

The scleractinian coral *Culicia rubeola* at Te Ākau Bream Bay

Literature review and distribution of *Culicia rubeola* identified within the proposed sand extraction area

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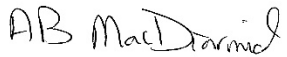
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Earth Sciences NZ Conflict of Interest: Earth Sciences NZ, and other associated parties, have extensive and many tens of millions of dollars investment in major aquaculture facilities all relying on continuous access to 4 M³ per sec of high quality 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, Earth Sciences NZ may oppose the extraction.

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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 until August 2025 when the consent was surrendered.

Benthic environmental surveys conducted by MBL at Te Ākau Bream Bay identified two species of scleractinian solitary cup coral (*Sphenotrochus* sp. and *Kionotrochus suteri*). These are both small (cup diameter < 10 mm) non-branching corals that live in mobile sediments such as sand, and are of importance to the sand extraction operation as all Scleractinia are protected under the Wildlife Act 1953. A summary of knowledge was prepared for these cup corals as part of MBL's substantive application under the Fast Track Approvals Act 2024. Following the lodgement of this application, a third species of scleractinian coral was confirmed from both Te Ākau Bream Bay and Pākiri, from samples previously mis-identified as *Kionotrochus suteri*. This additional species (*Culicia rubeola*) is similarly small but differs from the two other corals in that it is colonial rather than solitary and is placed within a different family. All recorded specimens of *Culicia rubeola* from both Te Ākau Bream Bay and Pākiri have been dead on collection.

The aim of this report is to summarise existing knowledge of the scleractinian coral *Culicia rubeola* 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 this coral.

There is little known about the ecology and reproduction strategies of *Culicia rubeola*, although some information is available for a closely related species where polyp sexes are separate and that it is a broadcast spawner with an annual reproductive cycle and spawning occurring in summer. Reproductive strategies are not always consistent within coral families, but this may give an indication of the most likely strategy for *Culicia rubeola*. There is also little information on the resilience of this species to physical disturbance though there is evidence in the literature that many corals, including some with similar life histories to *Culicia rubeola*, have the potential to regenerate both soft and skeletal tissues following damage and/or fragmentation.

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 *Culicia rubeola*. In addition, the proposed extraction area has a small footprint (< 0.04%) compared with that of the estimated suitable habitat for the species.

Should there be live specimens of *Culicia rubeola* within the proposed sand extraction area at Te Ākau Bream Bay then some mortality could be expected. However, considering all ecological and distributional factors, the impact of the proposed Te Ākau Bream Bay sand extraction on the population of this coral 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 and activities that affect such corals require application to Department of Conservation (DOC) for a Wildlife permit. With a permit therefore necessary for *Sphenotrochus ralphae* and *Kionotrochus suteri*, a report was commissioned to summarise existing knowledge of these cup corals within the proposed Te Ākau Bream Bay extraction area and elsewhere in Aotearoa New Zealand, and to make an assessment of the potential impact the proposed extraction may have on the populations of these corals (Beaumont et al. 2025).

On 8 May 2026, following the completion of this report and submission of MBL's substantive application under the Fast Track Approvals Act, a third species of scleractinian coral was confirmed from within both the previously extracted Pākiri site and the proposed Te Ākau Bream Bay sand extraction area. These samples had been previously mis-identified as *Kionotrochus suteri*. This additional species (*Culicia rubeola*) differs from the two other corals in that it is classified within a different family and is a colonial form rather than a solitary cup coral; 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 *Culicia rubeola*, found within the proposed Te Ākau Bream Bay extraction area and elsewhere in Aotearoa New Zealand, to complement the reports provided for the two cup corals in Beaumont et al. (2025) and inform an additional or revised application for a Wildlife Act authorisation. An assessment is also made, based on available information, of the potential impact the proposed extraction may have on the populations of this coral species.

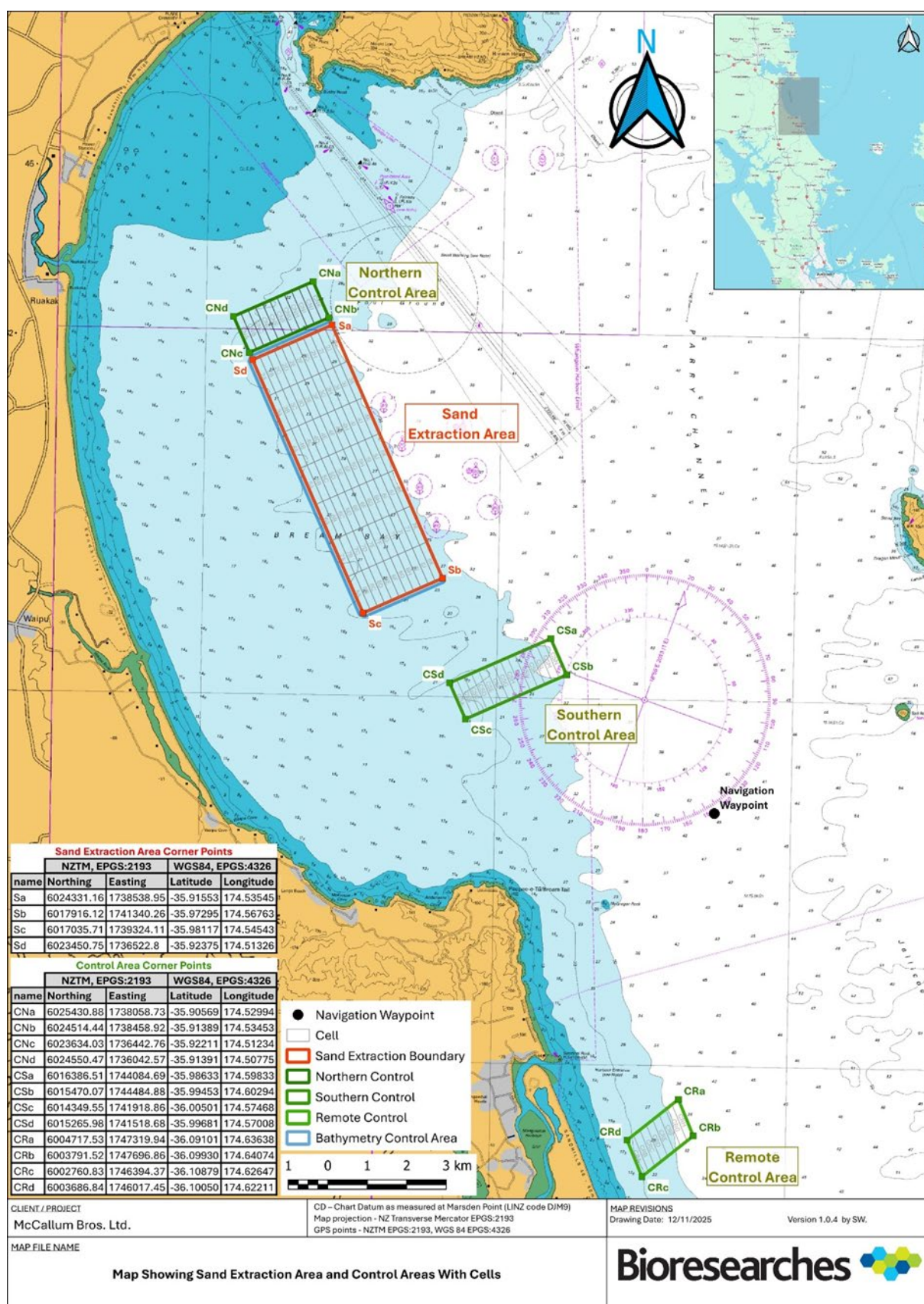


Figure 1-1: Map showing the location of the proposed sand extraction area within Te Ākau Bream Bay. Three proposed control areas are also shown, together with an inset box placing Te Ākau Bream Bay within a wider, regional context.

2 Methods

2.1 Taxonomy

Following reporting of the *Sphenotrochus* and *Kionotrochus* cup coral findings by Bioresarches to DOC, all samples of these species collected by MBL during monitoring studies were prepared for transfer to the Earth Sciences NZ invertebrate collection for long-term storage. During this process it was noticed that the samples contained a third species, all dead at the time of sampling. These were tentatively identified as *Culicia rubeola* by Bioresarches, with this identification later confirmed on the 8 May 2026 by Earth Science NZ experts in consultation with an overseas coral taxonomist (Dr Marcelo Kitahara (University of Sao Paulo, Brazil).

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 m²).

Previous surveys within MBL survey areas were sampled using a smaller PONAR grab (229 x 280 mm, 0.064 m²). 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 *Culicia rubeola* within the proposed extraction area in Te Ākau Bream Bay, the specimen databases described in Table 2-1 were interrogated for species location records of this coral species from within Aotearoa Territorial Sea (TS) and New Zealand's Exclusive Economic Zone (EEZ), as well as any records from the wider Pacific region. Many of the occurrence records held in the OBIS database were either sourced from Earth Sciences NZ, Auckland Museum, present also in iNaturalist observations, or their positions were duplicated in OBIS. For this assessment, all duplicated records were removed so that only one record per location was retained for describing their distribution and habitat.

2.3 Estimated 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-three 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). Values of these variables at each location record were determined and from these the range of each variable (minimum and maximum) was calculated as an estimate of the species tolerance. Note that, due to limited observations of *Culicia rubeola*, the tolerance ranges for some of these variables may be conservative.

