Poor Knights Islands Marine Reserve

Trial removal of the long-spined sea urchin (*Centrostephanus rodgersii*) at the Poor Knights Islands Marine Reserve

2023-2024

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Cover: *Centrostephanus rodgersii* barren at the Poor Knights Islands Marine Reserve. *Photo: Paul Caiger*

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Abstract

Recent research from northeastern Aotearoa New Zealand has identified the long-spined sea urchin (*Centrostephanus rodgersii*) as an emerging and major threat to reef ecosystems. This is of particular concern to the Tawhiti Rahi - the Poor Knights Islands Marine Reserve as there has been a large increase (9.3 times since 1999) in this species within shallow rocky reefs as well as on invertebrate-dominated rock wall habitats. To better understand the impact of this species on these iconic rock wall communities, a small-scale removal experiment was undertaken in 2023 at three rock wall sites dominated by long-spined sea urchins. This was conducted as a partnership between the University of Auckland (UoA), the Department of Conservation (DOC), and local hapū Te Whānau a Rangiwhakaahu. This report summarises the ecological results from the first year of the experiment.

The three long-spined sea urchin-dominated rock wall sites were were split into removal and unmanipulated control areas. Removal areas covered ~30-40 m of coast, extended to ~20 m depth, and had a total area of ~540-1000 m^2. Baseline ecological surveys and removal of long-spined sea urchins (through in-situ culling or collection) were undertaken in April 2023. A total of 4,140 long-spined sea urchins were removed initially, taking a total of 15 SCUBA diving hours. Follow up surveys to monitor removal effectiveness and ecological changes included long-spined sea urchin density, kelp cover, and benthic cover of species living on the rock walls. These surveys were conducted prior to removal as well as six months and one year post removal, with a further 1,230 long-spined sea urchins cleared from the removal sites over the one-year monitoring period.

After one year, kelp (*Ecklonia radiata*) canopy cover increased significantly and dominated the rock walls at two sites, but there was only a small increase at the third site Rikoriko Cave, which had lower light levels. The response of the rock wall communities within the removal areas varied among the three sites after one year. However, all sites showed a general trend of increasing turfing algae and bryozoans, with a decline in bare rock and encrusting algae. There was also no change in the unmanipulated control areas which remained dominated by the long spined urchins and bare rock and encrusting algae.

These initial results confirm the impact of long-spined sea urchins on rock wall communities and provide crucial insights into the recovery potential of these communities if they are removed. It also provides additional information on the practicality and feasibility of implementing large-scale long-spined sea urchins removals.

Keywords

Long-spined sea urchin, urchin barren, kelp, rock wall communities, marine reserve.

Introduction

Tawhiti Rahi or the Poor Knights Islands are a culturally, ecologically and economically important group of islands located 22 km off the east coast of Northland in Aotearoa New Zealand. Surrounding the islands is 24.1 km^2 of no-take marine reserve which has been protected since 1998 and has been protected from commercial fishing since 1981. The Poor Knights Islands Marine Reserve is an internationally renowned diving and snorkeling destination due to its unique ecosystems and incredible biodiversity. It is renowned for its vertical reef walls and caves that are covered with an amazing diversity of flora and fauna including sponges, bryozoans, sea squirts, anemones and encrusting algae. These invertebrate-dominated rock walls support reef fish and mobile invertebrate populations and host rare reef species such as black coral at depths (Sim-Smith & Kelly, 2009).

The long-spined sea urchin (*Centrostephanus rodgersii*) is found on subtidal rocky reef and is considered native to Aotearoa New Zealand (Balemi & Shears, 2023). The abundance of long-spined sea urchins has been increasing along the northeastern coastline of Aotearoa New Zealand (Balemi & Shears, 2023; Tebbett et al. 2025), which has been linked to climate induced oceanic warming and the overfishing of their main predators (kōura or rock lobster (*Jasus edwardsii*) and pawharu or packhorse lobster (*Sagmariasus verreauxi*)) in the region (Balemi & Shears, 2023;Thomas et al., 2021)). The long-spined sea urchin is known to be a highly omnivorous feeder, grazing on large algae and sessile (non-mobile) invertebrates (Day et al., 2024; Balemi et al., 2025). Unlike other grazers, sea urchins are known for their ability to eliminate large algae over vast areas, creating and maintaining “urchin barren” habitats that are largely devoid of large algae (Miller et al., 2022). Long-spined sea urchin overgrazing impacts have been documented on kelp forest ecosystems in Tasmania and in Aotearoa with significant losses to biodiversity and ecosystem function (Balemi & Shears, 2023; Ling, 2008; Ling & Keane, 2024). While the increases in long-spined sea urchins pose a threat to the diverse rock wall algal and invertebrate communities in northeast Aotearoa, there is currently limited information on their impacts on these habitats.

Historically, long-spined sea urchins were present in low numbers at the Poor Knights Islands Marine Reserve and nearby Mokohinau Islands (Choat & Schiel, 1982; Fell, 1949; Shears & Babcock, 2004). The shallow reefs were dominated by kelp forest canopy, such as *Ecklonia radiata* (Balemi & Shears, 2023). Kelp forests provide three-dimensional habitat for high biodiversity and biomass of marine life, as well as numerous ecosystem services such as carbon sequestration and coastal protection (Miller et al., 2022). Beneath this canopy was a rich understory of sessile invertebrates, such as turfing bryozoans, hydroids and massive sponges (Ayling, 1974; Battershill, 1986; Doak 1979). Shaded rock walls in caves and archways were historically dominated by diverse sessile invertebrate assemblages and lacked large algae such as kelp (Battershill, 1986). The endemic sea urchin or kina (*Evechinus chloroticus*) was the dominant sea urchin at the Poor Knights Islands (Balemi & Shears 2023).

Long term monitoring efforts at the Poor Knights Islands Marine Reserve and the unprotected Mokohinau Islands have shown a large increase in the long-spined sea urchin over the last two decades (Balemi & Shears 2023). Kina abundance and areas of kina barrens on shallow reefs have declined in the marine reserve since 1998, whereas the more voracious grazer, long-spined sea urchin, has increased (Balemi & Shears 2023). This has been associated with increases in urchin barren habitat on shallow reefs (<20m), dominated by long-spined sea urchins, that were historically kelp forest (Balemi & Shears, 2023). Many of the rock walls at Tawhiti Rahi are now urchin barrens with reduced coverage of sessile invertebrates and encrusting algae and increases in bare rock (Fig. 1, Balemi, 2024). These long-term changes suggest the long-spined sea urchin is majorly impacting rock wall communities in Tawhiti Rahi.

