Te Puna Mātaitai kutai exhibit ongoing loss of mauri
An update

for Te Komiti Kaitiaki Whakature i nga Taonga o Tangaroa

Look closely. It's your last chance – they have since been illegally harvested.

Until at least mid-2020, this dense 8-m wide bed of large (≥100 millimetres-long) kutai occupied a rock face from low-tide level to a depth of 10 m at the Black Rocks. By June 2022 they had been harvested, despite the widely-advertised ban in place. (Image: Brett Sutton, 12 June 2020)

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Summary Indefinite prohibition on the taking of mussels of any sort in Te Puna Mātaitai came into effect in March 2020 with the aim of allowing kutai (green-lipped mussel *Perna canaliculus*) stocks to rehabilitate.

Booth Whanau have conducted regular annual low-water *intertidal* surveys of kutai in the Mātaitai area since 2019, looking particularly for 1) persistence of harvestable mussels (at least 20 m^{-2} of kutai ≥60 mm in length), and 2) evidence of significant levels of juvenile recruitment (an average of ≥2 individuals <15-mm long per square metre). It appears there has been no significant intertidal juvenile recruitment among the Black Rocks kutai faces, nor at Tikitiki or Wiwiki rocks. But a noteworthy population of intertidal kutai persists on Howe Rock (including recent – but not abundant – new juvenile recruits). Nowhere did we encounter moribund (weakened, possibly diseased) kutai, or significant evidence of recent large-scale mortalities.

For *subtidal* kutai, the extensive dense bed of large individuals first observed in 2020 at 'Kutai Cove' on 'Motukutai' had by mid-2022 disappeared, almost certainly through harvesting. Some hundreds of kilograms live weight will have been involved. This has taken place within a Mana whenua rahui area that was in March 2020 formalised by Fisheries New Zealand (FNZ) as a complete ban on mussel harvesting within the Mātaitai. Moreover, this may have been among Bay of Islands' only remaining significant areas of this very distinctive subtidal biome, characterised by an almost-continuous mat of uniformly large kutai so dense that few plants or other invertebrates gain footing on the rock faces. Known-such subtidal communities are now exceedingly rare in New Zealand. This loss, and its implications for other mātaitai established in the expectation of protection/rehabilitation of key taxa and communities, might be the basis of formal korero with FNZ – whose task it is to police such customary closures.

The significant issue remains as to whether the decline of the Black Rocks kutai has resulted from overharvesting, disease, recruitment failure, etcetera – or some combination of factors. Harvesting has clearly been an issue, but ongoing low juvenile recruitment and/or survivorship of juvenile mussels appear to be the key drivers. Enigmatically, kutai settlement and growth continues apace in many inner parts of the Bay of Islands, particularly on man-made structures.

It is suggested that this report is made available by Te Komiti to FNZ, so they are aware of the lack of any measurable improvement intertidally in kutai populations within Te Puna Mātaitai since the 2020 ban on mussel harvesting, as well as the catastrophic loss of the subtidal bed there. FNZ should also be called upon to ensure adequate policing of the remaining stocks.

Background

Booth Whanau first surveyed Te Puna Mātaitai intertidal kutai (green-lipped mussel *Perna canaliculus*) populations at the Black Rocks and nearby (Figures 1 and 2) in August–September 2019 with the intention of establishing a baseline dataset concerning kutai distribution, abundance and size (Booth et al. 2019). The survey was repeated each subsequent winter, with the fresh imperative being to record any evidence of recovery in kutai stocks after the indefinite ban on mussel harvesting within the Mātaitai had come into effect on 23 March 2020 ([Fisheries] Notice No. MPI1120). (Three mussel species are involved: kutai, together with the blue mussel *Mytilus galloprovincialis* and the little-black mussel *Xenostrobus pulex* – but the latter two are not often encountered in the Mātaitai.) Using standardised, systematic visual searches, we examined the intertidal of certain rock faces for 1) any significant presence of harvestable (at least 20 m^{-2} of kutai ≥60 mm in length) kutai, and 2) evidence of any significant juvenile recruitment (an average of ≥2 individuals <15-mm long per square metre). The results have been provided each year to Te Komiti, our 2020 report (https://tepunamataitai.nz/images/mataitai/Fish_Forever_Report_Black_Rocks_kutai_FINAL.pdflink)

recommended for anyone wanting an overall assessment of factors likely to have been affecting the state of the kutai stocks at that time. Archived video footage for key sites is available upon request.

Extensive beds of medium to large *intertidal* kutai have until quite recently existed at the Black Rocks and nearby localities (see the overview on pages 17–22 in Booth 2020). Our intertidal surveys within Te Puna Mātaitai were focused on the Black Rocks (particularly the north side of 'Motukutai'), and Howe and Wiwiki rocks (Figure 1). Yet-other emergent rocks were checked for kutai as time and conditions allowed (Tikitiki and its surrounds) (Figure 1).

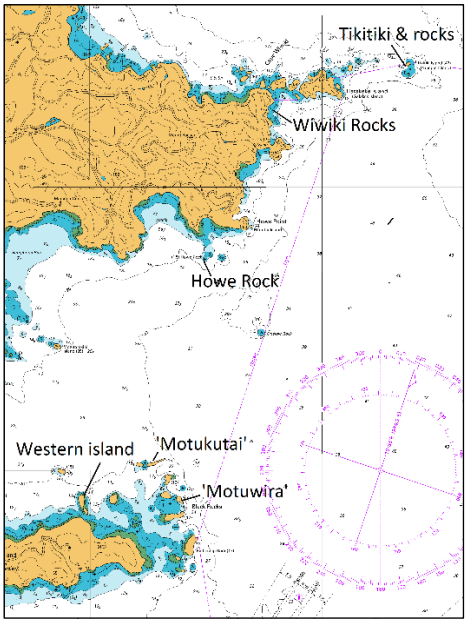


Figure 1. Kutai sampling sites within Te Puna Mātaitai. Some localities are assigned contrived monikers because Māori names are unknown.

Surveys were conducted from a slow-moving vessel, usually with two of us (one with video camera and another using binoculars) visually examining the intertidal zone, including the upper algal fringe (Figure 2). A landing was made once on Howe Rock.

