Volunteer free divers achieve impressive kina culling rates and learn from kina feeding behaviours at Maitai Bay

Vince Kerr, 2025

One of our volunteer divers in the process of culling kina, assisted by local fish

This report was prepared for the Te Rangi i Taiāwhiaotia Trust created to support conservation and hapū projects of Te Whānau Moana/Te Rorohuri hapū, Karikari Peninsula.

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Summary

For decades, New Zealand's kelp forests have been disappearing, eaten away by kina sea urchins after overfishing removed their natural predators. At Maitai Bay in Northland, this problem was particularly severe - underwater areas that should be lush forests had become barren moonscapes covered in urchins.

This report describes what happened when two dedicated volunteer divers, working with the local Te Whānau Moana/Te Rorohuri hapū, decided to do something about it. Over 75 days, they free dived repeatedly, systematically removing kina from designated reef patches within the community's rāhui (traditional restoration reserve).

The results were remarkable. The volunteers culled 42,930 kina, (approximately 10 tonnes green weight), while discovering that these creatures weren't simply sitting still waiting to be removed. Instead, kina were actively moving around the reef. Through repeated observations of the kina, our divers learned to work with the kina behaviours to increase their free diving kina culling performance.

In this report we have recorded the detail of this work to assist others in developing their strategies. We also offer some insight into how kina culling at scale can work hand in hand with marine protection, as is happening at Maitai Bay

Introduction

This report presents results of a volunteer free-diving-based kina (*Evechinus chloroticus*) culling program at Maitai Bay, Karikari Peninsula, Northland. A learn-by-doing approach was adopted as a method for staging culling efforts over time (several weeks). Observations of kina movement and feeding behaviours over repeated dives led to innovations in their diving strategies.

Te Whānau Moana/Te Rorohuri hapū of Ngāti Kahu iwi are mana whenua of the Karikari Peninsula and ultimately responsible for the lands, seas, environment and people residing there. For decades they have been concerned about the degradation of the region's marine life resulting from overfishing. The area in and around Maitai Bay is currently a key focus for the hapū. In 2017, Te Whānau Moana/Te Rorohuri laid a rāhui over the area to stop all fishing and taking of seafood to allow the area to recover.

A goal of the rāhui is that the natural predators of kina - large snapper and crayfish, will return to the reefs and allow the kelp forest to once again dominate the shallow reefs by restoring the natural balance of kina and the kelp forest. The shallow kelp forest habitats of Maitai Bay are the most productive habitats along the coastline and play key roles for nearly all species at some point in their life cycle. The kina barrens at Maitai Bay have now been present at current extents for decades as a result of overfishing of the key predator species.

A marine habitat map for the waters of Maitai Bay, the rāhui, and surrounding area was completed in 2020 (Kerr et al.). The maps cover an area of 748 hectares extending from shore as far seaward as 2.0 km and the 70m depth contour. Within this mapped area, the rāhui covers approximately 390 hectares in total area. In the mapped area, kina barrens covered 39.9% of the estimated historic area of high-productivity *Ecklonia* kelp forests extending to 20m depth, totalling 49.4 ha. See the Maitai Bay habitat map in Appendix 3.

The hapū rāhui committee has been investigating ways to assist the restoration process by culling kina densities down to a level that allows kelp forests to recover. Various culling and harvesting options are being considered. Prior to this year's project, the hapū supported a trial of kina culling methods in 2022 (Kerr and Wallace). In this trial, methodologies developed by the Auckland University research team (Miller et al. 2024a and 2022) were used on a small scale to test how they would work in practice at Maitai Bay. Recommendations were given on various aspects of the culling and harvesting options as well as practical information on monitoring kina numbers and planning and carrying out surveys.

In 2023, a hapū kina culling and harvest day was organised by the hapū rāhui committee to provide an opportunity to discuss options for culling and harvesting and provide an opportunity for the hapū members to get in the water and participate in the project (Northern Advocate, 2023). Discussions continue on how to practically manage kina culling and local harvest alongside the restoration going on in the rāhui. Adapting traditional knowledge and practice to these processes remains a primary goal.

Last summer (April 2025), a culling trial evolved out of the interest and desire of two volunteers who were camped at the Maitai Bay Campground. They were passionate to get involved in the restoration of the kelp forest and marine life generally at Maitai Bay. They approached the hapū committee members to seek guidance, support and permission to carry out work to assist the restoration. The committee members decided to support the idea, and I was asked to provide some oversight and assist the two divers to carry out their project.

In this report, we will present the data collected by our volunteer divers and offer a new perspective on culling kina with free diving.

Methods

The area selected for the project was on the north side of the Merita Peninsula (Maitai Pā) on the shallow reefs adjacent to the campground reef shown in Figure 1 below.

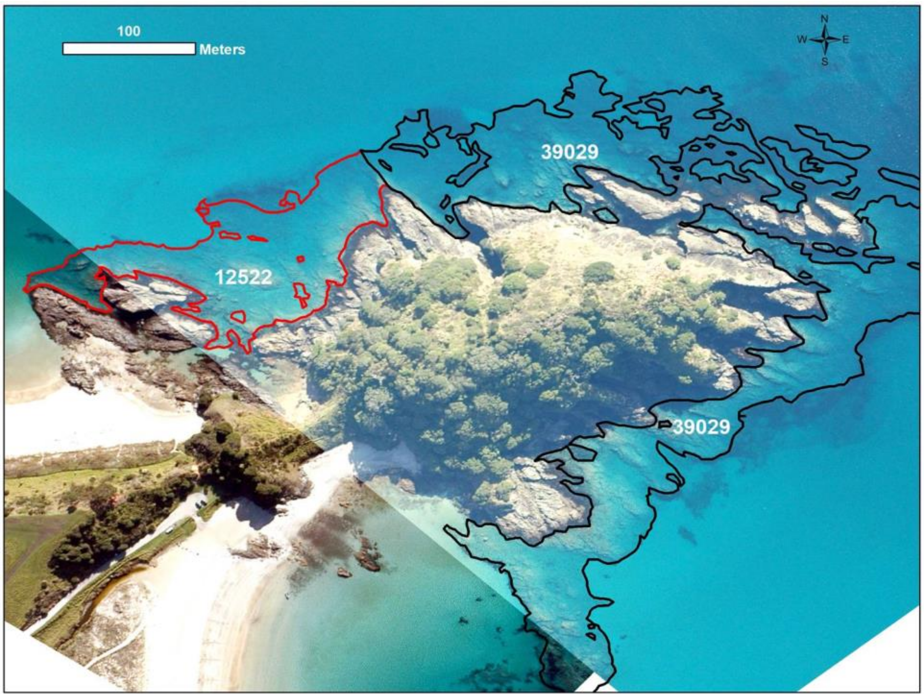

Figure 1 Location map of the culling trial area at Maitai Bay (Merita Peninsula outlined in red. The culling trial area is outline with a red line, the white numbers over the three areas are the spatial area of the kina barrens in m^2.

After some initial trial dives, the two divers began to divide the reef area into 'patches' of a size they estimated they could cover in several dives. All diving was done on snorkel with the two divers working together. Early in the project, the divers were making worthwhile observations and were keen to develop a system for recording daily results to assist the learning aspects of what they were doing. Twenty 'patches' were mapped within the study area for data recording. A map of the patches is shown below in Figure 2.