Bean plots were then produced to illustrate the distribution of *Culicia rubeola* across the range of each variable, shown separately for Te Ākau Bream Bay/ Pākiri sites (combined for this analysis as there were too few records from Bream Bay alone) and all other sites combined to identify any unique characteristics of the Te Ākau Bream Bay/ Pākiri habitat.

Each spatial environmental layer was masked to exclude areas outside of the observed range of values for *Culicia rubeola*. These masked environmental layers were then combined into a single layer to identify the most suitable habitat based on available environmental data for sample locations. This was done by simple addition of all 33 layers after setting the value in each remaining cell to 1. In this way cells with the highest number (33) represent the most suitable habitat and those with the lowest (0) represent the least suitable habitat. The estimated area of the most suitable habitat for *Culicia rubeola* (where all 33 environmental variables were in range) was calculated using geoprocessing tools in ArcGIS Pro 3.4.2. Note that environmental variable data layers were only available from within the 12 nautical mile 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 may result 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 of *Culicia rubeola* within Aotearoa New Zealand's Territorial Sea, based on its tolerance to this set of environmental parameters given the available sample location data.

2.4 Literature review

A literature review was conducted on available information on the life histories and anticipated impacts of the disturbance on *Culicia rubeola*. Where possible, qualifying statements as to the anticipated impact of MBL's proposed activities on this protected coral species has been included.

Table 2-1: Data sources interrogated for *Culicia rubeola* records. Note that most museum collection specimens would have been live on collection.

Source	Details
Earth Sciences NZ National Invertebrate Collection (NIC)	This specimen collection (NIC) is located at the Earth Sciences New Zealand Greta Point campus in Wellington and is Earth Sciences NZ'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 sample lots that have been collected over half a century of biological research (Schnabel et al. 2014). Collection records for <i>Culicia rubeola</i> were extracted on 18 May 2026 from the NIC specimen database niwainvert. Note that these records include all specimens of <i>Culicia rubeola</i> provided to Earth Sciences NZ by MBL.
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 <i>Culicia rubeola</i> , provided by Te Papa on 19 May 2026.
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. Some of the earliest specimens date from James Cook's voyages. Records of <i>Culicia rubeola</i> were extracted from the Auckland Museum online database on 18 May 2026.
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 <i>Culicia rubeola</i> within Aotearoa New Zealand and wider southwest Pacific were extracted on 18 May 2026 from their online portal (https://obis.org/).
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 "Research Grade" records (those confirmed by other users) of <i>Culicia rubeola</i> on 18 May 2026 using their online search tool at www.inaturalist.org .

3 Results

3.1 Available data on the distribution and habitat associations of *Culicia rubeola* are presented in this section. MBL survey data

Records of *Culicia rubeola* were only present in the 2024 data onwards (Table 3-1, Figure 3-1, Figure 3-2), perhaps because dead corals (of any species) were not quantified in previous surveys. All specimens recorded of *Culicia rubeola* were dead on collection. The specimens recorded in 2024 had been previously mis-identified and were treated as *Kionotrochus suteri* in Beaumont et al. (2025).

Table 3-1: *Culicia rubeola* specimens recorded in MBL data. Data from 2024 and 2025 surveys only. The five specimens recorded in 2024 had previously been mis-identified as *Kionotrochus suteri*. pSEA = proposed Sand Extraction Area, RCA = Remote Control Area (Figure 3 1). No sampling occurred at Te Akau Bream Bay in 2025.

Survey	Year	Area	Dead <i>C. rubeola</i> specimens
Pākiri	2024	All	2
Pākiri	2025	All	20
Te Ākau Bream Bay	2024	pSEA	2

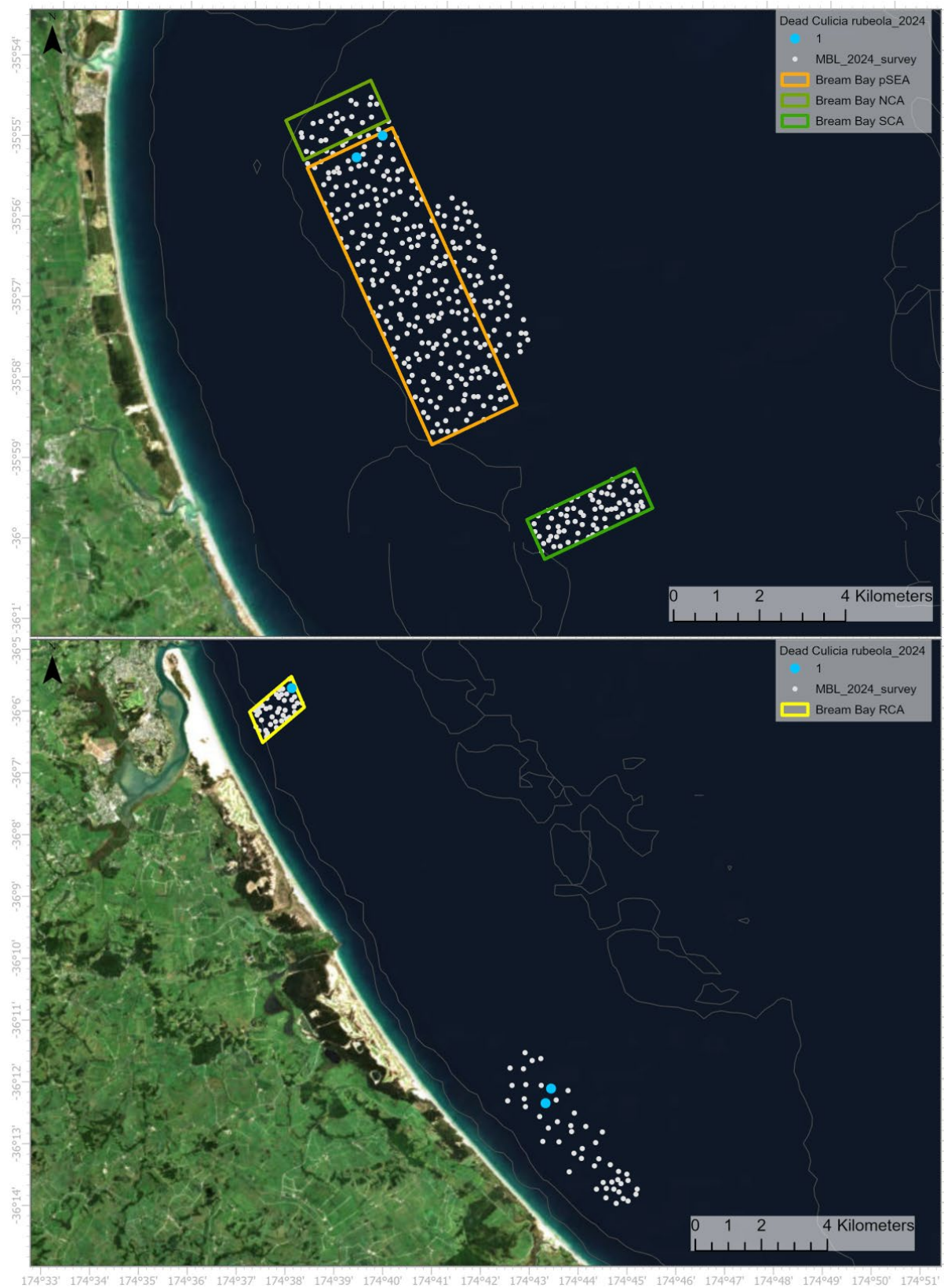


Figure 3-1: Dead *Culicia rubeola* specimens recorded within MBL's 2024 survey data. These records were originally mis-identified as *Kionotrochus suteri*. This plot is of the 2024 sample data only - dead corals were not quantified in previous surveys.