Figure 2. John Booth videos 'Motukutai' face (Chris and Robin are to the stern) as Webber navigates *Mahal*, June 2022. (Chris Booth)

Systematic observations on *subtidal* kutai in Te Puna Mātaitai have been far-more restricted – for obvious logistical reasons. Extensive beds of mainly-large subtidal kutai have until quite recently existed at the Black Rocks (Booth 2020). Indeed, these mussels were a recent feature of the Tall Ships hangi at Matauwhi Bay every new year for a decade or more!

An isolated and significant, extensive and apparently-pristine bed of large subtidal kutai at 'Kutai Cove', on 'Motukutai' (Figure 3), first came to our attention early in June 2020, and was video-surveyed later that month by Brett Sutton. Revealed was an 8-m wide population of almost-exclusively large (>100 mm long) kutai to a depth of about 10 m, forming dense, almost-continuous cover over large areas of vertical rock face that itself dropped about 18 m to the seafloor. The fortunes of this kutai bed have since been followed.

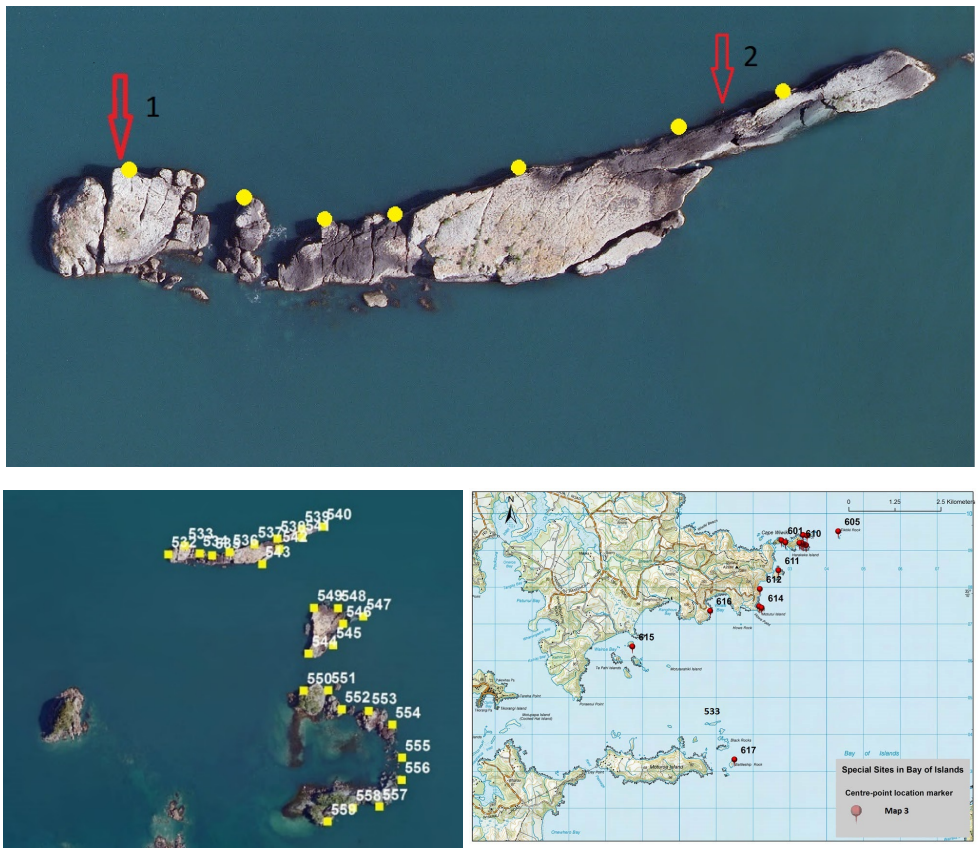


Figure 3. Upper: 'Motukutai'. Red arrows show sites with small clusters of intertidal mussels followed since 2019 (1, 'Kutai Cove'; 2, 'Eastern clusters'); filled yellow circles indicate approximate positions of Froude's (2016a) intertidal and shallow subtidal dive quadrats along the northern face of the island. Lower left: Full extent of Froude's (2016a) 5 m x 5 m algal surveys in May 2016 within Te Puna Mātaitai, where kutai presence was also noted. Lower right: Froude's (2016b) sites of ecological significance within Te Puna Mātaitai. The only site with new references to kutai are for Tikitiki (605 on map: 'Remnant mussel reefs in intertidal and subtidal.') and Battleship Rock (617: 'The occasional mussel').

The extent of any dead kutai on the seafloor of 'Motukutai' beneath current and recent-past intertidal and subtidal kutai populations can provide insight into kutai population dynamics. For example, large numbers of recently-dead kutai might indicate a disease event; absence of small dead kutai might point to poor juvenile recruitment. The seafloor at the base of the north face of 'Motukutai' (and elsewhere) is comprised largely of basalt boulders that might be expected to an extent to 'lock in' accumulations of dead shells. One diver's report to Te Komiti Kaitiaki Whakature i nga Taonga o Tangaroa (Waimate North) in December 2019 of 'a metre-depth' of dead shells recently observed on the seafloor beneath certain of the Black Rocks kutai faces (NZ Fishing News 2020) raised the possibility that water-quality issues and/or disease was resulting in heavy mortalities and recent declines among the kutai at that time. We have not, however, been able to confirm or replicate this observation in any way. Video footage of the seafloor on the north face of 'Motukutai'

by David Heller in 2019 and 2023, and Brett Sutton in 2022, revealed only occasional dead, apparently-large mussel shells, along with a few on protruding ledges higher up.

This document updates the 2022 report to Te Komiti Kaitiaki Whakature i nga Taonga o Tangaroa concerning kutai in Te Puna Mātaitai (Booth Whanau 2022) by providing new information on subtidal kutai at the Black Rocks and by summarising trends from the past four years of observation.

Key points concerning early life history of kutai

Kutai are in the main a shallow-water species, typically occupying hard surfaces from the intertidal down to about 15 m or so depth (although they are occasionally known down to 70 m, and extensive beds once occupied areas of soft substrate in northeast New Zealand). Certain characteristics of the early life history are key to kutai population dynamics.

