ATTACHMENT TWENTY-ONE

Assessment of Scleractinain Cup Corals Effects (NIWA)

McCALLUM BROS LTD

Established 1904

Scleractinian cup corals at Te Ākau Bream Bay

Literature review and distribution of cup corals identified within the proposed sand extraction area

Prepared for McCallum Bros Limited

December 2025

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NIWA CLIENT REPORT No: 2024322WN
Report date: December 2025
NIWA Project: MBL25301

NIWA Conflict of Interest: NIWA, and other associated parties, have extensive and many tens of millions of dollars investment in major aquaculture facilities all relying on continuous access to 4 M^3 per sec of high quality seawater from offshore water intakes (3 intake, 3 outfall x 2.4m diameter) in Te Ākau Te Ākau Bream Bay proximal to the proposed sand extraction area. Thus, NIWA may oppose the extraction.

Revision	Description	Date
Version 1.0	Final version sent to client	31 October 2024
Version 1.1	Section 3.1 updated with new data provided by client	18 December 2024
Version 2	Revised report sent to client	03 July 2025
Version 2.1	Revised report sent to client	17 July 2025
Version 3.0	Assessment of monitoring and cumulative effects added	26 November 2025
Version 4.0	Example of irregular coral growth added	18 December 2025

Quality Assurance Statement		
	Reviewed by:	David Thompson
	Formatting checked by:	Jess Moffat
	Approved for release by:	Alison MacDiarmid

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Executive summary

McCallum Bros Limited (MBL) is seeking resource consent to extract sand from an area within Te Ākau Bream Bay, Northland. The proposed sand extraction area forms a rectangle extending approximately northwest to southeast, roughly parallel with the central Te Ākau Bream Bay shoreline, in water between approximately 20 and 30 m deep and at least 4.7 km offshore. MBL have previously extracted sand from the Mangawhai-Pākiri embayment to the south of Te Ākau Bream Bay.

During benthic environmental surveys MBL identified two species of scleractinian solitary cup coral (*Sphenotrochus* sp. and *Kionotrochus suteri*) at Te Ākau Bream Bay. These are small, non-branching, corals (< 10 mm in size) that live in mobile sediments such as sand. All Scleractinia are protected under the Wildlife Act 1953.

The aim of this report is to summarise existing knowledge of the cup corals found within the proposed Te Ākau Bream Bay extraction area and elsewhere in Aotearoa New Zealand, and to make an assessment, based on available information, of the potential impact the proposed extraction may have on the populations of these corals.

Two species of *Sphenotrochus* are known to be present within Aotearoa New Zealand: *Sphenotrochus ralphae* and *Sphenotrochus squiresi*. A tentative identification of *Sphenotrochus ralphae*, together with the known depth range of *Sphenotrochus squiresi* being deeper than the MBL area of interest, means our discussion has focused on the distribution and habitat associations of *Sphenotrochus ralphae* and *Kionotrochus suteri*.

There is no evidence to suggest that the proposed sand extraction area at Te Ākau Bream Bay is particularly unique with respect to the habitat of these corals. In addition, the proposed extraction area has a small footprint (< 0.2%) compared to the identified suitable habitat for both species.

While little information is available on the life histories and behaviour of the cup coral species present within the Te Ākau Bream Bay area, evidence in the literature suggests that related species are well adapted to infaunal life and the challenges faced with living in mobile sediments. For example, these corals move vertically through sediments to escape burial, burrow into sediments and can return to an upright position after being overturned. In addition, many species of solitary cup coral can regenerate both soft and skeletal tissues following fragmentation. This is true even of relatively small fragments.

MBL's sand extraction process has the potential to cause mortality and/or damage to benthic faunal species as they pass through the draghead and screening deck. However, the presence of live *Sphenotrochus* corals within the previous active sand extraction area at MBL's Pākiri site suggests that cup corals may have some ability to survive the proposed disturbance at Te Ākau Bream Bay. This is perhaps not surprising given the ability of corals to move within sediments and regenerate tissues if damaged.

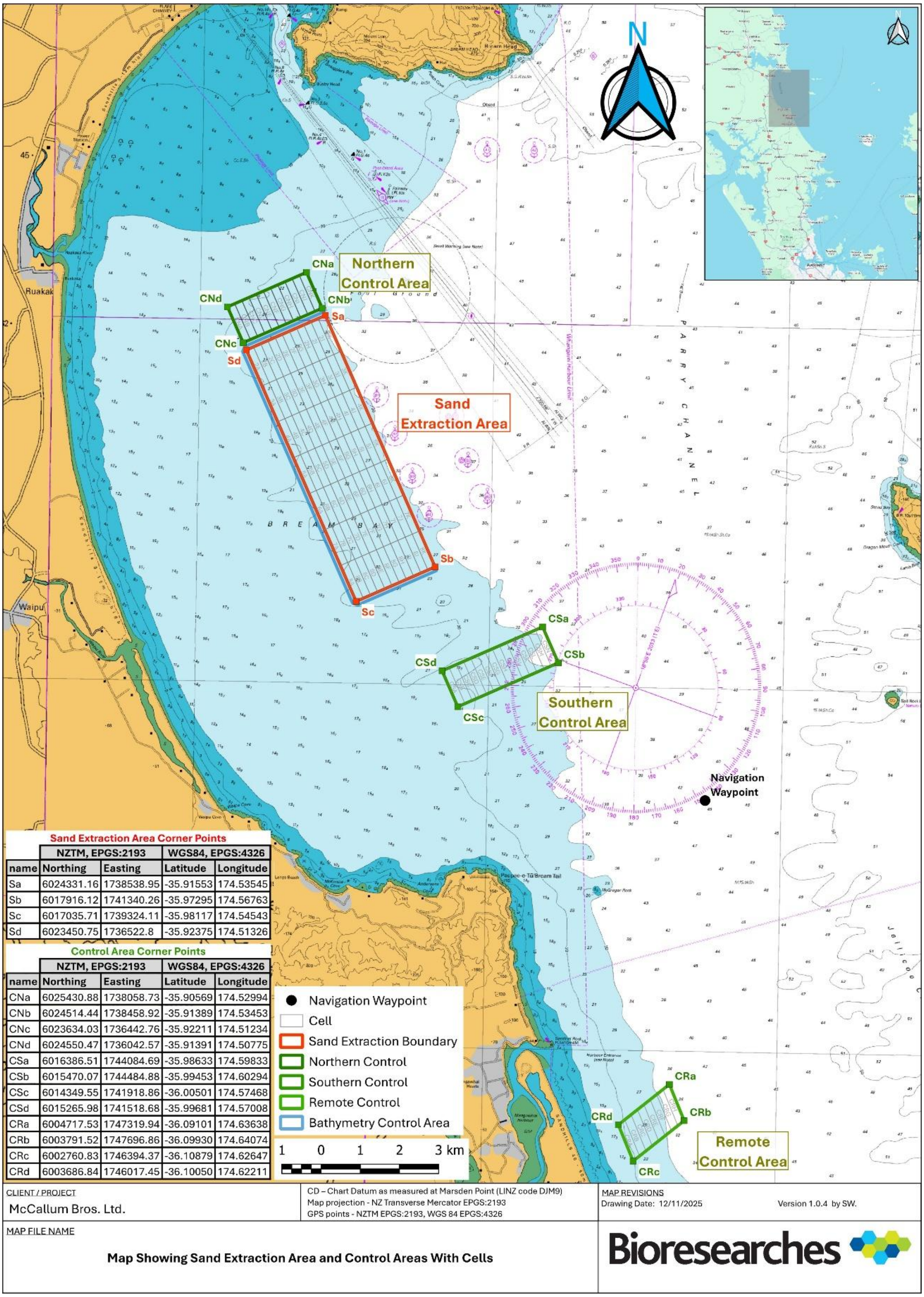
There will necessarily be some disturbance to, and probably some mortality of, both *Sphenotrochus ralphae* and *Kionotrochus suteri* resulting from proposed sand extraction within the Te Ākau Bream Bay area. However, overall, the impact of the proposed Te Ākau Bream Bay sand extraction on the population of these corals within Aotearoa New Zealand is considered likely to be minor to negligible.

1 Background

McCallum Bros Limited (MBL) is seeking resource consent to extract sand from an area within Te Ākau Bream Bay, Northland (Figure 1-1). The proposed sand extraction area forms a rectangle extending approximately northwest to southeast, roughly parallel with the central Te Ākau Bream Bay shoreline, in water between approximately 20 and 30 m deep and approximately 4.7 km offshore. MBL have previously extracted sand from Mangawhai-Pākiri embayment (hereafter referred to as Pākiri), to the south of Te Ākau Bream Bay.

During environmental surveys MBL identified two species of scleractinian solitary cup coral (*Sphenotrochus* sp. and *Kionotrochus suteri*) at Te Ākau Bream Bay. All Scleractinia (stony corals) are protected under the Wildlife Act 1953. Definitions for both stony coral and cup coral are provided in the glossary below.

The aim of this report is to summarise existing knowledge of the cup corals found within the proposed Te Ākau Bream Bay extraction area and elsewhere in Aotearoa New Zealand, and to make an assessment, based on available information, of the potential impact the proposed extraction may have on the populations of these corals.



Sand Extraction Area Corner Points

	NZTM, EPGS:2193		WGS84, EPGS:4326	
name	Northing	Easting	Latitude	Longitude
Sa	6024331.16	1738538.95	-35.91553	174.53545
Sb	6017916.12	1741340.26	-35.97295	174.56763
Sc	6017035.71	1739324.11	-35.98117	174.54543
Sd	6023450.75	1736522.8	-35.92375	174.51326

Control Area Corner Points

	NZTM, EPGS:2193		WGS84, EPGS:4326	
name	Northing	Easting	Latitude	Longitude
CNa	6025430.88	1738058.73	-35.90569	174.52994
CNb	6024514.44	1738458.92	-35.91389	174.53453
CNc	6023634.03	1736442.76	-35.92211	174.51234
CNd	6024550.47	1736042.57	-35.91391	174.50775
CSa	6016386.51	1744084.69	-35.98633	174.59833
CSb	6015470.07	1744484.88	-35.99453	174.60294
CSc	6014349.55	1741918.86	-36.00501	174.57468
CSd	6015265.98	1741518.68	-35.99681	174.57008
CRa	6004717.53	1747319.94	-36.09101	174.63638
CRb	6003791.52	1747696.86	-36.09930	174.64074
CRc	6002760.83	1746394.37	-36.10879	174.62647
CRd	6003686.84	1746017.45	-36.10050	174.62211

Figure 1-1: Map showing the location of the proposed sand extraction area within Te Ākau Bream Bay. Three proposed control areas are also shown, together with an inset box placing Te Ākau Bream Bay within a wider, regional context.

2 Methods

2.1 Taxonomy

Bioresearches advised that the following species were identified from within MBL's proposed sand extraction area: *Sphenotrochus* sp. and *Kionotrochus suteri*.

Two species of *Sphenotrochus* are known to be present within Aotearoa New Zealand: *Sphenotrochus ralphae* and *Sphenotrochus squiresi*. Although records from Te Ākau Bream Bay were recorded as *Sphenotrochus* sp., taxonomists who identified the MBL samples indicated that most were likely *Sphenotrochus ralphae* (Simon West, Bioresearches, personal communication). The images that NIWA have seen (two individuals) also appeared to be *Sphenotrochus ralphae* from the morphology visible in images.

While the two species of *Sphenotrochus* have overlapping depth ranges, *Sphenotrochus ralphae* has a shallower distribution (7-104 m) compared to *Sphenotrochus squiresi* (66-318 m but mostly recorded deeper than 100 m) (Cairns 1995). Due to the tentative identification of *Sphenotrochus ralphae*, together with the known depth range of *Sphenotrochus squiresi* being deeper than the MBL area of interest, our discussion has focused on the distribution and habitat associations of *Sphenotrochus ralphae* and *Kionotrochus suteri*.

2.2 Species location records

The abundance of stony corals (both live and dead) was recorded in a survey of MBL project areas in March 2024. Samples were collected using a ponar grab which sampled an area of 250 x 285 mm of seabed (0.071 m^2).

Previous surveys within MBL survey areas were sampled using a smaller ponar grab (229 x 280 mm, 0.064 m^2). Within these pre-2024 surveys, live stony corals were recorded by site/grab sample. However, dead coral skeletons were only recorded as a total across the 2023 survey with no detailed spatial information. No information was available on the abundance of dead coral skeletons in the pre-2023 surveys.

To provide regional and/or national context to the observations of cup corals within the proposed extraction area in Te Ākau Bream Bay, the databases described in Table 2-1 were interrogated for species location records of *Sphenotrochus ralphae* and *Kionotrochus suteri* within Aotearoa Territorial Sea (TS) and New Zealand's Exclusive Economic Zone (EEZ).

2.3 Species distribution

Incidental data recorded with coral observations were used, along with existing spatial environmental data layers, to characterise the habitats/environments that these species are associated with and to estimate the extent of suitable habitat.

Thirty spatial layers of environmental variables were available within Aotearoa New Zealand's Territorial Sea (out to 12 nautical miles) (Stephenson et al. 2023 and see Appendix A). These variables were extracted from each location record and the range of each variable calculated (minimum and maximum) for each species (*Sphenotrochus ralphae* and *Kionotrochus suteri*). Due to limited sampling the tolerance ranges for some of these variables may be conservative.

Bean plots were then produced to illustrate the distribution of each species across the range of each variable, shown separately for Te Ākau Bream Bay sites and all other sites combined to identify any unique characteristics of the Te Ākau Bream Bay habitat.

Each spatial environmental layer was masked to show only areas within the observed range of values for each species. These masked environmental layers were then combined into a single layer (for each species) to identify the most suitable habitat based on available environmental data for sample locations. This was done by simple addition of all 30 layers after setting the value in each remaining cell to 1. In this way cells with the highest number (30) represent the most suitable habitat and those with the lowest (0) represent the least suitable habitat. The estimated area of most suitable habitat for each species (where all 30 environmental variables were in range) was calculated using geoprocessing tools in ArcGIS. Note that environmental variable data layers were only available from within the Territorial Sea (TS). Therefore, the limited sampling and resulting approximate tolerance ranges for environmental variables, together with the exclusion of any possible habitat outside of the TS results in a conservative estimate of potential habitat. However, it should be noted that there are uncertainties in these estimates due to the effect of environmental parameters for which data were not available.

This is a simple and effective method for estimating suitable habitat but is not as sophisticated as a formal species distribution model, which typically identifies and uses only the most informative environmental predictors and incorporates their actual values at each presence location, as well as considering environmental conditions at absence locations. However, the generated plots provide a useful characterisation of the known habitat for each species within Aotearoa New Zealand's Territorial Sea, based on their tolerances to this set of environmental parameters given the available sample location data. Note that formal modelling was beyond the scope of the agreed work and not possible within the timeframe of this report. However, the benefits of formal modelling over the simpler method used are uncertain, partly because many of the records are from a very small area (MBL's project areas) limiting variability in associated environmental parameters to train the model.

Table 2-1: Data sources interrogated for *Sphenotrochus ralphae* and *Kionotrochus suteri* records. Note that most museum collection specimens would have been live on collection.

Source	Details
NIWA Invertebrate Collection (NIC)	This specimen collection (NIC) is located at NIWA's Greta Point campus in Wellington and is NIWA's repository for marine invertebrates from almost all phyla found in the Aotearoa New Zealand region, including the wider southwest Pacific Ocean and Ross Sea. It houses an estimated 350,000 collection lots that have been collected over half a century of biological research (Schnabel et al. 2014). Collection records for *Sphenotrochus spp.* and *Kionotrochus suteri* were extracted on 20 August 2024 from the NIC management database *niwainvert.*
Museum of New Zealand Te Papa Tongarewa Natural Environment collection (Te Papa)	The Te Papa natural history collections (hereafter referred to as Te Papa) are in two collection facilities in Wellington (located at Cable and Tory streets) and contain the national collection of plant and animal specimens housing more than one million collection lots. It is the largest, most comprehensive collection of Aotearoa New Zealand fauna and flora, with most major taxonomic groups of plants and animals represented. The database management software KEmu was queried to extract all records of *Sphenotrochus* spp. and *Kionotrochus suteri*, provided by Te Papa on 11 September 2024
Auckland War Memorial Museum Tāmaki Paenga Hira (Auckland Museum).	The Auckland Museum and collections are located in the Auckland Domain. The natural sciences collections cover terrestrial and aquatic botany, entomology, land vertebrates, marine fauna, geology and palaeontology specimens from across the Pacific region. The marine collection numbers an estimated 200,000 specimens and includes fish and invertebrates. The focus of the herbarium collection is on wild plants (native and naturalised) in all plant groups principally from northern Aotearoa New Zealand and its offshore islands. It is principally a research collection and provides evidence of Aotearoa New Zealand's changing flora. Some of the earliest specimens date from James Cook's voyages. Records of *Sphenotrochus* spp. and *Kionotrochus suteri* were provided by Auckland Museum on 2 October 2024.
Ocean Biogeographic Information System, Southwestern Pacific Node (OBIS-NZ)	This is an online database that provides species occurrences for a wide range of taxa within Aotearoa New Zealand's EEZ and the wider south Pacific region and has the highest number of invertebrate records for Aotearoa New Zealand waters of any database. Most biogenic habitats and their key habitat-forming species are represented to some level in this database. OBIS records for *Sphenotrochus* spp. and *Kionotrochus suteri* within Aotearoa New Zealand were extracted 10 September 2024.
iNaturalist	iNaturalist is an online social network of people sharing biodiversity information to help each other learn about nature. It is also a crowdsourced species identification system and an organism occurrence recording tool. iNaturalist was interrogated for records of *Sphenotrochus spp.* and *Kionotrochus suteri* on 12 September 2024.

2.4 Literature review

A literature review was conducted on available information on the life histories and anticipated impacts of the disturbance on the cup coral species identified within the proposed sand extraction area. Where possible, qualifying statements as to the anticipated impact of MBL's proposed activities on the protected cup coral species identified during survey work have been included.

3 Results

Available data on the distribution and habitat associations of *Sphenotrochus ralphae* and *Kionotrochus suteri* are presented in this section.

3.1 MBL survey data

The MBL survey for the proposed work included several discrete project areas within the wider Te Ākau Bream Bay area: the proposed sand extraction area at Te Ākau Beam Bay (pSEA), a northern control area (NCA), a southern control area within Te Ākau Beam Bay (SCA), and a Pākiri North Control Area (PNCA). In addition, MBL data were available from the Pākiri sand extraction area from previous consent applications. The MBL sites were all on sandy substrates with provided depths ranging from 18 to 32 m (mean 24.7 m ± 3.8).

