# INT2022-05 Determining the resilience of Fiordland corals to fisheries impacts

## Year 1 interim report
## June 2023

**Professor James J. Bell**
**Ms Miriam Pierotti**
**Victoria University of Wellington**

## Introduction

*Antipathella fiordensis* is a black coral species in the order Antipatharia, named because their chitinous skeletons are black. This species was first described as *Antipathes fiordensis* in New Zealand in 1990 from material collected in Fiordland (Grange, 1990), with a 2001 taxonomic revision of the Antipatharia placing this species in the newly created genus Antipathella (Opresko, 2001). *A. fiordensis* is classified as an 'at risk' species based on its restricted range under the New Zealand Threat Classification Scheme (Freeman et al., 2013). This species has primarily been reported from the Fiordland Marine Area, although it is possible that it also occurs in deeper water around other parts of the South Island, and a likely colony has recently been reported at Kapiti Island. In Fiordland *A. fiordensis* is particularly abundant, and perhaps most importantly it occurs in very shallow water, with the distribution ranging from 4-5 m down to several 100 m (based on our recent observations). In addition to its intrinsic importance, the study of *A. fiordensis* also provides a rare opportunity to act as model for other deeper, less accessible black coral species that are likely to have similar population characteristics and may also be impacted by fishing activity.

*A. fiordensis* is commonly found across the Fiordland Marine Area, often forming large (several m across) complex 3-dimensional tree-like structures, which have been estimated in previous research to be several hundred years old (Hitt et al. 2020). Although this species is often characterised by these massive structures, the reefs in Fiordland also support a high abundance of much smaller, younger colonies, suggesting populations may be highly dynamic. Black coral colonies are most associated with steep cliff areas, although they also occur on any rocky substrate (including boulders and cobbles).

Our current knowledge of *A. fiordensis* is based on early work focusing on its distribution and reproductive output (Grange, 1990), population genetics (Miller, 1997), relationships with mutualistic ophiuroids (Parker et al., 1997), growth/ultrastructure (Goldberg and Taylor, 1989), age (Hitt et al., 2020) and distribution in relation to salinity (Jiang et al., 2015). The 3-dimensional and fragile nature of *A. fiordensis* makes it particularly susceptible to potting, line damage and other bottom contact fisheries. In addition, the shallow and coastal nature of *A. fiordensis* in Fiordland also renders it susceptible to a range of local stressors including changes in salinity and sediment (e.g., due to changes in land use, rainfall or hydroelectric water flow) and global stressors such as ocean warming and acidification.

The specific project objectives of these services, delivered to The Department of Conservation through the Conservation Services Programme project INT2022-05 are:

1. Increase understanding of the ecology and impacts of fishing on protected corals in Fiordland, including the black coral *Antipathella fiordensis* and stylasterid corals (see NOTE 1).

2. Improve our understanding of the distribution of Fiordland black corals inside and outside of fished areas and ascertain the extent of overlap between fishing activity and coral habitat.

3. Determine patterns of genetic diversity and likely routes of connectivity within and between Fiords.

4. Use varied approaches (modelling, SCUBA and remotely operated vehicle ('ROV') surveys, pre-existing data) to inform our understanding of protected coral resilience to fishing impacts and threats in Fiordland, which can then be applied to these taxa in a wider context.

There are four main approaches to address the project objectives and here we report on the initial progress with regards to each of these approaches (see NOTE 2). This is a three year project.

1. Fisheries impacts – compiling data from fisher surveys, observer and effort data from MPI, abundance surveys and temporal monitoring, and creation of a database of colony health status /observed fishing impacts.
2. Distribution patterns – based upon SCUBA and ROV surveys, black coral size and abundance will be determined at multiple locations in Doubtful, Dusky and Breaksea Sounds, and resulting data combined with environmental correlates.
3. Population models - Existing data (subject to availability), coupled with SCUBA and ROV surveys, and 3D photogrammetry, will be used to create population models, and will incorporate estimated recruitment, mortality and growth rates.
4. Connectivity patterns between coral populations will be determined across vertical gradients, and between fished and unfished areas using genetic approaches.

