**I TE KŌTI TAIAO Ō AOTEAROA
IN THE ENVIRONMENT COURT
OF NEW ZEALAND**

**ENV-2019-AKL-117
ENV-2019-AKL-127**

UNDER	the Resource Management Act 1991 (the Act)
IN THE MATTER OF	appeals pursuant to Clause 14 of the First Schedule of the Act against decisions of the Northland Regional Council on the proposed Northland Regional Plan
BETWEEN	**Bay of Islands Maritime Park Incorporated** ENV-2019-AKL-117
	The Royal Forest & Bird Protection Society of New Zealand Incorporated ENV-2019-AKL-127
	Appellants
AND	**Northland Regional Council**
	Respondent

SUPPLEMENTARY STATEMENT OF EVIDENCE OF VINCE CARLYLE KERR

ON BEHALF OF TE URI O HIKIHIKI HAPU AND NGĀTI MANUHIRI

DATED 14 May2021

Solicitor Acting
Jason Pou
Tu Pono Legal Limited
1222 Eruera Street
Rotorua
E: pou@tupono.co.nz
Ph: 07 348 0043

Barrister Acting
Rob Enright / Ruby Haazen
Arapeta Chambers &
Magdalena Chambers
Wānaka / Tamaki Makaurau
E: rob@publiclaw9.com
Ph: +64 21 276 5787

Introduction

1. My name is Vincent Carlyle Kerr. I provided evidence in chief on behalf of the Te Uri o Hikihiki Hapū dated 25 March 2021.

2. My primary evidence addressed the marine ecological work that has been completed in the Mimiwhangata area relevant to the appeal raised by Te Uri o Hikihiki Hapū. I also presented evidence on the ecological and conservation values of the relief sought by the Hapū.

3. This supplementary evidence will address:

   a. how the proposed Rāhui Tapu area at Mimiwhangata was designed and summarises principles and international best practice alongside a context of design of protected areas in New Zealand; and
   b. report on recent field survey work and analysis of aerial photography aimed at checking on the current status of kina barrens in the proposed Rāhui Tapu area at Mimiwhangata

4. 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.

Development of Design Principles for full no take reserves

5. The design of full no-take reserves and systems or networks of reserves is not a new field of applied marine ecology. New Zealand pioneered in this area with the design of the first marine reserve at Leigh in the 1970's. Since that time, marine ecologists in New Zealand have steadily built a large body of information on design criteria and ecological understanding of the impacts and benefits of no take reserves. The benefits are many

and include: and range across multiple aspects of biodiversity protection, restoration of exploited specie, education and recreation.

6. In this evidence I will summarise the design principles and criteria that have been adopted internationally and the relationship of these principles and criteria with the formation of systems or networks of marine reserves. I will then speak specifically to the design process that has led to the current version of the Rāhui Tapu being proposed by Te Uri o Hikihiki.In New Zealand the development of practical guidelines for the design of marine reserves was pioneered by the late Dr. Bill Ballantine, who for many years was the manager of Leigh Laboratory in his role as a professor of marine biology with the University of Auckland. Dr. Ballantine's work is highly regarded internationally and is quoted throughout the international literature. Dr. Ballantine set out to create a set of principles to guide design, which was first published in 1997[1]. Much of the work leading to the principles arose out of observations and the many studies undertaken at the Leigh Marine Reserve in its first two decades since its establishment. It is a testament to his work that these principles are still used today and have formed the basis of the design process for numerous Marine Protected Networks around the world including the extensive guidelines and network targets adopted by the United Nations in their global Ocean conservation program. [2] [3] The principles also appear in modified form in the New Zealand MPA Policy and Implementation Guide. [4]

[1] Ballantine, W. J. 1997 *Design principles for systems of 'no-take' marine reserves.* Presented at a workshop on 'The Design and Monitoring of Marine Reserves' at Fisheries Centre, University of British Columbia, Vancouver, February 1997.
[2] IUCN World Commission on Protected Areas (IUCN-WCPA) (2008). Establishing Marine Protected Area Networks—Making It Happen. Washington, D.C.: IUCN-WCPA, National Oceanic and Atmospheric Administration and The Nature Conservancy. 118 p
[3] Secretariat of the Convention on Biological Diversity, 2004. Technical Advice On The Establishment and Management of a National System of Marine and Coastal Protected Areas, SCBD, 40 pages (CBD Technical Series no. 13).
[4] Ministry of Fisheries and Department of Conservation. (2008) Marine Protected Areas: Classification, Protection Standard and Implementation Guidelines. Ministry of Fisheries and Department of Conservation, Wellington, New Zealand. 54 p.

7. In his 1997 paper, Dr. Ballantine stated the principles for a core full no take reserve. In one section he stated his experience of what people could easily understand about the meaning of the principles:

"Over the past 30 years I have spoken on marine reserves to a large number of public meetings, schools, and other groups, including elected politicians. This experience covers several countries, many different regions. and a wide range of initial hostility/support. I have found that the great majority of people (even when they have only thought about the matter briefly) do believe the following points:

Representation:

(a) Different pieces of the sea (regions and habitats) have different animals and plants.
(b) We do not know all the species, still less what they all do.
(c) Keeping examples of all (and their habitats), until we do know, is common sense.
(d) Setting theoretical priorities for doing this is silly. It is like trying to rate the priority of parts of your own body - i.e. pointless unless you are forced to do so, and then pointless because it will happen anyway.

Replication

(a) Most knowledge depends on having more than one instance.
(b) For important things, we need separate examples, in case of accidents or mistakes.
(c) If 'undisturbed' examples of some habitats are popular for education, recreation or any other common use, then we need more of them.

