhai has declined. This coincides with the removal of mangroves from part of the harbour in the preceding winter and while cause and effect may not be proven a link is strongly suspected. Since this time a higher proportion of pairs does not reach breeding condition, they are less likely to replace lost clutches and they produce fewer young (table 1).

	Pre Mangrove removal 1995-2014	Post mangrove removal 2015-2019	Statistical significance
Average number of breeding pairs	3.9	4.6	P = 0.19
Average number of pairs that did not breed	0.3	1.8	P = 0.02*
Average clutch size	1.68	1.56	P = 0.15
Average number of nests per breeding pair	1.5	1.1	P < 0.001*
Average number of chicks fledged per year	3.4	2.8	P>0.001*

Table 2. A comparison of some breeding parameters before and after mangrove removal at Mangawhai Harbour. The larger number of pairs after mangrove removal does not reflect population growth, prior to 2015 the population was actively increasing so some small numbers are included in the average while since 2015 the population has been fairly stable and has not yet declined to former levels. Statistically significant differences are indicated by *.

2. For the first two years after mangrove removal clutch size declined markedly but since the 2017-18 season it has improved so the overall difference is not statistically significant (table 1) but egg viability appears to have declined so it is not actually a recovery.

3. In recent years there have been three congenitally infertile males in the population, whole clutches are lost to predators and storms or abandoned making changes in viability difficult to assess. I have assumed that, in a full two egg clutch, if one egg is able to hatch, the other would have hatched too unless the embryo failed to form or died prior to hatching. This

shows that of 28 two-egg clutches laid from 1995 to 2014 where at least one egg hatched, 88% of eggs hatched while from 2015 to 2019, from 10 clutches, only 60% of eggs hatched and this difference is statistically significant (P = 0.001) so egg viability has declined.

4. The fundamental problem has not been clearly identified but reduced breeding success in similar species overseas shows that similar patterns can be caused by food shortage and productivity can improve when food supply improves. Nesting colonies of little terns typically form near good food resources but when they fail 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. Food shortage seems to be a good working hypothesis for the recent issues with fairy tern productivity. For this reason, any useful food source should be managed with care.

6. In the past the productivity of fairy terns has not been impacted in such an enduring way. Temporarily increased mortality factors (flooding, storms and predation) have been the traditional problem and their recovery was able to begin as soon as the issue resolved. That is no longer the case, productivity, the ability to recover, has been impacted.

7. From historic data the average annual mortality of the whole fairy tern population was calculated at 6.4 birds (Maloney et al 2017). Since 2015 this target of 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 4.7 birds, well short of this target. During this time the population of fairy terns and the number of breeding pairs appears to have peaked and seems to have started declining from 11 breeding pairs in 2014-15 to 9 in the 2020-21 season. At this rate extinction is inevitable unless a suitable management response can be found and the jury is still out on what this should be.

References

Atwood, J.L.; Kelly, P.R. 1984. Fish dropped on breeding colonies as indicators of least tern food habits. Wilson Bulletin 96:34-47.

Atwood, J.L.; Minsky, D.F. 1983. Least Tern foraging ecology at three major California breeding colonies. Western Birds 14:57-72.

Bioresearches. 2019. Assessment of ecological effects:following sand extraction from the Auckland offshore sand extraction site. Report for Kaipara Ltd. Pp 93.

Burton, R.K.; Terrill, S.B. 2012. Least tern literature review and study plan development. Final report. H.T. Harvey & Associates, ecological Consultants. Prepared for U.S. Army Corps of Engineers, San Francisco. File 3081.

Catry, T.; Ramos, J.A.; Martins, J.; Peste, F.; Trigo, S.; Paiva, V.H.; Almeida, A.; Luis, A.; Palma, J.; Andrade, P.J. 2006. Intercolony differences in the diet and feeding ecology of Little tern adults and chicks in Portugal. The Condor 108:366-376.

Chiaradia, A.; Ropert-Coudert, Y.; Kato, A.; Mattern, T.; Yorke, J. 2007. Diving behaviour of Little Penguins from four colonies across their whole distribution range: bathymetry affecting diving effort and fledging success. *Marine Biology 151*:1535-1542.

Eglinton, S.M.; Perrow, M.R. 2014. Literature review of tern (*Sterna & Sternula*) foraging ecology. ECON Ecological Consultancy Ltd, Norwich.

