BEFORE THE ENVIRONMENT COURT
AT AUCKLAND
I MUA I TE KŌTI TAIAO O AOTEAROA
TĀMAKI MAKAURAU ROHE

UNDER	the Resource Management Act 1991
IN THE MATTER	of appeals under Clause 14 of Schedule 1 of the Act
BETWEEN	**BAY OF ISLANDS MARITIME PARK INCORPORATED**
	(ENV-2019-AKL-000117)
	ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND INCORPORATED
	(ENV-2019-AKL-000127)
	Appellants
AND	**NORTHLAND REGIONAL COUNCIL**
	Respondent

STATEMENT OF SUPPLEMENTARY EVIDENCE of VICTORIA ANN FROUDE

(MARINE ECOLOGY)

TOPIC 14 – MARINE PROTECTED AREAS

19 April 2021

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1. My name is Victoria Ann Froude. I provided evidence in chief on behalf of the Royal Forest and Bird Protection Society of New Zealand Inc ("Forest & Bird"), Bay of Islands Maritime Park Inc ("BOIMP") and Ngāti Kuta Hapū ki te Rawhiti ("Ngāti Kuta") dated 19 March 2021. My evidence addressed natural character and ecological significance for all the areas of interest where Ngāti Kuta, BOIMP and Forest & Bird are seeking additional marine protection measures. It also covered existing area-based controls on fishing activities within these areas.
2. This supplementary evidence addresses an April 2021 re-measurement of part of a 2016 series of quadrats on shallow rocky reef habitat in the outer Bay of Islands.
3. In my primary evidence I set out my qualifications and experience, and confirmed compliance with the Code of Conduct for Expert Witnesses. I confirm that I have also complied with the Code of Conduct in preparing this supplementary evidence.

SUMMARY OF SUPPLEMENTARY EVIDENCE

4. In April 2021 I undertook a re-measurement of part of a 2016 series of 25m^2 quadrats on shallow rocky reef habitat in the outer Bay of Islands. The 2021 re-survey covered those quadrats within the proposed Maunganui Bay-Oke Bay Rahui Tapu. This included 55 quadrats in Maunganui Bay, 64 quadrats in the nearshore waters from Maunganui Bay to Oke Bay, and 16 quadrats in Oke Bay itself.
5. The Maunganui Bay temporary fishing closure[1] has led to an increase in the numbers and size of the main predators of kina (*Evechinus chloroticus)*. The April 2021 re-measurement of quadrats established in 2016 showed a significant reduction in urchin barrens and a significant increase in kelp forest in the 2-10m depth range since 2016.
6. In contrast the area of nearshore marine environment extending south to and including Oke Bay has had no such controls. The April 2021 re-measurement of quadrats established in 2016 showed a significant increase in urchin barrens and a significant decrease in kelp forest in the 2-10m depth since 2016. The last remaining eastern Bay of Islands green-lipped mussel beds that were in this area in 2016 had disappeared by 2021.
7. The proposed Maunganui Bay – Oke Bay Rahui Tapu would retain the biodiversity gains of the existing Maunganui Bay temporary fishing closure. Over time there will be further biodiversity gains, including the ongoing recovery of kelp forest. The proposed Rahui Tapu would, over time, extend the Maunganui Bay biodiversity gains to a larger area. As explained in the evidence of Nick Shears a large area is necessary to reduce the edge-effect and therefore maximise biodiversity benefits.

[1] Maunganui Bay was first gazetted under s186A of the Fisheries Act in 20101 as being closed to all fishing except the harvest of kina. Since then, the local hapu, Ngati Kuta and Patukeha, have applied every two years for the temporary closure to be extended for further two years.

BACKGROUND

8. The original 2016 algal cover-urchin barrens assessment[2] of the eastern Bay of Islands originated from a 2015 request by Dr John Booth for me to review his draft manuscript about long-term changes in the marine environments of the Bay of Islands. As part of that review I observed that his time-sequenced aerial photo interpretation of areas missing shallow kelp forest did not always correspond with my extensive snorkelling and diving experience in the Bay of Islands. In particular, kelp cover and the extent of urchin barrens was more nuanced than a presence or absence along lengths of shoreline. There were also a number of locations where steep slopes or shadows on current day aerial imagery precluded any remote assessment of current day kelp condition.

9. While I had intended to assess all of the outer Bay of Islands rocky reef shoreline in 2016, sea conditions and other time commitments meant that while the survey of outer eastern Bay of Islands was completed, this was not the case for the outer western Bay of Islands. In total 561 shallow-reef 5 metre x 5 metre quadrats were assessed in 2016.

10. The 2021 re-survey only included quadrats surveyed in 2016[3] for Maunganui Bay, the shoreline from Maunganui Bay to Oke Bay, and Oke Bay itself.

11. Maunganui Bay was first gazetted under the temporary closure provisions of s186A of the Fisheries Act in 2010[4] as being closed to all fishing except the harvest of kina. Since then, the local hapu, Ngati Kuta and Patukeha, have applied every two years for the closure to be extended for further two years.

12. The near-shore waters and shoreline from Maunganui Bay to Oke Bay plus Oke Bay itself are part of the proposed Rahui Tapu for Maunganui Bay-Oke Bay. Within the proposed geographical extension to the temporary closure (i.e. the proposed Rahui Tapu) commercial fishers are not permitted to use Danish seine or trawl nets in this area. Commercial taking of scallops is also prohibited. Longlining and lobster potting are permitted. There are no current restrictions on amateur or recreational fishers apart from the standard rules for recreational fishing in the general area[5].