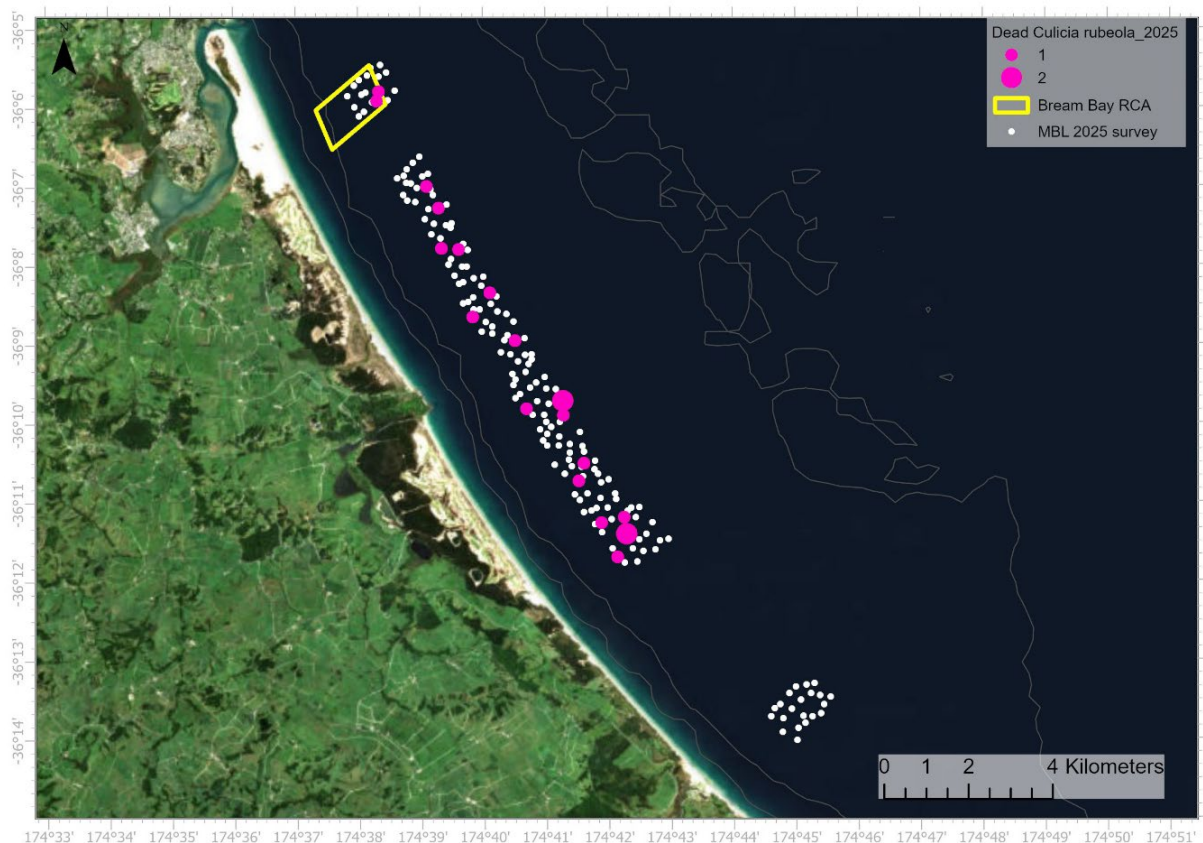


Figure 3-2: Dead *Culicia rubeola* specimens recorded within MBL’s 2025 survey data. The 2025 survey data were not available for inclusion in the Beaumont et al. (2025) report on cup corals and so these are new data. No sampling occurred at Te Ākau Bream Bay in 2025.

3.1.1 Te Ākau Bream Bay proposed Sand Extraction Area (pSEA)

Two specimens of *Culicia rubeola* were recorded from within the pSEA at Te Ākau Bream Bay. They were all deemed dead on collection.

The PONAR grab used in the 2024 Te Ākau Bream Bay survey sampled an area of 250 x 285 mm (or 0.07 m²) of seabed. Specimens recorded per grab ranged from zero to 1 colony (up to 4 polyps per specimen). The average density of *Culicia rubeola* within the proposed sand extraction area, standardised to individuals per m², is estimated to be 0.11 ± 0.08 inds./m².

3.2 Wider distribution of *Culicia rubeola* within Aotearoa New Zealand

Culicia rubeola is known to occur both within Aotearoa New Zealand and in the central and south-west and eastern Pacific including India and Hong Kong (see section 4). This section focuses on the distribution of *Culicia rubeola* within Aotearoa New Zealand.

All specimens of *Culicia rubeola* collected by MBL at Te Ākau Bream Bay and Pākiri comprised dead skeletal material. The life status of specimens from all other sources is uncertain but most of these are expected to have been alive at the time of capture/observation.

The largest contributor of occurrence records was iNaturalist, providing almost half of the 192 records (Table 3-2).

Table 3-2: Summary of available occurrence records of *Culicia rubeola* by source. Excludes duplicate records. Note that the number of records is given (not abundances). NIC = National Invertebrate Collection (Previously NIWA Invertebrate Collection), OBIS = Ocean Biogeographic Information System, MITs = Marine Invasives Taxonomic Service database.

Data source	Number of records
Auckland museum	34
iNaturalist	94
MBL/Earth Sciences NZ NIC	23
OBIS	41
MITs	15
Total	192

Depth of capture wasn't recorded for the iNaturalist observations and was also missing for several records from other sources, but where it was recorded most locations (over 80%) were less than 100 m deep and two-thirds were less than 40 m. This coral species also appears to have been recorded from intertidal habitat with some depths given as 0 or 1 m, and several records collected by scuba, snorkel, and even by hand. However, some of the OBIS records are from much deeper water (e.g., those from east of the Colville Ridge in the north), over 1000 m, and it may be that these have been mis-identified or the locality data incorrectly recorded. Further examination of the specimens would be required to confirm any misidentification.

Incidental records of habitat descriptions were available for some records obtained from the Auckland Museum and iNaturalist datasets. Habitats were mostly recorded as on or under rocks or rock crevices, in caves, on rock walls, under overhangs and kelp canopies, on low-tide rocks, or in one case "embedded in a sponge". These records are likely mostly of live specimens (or at least are from the location of the specimen when it was living) and strongly indicate a preference for hard rocky substrate in shaded locations, rather than mobile soft-sediment sandy, or muddy habitat. Some *Culicia rubeola* have also been observed attached to shells or shell fragments (including MBL samples) but those confirmed as coming from soft-sediment substrates have all been dead specimens.

3.2.1 Recorded distribution and predicted habitat of *Culicia rubeola*

Recorded occurrences indicate that *Culicia rubeola* is widespread around New Zealand, including most of the coastline of the North Island (excluding the southeast), the top of the South Island including Marlborough Sounds and Cook Strait, and Fiordland in the southwest of the South Island. Notably, there are no occurrence records from the east coast of New Zealand between Hawkes Bay and the southwest corner of the South Island. This coral has also been recorded from as far north as the Kermadec Islands, with some deeper records further west nearer the Colville Ridge (Figure 3-3.)

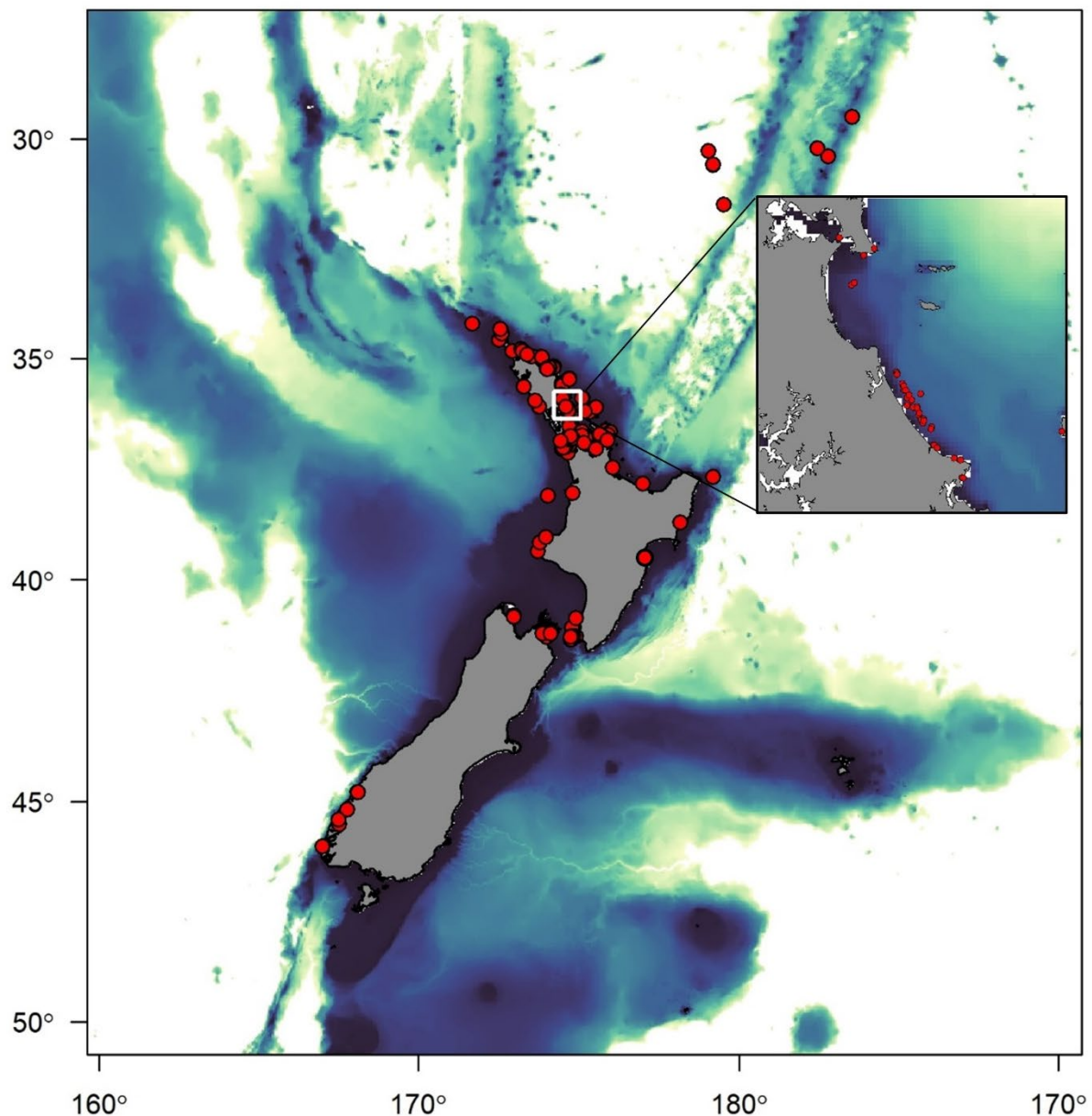


Figure 3-3: *Culicia rubeola* records from all sources within Aotearoa New Zealand. Inset shows the Te Ākau Bream Bay and Pākiri region. Colour gradient indicates bathymetry.

Thirty-three 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 *Culicia rubeola*. The observed range and frequency of a subset of these environmental layers for sites at Te Ākau Bream Bay (including Pākiri) and for all other sites are given in Figure 3-4. While there are differences between the regions (notably a higher mean percentage of sand in Bream Bay/Pākiri compared to other sites), the range of the environmental variables at Te Ākau Bream Bay/Pākiri sites were within the range of values at other sites.