- In the north, kutai mature within a year of settlement (and at about 30 mm shell length). Most spawn from June to December.
- The pelagic larval (veliger) stage lasts 3–4 weeks, their swimming confined largely to vertical movements. The larvae can potentially be transported large distances by currents.
- Most settlement is between late winter and early summer, but is highly variable spatially and temporally. Primary settlement ('postlarval recruitment') happens when kutai larvae 240–300 µm long transition to a benthic mode of life, and then metamorphose. Primary settlement onto beds of adult mussels is uncommon. Larvae typically settle on filamentous surfaces such as hydroids, bryozoans and certain algae, a mechanism possibly to avoid consumption by, or competition with, adults.
- Secondary settlement is the process by which juvenile mussels 0.3–6 mm long sever their byssus threads and migrate away from their initial settlement sites to re-settle elsewhere ('juvenile recruitment') (Figure 4). Most juveniles are thought to recruit onto mussel beds using either a form of byssopelagic migration ('mucus drifting'; 10s to 100s m), or by pedal crawling (in similar fashion to a garden snail; cm to m). For subtidal populations, at least some pedal crawling is indicated.
- Juvenile kutai may move many times like this before finally recruiting. A potential trigger for secondary settlement is the proximity of adult populations, possibly through waterborne chemical cues.

Figure 4. Secondary settlement of juvenile kutai among the byssal threads of a harvestable mussel at the well-known kutai population at Maunganui Bluff, north of Kaipara Harbour. (John Booth)

Trajectories of Te Puna Mātaitai kutai populations

Our four years of systematic annual surveys are examined here for any developing trends in kutai size, distribution and abundance. We also refer to earlier surveys and other material.

Intertidal kutai

1. 'Motukutai'

In certain places the vertical rock faces on the north face of 'Motukutai' had until quite-recently been festooned with harvestable intertidal mussels, they being popular for both recreational and traditional harvesters. Just a few small clumps remain today (Table 1). We cannot be sure when kutai first became noticeably depleted (there will be harvesters with a good handle on this – please sing out), but we believe it may have been 5–10 years ago according to location. The earliest-known formal intertidal and shallow subtidal ecological survey of certain of the Black Rocks (including 'Motukutai') was Vicky Froude's extensive and intensive 2016 Bay of Islands kelp/kina-barren survey (Froude 2016a). Certainly by then they were largely depleted. Although the presence of mussels was not her primary focus she reported that the faces of 'Motukutai' 'contained scattered mussels' (later confirmed to be kutai) in the intertidal, as well as down to 7 m subtidally. Her full account follows (page 71), with further clarifications in square brackets.

> Mostly walls on all sides, often 70–90 degree slopes. Visibility 7 m. Variable bottom depth depending on location. In the north ['Motukutai'] the intertidal contained scattered mussels, limpets and abundant barnacles. The first 2 m of subtidal wall had a cover of *Carpophyllum* (mostly *C. mas*[*c*]*halocarpum*) with *Cystophora*, occasional *Ecklonia*, abundant *Pterocladia*, some mussels, and some tall coralline turfs. Where mussels had been removed there were more low turfs and algal felts. For the subtidal walls from 2–7 m deep *Ecklonia* formed 10–30% of the cover with *Pterocladia*, tall coralline turfs, and encrusting fauna (sponges, anemones, bryozoans). Occasional mussels were present. Very few kina were seen. The kina that were seen were usually associated with areas of mussel removal. The northern most rock is a special site. Abundant blue maomao and sweep.
>
> The southern Black Rocks group [the remaining islands shown in Figure 3] is similar to the northern Rock but with slightly reduced visibility and less diverse encrusting fauna. The intertidal area was similar to the northern rocks plus the occasional *Lessonia*. There were fewer tall brown in the 2.5 m-7.5 m depth range. There was also a higher cover of encrusting fauna (especially in some locations), as well as more low turfs and algal felts.

The Booth Whanau survey along northern 'Motukutai' in September 2019 (Booth et al. 2019) revealed something similar to what Vicky Froude reported for 2016, and which we characterised as 'small clusters of medium-sized kutai' (Figure 5).

Figure 5. These groupings of kutai towards the eastern end of northern 'Motukutai' ('Eastern clusters') were – together with the cluster in 'Kutai Cove' – the most-populous observed intertidally in 2019, and had been whittled down to just a couple of clusters by 2022. The locality above is adjacent to and just east of the prominent rock that becomes visible at very low tide, as you will find out if you screw your navigation (red-arrowed 2 in Figure 3). (Chris Booth)

These clusters were examined in more detail in 2020, revealing 40–60 mm mussels – all kutai, with no blue or little-black mussels evident (Figure 6).

Figure 6. An example cluster of kutai from 'Eastern clusters' (5-cm gradations) in 2020. Enlargement of the images revealed no sign of small new recruits. (John Booth)

These 'Eastern clusters' clusters gradually became fewer and less populous over time. By the time of our most-recent survey, in 2022, just two miniscule patches of larger kutai, each comprised of six or so about 50 mm mussels, were observed. The story was much the same for intertidal clusters in 'Kutai Cove' (Figure 7). Nowhere was there evidence of moribund mussels, nor significant recent mortalities.

Figure 7. This cluster of intertidal kutai at 'Kutai Cove' in 2022 (red-arrowed 1 in Figure 3) appeared to have similar characteristics to those further east. (Chris Booth)

These observations of the intertidal at ‘Motukutai’ suggest an aging population without significant levels of juvenile recruitment. Note though that our surveys would *not necessarily* have led to detection of new recruits because of their small shell sizes – unless widespread and dense.

2. Others of the Black Rocks

Froude (2016a) reported that in 2016 the ‘southern Black Rocks’ group (Figure 3) was similar to the northern Rock (‘Motukutai’) in being largely depleted of kutai. And we observed no kutai at these localities during 2019–22, despite certain faces having also until quite-recently (about 5–10 years ago) contained harvestable intertidal mussels – including on ‘Motuwira’ and ‘Western Island’ (Figure 1, Table 1).

3. Howe Rock

The intertidal population was examined most years from 2019 (Figure 8, Table 1), but the imagery is not entirely comparable. We could not always get close enough to usefully replicate imaging of the population, and sea conditions – and other imperatives such as the urgent need for a dram of Jamesons – meant that landing was seldom possible. Nevertheless, it is clear that a significant intertidal population of large kutai has persisted on Howe Rock on its northeast point, since 2019. In June 2022 this was describable as a reasonably-healthy population of intertidal kutai (most 40–80 mm, but many being about 100 mm), together with a scattering of recent recruits (about 15 mm, although none smaller was encountered). The impression is, however, that the kutai were considerably-less abundant here than in 2019 – almost certainly through harvesting, together with poor juvenile recruitment. Again, there was no evidence for moribund mussels, nor significant recent mortality.