13. A variety of drivers can lead to the loss of kelp forests[6]. A common reason is sea urchin grazing. Sea urchin barrens have been found to have significantly fewer taxa than the

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[2] Froude, V. A. (2016). Kelp cover and urchin barrens in the Bay of Islands: a 2016 baseline. A report prepared for Bay of Islands Maritime Park. 72p. https://www.fishforever.org.nz/images/ff/documents/reports/Kelp_cover_and_urchin_barrens_in_the_Bay_of_Islands_FINAL_Dec_2016.pdf

[3] Froude, V. A. (2016). Kelp cover and urchin barrens in the Bay of Islands: a 2016 baseline. A report prepared for Bay of Islands Maritime Park. 72p. https://www.fishforever.org.nz/images/ff/documents/reports/Kelp_cover_and_urchin_barrens_in_the_Bay_of_Islands_FINAL_Dec_2016.pdf

[4] Fisheries (Maunganui Bay Temporary Closure) Notice 2010. Serial number 2010/399. Date of enactment 8/11/10. https://www.dia.govt.nz//pubforms.nsf/NZGZT/NZGazette150Nov10.pdf/$file/NZGazette150Nov10.pdf#page=36 accessed 14 April 2021.

[5] More details are in my evidence –in-chief

[6] Araujo, R.M.; Assis, J.; Aguillar, R.; Airoldi, L.; Barbara, I.; Bartsch, I.; Bekkby, T.; Christie, H.; Davoult, D.; 18 more. 2016. Status, trends and drivers of kelp forests in Europe: an expert assessment. *Biodiversity and Conservation 25*: 1319-1348.

kelp forests they replaced[7]. It has also been shown that if the numbers and size of the natural predators of sea urchins are able to increase sufficiently then kelp forest is eventually able to return[8]. In New Zealand the expansion of kelp forests and the loss of sea urchin barrens have been observed in long-term no-take marine reserves at Leigh[9] and Tawharanui[10]. These phenomena are often referred to as trophic cascades where one change leads to a series of consequential ecological changes.

14. The species primarily responsible for New Zealand sea urchin barrens has been the common sea urchin or kina (*Evechinus chloroticus*). The underlying driver for the loss of shallow kelp forests and the associated expansion of sea urchin barrens is typically considered to have resulted from reductions in the number and size of sea urchin predators. Without the predation pressure the numbers and sizes of sea urchins increase. In northern New Zealand the predators of small sea urchins are primarily larger snapper, (*Pagrus auratus*), packhorse lobster (*Sagmarissus verreauxi)* and red rock lobster (*Jasus edwardsii*)[11].

METHODOLOGY

15. In 2016 a number of potential survey methods were reviewed to find the best method for two people to complete a rapid survey of the cover type and levels for shallow rocky reef habitats along a long length of coastline. My focus was to assess algal cover and urchin barrens in the 2-10m depth range, which is where urchin barrens formed by the browsing of the common New Zealand sea urchin kina (*Evechinus chloroticus)* have been most common. So I was looking for a method that could:

    a. give detailed abundance data by cover class in the 2-10m depth range;

    b. rapidly provide sufficient replicates to detect changes over time and only needed two people in the field.

    c. avoid the need to use scuba, with its logistical complications (including being unable to accurately determine position underwater), limitations on bottom (i.e. assessment) time and requirements for additional people to be involved in the field work.

16. **Appendix 1** shows the location of analysis groups C (Maunganui Bay), D (Maunganui Bay to Oke Bay) and E (Oke Bay). It also shows the quadrat locations. **Appendix 2**

Bennett, S; Wernberg, T; Connell, S D; Hobday, A J; Johnson, CR; Poloczanska. 2015. The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests. *Marine and Freshwater Research*. DOI: 10.1071/MF15232

[7] Ling, S.D. 2008. Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state. *Oecologia 156*: 883-894.

[8] Shears, N.T.; Babcock, R.C. 2003. Continuing trophic cascade effects after 25 years of no-take marine reserve protection. *Marine Ecology Progress Series 246*: 1-16.

[9] Shears, N.T.; Babcock, R.C. 2003. Continuing trophic cascade effects after 25 years of no-take marine reserve protection. *Marine Ecology Progress Series 246*: 1-16.

[10] Dr.Roger Grace, personal communication

[11] Babcock, R.C.; Kelly, S.; Shears, N.T.; Walker, J.W.; Willis, T.J. 1999. Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series 189*: 125-134.

summarises the methods considered, and their advantages and disadvantages. It also clarifies what the different methods actually measure. The relative abundance results of different methods should not necessarily be compared as the area measured (and therefore what type of habitat/ location the results represent) can be different. I clearly specify that the quadrats I measure represent cover in the 2-10m depth range on rocky reef habitat.

17. The method chosen was "*percent cover within representative quadrats*". A quadrat size of $25m^2$ was selected as this was sufficiently large to capture local spatial variation but not so large that it could not be viewed at the same time. An added advantage was that it was sufficiently large that the boat person could select the depth, at least one corner and the orientation of the plot. This happened when the plots were initially established and when the plots were re-measured. The snorkeler swam between quadrats to assess the representativeness of the quadrats and note any other features of interest (e.g. presence of extensive of urchin barrens) between the assessed quadrats.