The spatial plots in Figure 3-5 show that the potential suitable habitat (within the range of most environmental predictors) for *Culicia rubeola* within Aotearoa New Zealand's Territorial Sea, as determined by environmental data layers, includes the entire coastline of both main islands, as well as Stewart Island and the Chatham Islands. Regions in range of all 33 variables are more restricted, however, but still include almost all the North Island coastline as well as large parts of the South Island western and northern coastlines. The South Island south and east coasts are excluded. Based on this distribution, the proposed sand extraction area at Te Ākau Bream Bay (15.4 km²) is less than 0.04% of the identified potential suitable habitat for *Culicia rubeola* (43,070.9 km²) within Aotearoa New Zealand (and likely a much smaller percentage of the complete distribution, including beyond Aotearoa New Zealand).

This estimate is only approximate for various reasons, including: 1) several of the *Culicia rubeola* observations were from outside of the spatial range of the environmental variable layers used and would likely increase the breadth of environmental conditions suitable for this coral if data were available, 2) all of the MBL observations were of dead specimens which may have been transported to the sandy substrate sample locations by wave and current actions and therefore may artificially expand the breadth of environmental conditions used to delimit suitable habitat, 3) the inherent error and low spatial resolution of the environmental predictors, or missing key predictors, and 4) the absence of abundance/density information in the observational data records.

However, there is a level of conservatism in the method used to estimate extent of suitable habitat in that it included only areas where *Culicia rubeola* has been found within the range of all 33 environmental parameters. Taking all these factors into consideration, the estimated percentages of sand extraction area relative to areas of suitable habitat are at the very least unlikely to be substantively overestimated.

Note that, as environmental data layers were only available between the Territorial Sea boundary and the nominal shoreline, in some places (e.g., Fiordland and off East Cape) records were either too close or too far from shore to be within the range of the environmental layers and therefore appear to be outside of suitable habitat. This adds a level of conservatism to the predicted extent of habitat suitability shown in red in the right-hand plot of Figure 3-5, as suitable habitat is known to occur at the location of these observations.

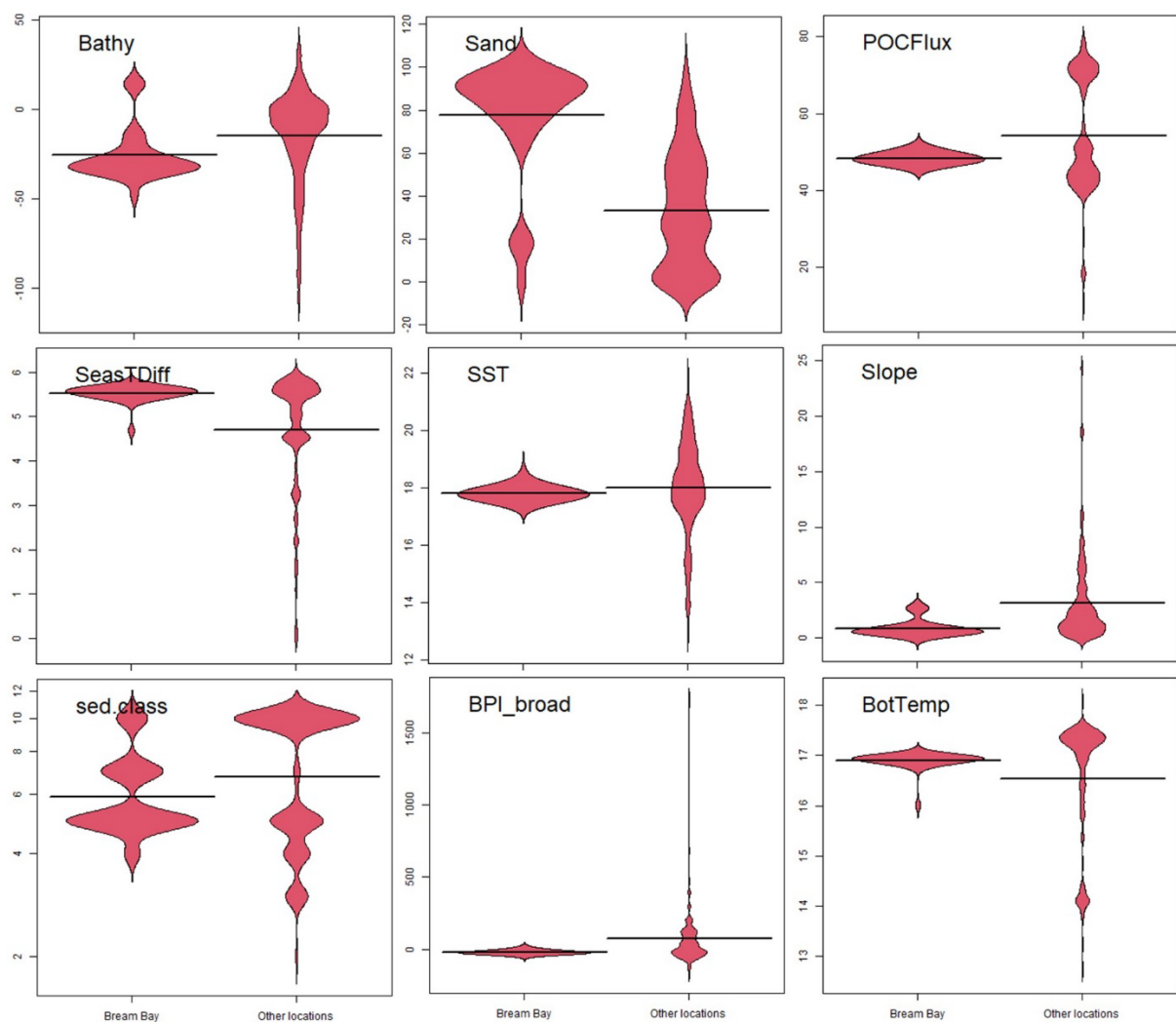


Figure 3-4: Bean plots show the spread of environmental variables extracted from locations of *Culicia rubeola* records at Te Ākau Bream Bay (including Pākiri) and all other sites. Within each plot, the left graph is Te Ākau Bream Bay (including Pākiri) data and the right graph is data from all other sites. The black horizontal bar shows the mean value. Bathy = bathymetric depth; Sand = percent sand; POCFlux = particulate organic carbon flux to the seafloor; SeasTDiff = seasonal sea surface temperature difference; SST = Sea Surface Temperature; Slope = angle/steepness of seabed; Sed.class = sediment classification; BPI broad = Benthic Position Index; BotTemp = Bottom (seabed) temperature. See Appendix A for details of each variable.