Figure 8. Upper: Main Howe Rock kutai bed, 2019. (Chris Booth) Lower: Closeup of kutai present within same locality in 2022. The callipers have a total length of 21 cm. Some of these look like blues, but they're not. (John Booth)

4. Wiwiki and Tikitiki rocks

These had until about seven years ago contained harvestable stocks, but they have since largely disappeared (Table 1) – probably through both harvesting and low juvenile recruitment.

Figure 9. Two semi-submerged rocks adjacent to south end of Tikitiki in 2019. Clusters of kutai were observable on larger rock whereas the smaller, more-northern rock was mantled in them (Site 5 in Booth et al. 2019). (Webber & Chris Booth, the original images being amenable to higher magnification)

Figure 10. Small harvestable quantities of kutai on small rock tucked into head of bay southwest of Harakeke Island in 2019 (Site 7 in Booth et al. 2019) (Webber & Chris Booth).

Table 1. Record of intertidal kutai presence within Te Puna Mātaitai for locations with useful continuity in sampling. Blank means no data. Harvestable means ≥20 m^{-2} of kutai ≥60 mm. √, evidence for significant juvenile recruitment (an average of ≥2 individuals <15-mm long per square metre); x, no evidence for significant juvenile recruitment (only when specifically investigated). Green indicates harvestable stocks, pink depleted stocks. *, Images or video footage is available from authors.

	Black Rocks				**Howe Rock**	**Shoreline Howe Point to Wiwiki Passage**	**Tikitiki**	**Tikitiki rocks**	**Source**
	'Motukutai'		**'Motuwhero'**	**'Western island'**					
	'Eastern clusters'	**'Kutai Cove'**							
2015/16	Harvestable		Harvestable	Harvestable		Harvestable	Harvestable	Many harvestable	Booth et al. (2019)
2016	'Scattered mussels [*Perna*]'		'Scattered mussels [*Perna*]'						Froude (2016a)
Aug/ Sep 2019	Occasional small clustersx*	Occasional small clusters*	None*	None*	Harvestable*	Harvestable in places*	Sparse*	Some harvestable*	Booth et al. (2019)
Jun 2020	Occasional small clusters*	Occasional small clusters*	None*	None*					Booth (2020)
Jun 2021	Occasional small clusters*	Occasional small clusters*		None*	Harvestable*	Occasional small clusters			Booth et al. (2021)
Jun 2022	Occasional small clusters*		None*		Harvestable√*				Here

Figure 11. Booths back from the briny, June 2020 after recognising for the first time that an extensive face of dense, large kutai persisted at 'Kutai Cove' (from left, Tim, John, Chris, Webber). (Dean Wright)

Subtidal kutai

1. 'Motukutai' subtidal

Froude (2016a) reported that the first 2-m depth of subtidal walls of 'Motukutai' had 'some mussels', and from 2–7 m there were 'occasional mussels'.

On 15 September 2019 David Heller video-ed extensively the subtide of the north face of 'Motukutai' (from just east of 'Kutai Cove' to near the 'Eastern clusters'), with kutai size and abundance usefully discernible (Figure 12). The subtidal mussels were mainly at 14–16 m depth, with small patches (up to six individuals) of mainly large (150–180) mm kutai. Because of the levels of invertebrate fouling – particularly anemones – many individual large mussels, as well as any juvenile recruits, would likely have been missed during video analyses. The video clips are available from the author, courtesy of David.

Figure 12. Groupings of 150–180 mm kutai at 14–16 m depth on the north face of Motukutai, 2019. (David Heller).

The intertidal survey on 8 June 2020 slightly to the east of where David Heller had videoed in 2019, at 'Kutai Cove', had revealed extensive clumps of large kutai very low in the intertidal (Figure 13). Follow-up underwater videos on the day from the sea surface by Tim Booth strongly indicated significant numbers of large kutai being present below, contiguous in places with the low-intertidal ones. (Vicky Froude's sampling quadrats did not to coincide with this face.)