18. Quadrats were established at approximately 50-75 metre intervals along the shore where there were appropriate substrate and conditions. If the initial quadrat location was inappropriate (e.g. not rocky substrate) the boat person selected another location. In some locations (such as the southern sandy beach/shore at Oke Bay) there were no suitable quadrat locations and so that section of coast was not included in the assessment. The boat operator recorded basic quadrat attributes including the GPS location (waypoint), depth at that point, quadrat depth range, quadrat substrate, quadrat slope median and range. The snorkeler provided the data for the latter three matters. In addition the boat operator recorded date, time, sea conditions, wind direction and speed. The snorkeler then assessed percent cover for a variety of cover classes including individual tall brown algae species, juvenile tall brown algae, red algae, algal turfs (usually coralline), algal felts, coralline paints, encrusting organisms, kina and the purple urchin (*Centrostephanus rodgersii*). Urchin barren type (typical or transitional) was identified. Any additional notes were made. More detail about the cover classes assessed, data collected, and types of urchin barrens is in Appendix 3. Once the assessment of a quadrat was completed the snorkeler swam along to the next quadrat (as directed by the boat operator). This swim helped the snorkeler to assess the representativeness of each quadrat and to identify other trends such as extensive urchin barrens or kelp forest.

19. The plots were able to be relocated in 2021 as the boat operator in 2016 had saved as a numbered waypoint the centre of each 5 x 5m quadrat on a modern chart-plotter. There were also a series of maps (aerial images) showing the locations of each plot. To relocate a plot the boat operator moved the cross-hairs of the plotter to the next waypoint and it lit up as a red circle with a 5m radius (when the plotter is zoomed in to a scale of 20mm=20m). The boat operator then rowed the inflatable so that its position cursor disappeared inside the waypoint.

20. Tidal corrections were made to all the depths recorded in 2016. This was done by identifying the state of the tide in half hour increments in 2016 and 2021 for each quadrat. This allowed the boat operator to use the adjusted depth to help correctly re-locate a quadrat in 2021. Other quadrat specific data collected in 2016 was also

referenced. The percent cover for each cover class was then assessed by the snorkeler free diving several times at each waypoint. How well each quadrat represented the nearby reef at that depth range was also assessed. These collective measures ensured that each re-measured quadrat fairly represented the section of shallow reef being sampled. There was, however, high variability between some nearby quadrats, depending upon the slope/orientation, the depth, the degree of exposure, and the succession history of the respective sites.

21. Additional swimming and free-diving surveys were undertaken in Karerarera Bay and Whapukapirau Bay to search for any remnants of the green-lipped mussel colonies found inside and outside the assessed quadrats in 2016.

RESULTS

2021 re-measurement

22. It has been more than ten years since the establishment of the Maunganui Bay no-take Rahui excluding kina. Kina was interpreted as *Evechinus chloroticus* in the early closure notices and then in later notices as both *Evechinus chloroticus and Centrostephanus rodgersii*.

23. My observations are that there has been a notable recent increase of kelp or tall brown algae cover in many of the shallow rocky reef habitats along with notable increases in larger snapper and overall increases in packhorse and red rock lobsters abundances. Other notable abundance increases include butterfish (*Odax pullus*) and red pigfish (*Bodianus unimaculatus*). In contrast the abundance of kina in many areas has decreased with *Centrostephanus* now being more abundant in some areas (e.g. White Reef).

24. The 2021 resurvey of the 55 Maunganui Bay quadrats found that tall brown algae (kelp forest) cover had increased significantly since 2016 in the shallow rocky reef habitat of 2-10m depth (see **Table 1**). This corresponded with a significant decrease in urchin barrens. The main areas where urchin barrens were still relatively extensive were the southern part of White Reef, south-east of Putahataha Island, the embayment mid-way along the eastern shore of Maunganui Bay and some of the area by Motuwheteke Island. The ratio of classical to transitional urchin barrens (see **Table 2** for definitions of different types of urchin barrens) in Maunganui Bay quadrats in 2021 was 2:1, down from 3:1 in 2016.

25. The shallow rocky reef habitats between Maunganui Bay and Oke Bay have also changed. The 2021 assessment found that the extent of urchin barrens has increased while the extent of tall brown algae cover has decreased in the 2-10m depth zone on rocky reef habitat (see **Table 1**). The ratio of classical to transitional urchin barrens in this sector in 2021 was 3: 1, up from 2:1 in 2016. Observed *Centrostephanus* numbers in the 2-10m depth range seemed to be higher, with most typically concentrated in cracks. In contrast kina were more likely to be out in the open.

26. In addition all the green-lipped mussels have gone. In 2016 subtidal green-lipped mussels were abundant in several of the southern bays. By 2021 all of these mussels had gone from both the quadrats and along any of the shoreline. However the distinctive

algae communities of which the mussels were a part remain to some degree, especially in the outer sections of Karerarera Bay and to a lesser extent Whapukapirau Bay.

27. The outer sections of Karerarera Bay differ from the rest of the shoreline in this unit in having a relatively high proportion of Ecklonia with a relatively narrow band of urchin barrens where it exists. The outer shallow reef slopes and walls have a particularly diverse cover. There is often a band of *Cytosphora* species covering a depth range of 1 metre or less, sometimes with *Carpophyllum* species[12]. There is then a 4+ metre depth band consisting of mixed red algae species (e.g. *Pterocladia lucida* and *Pterocladiella capillacea*, *Methanthalia abscissa),* diverse tall coralline turfs, common anemones, and juvenile tall brown algae species. Below this was an area dominated by *Carpophyllum* species and then *Ecklonia radiata*[13].

28. The southern part of Oke Bay is dominated by sand and has insufficient rocky reef habitat for assessing rocky reef cover in 25m^2 quadrats. This limits the number of quadrats compared to the other two sectors being discussed and so the confidence intervals are larger. The 16 Oke Bay quadrats run from part way along the eastern shore, across to eastern Moturahurahu Island and along its southern shore to the nearby western shoreline of Oke Bay. This sector also showed a significant decrease in the extent of tall brown algae and significant increase in the extent of urchin barrens in the 2-10m depth zone on rocky reef (see Table 1). The ratio of classical to transitional urchin barrens in Oke Bay quadrats in 2021 was 15: 1, up from 2.5:1 in 2016.