Surveys were conducted at Pākiri in 2003, 2006, 2011, 2017, 2019, 2023 and 2024 and in Te Ākau Bream Bay in 2024 (Figure 3-1). Cup corals were only recorded in the 2017, 2023 and 2024 surveys. A summary of coral observations at both Pākiri and Te Ākau Bream Bay is given in Table 3-1.

Figure 3-1: Location of MBL sampling sites in relation to the Te Ākau Bream Bay project areas. pSEA = proposed sand extraction area, NCA = northern control area, SCA = southern control area. RCA = Te Ākau Bream Bay Remote Control Area within the Pākiri embayment. With the exception of sampling within the Te Ākau Bream Bay RCA, sampling at Pākiri was associated with a previous sand extraction consent and occurred in 2003, 2006, 2011, 2017, 2019, 2023 and 2024. Sampling within Te Ākau Bream Bay was conducted in 2024.

Table 3-1: Summary of cup coral observations from MBL surveys at Te Ākau Bream Bay and Pākiri project areas. pSEA = proposed sand extraction area, NCA = northern control area, SCA = southern control area. Note that the Pākiri 2024 samples (*) include the Te Ākau Bream Bay remote control area. A total of 288 dead coral skeletons were reported from the 2023 survey but no further information was available as to which species or which sample locations.

Survey	Year	Area	No of Sites	*K. suteri* Live	*K. suteri* Dead	*S. ralphae* Live	*S. ralphae* Dead	*K. suteri* Total	*S. ralphae* Total	Juvenile/other Scleractinia Dead	Total cup corals
Pākiri	2017	All	74	0	n/a	16	n/a	n/a	n/a	0	**16**
Pākiri	2023	All	50	0	n/a	2	n/a	n/a	n/a	288	**290**
Pākiri *	2024	All	50	0	5	2	100	5	102	2	**109**
Te Ākau Bream Bay	2024	pSEA	231	2	7	7	209	9	216	0	**225**
Te Ākau Bream Bay	2024	NCA	24	0	0	0	0	0	0	0	**0**
Te Ākau Bream Bay	2024	Anchorage area/Other	68	0	0	3	84	0	87	0	**87**
Te Ākau Bream Bay	2024	SCA	110	0	5	1	209	5	210	3	**218**
Total			**607**	**2**	**17**	**31**	**602**	**19**	**633**	**5**	**945**

3.1.1 Live corals

A total of 33 live corals were recorded within MBL's project areas (Table 3-2 and see Table 3-1 for a summary of all MBL sampling). Of these, two were *Kionotrochus suteri* and 31 were *Sphenotrochus ralphae*.

Table 3-2: Live cup corals recorded within the MBL benthic environmental surveys.

Survey	Date	Depth cd (m)	Area	Site	*Sphenotrochus* sp. (Alive)	*Kionotrochus sutrei* (Alive)
Te Ākau Bream Bay	6 Mar 2024	29.5	Stage 1	4O1	1	
Te Ākau Bream Bay	6 Mar 2024	30.3	Stage 1	5M2	1	
Te Ākau Bream Bay	6 Mar 2024	29.9	Stage 1	5M3	1	
Te Ākau Bream Bay	20 Mar 2024	23.9	pSEA	6F3	1	
Te Ākau Bream Bay	20 Mar 2024	21.0	pSEA	7J3	1	
Te Ākau Bream Bay	20 Mar 2024	19.4	pSEA	8A2	1	
Te Ākau Bream Bay	21 Mar 2024	24.4	pSEA	2I1	2	1
Te Ākau Bream Bay	21 Mar 2024	23.1	pSEA	3E3	1	
Te Ākau Bream Bay	21 Mar 2024	24.6	pSEA	8K1	1	
Te Ākau Bream Bay	21 Mar 2024	25.0	pSEA	4H3		1
Te Ākau Bream Bay	23 Mar 2024	31.1	Control	CRH3	1	
Pākiri	15 Dec 2017		Area 1	T7-E	15	
Pākiri	15 Dec 2017		Control	T10-03	1	
Pākiri	1 Sep 2023		Area 1	A1S-42	2	
Pākiri	14 Mar 2024		Area 1	A1S-41	1	
Pākiri	14 Mar 2024		Area 1	A1S-50	1	
Total					**31**	**2**

The two live specimens of *Kionotrochus suteri* were recorded at two sites (1 specimen at each site) within the Te Ākau Bream Bay pSEA survey conducted in March 2024 (Figure 3-2). No live specimens of *Kionotrochus suteri* were recorded within the Pākiri embayment.

Live specimens of *Sphenotrochus ralphae* were recorded at 15 sites with a maximum abundance at any site of 15 individuals. Live *Sphenotrochus ralphae* were present within the pSEA, the Pākiri extraction area and the PNCA but not in the two Te Ākau Bream Bay control areas (SCA and NCA). They were also present in samples collected from within the vessel anchoring zone adjacent to the Te Ākau Bream Bay extraction area (Figure 3-3).

The records of live *Sphenotrochus* sp. at Pākiri are of particular interest given this is a previously dredged area. Fifteen live *Sphenotrochus* specimens were recorded at site T7-E on the 15 December 2017. This site is in the vicinity of the sand extraction area, but it is not known if sand extraction had occurred in close proximity to this site prior to sampling. However, during post extraction recovery monitoring at Pākiri, four live specimens of *Sphenotrochus* were recorded in samples collected from sites within 100 m of dredge tows, three of which were within approximately 20 m of known dredge tows (Table 3-3). The time between active sand extraction operations at Pākiri and sampling (i.e. recovery time) was between 474 and 660 days. One live specimen was recorded in samples collected on the 14 March 2024 at site A1S-41 which was approximately 6-21 m from a dredge tow on three occasions between 28/5/2022 and 22/10/2022.

Table 3-3: Cup corals recorded at Pākiri. Distance from dredge is approximate. Accuracy of dredge tack considered ± 10 m, accuracy of grab sampling is considered likely to be ± 5 m. No *Kionotrochus suteri* were recorded at Pākiri.

Survey	Date	Site	S. ralphae Total	S. ralphae Alive	S. ralphae Dead	Dredged date	Recovery Days	Distance from dredge (m)
Pākiri	15/12/2017	T7-E	15	15	0	Uncertain	n/a	n/a
Pākiri	14/03/2024	A1S-50	13	1	12	24/05/2022	660	97
Pākiri	1/09/2023	A1S-42	2	2	0	15/05/2022	474	17
Pākiri	14/03/2024	A1S-41	2	1	1	28/05/2022 08/06/2022 22/10/2022	656 645 509	6 21 9
Pākiri	15/12/2017	T10-03	1	1	0	No	n/a	n/a

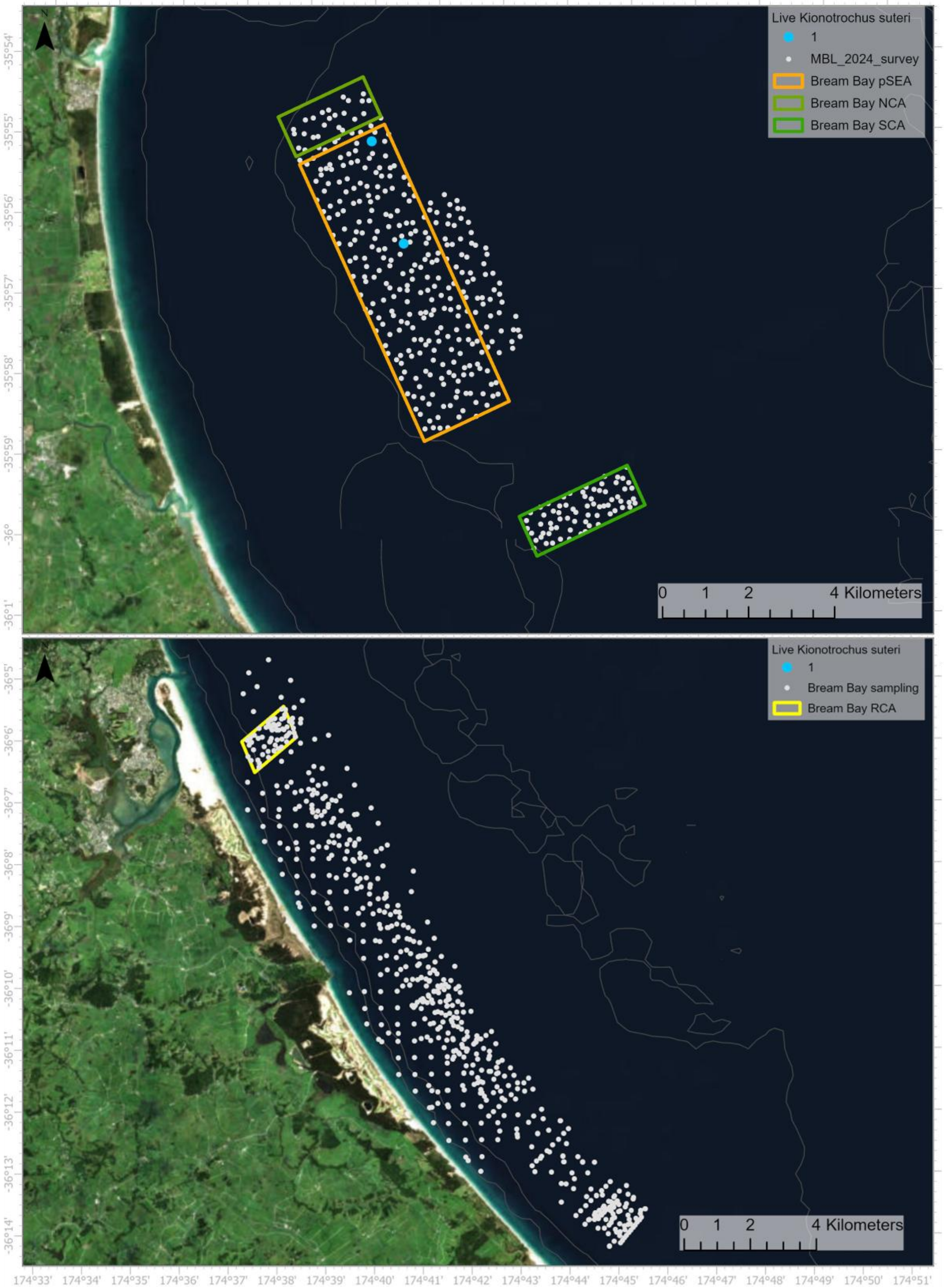


Figure 3-2: Live *Kionotrochus suteri* records within the MBL survey data. Blue dots represent live corals. Top: Te Ākau Bream Bay sampling. Bottom: Pākiri sampling, including the Te Ākau Bream Bay remote control area. Live corals were recorded in the 2024 survey only.

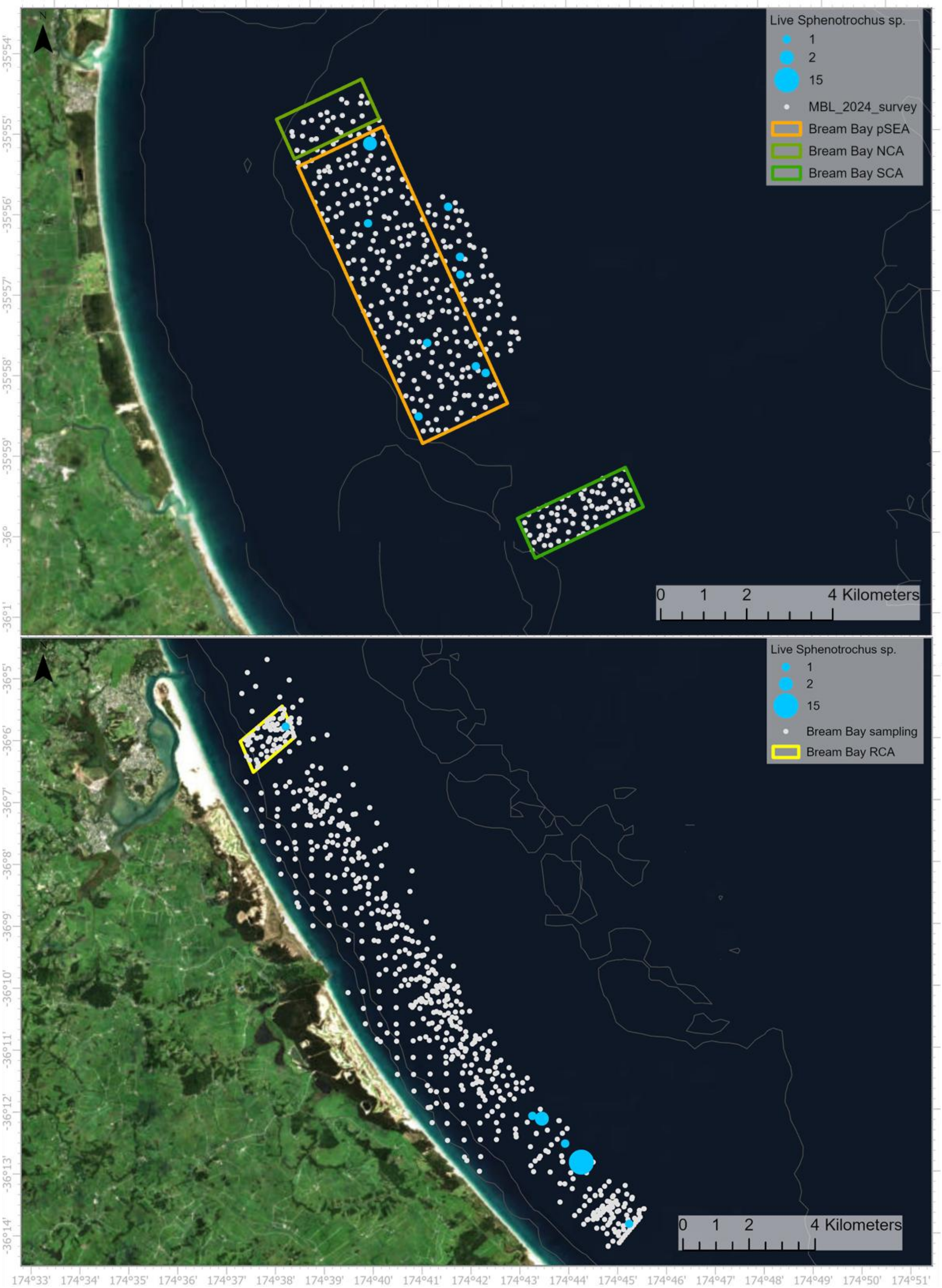


Figure 3-3: Live records of *Sphenotrochus ralphae* within the MBL survey data. Blue dots represent live corals. Top: Te Ākau Bream Bay sampling. Bottom: Pākiri sampling, including the Te Ākau Bream Bay remote control area. Live corals were recorded from surveys in 2017, 2023 and 2024.

3.1.2 Dead coral skeletons

A total of 602 dead *Sphenotrochus ralphae* and 17 dead *Kionotrochus suteri* skeletons were recorded in the 2024 survey of the Te Ākau Bream Bay project areas and post-extraction monitoring survey at Pākiri (Table 3-1). There were an additional five specimens of juvenile and/or damaged cup corals that were not identified further.

Dead specimens of *Kionotrochus suteri* were recorded in the Te Ākau Bream Bay pSEA, SCA, RCA and in the post-extraction monitoring sampling at Pākiri. No dead *Kionotrochus suteri* were recorded in the Te Ākau Bream Bay NCA or the sampling outside of project areas (e.g. within the anchorage area immediately to the east of the pSEA) (Figure 3-4).

Dead specimens of *Sphenotrochus ralphae* were recorded in the Te Ākau Bream Bay pSEA, SCA, RCA, the Te Ākau Bream Bay anchorage area and the Pākiri post-extraction monitoring area but not within the Te Ākau Bream Bay NCA (Figure 3-5).

Note that a further 288 dead coral skeletons were also recorded in previous sampling (2023 survey) within a wider area of the Pākiri embayment, of which 10 were likely *Kionotrochus suteri* and 218 likely *Sphenotrochus ralphae*. No sample specific data were associated with these records. No records were kept of dead coral specimens in earlier surveys.

Many of the specimens recorded from within MBL's project areas were dead skeletons of cup corals and it is not known by how much these skeletons are moved across the seafloor by currents and/or wave action. It has been assumed that the presence of a dead cup coral skeleton indicates suitable cup coral habitat and the possibility that this species is present, or has been present, within this area.