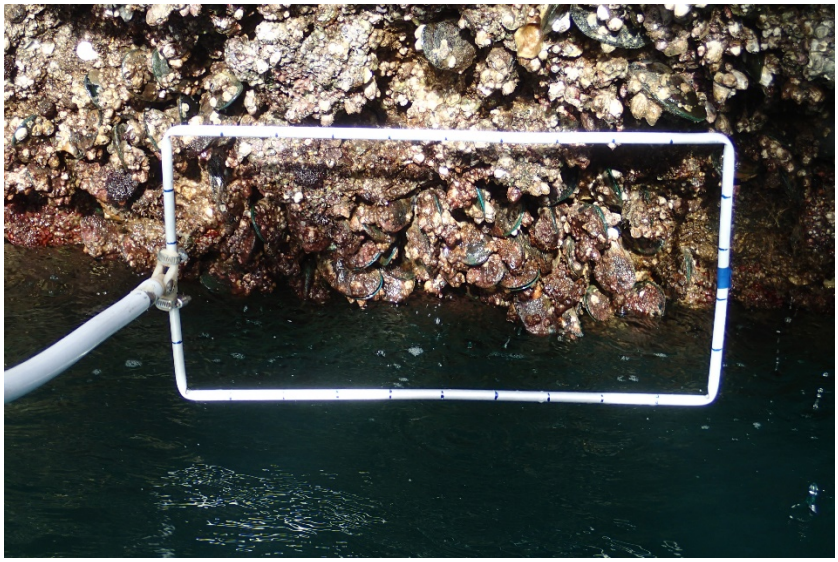
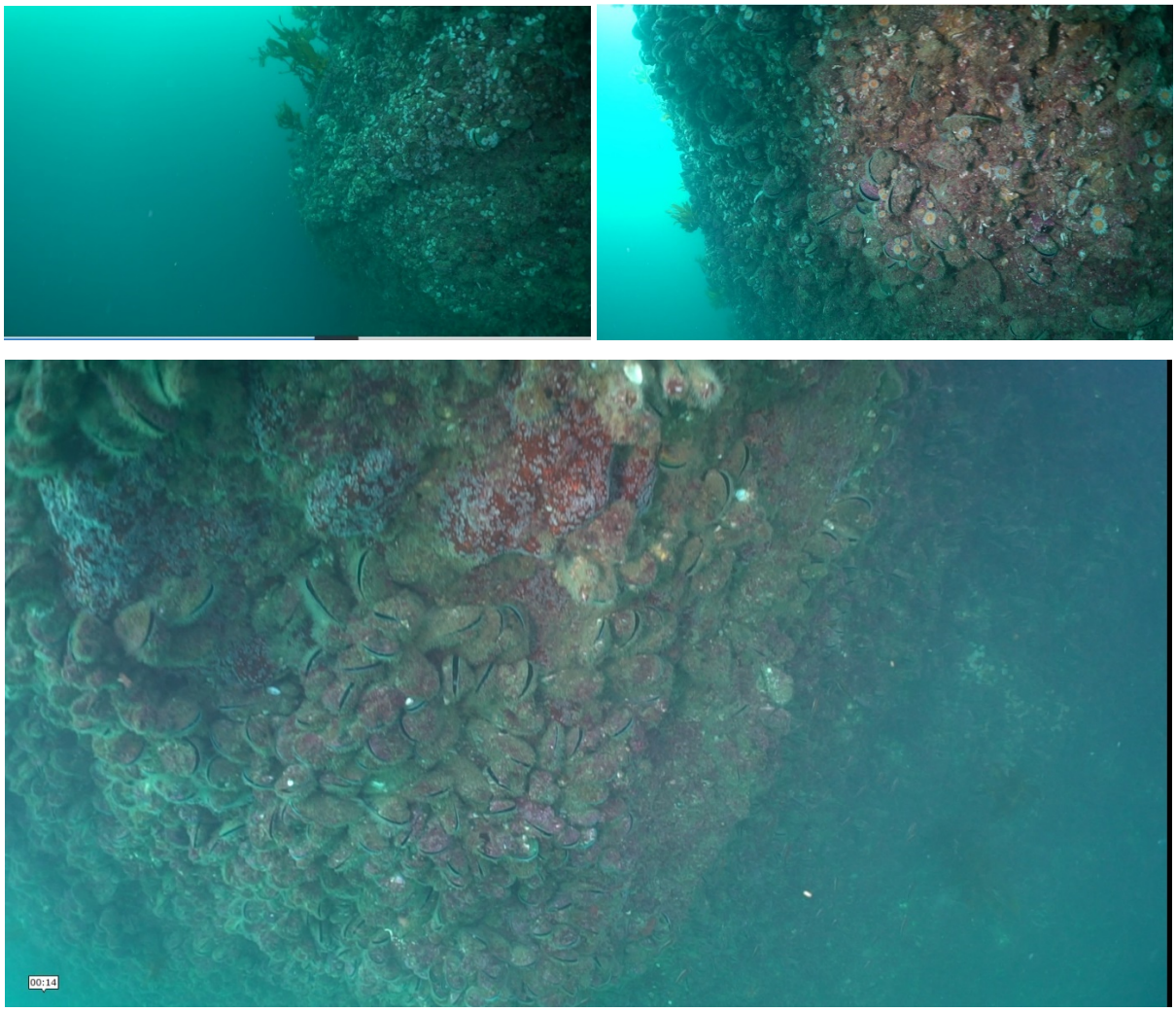


Figure 13. Upper: Low intertidal kutai at 'Kutai Cove', 2020. The mussels all appear to be large (5-cm gradations) (John Booth). Lower: View from surface directly below the intertidal mussels on the same day. (Tim Booth)

Soon after, on 12 June 2020, Brett Sutton's video survey of the site revealed an 8-m wide population of almost-exclusively large (≥100 mm long) kutai to a depth of about 10 m (the face here is about 18-m deep), forming dense, almost continuous cover (Figure 14; the imagery is available from the authors, courtesy of Brett). Kutai of this size can be expected to be ≥3 y old, based on Hickman (1979). A systematic count of the visible large (≥60 mm) kutai, based on every 10-second image from the video, gave a mean of mean of 108.3 ± 12.7 (SE) individuals – although their sheer densities made tallies problematic. The panel of images below provide a sense of the physical and biological nature of the 'Kutai Cove' rock face in 2020. No kina, or potentially-predatory starfish were observed.



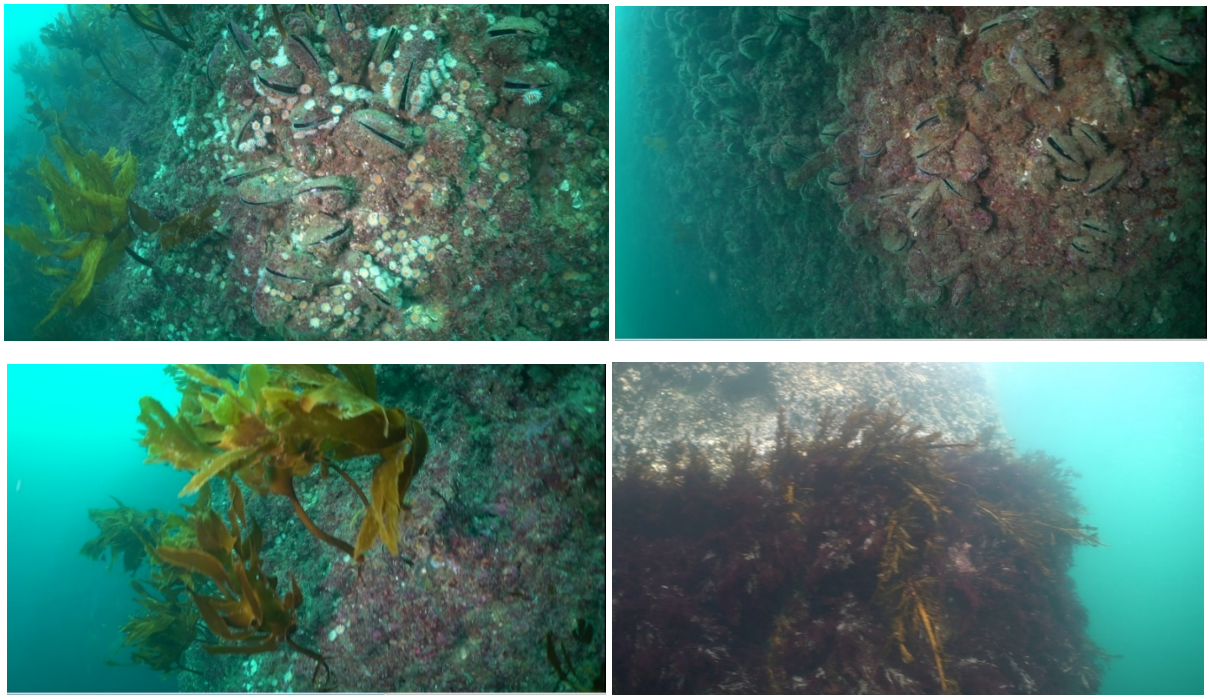


Figure 14. Imagery of the nature of the subtidal rock face at 'Kutai Cove', June 2020. Images are displayed from top left as a vertical dive to 5.5 m, followed by a horizontal transect for about 5 m, then return to the surface. (Brett Sutton)