29. The former areas of subtidal and intertidal green-lipped mussels around the eastern and northern shores of Moturahurahu Island were largely gone in 2016. Most of the mussels here had been harvested by 2012 apart from a very small patch in a high wave energy zone. The eastern shore, where the green-lipped mussels used to be, has relatively abundant red algae, patchy tall brown algae (*Carpophyllum, Cystophora*, and *Ecklonia*), common anemones, tall coralline turfs and kina.

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[12] *Cytosphora* and *Carpophyllum* are tall brown algae genera
[13] tall brown algae species

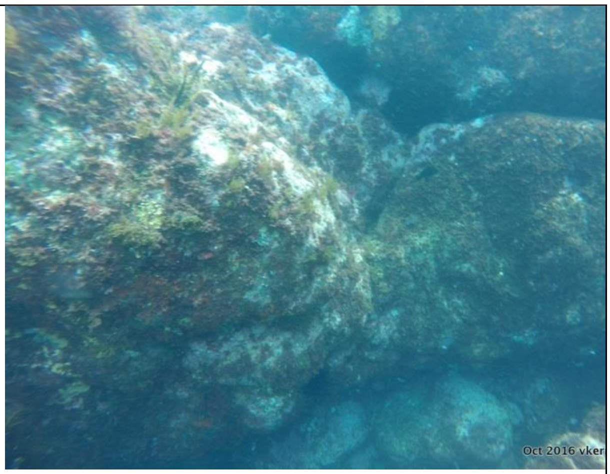
Table 1: Tall brown algae and urchin barren cover in 25m^2 quadrats in 2-10m depth range on rock reefs; Comparison between 2016 and 2021 for Maunganui Bay, Maunganui Bay to Oke Bay and for Oke Bay (percent cover +/- 95% confidence intervals)

Percent cover	**Maunganui Bay % cover**	**Coast from Maunganui Bay to Oke Bay % cover**	**Oke Bay % cover**
Number of quadrats	55	64	16
Tall brown algae cover 2016 & 95% CI 2021 & 95% CI	46.3 +/-6 77.8 +/-5	48.4 +/-4.6 36.5 +/-5.7	38.7 +/-9 19.2 +/-9.7
Total urchin barrens cover 2016 2021 & 95% CI	42.4 18.07 +/-5	39.2 58.4 +/-6	53.8 78.9 +/- 10.4

Table 2: Types of urchin barrens in the study area

Type of urchin barrens	**Description**
Classical urchin barrens	This is based on cover categories and the pattern of those categories. Included are turfs (especially low turfs), algal felts, coralline paints and space occupied by urchins. Excluded are all tall brown algae including juveniles. Also excluded are red, other brown and green algae except where they form low turfs or algal felts. Patches of sand and small cobbles are excluded as they are generally unsuitable substrates for macro-algae. Mussel-communities and extensive areas of encrusting sponge and anemone growth on walls are also excluded. Areas of abraded bare rock are also excluded although these are rare in subtidal environments.
Transitional urchin barrens/ urchin modified habitat	This includes the same cover categories as classical barrens. What differs is that the barrens are patchy with remnant or regenerating tall brown and other tall algae species. Patchy tall brown algae are typically scattered through low stature cover classes found in classical urchin barrens. Tall turfs (than 5cm) can also be present.

Classical urchin barren



Classical urchin barren

Transitional urchin barren

Transitional urchin barren

DISCUSSION

30. The changes in the extent of tall brown algae (kelp forest) cover and urchin barrens observed for Maunganui Bay were large. Reversing urchin barrens can be a very slow process. It is probable that for the first five years of no-take except for kina (2010-2016) there was relatively little change in either the extent of tall brown algae cover or urchin barrens (in the 2-10m depth zone on rock reefs). The progress of the next five years (2016-2021) seems to have been relatively fast. It seems that the cumulative effect of not removing the predators (especially larger snapper and rock lobsters) plus the ongoing removal of urchins by divers (to feed snapper) and by hapu members[14], has led to a much more favourable environment for the expansion in the extent of tall brown algae and the reduction in urchin barrens within Maunganui Bay.

31. The closure area at Maunganui Bay is relatively small. There is only the western boundary where snapper and lobsters moving out of the no-take area can be harvested. As explained in Dr Nick Shears' evidence, in contrast to Leigh and Tauwharenui, the

[14] Regular personal observations in both cases

seabed depth on the outer (here western) boundary increases rapidly quickly to 40m. This may have helped promote the recovery of tall brown algae species by reducing the likelihood of the kina predators migrating beyond the no-take area at this early stage at least. As the evidence of Nick Shears describes, over time larger no-take areas deliver greater biodiversity benefits.

32. It will be critical to maximise the retention of lobsters within the Rahui Tapu as lobsters seem to be the main predators[15] for the larger purple urchin Centrostephanus[16]. Centrostephanus grazing can form barrens at greater depths than those formed by kina (*Evechinus chloroticus)* grazing. A 2016-17 resurvey of 156 eastern Tasmanian transects established in 2001-02 found a 10.5% annual increase in urchin barrens resulting from Centrostephanus grazing in the 4-40m depth range[17]. Over recent years commercial lobster pots have been regularly placed close to the western boundary of the Maunganui Bay temporary closure area.

33. In contrast to Maunganui Bay itself, the coast between Maunganui Bay and Oke Bay, has not been a no-take area. The extent of urchin barrens in the 2-10m depth range has increased significantly since 2016. The loss of the green-lipped mussel beds in this area since 2016 is part of the serial loss of subtidal and intertidal green-lipped mussels in the eastern Bay of Islands. In 2016 those mussel beds had been the last stronghold in the eastern Bay of Islands. As with the rest of the Bay of Islands the likely cause of the green-lipped mussel decline was human harvesting[18] . The remnant -cover for these former mussel beds is ecologically diverse, especially in outer Karerarera Bay and to a lesser extent Whapukapirau Bay.