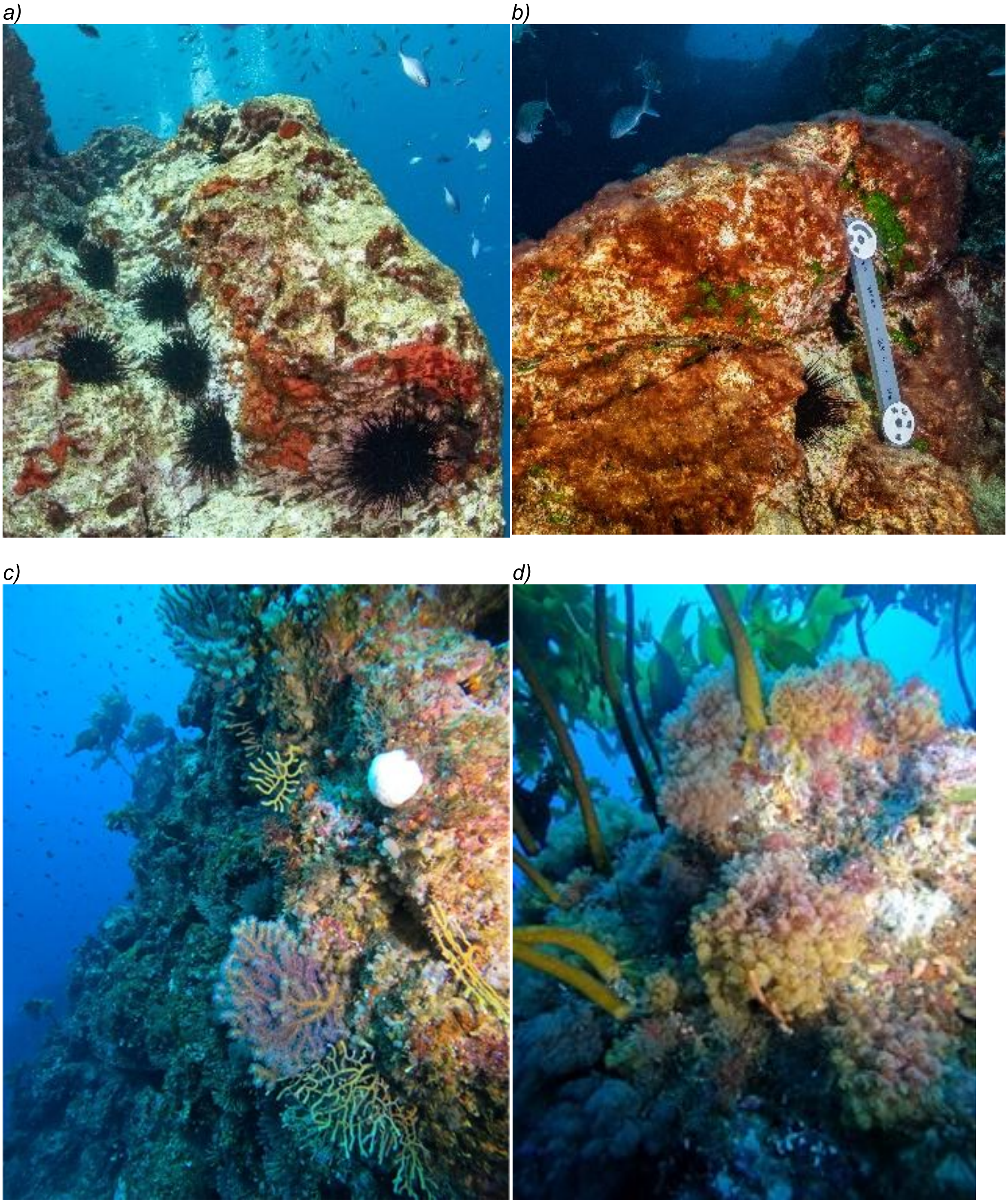

Figure 1. Examples of long-spined sea urchin dominated urchin barrens (a and b) and healthy rock walls (c and d) in the Poor Knights Islands Marine Reserve. Photo credits: a. Paul Caiger; b. Arie Spyksma; c and d. Celia Balemi.

The increase in long-spined sea urchin and associated loss of rocky reef biodiversity is a major threat to the ecological, cultural and economic values of the Poor Knights Islands Marine Reserve. To better understand this issue, Te Papa Atawhai - the Department of Conservation (DOC) worked in partnership with Te Whānau a Rangiwhakaahu and the University of Auckland (UoA) to undertake an experimental removal of long-spined sea urchin from rock wall habitats at three sites within the Poor Knights Islands Marine Reserve. Urchin removal typically leads to rapid kelp recovery within kelp forest ecosystems (Miller et al., 2024; Miller et al., 2022), thus it was predicted that removals would promote recovery of rock wall habitats in the trial areas.

The aim of the experiment was to better understand the impacts of long-spined sea urchin population increases on rock wall communities and the recovery potential of these habitats. In addition, the removal experiment aimed to provide information on the effort and logistics required for removing long-spined sea urchin to help guide future control programs.

There were three objectives identified for the trial:

- Objective 1 – Use transect surveys to estimate the abundance of long-spined sea urchin and other urchin populations in three trial removal areas and control areas to assess any changes in urchin density, and assess the rate (if any) of re-incursion by long-spined sea urchin back into the removal areas.
- Objective 2 – Use photoquadrat surveys in three trial removal areas and associated control areas to assess the changes in the rock wall communities (% covers) related to the removal of long-spined sea urchins, and assess how this may change over a one-year period following removal.
- Objective 3 - Use visual estimates to assess changes, if any, in the overall canopy cover of the kelp *Ecklonia radiata* after long-spined sea urchin removal.

This report summarises the main findings of this experiment one year after the initial long-spined sea urchin removals.

Methods

Sites

Tawhiti Rahi or the Poor Knights Islands are located 22 km east of Tūtūkākā in northeastern Aotearoa, New Zealand (Fig. 2). This archipelago is made up of two main islands - Tawhiti Rahi (being the largest) and Aorangi, with smaller pinnacles and outcrops surrounding them. They are strongly influenced by the warm water of the East Auckland Current, with sea temperatures ~ 1°C warmer than the mainland coast, which has led to a diverse assemblage of subtropical and temperate species (Shears & Babcock, 2004).