Network

(a) Covering all the options is better than picking one, especially if we know very little.

(b) The dispersal and migrations of different species will be different

(c) Currents are likely to vary a lot between years.

(d) A system should maximise the benefits by multiplying the possibilities. It should not calculate the theoretically 'best' arrangement and just have that one.

Amount

(a) The area where fishing is allowed is less important than the state of the fish stocks.

(b) Banning fishing in 20% of the area of a stock is likely to be helpful in the long run.

(c) Fishing and mining are not the only uses of the sea or the most important ones - merely those that are easiest to argue about.

(d) *The really important functions of the sea - like control of the world climate - are only dimly recognised and far from understood. (e) A 'no-take' marine reserve system must be able to sustain itself, and should aim at sustaining all the functions of the sea."*

8. Dr. Ballantine summarised the principles at the end of the paper in the context of how they should be considered alongside socio-economic considerations:

"There are already enough examples of 'no-take' marine reserves to show they are practical in socio-political terms and provide a wide range of benefits.

2. The benefits include:

(a) direct benefits - to scientific research, education at all levels, many forms of recreation, provision of information to management, monitoring natural marine variation and the conservation of marine diversity (genetic, species and habitat).

(b) indirect benefits - by providing marine ecosystem support and general insurance against unpredictable or unpreventable events, especially for harvested species.

3. These benefits would be optimised if 'no-take' systems had the following principles:

(a) ***representation*** *(of all biogeographic regions and all ecological habitats in these)*

(b) replication (several separate examples of each representation)

(c) network design (maximising the pathways for recruitment and other support)

(d) a total amount sufficient for the system to be self-sustainable.

4. The ***total amount*** *(by area) required to provide for the direct benefits would need to be at least 10%, the total amount to optimise the indirect benefits would be ~ 20-30%.*

5. Moving to systems of marine reserves, and applying the above principles in the order stated, avoids most of the scientific problems that arise in 'one-by-one' or problem- solving approaches. Detailed predictions of effects are no longer expected and difficult cases at each level (biogeographic, ecological, replication, network) can be treated as simple decisions at the next level.

6. Accepting the principle of representation removes any scientific need to place regions or habitats in an order of priority. The principles of representation, replication and network design mean there is no scientific need to precisely locate the sites, nor for detailed survey data *to achieve this.*

7. Provided that the principles are adhered to, it is scientifically permissible for socio- political reasons to be used to develop the detailed priorities and precise locations of actual 'no-take' reserves in the system.

8. Moving to multi-purpose systems of marine reserves (and accepting the principles) avoids most of the political problems that are serious at present when each reserve is considered separately. The general public will give active support to sensible systems, whereas local proposals attract little attention except from those adversely affected.

More tools more information but the principles remain

9. In the last two decades information supporting marine protected area design has grown and there have been a number of large networks established [5] [6] [7]. There is refinement in our understanding of each of the principles and we have learned collectively a lot about the process of establishing reserves and networks. We now have a clearer picture of the '*Amount*' principle. Scientific consensus is clear that networks should contain a core system of fully no-take reserves that deliver the maximum benefits to fisheries and biodiversity protection and restoration when the 20-30% of all habitats are incorporated in the protection network. This body of work was summarised in a review paper calling for this to be the accepted amount goal for network design criteria. This goal figure has since been accepted by the IUCN biodiversity program.

[5] Fernandes, L. et al (2005). Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory on marine protected areas. Conservation Biology, 19 (6). pp. 1733-1744. http://eprints.jcu.edu.au/6122/

[6] Bernstein, B., Ludicello, S., Stringer, C., 2004. Lessons Learned from Recent Marine Protected Area Designations in the United States A Report to: The National Marine Protected Areas Center NOAA. The National Fisheries Conservation Center, Ojai, California.

[7] Munguia-Vega, A., Green, A.L., Suarez-Castillo, A.N. *et al.* Ecological guidelines for designing networks of marine reserves in the unique biophysical environment of the Gulf of California. *Rev Fish Biol Fisheries* **28,** 749–776 (2018)

10. Many ecological research programs have looked at the size question in design of reserves. In determining the most appropriate size there has been great progress in looking at a range of ecological factors (the list of ecological factors is in fact is very long) including: species home ranges, protection of genetic diversity, larval transport and recruitment, ecological roles of keystone species, behaviour studies, predatory-prey interactions, and full scale trophic level and ecosystem modeling projects. While all these areas of investigation inform design they don't necessarily produce perfect or 'best' answers to design questions. As Dr Ballantine predicted, there is no one answer and no perfect design, what is important is that we have enough of everything in full protection for system properties and connectivity to operate. Researchers can demonstrate specific results pertaining to target species and test reserves size and configuration for that species, however, while this is helpful it is also clear that the marine ecology and individual species go about their lifestyle at vastly different scales. It is also apparent that in the sea all scales matter and there is connectivity between them. For example, a marlin has a home range of hundreds or thousands of kilometers while its food species and their food webs may have much smaller home ranges. A kelp plant or some invertebrates may have a home range of only hundreds of meters. They can both benefit from protection from disturbance, however there is no one size that is best for a reserve design.

11. There are numerous examples of how networks have been designed and what is working and what is not and there are excellent guideline publications that synthesize this knowledge into practical approaches. I would like to quote this summary of key concepts relating to size and

shape of reserves from the IUCN publication, *Establishing Marine Protected Area Networks—Making It Happen.* [8]

"Key aspects to maximize individual MPA contribution to the network:

Size

• To ensure self-seeding of a reserve it should be as large as the mean larval dispersal distance of the target species (Shanks et al. 2003, Botsford 2001). Aim for MPAs that are 10 to 20 km in diameter across their minimum width.