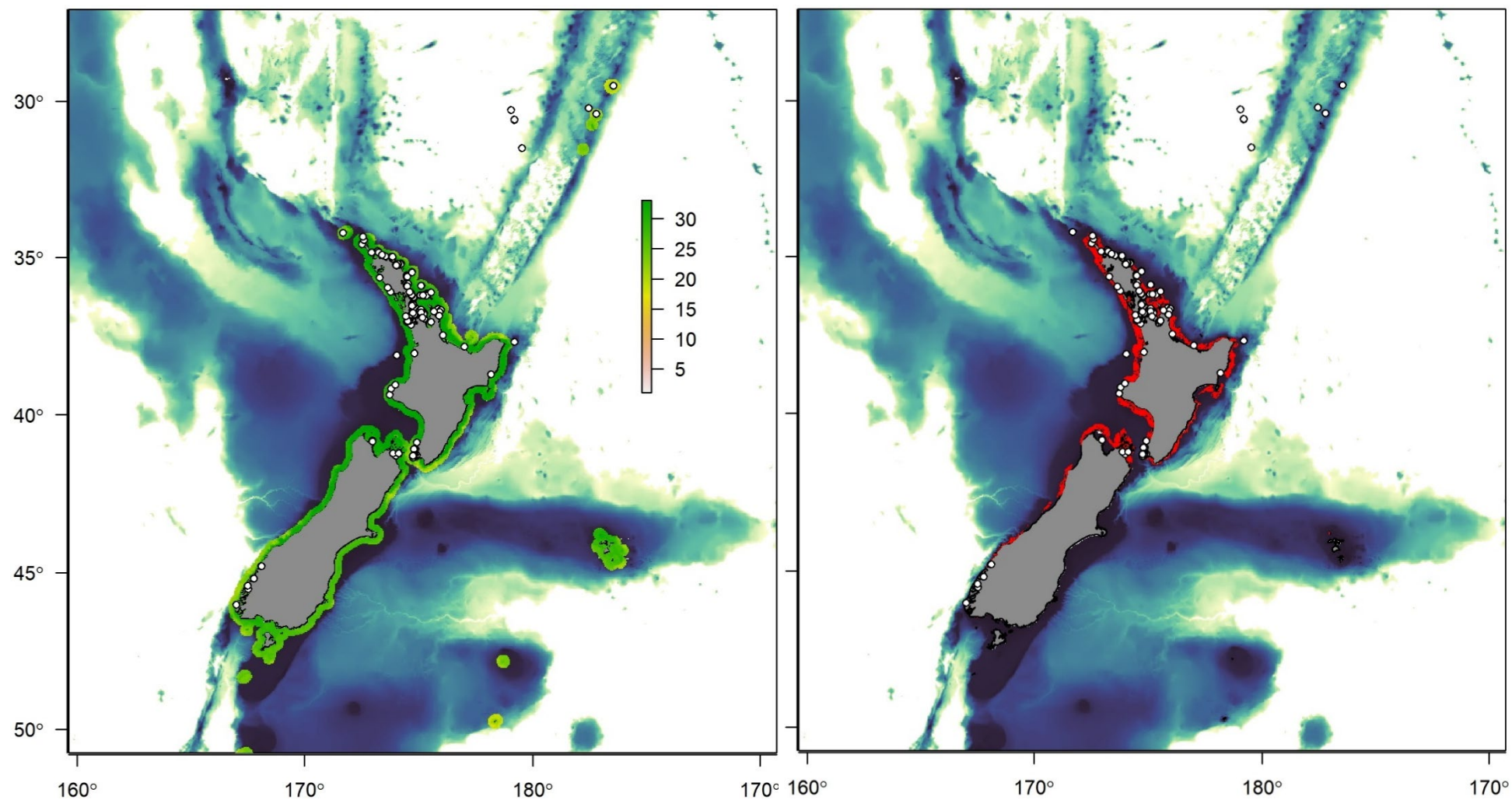


Figure 3-5: Potential suitable habitat for *Culicia rubeola* determined from environmental data layers. Left: Gradient of suitability based on the number of environmental variables within the species tolerance. Right: Potential suitable habitat where all 33 environmental layers were within the range of values recorded at known *Culicia rubeola* locations. Environmental data layers (Appendix A) were only available between the Territorial Sea boundary and the nominal shoreline. In some places (e.g., Fiordland and off East Cape) records were too close or too far from shore to be within the range of the environmental layers and therefore appear to be outside of suitable habitat.

4 Ecology of *Culicia rubeola*

Culicia rubeola (Quoy and Gaimard 1833) is a species of ahermatypic (non-reef-building) scleractinian coral in the family Rhizangiidae. Species within this family are characterized by small, encrusting colonies of corallites (the outer skeletal part of individual polyps) that are interconnected at their bases (Cairns 1995; Viswambharan et al. 2021; Viswambharan and Sreenath 2024). Despite their wide distribution, the Rhizangiidae are among the least studied groups of azooxanthellate corals (those which do not rely on symbiotic algae for nutrition), this being attributed to their small size, challenges in morphological identification, and lack of information on their ecological preferences (Viswambharan and Sreenath 2024).

Culicia rubeola (Figure 4-1 and Figure 4-2) was one of the first reported species of Scleractinia reported from the New Zealand region (Cairns 1995). Although Cairns (1995) concluded this species was probably endemic to Aotearoa New Zealand, it has since been documented in India (Viswambharan and Sreenath 2024) and Hong Kong (Lam et al. 2008) and OBIS includes records from the Central and south-west and eastern Pacific, in the littoral zone (to 55 m).

Within Aotearoa New Zealand, published accounts and the observations we have assembled show *Culicia rubeola* has been recorded from all coasts of the North Island and off Fiordland (Cairns 1995), the Kermadecs (Richards and Liggins 2015), Rakitu Island (off Great Barrier Island, Brook 1982), the Whanganui shelf (Squires 1960), and Pelorus Sound (Watts et al. 2015).

Culicia rubeola was originally placed in a different genus, as *Dendrophyllia rubeola* after it was collected in the early 1800 during the voyage of the French *Astrolabe*. The original collection locality is listed as ‘Tamise’ (=Thames) River, depth unknown. Later distribution records were provided by Squires and Keyes (1967, from various locations around the North Island) and Cairns (1995). It was described by Cairns (1995) as having “colonies low and encrusting, formed by reptoid budding from short, flat stolons.” with the largest colonies up to approximately 60 mm in diameter and consisting of about 200 corallites. Calices are circular and mostly 3.5-4.5 mm in diameter (Cairns 1995), but can be up to 6.0 mm in sheltered environments (Brook 1982).

This species lives attached to hard substrates such as bivalve shell with a depth range of 0–82 m (Figure 4-3, Cairns 1995). Brook (1982) described *Culicia rubeola* as living on vertical to horizontal rock surfaces below 15 m and in crevices in shallower water off Great Barrier Island, Viswambharan and Sreenath (2024) on natural substances like rocks of dead corals in the Indian region, and Watts et al. (2015) described *Culicia rubeola* attached to rope long-line droppers on mussel farms in Pelorus Sound, Marlborough Sounds.



Figure 4-1: *Culicia rubeola*. Images taken from (NIWA 2022).

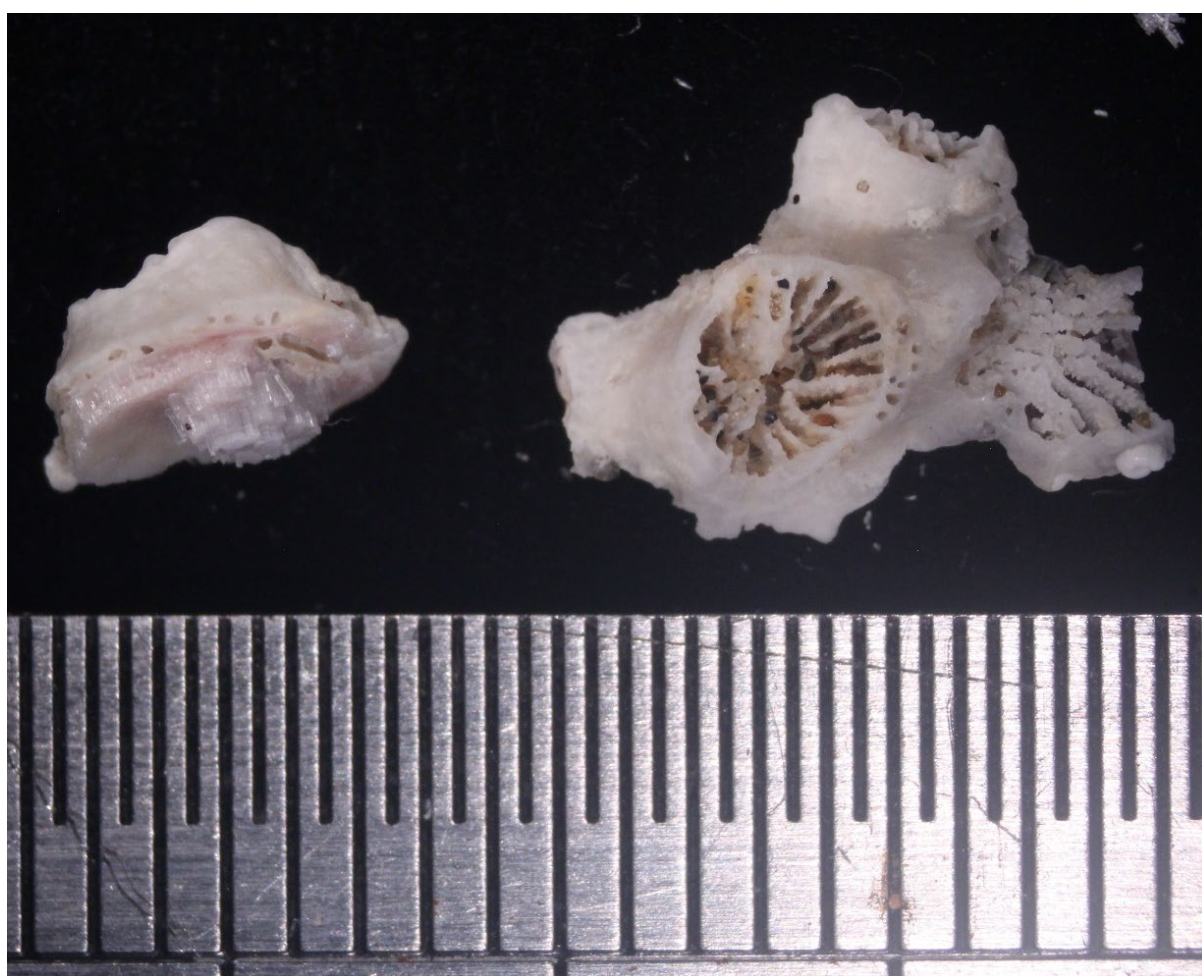


Figure 4-2: Two specimens of *Culicia rubeola* from a sample collected at Pākiri. Image of NIC specimen 183334 taken by Diana Macpherson (Earth Sciences NZ) with a ruler as a scale bar. The left hand specimen has layers of mollusc shell underneath showing that this was previously attached to a shell.