34. The reduction in tall brown algal cover (kelp forest) and the increase in urchin barrens in Oke Bay were significant. While the number of quadrats was lower than in the other two sectors, there was a clear trend. Of particular note was the increase in the ratio of classical urchin barrens to transitional barrens from 2.5:1 in 2016 to 15:1 in 2021, signifying an ongoing degradation of the remnant kelp forests. This Oke Bay area and the adjoining reefs are subject to relatively high levels of recreational fishing, primarily because Oke Bay is a popular sheltered anchorage.

CONCLUSION

35. Maunganui Bay has been closed to all fishing, except for the taking of kina, since 2010. This has led to an increase in the numbers and size of the main predators of kina (*Evechinus chloroticus).* The April 2021 re-measurement of quadrats established in 2016

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15 Department of Primary Industries, Parks, Water and Environment, Tasmania. Long Spined Sea Urchin Strategy. https://dpipwe.tas.gov.au/sea-fishing-aquaculture/sustainable-fisheries-management/fisheries-management-strategies/long-spined-sea-urchin-strategy

16 Centrostephanus arrived in New Zealand on the east Auckland current; and in Tasmania on the East Australian current from New South Wales (Johnson et al 2005 Establishment of the Long-spined sea urchin *Centrostephanus rodgersii* in Tasmania: first assessment of potential threats to fisheries. FRDC Project 2001/044)

17 Ling SD & Keane JP2018. Resurvey of the longspined sea urchin (*Centrostephanus rodgersii)* and associated barren reef in Tasmania. Institute for Marine and Antartic Studies, University of Tasmania, Hobart, Australia

18 I have observed harvest pressure sequentially remove green-lipped mussel beds from throughout the eastern Bay of Islands.

showed a significant reduction in urchin barrens and a significant increase in kelp forest in the 2-10m depth range since 2016.

36. In contrast, the area of nearshore marine environment extending south to and including Oke Bay has had no such controls. The April 2021 re-measurement of quadrats established in 2016 showed a significant increase in urchin barrens and a significant decrease in kelp forest in the 2-10m depth since 2016. The last remaining eastern Bay of Islands green-lipped mussel beds that were in this area in 2016 had disappeared by 2021.

37. The proposed Maunganui Bay – Oke Bay Rahui Tapu would allow the biodiversity gains of the existing Maunganui Bay temporary fishing closure to be retained. Over time there will be further biodiversity gains, including the ongoing recovery of kelp forest. The proposed Rahui Tapu would, over time, extend the Maunganui Bay biodiversity gains to a larger area. As explained in the evidence of Nick Shears a large area is necessary to maximise biodiversity benefits.