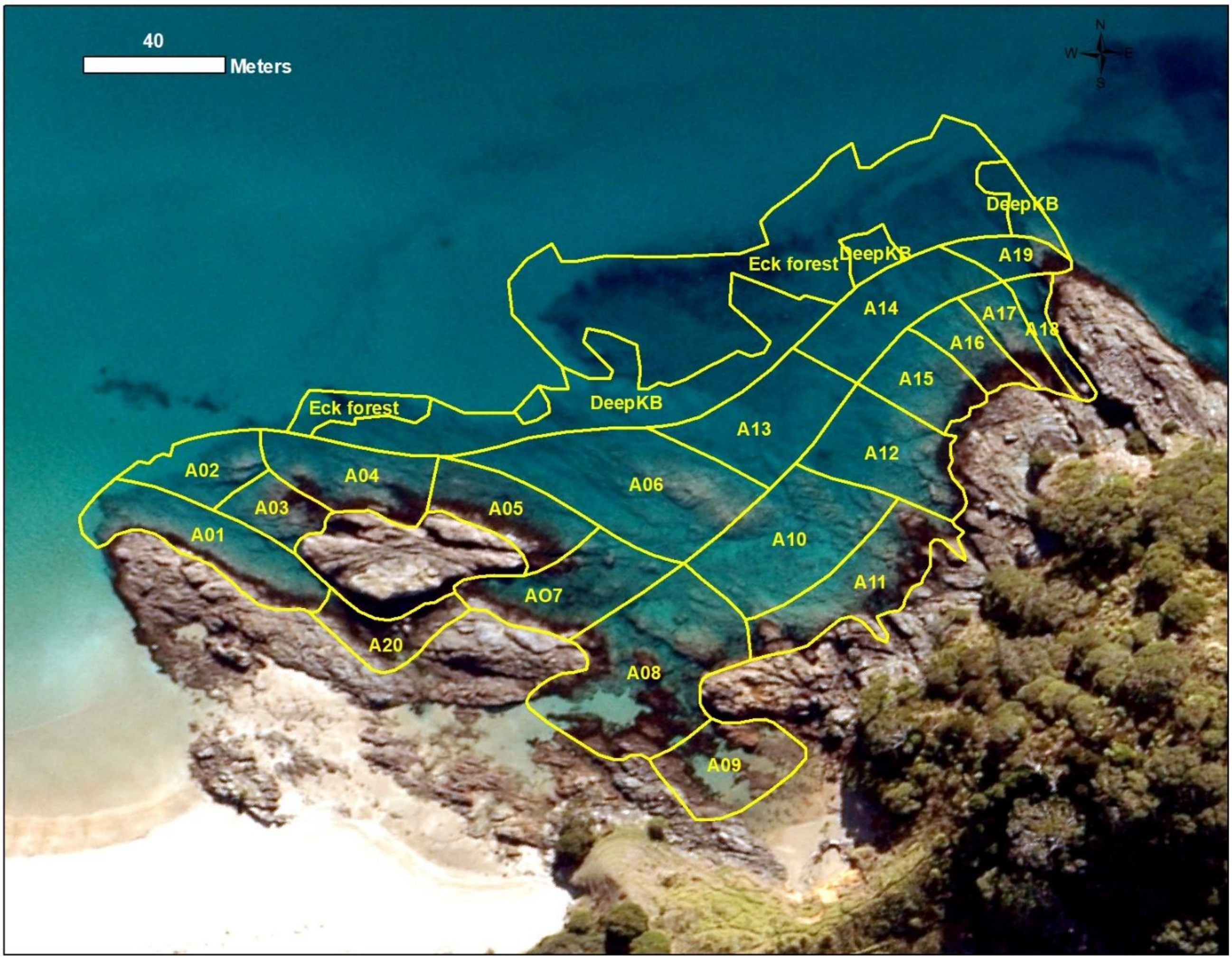

Figure 2 Map of the patches created to record details of the culling operation

The parameters for the data recording were:

Date, **dive #**, **patch name**, **kina # culled**, **centros # culled**, **dive time**, **effort**, **depth**, **phase of the culling operation**, **patch # of visits**.

Note: *'Centros'* is shorthand for a second urchin species *Centrostephanus rodgersii*.

Typically, two dives of around an hour's duration were done on all days where the conditions were good enough to carry out the culling operation.

The divers were also asked to write a brief description of the characteristics of each patch in relation to the general ecology of the reef and reef community and observations of things of interest they encountered that may impact on the culling operation in that patch. These notes have been included in this report as Appendix 3.

The initial drawings of the study area and approximate boundaries of the patches were drawn over an aerial photo. This patches map image was brought into an ArcGIS project. Polygons drawn for the patches allow calculation of each patch area for analysis and future planning.

Safety Considerations

This culling trial evolved from two snorkelers doing their own thing and gradually became a more structured trial with more intense diving. At the point where I became involved, I went through a training session with the divers to assure that they understood the safety strategies required to carry out repeated, high energy dives. They were keen to learn best practice methods around avoiding shallow water black-out, which is the main risk involved in this diving. It is very important that any group or individuals involved with culling kina with free diving, receive this sort of briefing or training and practice buddy diving at all times while working.

Results and Observations

The raw data recorded by the volunteer dive team can be examined in Appendix 1. Their data was recorded on the basis of two divers for all entries. While this was convenient and logical for their daily dive record, for this report the raw data is transformed to a single diver basis. This enables a standardised way of evaluating effort and work completed on a per diver basis. See Appendix 2.

The dive team settled on a system that involved going over each patch several times over a period of weeks. The time intervals for each patch can be tracked in the raw data table in Appendices 1 and 2. There was considerable variation in depth and complexity of the reef surface, which affected their approach on any given day. They also made use of tide levels to assist their work—for example, doing the deepest part of the patch on a big low tide and working in the shallowest areas at high tide.

Tables 1 and 2 include analysis results of the raw data to better understand how diving effort was employed over time and opportunities to maximise productivity of the diving operation. The tables split the data into two groups of dives. Table 1 looks at dives that were recorded as *Start, Continuation, Completion and Maintenance* for each patch. Table 2 looks at the data of nine dives made towards the end of the project, that the dive team recorded as 'touch-ups'. The Table 2 dives were done after the patch was thought to be mostly completed. This will be described further in the observations section below.

Table 1 totals the raw data for the series of dives made on each of the twenty patches and is calculated on a single diver basis. Column 3 refers to 'centros', *Centrostephanus rodgersii*, which is a large purple, long-spined urchin originating from New South Wales, Australia. centros became established in Northern New Zealand some eighty years ago and are now increasing in numbers significantly, posing a second threat of overgrazing kelp species, (Balemi & Shears 2023).

Columns 2 and 3 show the total number of urchins of each species which were culled on each patch. Column 4 shows the total number of dives completed on each patch by the two divers (single diver dives total). Column 5 lists the area in square metres for each patch. Total diving time for the two divers is shown in column 6. The last two columns (7 and 8) are calculations done for each patch producing an average kina culling rate and the number of kina culled per square metre for each patch.

The average kina culled per minute is a measure that most studies use to track the productivity of the divers. In this trial across the twenty patches, the range was from a low of 5.56 kina culled per minute (A20) to a high of 12.75 (A07) with an overall average of 8 kina per minute. These figures compare well with the range of culling rates reported in the previous trial at Maitai Bay (Kerr and Wallace 2022), which was scuba based and had an estimated culling rate at 15 kina per minute. As noted in the 2022 report, this small trial was mainly focused on an area of high kina density and feeding front activity, which was thought to result in a high culling rate. In the Auckland University culling research, the rates achieved on scuba were in a range between 7-15 kina per minute (Miller et al. 2024).

Ideally in a kina culling trial, an estimate of kina density before and after culling would be completed. In this case, the project was well underway before survey planning advice was available to the divers. We also did not complete a post-cull survey. With the data we have, however, we could calculate a figure for each patch representing the average number of kina culled per square metre, which appears in the last column. The values ranged from 0.34 (A01) to 9.07 (A19) with an average of 3 for all patches.

Patch	**Sum of Kina Culled #**	**Sum of Centros Culled #**	**Number of dives**	**Area of patch meters^2**	**Diving time minutes**	**Avg. Culling rate kina per minute**	**# Kina culled per M^2 of patch**
A01	300	0	2	879	40	7.50	0.34
A02	700	9	2	440	60	11.67	1.59
A03	1,213	20	4	314	120	10.11	3.86
A04	2,850	19	8	683	290	9.83	4.17
A05	3,650	19	8	620	370	9.87	5.89
A06	5,380	42	10	1,430	640	8.41	3.76
A07	1,020	3	4	785	80	12.75	1.3
A08	1,295	0	4	1,610	210	6.17	0.8
A09	300	0	2	663	50	6.00	0.45
A10	2,705	10	8	1,098	370	7.31	2.46
A11	3,101	17	8	861	440	7.05	3.6
A12	2,600	3	8	789	360	7.22	3.29
A13	1,570	22	4	834	180	8.72	1.88
A14	500	0	2	743	60	8.34	0.67
A15	2,255	8	8	467	310	7.28	4.83
A16	2,546	2	8	321	370	6.88	7.93
A17	1,275	2	4	291	170	7.50	4.38
A18	1,700	21	8	217	250	6.80	7.83
A19	2,150	18	6	237	280	7.68	9.07
A20	500	5	2	397	90	5.56	1.26
Average	**1,881**	**11**	**6**	**684**	**237**	**8**	**3**
Totals	**37,610**	**220**	**110**	**13,679**	**4,740**		

Table 1 Recorded values and calculations for the twenty patches covering the main culling period totalling 110 dives (single diver basis). Note the calculated area of each patch has been included in this table.