• To meet both fishery and conservation goals, intermediate sizes of MPAs and a variation of sizes within a network is considered ideal.

• If the design is focused on target species, optimal sizing may differ depending on the particular species characteristics.

• One approach to network design is to establish the size of MPA based on adult neighborhood sizes of highly fished species, and space the MPA based on larval neighborhood scales.

Spacing

• To facilitate dispersal and promote connectivity between MPAs, MPAs should be placed appropriately to capture the middle range of dispersal distances. Spacing guidelines vary by habitat and region, with estimates ranging from 10 to 20 km of one another (Shanks et al. 2003) to 50 to 100km (CDFG 2007) to capture effective connectivity.

• MPAs should be spaced to capture the biogeographic range of variation in habitat and species.

• Variable spacing is better than fixed spacing when there are several small MPAs rather than a few large MPAs."

---

[8] IUCN World Commission on Protected Areas (IUCN-WCPA) (2008). Establishing Marine Protected Area Networks—Making It Happen. Washington, D.C.: IUCN-WCPA, National Oceanic and Atmospheric Administration and The Nature Conservancy. 118 p.

Shape

• The shape of the MPA should capture the gradient from onshore-offshore or habitat-habitat shifts of species of interest.

• A shape that allows for clear marking of boundaries for both resource users and enforcement personnel awareness may increase effectiveness. MPAs should be contiguous, compact and easily delineated.

• When designing shape for biodiversity conservation it is important to minimize edge habitat and maximize interior protected area. In contrast, for fisheries management, it is important to consider the type and spatial extent of the habitat bordering the MPA, since this will influence emigration (e.g. continuous habitat inside and outside of the reserve will enhance spillover effects (Carr et al. 2003)).”

Design history and process for the Mimiwhangata Rāhui Tapu area

12. The design of the current Rahui Tapu area had its beginning during the second Mimiwhangata investigation period beginning in 2000. The investigation itself, which is detailed in my primary evidence, was developed to support consideration of a marine protection proposal if it was determined that the current Marine Park arrangement was not effective.

13. Between 2000 and 2003, as the monitoring work and habitat mapping progressed the conclusion was reached by the science team that the Marine Park arrangement was not working and there were serious biodiversity decline issues.

14. The Te Uri o Hikihiki kaumatua in 2003-2004 made a decision to support an application for a Marine Reserve at Mimiwhangata for the purpose of

restoring the marine life there. The Kaumatua declared a Rāhui over the waters of Mimiwhangata at that time. With the cooperation of the Department of Conservation (**DOC**), the Hapū articulated their desire to establish a co-management regime for the Marine Reserve and they requested a generational review to be established similar to what exists for the Te Tapuwae Ronokako Marine Reserve on the Gisborne Coast. On this basis, design work then progressed under the guidance of the Kaumatua.

15. I lead the design work for DOC. At that time we set ourselves the goal of designing a reserve that:

    (a) met local criteria;

    (b) achieved restoration of the key predator species; snapper and crayfish; and

    (c) allowed for the shallow kelp forests to restore.

16. We also aimed to design a reserve that would meet all of the requirements to contribute to network goals at the Northland scale as understood at that time from best international practice.

17. By 2004 we had good quality habitat mapping and a good picture of the status of the key species, snapper *Pagrus auratus* and the main crayfish *Jasus edwardsii* and their role in controlling sea urchins in balance with the kelp forests. For both species we had new knowledge about home ranges of these two species and information on spillover, behavioral changes in the reserves happening with these and other species [9] [10] [11] [12]

---

[9] Babcock R.C., Attwood C.G., Egli D.P., Parsons D. & T.J. Willis (2002). Optimising Marine reserve design in New Zealand - Part II: Individual-Based models. Leigh Marine Laboratory, report to the Department of Conservation.

[10] Ballantine, W.J. 2014, ***Fifty years on: Lessons from marine reserves in New Zealand and principles for a worldwide network.***
Biological Conservation Volume 176, pages 297-307.

[13] [14] [15] [16]. At the Leigh Marine Reserve we were also learning about the 'edge affect' where fishing near the boundaries was affecting these two species (snapper and crayfish) within in the reserve, a certain distance from the boundaries. As a result of this information, along with the habitat mapping and ecological information, we formed a specific local criteria for the reserve design, which I will summarise as follows:

(a) bigger is better;
(b) shoreline distance at least as long as the Leigh Marine Reserve (6km) or longer if possible;
(c) offshore boundaries would if possible go out to at least 2km offshore;
(d) include the widest diversity of habitats possible ranging from the deep reefs (>30m depth) to the intertidal habitats;
(e) the widest possible range of exposures would be included,
(f) boundaries should wherever possible avoid cutting through major habitat areas;
(g) reef edges and adjoining soft sediment edge habitats should be included wherever possible;
(h) Connectivity between the shallow reefs (<30m depth) and the deep reefs (>30m depth) would be maximized wherever possible; and

---

[11] Willis T.J., Millar R.B. & R.C. Babcock (2003). Protection of exploited fishes in temperate regions: high density and biomass of snapper Pagrus auratus (Sparidae) in northern New Zealand marine reserves. Journal of Applied Ecology, 40: 214-227

[12] Gell, F.R. and Roberts, C.M. 2003: Benefits Beyond Boundaries: the fishery effects of marine reserves. TRENDS in Ecology and Evolution. Volume 18, Number 9, 9 September 2003.