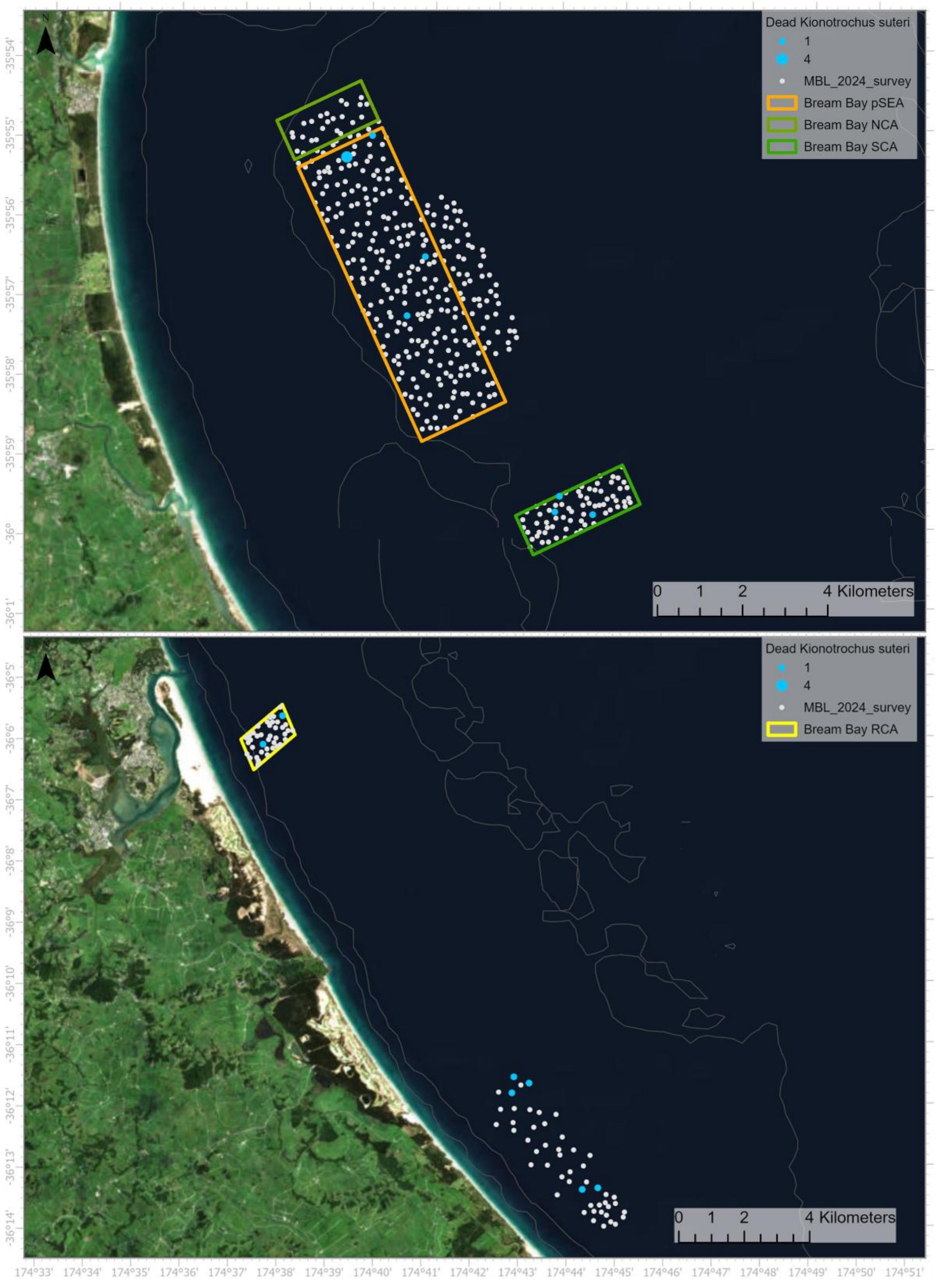


Figure 3-4: Dead *Kionotrochus suteri* recorded in the 2024 survey. Blue dots represent dead corals. Top: Te Ākau Bream Bay sampling. Bottom: Pākiri sampling, including the Te Ākau Bream Bay RCA. Dead coral skeletons were not quantified in previous surveys.

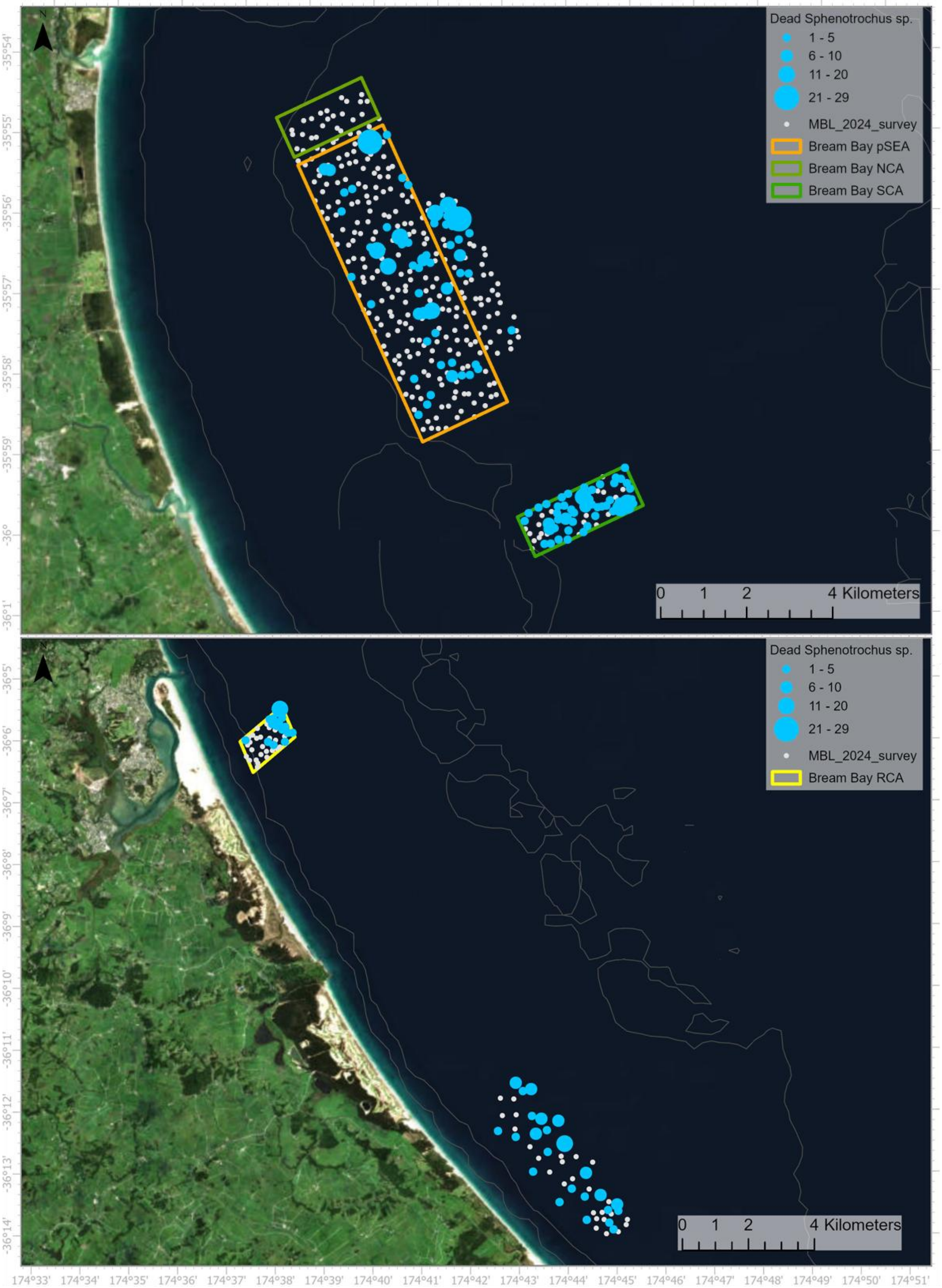


Figure 3-5: Dead *Sphenotrochus ralphae* recorded in the 2024 survey. Blue dots represent dead corals. Top: Te Ākau Bream Bay sampling. Bottom: Pākiri sampling, including the Te Ākau Bream Bay RCA. Dead coral skeletons were not quantified in previous surveys.

3.1.3 Te Ākau Bream Bay pSEA

In total, 225 coral specimens were recorded from within the Te Ākau Bream Bay pSEA. Of these, nine were live specimens (7 *Sphenotrochus ralphae* and 2 *Kionotrochus suteri*) and 216 were dead specimens (209 *Sphenotrochus ralphae* and 7 *Kionotrochus suteri*).

The ponar grab used in the 2024 Te Ākau Bream Bay survey sampled an area of 250 x 285 mm (or 0.07 m^2) of seabed. Specimens recorded per grab ranged from zero to 29 individuals (dead specimens of *Sphenotrochus ralphae*). The maximum recorded number of live specimens in any grab sample was one specimen for *Kionotrochus suteri* and two specimens for *Sphenotrochus ralphae.* Average densities of corals, standardised to individuals per m^2, within the proposed sand extraction area are given in Table 3-4.

Table 3-4: Average densities of coral specimens recorded in grab samples across the proposed sand extraction area at Te Ākau Bream Bay.

Taxon	Status	Average density (inds./m^2) ± SE
Kionotrochus suteri	Alive	0.11 ± 0.08
Kionotrochus suteri	Dead	0.37 ± 0.23
Sphenotrochus ralphae.	Alive	0.37 ± 0.16
Sphenotrochus ralphae	Dead	11.11 ± 2.52

3.2 Wider distribution

The available species location records are summarised in Table 3-5. With the exception of the MBL data which are quantitative, most of the records available for use are museum-style records which are qualitative rather than quantitative. They do, however, give an insight into the spatial distribution of these species.

Table 3-5: Summary of available species location records of *Sphenotrochus* spp., *Sphenotrochus ralphae* and *Kionotrochus suteri*. Note that the number of records is given (not abundances). NIC = NIWA Invertebrate Collection, OBIS = Ocean Biogeographic Information System.

Data source	All *Sphenotrochus* records	*Sphenotrochus ralphae*	*Kionotrochus suteri*
MBL	148	(148)	16
NIC	17	9	43
Te Papa	9	6	20
OBIS	135	26	162
Auckland Museum	23	21	21
iNaturalist	2	0	0

The two records of "*Sphenotrochus*" from iNaturalist were recorded from shallow depths at Pākiri but these were not identified to species. Only specimens identified as *Sphenotrochus ralphae* have been included in formal analyses (together with MBL records of *Sphenotrochus* sp. which are assumed to be *S. ralphae*).

3.2.1 *Sphenotrochus ralphae*

A spatial plot of available *Sphenotrochus ralphae* records (Figure 3-6) shows this species is distributed from Manawatāwhi Three Kings Islands to the Taranaki coastline on the west coast. However, the majority of records are situated along the north-east coast of Te Ika a Māui North Island of Aotearoa New Zealand.

Incidental records of habitat descriptions were available for some records exported from the Auckland Museum and from Te Papa datasets and are summarised in Table 3-6. The descriptions range from fine to medium sand through to pebbles, shell and algae. There were also records of a specimen attached to an *Ecklonia radiata* (kelp) blade in a rocky area near medium, coarse, shelly sand; a specimen associated with intertidal greywacke rock; and a specimen in the stomach contents of a fish (tarakihi, *Nemadactylus macropterus*). In addition, Brook (1982) noted *Sphenotrochus ralphae* specimens in fine sand, medium to coarse sand and also pebble gravel.

Thirty environmental data layers, with a spatial extent from the shoreline to the 12 nautical mile Territorial Sea boundary, were used to predict the suitability of habitat for *Sphenotrochus ralphae*. The observed range and frequency of a subset of these environmental layers for sites at Te Ākau Bream Bay (including Pākiri) and at other sites are given in Figure 3-7. While there are differences between the regions (e.g., a higher mean percentage of sand), the range of environmental variables at Te Ākau Bream Bay/Pākiri sites were within the range of values at other sites.

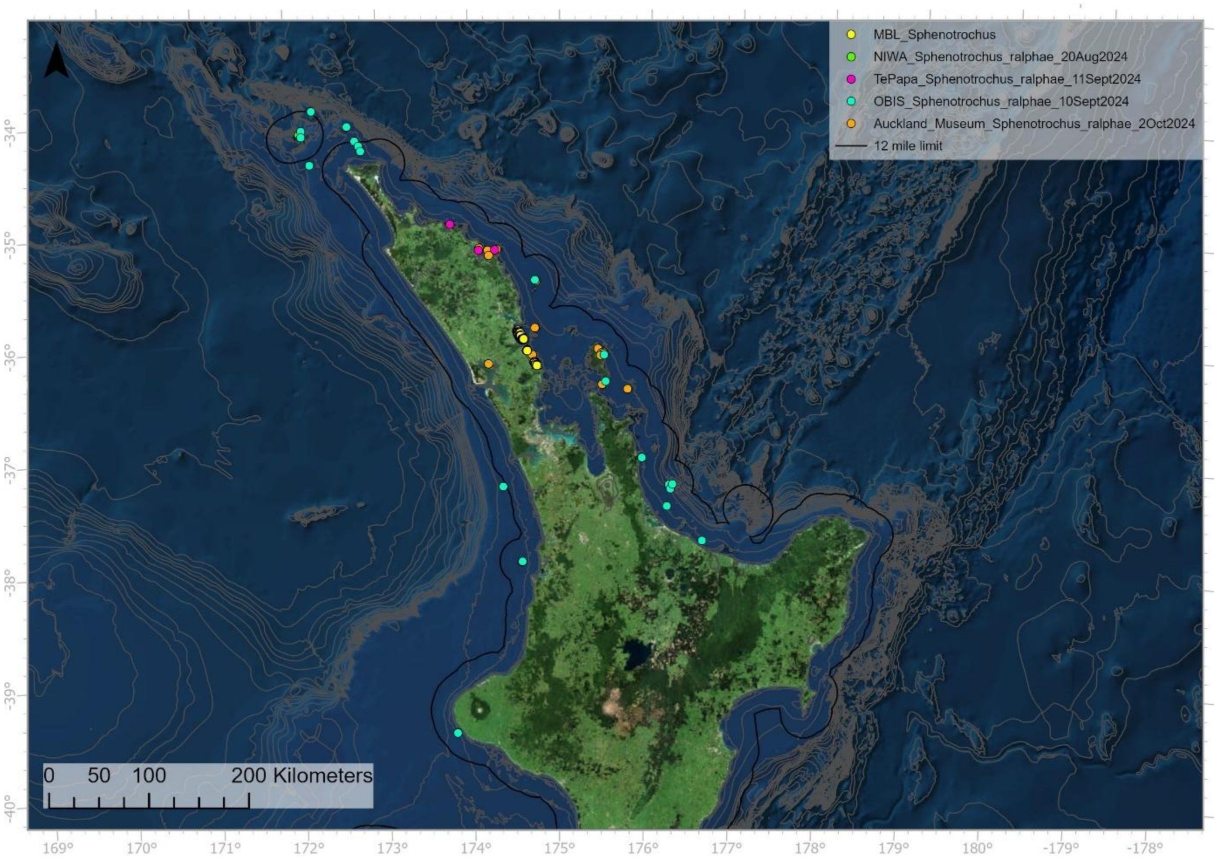


Figure 3-6: Distribution of *Sphenotrochus ralphae* records within Aotearoa New Zealand's EEZ. No records were located in the southern North Island or in South Island.

Table 3-6: Incidental observations of habitat associated with records of *Sphenotrochus ralphae*. Recorded within Auckland Museum and Te Papa datasets.

Habitat	Frequency
Fine to medium sand	1
Medium sand	1
Shelly medium sand	1
Coarse shell sand	1
Shell and sand	2
Sandy shelly gravel	1
Sand and gravel	1
Pebbly coarse sand	1
Pebbly fine shell gravel	1
Shell, algae and sand	1
Slightly sandy shell gravel	1
Pebbles, shell and algae	1
On *Ecklonia radiata* blade, in rocky area near medium coarse shelly sand.	1
Intertidal greywacke rocks	1
In stomachs of tarakihi	1

The spatial plots in Figure 3-8 show the potential suitable habitat for *Sphenotrochus ralphae* within Aotearoa New Zealand's Territorial Sea, as determined by environmental data layers, extends along both the east and west coasts of northern New Zealand, including Te Tai Tokerau Northland, Waikato, Te Moana-a-Toitehuatahi Bay of Plenty and Tairāwhiti East Cape coastlines. There were also observations from the Taranaki coastline and Manawatāwhi Three Kings Islands. The proposed sand extraction area at Te Ākau Bream Bay (15.4 km^2) is less than 0.2% of the identified potential suitable habitat for *Sphenotrochus ralphae* (7,847.3 km^2).

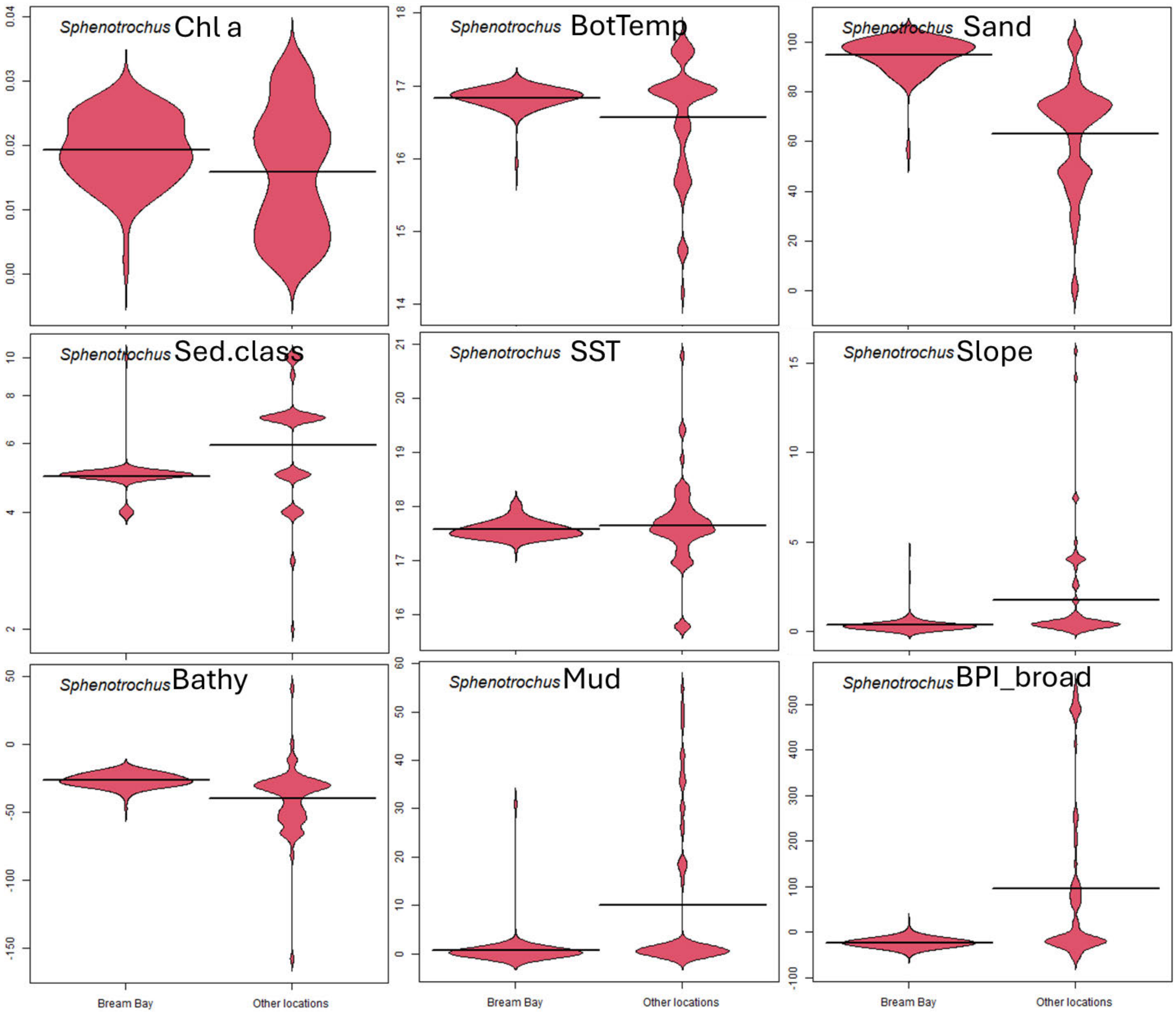


Figure 3-7: Bean plots show the spread of environmental variables extracted from locations of *Sphenotrochus ralphae* records at Te Ākau Bream Bay (including Pākiri) and all other sites. Within each plot, the left graph is Te Ākau Bream Bay (including Pākiri) data and the right graph is data from all other sites. The black horizontal bar shows the mean value. Chl a = Chlorophyll *a*, BotTemp = Bottom (seabed) temperature, Sand = percent sand; Sed.class = sediment classification; SST = Sea Surface Temperature; Slope = angle/steepness of seabed; Bathy = bathymetric depth; Mud = percent mud; BPI broad = Benthic Position Index. See Appendix A for details of each variable.