The variation in the figures for kina culled per square metre indicates that there are significant environmental or behavioural drivers affecting observed kina density. In our 2022 study (Kerr & Wallace), we did an accurate pre-culling census of kina for a similar reef area on the south side of Merita Peninsula. The 2022 pre-cull survey produced an average kina density of 8 kina per square metre, but the pre-culling data had a large range of densities from 40 kina per square metre to 0 kina per square metre. These large culling rate variations across the reef likely reflect variations in food sources, complexity of reef structure, feeding fronts forming, or other unknown factors. During the first 110 dives, the divers aimed to clear the patches as best they could. The restoration goal is a target average density of 1 kina per square metre or less. In this trial the divers only visually estimated the kina numbers reaching the target density. We did not do detail pre or post kina density monitoring needed to test their visual estimates.

Diver observations and comments on possible causes of variation in kina densities and culling rates across the 20 patches:

1. The divers were unable to cover entire patches effectively; this could involve depth limiting the diving or complex terrain providing hiding places for kina. Reef edges in the study area varied from 6-10m in depth.
2. Formation of feeding fronts results in areas of high kina density, which result in high culling rates.
3. Reef characteristics, such as roughness, cracks and crevices, and caves, are variable across this reef.

Table 2 below provides another way to look at the effectiveness of the survey and the variations of kina density observed. Following the 110 dives completed over the twenty patches, the divers changed their approach to a swim pattern where they covered as many of the patches as possible, 'checking' that there were not kina reappearing in areas they felt they had completed or that they had simply missed areas of kina. They referred to these eighteen dives at the end of the project as 'touch-ups'.

	Sum of Kina Culled #	**Sum of Centros Culled #**	**Number of dives**	**Area all patches M²**	**Diving time minutes**	**Avg. Culling rate kina/minute**	**# Kina culled per M² of patch**
‘Touch-up' and maintenance dives all patches	5,320	77	18	13,679	960	5.54	0.39

Table 2 Results and calculations here represent the last stage of the diving, eighteen dives (single diver basis) completed at the end of the survey period described as 'touch-up dives' by the divers.

For the ‘touch-up dives’, the average number of kina culled per square metre of patch (calculation based on sum of all patches) is low at 0.39 kina per square metre. This low figure suggests that the work of the prior 110 dives had greatly reduced kina density, possibly near the desired target of 1 or less kina per square metre. Unexpected but significant is that their average culling rate on these dives was an impressive 5.54 kina per minute, and the total kina culled was 5,320 from the 18 dives. These results illustrate that during this 'touch-up' stage, divers were still culling large numbers of kina and working efficiently but over much larger areas in each dive, essentially swimming over the whole study area or large portions of it.

As the divers were working out how to structure their diving and observations, they were asked to record qualitative descriptions of the dives to enable us to better evaluate the multi-pass approach. For each patch, the dives were recorded as one of four phases: ***start, continuation, complete, and maintenance***. The top half of the table summarises the data broken down into these dive 'phase' descriptions.

The culling rate over the sequence of dives on each patch shows a steady decline of average culling rate starting with 8.37 for the first dives to an average of 3.84 for the last maintenance dives. This is expected and suggests the divers were making steady progress at lowering the kina numbers as they progressed through the dives.

The dives were also recorded with an 'effort' description of: ***medium, cruising, or intense***. These descriptions reflected a variety of factors that affected the divers’ work output on a given day, such as visibility, wave surge, wind chop, difficult terrain, and variations of depth. It is interesting that the average culling rate per square metre did not vary much between the dive types and remained at a good rate for free diving culling. It is likely that on some days and conditions the divers worked harder to deal with adverse conditions like swell and poor visibility.

By Phase	**Kina Culling #**	**Centros Culling #**	**Diving Time (min)**	**Number of dives**	**Avg. Culling rate kina/minute**
Start	17,326	94	2,070	46	8.37
Continuation	11,483	64	1,460	34	7.87
Complete	2,175	5	450	14	4.84
Maintenance	1,150	19	300	12	3.84
By Type	**Kina Culling #**	**Centros Culling #**	**Diving Time (min)**	**Number of dives**	**Avg. Culling rate kina/minute**
Cruising	4,308	41	690	20	6.60
Medium	4,550	4	610	18	7.07
Intense	23,276	129	2,980	62	7.81

Table 3 Analysis of dive descriptions not including 'touch-up dives' (single diver basis)

Grand Totals	
# of kina culled	42,930
# Centros culled	297
# of dives single diver	128
diving time single diver hours	95

Table 4 Totals summary for all dives completed in the project.

A final tally of 42,930 kina and 297 centros were culled in this trial. The kina number culled equates to approximately 10 tonnes of kina in green weight. The diving was done over 75 days from the end of March until the middle of June with two divers in the water for all dives. Approximately 1.2 ha of reef was culled in the 95 hrs of diver time. The 95 hrs total dive time converts to 79 diver hours/ha. Kelsey Miller and the Auckland University research team (2024a), estimated the time required for scuba culling at 50 diver hrs/ha. When comparing these figures it is important to understand our culling rates are estimated from the diver notes and were not tested against the final target kina density, whereas in the Auckland research final kina density were carefully monitored.

Centrostephanus rodgersii records

There have been continuous observations of the large-spined, purple sea urchin, *Centrostephanus rodgersii*, over the eight years of monitoring at the rāhui, but this is our first actual count of the centros. While the total number of culled centros appears very small compared to the kina culled, it is important to understand that at the beginning of the rāhui, this number would have been 5 or 10 for the area culled. This change represents rapid growth of this species from being rare to an established and widespread population. The increase of centros has been noticeable over the last eight years. Centros are much bigger urchins than kina, so their numbers are expected to be lower than kina. Also, finding 90% of centros to cull is a much harder diving task because of their preference for caves, cracks and crevices.

Key Observations

A significant value of this diving study was its focus on, one discrete area with many dives repeated over the same reef consistently over several months. This enabled many observations of things that are simply not seen in one-off dives. The divers regularly reported noticing new patterns in behaviours and discovering species new to them. Many hours was spent discussing these observations following the day's diving, testament to the complex ecology of our shallow reefs. Three key observations occurred consistently and could inform future restoration efforts.

Observation 1: At the start of the culling, most patches with shorelines had one or more concentrations of kina assembled at the boundary between the kina barren and the shallow mixed forest zone. These kina aggregations varied in total number from 30-50 to hundreds with very high densities (40-60 kina per square metre). Some aggregations were in full feeding front mode, literally felling kelp plants and extending the kina barren area into the intertidal zone. Smaller aggregations were commonly found near the shallowest part of the kina barren. These shallow aggregation patterns were advantageous for free divers who could work efficiently in depths of less than 4m.

Observation 2: In the first month, divers worked different patches based on daily conditions and their desire to explore the whole area. This resulted in time gaps between diving sessions on particular patches. Over one to two weeks, they observed kina moving up into the shallow areas where culling had initially been concentrated. On second passes over mostly cleared areas, divers again found significant numbers of kina and could cull them at reasonable work rates. Essentially the kina to some degree were solving the problem of the divers not being able to work as efficiently at deeper reef levels. This kina movement trend was consistent over the two and a half months of diving. As Table 1 shows, some patches had 4 or 5 culling sessions.

Observation 3: This project provided a special opportunity to observe how reef fish and invertebrates responded to culling activity. Context is important here. The culling trial area is centrally located in the rāhui, which has had full protection from fishing for eight years. Our monitoring programme shows that snapper numbers have steadily increased across all age and size classes, and their behaviours are now very different from before the rāhui. Where fishing occurs, snapper are very shy and quickly leave areas with divers, often remaining unseen. In the rāhui, snapper behaviour is the opposite, they are attracted to divers, apparently curious and hoping divers will create feeding opportunities.