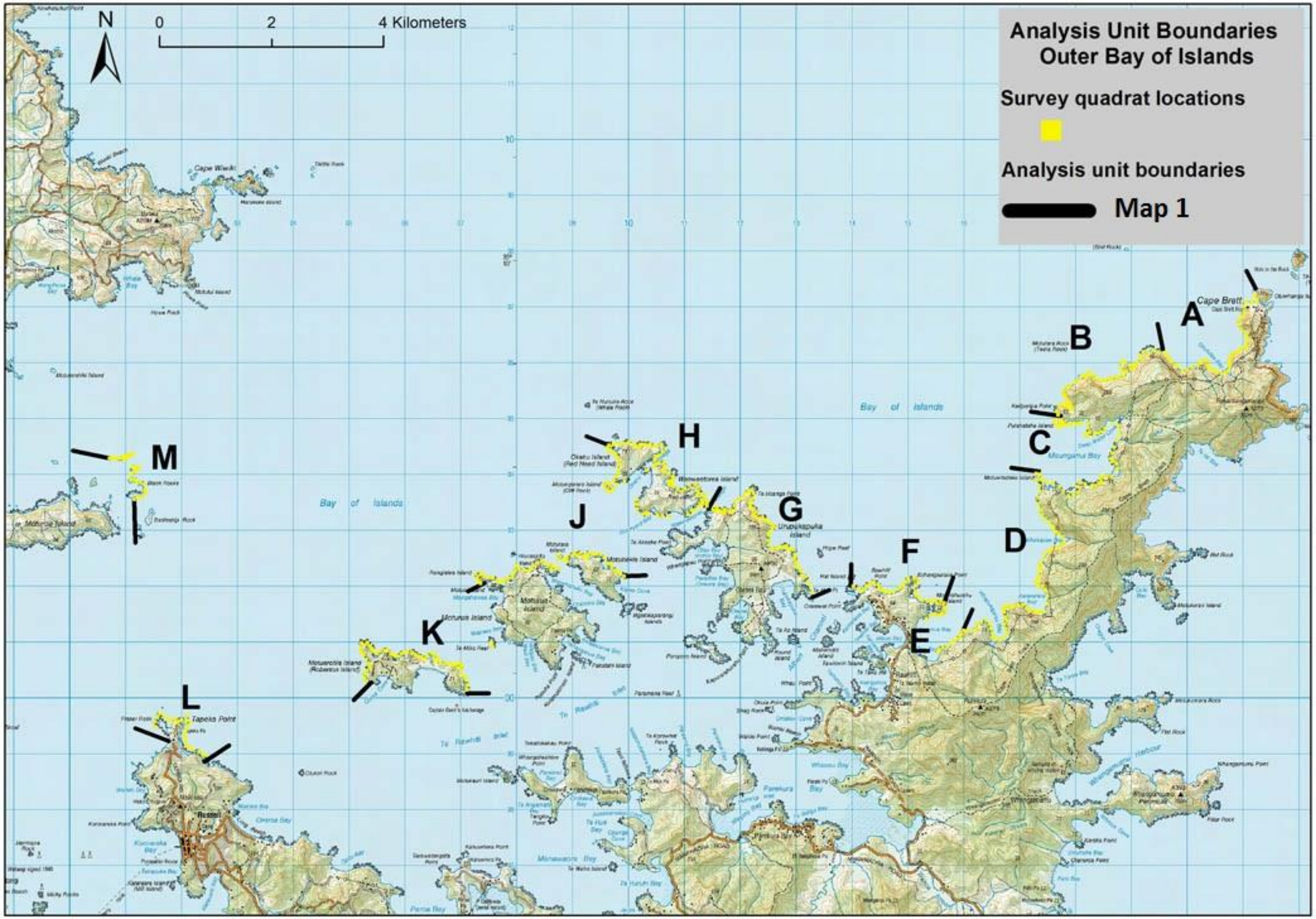
Victoria Froude

19 April 2021

Appendix 1

Maps 1, 2 and 3 are from the 2016 survey report[19]. Map 1 shows the analysis units for the 2016 assessment. The April 2021 assessment was for Analysis Unit C (Maunganui Bay), D (Coast from Maunganui Bay to Oke Bay), and E (Oke Bay). Maps 2 and 3 show the location of the quadrats assessed in 2016. Map 2 shows the northern half of Maunganui Bay while Map 3 shows the southern half of Maunganui Bay plus the coast between Maunganui Bay and Oke Bay plus Oke Bay itself. Areas to the north of Maunganui Bay and west of Oke Bay were not included in the April 2021 survey.

[19] Froude, V. A. (2016). Kelp cover and urchin barrens in the Bay of Islands: a 2016 baseline. A report prepared for Bay of Islands Maritime Park. 72p. https://www.fishforever.org.nz/images/ff/documents/reports/Kelp_cover_and_urchin_barrens_in_the_Bay_of_Islands_FINAL_Dec_2016.pdf