Note that a few records plot outside of the predicted range based on overlap of all 30 environmental layers which each record should lie within. A few of these records were at the minimum or maximum value for a variable but were missed in the masking process due to rounding error. Had these values been rounded up and included there would potentially have been false-positives within the predicted habitat area. As such this is a conservative estimate of habitat and there are a few species records that plot outside of the predicted range. Other records that plot outside of the predicted range lie outside of the Territorial Sea and therefore outside of the range of the available environmental data layers.

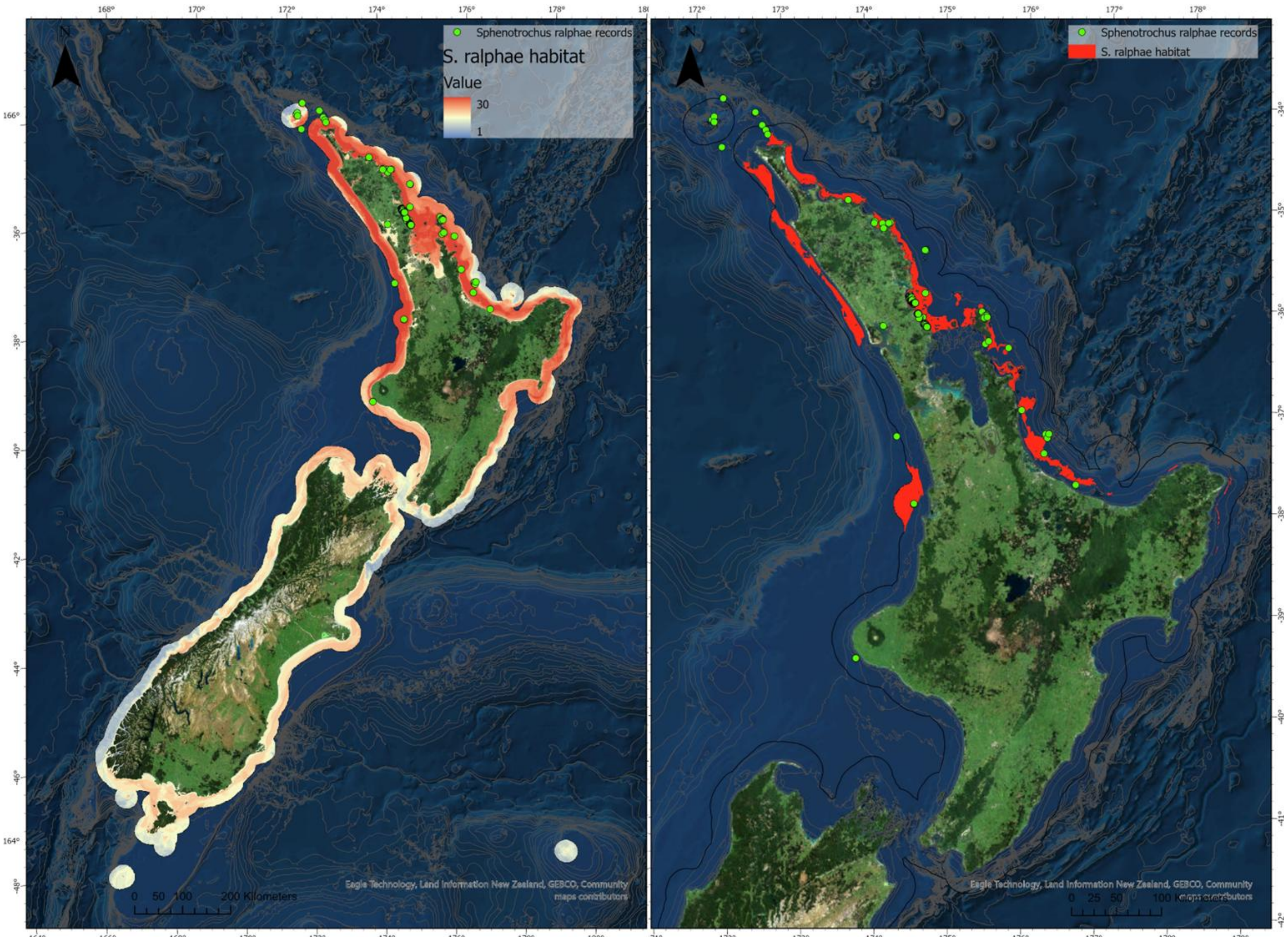


Figure 3-8: Potential suitable habitat for *Sphenotrochus ralphae* determined from environmental data layers. Left: Gradient of suitability based on the number of environmental variables within the species tolerance. Blue is low and red is high. Right: Potential suitable habitat where all 30 environmental layers were within the range of values recorded at known *Sphenotrochus ralphae* locations. Environmental data layers (Appendix A) were only available within the Territorial Sea. Note that where records appear to be outside of suitable habitat (e.g. off Taranaki) is due to a rounding issue with the data as these sites were at the outer limits of the environmental data ranges.

3.2.2 *Kionotrochus suteri*

A spatial plot of available *Kionotrochus suteri* records (Figure 3-9) shows this species is distributed from Manawatāwhi Three Kings Islands along the east coast to Tairāwhiti East Cape as well as down the west coast of Te Tai Tokerau Northland and Waikato.

Incidental records of habitat descriptions were available for some records exported from the Auckland Museum and from Te Papa datasets and are summarised in Table 3-7. The descriptions range from very fine muddy sand through to sand and gravel, and pebbles, bryozoan and shell. There is also a record of a specimen in the stomach contents of a fish (tarakihi). In addition, Brook (1982) noted *Kionotrochus suteri* specimens living in muddy fine sand.

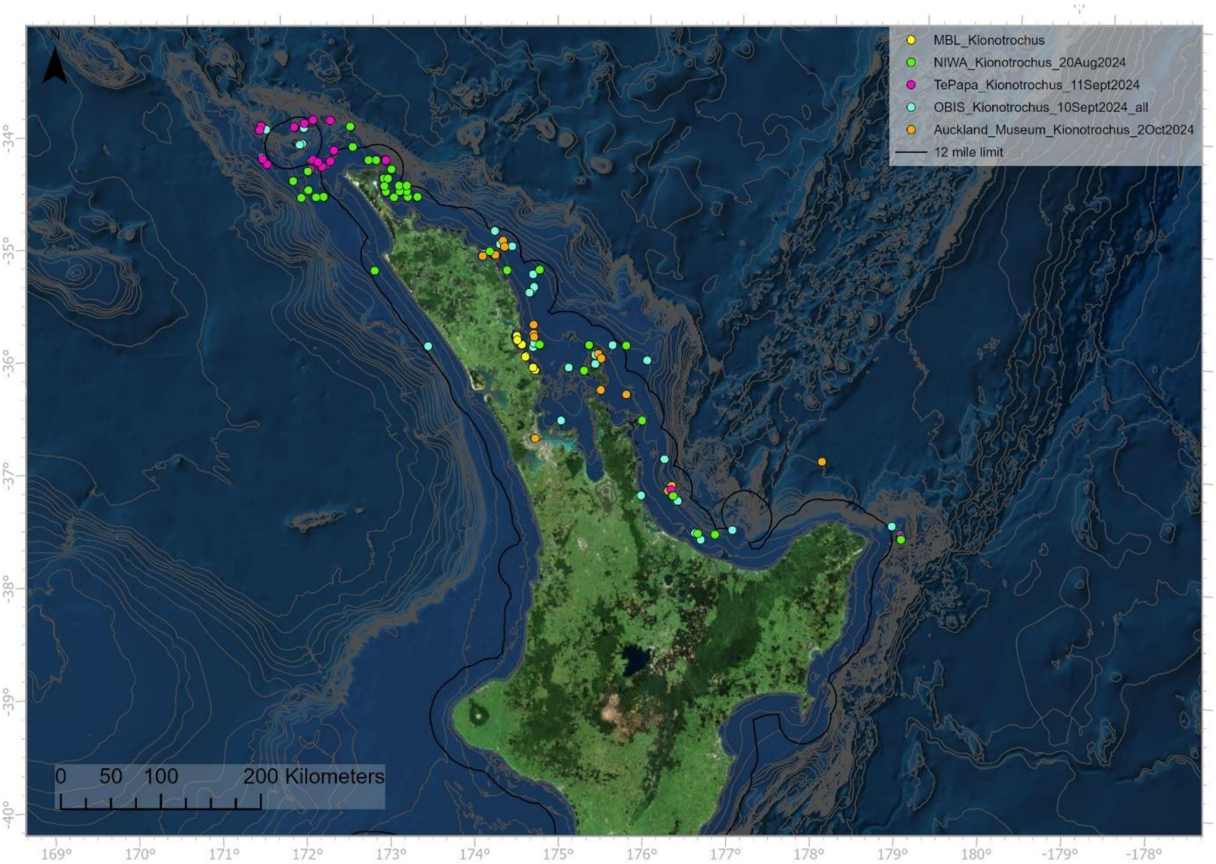


Figure 3-9: Distribution of *Kionotrochus suteri* records within Aotearoa New Zealand's EEZ. No records were located in the southern North Island or in South Island.

Table 3-7: Incidental observations of habitat of *Kionotrochus suteri* from datasets. Recorded within Auckland Museum and Te Papa datasets only.

Habitat description	Frequency
Very fine, muddy sand	3
Muddy fine sand	1
Muddy medium sand	1
Muddy shelly fine sand	1
Fine to medium sand	1
Medium sand	1
Medium to coarse sand	1
Shelly fine sand	1
Shell and sand	1
Sand and gravel	1
Pebbles, Bryozoa and shell	1
Bryozoa and shell	1
In stomachs of tarakihi	1
Mixed recent and fossil fauna	1

The observed range and frequency of a subset of the 30 environmental data layers extracted from *Kionotrochus suteri* locations at Te Ākau Bream Bay (including Pākiri) and at other sites are given in Figure 3-10. While there are differences between the regions, for example mean values of Chl a, Bathy, BotTemp and Sand were higher at Te Ākau Bream Bay, the range of environmental variables at Te Ākau Bream Bay/Pākiri were within the range of values at other sites.

The spatial plots in Figure 3-11 show that the potential suitable habitat for *Kionotrochus suteri* within the Aotearoa New Zealand Territorial Sea extends along both the east and west coasts of northern New Zealand, including Te Tai Tokerau Northland, Waikato, Te Moana-a-Toitehuatahi Bay of Plenty and Tairāwhiti East Cape coastlines. There were also observations from Manawatāwhi Three Kings Islands. The proposed sand extraction area at Te Ākau Bream Bay (15.4 km^2) is approximately 0.05% of the identified suitable habitat for *Kionotrochus suteri* (28,960.7 km^2).

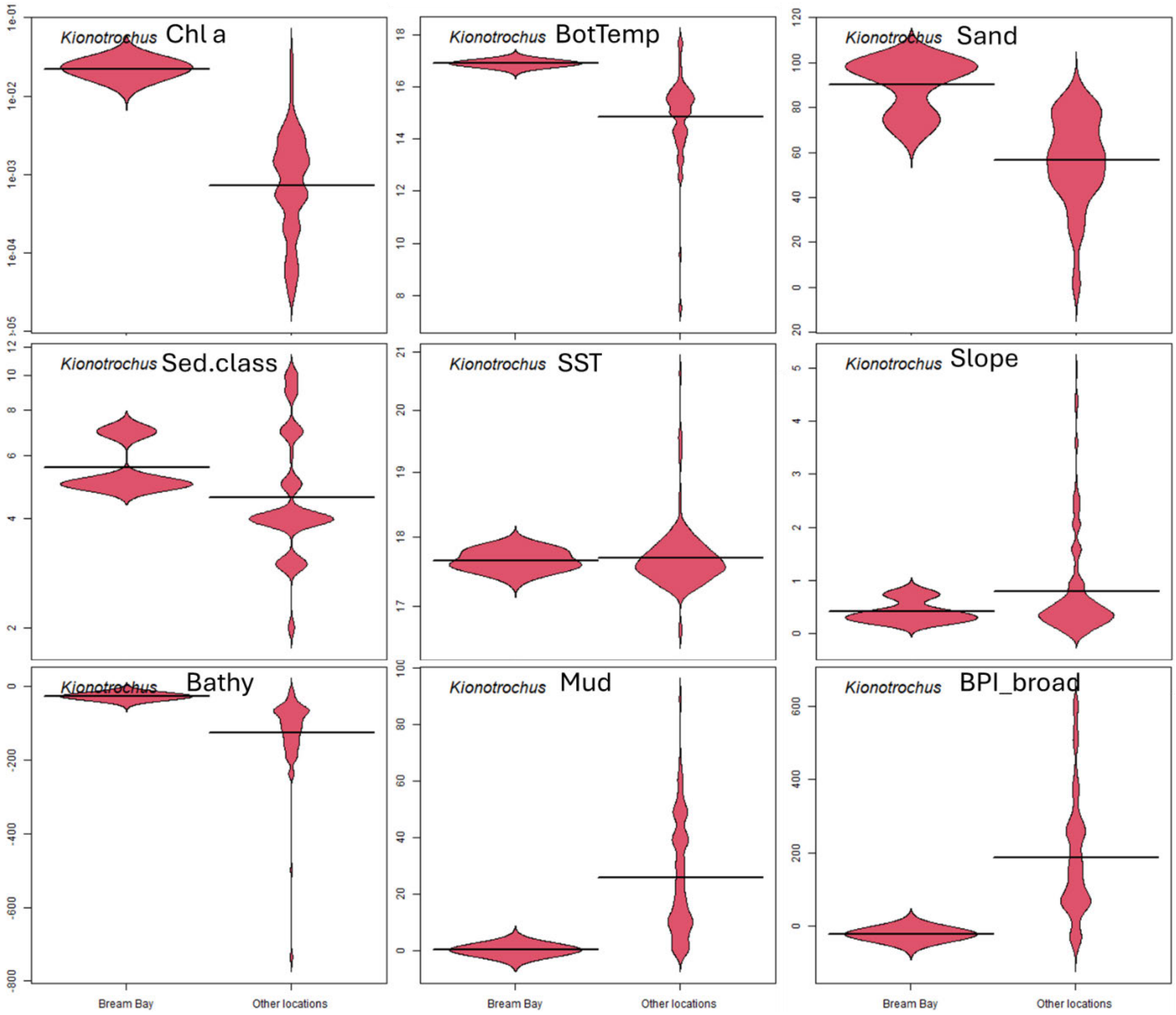


Figure 3-10: Bean plots showing the ranges of some environmental values at *Kionotrochus suteri* record locations. Within each plot, the left graph is Te Ākau Bream Bay (including Pākiri) data and the right graph is data from all other sites. Chl a = Chlorophyll *a*, BotTemp = bottom temperature, Sand = percent sand, Sed. class = sediment classification, SST = Sea Surface Temperature, Slope = angle of seabed, Bathy = bathymetric depth, Mud = percent mud, BPI_broad = Benthic Position Index. For each plot, sites at Te Ākau Bream Bay are on the left and all other sites on the right of the plot. See Appendix A for details of each variable.

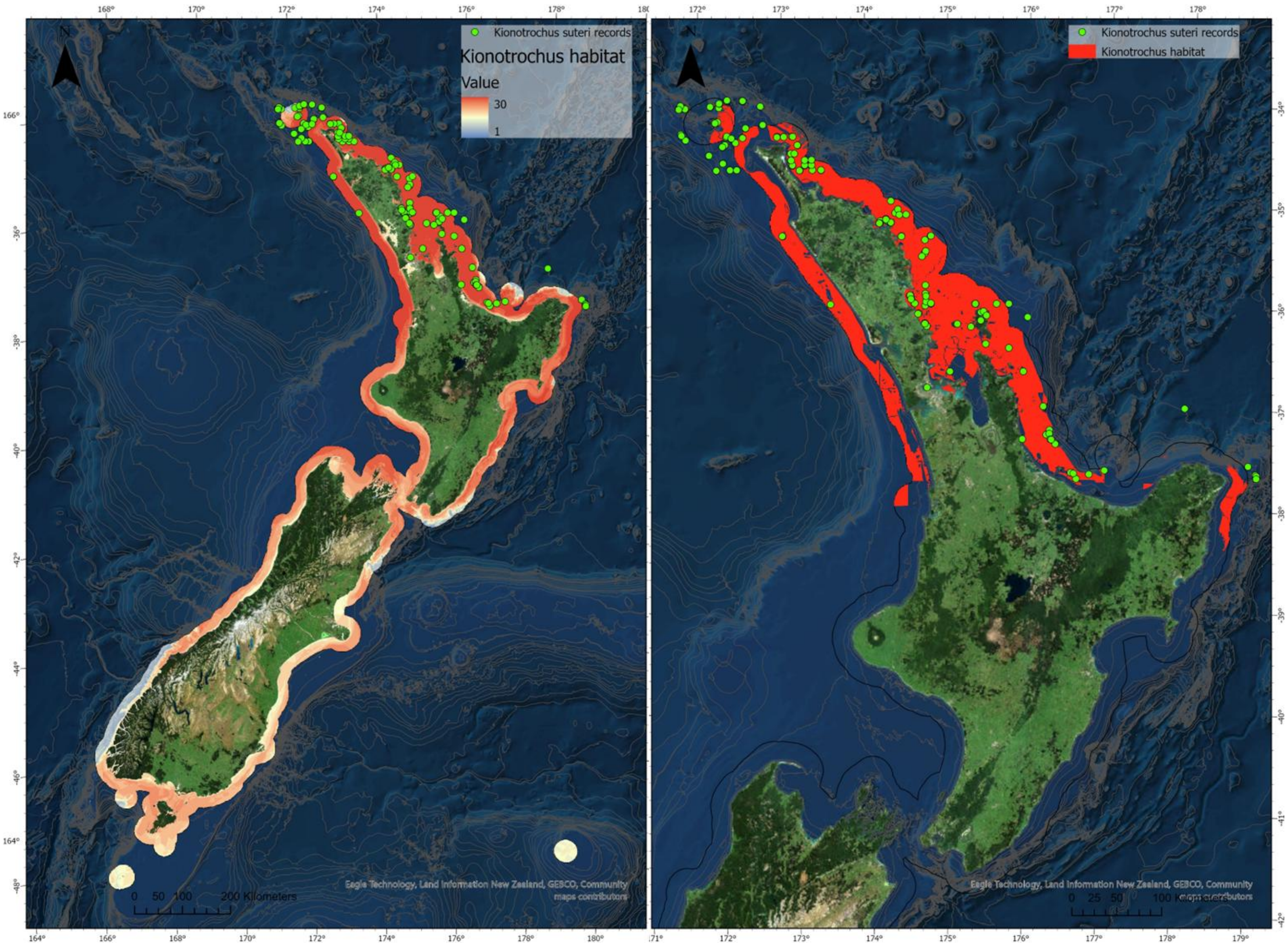


Figure 3-11: Potential suitable habitat for *Kionotrochus suteri* determined from environmental data layers. Left: gradient of suitability, based on the number of environmental variables within the species tolerance. Blue is low and red is high. Right: Potential suitable habitat where all 30 environmental layers (Appendix A) were within the range of values recorded at known *Kionotrochus suteri* locations. Environmental data layers were only available within the Territorial Sea.