When culling began, resident fish (especially snapper) came in for free meals. As culling continued over days and weeks, divers witnessed a slow but steady increase in fish numbers until there were noticeably more fish at culling sites than on nearby reef areas. What happens to the culled kina? Could the quantity of broken kina harm the reef? Our experience suggests no concern is warranted. One surprise observation was how quickly kina remains disappeared, with virtually no sign of culled kina after a few days. They had been literally absorbed into the reef community. This observation, along with the noticeable increase in fish and marine life accompanying the culling trial, contrasts sharply with the notion that culling kina to rebalance the reef is too extreme or harmful to consider.

We will touch on the possible significance of these observations to the longer term restoration process in the next section.

Figure 3 An example of the reef fish feeding and quickly re-cycling the broken kina in the culling operation. The divers were followed at all times by a large number of snapper feeding on the smashed kina.

Discussion

Limitations of the kina trial

While the current kina culling trial represents a step forward for the restoration process, the observations, culling strategies, and work rate data must be considered only as an example of what we did in a particular situation and reef environment. Many environmental conditions that influence kina behaviour and their ability to create and maintain kina barrens are highly variable. Key variables are the contours and roughness of the reef, the shape of the reef, wave exposure, and slope profile. All these factors interact with each other, impacting kina's effect on kelp loss while also affecting the diver's ability to work productively.

Importantly, we did not do accurate pre- and post-culling kina density counts, which can be thought of as a way to measure whether your culling strategy achieved the goal of an average target kina density of 1 kina per square metre or less. This is the threshold density that research has shown in Northern New Zealand allows kelp recruitment and reestablishment of a forest (Miller et al. 2024a). In our case, tracking kina density in the culled area will be followed closely next summer, along with observations of kelp recruitment. In situations like ours where post-culling density surveys aren't done, careful monitoring in the following year can ensure that goals are being met. Kelp recruitment as well as kina density surveys can be used as a form of post culling follow-up work.

Figure 4 An example of the newly recruited kelp plants settling on the reef. The light green kelp plants are *Ecklonia radiata* the dominant kelp species which after a year will be reaching 1 m height if kina numbers are reduced.

Free diving vs SCUBA

This free diving culling trial showed that medium-skill-level divers could produce very worthwhile results. To a degree, this was a best-case example for a free diving approach because the trial reef was semi-sheltered and most of the reef area was within realistic free diving depths of 0-8m, aided by better-than-average visibility for the Northland coast. That said, there are many areas with similar shallow reef characteristics and large kina barrens. In practice, we need to adapt to the idea that much can be achieved with a free diving approach. There are many opportunities to train or attract medium-level free divers either as volunteers or paid workers. In contrast, there are far fewer SCUBA divers who may volunteer or work as paid crew, which bears a high operational cost, limiting our ability to scale up the size and extent of culling projects. The bottom line is that it is up to all groups who want to engage in kina culling to work out what approach to use for any given reef situation, the people available, funding, and skill levels of the divers.

While this study highlights an ideal free diving situation, other shallow reefs, especially in more exposed locations, will have areas where free diving effectiveness would drop off markedly compared to SCUBA-based diving. As deeper diving is required on a given reef, the skill levels of free divers quickly rise to advanced levels to maintain culling productivity. SCUBA diving in contrast requires basic competencies and some training on culling but does not require advanced qualifications, training, or skills. The conclusion here is that each project needs to be carefully designed around how to best use diving approaches and available resources. It is not really a question of scuba versus free-diving, more a question of which strategy best fits the conditions and the personnel available or how they complement each other. Where scuba diving and free diving are both used, I would suggest that a good strategy would be for the scuba team came in to complete the job after the free diving team had done what they could do efficiently. It is very difficult for a free diver to work alongside the scuba diver, as the diving techniques are so different. The result is that the two divers manage their depth differently and will likely struggle to keep track efficiently of where each other are working or have worked.

Culling vs Harvesting

Every group who engages in active kelp restoration, regardless of scale, will likely need to consider decisions on balancing culling and harvesting or choosing only one strategy. This will be affected by local views on the merits of each option. Trials and research so far have clearly shown that, if your primary focus is culling as much area as possible, you would solely focus on culling. It is easy to visualise that this would be faster. However, highly skilled kina divers can harvest at rates not far behind culling; the real limit on harvesting at larger scales is the logistics of getting the kina harvested, handled, and distributed to a worthwhile market or local families, marae, etc. At scale, achieving this comes at a cost for equipment and labour. A harvest-based operation could suit a small-scale project but would be difficult to operate at large scales. Culling, in contrast is not as limited at larger scales in these ways. A second factor to consider with a harvesting strategy on kina barrens, is the quality of the kina, specifically size, taste and in some cases colour. There will be traditional ways to assess these qualities for all hapū groups, but equally there is a recent Auckland University research study (Miller et al, 2024b) which tests kina quality and compares results between kina barrens and healthy kelp forests areas. A detailed look at the seasonal changes is also featured in this report.

A variation on the harvest strategies is to harvest in the kina barren and then transfer the animals to a local kelp forest with low kina numbers resulting from localised overfishng. Alternatively a kina barren kina could be harvested to grow on and fatten for markets or local consumption in tanks on land or enclosures in the sea. While these options have appeal in certain situations, they add significant costs to any operation but could contribute to overall restoration goals. There is also the possibility to redirect monetary gains from selling kina products (especially if exported) to support local restoration work, skill development and employment.

Setting aside economics and logistics, there are cultural or philosophical issues that can arise in regard to culling or harvesting kina. We suggest hapū and communities thoroughly discuss culling or harvesting issues with all involved because intervening with the balances of key species and culling large numbers of valuable food species needs careful understanding and consideration. People need an opportunity to learn about the culling and restoration processes and explore the idea of culling as an adaptation of what is considered 'tika' (acceptable practice) in a traditional cultural context. It is a mistake to underestimate how important these decisions are. Traditional knowledge and practice is highly valued for a reason: it has stood the test of time. However, 'modern threats' to our coastal ecology are unprecedented; there was no past experience with the drastic impacts of overfishing we now face. These are big challenges.

Volunteer culling: Potential for kelp forest restoration

I view the volunteer project at Maitai Bay as an amazing success in terms of the work achieved by just two very dedicated divers. The results speak for themselves. Via observation, we discovered that free diving can achieve more than what we previously thought was realistically possible. Our divers found that as they progressed through their work, kina were moving up from deeper zones to shallower depths where repeat culling could be done efficiently in free diving mode. Working with this kina behaviour changed what was possible to achieve.

We also found that during the course of the project, other divers staying at the campground asked to dive with our two divers to observe and help with the culling. This was an unplanned demonstration that there is interest out there to get involved and make a difference for the restoration.

It is beyond the scope of this report to map out how to expand this work to larger volunteer scales and across different skill levels, incorporating training and the many options possible. We simply want to say that there is potential to greatly expand on what is presented in this report and what we experienced. A key factor is having inspired and motivated divers of at least medium free diving skill levels, to literally lead the way. In this trial, our divers worked their way up to impressive work outputs very quickly, but depending on the focus of a project, work output goals might be much more modest. For example, if a student group's primary goal was to learn diving skills and engage with the diving and reef environment, the culling rate they achieved would not be the primary goal. In this case, the culling or harvest output would be a fraction of what our divers achieved, but the educational and awareness benefits could be very significant. Small-scale projects or training-based projects would make small contributions to kelp forest regeneration, but done at large scales in many locations, these small results could become significant.

Feeding fronts working in a 30-year-old kina barren: What are the implications for the reef community?

Kina and some of the other urchin species around the world have an ability to move around the reef and at times form aggregations numbering in the hundreds that attack full-grown kelp plants as a group. This allows them to perform the difficult job of actually cutting down a big kelp plant and then swarming onto it and consuming it. This is a pretty impressive act for an invertebrate with no form of advanced brain or nervous system. This behaviour of kina has been known, but there haven't been studies done on how kina behaviours adapt to the demands of living on a long-term kina barren. From observations made in this culling project, we suggest it is possible to enhance free diving productivity by understanding what the kina are doing as they adapt to living on a degraded reef.

From long-term observations I have made over decades diving in kelp forests and kina barrens, I have observed regular movement of the kina consistent with what our volunteer divers reported seeing. There are two main points that need to be explored: 1) Feeding fronts are constantly forming in long-term stable kina barrens wherever kina can access patches of live kelp growing. 2) On long-term extensive kina barrens, often the shallow mixed forest zone of kelp, once believed to be unpalatable to kina becomes a target for feeding aggregations and becomes progressively reduced in area over long time periods with profound negative ecological implications for the reef.