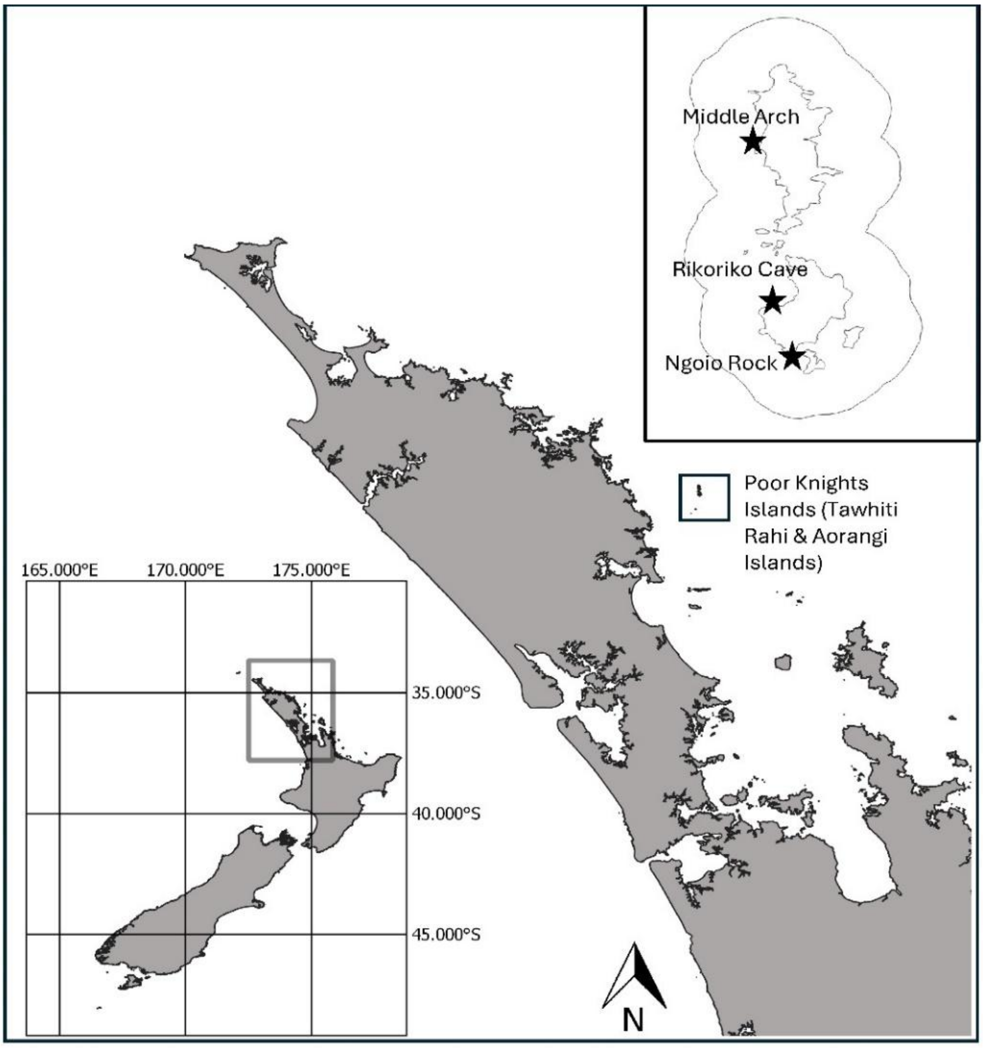

Figure 2. Map of Tawhiti Rahi - the Poor Knights Islands in northeastern Aotearoa New Zealand with the three long-spined sea urchin removal sites represented as black stars.

In March 2023, three Tawhiti Rahi sites identified as urchin barrens dominated by long-spined sea urchin were selected as suitable for removal trials. The sites were located at Middle Arch, Ngoio Rock, and Rikoriko Cave, on the western side of the islands (Fig. 2). All three sites are made up of rock walls of varying depths. The Middle Arch and Ngoio Rock walls are west and south-facing respectively, in open areas of coastline, whereas the Rikoriko Cave site is located within the cave on the western wall and is almost completely shaded. The removal area at all sites extended from the low tide mark down to ~20 m depth, had a high density of long-spined sea urchin and were generally dominated by crustose coralline algae and bare rock, characteristic of being overgrazed by long-spined sea urchins. At the two illuminated sites (Middle Arch and Ngoio Rock), there was a shallow subtidal band (<2 m) of large brown seaweeds, below which long-spined sea urchins dominated to depths of ~18-20 m, with *Ecklonia radiata* kelp present beneath this depth.

Long-spined sea urchin removal experiment

In April 2023, removal areas of ~30-40 m (Table 1) along the rock wall were selected at each site with experimental control areas of approximately the same size (where long-spined sea urchin numbers were not manipulated) adjacent to each removal area. Each site was divided into 10 x 10 m zones with Upper and Lower (<10 m depth, 10-20 m depth) depths at every 10 m along a transect tape which ran horizontally through the removal and control areas (Fig. 3).

Table 1. Length and depth of long-spined sea urchin removal areas in Tawhiti Rahi – the Poor Knights Islands. Approximate area for each site takes into consideration topographical complexity and depth variations across the length of the removal area.

Site	Area Length (m)	Max area Depth (m)	Approx area (m^2)
Ngoio Rock	40	20	1000
Middle Arch	30	20	540
Rikoriko Cave	35	20	630
Total	105	20	2170

Figure 3. Example of transect tapes marking boundary of control areas (left) and long-spined sea urchin removal areas (right) at the Ngoio Rock site in Tawhiti Rahi - the Poor Knights Islands. Photo credit: Paul Caiger.

Pre-removal surveys

Surveys of urchin density, kelp cover, and rock wall communities were undertaken before initial long-spined sea urchin removal, and at 6 months and one year post removal. To assess the density of long-spined sea urchins (Objective 1), SCUBA divers completed three random 5 x 2 m transects within each 10 x 10 m zone counting the number of long-spined sea urchins. Kina density was also recorded, but only 4 individuals were recorded in the initial surveys across all sites, so data are not presented. The percentage canopy cover of the kelp *Ecklonia radiata* was estimated from each 10 x 10 m plot (Objective 2).

Rock wall communities were surveyed using ten 0.25 m^2 photoquadrats (GoPro 10 with a 5000 lumen underwater light) within each of the 10 x 10 m plots (Objective 3). From the photos, the percentage cover of the various taxa (groups of different species of organisms) was analysed using the software Squidle+ with 50 random points overlayed over each photo. These species were analysed to the lowest taxonomic level where the resolution of GoPro photos allowed.

Long-spined sea urchin removal and maintenance

Two forms of removal techniques were used - manual crushing and collection then crushing. Manual crushing involved crushing long-spined sea urchins in place using a steel bar. The remains are left in place where they break down naturally or be consumed by other species (Fig. 4a). Collection involved collecting the long-spined sea urchins into a basket lifting the basket onto a boat, crushing them on board the boat and disposing the remains into deep water within the reserve in an area over sand with high water motion away from the removal site (Fig. 4b). While manual crushing is significantly faster, collection and utilisation of sea urchins is a cultural preference of minimising waste, though was not always feasible (Miller & Shears, 2023).

Manual crushing was used to remove long-spined sea urchins at Middle Arch and Ngoio Rock. Long-spined sea urchins were collected at Rikoriko Cave where possible due to concerns around high diver traffic and low water motion to disperse remains. Long-spined sea urchins that could not be collected were manually crushed.

Follow up visits were carried out at the sites in May and July/August 2023 to remove any long-spined sea urchins that had been missed or moved back into the removal areas, to maintain a low sea urchin density. Long-spined sea urchins were also culled or moved back to the surrounding controls once the 6 month and one-year surveys had been completed. Urchins were moved rather than culled as it was assumed they came from the control areas, thus would have reduced the overall count of urchins in the control area.

Sea urchin removal was carried out under Ministry of Primary Industries Special Permit 731-2.

a)

b) 

Figure 4. Photographs of long-spined sea urchin trial removals in the Poor Knights Islands Marine Reserve showing a) manual crushing of long-spined sea urchins using metal pipe, and b) collection of long-spined sea urchin into baskets. Photo credits: Arie Spyksma.