NOTE 1: That while ROV video collected during this project will contain some information on the distribution of stylasterids (since they generally occur below 30 m), there is no provision in this contract to analyse data for these videos, and further specific survey work is outside the scope of this contract.

NOTE 2: This contract started in April 2023 and therefore this report only contains progress to date and several of the methodologies/approaches are still under development.

## Progress to date and method development

Although black corals are found throughout the Fiordland region, this project is exclusively focused on Doubtful, Breaksea and Dusky Sounds (Figure 1) because: 1) resource availability prohibits working across the entire distribution range of black corals in the fiords; 2) these three fiords are relatively easy to access; and 3) there are extensive ecological data sets available for these areas and we have existing projects here, which will be drawn upon for this project. Our research includes areas inside and outside of the Fiordland Marine Area habitat protection zone, and the specific areas we have visited to date are shown in Figures 2, 3 and 4.

Cruises completed to date:

We have already completed three research cruises in 2023, during which some work that contributes to this project was undertaken opportunistically. These cruises were not exclusively focused on black coral research, and the funding allocation from CSP only supports one such research trip during each year of the project:

January 9th-14th 2023 – RV Southern Winds – focused on Doubtful and Thompson sounds
March 17th-22nd 2023 – MV Pembroke – focused on Dusky and Breaksea Sounds
May 17th-13th 2023 - MV Pembroke – focused on Dusky and Breaksea Sounds