[13] Parsons, D.M., Babcock, R.C., Hankin, R.K.S., et al., 2003. Snapper *Pagrus auratus* (Sparidae) home range dynamics: acoustic tagging studies in a marine reserve. Mar. Ecol. Prog. Series 262, 253–265.

[14] Langlois, T.J., Anderson, M.J., Babcock, R.C., Kato, S., 2006. Marine reserves demonstrate trophic interactions across habitats. Oecologia 147, 134–140.

[15] Freeman DJ, MacDiarmid, A.B., Taylor, R.B. (2009) Habitat patches that cross marine boundaries: consequences for the lobster *Jasus edwardsii*. Marine Ecology Progress Series

[16] MacDiarmid, A. B., Freeman, D., Kelly, S., 2013. Rock lobster biology and ecology: contributions to understanding through the Leigh Marine Laboratory 1962–2012, New Zealand Journal of Marine and Freshwater Research, 47:3, 313-333

(i) boundaries and seaward corners would be established with the most practical approach to ease navigation at sea and support compliance.

18. In 2004-2005 an initial design was completed and a proposal was presented to the public in the form of a consultation document [17]. There was also a detailed boundary investigation and report released at this time exploring local criteria (6) above [18].

19. From the consultation process in 2004 considerable input was received from submitters, which is summarised in the boundary report.[18]

20. By 2006 this new information was applied to the initial design and the boundaries were consequentially changed to what is shown as the Rāhui Tapu proposal currently. Essentially these changes made allowance for some recreational fishing to continue at the West and East ends of the proposed reserve. In 2006, a formal Marine Reserve Application had been prepared and was close to notification when DOC made the decision to withdraw from Marine Reserve applications. This decision coincided with release of the first version of the MPA Policy document. DOC stated at the time of the release of the MPA policy that all 'current' marine reserves projects would be 'incorporated' into the new MPA forum processes introduced in the Policy. From this turning point in 2006 marine conservation projects in Northland have been community and hapu lead with funding mainly coming from community based organisations and the philanthropic sources.

[17] Kerr, V.C., Grace, R.V., 2004. Marine Reserve Proposal Mimiwhangata Community Discussion Document. Department of Conservation.
[18] Fleming, A., Hawkins K., 2005. Boundary Options Assessment Report associated with the Mimiwhangata Marine Reserve Proposal. Northland Conservancy, Department of Conservation.

21. In the years following the events of 2006, Te Uri o Hikihiki remained dedicated to the kaupapa. There were several attempts to negotiate with Government Departments to support the proposal (which was renamed as the Rāhui Tapu proposal) . The only substantive changes to the proposal from 2006 onwards were in the management sections where the goal statements around co-management and implementation of those goals were strengthened with more practical detail added. Over the years from 2006 leading to the current Appeal case the Hapū has been supported by the Mountains to Sea Conservation Trust and Forest & Bird Protection Society. I have also supported the Hapū in providing ongoing ecological advice. The work from 2006 has mainly focused on management options and consultations with Government. There has been no other substantive changes made to the Rāhui Tapu proposal design during these years from 2006 to the present proposal.

Summary of design features of the Rahui Tapu proposal

Size matters

22. The Rāhui Tapu proposal is 4,890 hectares in total size, with the West and East buffer areas being 672 and 551 hectares in size respectfully. In comparison the Leigh Marine Reserve which is 518 ha in size, the Rāhui Tapu proposal is over nine times the size of the Leigh Marine Reserve. Of the 43 marine reserves on the mainland coastal area of New Zealand only two are bigger than the Rāhui Tapu proposal. Kahurangi on the West Coast of the South Island is 8,419 ha and Hikurangi at Kaikoura is 10,416 hectares. Kahurangi and Hikurangi are both more recently established reserves and thus their size reflects a general shift to larger reserves where this is practical. The Hikurangi reserve has a very small coastline with a larger area offshore covering the Kaikoura canyons.

23. With today's knowledge it is clear that the Leigh Marine Reserve should have extended further out to sea to include the outer deep reef areas and sufficient edge habitats and adjoining soft sediment areas where crayfish from the reserve regularly forage for food. While this is just one aspect of big is better, in the case of the Leigh Marine Reserve it has proved to be an important consideration. [14] [16]

24. The Mimiwhangata Rāhui Tapu has a coastline of 9.2 km with the West buffer area and the East buffer area having a coastline of 5.0 km and 3.2 km respectfully. This compares with the Leigh Marine Reserve coastline, which is approximately 6 km long. (Note these measurements of coastline length are approximate, as they will vary depending on the scale at which they were drawn).

25. In the early stages of creating a marine protected area network, each reserve contributes to representation of habitats by default as in Northland's case where there are no open coast protected areas other than the offshore Poor Knights Islands. It is typically hard for people to appreciate the sizes of the habitats and the coastal systems we are dealing with. To create some perspective around the area sizes involved with the Rāhui Tapu proposal I have calculated the area values represented in Table 1 below. While at first glance the areas of the habitats in the Rāhui Tapu may appear large, they are actually quite small in relation to Northland's East Coast, which is a logical scale to assess system or network connectivity and design.

26. Based on the 2009 Northland habitat map[19], deep reef systems for all of Northlands East Coast total 156,000 ha. The deep reef area within the Rāhui Tapu is about 1,800 ha which is approximately 1.2 % of the larger

[19] Kerr, V.C. 2010. Marine Habitat Map of Northland: Mangawhai to Ahipara Vers. 1. Technical Report, Department of Conservation, Northland Conservancy, Whangarei, New Zealand.