Data analysis

To evaluate if there were differences in the overall rock wall communities at each site pre removal and one year post removal, multivariate PERMANOVA was used. A Bray-Curtis resemblance matrix was constructed from the percentage cover data based each of the 10 x 10 m plots within each site. Using 999 permutations, PERMANOVA tested the fixed factors of Time (Pre Removal, One Year) or Area (Control, Removal) with the Zone (each 10 x 10 m plot) as a random variable nested within Area.

A non-metric multi-dimension scaling (nMDS) was used to visualise the rock wall communities of the removal and control areas, pre removal and one year post removal. The vectors showing the correlation between the nMDS scores and each taxa category were also presented to indicate how the community changed through time and how each treatment was correlated to the taxa categories.

The PERMANOVA analysis was conducted in Primer 7 and nMDS was conducted in R studio.

Results

Long-spined sea urchin removals

During the original removals a total of 4,140 long-spined sea urchins were removed across the three sites taking 15 diver hours (Table 2). During follow-up visits in May and July/August 2023, another 503 were removed (Table 3). Six months post removal 301 long-spined sea urchins were removed from the three sites and 430 were removed after one year (Table 3).

Long-spined sea urchins removed during follow up clearances included a mix of larger urchins near the edge of the removal area that had encroached across the boundary and emergent small urchins that had presumably been cryptic and hidden during initial clearances. At six months and one year, the long-spined sea urchins within the removal areas were mostly moved to the surrounding control areas, with only those that could not be removed (due to cryptic behaviour) being culled.

Table 2. Long-spined sea urchins removed and time taken for removal from each of the three sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in the Poor Knights Islands Marine Reserve, in the first removal.

Site	Number removed	Est Density (m^2)	Removal time (mins)	Removal time (hours)	Removal rate (#/min)	Area/ hour (m^2)	Method
Middle Arch	948	1.8	157	2.6	6.04	206.4	Culled 100%
Rikoriko Cave	842	1.3	307	5.1	2.74	123.1	Collected 88% and culled 12%
Ngoio Rock	2350	2.4	435	7.3	5.40	137.9	Culled 100%
Total	**4140**		**899**	**15.0**	**4.73**		

Table 3. Long-spined sea urchins removed from each of the three sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in the Poor Knights Islands Marine Reserve, over the one-year experimental period.

Date	Activity	Middle Arch	Rikoriko Cave	Ngoio Rock	Total removed
Apr-23	Initial removal and surveys	948	842	2350	4140
May-23	Re-clear	186	46	112	344
Jul-23	Re-clear	61	48	50	159
Nov-23	6-month survey and re-clear	74	90	137	301
Apr-24	One year survey and re-clear	87	156	187	430
	Total	**1438**	**1121**	**2811**	**5374**

Objective 1 - Long-spined sea urchin density

Prior to removals, long-spined sea urchin density was ~1-2 per m^2 at all sites and tended to be lowest at Rikoriko Cave (Fig. 5). At 6-month and one-year post-removal, long-spined sea urchin density in removal areas remained at low levels (~0.1-0.2 per m^2) with no change within the control areas. Most of the long-spined sea urchins recorded in removal areas at 6-month and one year post removal were juveniles (<50 mm) that had likely been highly cryptic during the initial removals and had since emerged from cracks and crevices.

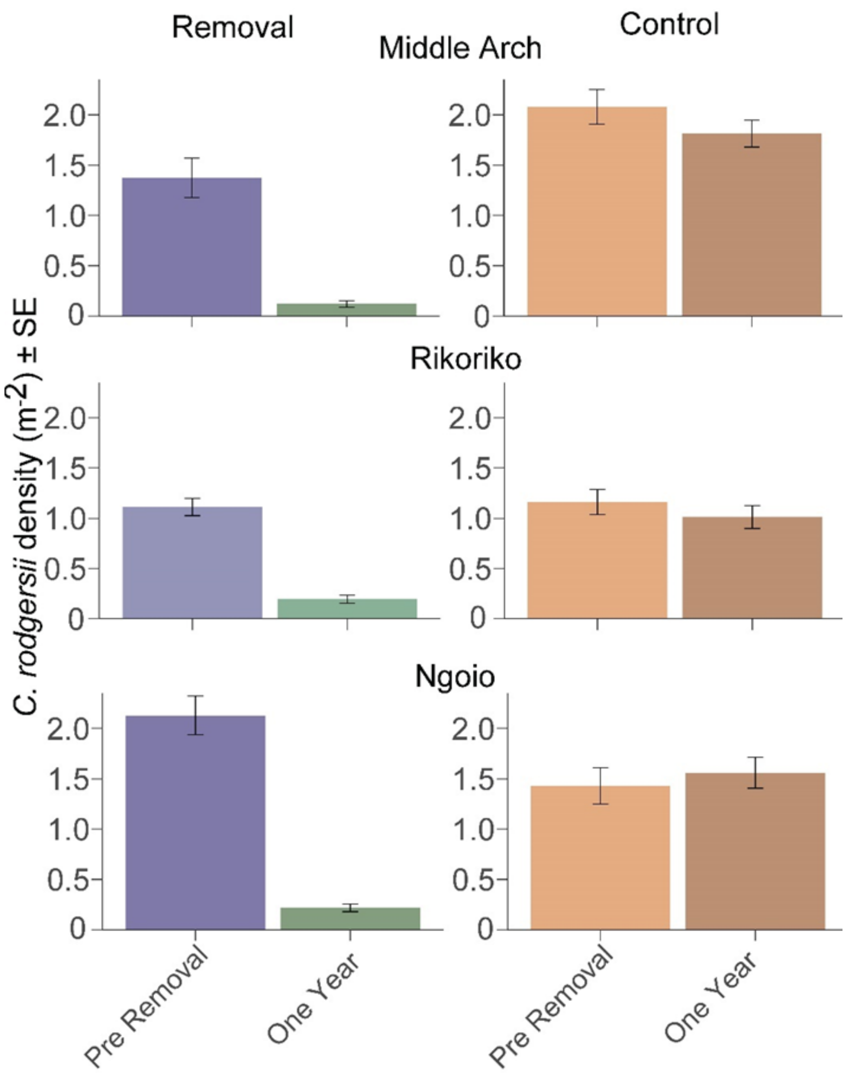

Figure 5. Mean density (± standard error) of long-spined sea urchins at the three rock wall sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in the Poor Knights Islands Marine Reserve, within the urchin removal areas (left) and control areas (right), pre removal and one-year post removal.

Objective 2 - Rock wall communities

Prior to removals, the rock wall community composition did not statistically differ between the removal and control areas (Table 4). One year following removals, the rock wall community composition significantly differed from controls and from pre removal areas at all three sites. Community composition in the control areas did not significantly change over the one-year period.

The differences in community composition in the urchin removal areas after one year are observed when plotted in non-metric multidimensional space (NDMS) (Fig. 6). The community composition of control areas at both time points, as well as the removal areas prior to urchin removal, were similar at all three sites. In comparison, the community composition of removal areas after one year following long-spined sea urchin removal diverged from the other groups at all three sites.