4 Ecology of cup corals

4.1 Turbinoliidae cup corals

Sphenotrochus ralphae and *Kionotrochus suteri* are both members of the family Turbinoliidae (Cnidaria, Scleractinia). Note that in historical literature these corals are referred to as being within a subfamily Turbinoliinae. However, this subfamily is currently unaccepted and is considered a junior subjective synonym with the family Turbinoliidae (Hoeksema and Cairns 2024). Therefore, the family is referred to as Turbinoliidae throughout this document.

Vaughan and Wells (1943) described the Turbinoliidae, first known in the late Cretaceous, as a small group especially adapted to life on an unstable substratum. This family is composed exclusively of free-living, solitary corals that only inhabit soft-bottom substrates (e.g., sand and mud) at depths beyond the reach of vigorous wave motion (Vaughan and Wells 1943; Cairns 1997).

Turbinoliidae are azooxanthellate, non-constructional and ahermatypic (not reef building) and occur mostly in moderately deep water in temperate and tropical seas (Vaughan and Wells 1943; Cairns 1997). The corallum (skeletal “cup”) of Turbinoliidae are small, usually less than 10 mm in calicular diameter (CD). Their small size and apparent interstitial habit within sandy substrates at lower shelf to upper slope depths have resulted in the collection of relatively few turbinoliid specimens, and little is known about their modes of life and life history traits (Cairns 1997).

4.1.1 *Sphenotrochus ralphae*

Cairns (1997) described the *Sphenotrochus* genus (recent rather than fossil records) as widespread, including the following: tropical eastern Pacific (lower California and Galapagos Islands), Indo-West Pacific; western Atlantic from Caribbean to Patagonia, eastern Atlantic from South Africa to North Sea with a depth range of 7-403 m. The coralla of *Sphenotrochus* cup corals rarely exceed 10 mm in greater calicular diameter (GCD). Two species are known to exist within Aotearoa New Zealand: *Sphenotrochus ralphae* (depth range 7-104 m) and *Sphenotrochus squiresi* (depth range 66-318 m).

Sphenotrochus ralphae (Squires 1964) is endemic to Aotearoa New Zealand, with a distribution ranging from Pungarehu Cape Egmont (Taranaki) to Te Moana-a-Toitehuatahi Bay of Plenty, including off Manawatāwhi Three Kings Islands (Cairns 1995). This species has a small triangular corallum with flat faces and rounded edges. The corallum is white or sometimes porcellanous and measures up to 9 mm in height (Figure 4-1).

Figure 4-1: Images of *Sphenotrochus ralphae*. Specimens collected during the 2024 Te Ākau Bream Bay survey and photographed alongside a ruler for scale with each black line 1 mm apart. Left: top view; Right: side view. Photo credit: Simon West.

4.1.2 *Kionotrochus suteri*

Kionotrochus suteri was first described by Dennant (1906). He noted that "this interesting coral was dredged at a depth of 100 fathoms by Mr Henry Suter and Mr Charles Hedley about 15 miles outside Great Barrier Island, New Zealand. It is evidently very abundant, as a large number of specimens have been sent to me. About 20 of them are full-grown and tolerably perfect; 20 others are also adult, but worn; in addition, there are more than 30 of the juvenile discoid forms previously mentioned, a few of which are still attached to minute shell fragments."

Kionotrochus suteri is endemic to Aotearoa New Zealand with a known distribution from off Tairāwhiti East Cape to just north of Kaipara Harbour, including Manawatāwhi Three Kings Islands (Cairns 1995, 1997). The reported depth range for this species is 31-622 m (with most records between 100-200 m) (Brook 1982; Cairns 1995). Note that the MBL survey sites were in depths of 18-32 m so at the shallowest extent of the reported depth range for this species.

This species is up to 6.8 mm in CD and 6.5 mm in height (Cairns 1995, Figure 4-2). The corallum is white and often attached to a bivalve shell. Mature specimens have a conical corallum with a rounded base. It is a commonly collected coral that can be found in relatively shallow water in the Aotearoa New Zealand region and has been studied and redescribed several times (Cairns 1995 and references therein).

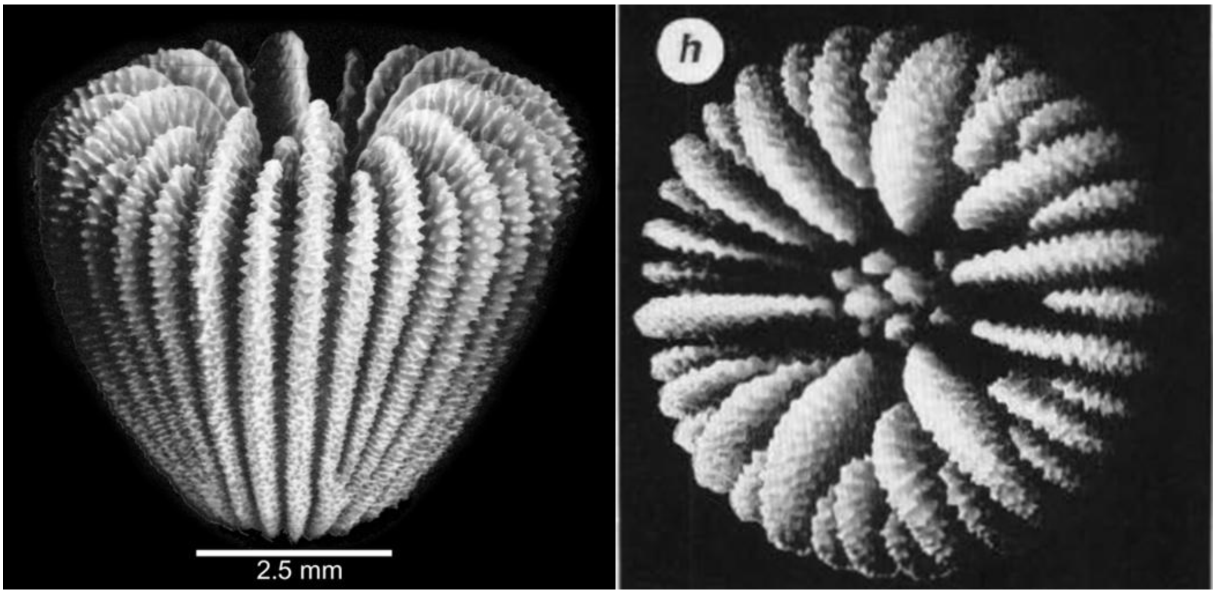


Figure 4-2: Images of *Kionotrochus suteri*. Images taken from Cairns (1995; 1997, plates 25 and 3 respectively).

4.2 Cup coral reproduction

Reproduction has a fundamental role in the population dynamics and distribution of benthic animals. Understanding reproduction characteristics, larval dispersal and population connectivity is key for successful management and conservation of marine systems (e.g., Beaumont et al. 2024). However, basic information on the reproductive biology of many scleractinian coral species is limited or entirely lacking, particularly from temperate zones (Marchini et al. 2022).

Corals have a relatively simple life cycle including a dominant benthic polyp phase and a shorter planula larva phase. The sessile polyp phase often includes one or more forms of asexual budding or reproduction as well as repeated cycles of sexual reproduction (Harrison 2011).

There are two modes of sexual reproduction within the Scleractinia: broadcasting and brooding. In broadcast spawning, large numbers of male and female gametes are released into the water column. Fertilization occurs externally and propagules disperse with water currents until they settle onto a suitable hard substrate and develop into a new coral polyp. In brooding corals, fertilisation occurs within the polyp and small numbers of relatively large planula larvae are released into the water column where they also disperse and settle onto a suitable hard substrate. It is considered likely that the dispersal potential of larvae from brooding corals is lower than in broadcasting corals.

Asexual reproduction also has several forms and includes colony fragmentation resulting from storm and wave impacts or other damage, colony fission, longitudinal and transverse division, polyp expulsion or polyp “bail out”, growth and detachment of polyp balls and budding of polyps from an anthocaulus, and autotomy (self-amputation) and regeneration of tissues (e.g., Harrison 2011; Sentoku et al. 2022). In solitary corals, asexual reproduction results in the production of new individuals that are genetically identical clones.

Harrison (2011) reviewed the sexual reproduction of scleractinian corals and noted that “the range of reproductive processes and modes in corals partly reflects the extraordinary ability of cnidarian cell lines to differentiate, dedifferentiate, and redifferentiate, which provides their tissues with remarkable developmental plasticity and adaptability”.

Information on the reproduction of scleractinian solitary corals and those living in temperate zones is notably scant (Goffredo et al. 2005). However, transverse division is restricted to certain solitary corals living in soft substrates (e.g., Maghsoudlou et al. 2021) and is considered to be advantageous where stable settlement sites available for sexually produced larvae may be scarce (Tokuda and Ezaki 2012). This method of reproduction is described in detail below.

4.2.1 Turbinollidae

Vaughan and Wells (1943) described the Turbinoliidae as "a small group especially adapted to life on an unstable substratum (e.g., sand) affording few places to fixation of the free-swimming planula. Except in the very earliest stages, these strictly solitary corals are unattached, the edge-zone completely covering the exterior of the corallum which lies loose on the bottom or perhaps partly embedded in it, as in some actiniarians".

4.2.2 Sphenotrochus ralphae

There is little information on the reproductive biology of *Sphenotrochus ralphae*. However, a "bipolar" specimen of the *Sphenotrochus* genus was observed in depths of 15-20 m in the Mediterranean Sea by Rossi (1961), with a mouth and tentacle grown at both the upper and lower extremity (Figure 4-3). It was suggested that the lower extremity generates a new polyp opposite the upper extremity, which would be a form of asexual reproduction.

Cairns (1995) noted that transverse division is lacking (does not occur) in members of the genus *Sphenotrochus*. However, Cairns (1995) also remarked that "in two of the approximately 200 coralla examined, the calice was in the process of intratentacular division". Intratentacular division is the development of a new polyp on the oral disc, inside the ring of tentacles. This can form individual, separate polyps or a row of partially separated polyps sharing an elongate oral disc with a series of mouths. Tentacles grow around the margin of this elongated oral disc and not around the individual mouths.

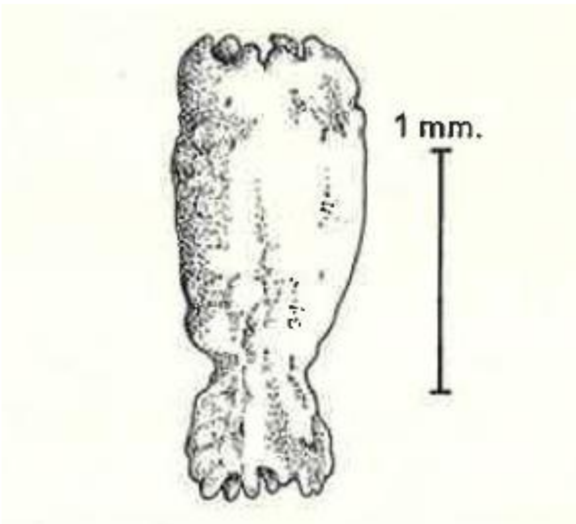


Figure 4-3: Image taken from Swedmark (1964). Interstitial madreporian, *Sphenotrochus* sp., a bipolar form belonging to the family Caryophyllidae. Note that the *Sphenotrochus* genus was previously in the family Caryophyllidae. Specimen from sublittoral shell dune at Roscoff.

While none of the specimens recorded within the MBL survey data were attached to hard substrates (Simon West, personal communication), incidental observations of habitat in section 3.2.1 above showed that specimens of *Sphenotrochus ralphae* do attach to substrates such as the blade of the kelp *Ecklonia radiata*. This would suggest that *Sphenotrochus ralphae* may use some form of asexual budding or division within its reproductive strategies.

4.2.3 *Kionotrochus suteri*

Kionotrochus suteri is known to reproduce asexually through transverse division. Dennant (1906) noted that "in adults the corallum is free, with a rounded convex base, which shows a very small scar of former attachment at its centre. Very young individuals are fixed generally to shell fragments, and the corallum then has a flatly adherent base and perpendicular wall. The gradations from such form to those with a free rounded base is clearly traceable amongst the smaller specimens. The scar of former attachment becomes less and less conspicuous as the corallum increases in size."

Brook (1982) also recorded specimens of *Kionotrochus suteri* of both free-living and small attached forms. The attached specimens were on bivalve shells or shell fragments and mostly attached to sculpted rather than unsculpted surfaces and suggested larvae may prefer to settle to substrates with some relief (as opposed to smooth surfaces). Brook (1982) also suggested that *Kionotrochus suteri* at their location (Rakitu Island, near Great Barrier Island) had a patchy, localised, distribution and that this could be due to limited larval dispersal and the asexual budding through transverse division increasing the local population. Additionally, Brooke (1982) reported the first record of a specimen of *Kionotrochus suteri* undergoing intratentacular budding. This specimen was attached to a shell fragment.

Examples of the attached form (anthocaulus) and a recently budded free-living form (anthocyathus) of *Kionotrochus suteri*, taken from Cairns (1995), are shown in Figure 4-4. A recently budded anthocyathus collected during an MBL survey is shown in Figure 4-5.

No further information was found on the reproduction of this species. The timing or seasonality of reproduction remain unknown.

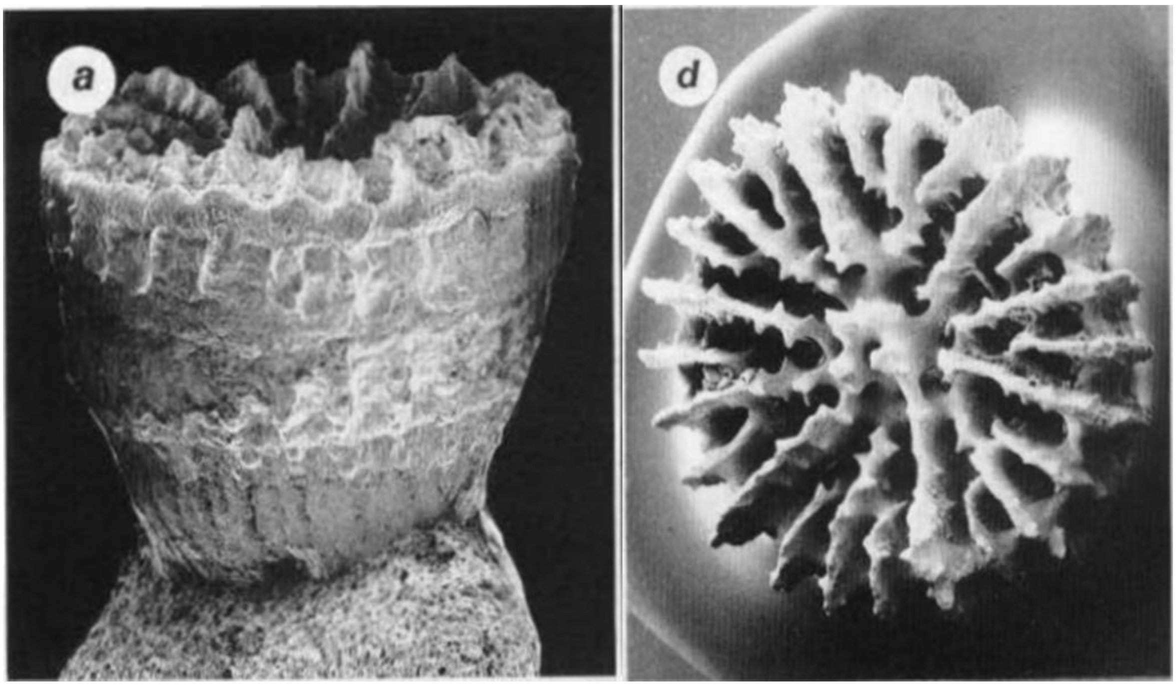


Figure 4-4: Asexual budding in *Kionotrochus suteri*. Image taken from Cairns (1995), Plate 26. Side view of anthocaulus (attached form, x 23 magnification) and of a recently budded anthocyathus (free-living form, x 24 magnification).

Figure 4-5: Example of an apparently recently budded anthocyathus of *Kionotrochus suteri* collected during an MBL survey. Photographed alongside a ruler for scale with each black line 1 mm apart. Left: side view; Right: top view. The age of this individual, or time since budding occurred, is unknown.

4.2.4 Similar species

Deltocyathoides orientalis (Turbinoliidae) is a small bowl-shaped solitary azooxanthellate scleractinian with a maximum recorded size of up to 8.4 x 4.9 mm (similar in size to *Sphenotrochus ralphae* and *Kionotrochus suteri).* This species also exhibits asexual reproduction by transverse division. The schematic in Figure 4-6 (taken from Sentoku et al. (2022)) shows the process of reproduction by transverse division in *Deltocyathoides orientalis*. Sentoku et al. (2022) described a dimorphic life cycle whereby a planula larva attaches to a hard substrate (e.g., a shell, image Figure 4-6 A) and develops into a coral polyp (an anthocaulus, image B). This anthocaulus produces an anthocyathus (image C) which is released, via transverse division, and becomes a free-living coral inhabiting mobile sediments. This anthocyathus reproduces sexually to produce planktonic planula larvae which travel in the water column until they find a suitable attachment site (e.g. shell, gravels) on which to develop into a coral polyp (another anthocaulus). Sentoku et al. (2022) noted that anthocyathi only reproduce sexually after division and that anthocauli were found to regrow and repeatedly produce anthocyathi by transverse division. While the mechanism for reproduction is well documented in *Deltocyathoides orientalis*, little is known about the juvenile stage(s) of the lifecycle or the frequency of reproduction (Sentoku et al. 2022).