Analysis Unit Boundaries
Outer Bay of Islands
Survey quadrat locations
Analysis unit boundaries
Map 1
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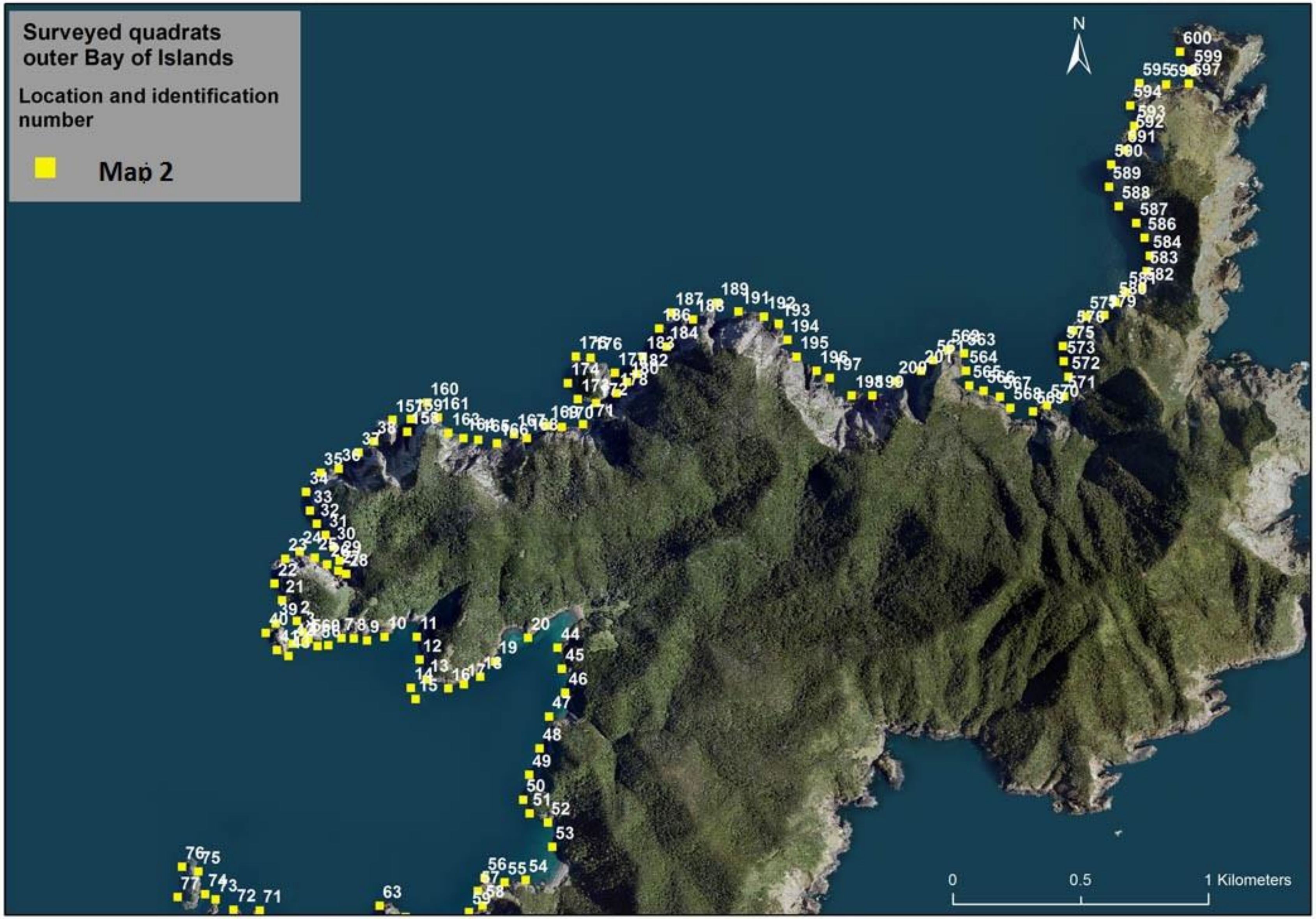
Surveyed quadrats
outer Bay of Islands
Location and identification number
Map 2
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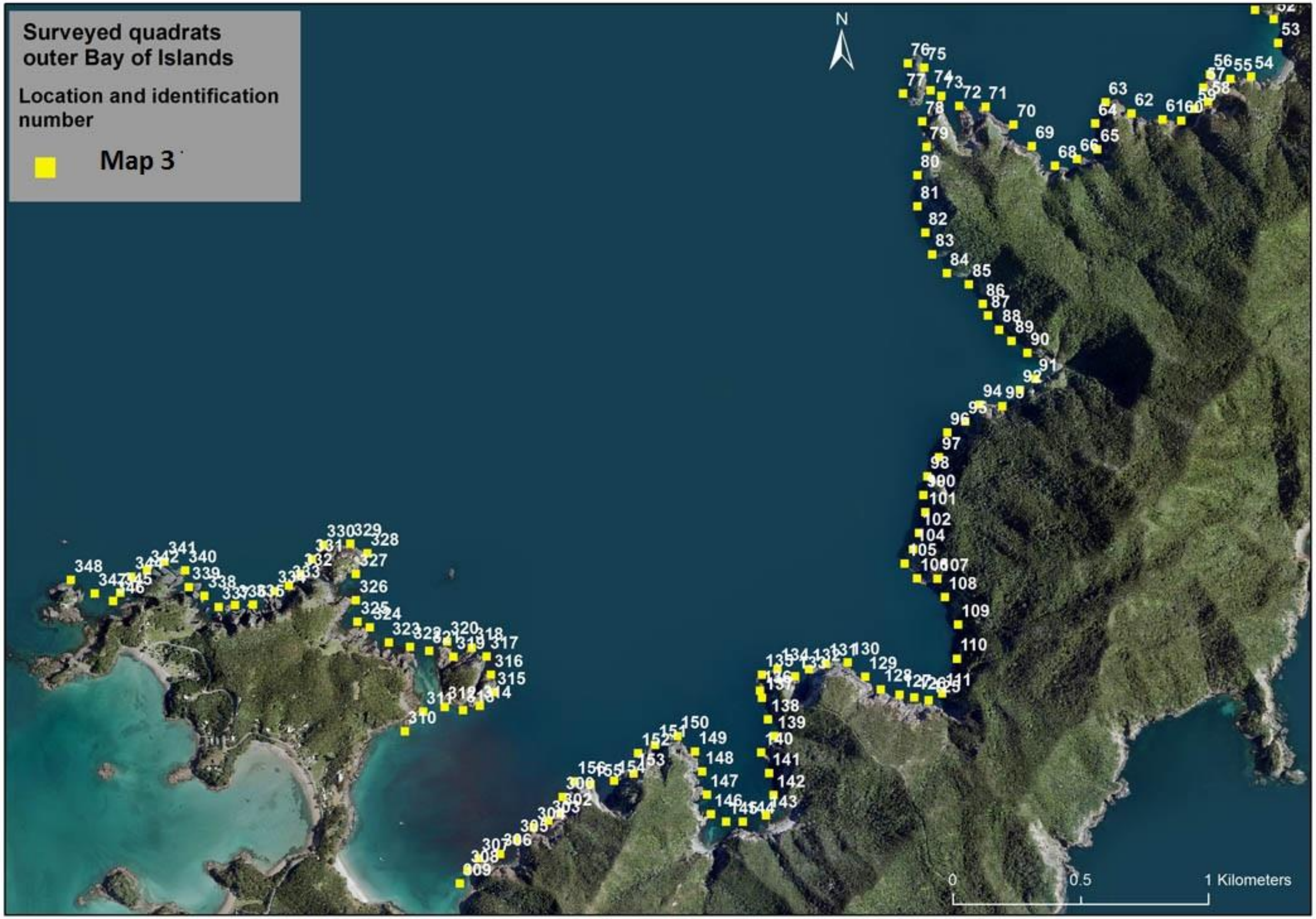
Surveyed quadrats
outer Bay of Islands
Location and identification number
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Appendix 2

Table 1: Comparison of methods for measuring algal cover and urchin barrens in shallow rock reef environments

Method	What is measured	Advantages	Disadvantages	Possible mitigation
Habitat mapping side scan sonar	Habitat structure/ type	Such mapping has been done for eastern Northland Provides an overall habitat map Can assess structure to depths > 30m	Not at a detailed scale Focus is on structure not biological composition Local topography can affect the extent to which urchin barrens can be accurately identified in some locations	
Satellite or aerial imagery interpretation	Extent of urchin barrens in shallows	Remote sensing is relatively quick Visual representation Can be repeated	Local topography can affect the extent to which urchin barrens can be accurately identified especially in deeper and steeper locations or where there are shadows Tends to identify larger shallow and low gradient urchin barrens Water clarity and image quality significantly affects the maximum depth where urchin barrens can be clearly distinguished from other features or substrates Limited capacity to identify more complex covers and environmental patterns beyond those in very shallow environments	Seek out high quality imagery when water clarity is relatively high and lighting conditions are optimal
Transects with cover assessed at regular points along a measuring tape	Cover category at points	Can get a lot of point data	Requires the use of scuba equipment which is logistically complex Typically the data is analysed by transect and completing sufficient transects is logistically difficult (especially given scuba limitations) Difficult to relocate transect unless the	