There seems to be a pattern playing out over time where kina aggregate, attack the shallow mixed forest, reducing its size, then retreat and disperse, followed by repeated attacks over years with the result that the kina barren very slowly grows upwards and the shallow mixed forest reduces and in extreme cases disappears.

Figure 5 This feeding front image is taken on the shore of one of two Waikura islands immediately across the Bay from the culling trial area. Note the dark green band of seaweed above the small patch of light green coloured *Ecklonia radiata.* The dark green seaweed is our native *Caulerpa flexilis* (rimurimu). The native *Caulerpa* in the image is growing where a previous kina feeding front has eaten the kelp back to just a thin line of shallow mixed forest at the bottom of the intertidal zone. Our native *Caulerpa* appears to be increasing on the kina

barrens and is now common at Maitai Bay. It appears to have some resistance to kina browsing, but also naturally periodically dies back. This current kina feeding front will be interesting to watch to see what happens. I have been observing this dynamic closely for eight summer seasons and have seen a gradual loss of the shallow mixed forest with periodic kina feeding fronts advancing upwards.

Mimiwhangata Example

The image in Figure 6 below is a dramatic example of the result of these prolonged feeding front behaviours I observed in the early 2000s at Mimiwhangata, (Kerr and Grace, 2005). From this point on, I started to observe the kina feeding fronts moving up into the shallow repeatedly. The image from Mimiwhangata has haunted me ever since. It could be labelled '*the last kelp plant gone*'. I have done recent dives at this location and the kina barren remains dominant there with a few scattered kelp plants present.

Figure 6 Example of the worst case of kina feeding fronts removing the entire shallow mixed forest zone kelp forest. The image was taken in the early 2000's at Cocker's Rock gut, Rimariki Island, Mimiwhangata.

Maitai Bay Monitoring

At Maitai Bay, as part of our yearly monitoring, we use a timed swim method where we regularly record presence and number of all reef fish. There are 13 transects, each about 300 metres long, which we swim along the shoreline on snorkel. We typically do 3-5 repetitions of these swims each year, adding up to considerable observation time of a broad range of our reefs. Over this period, I have watched the example witnessed at Mimiwhangata in the early

2000s repeat itself on transects at Maitai Bay. At Maitai Bay there are very few examples of the extreme case as seen in the Mimiwhangata image but my estimate of the loss of kelp in this shallow zone of mixed kelp species would be in the range of 30% overall and this figure has increased over the eight years of the Rāhui.

Crucial unanswered questions are: 1) Will our long term kina barrens not in protection areas eventually lose their shallow mixed forest zone remnants, and 2) What are the on-going ecological implications of losing this very diverse and specialised zone of the kelp, especially on shallow reefs where the worst of our kina barrens have no kelp surviving at the bottom reef boundary of the kina barren.

Shallow Feeding Front Target Strategy

Our two volunteer divers described kina movement and aggregations forming in the shallows, and a number of feeding fronts working their way into the shallow mixed forest zone and even the intertidal zone. They told this story of kina behaviour back to me with no prompting. We discussed how to use this information. We came up with the idea that at Maitai Bay, we could consider using a strategy in future literally swimming the entire shoreline and just target the feeding aggregations assembled at the shallow boundaries of the kina barren. We could repeat this approach over time as the remaining kina form new feeding groups and move back up in the shallows periodically. In doing this, we are culling at a very high rate in terms of kina per minute and stopping the loss of the remaining at risk kelp remnants. This is a tempting strategy for the situation at Maitai Bay eight years into the Rāhui, where we know the predators are now returning and will, in time, tip the overall kina/kelp balance back to kelp forest. In this approach, we help the process by culling large numbers of kina now and stopping the current losses occurring to the last remnants of kelp. To put some numbers to this idea I roughly measured the shoreline distances inside the Bay. The shoreline distance of the current culling trial is approximately 1 km. The shoreline distance of the remainder of the inside portion of Maitai Bay is approximately 7.5 km. This is only an indication of the size of the job at Maitai Bay as reef areas along shorelines vary greatly.

Is there more going on ecologically than what we observe and measure?

In this section, I ask the reader to allow me some latitude to explore ideas about some of the more unseen aspects of fish behaviour and ecology of our shallow reefs. For me, the things we readily observe and can measure are like signposts to guide you in entering the world of our shallow reefs. But we should never kid ourselves that these visible signs are the whole story. In the ocean, there is a world of behaviours and things going on that are largely unseen, unheard, or ‘un-tasted’ to us. We are simply terrestrial beasts and our time on the reef represents a tiny fraction of the day or the year. Now that we are considering kina culling at significant scales, it is worth considering what could be happening that we don't see or can't measure. I did several photography dives observing our two volunteer divers, which prompted me to think about the dramatic behaviours on display by the fish doing their part of the culling operation. I have made some notes based on these observations and a lifetime of diving and learning about fish behaviour. I suggest there are likely unexpected benefits at play.

Sound travel matters in the Ocean

When culling is underway, with the human ear you hear a distinct metallic tap, tap, tap. The divers hit the kina reasonably hard with their hammers, striking the rock below often. Underwater, this sound has a sort of ring to it and is noticeably loud if you are still and listening. This begs the question: how far does this particular sound travel underwater? The answer: a long way, probably hundreds of metres, possibly even further for some species that are really good at listening, such as snapper, kingfish or sharks listening for signs of a disturbance or feeding opportunity.

With the large numbers of fish swarming over the smashed kina, there is a lot of very fast swimming and swirling around, especially with the younger fish. This intense movement in the water creates a low-frequency sound wave of sorts that travels long distances through water, again a strong attractive signal going long distances with the message something unusual is happening and could be a feeding opportunity. We don't hear or feel this sound, but many fish and other marine life definitely do.

In our trial with the repeated culling dives in one area, the fish numbers increased dramatically over the weeks and many were taking up residence. At the end of the trial, I would estimate that there was roughly double the snapper including all the size classes hanging out in the vicinity of the culling areas compared to the adjacent similar reef areas.

Consider this: we know from numerous research studies that shallow rocky reefs naturally produce a sound profile made up of all the various noises the fish and invertebrates make, (Wilson et al. 2023) This distinctive sound profile travels significant distances. The hundreds of species involved with the reefs use these sound signals to home in on signals that mean something to their species and the particular stage of their life cycle. For the predator species, they are acutely aware and attracted to reef areas where there is high diversity and lots of activity. There is a similar dynamic going on with chemical signals emanating from reefs that provide certain cues to marine life to be attracted to a reef. In this way, for reefs, the rich get richer and the poor get poorer. This in part explains why full no-take reserves are so effective at restoring the shallow reef communities. They literally give off very different auditory and chemical signals to the surrounding area which is typically impoverished as a result of overfishing.

Returning to our current culling trial, we don't know if our two months of culling will cause any sort of lasting effect on the general increase that is occurring naturally on the rāhui reefs, but I pose this as a question, perhaps a valuable research question. Can this particular multi-pass free diving approach result in an added benefit of accelerating the natural progression of predators and marine life generally returning to the reef in a full no-take reserve situation or even in the less likely scenario in a fished area? A related question also arises: could this benefit be of greatest value at the very beginning of a no-take reserve being established? Think of it like an advertising campaign to attract marine life to return.

The key context of protection levels and kina culling

Kina culling and harvest projects aiming to aid restoration goals are in their infancy in Northern New Zealand. Areas have been chosen for treatment on an opportunist basis or simply randomly. However, because of the extent of kelp forest loss in Northland and Northeast New Zealand, we are forced to consider how to maximise gains with treating only some relatively small portions of the total area in kina barrens. Ideally efforts to restore kelp forest by culling or targeted harvest are supported by advancing reform in fisheries management and work towards a recommended goal of a network long term fully protected areas, (Ballantine, 2014), (Peleg et al. 2023).

So where would culling projects give the greatest returns relating to protection levels?

Below I have offered some scenarios as a theoretical model example. A bottom line result would be how much culling and monitoring and over what time period would be required to result in a restored kelp forest, at a given level or stage of marine protection versus, culling areas with open fishing.