In June 2022, near-surface snorkelling by Chris Booth strongly suggested that the mussels in 'Kutai Cove' bed had largely disappeared, but it was not until the end of 2022 that Brett Sutton – with dive support from Corinna Rihari-Allen – was able to revisit the site for formal assessment.

On 12 December 2022, the kutai present along Brett Sutton's 7-m deep transect in 'Kutai Cove' were confined to small, sparse patches of up to a dozen or so large, heavily fouled individuals over a 12-m width of rock face, most being at depths of 3–10 m (Figure 15). The ecology of the face had changed dramatically from 2020, its remnant clumps of kutai appearing similar to what David Heller had videoed further east in 2019 (Figure 12). The kutai were mainly 60–160 mm long (most >100 mm); small ones were uncommon. The count of the visible large (≥60 mm) kutai, based on every 10-second image from the video, gave a mean of 2.2 ± 0.5 (SE) individuals (a value comparable to the 108.3 ± 12.7 individuals in 2020 for the same site). All kutai appeared healthy (closing upon being tapped), although some appeared less-well attached than might be expected. In contrast to what was observed in 2019 further east (Figure 12), this rock face had relatively-sparse anemones (the white patches, probably *Anthothoe albocincta*). This was possibly because harvesting had taken place quite recently, although establishment- and growth-rates of this anemone are unknown.

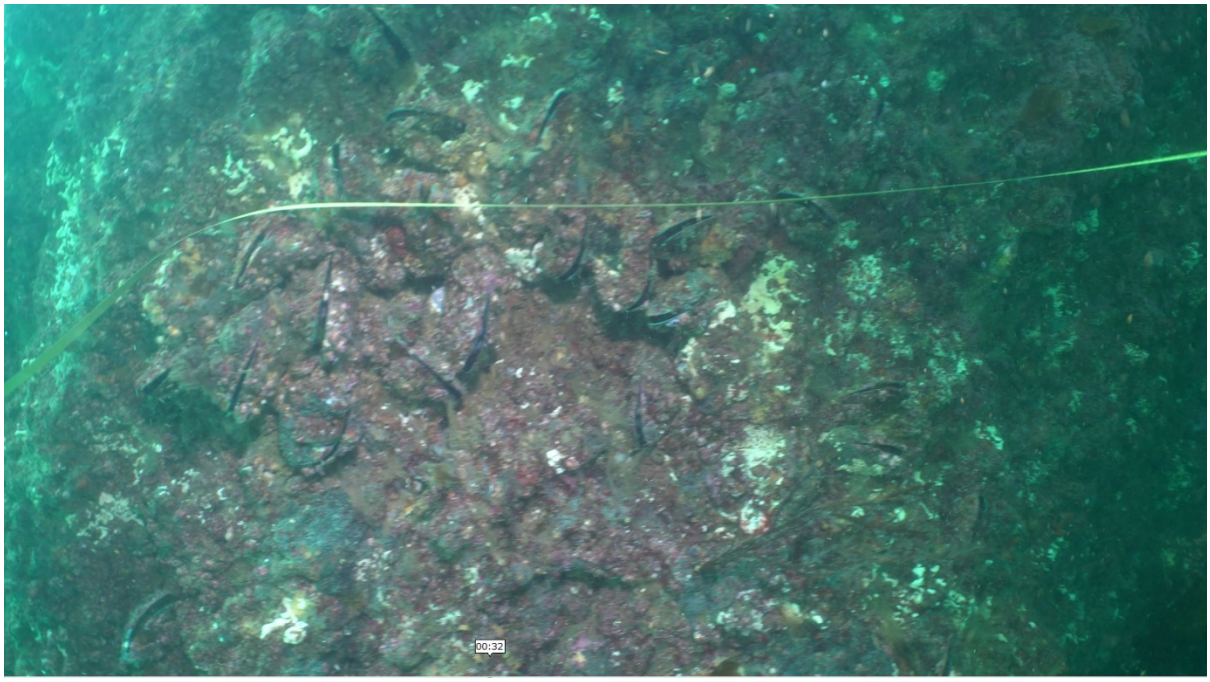


Figure 15. Example images of rock faces and kutai clusters along 7-m deep horizontal transect, 'Kutai Cove', December 2022. The group of kutai in the lowest image was the most populous encountered. (Brett Sutton)

David Heller's March 2023 close-up observations of the 'Kutai Cove' subtidal rock face revealed no signs of new kutai recruits on either the 'harvested areas' or among the mussel clumps themselves, nor scraping that might have been associated with removal of shellfish using hand tools.

No potentially-predatory starfish, and only an occasional kina, were observed at any depth at any time in 'Kutai Cove'. No predatory fish large enough to tackle large kutai were observed, although large snapper (among others) will certainly frequent the place from time to time.

2. 'Motukutai' seafloor

In dives by David Heller in 2019 (east from 'Kutai Cove') and 2023 ('Kutai Cove'), and Brett Sutton in 2022 ('Kutai Cove'), no significant quantities of dead kutai were observed on the seafloor. Individual accumulations at most amounted to half a dozen shells.

East of 'Kutai Cove' in 2019, very few dead mussels, and no live ones, were visible on the seabed (videoed by David Heller at three separate spots – videos 3, 4 and 12).

Physically, the 18-m deep seafloor at 'Kutai Cove' is dominated by towering, vertically-segmented basalt faces, with scatterings of large and small boulders at the base (Figure 16). In 2022, there was a sprinkling of what appeared to be recently-dead single kutai valves, a single still-articulated (probably live) shell, and small quantities of shell hash. There was also a handful of large, isolated, live kutai, presumably dislodged from above. The biodiversity was interestingly varied, comprised mainly of sedentary suspension feeders (mainly sponges) and encrusting organisms, and lithothamnium paint. Little silt was evident and it was too deep here for macroalgae.