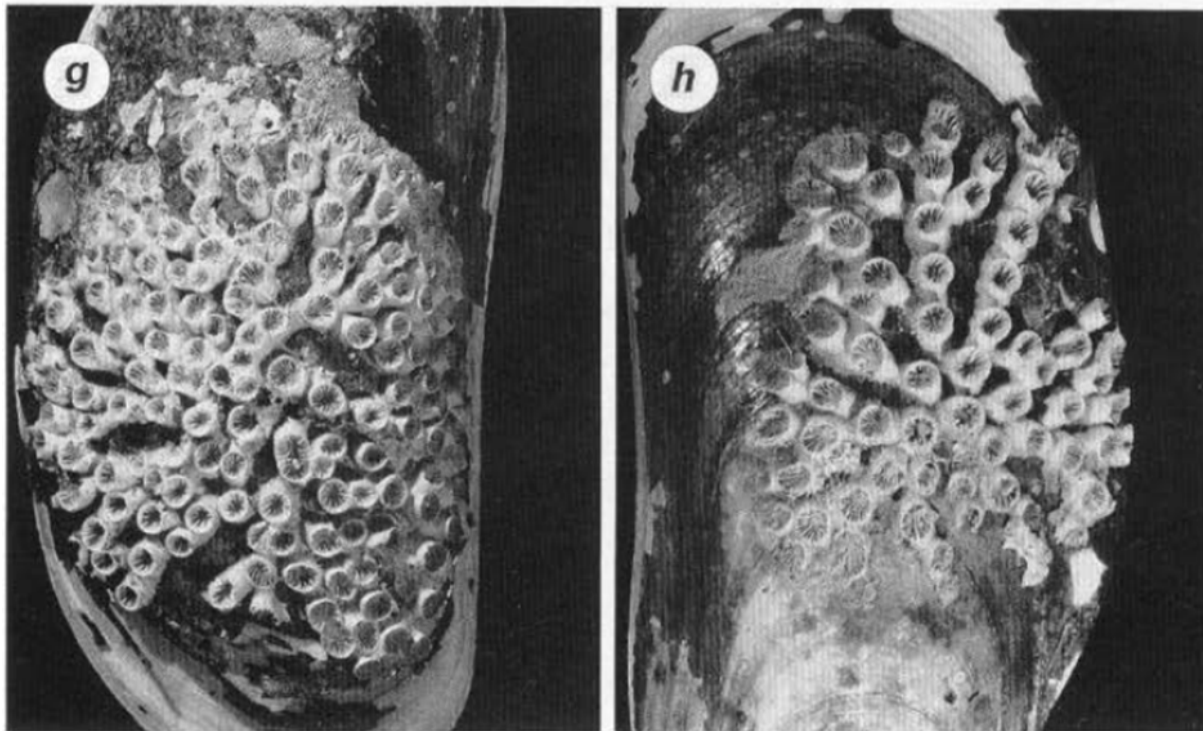


Figure 4-3: *Culicia rubeola* attached to a bivalve shell (the green-lipped mussel *Perna canaliculus*). Images taken from Cairns (1995).

4.1 Reproduction

The importance of reproduction in the population dynamics and distribution of benthic animals, together with a general overview of coral reproduction, was described in Beaumont et al. (2025). However, information on the reproduction of scleractinian solitary corals and those living in temperate zones is notably scant (Goffredo et al. 2005).

There was no information found on any aspect of the reproduction of *Culicia rubeola* specifically, however Szmant-Froelich et al. (1980) conducted an 18-month study of reproduction on *Astrangia danae*, a species within the same family, on the east coast of the US. This species is similar to *Culicia rubeola* in that it is also a small encrusting coral, with polyps 3–5 mm in diameter, and attaches to rocky surfaces and shells. Although, unlike *Culicia rubeola*, this species is found both with and without endosymbiotic dinoflagellates (zooxanthellae). Szmant-Froelich et al. (1980) concluded that *A. danae* is dioecious (polyps are either male or female and all polyps within a colony were the same sex) and a broadcast spawner. It has an annual reproductive cycle with spawning occurring during August (in Narragansett Bay where the study was conducted). Egg production was estimated at up to 6000 eggs per polyp. The smallest colonies used in this experiment (from 6 to 9 polyps) had an estimated age of 1 to 3 years and were reproductively mature. Reproductive strategies are not always consistent within coral families, but this may give an indication of the most likely strategy for *Culicia rubeola*.

4.2 Growth rates and longevity

The importance of metrics such as growth rates and/or longevity when considering the vulnerability of a species to anthropogenic disturbance were described in Beaumont et al. (2025), together with a summary of available information on the growth and longevity of solitary cup corals. Reported longevities were in the range of approximately 7–12 years and reported growth rates ranged from 0.3 mm to 3.1 mm per year, with the exception of *Flabellum rubrum* with possible growth rates of up to 0.5 cm per month.

While there is no information on the growth rates or longevity of *Culicia rubeola* in the available literature, Brook (1982) suggested that this species may produce larger coralla in habitats sheltered from wave action than it does in more exposed habitats, though they noted there were insufficient data to verify this.

There was little information in the literature on the linear growth rates of small colonial temperate scleractinians, but Szmant-Froelich et al. (1980) noted that small colonies (from 6 to 9 polyps) of *Astrangia danae* had an estimated age of 1 to 3 years and were reproductively mature. Another species that may provide some insight is *Astroides calycularis*, an azooxanthellate coral in the Dendrophylliidae family. This coral is native to the western Mediterranean Sea and is also found in the Atlantic Ocean where it inhabits shallow rocky substrates down to approximately 50 m water depth. Like *Culicia rubeola*, *A. calycularis* is colonial, forming colonies up to approximately 20–30 cm in diameter and about 10 cm in height. While no information was found on linear growth, Carbonne et al. (2021) recorded calcification rates, during a six-month laboratory experiment looking at the response of corals to low pH, of between $1.0 \pm 0.2 \text{ mg CaCO}_3 \text{ cm}^{-2} \text{ day}^{-1}$ and $0.2 \pm 0.1 \text{ mg CaCO}_3 \text{ cm}^{-2} \text{ day}^{-1}$. Carbonne et al. (2024) recorded calcification rates for *A. calycularis* to be in the region of $0.2 - 0.3 \text{ mg CaCO}_3 \text{ cm}^{-2} \text{ day}^{-1}$ during a three-month study into the effects of heat waves and ocean warming on temperate scleractinian corals.

4.3 Resilience of *Culicia rubeola* to disturbance

MBL's sand extraction process was described in detail in Beaumont et al. (2025). 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 ($> 2 \text{ mm}$) 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) also 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 ($< 10 \text{ mg/L}$), 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).

4.3.1 Available information on resilience of *Culicia rubeola* 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. As described in Beaumont et al. (2025), there is ample evidence in the literature to show that elevated sedimentation (suspended or deposited) can negatively impact on the health of corals. However, 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).

In a study in the Indian region, Viswambharan and Sreenath (2024) concluded that *Culicia* is resilient to high turbidity (suspended sediments). However, their study was on *Culicia stellata* rather than *Culicia rubeola*. No further information was found on the resilience of *Culicia rubeola* to disturbance.

However, as discussed in Beaumont et al. (2025) with respect to *Sphenotrochus ralphae* and *Kionotrochus suteri*, many coral species are known to have some regenerative potential following physical disturbance. In addition, Luz et al. (2021) described the regenerative capacity of cnidarians as having an essential role in the maintenance and restoration of coral reef ecosystems by allowing faster recovery from disturbances and more efficient small-scale dispersal (by fragmentation combined with regeneration).

Luz et al. (2018) describes the “extreme regeneration” capacity of two sun corals within the family Dendrophylliidae (*Tubastraea coccinea* and *T. tagusensis*) that inhabit shallow rocky reefs in the Atlantic region. Colonies of both species were broken into 120 fragments (skeleton and tissue) devoid of differentiated tissue (e.g. mesenteries, mouth or tentacles). The fragments had high survival rates (83%) with tissue fragments developing complete polyps in approximately 25 days (Figure 4-4).

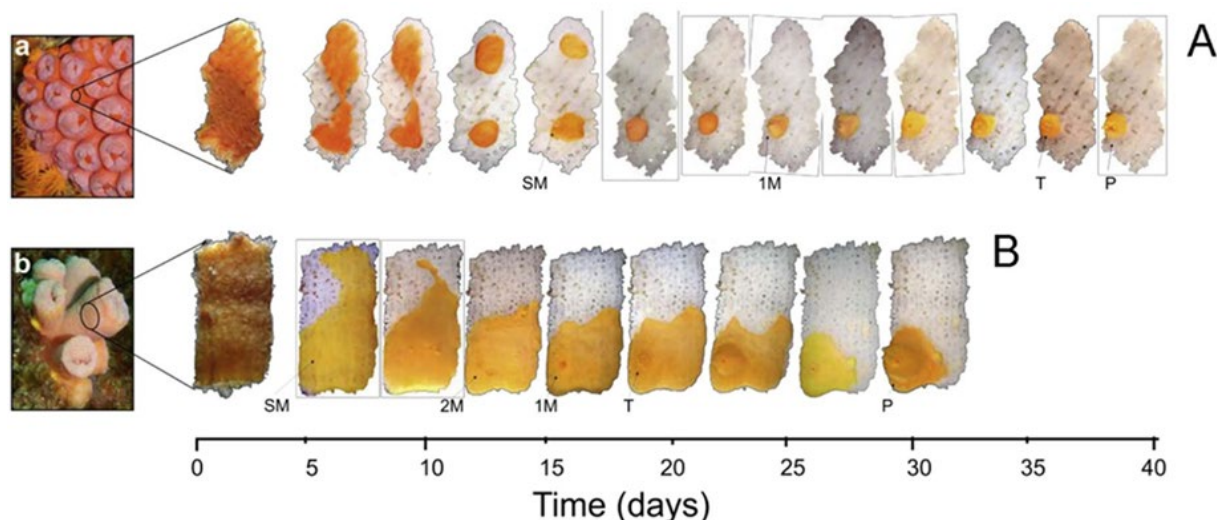


Figure 4-4: Regeneration process in fragments of A) *Tubastraea coccinea* and B) *T. taguensis*. A) *Tubastraea coccinea* (24°C) and B) *T. taguensis* (30°C), showing the formation of two mouth rudiments that may either lead to the development of two separate polyps or to further reorganisation with the loss of one of the openings and the development of a larger polyp. Both fragments were fed. “SM” : Starting mouth formation. “1M” and “2 M”: 1 or 2 mouth rudiments, respectively. “T” tentacles. “P”: Full formed polyp. Scale bar 5.0 mm. Figure reproduced from Luz et al. (2018).