Northland deep reef area, whereas our protection goal would be 10% - 30% of the total habitat area in full protection to maximize benefits. From this perspective the Rāhui Tapu areas are small. Another context is that we are at the beginning of developing a protected area network in our coastal waters, and each step forward demonstrates and grows the overall system benefits of the network. [1]

Table 1 Calculated area values of habitats in the proposed Rāhui Tapu. (Note: source of area calculations for the Rahui Tapu are derived from Kerr & Associates GIS project and are unpublished.)

Habitat	Size
shallow *Ecklonia* forest reef <30m depth	300 ha
kina barren	180 ha
deep reef high relief >30m depth	300 ha
deep reef low relief and patch reef >30m depth	1,500 ha
Mimiwhangata's Rāhui Tapu deep reef as a % of East Coast Northland's deep reef area	1.2%

Habitat quality and diversity

27. The Rāhui Tapu proposal as described in my primary evidence and commented on in the primary evidence of Dr Shears has a high diversity of habitats and exposures. It is near the top of the list of Northland sites in fish diversity and includes virtually every exposure type and corresponding marine community and habitat found on Northland's East Coast. The proposal area also includes connectivity between this diverse array of shoreline and shallow habitats and shallow reef kelp forest

habitats and deep reefs. There is no other coastal marine reserve in New Zealand that has this extensive array of values.

28. Mimiwhangata is also strategically positioned in a triangle with the Poor Knights Marine Reserve and Cape Brett making connectivity gains and emergent benefits of network connections between these high quality habitats an important possibility for the future. Connectivity between reserves in the network is one of the most important design criteria with benefits growing exponentially as connectivity between reserve increases. [1] [10] [20] [12] [21]

29. For all these reasons the Rāhui Tapu area is expected to become a valuable contribution and design example for our emerging network of fully protected areas.

ANALYSIS OF KIN BARREN FIELD WORK

30. I have been asked by Te Uri o Hikihiki to do a check of the current status of the kina barrens. The last detailed mapping of the habitats and the kina barrens at Mimiwhangata was completed in 2004. [22] There has been no detailed study of kina barrens at Mimiwhangata since 2004, however I routinely check any new aerial photographs that come available and I have visited the area diving a number of times over the years.

[20] Roberts CM et al (2017) Marine reserves can mitigate and promote adaptation to climate change. Proc Natl Acad Sci USA 114:6167–6175. https://doi.org/10.1073/pnas.1701262114

[21] Sala E, Costello C, Dougherty D, Heal G, Kelleher K, et al. (2013) A General Business Model for Marine Reserves. PLoS ONE 8(4): e58799.

[22] Kerr, V.C., Grace, R.V., 2005. Intertidal and subtidal habitats of Mimiwhangata Marine Park and adjacent shelf. Department of Conservation Research and Development Series 201, 55 p.

31. I have not noticed any change in the status of the barrens over that time from these cursory observations. To complete a rapid survey of the kina barrens recent online aerial imagery was searched and a day of field based survey was completed at two reefs using a drop photo frame camera system.

Methodology field survey

32. A collection of aerial imagery having good quality visibility of the subtidal reefs from years 2016, 2018 and 2019 was georeferenced into layers in ArcGIS to compare to the 2005 habitat map and historic aerial imagery (source Grace & Kerr) from 2003 and 2006. Two reefs were selected to examine with a combination of methods utilizing comparison of overlaid imagery and habitat map layers in the GIS project and field ground truthing utilizing a 1 m^2 quadrat drop camera system. Transects lines of approximately 100m length were selected that crossed the profile of the reefs in the depth range of 4-8 m. Three transects were completed. The GoPro camera was set on continuous shooting at 5 second intervals taking 7 mega pixel images. The boat was moved slowly along the transect line while the frame was dropped to the bottom at approximately every 5-10 m intervals. In post processing an image was selected for analysis from each drop position when the frame was on the bottom and there was reef habitat. A score was recorded for the number of kina seen in the 1m^2 frame. The percentage of macro algal cover was estimated and notes were kept on the species of macro algae present.

Figure 1 The GoPro drop camera quadrat apparatus used for the field survey

Aerial photography method and analysis

33. Imagery from Google earth taken in 2016 and 2018 was obtained which had sufficient quality to support subtidal habitat interpretation and comparison with the aerial layers from 2003 & 2006 and the 2005 habitat map [1] for Mimiwhangata. The image layers were georeferenced in ArcGIS and assembled as layers allowing reef features and kina barren condition to be compared at relatively fine scales (down to 1:500 scale). A large area (1 km x 2 km) between the Mimiwhangata headland and Rimariki Island was selected for the comparison. This area has the largest area of kina barrens in the Mimiwhangata Park and is complex in terms of coastline and exposure to wave energy providing a good area to test the persistence of the kina barrens since the 2004 period. Examples of the imagery are shown in Figures 2 & 3 below with the photo frame quadrat transects indicated by red lines.