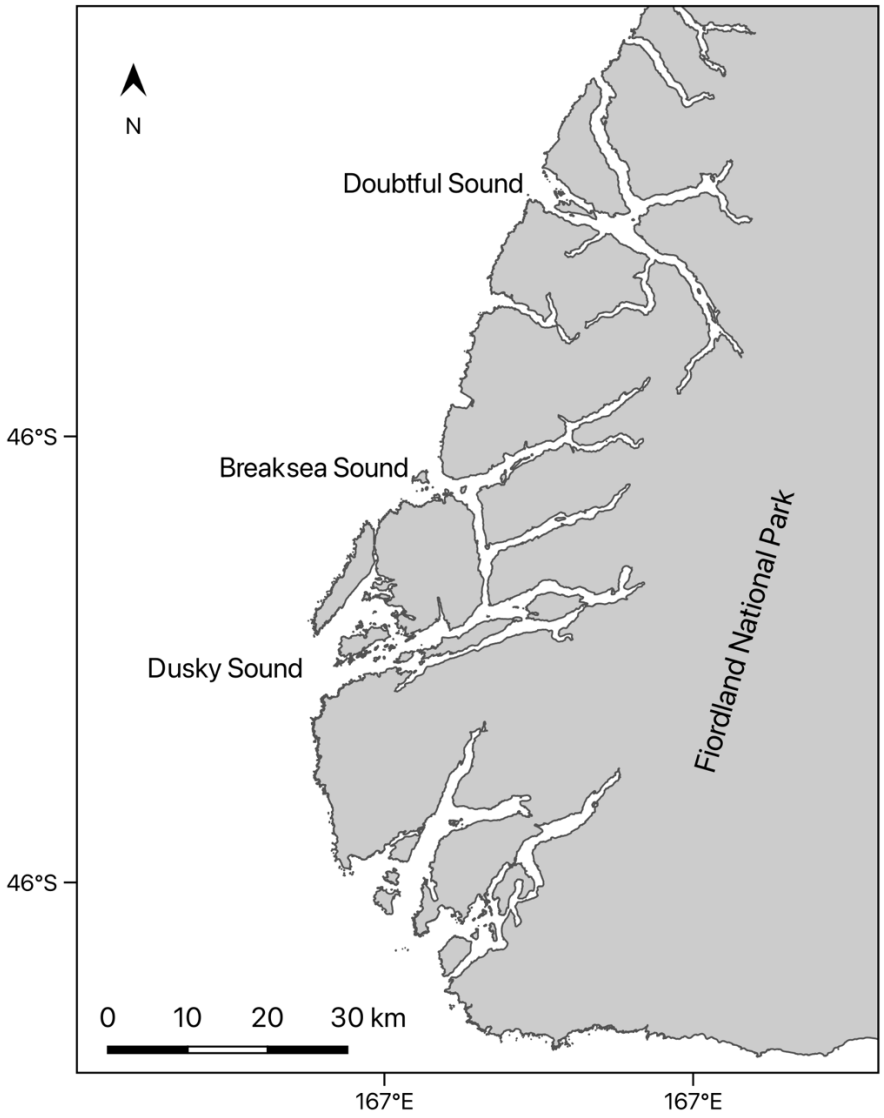


**Figure 1**. Location of Doubtful, Breaksea and Dusky Sounds in Fiordland

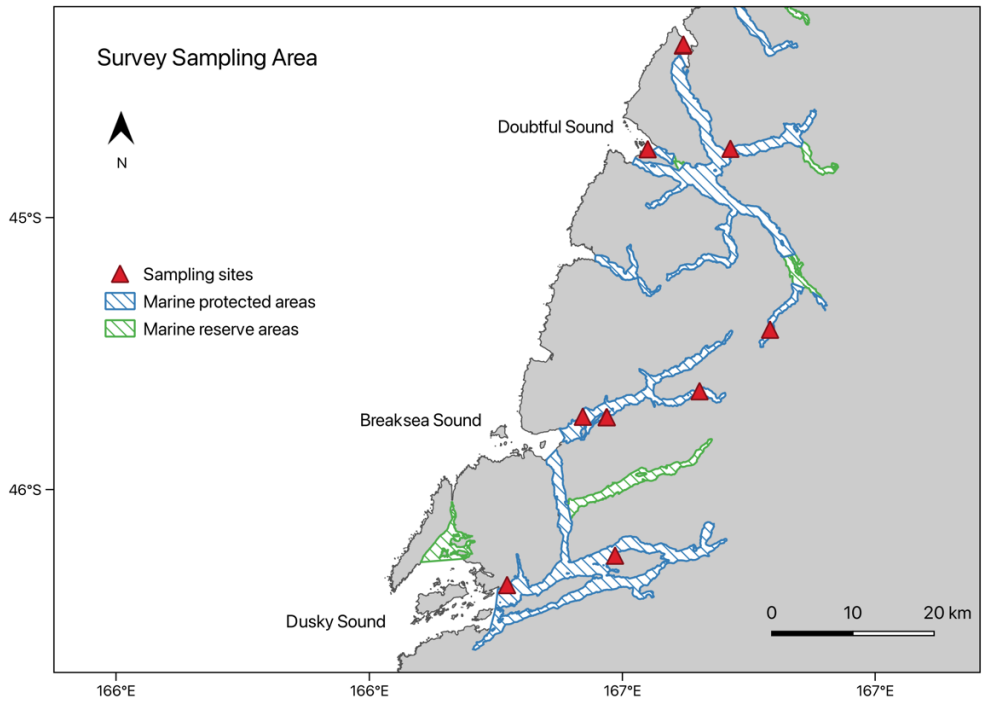


**Figure 2.** Sampling locations visited during the 2023 research cruises in Fiordland where specific black coral work was conducted. See subsequent Figures for specific abundance and genetic sampling locations.

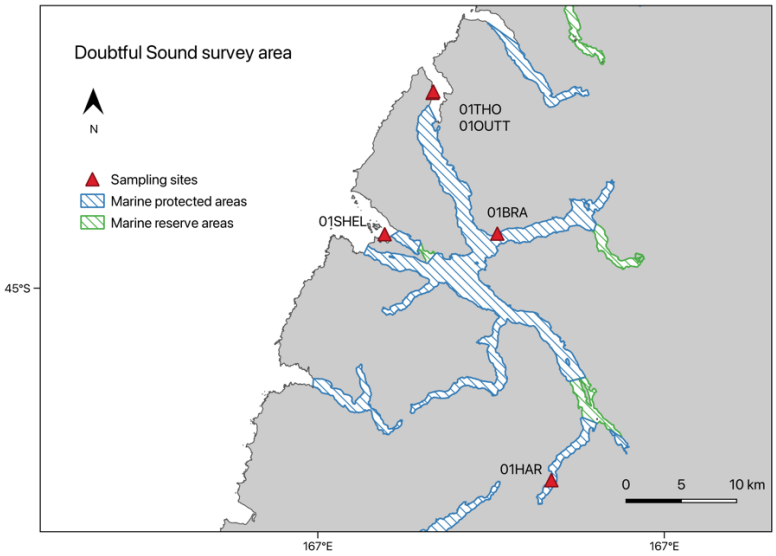


Figure 3. Sample sites and codes in Doubtful Sound.