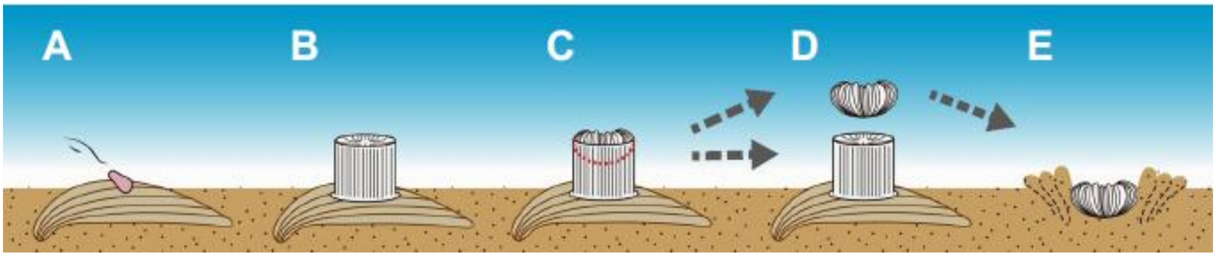


Figure 4-6: Figure 7 from Sentoku et al. (2022) showing the dimorphic life cycle of the azooxanthellate scleractinian coral *Deltocyathoides orientalis*. A) Coral planula attaching to shell fragment on soft substrate. B) Anthocaulus. C) Anthocyathus occurring at the upper interior of the anthocaulus. D) Division of the anthocyathus from anthocaulus. E) Anthocyathus burrowing into a soft bottom substrate immediately after division.

Sentoku et al. (2022) noted that immediately after division, *Deltocyathoides orientalis* shifts to a burrowing lifestyle that efficiently utilises the soft-substrate environments, which probably increases its survival rate and concluded that the automobility of the anthocyathi, including burrowing, escape from burial, and righting behaviours, implies that the species is actively utilising habitats within the seafloor.

Transverse division has also been documented in *Peponocyathus duncani* (Turbinoliidae), *Bourneotrochus stellulatus* (Caryophylliidae) and *Truncatoflabellum* (Flabellidae) (e.g., Maghsoudlou et al. 2021; Sentoku et al. 2022). It is also considered likely that members of the Fungiidae family use autotomy (self-amputation) for asexual maintenance and/or growth of populations, particularly on soft substrates where larval propagules may not survive (e.g., Chadwick and Loya 1990; Yamashiro and Nishihira 1998). Buhl-Mortensen et al. (2007) suggested this may also be true of the Flabellum species they studied.

While sexual condition (e.g. gonochorism (male or female gametes in a polyp) vs hermaphroditism (both male and female gametes present within a single polyp) in scleractinians tends to be phylogenetically correlated and therefore constant through genera and families, reproductive mode (brooding vs broadcast spawning) tends to be adaptive and is, therefore, variable (Goffredo et al. 2005). This means that it is not possible to determine the reproductive mode using information from other members of the same genus or family. For example, in the deep sea, *Flabellum* spp. in the northeast Atlantic Ocean are broadcast spawners, whereas Antarctic representatives are brooders (Waller et al. 2008). However, of the studies found on temperate, ahermatypic, azooxanthellate solitary corals in shallow depths where reproductive mode has been determined, both species were brooders (*Leptopsammia pruvoti* (Dendrophyllidae, Goffredo et al. 2010); *Caryophyllia huinayensis* (Caryophyllidae, Heran et al. 2023)).

4.3 Cup coral growth rates and longevity

The rate of growth and/or longevity are important metrics when considering the vulnerability of a species to anthropogenic disturbance. A meta-analysis conducted by Hiddink et al. (2019) showed decreases in the relative abundance of long-lived fauna in fishery-trawled areas were greater than those of fauna with shorter life spans. These differences were attributed to the lower intrinsic rates of increase in long-lived fauna and, consequently, to their lower capacity to sustain trawling-induced mortality. Intrinsic rate of increase was estimated to be seven times lower for long-lived (> 10 years) than for short-lived fauna (1-3 years) from which it can be inferred that populations with greater longevity have an increased sensitivity to trawling disturbance.

Growth rates can be determined by direct observation, enumeration of growth bands from coral skeletons, and/or use of radiometric dating to trace isotopes of coral skeletons (Tracey et al. 2018). Tracey et al. (2018) also noted that growth rates of corals commonly decrease with age and that factors such as temperature, pH, salinity, food availability, sedimentation, hydrography, and geomorphology or substrate of seabed have all been shown to affect growth in deep-sea corals.

While there was no available information on the growth rates or longevity of *Sphenotrochus ralphae* or *Kionotrochus suteri* in the literature, temperate and semi-temperate corals appear to deposit two growth bands per year, with a high density band in winter and a low density band in summer (Goffredo et al. 2010 and references therein). Growth rates have been determined for other temperate shallow solitary cup corals as described below and summarised in Table 4-1.

Flabellum rubrum (family: Flabellidae) is a solitary cup coral found in both littoral and sub-littoral zones of the Aotearoa New Zealand shelf (Squires 1963), with a reported depth range from the intertidal to approximately 155 m. *Flabellum rubrum* is a larger species than those found within MBL's area of interest, with a maximum recorded height of 48.3 mm. It is also a species which attaches to hard substrates (including shells and pebbles) rather than living amongst mobile sediments. Squires (1963) summarised existing growth data on *Flabellum rubrum* and noted allometric growth rates (varying with age) in data generated from settlement panels placed in-situ for varying periods of time. Young corals (specimens aged 1 month and 6 months) increased in size by 0.5 cm per month and older corals (9 months) increased by 0.16 to 0.4 cm per month, implying that the largest specimen (48.3 mm) could be less than one year in age (Squires 1963). However, Squires (1963) also noted that if growth was estimated using growth bands, and if considered annual, the growth rate would be 2.5 mm per year, with an estimated life span of 12 years. This latter growth rate is more aligned with growth rates reported below for other species.

Balanophyllia europaea (family: Dendrophyllidae) is a solitary zooxanthellate coral endemic to the Mediterranean Sea. Özalp et al. (2018) determined skeletal biometry, growth and parameters of specimens collected at depths of 1, 11 and 21 m in Turkey. They also found mean skeletal growth rate at each depth decreased exponentially with age. On average, skeletal growth rate decreased from 3.1 mm per year at less than 5 years of age to 2.4 mm per year between 5-10 years to 1.8 mm per year at greater than 10 years of age.

Leptopsammia pruvoti (family Dendrophyllidae) is an ahermatypic, azooxanthellate, solitary scleractinian coral, found in the Mediterranean Sea and from Portugal to southern England and Ireland where it inhabits rocky walls from 0-70 m water depth. Goffredo et al. (2010) determined the growth rates of specimens collected at 16 m water depth using growth band counts. As above, the growth rate of this species also decreased as a function of coral length. Reported growth rates of the smallest specimens (0-4 mm in size) were 1.0 mm per year, of medium sized specimens (4-6 mm in size) were 0.7 mm per year and of the largest specimens studied (6-8 mm in size) were 0.3 mm per year. The largest individuals (7 mm in length) were estimated to be 10 years old (Goffredo et al. 2010).

Caryophyllia smithii (family Caryophyllidae) is a shallow water, temperate, species of solitary coral. It is found associated with hard substrates (e.g., boulders) as well as being attached to pebbles, shells or polychaete tubes on mobile sediments, with a depth range from the lower shore to at least 230 m (Wilson 1975). Bell and Turner (2000) studied specimens collected from hard substrates in 11-20 m water depth in Lough Hyne, Ireland, and found that significant differences in size, shape and density occurred between populations in areas with different sedimentation regimes. The size of *C. smithii* was shown to be significantly greater in wave sheltered environments than in wave exposed conditions on rock wall communities (< 30 m water depth, Bell 2002). Fowler and Laffoley (1993) noted that the transparent bodies of *Caryophyllia* species enabled accurate measurements of their calcareous skeletons to be recorded. As with other species discussed here, the growth rate of *C. smithii* was not constant with age. Growth was fastest (100-300% increase) in the first 7 years, then approximately 0.5 mm per year thereafter.

While the growth rates and longevity of *Sphenotrochus ralphae* or *Kionotrochus suteri* are yet unknown, they may be similar to the reported ranges of other similar shallow-water species. There is a general consensus that the growth of small shallow-water cup corals decreases with a function of coral length (i.e., growth rate slows as the coral grows). Reported longevities are in the range of approximately 7-12 years. Reported growth rates ranged from 0.3 mm to 3.1 mm per year, with the exception of *F. rubrum* with possible growth rates of up to 0.5 cm per month.

Growth rates reported in deep sea species are not dissimilar but deep-sea species are estimated to have longer life spans. For example, Risk et al. (2002) showed the deep sea cup coral *Desmophyllum cristagalli* growth to be 0.5-1 mm per year and estimated longevity to be greater than 200 years. Hamel et al. (2010) estimated the in-aquaria growth of *Flabellum alabastrum* (collected from 600-1200 m) to be 1-5 mm per year, with the largest individuals (approximately 43 mm calyx height) estimated to be at least 45 years old.

Table 4-1: Summary table of known growth rates for shallow temperate cup corals.

Species (max size)	Depth	Location	Habitat	Growth rate (age of specimen)	Longevity	Reference
Flabellum rubrum (48.3 mm)	0–155 m (sampled at 100 m)	New Zealand	Hard substrates (including pebbles/shells)	0.5 cm/month (1-6 months) 0.16-0.4 cm/month (9 months) Or 2.5 mm/yr (growth bands)	~ 12 years	Squires (1963)
Balanophyllia europaea (29.5 mm)	0-50 m (sampled at 1-21 m)	Turkey	Rocky substrates	3.1 mm/yr (< 5 years) 2.4 mm/yr (5-10 years) 1.8 mm/yr (> 10 years)	> 10 years	Özalp et al. (2018)
Leptopsammia pruvoti (7 mm)	0-70 m (sampled at 16 m)	Mediterranean Sea	Rocky walls	1 mm/yr (0-4mm) 0.7 mm/yr (4-6mm) 0.3 mm/yr (6-8mm)	10 years	Goffredo et al. (2010)
Caryophyllia smithii (19 mm)	0-230 m (sampled at 13-25 m)	UK	Hard substrates and attached to shells/pebbles/worm tubes in mobile sediments	100-300% increase in first7 years ~0.5 mm/year (> 7 years)	> 7 years	Fowler and Laffoley (1993)

4.4 Resilience of cup corals to disturbance

4.4.1 MBL's sand extraction process

Sand extraction occurs using a trail suction hopper dredge (the "*William Fraser*") where sand is predominantly transported directly from the extraction area to MBL's depot at the Port of Auckland (or other destination port). The *William Fraser* was purpose built and includes technologies to improve performance and reduce environmental impact (McCallum 2022). These include:

- A Dutch-designed screening deck, rather than flume pipes, which reduces damage to live animals passing through the draghead and increases the screening efficiency.
- Moon pools to immediately deliver the over-size [material] and sediment discharge below the water line to minimise turbidity.
- The moon pool system also reduces the aeration of the sediment and/or biota, which decreases their settling time, and therefore the time they may be vulnerable to predation, compared to the flume pipe and discharge over the side of the boat method.

McCallum (2022) provided details of MBL's sand extraction operation. In summary, the sand slurry is fluidised at the draghead via suction pulling sand and water through the draghead at the seabed. The sand slurry then moves up the draghead pipe, through a pump and onto the vessel where it is discharged onto a screen deck that utilises a 2 mm screen mesh to prevent larger material going into the load of the hopper. Oversized material (> 2 mm) passes across the top of the screen and drops, via a pipe, into the forward port side moon pool where it drops through the vessel and exits, at keel height, under the vessel to return to the seabed.

However, passage through the sand dredge and across the screens is not without some risk to the larger macrofauna and there is the potential that organisms could be damaged or destroyed by passage through the dredge (West 2022). West (2022) summarised survivorship studies of seabed biota which showed that 92% of individuals survived going through the pumping and screen system on the *William Fraser* (sampled at 10 m). Survival rates were to some degree dependent on the size of the animal and any natural protection (e.g., presence of robust shells, West and van Winkel (2025)). For example, West (2022) concluded that sand extraction was more likely to kill larger sand dollars and paddle crabs (*Fellaster zelandiae* and *Ovalipes catharus*, respectively) but that juveniles of both species were likely to survive passage through the dredge pump and screening plant. Mortality occurred in some larger specimens of the bivalve *Dosinia subrosea* but the majority of individuals less than 20 mm in size were deemed to be undamaged. No lethal effects were recorded for gastropods. West (2022) also considered it likely that fragile species such as brittle stars would suffer greater rates of damage than hard shelled molluscs. The survivability of cup corals was not assessed.

It is worth noting that the survivorship studies examined specimens as they left the *William Fraser* and did not consider disturbance on the seabed such as burial by deposited sediments or temporary increases in suspended sediments. However, West (2022) noted that the primary cause of suspended solids is the sediment extracted from the seabed, some of which either passes over the weir boards from the sand hopper or is entrained in the water passing across the screening deck and then out of the moon-pool discharge points under the vessel. Furthermore, West (2022) noted that the plume of elevated suspended solids created behind the sand dredge is weak in concentration (< 10 mg/L), localised and short lived. In addition, plume sampling during sand extraction at Pākiri showed total suspended solids (turbidity) was returned to ambient conditions after approximately 26 minutes (Jacobs 2020).

4.4.2 Available information on resilience of cup corals to disturbance

The proposed sand extraction activities at Te Ākau Bream Bay will necessarily cause periods of elevated suspended sediments and sediment movement/deposition to at least the immediate area of dredging. There is ample evidence in the literature to show that elevated sedimentation (suspended or deposited) can negatively impact on the health of corals (Erftemeijer et al. 2012). This can be through sublethal effects such as reduced growth and larval survival (Larsson et al. 2013; Järnegren et al. 2017; Moeller et al. 2017), loss of coenosarc tissue (Larsson and Purser 2011; Mobilia et al. 2023) and immune and metabolic responses (Sheridan et al. 2014). Elevated suspended sediments can also lead to polyp mortality (e.g., Mobilia et al. 2023).

Scleractinian corals employ a variety of mechanisms to remove deposited sediment particles including passive removal (e.g., use of water currents) or active removal such as polyp inflation (Riegl 1995; Bongaerts et al. 2012) and mucus production (Sheridan et al. 2014). These active removal mechanisms can be energy intensive and can direct resources away from normal metabolic functions such as growth, reproduction, and immunity (Sheridan et al. 2014).

Mobilia et al. (2023) investigated the physiological response of *Goniocorella dumosa*, a deep-sea branching coral found within the Aotearoa New Zealand region, to pulses (i.e., repetitive, non-continuous exposure) of elevated suspended sediment concentrations, typical of fishing and mining activities, and their recovery ability in the short term and found progressive deterioration of coral condition over the experiment. They allowed a 5-day recovery period between elevated suspended sediment pulses and concluded that this species required a longer recovery time frame between exposure events and that sublethal effects of elevated suspended sediments could be long-lasting. The deep-sea (cold water) branching coral *Lophelia pertusa* has also been shown to tolerate long-term exposure to elevated suspended sediments (Larsson et al. 2013) though it was noted that coral larvae are less tolerant to disturbance from suspended sediments than mature specimens.

In contrast to the experimental work described above on deep-sea corals, species living in relatively shallow, mobile sandy substrates, such as *Sphenotrochus ralphae* and *Kionotrochus suteri,* could be expected to have some tolerance to, or adaptations to deal with, suspended or deposited sediments from natural disturbance such as bioturbation and/or storm events. Records of live *S. ralphae* in MBL samples collected from sites within approximately 20 m of known sand extraction tows, with one specimen at a site that had been extracted on three occasions between 28 May and 22 October 2022, also suggests that this species has some resilience to disturbance from sand extraction processes.

While no available literature was found on behaviour or on the response or tolerance thresholds of *Sphenotrochus ralphae* or *Kionotrochus suteri* to disturbance events, researchers in Japan have shown the adaptations and resilience of a similar species of coral (also a Turbinoliidae) to both burial by deposited sediments and physical damage. Sentoku et al. (2016) investigated the adaptation of *Deltocyathoides orientalis* to an infaunal mode of life using specimens collected between 94 and 115 m on soft bottom substrates. This depth range is deeper than MBL's proposed study area but within the depth range of both *Sphenotrochus ralphae* and *Kionotrochus suteri*. They concluded that *Deltocyathoides orientalis* is well adapted to an infaunal mode of life with the ability to burrow into sediments, to move vertically through sediments to escape burial, and to return to an upright position after being overturned. They showed that this movement occurs due to repeated expansion and contraction of peripheral soft tissues – a unique muscle-membrane system associated with deeply incised inter-costal spaces characteristic of turbinoliid corals. A specimen of *Deltocyathoides orientalis* can be seen moving vertically through approximately 1 cm of deposited sediments to escape burial in Figure 4-7, with tentacles appearing at the sediment surface from 250 minutes following burial.

The ability of *Deltocyathoides orientalis* to retract into the sediment is considered an anti-predator response, similar to that of the burrowing and tube-dwelling anemones (Sentoku et al. 2022).