Figure 2 The aerial image is from the Grace and Kerr collection taken June 2006. The three transects used for the photo frame quadrats are indicated in red (map scale 1:5,000)

34. Figure 2 above gives us a view of the kina barren condition as of 2006. This image allows for reliable interpretation of the three main shallow subtidal habitats featuring in the 2005 habitat map; shallow mixed weed, kina barrens and *Ecklonia radiata* kelp forest. The shallow mixed weed can be seen typically as a dark band situated just below the low tide mark and extending downwards to 1-4m depth varying with exposure. This group of kelp species is resistant to wave action and is also typically more resistant to kina grazing than *Ecklonia radiata*. In persistent kina barrens the kina can gradually reduce this zone of the kelp forest community. This band of kelp is seen as a dark band along the shoreline or around rocks. Below the shallow mixed weed zone in most areas there is a zone extending down the reef, which appears lighter in the

image and at higher magnification, can be recognised as bare rock. This is the kina barren zone. Typically near the bottom of the reef or at about 12-15 m depth the kina barren reaches a solid stand of *Ecklonia radiata* kelp which extends downwards to a soft bottom edge or a depth of 30m where lack of light limits the range where the *Ecklonia* kelp can grow. In the Figure 2 image these bands of *Ecklonia* kelp can be seen as darker areas at the deeper edges of the reefs.

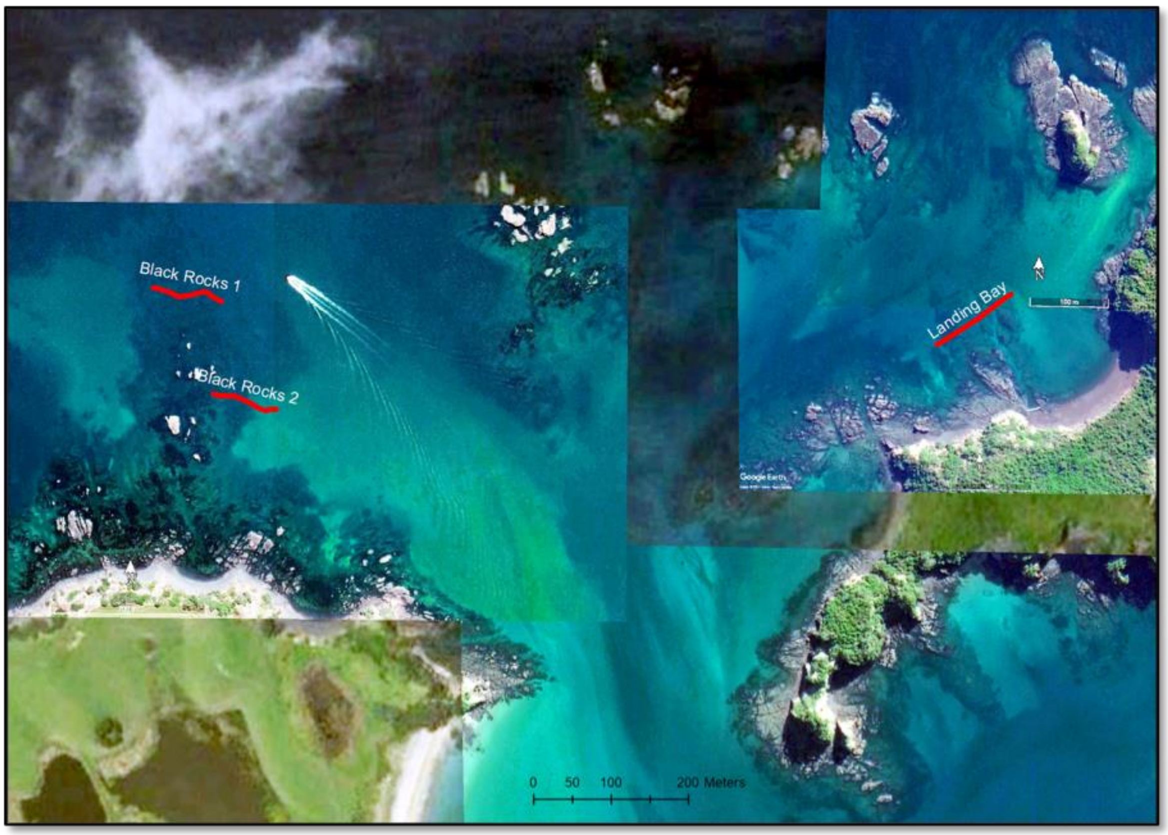

Figure 3 Aerial layers sourced from Google Earth imagery. The layer covering Black Rock Reef is from 2016 and the coverage of Landing Bay reef and the layer in bottom right corner was taken in 2019 (map scale 1:5,000)

35. Figure 3 shows the study area with an overlay of the recent images taken in 2016 and 2019. The quality and resolution of these images is

not quite at the high standard of the 2006 image, however in my opinion the quality was good enough to allow comparison of the spatial extent of the kina barren areas.

Result of aerial imagery analysis

36. The capabilities of the GIS environment allows for the various images to be turned off and on and also ‘swiped’ over the top of each other facilitating careful examination of the habitat boundaries. The interpretation in this way can be compared with the 2005 habitat map shown below in Figure 4. The reefs in the test area depicted in Figures 2-4 were examined looking for changes in the habitat boundaries. I was not able to find any of the reefs in this area that showed significant change in status of the kina barren extent between 2006 and 2016-2019.