Method	What is measured	Advantages	Disadvantages	Possible mitigation
			tape runs from, and at right angles to, the shore. Even then there is a risk that in complex shallow reef environments that much of the points in repeated measurements are in different locations	
Percent cover in representative quadrats	% cover by cover class % typical and transitional urchin barrens % cover of tall brown algae (kelp)	Standard approach to cover assessment, especially in terrestrial and lake environments Assessment of % cover by snorkel in 25m² quadrats means that is logistically possible to get sufficient replicates to show change over time	The method is useful for assessing the % cover and urchin barrens within the 2-10m depth zone on rocky reefs. This is the depth range which has been where kina barrens have been most common. It would be more difficult to use snorkel to assess the extent of *Centrostephanus* barrens which are typically deeper. There is a risk that quadrat placement can be subjective It may be difficult to exactly relocate quadrats	Protocols can be used to minimise subjectivity in initial quadrat placement and to relocate quadrats when re-measuring Quadrat data for each analysis unit is analysed as a block and so it is not critical that each re-measured quadrat is in the same location

Appendix 3; Quadrat methodology detail

Table 1: Cover classes assessed for each quadrat

Cover class category	**Cover class**	**Description and notes**
Tall brown algae cover	*Ecklonia radiata*	
	Carpophyllum spp	
	Lessonia	Found in the most exposed sites (not in the quadrats assessed in April 2021)
	Cystophora spp	
	Other tall browns	e.g. *Landsburgia*
	Juvenile tall brown algae species	
Low brown algae	Low brown algae species	
Red algae (excluding coralline turfs)		*Pterocladia lucida, Pterocladiella capillacea and Methanthalia* are the most common non-coralline red algae found in the shallows of the Bay of Islands
Green algae		
Turfs	Turfs including corallines and brown algae	This primarily consists of non-encrusting coralline algae Where the turf was taller than 5cm it was recorded as "tall turf".
Algal felts		Filamentous low brown algae, usually found in more sheltered sites.
Encrusting	Encrusting sponges and anemones	Encrusting sponges and anemones are typically found on walls and in darker locations such as caves and arches. Sponges are also found in deeper lower-light sites below the kelp forest. Sponges and anemones are present in lesser amounts in more open rocky reefs often in microsites where there is less light or maybe they initially developed under kelp forest.
Coralline paints		These include pink and purple encrusting coralline algae species, and red crusting algae
Mussel communities		Present in the survey area in 2016, it had completely gone by 2021
Bare rock		This is abraded subtidal rock without biological cover. In practice very little shallow subtidal rock is bare
Cobbles		Where rocky reefs are patchy a small area of cobbles may be included in a corner of the quadrat.
Sand		In most cases this is sand washed up onto rock. Occasionally where reefs are patchy a small area of sand may be included in a corner of the quadrat
Kina		% cover and median size class. The latter is for the mainland Eastern Northland context (S, M,L)
Centrostephanus		% cover and median size class. The latter is for the mainland Eastern Northland context (S, M,L)

Table 2: Other data collected at each quadrat point

Data item	Notes
Quadrat number	As assigned sequentially by the GPS chartplotter
Locality	Broad locality name
GPS	Eastings & northings using WG84 datum (with decimal minutes rather than seconds)
Depth at GPS point	Depth at the GPS position was recording
Date	Date of assessment
Time	Start time for quadrat assessment
Depth range	For the assessed quadrat at the time of assessment
High tide time	Nearest high tide
Exposure class	This is for the quadrat overall (3 classes: sheltered, partly exposed and exposed)
Analysis unit	Sites from a similar locality and average exposure class are grouped into analysis units or sectors. Thirteen analysis units were used for this project. Table 4 lists the analysis units and Map 1 shows the boundaries of these units
Substrate (and basic geomorphology)	This is the primary substrate and geomorphology and primarily includes: rock wall (if >55 degrees slope), rock slope(s), rock flat, rock platform and boulders.
Other geomorphology	This is an optional column that can be used to record additional geomorphology information if required. It can include substrate that is present in low levels (e.g. boulders, broken rock, sand or cobbles). This is most likely where the rock reefs are patchy in a matrix of sand or cobbles. Sometimes the orientation of a wall is included where it is not obvious.
Visibility	Underwater visibility rounded to the nearest metre
Wind	Direction and speed in knots at the quadrat site at time of assessment
Swell	Swell size at the quadrat site at the time of assessment
Median slope	Of the quadrat overall (in degrees)
Slope range	Of the quadrat overall (in degrees)
Representativeness	This indicates how representative the quadrat cover is compared to that found in nearby areas with a similar substrate and at a similar depth (3 classes-typical (T), moderately representative (M) and not-typical (N). In practice the "N" class was rarely used as we tried to avoid non-typical sites.
Notes	Observations included unusual or notable fish seen, characteristics of the encrusting cover, and observations about the cover seen between quadrats. The latter focused on the extent of kina barrens.

Table 3: Analysis units used in 2016

Group	Geographical area or sector
A	Cape Brett- Pig Gully/Ohututea Bay
B	Pig Gully-Maunganui Bay/Kariparipa Point
C	Maunganui Bay
D	Motuwheteke Island-Whapukapirau Bay
E	Oke Bay-Opourua Bay-Moturahurahu
F	Moturahurahu Island- Albert Channel
G	Urupukapuka Outer-Waewaetorea Passage
H	Outer Waewaetorea & Okahu Islands
I	Sheltered Waewaetorea & Okahu
J	Outer Motukiekie-Moturua Islands
K	Outer Motuarohia
L	Outer Tapeka
M	Black Rocks

In April 2021, groups C, D and E were re-measured