Table 4. PERMANOVA pair-wise comparison in the overall rock wall community composition at three sites (Middle Arch, Rikoriko Cave and Ngoio Rock), comparing control areas with long-spined sea urchin removal areas over time (pre removal and one year post removal). Bold *p*-values indicate significant differences ($p < 0.05$).

Middle Arch	F	*P value*
Pre Removal (Control) – Pre Removal (Removal)	0.54	0.70
Pre Removal (Control) – One year (Control)	0.44	0.79
Pre Removal (Removal) – One year (Removal)	5.16	**0.02**
One year (Control) – One year (Removal)	4.15	**0.03**

Rikoriko Cave	F	*P value*
Pre Removal (Control) – Pre Removal (Removal)	2.88	0.11
Pre Removal (Control) – One year (Control)	1.24	0.30
Pre Removal (Removal) – One year (Removal)	20.32	**0.03**
One year (Control) – One year (Removal)	4.93	**0.01**

Ngoio Rock	F	*P value*
Pre Removal (Control) – Pre Removal (Removal)	0.65	0.63
Pre Removal (Control) – One year (Control)	0.76	0.51
Pre Removal (Removal) – One year (Removal)	24.53	**0.02**
One year (Control) – One year (Removal)	24.42	**0.03**

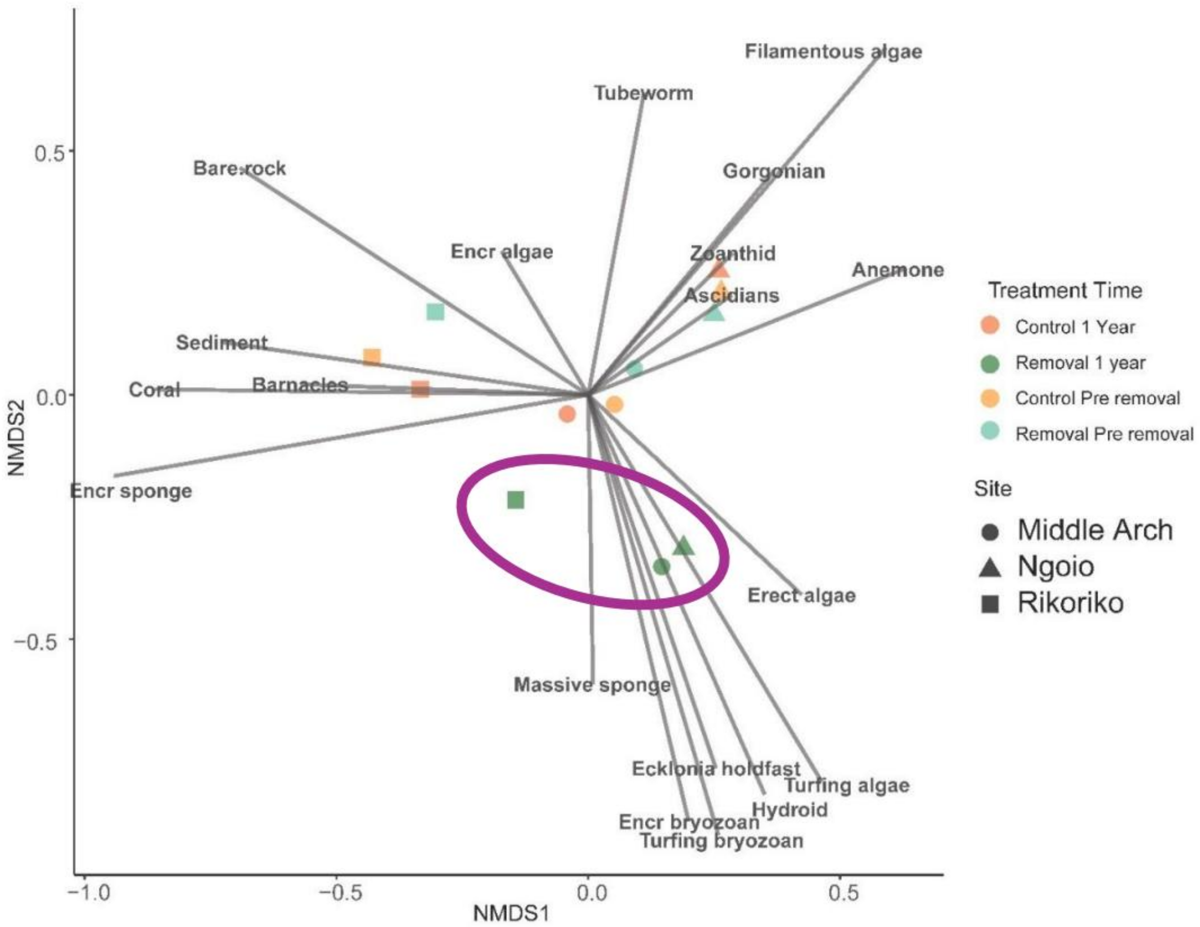

Figure 6. nDMS ordination plot showing the community composition in control areas and long-spined sea urchin removal areas at the Poor Knights Islands Marine Reserve at the three sites; Middle Arch (circle), Rikoriko Cave (square) and Ngoio Rock (triangle). Site colours represent control or removal areas assessed pre removal or one year post removal. Overlayed vectors show correlations between the MDS axes and rock wall taxa categories. The three removal sites at one year post removal are encircled in purple.

The three sites showed similar changes in rock wall communities within the removal areas after one year (Fig. 7 & 8). At all sites, turfing algae and bryozoans increased, whereas bare rock and encrusting algae declined. At Middle Arch and Ngoio Rock, there were declines in filamentous algae. Within Rikoriko Cave and at Ngoio Rock removal areas, there was also an increase in encrusting bryozoans. After one year post removal, hydroids and *Ecklonia radiata* holdfast cover slightly increased in the removal areas at Ngoio Rock, and encrusting sponges slightly declined at in the removal areas at Middle Arch (Fig. 8).