Table 2. Record of subtidal kutai presence within Te Puna Mātaitai for locations with some continuity. Blank means no data. Harvestable means at least 20 m^{-2} of kutai ≥60 mm; √, evidence for significant juvenile recruitment (an average of ≥2 individuals <15-mm long per square metre); x, no evidence for significant

juvenile recruitment (given only when specifically investigated); *, Images or video footage available from authors. Green indicates harvestable stocks, pink depleted stocks.

	'Motukutai'				**Source**
	North face		**'Kutai Cove'**		
	Subtidal, above seafloor	**Seafloor (sometimes on higher ledges too)**	**Subtidal, above seafloor**	**Seafloor**	
2016	'scattered mussels [*Perna*]'				Froude (2016a)
Sep 2019	Occasional small clusters (<6) large kutai, and individuals, particularly at 14-16 m (x) (only east of gap)*	Scatters of large valves (only east of gap)*			Heller in Booth et al. (2019)
Jun 2020			Vast numbers large kutai*		Sutton in Booth et al. (2020)
Jun 2021			Low intertidal*		Booth et al. (2021)
Dec 2022/ May 2023			Clumps of up to 12*	Scatters of large valves and occasional live large individuals*	Sutton, Heller (here)


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Figure 16. Representative imagery from the base of the 'Motukutai' rock face (18 m), December 2022. The mussel shells shown include the largest groupings observed; a (probably) live mussel is in the second row. (Brett Sutton)

Overall, the observations are consistent with recent (probably within the previous 12 months), hand harvesting of the subtidal kutai. A natural-mortality event is most unlikely: had there been recent high natural mortality among the kutai, freshly-dead shells should have been evident in the imagery, trapped among the seabed topography. The absence of visible silt suggests low levels of siltation here and/or tidal flows with sufficient velocity to prevent sediment build-up. Accordingly, our observations are not consistent with disease, weakness through poor water quality or sedimentation, nor heavy, non-human predation among the kutai.

Discussion

There is strong evidence for continuing decline in the status of Te Puna Mātaitai's kutai stocks – a tangible and poignant loss of mauri. There appears to have been little if any juvenile recruitment, and/or low survivorship of juvenile mussels, at most, if not all, of the intertidal locations sampled since 2019. And there has apparently been recent large-scale, ecosystem-altering harvesting of at least one significant subtidal kutai population, with no evidence of subsequent juvenile recruitment having taken place.

Intertidal main stocks

Casting back, the once-significant Black Rocks intertidal kutai appeared to have largely gone by 2016 (Froude 2016a). The best-available estimate is that some were still harvestable in about 2015 (Table 1, but more data are welcome). Clusters of kutai visible on 'Motukutai' continued to become increasingly less populous after 2019 – rather than disappearing altogether as might be expected if harvesting alone had been implicated. Presumably this attrition can be attributed to aging and/or predation, rather than to disease outbreak or poor water quality that might more likely have seen to their complete loss.

Is the demise of intertidal kutai within the Mātaitai fairly attributable simply to 'overharvesting'? A comparable intertidal population is at Maunganui Bluff, a location readily reached by vehicle and where harvesting is intense. Most of the mussels there are medium-sized (around 60–70 mm), and yet the fishery persists through ample levels of juvenile recruitment (Figure 4). For Te Puna Mātaitai kutai, the stock collapse might be more appropriately attributed mostly to low juvenile recruitment and/or poor survival rates among juvenile recruits. This in the face of kutai settlement and growth continuing apace in many inner parts of the Bay of Islands, particularly on man-made structures.

In our 2020 report we concluded: 'Critically, the Black Rocks kutai population appears to be recruitment-limited – new, small mussels are not immediately evident in either the intertidal or in the (much less-well observed) subtidal populations'. This remains our major concern.

Nature of the kutai loss that has taken place subtidally

Harvesting of the subtidal bed at 'Kutai Cove', on 'Motukutai', is the first reasonably-well-documented record, with 'before-and-after' imagery, of the loss of a significant subtidal Bay of Islands population of large kutai. We estimate that several hundred kilogrammes live weight of shellfish was involved in what appears to have been a reasonably thorough exercise in bulk harvesting. Moreover, it was possibly among the last remaining examples of this community known anywhere (Professor Andrew Jeffs, University of Auckland, pers. comm.).

Numerous accounts refer to huge beds of subtidal kutai – particularly on soft substrates – that once populated northeastern waters, especially in the Firth of Thames (FoT) and inner Hauraki Gulf (HG) (eg, Jeffs et al. 1999). These FoT-HG beds appear to have been comprised mainly of 100–160 mm individuals, but with significant representation too of new recruits coming through (Greenway 1969). And they were trawled and dived to virtual extinction, with far-reaching ecological ramifications (eg, Paul 2012).

There appears to be scant information on the ecological and productivity characteristics of these 'pristine'/lightly-harvested kutai beds before they were dredged. Despite up to 2500 t (mean about 1360 t) green weight being harvested annually in FoT/HG between 1927 and 1966, only a single panel of shell-length distributions appears to be available (Figure 17). Greenway (1969) had selected a large, well-stocked area off Matingarahi Point, near the western shore of FoT, to sample between 1961 and 1967, its initial size distribution typical of other areas in FoT/HG containing large quantities of mussels. Annual sampling at Matingarahi Point showed a rapid decline in mussel abundance after commercial dredging began in 1962.

What stands out is the strong representation of a single, large size class in the pristine/lightly-harvested kutai but with firm (albeit declining with time) evidence for ongoing juvenile recruitment and growth of those juveniles to harvestable size. According to Greenway 'the pronounced mode at 12–13 cm and the distribution's marked negative skew possibly reflect[ed] the dominance of one age-group, but [and?] more probably result[ed] from the species' rapid initial growth rate'.