Ehrler, M.L.; Elliott, M.L.; Roth, J.E.; Steinbeck, J.R.; Miller, A.K.; Sydeman, W.J.; Zoidis, A.M. 2006. Oakland Harbour deepening project (-50'): Least Tern, fish and plume monitoring report. Tetra Tech, Inc., San Francisco, California. July 2006.

Ferreira, S.M.; Hansen, K.M.; Parrish, G.R.; Pierce, R.J.; Pulham, G.A.; Taylor, S.. 2005. Conservation of the endangered New Zealand fairy tern. *Biological Conservation 125*:345-354.

Harris, M.C.; Preddy, J.M.; Pulham, G.A. 2019. Seasonal use of Slipper and Spectacle Lakes by New Zealand fairy tern (*Sternuila nereis davisae*) and Caspian tern (*Hydroprogne caspia*). *Notornis 66*:31-33.

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

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

Lagnaz, E. 2018. Monitoring and management of the New Zealand Fairy Tern/*Tara iti* (*Sternula nereis davisae*) and other shorebirds at Pakiri 2017/17 breeding season. Unpublished report to the Department of Conservation, Warkworth.

Lagnaz, E. 2020. Monitoring and management of the New Zealand fairy tern/*Tara iti* (*Sternula nereis davisae*) and other shorebirds at Pakiri for the 2019-20 breeding season. Unpublished report to the Department of Conservation, Warkworth.

Maloney, R.; Seddon, P.; Steeves, T.; Cleland, S. 2017. Review of the Tara-iti/ Fairy Tern recovery programme. Department of Conservation report.

Moon, G. 2005. New Zealand birds in focus. A photographer's journey. Reed Publishing (NZ) Ltd. Auckland.

Morrison, M.A.; Jones, E.G.; Consalvey, M.; Berkenbusch, K. 2014. Linking marine fisheries species to biogenic habitats in New Zealand: a review and synthesis of knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 130, Ministry for Primary Industries, Wellington.

Ogle, S. 2020. Monitoring and management of the New Zealand fairy tern/Tara iti (*Sternula nereis davisae*) at Te Arai for the 2019-20 breeding season. Unpublished reort to the Department of Conservation, Whangarei.

Parrish, G.R.; Pulham, G.A. 1995a. Observations on the breeding of the New Zealand Fairy Tern. Tane 35:161-173.

Paiva, V.H.; Ramos, J.A.; Martins, J.; Almeida, A.; Carvalho, A. 2006a. Foraging habitat selection by Little Terns *Sternula albifrons* in an estuarine lagoon system of southern Portugal. *Ibis150*:18-31.

Paton, J.C.; Rogers, D. 2009. Ecology of breeding Fairy Terns *Sternula nereis* in the Coorong. *Report for the Wildlife Conservation Fund.*

Perrow, M.R.; Gilroy, J.J.; Skeate, E.R.; Tomlinson, M.L. 2011. Effects of the construction of Scroby Sands offshore wind farm on the prey base of Little Tern *Sternula albifrons* at its most important UK colony. *Marine Pollution Bulletin 62:1661-1670*.

Rathe, C.; Lagnaz, E. 2014. Monitoring and management of the New Zealand fairy tern/*Tara iti* (*Sternula nereis davisae*) and other shorebirds at Papakanui and Pakiri 2013-2014. Unpublished report to the Department of Conservation, Warkworth.

Riensche, D.L.; Elliott, M.L.; Euing, S.H. 2012. Breeding status, nesting densities and diet trends of two endangered California Least Tern colonies. Journal of Environmental Science and Engineering B 1:1135-1145.

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

Sherfy, M.H.; Anteau, M.J.; Shaffer, T.L.; Sovada, M.A.; Stucker, J.H. 2012. Foraging ecology of least terns and piping plovers nesting on Central platter IVER sandpits and sand bars. U.S. Geological Survey Open-File Report 2012-1059. 50pp.

Stanbury, M. 2016. Fairy tern monitoring report Mangawhai/Waipu 2015/16 breeding season. Unpublished report to the Department of Conservation, Whangarei.

Taylor, G.A. 2008. Maximum dive depths of eight New Zealand Procellariiformes, including *Pterodroma* species. *Papers and Proceedings of the Royal Society of Tasmania 14*:89-98.

Wilson, D. 2004. A fairy tern (*Sterna nereis davisae*) breeding attempt at Pakiri Beach, 2003-20043. Unpublished report to the department of Conservation, Warkworth.