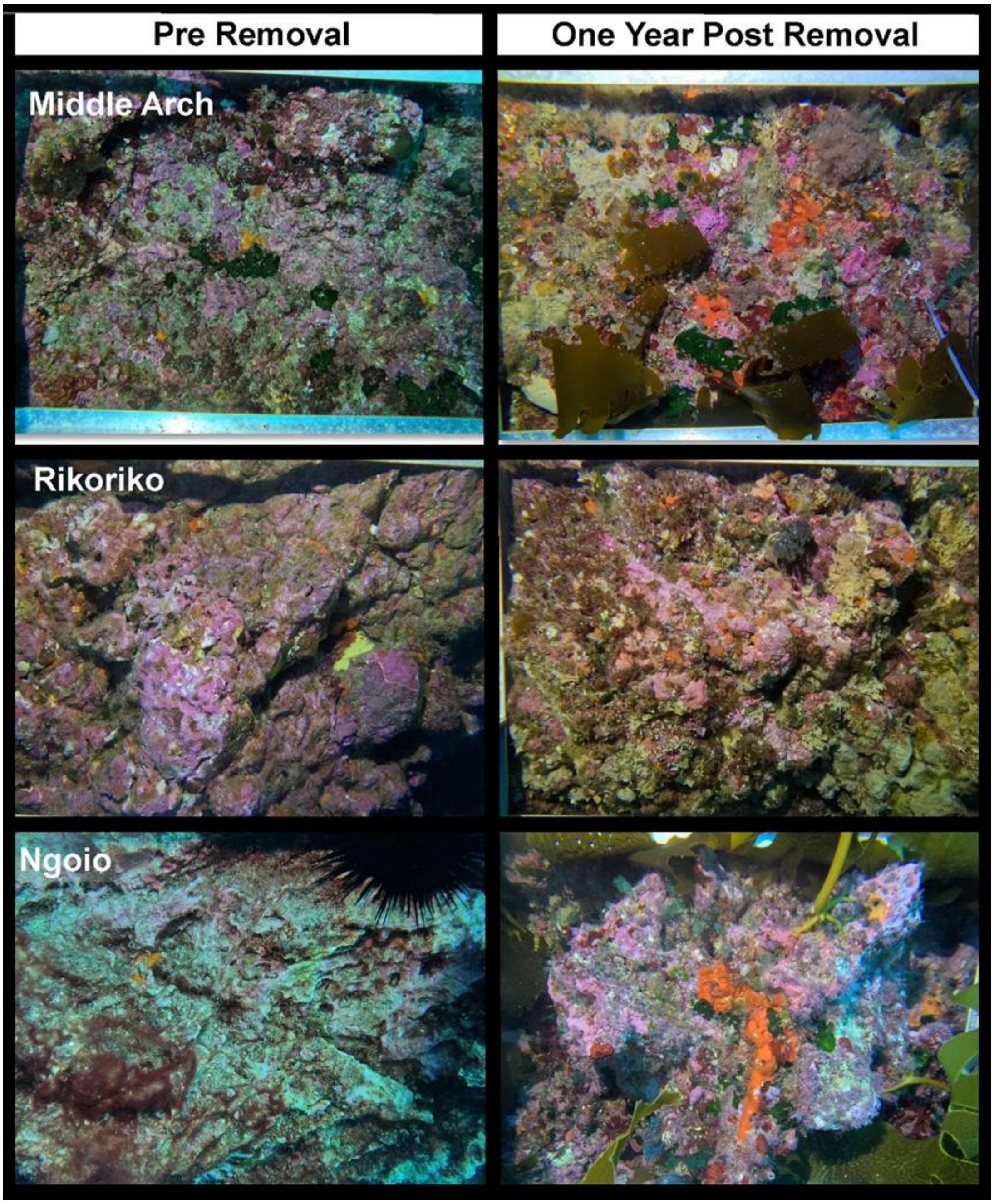

Figure 7. 0.25m^2 Photoquadrats of long-spined sea urchin removal areas, shown pre removal (left) compared to the same zone (10m x 10m plot) one year post removal (right), from the three sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in Poor Knights Islands Marine Reserve.

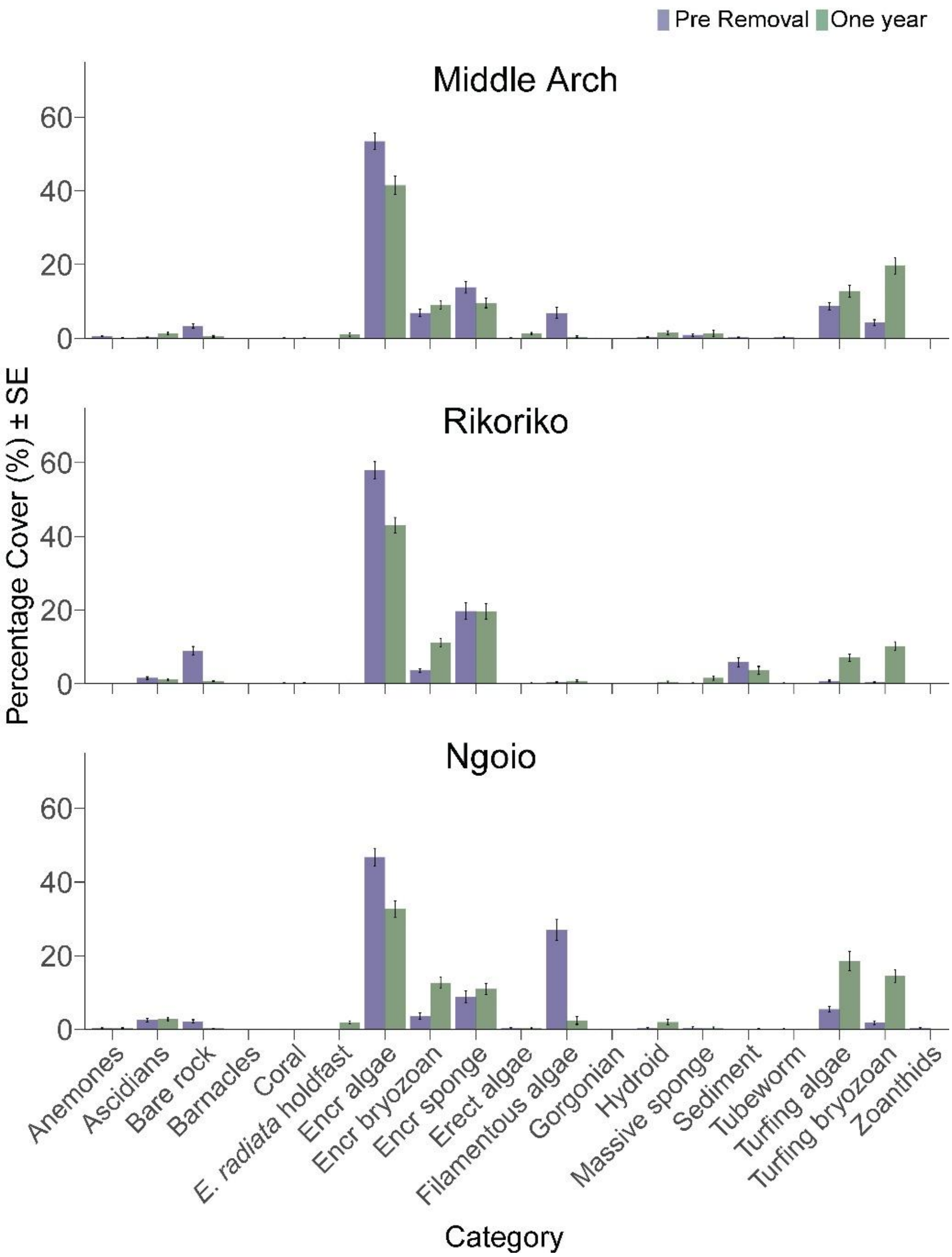

Figure 8. Percentage cover (± standard error) of taxa identified within the same zones (10 x 10 plot) within the long-spined sea urchin removal areas pre removal (purple) and one year post removal (green), from the three sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in the Poor Knights Islands Marine Reserve.