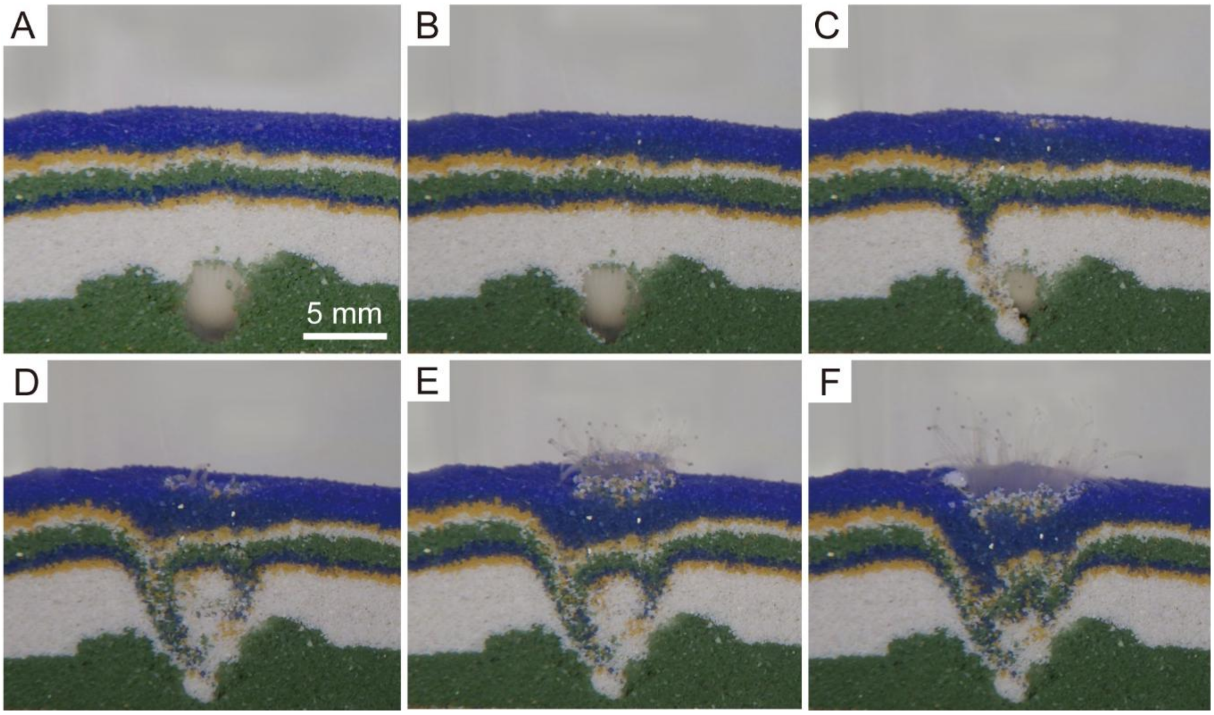


Figure 4-7: Figure S4 from Sentoku et al. (2016): A time-lapse series demonstrating a coral escaping from sediment burial. A) A *Deltocyathoides orientalis* cup coral buried under layers of differently coloured substrate (0 min); B) elapsed time 150 min; C) 200 min; D) 250 min; E) 300 min; F) 350 min. Layers of coloured sand demonstrate the method of movement. Coral tentacles can be seen breaking the sediment surface after 250 minutes.

Deltocyathoides orientalis can also regenerate both the skeleton and soft body parts following physical damage (Sentoku et al. 2017). This regeneration can be seen clearly in Figure 4-8, with the yellow section of each of the smaller images showing the extent of the original fragment before re-growth. The authors noted that even small fragments of individuals (retaining just 10% of the original corallum profile) regenerated and repaired, that a mouth surrounded by tentacles formed relatively quickly, and that after 188 days the fragmented individuals were able to burrow into soft bottom substrates.

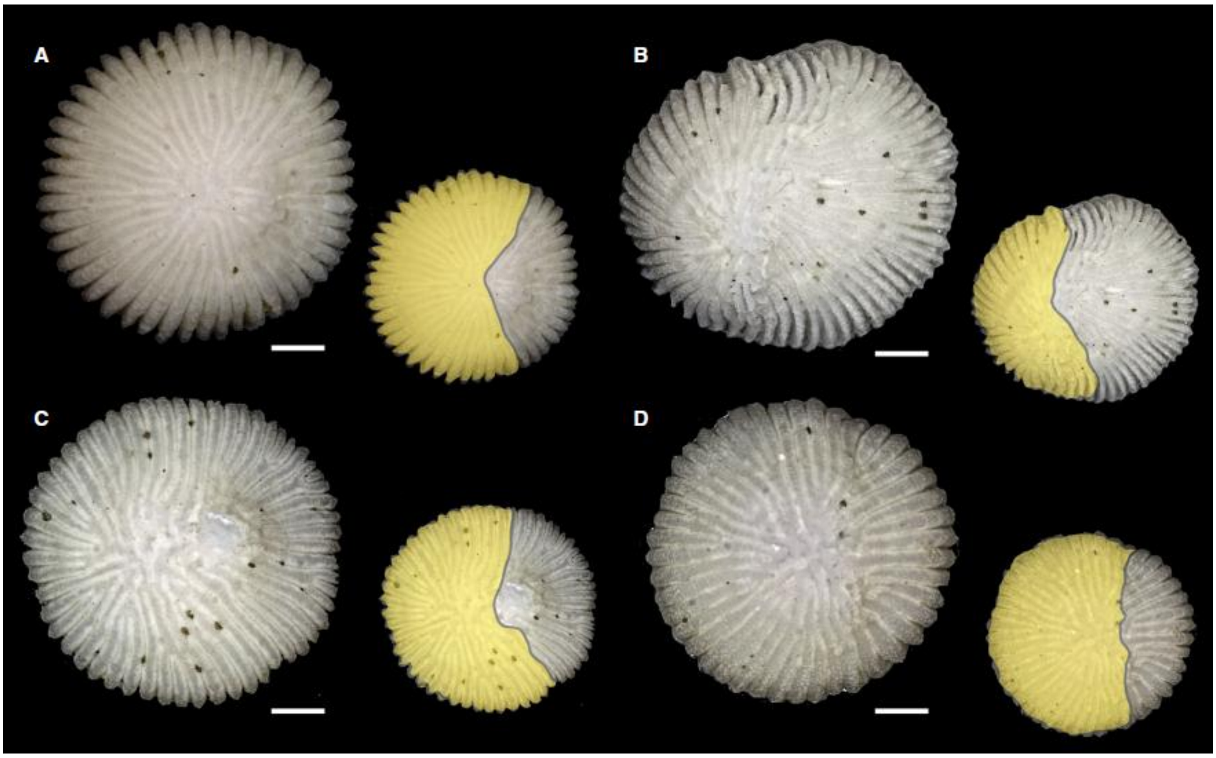


Figure 4-8: Figure 2 from Sentoku et al. (2017) showing regeneration of coral fragments. A-D, bottom views of *Deltocyathoides orientalis* regenerated from large obtuse-angled fragments (original fragments show in yellow to right). Scale bars = 1 mm.

The regeneration of skeletal material and/or soft tissue is not unique to *Deltocyathoides orientalis* but is also exhibited by members of the Fungiidae and Flabellidae families of solitary corals (e.g., Chadwick and Loya 1990; Buhl-Mortensen et al. 2007). Chadwick and Loya (1990) examined the regeneration of tissue and skeletal structures in *Fungia granulosa* (family Fungiidae), a common solitary coral in the Red Sea (sampled in water depths of 10 m). They estimated a recovery time of 4-10 months for small corals (30-60 mm in length) following a 10-40% skeletal loss, with large corals (61-90 mm) regenerating much more slowly (if at all). They noted that for *Fungia granulosa*, regeneration of fragments depended upon the presence of a mouth which did not appear to be the case with *Deltocyathoides orientalis* above.

The ability to regenerate following fragmentation is integral to the survival of individuals and of population recovery following disturbance events such as predation or seabed dredging (Sentoku et al. 2016). Given the similarities in morphology and habitat between *Sphenotrochus ralphae* and *Kionotrochus suteri* and the species described above, it is considered likely that *Sphenotrochus ralphae* and *Kionotrochus suteri* also have the ability for regeneration following fragmentation and for movement within sediments to escape burial.

Of note is a specimen of *Sphenotrochus ralphae* collected during MBL's survey work in Te Ākau Bream Bay from within the shipping anchorage area. The specimen has an irregular growth form as shown in Figure 4-9, alongside a regular shaped specimen for comparison. It is considered likely that the irregular growth is the result of physical damage and possibly shows recovery/regeneration. Both specimens shown in Figure 4-9 were alive on collection.

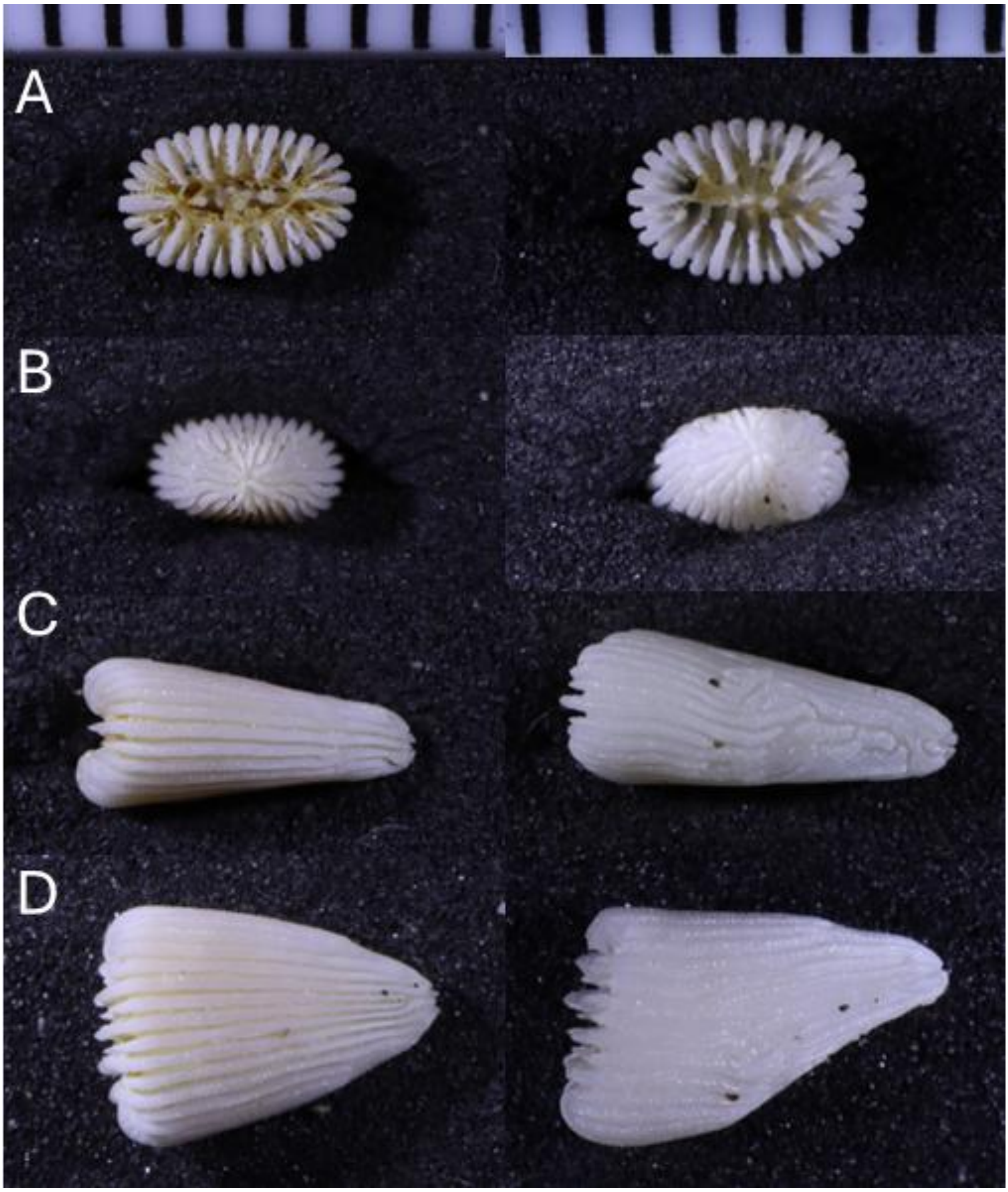


Figure 4-9: Two *Sphenotrochus ralphae* specimens collected during MBL survey work in Te Ākau Bream Bay. Left: regular growth form. Right: irregular growth form likely the result of physical damage and possibly recovery/regeneration. A: calicular view, B: base, C:thecal edge, D: thecal face. Both corals were alive on collection. The scale bar.is in mm.

4.4.3 MBL's proposed environmental monitoring

MBL will conduct environmental monitoring in both the proposed sand extraction areas and control areas of Te Ākau Bream Bay in order to identify benthic ecological or bathymetric changes arising from sand extraction. This monitoring is detailed in MBL's Environmental Monitoring Management Plan (EMMP). Monitoring will be conducted in years 2-7 (inclusive) then every 3rd year for the remainder of the consent duration.

Three aspects of the environmental monitoring have the potential for disturbance to cup corals through contact with the seafloor: drop camera, ponar grab, and benthic dredge tows.

Drop camera

A drop camera will be used to quantify benthic species and communities within the proposed sand extraction and control areas within Te Ākau Bream Bay. At each sampling period, at least three camera drops will be made within each of 77 extraction cells and five drops per cell in the 33 cells within the control area (a total of at least 396 deployments).

The frame of the drop camera rests on the seafloor during the camera survey. The camera frame is 1 m^2 with a large void in the centre to image the sediments (Figure 4-10). An area of approximately 0.05 m^2 makes contact with the seabed at each deployment, or approximately 19.8 m^2 in total for each sampling period. It is estimated that approximately two (2.2 ± 1.6) live *Kionotrochus suteri* and seven (7.3 ± 3.2) live *Sphenotrochus ralphae* could be present within the 19.8 m^2 of disturbed sediments (Table 42).

Any corals present within the area of sediment covered by the drop camera frame could be damaged and/or shunted deeper into the sediments. However, given the potential for cup corals from the Turbinoliidae family to move through sediments and regenerate broken structures, any corals disturbed by the camera frame would be expected to survive.

Figure 4-10: MBL's drop camera frame. Image credit: Shayne Elstob, MBL.

Table 4-2: Average densities of corals within Te Ākau Bream Bay and estimated population of corals for each monitoring gear type. Average density of corals was determined from pre-consent monitoring within Te Ākau Bream Bay. The area provided is the estimated contact area of the seabed for each gear type. The estimated abundance of corals does not allow for the expected patchiness in the distribution of the corals within Te Ākau Bream Bay but is the best estimate available.

			Estimated abundance of corals (inds./m^2 ± SE)		
Taxon	**Status**	**Average density (inds./m^2 ± SE)**	**Drop camera (19.8 m^2)**	**Grab sampling (28.1 m^2)**	**Epibenthic dredge (8,250 m^2)**
Kionotrochus suteri	Alive	0.11 ± 0.08	2.2 ± 1.6	3.1 ± 2.2	937.2 ± 681.6
Kionotrochus suteri	Dead	0.37 ± 0.23	7.3 ± 4.5	10.4 ± 6.5	3,152.4 ± 1,363.2
Sphenotrochus ralphae	Alive	0.37 ± 0.16	7.3 ± 3.2	10.4 ± 4.5	3,152.4 ± 1,959.6
Sphenotrochus ralphae	Dead	11.11 ± 2.52	220.0 ± 50.0	312.4 ± 70.9	94,657.2 ± 21,470.4

Grab sampling

A modified standard ponar grab sampler (Figure 4-11), or similar quantitative technique, with a sample area of at least 250 x 285 mm (0.071 m^2) and a bite depth of approximately 100 mm, will be used to sample sediments for the analyses of sediment texture and macrofauna. At each sampling period, at least three grab samples will be collected from each of 77 extraction cells within the sand extraction area together with at least five grab samples from each of 33 cells within the control areas. Assuming a total of 396 deployments (which is the minimum number of deployments that will be made), an area of at least 28.1 m^2 will be disturbed/collected from across Te Ākau Bream Bay.

Figure 4-11: Modified standard ponar grab. Left: collecting a sediment sample on the seabed. Right: Sediment sample being emptied into a bucket. Image credit Simon West, Bioresearches.

Upon arriving at the surface, collected sediment samples are deposited into a clean fish bin. The sample is then homogenised by mixing and two 100 ml subsamples taken for analysis of sediment properties. Remaining sediments will be puddle washed through both 3 mm and 1 mm sieves using seawater. Sediments retained on the 3 mm sieve will be visually assessed for the presence of protected species such as cup corals. If live cup corals are detected, these will be photographed, enumerated and returned to the seafloor. All remaining sediments on the 3 mm and 1 mm sieves are preserved in 70 % ethanol and transported to the laboratory for detailed macrofaunal analyses. It is anticipated that most corals present within sediments collected through grab sampling will be returned to the lab and therefore suffer mortality.

Using the average density of corals observed within pre-consent monitoring within Te Ākau Bream Bay, it is estimated that approximately three (3.1 ± 2.2) live *Kionotrochus suteri* and 10 (10.4 ± 6.5) live *Sphenotrochus ralphae* could be present within 28.1 m^2 of sediments, the minimum area of sediments likely to be disturbed by grab sampling within each sampling period (Table 4-2).

Epibenthic dredge

At each sampling period, a single dredge tow will be conducted spread across every two cells (adjoining along the seaward side) of the proposed extraction area and three control areas, resulting in 55 tows in the sand extraction area and 16 in the control areas combined. The dredge (Figure 4-12) is 600 mm wide and will be towed at low speed (~<1kt) for approximately 200 m (approximately 120 m^2 per tow, or 6,600 m^2 in the sand extraction area and 1,920 m^2 in the control areas).

The dredge net has a 35 mm mesh. All material retained within the dredge is sorted onboard, identified and returned to the seabed, with exposure to air being minimised where possible.

Figure 4-12: Epibenthic dredge being deployed. Image credit: Simon West, Bioresearches.

Approximately 937 (937.2 ± 681.6) live *Kionotrochus suteri* and 3,152 (3,152.4 ± 1,363.2) live *Sphenotrochus ralphae* could be present within the 8,520 m^2 of seabed disturbed by the epibenthic dredge tows (Table 4-2).

The dredge is fitted with a 35 mm mesh bag which should allow free living cup corals that enter the dredge to return to the seabed.

Kionotrochus suteri is known to have both free-living (anthocyathus) and attached (anthocaulus) forms, with anthocauli often attached to shells/shell fragments (see section 4.2). *Sphenotrochus ralphae* is not known to have an anthocaulus stage, however, there is a record of a *Sphenotrochus ralphae* attached to blades of kelp (see section 4.2 above) which suggests this species may also have an anthocaulus form.

Free-living (anthocyathus) forms of cup corals are expected to pass through the 35 mm mesh of the dredge net. However, it is likely that any anthocauli attached to shells greater than 35 mm in size within the dredged area would be retained within the dredge net.

Corals disturbed by the dredge and remaining on the seabed may suffer some physical damage as a result of the dredge passing over them. Corals retained in the dredge net and returned to the seafloor may also suffer some physical damage. There is also the possibility of increased predation by fish and mobile invertebrates attracted to disturbed sediments. Corals damaged and/or fragmented to the extent that they cannot move through sediments may suffer mortality if buried. However, given the potential for cup corals within the Turbinoliidae family to move through sediments and regenerate structures it is expected that at least some corals will survive the disturbance.