Luz et al. (2021) assessed the regenerative capacity of four colonial species of the family Dendrophylliidae and showed that all dendrophylliids displayed regenerative ability. This study included *Tubastraea coccinea* which is a small azooxanthellate colonial coral. The first complete and viable dendrophylliid polyps were noticeable 14 days post fragmentation. Of the 192 coral fragments, 43 % had undergone complete regeneration (growth of a new polyp) by day 31 and by day 77 an additional 90 % of fragments had undergone complete regeneration, of which 17 % also had secreted skeletons. The high survival rates were independent of whether or not food was supplied or fragment size. However, regeneration rates varied between species and were influenced by fragment size with smaller fragments taking longer to regenerate.

While the species studied by Luz et al. (2018) and Luz et al. (2021) were all in the family Dendrophylliidae (*Culicia rubeola* is in the family Rhizangiidae, though was originally named *Dendrophyllia rubeola*), *Tubastraea coccinea* has some similarities to *Culicia rubeola* in that they are both small azooxanthellate colonial scleractinians which inhabit shallow reef environments. Given these similarities, it is considered likely that *Culicia rubeola* may also have the ability to regenerate following physical damage or fragmentation. However, it is considered unlikely that these corals have the ability to burrow or move through sediments and so any corals that become detached from their substrate (e.g. shells) would likely suffer mortality if buried by sediments/mobile sands.

However, at this stage there have been no live *Culicia rubeola* found within the proposed sand extraction area at Te Ākau Bream Bay. It is not known whether *Culicia rubeola* live within the proposed sand extraction area attached to bivalve shells (there are no known rocky reefs within this area) or whether the dead skeletons originated from nearby reefs and have been moved into the area once dead.

4.3.2 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. This is discussed in more detail in Beaumont et al. (2025). As no live *Culicia rubeola* have been recorded within the proposed sand extraction and control areas within Te Ākau Bream Bay it is not possible to provide an estimate of live corals that might be disturbed. However, the estimated abundance of potentially disturbed dead coral skeletons is given in Table 4-1.

Table 4-1: Average densities of dead *Culicia rubeola* 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.

Taxon	Status	Average density (inds./ m ² ± SE)	Estimated abundance of dead corals (inds./ m ² ± SE)		
			Drop camera (19.8 m ²)	Grab sampling (28.1 m ²)	Epibenthic dredge (8,250 m ²)
<i>Culicia rubeola</i>	Dead	0.11 ± 0.08	2.2 ± 1.6	3.1 ± 2.2	937.2 ± 681.6

5 Summary

The local distribution of *Culicia rubeola* appears to comprise the coastlines of much of Aotearoa New Zealand, including Te Ākau Bream Bay, with a concentration of observations in the northern half of the North Island. This conclusion is based on a combination of spatial plots of species location records from a range of sources and from an analytical assessment of potential suitable habitat using available environmental data layers encompassing the Territorial Sea. There is no evidence from these analyses to suggest that the proposed sand extraction area at Te Ākau Bream Bay is unique with respect to the habitat of *Culicia rubeola* or that it represents any hotspot of its distribution. In fact, given that no live specimens of this coral have been recorded from the proposed sand extraction area, and its apparent preference for attachment to hard substrates, the opposite is probably true. The main areas of uncertainty in the assessment of distribution stem from the spatial limitations and inherent error in the environmental variables used in the analysis and the absence of species density information in the observations, and while the area of most suitable habitat has been estimated for the Territorial Sea, the wider distribution in New Zealand's EEZ remains unknown. Note that this species is not endemic and is also present in the central, south-west and eastern Pacific.

Based on the analytical assessment of distribution, the proposed extraction area represents less than 0.04% of the predicted suitable habitat of *Culicia rubeola* in the New Zealand region.

The Rhizangiidae family is among the least studied groups of azooxanthellate corals (Viswambharan and Sreenath 2024) and as a result there was little information in the literature about the life history (reproduction, growth rates etc.) of *Culicia rubeola*. However, evidence in the literature suggests that many scleractinians, including members of the family Dendrophylliidae of which *Culicia rubeola* was originally attributed to, are capable of regenerating both soft tissue and skeletal tissues following damage or fragmentation. This is true of even relatively small fragments.

At this stage no live specimens of *Culicia rubeola* have been recorded from within the proposed sand extraction area at Te Ākau Bream Bay. This species requires a hard substrate to attach to and there are no rocky reefs present within the proposed extraction area. However, as this species is known to attach to bivalve shells it is possible that live specimens exist within the area. It is also possible that the live specimens live on reefs outside of the proposed extraction area and that the dead skeletons have been brought in through processes such as the movement of currents and storm events.

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, items larger than 2 mm (such as *Culicia rubeola*) would be returned to the seabed. This would have little to no impact on dead coral skeletons, except perhaps further fragmentation. However, should there be live specimens within the proposed extraction area the probability of survival is probably less than for *Sphenotrochus ralphae* and *Kionotrochus suteri* due to the assumed lack of ability to move within sediments and/or return to an upright position as *Culicia rubeola* is considered less adapted for life in mobile sediments.

Given the relatively wide distribution and the absence of live specimens recorded (to date), 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 these corals outside of the proposed extraction area together with assumptions made about the resilience of this species using published research on other corals with similar morphology and or habitat preferences.

6 Acknowledgements

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7 Glossary of abbreviations and terms

Coralla	The skeletal "cups" of the cup coral
Corallite	The cuplike calcareous skeleton of a single coral polyp
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 Hjørvarsdóttir 2019).
Draghead	The heavy steel component at the end of the suction pipe used to remove sand from the seabed
EEZ	Exclusive Economic Zone
Endemic	Only found in Aotearoa New Zealand
Earth Sciences NZ (ESNZ)	The New Zealand Institute for Earth Science, formerly NIWA
MBL	McCallum Brothers Limited
MITs	Marine Invasives Taxonomic Service
NIC	Earth Sciences NZ National Invertebrate Collection
NIWA	National Institute of Water and Atmospheric Research, now Earth Sciences NZ
OBIS	Ocean Biogeographic Information System
pSEA	proposed Sand Extraction Area at Te Ākau Bream Bay
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.
Te Papa	Museum of New Zealand Te Papa Tongarewa
TS	Territorial Sea

8 References

- Beaumont, J., Anderson, O., Mills, S. (2025) Scleractinian cup corals at Whanga-a-Tamure Bream Bay. Literature review and distribution of cup corals identified within the proposed sand extraction area. *NIWA Client report 2024322WN* Version 4: 62. Prepared for McCallum Brothers Limited.
- Behrenfeld, M.J., Falkowski, P.G. (1997) Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology and Oceanography*, 42: 1–20.
- Bongaerts, P., Hoeksema, B.W., Hay, K.B., Hoegh-Guldberg, O. (2012) Mushroom corals overcome live burial through pulsed inflation. *Coral Reefs*, 31: 339. doi 10.1007/s00338-011-0862-z
- Brook, F.J. (1982) The scleractinian coral fauna of Rakitu Island, north-eastern New Zealand. *Tane*, 28: 163–173.
- Cael, B., Bisson, K., Follett, C.L. (2018) Can rates of ocean primary production and biological carbon export be related through their probability distributions? *Global biogeochemical cycles*, 32: 954–970.
- Cairns, S.D. (1995) The marine fauna of New Zealand: Scleractinia (Cnidaria: Anthozoa). *New Zealand Oceanographic Memoir*, 103: 139.
https://docs.niwa.co.nz/library/public/Memoir%20103_Scleractinia_of_New_Zealand%20-%201995.pdf
- Carbonne, C., Comeau, S., Plichon, K., Schaub, S., Gattuso, J.-P., Teixidó, N. (2024) Response of two temperate scleractinian corals to projected ocean warming and marine heatwaves. *Royal Society Open Science*, 11(3): 231683.
<https://doi.org/10.1098/rsos.231683>
- Carbonne, C., Teixidó, N., Moore, B., Mirasole, A., Guttierrez, T., Gattuso, J.-P., Comeau, S. (2021) Two temperate corals are tolerant to low pH regardless of previous exposure to natural CO₂ vents. *Limnology and Oceanography*, 66: 4046–4061. doi: 10.1002/lno.11942
- CARS2009 (2009) CSIRO Atlas of Regional Seas (CARS) – 2009. Available from <https://researchdata.edu.au/csiro-atlas-regional-cars-2009/15210>.
- Dunn, J.R., Ridgway, K.R. (2002) Mapping ocean properties in regions of complex topography. *Deep-Sea Research Part I: Oceanographic Research Papers*. DOI: 10.1016/S0967-0637(01)00069-3
- Fletcher, W.J. (2005) The application of qualitative risk assessment methodology to prioritize issues for fisheries management. *Ices Journal of Marine Science*, 62: 1576–1587.
- Folk, R.L., Andrews, P.B., Lewis, D.W. (1970) Detrital sedimentary rock classification and nomenclature for use in New Zealand. *New Zealand Journal of Geology and Geophysics*, 13: 937–968.