Objective 3 - Kelp canopy cover

The cover of *Ecklonia radiata* increased within the removal areas at Middle Arch and Ngoio Rock after one year, increasing from 15% to 45% and 6% to 58% respectively (Fig. 9). Minimal changes were observed in control areas. There was little change observed at Rikoriko Cave, with only a small number of juvenile kelps recorded in the removal area after one year.

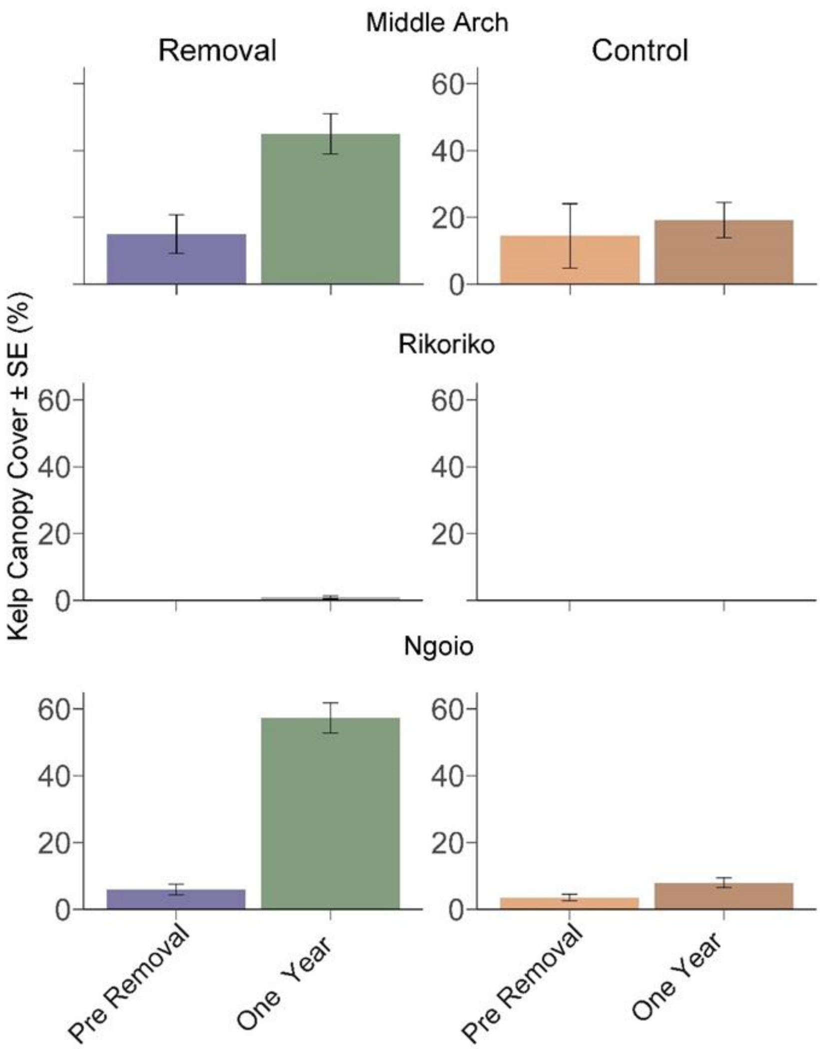

Figure 9. Mean canopy cover (± standard error) of *Ecklonia radiata* kelp at the three rock wall sites (Middle Arch, Rikoriko Cave and Ngoio Rock) in Tawhiti Rahi - the Poor Knights Islands, within the long-spined sea urchin removal areas (left) and control areas (right), pre removal and one-year post removal.

Discussion

These results demonstrate rapid changes in rock wall communities following long-spined sea urchin removals. Over the year following urchin removals, all removal areas exhibited changes in rock wall community composition, including increases in turfing algae and bryozoans, as well as large increases in kelp at two sites. Little to no change was observed within the non-manipulated control areas which had greater areas of bare rock, likely due to the grazing of long-spined sea urchins upon algae and sessile invertebrates (Balemi et al. 2025). Long-spined sea urchin densities are rapidly increasing in northeast Aotearoa New Zealand (Balemi & Shears, 2023; Tebbett et al. 2025). These removals reveal the significant impacts of their high densities on reducing rock wall community biodiversity and biomass in the Poor Knights Islands. The reduced coverage of sessile invertebrates and greater proportions of bare rock in control areas indicates that grazing from long-spined sea urchins is likely reducing the productivity and ecosystem function of these rock wall communities.

The rapid recovery of the kelp *Ecklonia radiata* on rock walls is consistent with other urchin removal experiments in northeastern Aotearoa New Zealand where the removal of kina from urchin barrens resulted in the rapid recolonisation of kelp and other large seaweeds (Miller et al., 2024). The extent of kelp recovery varied among the three sites with only a small increase at Rikoriko Cave. This is highly likely related to a combination of low light levels and low water motion in the cave, potentially causing low growth and/or low propagule supply at this site (Wernberg et al., 2019). The other sites had large recoveries with three times the amount of kelp at Middle Arch and 9.7 times at Ngoio Rock. The recovery of the kelp indicates the species associated with the kelp habitat may also return over time. In Australia, the removal of urchins promoted the recovery of the kelp with higher densities of abalone (pāua) compared to barren sites (Keane et al., 2019).

The removal of long-spined sea urchins also promoted recovery in the benthic communities, consistent with a release in grazing pressure and increase in kelp canopy. Within the removal areas, declines in bare rock, encrusting and filamentous algae were observed, as well as increases in turfing algae and bryozoans. Despite the significant changes in rock wall communities observed within the removal areas, it is likely that more time is needed for full ecosystem recovery, particularly for sessile invertebrate species. In addition, we were unable to compare the restored habitat to comparable ungrazed rock wall habitats to assess restoration potential. Comparable research was undertaken in North America with the removal of a similar urchin species (*Centrostephanus coronatus*) and found that it took 27 months for the rock wall community to recovery to a point where it was indistinguishable from the ungrazed control (Vance, 1979). This suggests that at least 2 years may be required to see a full recovery of these rock wall communities, however, this will depend on the life history characteristics of these individual species. Other sea urchin removal studies in northeastern Aotearoa New Zealand have shown changes in canopy cover and benthic community continue for at least three years, with up to a 50% increase in canopy cover between years 2 and 3 at one site (Miller, unpubl. data), suggesting longer time periods may be required to reach full recovery, particularly for slower growing species. While restoration shows great benefit, it is likely to be as beneficial as prevention.

The urchin removal areas in this study are relatively small (30-40 m length of rock wall) meaning that regular and ongoing removals are needed to remove sea urchin migrating into the area and maintain the treatments. Removal of urchins over larger areas (>1 ha) has been shown to reduce reinvasion rates (Miller et al. 2024) and therefore result in a greater response to removal with longer-lasting impacts. Therefore, it is likely that long-spined sea urchin removal over larger areas as part of a wider management strategy would yield greater beneficial results due to less edge effects (Miller et al. 2022). Reinvasion rates will also vary across species, as some urchins move more than others. However, it is important to note that sea urchin removal does not provide a long-term restoration solution on its own, as long-spined sea urchins are likely to both migrate in and recruit into removal areas. Multiple management approaches are likely to be needed to provide longer-term benefits, such as measures to rebuild predator populations both locally at the Poor Knights Islands and over larger scales.