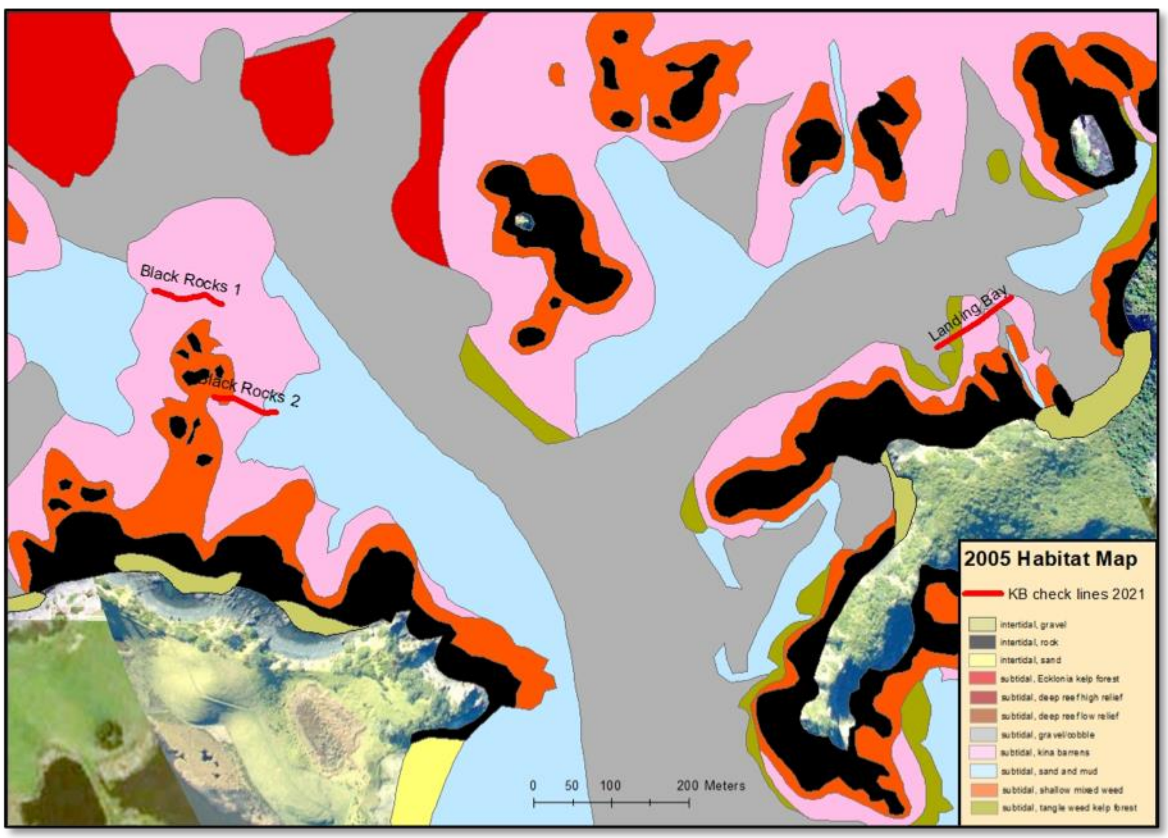

Figure 4 Photo frame transects shown as red lines located on the 2005 habitat map[1], kina barren areas are colored pink

Results of drop cam 1m² photo quadrats

37. Table 1 below shows the results of the photo frame drop cam survey on the three transect completed.

Table 1

reef transect name	average kina count number per square meter	average kelp % cover	highest kina count per square meter	number of photo quadrats scored
Black Rocks 1	5.5	15.4	16	12
Black Rocks 2	3.0	3.5	20	10
Landing Bay	6.2	1.2	10	13

38. Kina density per square meter is a standard measure used to track formation of kina barrens, persistence of kina barrens and in restoration trials based on kina culling. Kina densities greater than $4/m^2$ are considered high enough to lead to formation of new kina barrens. Kina densities near zero are currently considered a threshold for kelp recovery (pers. com Dr. Nick Shears).

39. The average kelp coverage results ranging from 1.2 – 20 % are within the range of what is seen on kina barrens. In this case of these two reefs most of kelp plants growing were young *Carpophyllum flexulosum* that is found typically in areas of low exposure and can form tall dense forests up to 2m high. This kelp species is known to be less palatable to kina but in these locations is unlikely to form a permanent forest as the wave energy level is expected to be too high for them to persist.

Interpretation of the photo frame results

40. In my opinion the imagery and data derived from the photo frame transects supports a conclusion that these areas are persisting as long-term kina barrens and have not substantially changed since the mapping period of 2004-2005. This conclusion is consistent with other studies of long-term persistence of kina barrens here in Northland and overseas [23] [24]. Please refer to my primary evidence sections 38-48 for more detailed discussion of the persistence and ecological implications of kina barrens in Northland.

Observations on the water of kina barren extent

41. During the course of the field survey recently conducted at Mimiwhangata I was able to drive over most of the reefs shown in Figures 2 & 3. Visibility into the water was about 6m on the day of the survey. This allowed me to directly observe the kina barren status in these shallower areas. Everything I observed directly from the boat was

[23] Ling, S.D., Johnson, C.R., Frusher, S., Ridgway, K., 2009. Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. Proc. Natl. Acad. Sci. USA 106, 22 341–22 345.
[24] Ling, S.D. et al., 2015. Global regime shift dynamics of catastrophic sea urchin overgrazing. Phil. Trans. R. Soc. B 370: 20130269.

consistent with the conclusion that the kina barrens in the study area are persistent and consistent with the mapping done in 2004.

Examples of the photo frame quadrats from each of the three transects completed are shown below in Figures 5-7.