4.4.4 Assessment of cumulative impacts

In addition to the proposed sand extraction operation at Te Ākau Bream Bay, it is important to consider other treats/disturbance events to the benthic communities within proposed sand extraction area. MacDiarmid et al. (2012) used expert knowledge to conduct an assessment of the relative and combined impact of 65 potential threats on marine habitats within New Zealand's TS and EEZ. They found shallow coastal habitats could be impacted by up to 52 non-trivial threats deriving from human activities and concluded that ocean acidification and rising sea temperatures were the two highest threats to NZ's marine habitats as a whole.

Two known sources of existing or previous physical disturbance to benthic communities within the proposed sand extraction area are storm events and fishing.

The increased wave and current energy during storm events can physically disturb seabed fauna through the movement and/or resuspension of sand particles and the formation of sand waves. The resulting turbidity and movement of sediments can alter the structure of faunal communities (e.g., Lundquist et al. 2013) with some functional groups responding negatively to disturbance (e.g., emergent epifauna, which would include cup corals) and others (e.g., opportunistic taxa) responding positively to disturbance. A study in the eastern Bering Sea even showed that storms can have an overall greater effect on the benthos than bottom trawling (McConnaughey and Syrjala 2014).

Commercial and non-commercial fishing is widespread throughout the coastal waters of Te Ākau Bream Bay (Boyd 2025) and include bottom trawling, scallop dredging, longlines, set nets and recreational fishing. Of these, bottom trawling and scallop dredging have the greatest bottom contact and are thus likely to have the greatest impact on cup corals.

Bottom trawling has been shown to cause significant reduction in species diversity, spatial heterogeneity, and populations (e.g., Thrush et al. 1995; Jennings and Kaiser 1998). The effect of bottom trawling has been shown to increase with longevity with a 2-3 x larger effect on biota living greater than 10 years than on biota living 1-3 years (Hiddink et al. 2019; Bradshaw et al. 2024).

While it is not possible to quantify the cumulative effects of multiple stressors on cup corals within the proposed sand extraction area at Te Ākau Bream Bay, it is worth noting that previously disturbed areas are considered relatively insensitive to additional disturbances as compared with more pristine areas, where sizable effects are likely (e.g., Thrush et al. 1995; McConnaughey and Syrjala 2014 and references therein).

5 Summary

5.1 Distribution

The distribution of both *Sphenotrochus ralphae* and *Kionotrochus suteri* appear to be relatively widespread both within the wider Te Ākau Bream Bay and Pākiri regions and across northern Aotearoa New Zealand. This has been determined from both spatial plots of species location records and from assessing potential suitable habitat using available environmental data layers within the Territorial Sea. There is no evidence to suggest that the proposed sand extraction area at Te Ākau Bream Bay is unique with respect to the habitat of these corals, though it is at the upper depth range for *Kionotrochus suteri*. Note that while the area of most suitable habitat has been estimated for the Territorial Sea, the wider distribution in New Zealand's EEZ remains unknown. The population densities of corals outside of the Te Ākau Bream Bay and Pākiri survey sites remains unknown. However, the proposed extraction area has a small footprint (less than 0.2% for *Sphenotrochus ralphae*, and approximately 0.05% for *Kionotrochus suteri*) compared to the identified potential suitable habitat for both species.

5.2 Reproduction

Kionotrochus suteri is known to reproduce through transverse division. Some forms of this coral live attached to hard substrates and reproduce asexually to produce free-living forms that inhabit soft sediments. The free-living forms produce planula larvae through sexual reproduction, which settle onto hard substrates. As such this species requires habitat that includes both mobile sediments and the availability of hard substrates such as shells. This species may also reproduce by intratentacular budding.

Less is known about the reproduction of *Sphenotrochus ralphae* though there is some evidence of asexual budding in this species and attachment to substrates such as kelp blades.

Reproduction by transverse division does not enable dispersal beyond the immediate area and the dispersal of planula larvae or potential fecundity/timing of reproduction for both species remain unknown. However, records show that these species are relatively widespread across the Te Ākau Bream Bay and Pākiri regions, and northern New Zealand in general, and so there is the potential for recovery from source populations following relatively small-scale disturbances.

5.3 Growth rates

While the growth rates and longevity of *Sphenotrochus ralphae* or *Kionotrochus suteri* are unknown, they may be similar to the reported ranges of other similar shallow-water species. There is a general consensus that the growth of small cup corals decreases with a function of coral length (growth slows as the coral grows). Reported longevities of similar species were in the range of approximately 7-12 years. Reported growth rates typically ranged from 0.3-3.1 mm per year. While growth rates were similar to reported rates within deep-sea solitary coral species, estimates of longevity suggest that deep sea solitary corals may have longer lifespans than shallow water species.

5.4 Resilience of corals to disturbance

While there is little available information on the behaviour or life histories of *Sphenotrochus ralphae* or *Kionotrochus suteri*, evidence in the literature suggests that members of the Turbinoliidae family of cup corals are well adapted to infaunal life and the challenges faced with living in mobile sediments. For example, corals can move vertically through sediments to escape burial (at least up to 1 cm), can burrow into sediments (perhaps as a predator avoidance strategy) and can return to an upright position after being overturned. In addition, many species of solitary cup coral, including those within the Turbinoliidae family, can regenerate both soft and skeletal tissues following fragmentation. This is true even of relatively small fragments (approximately 10% of original coral).

MBL's sand extraction process has the potential to cause mortality and/or damage to benthic faunal species as they pass through the draghead and screening deck. However, previous survivorship studies showed that many benthic faunal species, particularly those smaller than approximately 20 mm, did survive this process at MBL's extraction site in the Mangawhai-Pākiri embayment, at least as far as being returned to the seafloor. Cup corals were not included in survivability studies. However, the presence of live *Sphenotrochus* corals within the sand extraction area at MBL's Pākiri site suggests that cup corals may have some ability to survive the proposed disturbance at Te Ākau Bream Bay. This is perhaps not surprising given the ability of corals to move within sediments and regenerate tissues if damaged.

It should be noted, however, that fragmented parts of corals would be unlikely to have the ability to escape sediment burial and may also be prone to predation on the seabed (e.g., Thrush et al. 1995). As such, some mortality of fragments would be expected but the extent of such mortality is unknown. Sentoku et al. (2017) noted that fragmented corals were able to burrow into sediments 188 days (a little over 6 months) following fragmentation. Survival of coral fragments following sand extraction would, therefore, be increased by returning damaged corals and/or fragments to an area that will remain undisturbed by active sand extraction for at least 7 months. It is, however, considered likely that repeated disturbance could reduce the resilience or survivability of cup corals following damage or fragmentation.

MBL anticipate an extraction reoccurrence rate of up to 1 year within each of the 77 sand extraction cells within the pSEA at Te Ākau Bream Bay (McCallum Bros Limited 2025). Therefore, extraction cells are expected to remain undisturbed for at least seven months after an extraction event.

5.5 Impact of MBL's proposed activities on cup corals

There will necessarily be some disturbance to, and possibly mortality of, both *Sphenotrochus ralphae* and *Kionotrochus suteri* resulting from proposed sand extraction and environmental monitoring within the Te Ākau Bream Bay area. However, from the available information presented above, the impact of the proposed Te Ākau Bream Bay sand extraction and monitoring on the population of these corals within Aotearoa NZ is considered likely to be minor to negligible**.**

This assessment was made using the table provided in Appendix B, adapted from Fletcher (2005). While the proportion of affected habitat would fall within the "negligible" consequence level, our assessment is that the impact is likely to be minor to negligible. This is due to the lack of population data for cup corals outside of the proposed extraction area together with assumptions made about the resilience of these cup coral species using published research on similar overseas corals within the same family (Turbinoliidae).

6 Acknowledgements

We thank Simon West (Bioresearches) for providing information on cup coral specimens collected during MBL surveys, Sam Davidson (NIWA) for GIS advice, and David Thompson (NIWA) for the internal review of this report.

7 Glossary of abbreviations and terms

Anthocaulus	The attached form of the coral which reproduces asexually. A stalk-like basal portion of a zooid in some solitary corals, from which the oral portion is pinched of to form a new zooid (anthocyathus).
Anthocyathus	The free-living form of the coral which reproduces sexually. The oral disk that is pinched off from the basal portion (anthocaulus) in some solitary corals. This enlarges to become a new zooid.
CD	Calicular diameter of corallum. This is the mean of the GCD and the Lesser Calicular diameter.
Corallum	The skeletal "cup" of the cup coral
Cup corals	Cup corals are a form of non-reef building (solitary) stony corals (Order Scleractinia). They can occur as solitary individuals or they can clump. Some cup coral species live attached to hard substrates, other species live in or on mobile or soft sediments. (See Tracey and Hjorvarsdottir 2019).
EEZ	Exclusive Economic Zone
Endemic	Only found in Aotearoa New Zealand
GCD	Greater calicular diameter of corallum
MBL	McCallum Brothers Limited
NIC	NIWA Invertebrate Collection
NIWA	National Institute of Water and Atmospheric Research
OBIS	Ocean Biogeographic Information System
Stony corals	All corals within the taxonomic order Scleractinia. Stony corals are marine animals in the phylum Cnidaria that have a hard skeleton made from calcium carbonate. Stony corals can be either solitary (e.g., cup corals) or colonial (e.g., branching habitat-forming corals). All stony corals are protected under the Wildlife Act 1953.

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Appendix A Environmental data layers

Description of spatial environmental predictor variables (*n*=20) collated for species distribution models. Table copied from Stephenson et al. (2023) (table modified from Stephenson et al. (2022)). See Stephenson et al (2022) for references cited here.

Abbreviation	Full name	Description	Source
Bathy	Bathymetry	Depth at the seafloor was interpolated from contours generated from various sources, including multi-beam and single-beam echo sounders, satellite gravimetric inversion, and others (Mitchell et al., 2012).	Mitchell et al. (2012)
Beddist	Benthic sediment disturbance	One-year mean value of friction velocity derived from (1) hourly estimates of surface wave statistics (significant wave height, peak wave period) from outputs of the NZWAVE_NZLAM wave forecast, at 8-km resolution, (2) median grain size (d50), at 250 m resolution, (3) water depth, at 25-m resolution. Benthic sediment disturbance from wave action was assumed to be zero where depth ≥ 200 m.	Swart (1974); updated in 2019
BotNi	Bottom nitrate	Annual average water nitrate concentration at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from Dunn et al. (2002). The oceanographic data used to generate these climatological maps were computed by objective analysis of all scientifically quality-controlled historical data from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atlas of Regional Seas database (CARS2009, 2009).	NIWA, unpublished
BotOxy	Dissolved oxygen at depth	Annual average water oxygen concentration at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from Dunn et al. (2002). Oceanographic data from CARS2009 (2009).	NIWA, unpublished
BotPhos	Bottom phosphate	Annual average water phosphate concentration at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from Dunn et al. (2002). Oceanographic data from CARS2009 (2009).	NIWA, unpublished
BotSal	Salinity at depth	Annual average water salinity concentration at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from Dunn et al. (2002). Oceanographic data from CARS2009 (2009).	NIWA, unpublished
BotSil	Bottom silicate	Annual average water silicate concentration at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from Dunn et al. (2002). Oceanographic data from CARS2009 (2009).	NIWA, unpublished
BotTemp	Temperature at depth	Annual average water temperature at the seafloor (using Aotearoa New Zealand bathymetry layer) based on methods from (Ridgway et al., 2002). Oceanographic data from (Cars2009, 2009).	NIWA, unpublished

Abbreviation	Full name	Description	Source
BPI_broad	BPI_broad	Terrain metrics were calculated using an inner annulus of 12 km and a radius of 62 km using the NIWA bathymetry layer in the Benthic Terrain Modeler in ArcGIS 10.3.1.1 (Wright et al., 2012). Bathymetric Position Index (BPI) is a measure of where a referenced location is relative to the locations surrounding it.	NIWA, unpublished
BPI_fine	BPI_fine	Terrain metrics were calculated using an inner annulus of 2 km and a radius of 12 km using the NIWA bathymetry layer in the Benthic Terrain Modeler in ArcGIS 10.3.1.1 (Wright et al. 2012). Bathymetric Position Index (BPI) is a measure of where a referenced location is relative to the locations surrounding it.	NIWA, unpublished
Chl a	Chlorophyll-a concentration	A proxy for the biomass of phytoplankton present in the surface ocean (to ~30 m). Blended from a coastal Chl-a estimate (quasi-analytic algorithm (QAA), local aph*(555)) and the default open-ocean chl-a value from MODIS-Aqua (v2018.0).	NIWA unpublished; Based on processing described in Pinkerton et al. (2018) and updated in Pinkerton et al. (2020).
Chl-a.Grad	Chlorophyll-a concentration spatial gradient	Smoothed magnitude of the spatial gradient of annual mean chlorophyl-*a* concentration. Derived from Chl-a described above.	NIWA unpublished, updated in 2020; Based on processing described in (Pinkerton et al., 2018)
Detrital absorption	Total detrital absorption coefficient at 443 nm, including due to coloured dissolved organic matter (CDOM) and particulate detrital absorption. Estimated using quasi-analytic algorithm (QAA) applied to MODIS-Aqua data, blended with *adg_443_giop* ocean product (Werdell, 2019).	NIWA unpublished, updated in 2020; Based on processing described in (Pinkerton et al., 2018). Processing for *adg_443_giop* ocean product described in (Werdell, 2019).	Detrital absorption
Seabed incident irradiance	Broadband (400–700 nm) incident irradiance (E m-2 d-1) at the seabed, averaged over a whole year. Estimated by combining incident irradiance at the sea surface ((Frouin et al., 2012); this table), diffuse downwelling irradiance attenuation (KPAR; this table) and bathymetric depth at monthly resolution. Derived from blended coastal (QAA) and open-ocean attenuation products.	NIWA unpublished, updated in 2020, based on processing described in Pinkerton et al. (2018)	Seabed incident irradiance
POCFlux	Downward vertical flux of particulate organic matter at the seabed	Net primary production in the surface mixed layer estimated as the VGPM model ((Behrenfeld and Falkowski, 1997); this table). Export fraction and flux attenuation factor with depth estimated by refitting sediment trap and thorium-based measurements to environmental data (VGPM, SST) as Lutz et al. (2002), Pinkerton et al. (2016) and using data from Cael et al. (2017).	NIWA unpublished, updated in 2020. Based on processing described in Pinkerton et al. (2016) with new data from Cael et al. (2018).

Abbreviation	Full name	Description	Source
PB555nm	Particulate backscatter at 555 nm (previously used to generate 'turbidity')	Optical particulate backscatter at 555 nm estimated using blended coastal and ocean products. Coastal: QAA v5 product bbp555 from MODIS-Aqua data. Ocean: *bbp_555_giop* ocean product (Werdell, 2019). Result calculated as long-term (2002–2017) average.	NIWA unpublished, updated in 2020; Based on processing described in Pinkerton et al. (2018). Processing for *bbp_555_giop* ocean product described in Werdell (2019).
Annual amplitude of sea floor temperature	Smoothed difference in seafloor temperature between the three warmest and coldest months. Providing a measure of temperature amplitude through the year.	NIWA, unpublished data, updated in 2018	Annual amplitude of sea floor temperature
Sed.class	Sediment classification	Classification of Mud, Sand and Gravel layers (this table) using the well-established (Folk et al., 1970) classification. Subtidal rocky reefs (this table) were incorporated. This classification provides a broad measure of hardness Mud – Rock.	NIWA unpublished, updated in 2020
Slope	Slope	Bathymetric slope was calculated from water depth and is the degree change from one depth value to the next.	NIWA, unpublished, updated in 2019
SSTGrad	Sea surface temperature gradient	Smoothed magnitude of the spatial gradient of annual mean SST. This indicates locations in which frontal mixing of different water bodies is occurring (Leathwick et al., 2006). Derived from SST described above at two resolutions and merged.	NIWA unpublished, updated in 2020
TC	Tidal Current speed	Maximum depth-averaged (NZ bathymetry) flows from tidal currents calculated from a tidal model for New Zealand waters (Walters et al., 2001). Tidal constituents (magnitude A and phase phi, represented as real and imaginary parts X + iY = A*exp(i*phi)) for sea surface height and currents (8 components) were taken from the EEZ tidal model, on an unstructured mesh at variable spatial resolution. The complex components were bilinearly interpolated to the output grid.	Walters et al., 2001; NIWA unpublished, updated in 2020

Appendix B Consequence levels for the intensity of the activity

Table B-1: Consequence levels for the intensity of the activity. Summary descriptions of the six sets of consequence levels for the proportion of the habitat affected, the impact on the population, community or habitat, and the likely recovery period. Adapted from Fletcher (2005).

Consequence level	Proportion of habitat affected	Population/community/habitat impact	Recovery Period
1 - Negligible	Affecting <1% of area of original habitat area	Interactions may be occurring but unlikely to be ecologically significant (<1% changes in abundance, biomass, or composition) or be detectable at the scale of the population, habitat or community	No recovery time required
2 - Minor	Measurable but localized; affects 1-5% of total habitat area	Possibly detectable with 1-5% change in population size or community composition and no detectable impact on dynamics of specific populations	Rapid recovery would occur if activity stopped – less than 8 weeks
3 - Moderate	Impacts more common; 6-20% of habitat area is affected	Measurable with 6-20% changes to the population, habitat or community components without there being a major change in function	Recovery in >2 months to 1-2 years if activity stopped
4 - Major	Impacts very widespread; 21-50% of habitat is affected/removed	Populations, habitats or communities substantially altered (21-50%) and some function or components are missing/declining/increasing well outside historical ranges. Some new species appear in the affected environment	Recovery occurs in 2-10 years if activity stopped
5 - Severe	Impact extensive; 51-90% affected	Likely to cause local extinctions of vulnerable species if impact continues, with a 51-90% change to habitat and community structure and function. Different population dynamics now occur with different species or groups now affected	Recovery period 1-2 decades if activity stopped
6 - Catastrophic	Entire habitat in region is in danger of being affected; >90% affected/removed	Local extinctions of a variety of species are imminent/immediate. Total collapse of habitat, community or ecosystem processes. The abundance, biomass or diversity of most groups is drastically reduced (by 90% or greater) and most original ecological functional groups (primary producers, grazers etc.) have disappeared	Long term recovery to former levels will be greater than 1-2 decades or never, even if activity stopped