Conclusions

This report demonstrates the significant impact of long-spined sea urchins on rock wall communities, as well as their recovery potential following the removal of long-spined sea urchins. These findings provide insights into the effort required for removal interventions to reduce long-spined sea urchin densities in rock wall habitats (objective 1). Multiple follow-up clearings were required after the initial removals to keep long-spined sea urchin numbers low in removal areas. These trial removals lead to large changes in rock wall communities within removal areas (objective 2) as well as induced large increases in kelp canopy cover at two sites (objective 3).

While these results indicate that active removal of long-spined sea urchins can result in recovery of these rock wall ecosystems, this is unlikely to provide a long-term solution on its own as it does not address the main causes of the increase in long-spined sea urchins in Aotearoa New Zealand. As with urchin barren management elsewhere, multiple management approaches are likely to be needed in conjunction with long-spined sea urchin removal to provide greater benefits to rock wall habitats. Addressing the drivers of increasing long-spined sea urchin densities while mitigating their impacts will continue to be of importance to ensure the resilience of reef ecosystems at the Poor Knights Islands Marine Reserve.

Author contributions

CAB: Writing – original draft, Conceptualization, Formal Analysis, Methodology; ML: Writing – review & editing, Conceptualization, Methodology, Project administration; AD: Writing – review & editing; KIM: Writing – review & editing, Conceptualization, Methodology; COB: Conceptualization, Methodology; AS: Writing – review & editing; Conceptualization, Methodology, Project administration; PC: Conceptualization, Methodology; ED: Writing – review & editing, Conceptualization, Methodology; NS: Writing – review & editing, Conceptualization, Methodology, Project administration.

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Data availability statement

The data is available on request from DOC.

References

Ayling, A. (1974). Offshore kelp forests. *New Zealand's Nature Heritage*, *2*(22), 605-609. Auckland, New Zealand.

Balemi, C. A. (2024). *Long-term trends and ecological impacts of the subtropical sea urchin Centrostephanus rodgersii in northeastern Aotearoa New Zealand* (Doctoral thesis, University of Auckland). University of Auckland Research Repository.

Balemi, C. A., Pan, S. & Shears, N.T. (2025). Broad dietary niche of irrupting subtropical sea urchin exacerbates threatens to multiple temperate reef habitats. *Marine Ecology Progress Series*, *757*, 131-144. doi:10.3354/meps14809

Balemi, C. A., & Shears, N. T. (2023). Emergence of the subtropical sea urchin *Centrostephanus rodgersii* as a threat to kelp forest ecosystems in northern New Zealand. *Frontiers in Marine Science*, *10*, 1224067. doi:10.3389/fmars.2023.1224067

Battershill, C. (1986). *Marine benthos of caves, archways, and vertical reef walls of the Poor Knights Islands.* Leigh Marine Laboratory, University of Auckland.

Choat, J., & Schiel, D. R. (1982). Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. *Journal of Experimental Marine Biology and Ecology*, *60*(2-3), 129-162. doi:10.1016/0022-0981(82)90155-1

Day, J. K., Knott, N. A., Swadling, D. S., Ayre, D. J., Huggett, M. J., & Gaston, T. F. (2024). Investigating the diets and condition of *Centrostephanus rodgersii* (long-spined urchin) in barrens and macroalgae habitats in south-eastern Australia. *Marine Ecology Progress Series*, *729*, 167-183. doi:10.3354/meps14506

Doak, W. (1979). *The Cliff Dwellers: An undersea community*. Auckland, New Zealand: Hodder and Stoughton. ISBN 0340245530

Fell, H. B. (1949). The occurrence of Australian echinoids in New Zealand waters. *Records Auckland Institute Museum*, *3*, 343-346.

Keane, J. P., Mundy, C., Porteus, M., & Johnson, O. (2019). Can commercial harvest of long-spined sea urchins reduce the impact of urchin grazing on abalone and lobster fisheries? IMAS-FA, University of Tasmania. https://www.frdc.com.au/sites/default/files/products/2013-026-DLD.pdf

Ling, S. D. (2008). Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: A new and impoverished reef state. *Oecologia*, *156*(4), 883-894. doi:10.1007/s00442-008-1043-9

Ling, S. D., & Keane, J. P. (2024). Climate-driven invasion and incipient warnings of kelp ecosystem collapse. *Nature Communications*, *15*, 400. doi:10.1038/s41467-023-44543-x

Miller, K. I., Balemi, C. A., Bell, D. R., Blain, C. O., Caiger, P. E., Hanns, B. J., Kulins, S. E., Peleg, O., Spyksma, A. J., & Shears, N. T. (2024). Large-scale one-off sea urchin removal promotes rapid kelp recovery in urchin barrens. *Restoration Ecology*, *32*(1), e14060. doi:10.1111/rec.14060

Miller, K. I., Blain, C. O., & Shears, N. T. (2022). Sea urchin removal as a tool for macroalgal restoration: A review on removing "the spiny enemies". *Frontiers in Marine Science*, *9*, 831001. doi:10.3389/fmars.2022.831001

Miller, K. I., & Shears, N. T. (2023). The efficiency and effectiveness of different sea urchin removal methods for kelp forest restoration. *Restoration Ecology*, *31*(1), e13754. doi: 10.1111/rec.14060

Shears, N. T., & Babcock, R. C. (2004). *Community composition and structure of shallow subtidal reefs in northeastern New Zealand*. Wellington, New Zealand. Department of Conservation.

Sim-Smith, C., & Kelly, M. (2009). *A literature review of the Poor Knights Islands Marine Reserve*. Wellington, New Zealand. Department of Conservation.

Tebbett, S. B., Edgar, G. J., Balemi, C. A., Keane, J. P., Shears, N. T., Spyksma, A. J., ... & Ling, S. D. (2025). Climate-driven trans-Tasman population increase of the habitat-modifying, range extending sea urchin *Centrostephanus rodgersii*. *Journal of Environmental Management*, *392*, 126842. doi: 10.1016/j.jenvman.2025.126842

Vance, R. R. (1979). Effects of grazing by the sea urchin, *Centrostephanus coronatus*, on prey community composition. *Ecology*, *60*(3), 537-546. doi:10.2307/1936074

Wernberg, T., Coleman, M. A., Babcock, R. C., Bell, S. Y., Bolton, J. J., Connell, S. D., Hurd, C. L., Johnson, C. R., Marzinelli, E. M., Shears, N. T., Steinberg, P., Thomsen, M. S., Vanderklift, M., Vergés, A., & Wright, J. (2019). Biology and ecology of the globally significant kelp *Ecklonia radiata*. *Oceanography and Marine Biology: An Annual Review, 57*: 265-324. doi:10.1201/9780429026379-6