Scenario 1 - Open fishing: Year 1: Intensive culling carried out to kina density target levels. Year 2: Check that target kina density levels are maintained and follow-up culling done as needed.

In Scenario 1, monitoring and follow-up culling would need to be continued annually or bi-annually until kelp forest recruitment and establishment was successful (expected in 3-5 years). In year 5 and continuing indefinitely, without major changes in current fishing of key predator species, kina densities would need to be monitored periodically say every three years and it is likely follow-up culling operations would be needed to maintain target kina densities.

Scenario 2 Newly established fully protected area Year 1-3

The Scenario 2 situation is much like working with unprotected area in terms of the amount of culling required to re-establish the kelp forest quickly because there are not yet significant numbers of larger size snapper or crayfish in the reserve to aid in transition from kina barrens to kelp forest. However, in some situations the predator species do move in quicker, and we do not know yet to what degree the culling or harvesting, during these early years, would accelerate the return of the predators to the reefs. There is however, I suggest this is possible. Many repeats of culling may be needed to achieve the restoration of the kelp forest. This number could range between 0 to several but would be expected to be limited as the predators recover in the reserve and can resume their ecological role. We would expect that the time required for the reef to restore its kelp forest to be reduced, which without culling assistance, naturally occurs within two decades.

Scenario 3 Recently established fully protected area (say 3-10 years since establishment)

Maitai Bay fits Scenario 3. It could be that this is the **sweet spot** in terms of bang for bucks returns from using a culling strategy. Year 1 of culling is completed and simply monitored with follow-up culling. From there onwards, monitoring yearly or bi-annually and quickly shifting to tri-annually or no monitoring as the kelp forest is establishing. In this scenario, the predators have partially returned to the system and in the first culling year, increasing in subsequent years, their numbers increase to a level where the balance is re-established between kina grazing and kelp recruitment. Culling is no longer being required.

Scenario 4 Established fully protected area (say ten years or more since establishment)

In Scenario 4, the most likely action could be to monitor kina density target levels and kelp recruitment. If monitoring showed that substantial kina barren area were persisting and kina density were well above target levels, then localised culling or harvesting operations could be carried out. Otherwise, the reserve could simply be left to continue with its own natural kelp forest restoration trajectory with no culling. Monitoring of predator populations in the reserve could assist in the above decision making. It is possible in this scenario that some culling could attract additional predators to move into the reserve, assisting the shift to kelp forest. Not all reserves will follow any set time frame of restoration, due to the multitude of factors at play. It is also important reefs within a local area vary a great deal even across small distances which can result in how long they take to achieve the shift back to kelp forest.

Scenario 5 Do nothing

In Scenario 5, there is no expected change to established kina barrens. They can be expected to change in extent from year to year but overall be quite stable. That's the picture at large scale but zoom into smaller scales and you see a different story of kina moving systematically to whatever food sources are available. In the Maitai Bay example, this has meant a decrease in the shallow mixed forest zone, as the kina, over decades exhaust feeding resources that are preferred. Ecologically, this scenario is very dangerous for the reef. Reef species that are completely dependent on this last refuge of kelp, have no option but to leave this reef, and with their departure more ecological processes and connections are lost.

To summarise, if the above hypothetical models of managing culling for restoration results are valid, culling in open fishing areas requires far more effort to achieve kelp forest restoration and needs to be continuous over time—in other words, it has to be maintained long-term with repeated culling. In contrast, the three scenarios of fully protected areas offer a reducing scale of culling work to achieve the shift back to kelp forest, with the established reserve reaching a stage requiring no human intervention. Obviously, considering the scale of the problem, working with the natural restoration efficiency of full no-take reserves is hugely advantageous at large scales.

The question of scales and the massive task of kelp forest restoration for Northland

For anyone who doubts that restoration of kelp forests is a large task, I suggest you can do your own calculations based on the Miller et al. (2024) research results and data from our current trial and our previous trial done in 2022 (Kerr & Wallace). That gives you an idea of what it would take to work with an area the size of Maitai Bay. Then, if you want to look at the big picture, go to a recent research paper which provides an estimate of the total area of kina barrens in Northland (Kerr et al. 2024). The numbers and maps are all there for everyone to see. This is not rocket science—you can do these calculations with simple arithmetic. Considering the immense value of kelp forests to people and our coastal ecology, I hope you are shocked and horrified about how large the restoration task is.

Estimated extent of kina barrens in Northland: 30 square kilometres

Once you recover from the initial shock of this loss, what's important is to make a start and focus efforts on the best we can do with the resources at hand. All projects that assist the restoration are good and should be applauded. But there is a take-home lesson here. At the

Northland scale, we need a significant area in full protection to work alongside our modest human intervention efforts. That is what will work to tip the balance at regional scales. The natural processes at play can work and full restoration of kelp forests can be achieved, but these natural processes are the key to reversing the losses to overfishing at the Northland scale.

A good start point would be to have 20% of the coast in no fishing areas. These areas could become the priority for culling projects, so that the human effort worked hand in hand with the natural progression of predators returning to the reef. We know a lot about our kina barrens, we have advanced mapping information, and we have sophisticated marine protection planning tools and people who know how to use them. We have no real excuse not to take action.

Conclusion

For the reader new to this topic, for managers, decision makers and working biologists there is a lot to consider here. We have taken this opportunity to bring observations and research findings together to help people to make decisions, and get motivated to act. I hope everyone can agree that the loss of kelp forest in Northeast New Zealand is something we should not ignore.

We now have to decide whether or not to assist kelp forest restoration. It is that simple. Delays calling for more research only, more debate, more consultation, more deliberation, more Government procrastination in reforming fisheries management etc. instead of acting will multiply the on-going losses. Kina barrens are not a one off loss or natural variation, they set in motion a degradation process of our coastal ecology – each year we lose more.

Communities, hapu and iwi have blueprints of how to organise local projects to assist kelp forest restoration by culling or harvest based projects. With every project there will be much learned and efforts will become more efficient over time. Scale matters, bigger is better, but small is good. Doing nothing is bad as losses continue on your kina barren. It’s a simple equation really.

The exciting part about these hands on approaches to assisting kelp forest restoration is that they can really make a difference. If you dive deeply into what is presented in this report, there are clear indications that your kina barren has a rather uphill struggle to reach that tipping point where the kelp forest can once again return. There are many things that have been lost in the process of creating a kina barren and they can take a long time to restore. In doing kina culling or harvest operations we are learning that we can assist the restoration processes, even if we don’t understand how it all works. The point here is that we should begin.

Acknowledgements

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Our two hard working volunteer divers

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Appendix 1 Raw data diver and diver observation records of daily dives, (based on 2 divers)