- Goffredo, S., Radetić, J., Airi, V., Zaccanti, F. (2005) Sexual reproduction of the solitary sunset cup coral *Leptopsammia pruvoti* (Scleractinia: Dendrophylliidae) in the Mediterranean. 1. Morphological aspects of gametogenesis and ontogenesis. *Marine Biology*, 147: 485–495. DOI 10.1007/s00227-005-1567-z
- Jacobs (2020) *Pākiri Sand Extraction Consent Application- Water Quality Technical Report*. Report IZ111900-NP-RPT-003, V2. Prepared for McCallum Brothers Limited, August 2020 299.
- Lam, K., Morton, B., Hodgson, P. (2008) Ahermatypic corals (Scleractinia: Dendrophylliidae, Oculinidae and Rhizangiidae) recorded from submarine caves in Hong Kong. *Journal of Natural History*, 42: 9–12.
doi.org/10.1080/00222930701862724
- Leathwick, J., Elith, J., Francis, M., Hastie, T., Taylor, P. (2006) Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. *Marine Ecology Progress Series*, 321: 267–281.
- Lutz, M., Dunbar, R., Caldeira, K. (2002) Regional variability in the vertical flux of particulate organic carbon in the ocean interior. *Global biogeochemical cycles*, 16: 11–18.
- Luz, B.L.P., Capel, K.C.C., Zilberberg, C., Flores, A.A.V., Migotto, A.E., Kitahara, M.V. (2018) A polyp from nothing: The extreme regeneration capacity of the Atlantic invasive sun corals *Tubastraea coccinea* and *T. tagusensis* (Anthozoa, Scleractinia). *Journal of Experimental Marine Biology and Ecology*, 503: 60–65.
- Luz, B.L.P., Miller, D.J., Kitahara, M.V. (2021) High regenerative capacity is a general feature within colonial dendrophyllid corals (Anthozoa, Scleractinia). *Journal of Experimental Zoology (Molecular and Developmental Evolution)*, 336: 281–292.
- Mitchell, J.S., Mackay, K.A., Neil, H.L., E.J., M., Pallentin, A., Notman, P. (2012) Undersea New Zealand, 1:5,000,000. *NIWA Chart*, Miscellaneous Series No. 92.
- NIWA (2022) NIWA Invertebrate guide sheets to complement current by-catch guides 2022-2023: 22.
- Pinkerton, M., Gall, M., Wood, S., Zeldis, J. (2018) Measuring the effects of bivalve mariculture on water quality in northern New Zealand using 15 years of MODIS-Aqua satellite observations. *Aquaculture environment interactions*, 10: 529–545.
- Pinkerton, M., Rickard, G., Nodder, S., Macdonald, H. (2016) Climate change impacts and implications: net primary production, particulate flux and impacts on fish species in the New Zealand region: 62.
- Pinkerton, M.H., Décima, M., Kitchener, J.A., Takahashi, K.T., Robinson, K.V., Stewart, R., Hosie, G.W. (2020) Zooplankton in the Southern Ocean from the continuous plankton recorder: Distributions and long-term change. *Deep Sea Research Part I: Oceanographic Research Papers*, 103303.
<https://doi.org/10.1016/j.dsr.2020.103303>

- Quoy, J.R.C., Gaimard, J.P. (1833) Voyage de la corvette l'Astrolabe: exécuté par ordre du roi, pendant les années 1826-1827-1828-1829, sous le commandement de M. J. Dumont d'Urville. *Zoologie*, 2(2): 321–686.
- Richards, Z.T., Liggins, L. (2015) Scleractinian corals and crown-of-thorns seastars of the Kermadec Islands. In: T. Trnski & H.A. Schlumpf (Eds). *Bulleting of the Auckland Museum*: 337–340.
- Ridgway, K., Dunn, J., Wilkin, J. (2002) Ocean interpolation by four-dimensional weighted least squares—Application to the waters around Australasia. *Journal of atmospheric and oceanic technology*, 19: 1357–1375.
- Riegl, B. (1995) Effects of sand deposition on scleractinian and aclyonacean corals. *Marine Biology*, 121: 517–526.
- Schnabel, K., Nelson, W., Kelly, M., Anderson, O., Chin, C., Davey, N., Forman, J., Gordon, D., Lörz, A.-N., Mills, S., Neill, K., Page, M., Stevens, D., Tracey, D., Jones, E., Morrison, M. (2014) Unlocking biodiversity data in the NIWA Invertebrate Collection (NIC) through identification of specimens and updating databases (COBR1408, objective: Identification of Invertebrates). *NIWA Client Report* WLG2014-42. Prepared for Coasts and Oceans National Centre.
- Sheridan, C., Grosjean, P., Leblud, J., Palmer, C.V., Kushmaro, A., Eeckhaut, I. (2014) Sedimentation rapidly induces an immune response and depletes energy stores in a hard coral. *Coral Reefs*, 33: 1067–1076.
- Squires, D.F. (1960) Additional Rhizangiid corals from the Wanganui series. *New Zealand Journal of Geology and Geophysics*, 3:1: 1–7.
doi.org/10.1080/00288306.1960.10423139
- Squires, D.F., Keyes, I.W. (1967) The marine fauna of New Zealand: Scleractinian corals. New Zealand Oceanographic Institute Memoir No. 43. *New Zealand Department of Scientific and Industrial Research Bulletin*, 185: 55.
- Stephenson, F., Brough, T., Lohrer, D., Leduc, D., Geange, S., Anderson, O., Bowden, D., Clark, M.R., Davey, N., Pardo, E., Gordon, D.P., Finucci, B., Kelly, M., Macpherson, D., McCartain, L., Mills, S., Neill, K., Nelson, W., Peart, R., Pinkerton, M.H., Read, G.B., Robertson, J., Rowden, A.A., Schnabel, K., Stewart, A., Struthers, C., Tait, L., Tracey, D., Weston, S., Lundquist, C. (2023) An atlas of seabed biodiversity for Aotearoa New Zealand. *Earth System Science Data*, 15: 3931–3939.
doi.org/10.5194/essd-15-3931-2023
- Stephenson, F., Brough, T., Lohrer, D., Leduc, D., Geange, S., Anderson, O., Bowden, D., Clark, M.R., Davey, N., Pardo, E., Gordon, D.P., Finucci, B., Kelly, M., Macpherson, D., McCartain, L., Mills, S., Neill, K., Nelson, W., Peart, R., Pinkerton, M.W., Read, G., Robertson, J., Rowden, A., Schnabel, K., Stewart, A., Struthers, C., Tait, L., Tracey, D., Weston, S., Lundquist, C. (2022) An Atlas of seabed biodiversity for Aotearoa New Zealand, Zenodo [dataset].
- Swart, D.H. (1974) Offshore sediment transport and equilibrium beach profiles. *Publications of the Delft Hydraulics Laboratory*: 131.

- Szmant-Froelich, A., Yevich, P., Pilson, M.E.Q. (1980) Gametogenesis and early development of the temperate coral *Astrangia danae* (Anthozoa: Scleractinia). *Biological Bulletin*, 158: 257–269.
- Tracey, D., Hjørvarsdóttir, F. (2019) The state of knowledge of deep-sea corals in the New Zealand region. DOC Contract DOC18399 (POP2017-07). *NIWA Science and Technology Series* 84: 134. ISSN 1173-0382
- Viswambharan, D., Sreenath, K.D. (2024) Morphological traits and spatial distribution of azooxanthellate corals of Rhizangiidae in the Laccadive Sea. *Journal of the Marine Biological Association of the United Kingdom*, 104(124): 1–7.
<https://doi.org/10.1017/S0025315424001103>
- Viswambharan, D., Sreenath, K.R., Jasmine, S., Joshi, K.K., Sreeraj, C.R., Mohan, S., Rohit, P. (2021) Occurrence of the supposedly endemic Australian azooxanthellate coral *Astrangia woodsi* Wells, 1955 in the eastern Arabian Sea. *Marine Biodiversity*, 51: 84. <https://doi.org/10.1007/s12526-021-01229-1>
- Walters, R.A., Goring, D.G., Bell, R.G. (2001) Ocean tides around New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 35: 567–579.
- Watts, A.M., Goldstein, S.J., Hopkins, G.A. (2015) Characterising biofouling communities on mussel farms along an environmental gradient: a step towards improved risk management. *Aquaculture environment interactions*, 8: 15–30. doi: 10.3354/aei00159
- Werdell, P.J. (2019) Inherent Optical Properties (IOPs) Algorithm Theoretical Basis Document. Available from <https://oceancolor.gsfc.nasa.gov/atbd/giop/> (accessed 27/07/2020 2020).
- West, S. (2022) Statement of evidence of Simon West for McCallum Bros Limited. Marine Ecology. 23 December 2022. Environment Court at Auckland: 71.
- Wright, D.J., Pendleton, M., Boulware, J., Walbridge, S., Gerlt, B., Eslinger, D., Sampson, D., Huntley, E. (2012) ArcGIS Benthic Terrain Modeler (BTM), v 3.0. *Environmental Systems Research Institute*.

Appendix A Environmental data layers

Table A-1: Description of key spatial environmental predictor variables (n=20) collated for species distribution models. Description of key 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 and Ridgway 2002) . Oceanographic data from CARS2009 (2009).	ESNZ, 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).	ESNZ, 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).	ESNZ, unpublished

Abbreviation	Full name	Description	Source
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).	ESNZ, 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).	ESNZ, unpublished
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.	ESNZ, 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.	ESNZ, 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).	ESNZ 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 chlorophyll-a concentration. Derived from Chl-a described above.	ESNZ unpublished, updated in 2020; Based on processing described in (Pinkerton et al., 2018)

Abbreviation	Full name	Description	Source
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 ($E_m - 2 \text{ d} - 1$) 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. (2018).	ESNZ 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.	ESNZ 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.	ESNZ 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.	ESNZ , 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.	ESNZ 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 $X + iY = A \cdot \exp(i \cdot \phi)$) 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; ESNZ 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