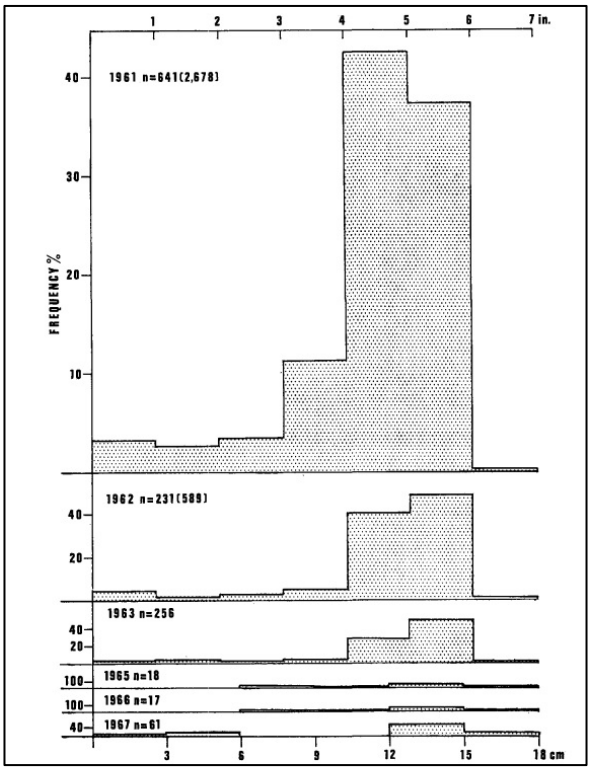

Figure 17. Matingarahi Point (off western shore of Firth of Thames) kutai length-frequencies, 1961–67 (Greenway 1969). The declines in catches with time were attributed to dredging.

It appears that the most-detailed *recent* appraisal of the ecological functioning, productivity and characteristics of unfished/lightly-fished populations of these now-virtually extinct kutai beds of the northeast of the country is that of Ian McLeod (2009). Six subtidal soft-sediment beds, and one rocky intertidal bed, between north of Auckland and Ohiwa Harbour in the Bay of Plenty were examined in 2007–09. These were arguably shellfish beds linkable to ancient times. Although all but one were on

soft substrates, the populations are nevertheless considered comparable in several ways to those on the vertical subtidal rock faces of the Black Rocks.

Figure 18. Kutai on Okiwi Estuary sand, Great Barrier Island. (McLeod 2009)

The main points and conclusions from McLeod's study of six mussel reefs were as follows (with available 'Kutai Cove' 2020 values in parentheses in bold).

- Spatial extent varied from 10–640,000 m^2. **(80 m^2)**
- Proportions of the substratum covered in three main sites were 26–63%. **(about 70%)**
- Mean densities within aggregations in three main sites varied from 450–1200 individuals m^{-2}. **(ca. 1000 m^{-2})**
- All size structures were unimodal (60–120 mm), with differing size structures by site. **(unimodal at about 100–160 mm)**
- The small mobile invertebrate associated assemblage had on average four times the average density, seven times the biomass, six times the productivity, and greater species richness than the bare sediment areas that replaced the mussels.
- Mussel-associated fish assemblages had a ten-fold higher density of fish than adjacent areas.
- The mussel reef assemblage had the highest secondary productivity of any marine habitat yet recorded in New Zealand, 977 g AFDW (ash-free dry weight) m^{-2} y^{-1}, of which 729 g AFDW m^{-2} y^{-1} was contributed by the mussels themselves and 248 g AFDW m^{-2} y^{-1} by small mobile invertebrates.

These characteristics clearly mean dense subtidal beds of large kutai are ecologically significant, made all the more so because of their now virtual extinction in Aotearoa New Zealand.

Overview

Kutai within Te Puna Mātaitai continue to exhibit loss of mauri, adult populations continuing to decline and with little evidence for new recruits. The main reason for this appears to be poor juvenile recruitment under still-lingering fishing pressure. The 'Kutai Cove' subtidal bed of dense, large kutai was possibly historically (few if any others being known to remain) and ecologically significant – but has now been harvested.

Nevertheless, the Black Rocks area still potentially affords rare opportunity to examine the detail around this subtidal ecological community. It would seem to us unlikely that not a single bed survives within such a complex physiography.

Although the data presented in this appraisal are hardly knife-edge science, they are nevertheless valuable. Imagine if the 39 y of kutai harvesting in FoT/HG had not been represented by even a single length-frequency; and how much more valuable Greenway's account of the 1961 Matingarahi Point bed would be if it had been supplemented by a detailed ecology. Indeed, the video footage of David Heller ('Eastern faces' and 'Kutai Cove') and Brett Sutton ('Kutai Cove') provide pivotal insight into the ecology of subtidal beds like this – and may be exceptional.

Kutai joins other bivalve stocks in Bay of Islands and elsewhere in east Northland in exhibiting greatly-reduced productivity over the past ca 10+ y: cockles, scallops and (in places) oysters. Resolving the conundrum as to why kutai on long-established beds in the main basin of the Bay fail to recover, yet they continue to flourish in inner parts of the Bay of Islands, particularly on anthropogenic structures, is the stuff of science.

It is suggested that Te Komiti sends this report to Fisheries New Zealand, so they are aware of the absence of any measurable improvement intertidally in kutai populations within Te Puna Mātaitai, as well as the catastrophic loss of the subtidal bed there. FNZ should also be called upon to ensure adequate policing of the remaining stocks.

Future surveys

- Given their steady trajectory to oblivion over the past >4 years, it seems hardly worthwhile examining Black Rocks intertidal kutai populations every year; every second year should suffice. The presence of new juvenile recruits (<15 mm) are probably more important to follow than that of large adults – it is juvenile recruits that are most-important to sustainability at this time (assuming there remains ongoing larval presence within the Bay of Islands).
- But *intertidal* surveys might be extended geographically, to be more representative of the large area contained within Te Puna Mātaitai. And Howe Rock needs enhanced attention, being the only-known remaining harvestable bed within Te Puna Mātaitai. Island landings to follow particular clusters of kutai using video and photo-quadrats are required.
- And the status of the *subtidal* kutai on the north face of 'Motukutai' should also be followed every second year, with particular attention on new juvenile recruits.
- Are there previously-unrecognised significant subtidal beds still existing within the Black Rocks, or other similar places within the Mātaitai (eg, off Howe Rock or Te Pahi Islands)? If so, they are extremely important to protect and conserve – because such beds are now simply so rare nationally.
- Intertidal mussels are physically removed (some metres, vertically) from the low-subtidal/ subtidal ones. We know of no example of a seamless transition between intertidal and subtidal kutai. This may argue for intertidal stocks being considered ecologically independent of low-subtidal/subtidal ones, they possibly having quite different recruitment dynamics.

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