Date	Dive	Patch	Kina Cull #	Centros Cull #	Dive Time (min)	Viz	Type	Depth	Phase	Patch visit #
28/03/2025	D14a	**A01**	300	0	20	good	Intense	Mixed	Start	1
8/04/2025	D21b	**A02**	700	9	30	good	Intense	Mixed	Start	1
28/03/2025	D14b	**A03**	700	20	40	good	Intense	Mixed	Start	1
28/03/2025	D15a	**A03**	513	0	20	good	Medium	Mixed	Continuation	2
28/03/2025	D15b	**A04**	1500	13	70	good	Intense	Mixed	Start	1
7/04/2025	D20b	**A04**	500	0	20	good	Intense	Mixed	Continuation	2
8/04/2025	D21a	**A04**	600	0	30	good	Intense	Mixed	Complete	3
2/06/2025	D39b	**A04**	250	6	25	6m	Cruising	shallow	Maintenace	4
27/03/2025	D13b	**A05**	1500	10	60	good	Intense	Mixed	Start	1
7/04/2025	D20a	**A05**	700	3	40	good	Intense	Mixed	Continuation	2
20/05/2025	D32	**A05**	1200	4	60	10m	Medium	shallow	Complete	3
2/06/2025	D39a	**A05**	250	2	25	6m	cruising	shallow	Maintenace	4
5/04/2025	D18	**A06**	1200	15	60	good	Intense	Mixed	Start	1
6/04/2025	D19b	**A06**	1030	6	50	good	Intense	Mixed	Continuation	2
15/05/2025	D30	**A06**	1100	4	90	5m	Intense	Deep	Continuation	3
22/05/2025	D34	**A06**	850	6	60	8m	Intense	Deep	Continuation	4
24/05/2025	D36	**A06**	1200	11	60	15m	Intense	Deep	Continuation	5
27/03/2025	D13a	**A07**	900	3	30	good	Intense	Mixed	Start	1
6/04/2025	D19a	**A07**	120	0	10	good	Medium	Mixed	Complete	2
20/03/2025	D07	**A08**	1195	0	90	good	Intense	Mixed	Start	1
21/03/2025	D08a	**A08**	100	0	15	good	Medium	Mixed	Complete	2
23/03/2025	D10a	**A09**	300	0	25	good	Medium	shallow	Start	1
21/03/2025	D08b	**A10**	1005	0	60	good	Intense	Mixed	Start	1
23/03/2025	D10b	**A10**	300	0	25	good	Intense	Mixed	Continuation	2
9/04/2025	D22a	**A10**	800	6	40	good	Intense	Mixed	Continuation	3
21/05/2025	D33	**A10**	600	4	60	8m	Cruising	shallow	Continuation	4
22/03/2025	D09	**A11**	1001	0	60	good	Medium	shallow	Start	1
9/04/2025	D22b	**A11**	800	4	40	good	Medium	shallow	Continuation	2
23/05/2025	D35	**A11**	600	12	60	12m	Cruising	shallow	Continuation	3
31/05/2025	D37	**A11**	700	1	60	6m	Cruising	shallow	Complete	4
15/03/2025	D01	**A12**	600	0	45	good	Intense	Mixed	Start	1
20/03/2025	D06	**A12**	1000	0	70	good	Intense	Mixed	Continuation	2
24/03/2025	D11a	**A12**	800	0	50	good	Medium	Mixed	Complete	3
10/04/2025	D23a	**A12**	200	3	15	good	Intense	Mixed	Maintenace	4
30/03/2025	D16	**A13**	600	12	40	good	Intense	Mixed	Start	1
31/03/2025	D17	**A13**	970	10	50	good	Intense	Mixed	Start	2
25/03/2025	D12a	**A14**	500	0	30	good	Intense	Mixed	Start	1

16/03/2025	D02	**A15**	600	0	50	good	Intense	Mixed	Start	1
18/03/2025	D05	**A15**	1005	0	60	good	Intense	Mixed	Continuation	2
10/04/2025	D23b	**A15**	350	3	25	good	Medium	Mixed	Complete	3
4/05/2025	D25c	**A15**	300	5	20	good	Cruising	Mixed	Maintenace	4
17/03/2025	D03	**A16**	996	0	60	good	Intense	Mixed	Start	1
24/03/2025	D11b	**A16**	400	0	50	good	Intense	Mixed	Continuation	2
25/03/2025	D12b	**A16**	700	0	40	good	Medium	Mixed	Complete	3
10/04/2025	D23c	**A16**	450	2	35	good	Medium	Mixed	Maintenace	4
17/03/2025	D04	**A17**	975	0	60	good	Intense	Mixed	Start	1
10/04/2025	D23d	**A17**	300	2	25	good	Medium	Mixed	Complete	2
10/04/2025	D23e	**A18**	300	3	25	good	Intense	Mixed	Start	1
4/05/2025	D25a	**A18**	500	12	35	poor	Cruising	Mixed	Continuation	2
16/05/2025	D31a	**A18**	650	4	45	8m	Intense	Deep	Complete	3
8/06/2025	D42b	**A18**	250	2	20	7m	Medium	Deep	Continuation	4
4/05/2025	D25b	**A19**	500	5	35	poor	Cruising	Mixed	Start	1
16/05/2025	D31b	**A19**	650	3	45	8m	Intense	Deep	Continuation	2
21/06/2025	D44	**A19**	1000	10	60	10m	Intense	Mixed	Start	1
1/06/2025	D38	**A20**	500	5	45	6m	Cruising	shallow	Start	1
3/05/2025	D24	**ALL**	500	9	45	poor	Cruising	Mixed	Touch ups	
5/05/2025	D26	**ALL**	1100	14	90	3m	Medium	Mixed	Touch ups	
6/05/2025	D27	**ALL**	1000	12	70		Cruising	Mixed	Touch ups	
13/05/2025	D28	**ALL**	250	5	45	1m	Cruising	Mixed	Touch ups	
14/05/2025	D29	**ALL**	250	4	45	1m	Cruising	Mixed	Touch ups	
2/06/2025	D40	**ALL**	700	4	55	6m	Cruising	shallow	Touch ups	
3/06/2025	D41	**ALL**	500	6	45	5m	Cruising	Mixed	Touch ups	
8/06/2025	D42a	**ALL**	320	8	25	7m	Medium	Mixed	Touch ups	
15/06/2025	D43	**ALL**	700	15	60	8m	Medium	Mixed	Touch ups	

Appendix 2 Diver description of patches and ecological notes

Diver Descriptions of Maitai Bay Kina Culling Zones

Karikari Peninsula, Northland, Aotearoa New Zealand baseline Condition: Prior to Kina Removal (Pre-Culling Status)

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Introduction

These notes outline the ecological characteristics of each reef zone within the Maitai Bay culling site, as shown in the provided map. These descriptions reflect the pre-culling condition of the benthic environment, during which kina (*Evechinus chloroticus*) overgrazing was prominent across many zones. The culling has since significantly reduced kina populations, allowing early signs of macroalgal recovery in many of the previously degraded areas. In some areas new recruits of kelp are showing as small plants approximately 50-100 mm high which appear to be surviving with no kina grazing affecting them.

The spatial arrangement of zones (A01 to A20) reflects the natural reef structure from the southwestern rocky promontories to the northeastern headland, including submerged reef "islands," channels, and sandy interfaces. Each zone varies in depth, exposure, substrate complexity, and ecological state.

All kina culling efforts are conducted by moderately skilled free divers using non-invasive methods (other than culling kina), tailored to local environmental conditions.

Patch Descritions

A01 – Western Reef Outcrop

This zone encompasses a prominent shallow reef outcrop, bordered by macroalgae- rich edges and extending into deeper barren flats (6-8m). Before culling, kina had established dense aggregations both in the deeper regions and encroaching into the high intertidal fringe, contributing to macroalgal decline

A02 – Elevated Reef Platform ("The Island")

An isolated rocky rise surrounded by reef, combining bare substrate and sparse algal coverage. This zone was a notable kina grazing site with visible patchiness in macroalgal presence. Helpful to distinguish between shallow mixed forest and *Ecklonia* forest zones in the narrative here03 – Shallow Algal Reef with Structural Complexity

Dominated by shallow macroalgal cover and numerous crevices, this reef supported high densities of both kina and Centros. Grazing pressure was evident across the reef face. kina barrens dominate

A04 – Diverse Reef with Macroalgal Pockets

This heterogeneous very mixed terrain zone featured shallow macroalgae interspersed with overhangs, slabs, and deep barren areas. Feeding fronts were prominent in depth, and cryptic kina and Centros were well-concealed in structural gaps.

A05 – Transitional Reef with Feeding Fronts

A mix of shallow macroalgal reef and deeper exposed bare substrate. Heavy kina grazing was present at all depths, with evidence of macroalgal decline up to upper intertidal levels.

A06 – Central Submerged Platform

A broad, flat reef structure accessed mostly during low tide. Located near a sand interface, it was largely barren and overgrazed, with degraded algae and widespread kina presence.

A07 – Mixed Substrate with Vertical Relief

A varied seafloor combining sandy flats, boulder fields, reef walls, and overhangs. Kina clusters occupied open areas base zones, boulders, and kelp-covered vertical surfaces. Subtidal zones hosted concentrated aggregations.

A08 – Shallow-to-Deep Reef Gradient

Combining sandy and rocky substrates, this area contained crevices and deeper barren expanses. Feeding fronts and kina clusters were common throughout, with hidden Centros in ledges and overhangs. Same as AO7

A09 – Sandy Inlet with Rocky Microhabitats

Fine reddish sand dominates this area, with low visibility and patchy kelp habitats on scattered rocks. Kina were irregularly distributed around these features. Quite a bit of this patch is shallow mixed forest and intertidal yet with significant kina numbers

A10 – Deep Bare Zone

A largely barren deepwater zone with dense kina aggregations and prominent feeding fronts. Limited algal presence was observed.