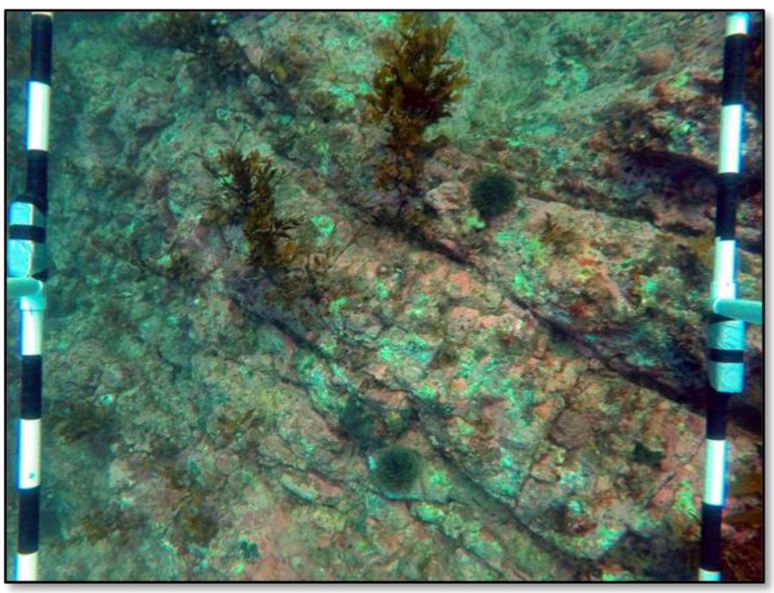

Figure 5 Black Rock Reef transect 1, three young plants species, *Carpophyllum flexulosum* can be seen and several kina

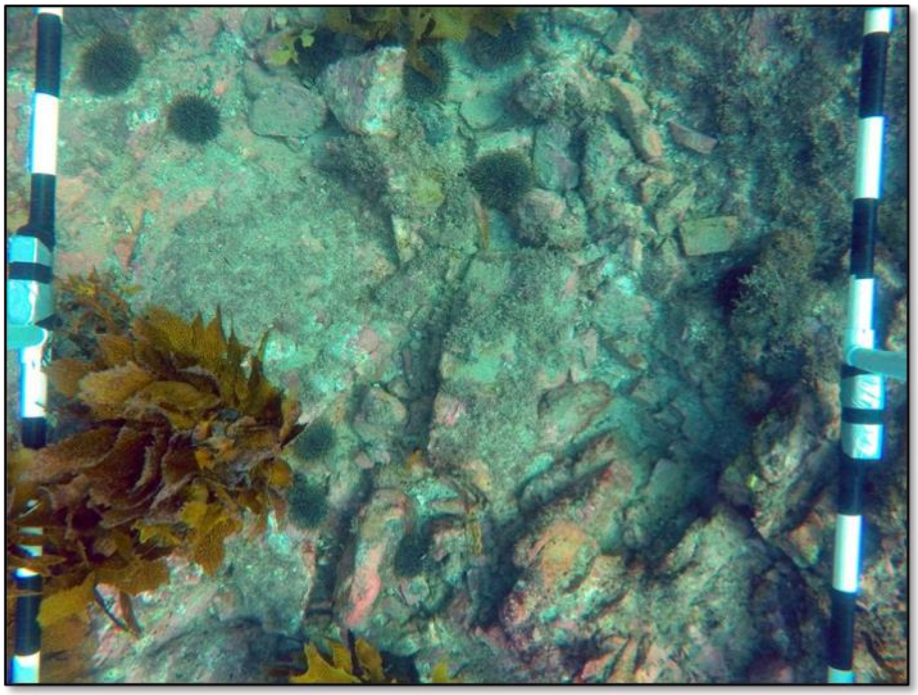

Figure 6 Black Rock Reef transect 2, kelp plant is a young *Ecklonia radiata*

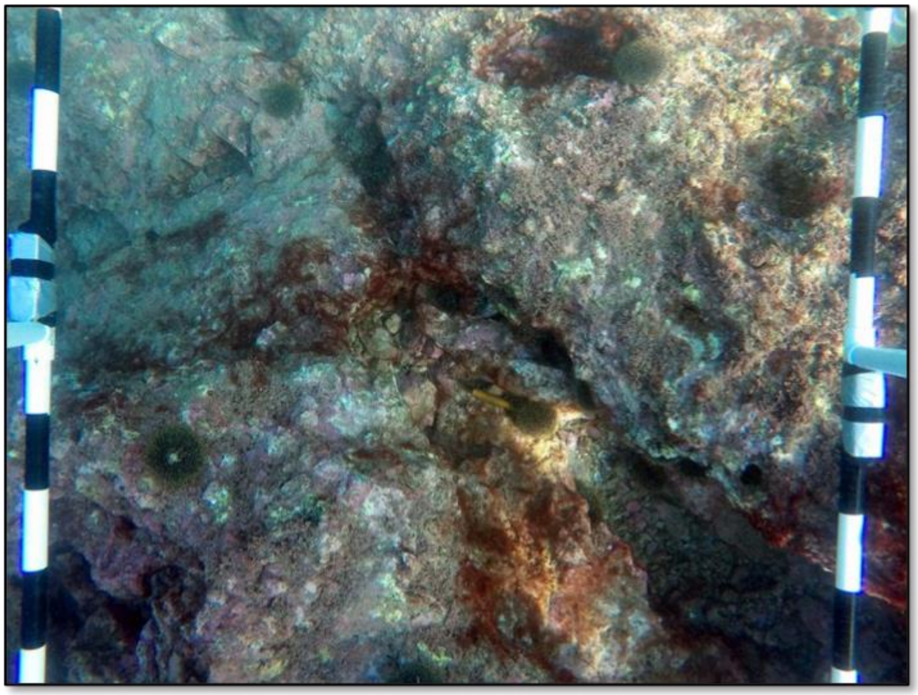

Figure 7 Landing Bay transect no kelp present and kina scattered over the area

Dated 14 May 2021