A11 – Shallow Reef with Kelp Corridors

Characterized by extensive macroalgal growth, including large kelp species, and numerous gullies extending shoreward. Kina clustered around rock bases, kelp holdfasts, and tidal fringes.

A12 – Reef Transition Zone

Shallow algal-covered rock merging into deeper barrens. Feeding fronts and kina encroachment were seen from depth to the upper reef slope.

A13 – Mid-Reef Slope

Sparse algae on rock with deeper barren areas. Kina and feeding fronts dominated. Towards shore, thicker algae provided concealment for kina at their base, occasionally above low tide level in the Intertidal zone.

A14 – Deep Gullied Barren

Deep zone only accessible at very low tide free-diving, with bare substrate and gullies. Feeding fronts and aggregations were often observed in crevices.

A15 – Sloped Reef with Patchy Algae

Sparsely vegetated rocky reef with deeper barrens. High kina densities and degraded macroalgae, especially toward the reef slope. Shallow mixed forest algal patches harbored kina at their bases.

A16 – Reef Edge with Macroalgal Fringe

Similar to A15, featuring rock sparsely covered by algae and deeper bare substrate. Kina were observed in dense aggregations throughout.

A17 – Narrow Reef Corridor

A transitional slope 0-6-8m with patchy algae and extensive kina grazing. Concealed kina were found under remaining algal bases in shallower parts.

A18 – "The Wall"

A vertical reef face transitioning from deep to shallow. Despite high macroalgal potential, it was extensively overgrazed. Kina clusters dominated both high and low relief features.

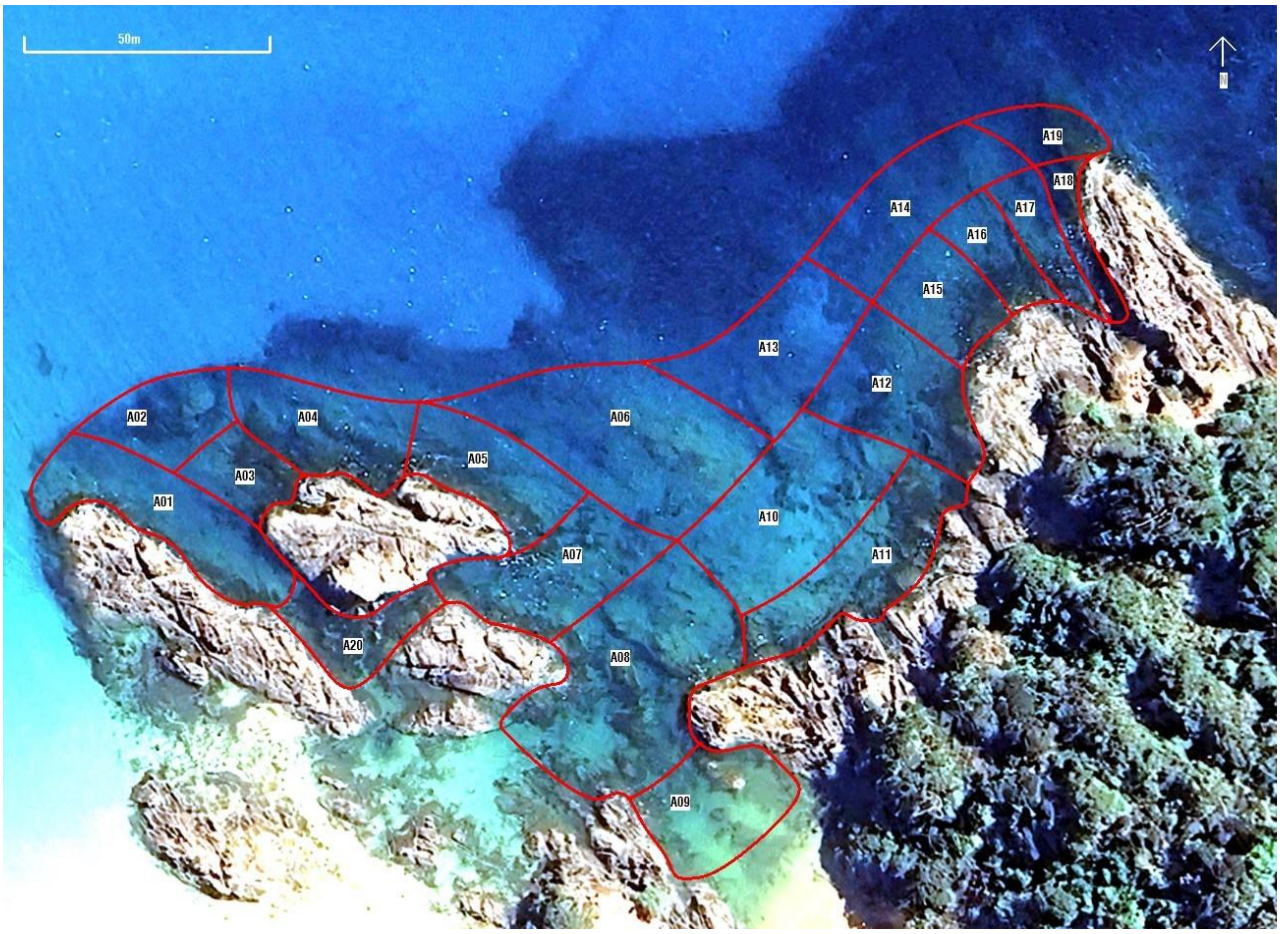
A19 – Northeastern Shelf

A raised rocky platform with moderate algal growth and significant kina presence. Deep plateaus and slopes also showed signs of heavy grazing.

A20 – Southwestern Gully System

Confined between larger reef heads, this area featured gulleys, boulders, and slabs. Kina and some Centros were concentrated around rock bases and kelp holdfasts.

Post-Culling Summary



Since March 2025, kina culling efforts combined with the long term Rāhui have considerably reduced overgrazing in most zones. Areas once dominated by barrens now show early potential recovery signs, including regrowth of native macroalgae (*Ecklonia radiata*) and re-colonization of habitat by invertebrates and fish, including crayfish and small new recruits. In some zones, a purple turf-like seaweed has begun to colonize previously barren surfaces. While there is speculation that this turf algae may compete with *Ecklonia*, both species are currently showing signs of establishment. Continued observation will help assess whether these two algae types can coexist and contribute positively to habitat recovery. Ongoing monitoring aims to track long-term ecosystem recovery.

Culling Types (strategies)

These refer to the diver's approach and diving intensity of kina culling activity during a dive session, depending on environmental conditions, diver energy, and kina density:

Intense

Focused and high-effort culling session targeting a single area. Divers aim to remove the maximum number of kina in one session. Suitable for high-density kina zones where kina are easily visible and abundant. Requires good visibility, calm conditions, and high diver fitness.

Medium

Moderate-intensity effort, often due to reduced kina density or challenging conditions (e.g. reduced visibility, mild swell). Kina may be harder to locate but are still present in significant numbers. Divers spread effort more broadly while still aiming for substantial removal.

Cruising

Low-intensity, flexible effort often done during poor conditions (e.g. rough water, low visibility), or when divers are conserving energy. Typically involves surface work in shallow zones and opportunistic kina removal while exploring multiples or singular patches. Often used during maintenance or touch-up phases.

Culling Phases

These reflect the progressive stages of kina removal within a defined zone:

Start

Initial intervention phase where kina density is typically high. Culling begins with full- area assessment and potential for prioritization of high-density fronts. Usually paired with Intense culling type.

Continuation

Follow-up sessions that deepen the clearing already underway. Focuses on areas missed during the start or newly exposed kina. Kina numbers are still moderate.

Complete goal visually estimate and average density of approx. 1 kina/m2 or less

Zone has been thoroughly culled, with most visible kina removed at the free-diving depths. May still contain low, scattered individuals. Marks the end of the major intervention period**.** Note: this "Complete" status applies to depths accessible by free diving; deeper zones beyond practical free-diving limits may still require follow-up work by SCUBA divers

Maintenance

Regular revisits to ensure kina do not recolonize. Involves lower-intensity culling (often **Cruising**) to remove any new individuals or clusters that appear post- completion

Touch-ups

Broad survey-style dive across multiple zones, focusing on opportunistic kina removal without targeting a specific site. Often combined with ecological observation and light monitoring.

Appendix 3 Habitat map of Maitai Bay