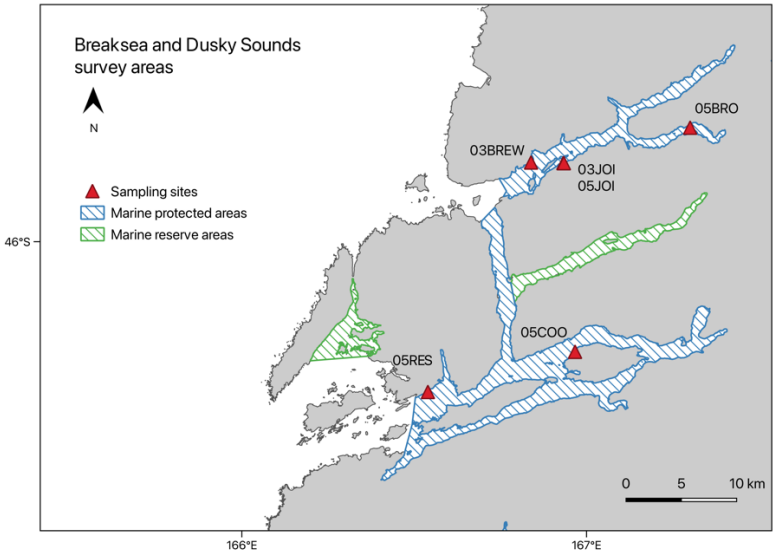


Figure 4. Sample sites and codes in Breaksea and Dusky Sounds.

**Fisheries impacts**

The approaches being considered for this component include compiling data from fisher surveys, observer and effort data from MPI, abundance surveys and temporal monitoring, and the creation of a database of colony health status/observed fishing impacts/presence of pots.

So far we have only focused on collecting information on 'loose' fishing pots and other gear, which has been collected as we have conducted our abundance surveys and during the collection of genetic samples. We have recorded the location, depth, condition and any other data/information about the pots/lines we observed.

**Distribution patterns**

We have already conducted surveys at a nine locations in the fiords and are collecting abundance data based on shallow (15-18 m) and deep (>50 m) surveys. We have used 3 x 20 m transects (2 m either side of the tape) for shallow observations using SCUBA, with size (width and height) measured for each coral observed in the transects. For deeper surveys, we have used a combination of our Boxfish Remotely Operated Vehicle and our Chasing ROV with a Gopro Hero 10 mounted. Where possible, we drive the ROV along approximately 60 m of reef (based on using the ROV lasers). This information is then used to estimate abundance and size. It is important to note that ROV surveys in Fiordland are not straightforward and it will only likely be possible to survey a small number of deep water sites. We anticipate continuing to collect deep water data through the 3 years of the project.

**Population models**

We plan to use preexisting data collected by The Cawthron Institute and NIWA as part of the long-term Meridian Energy monitoring programme. We have requested access to monitoring photographs taken between 2008 and 2021 at multiple sites across Doubtful Sound. These photographs are taken off the same area of reef. We will specifically extract information on settlement and mortality rates for black corals as we will be able to track these events through time from the pictures. A request for access to the data has been discussed with Cawthron and a data request has been sent to Meridian Energy and we expect to have a reply within 2 months. We will use this data to parameterise a size structured model, and specifically we will reassess all the photographic data collected as part of the Meridian monitoring programme to estimate recruitment and mortality rates. This will be used, combined with our abundance data, to parameterise our models. Grow rates will be determine using 3D photogrammetry, which we have recently trialled using several methods. By combining 3D photogrammetry of specific corals, with the 3D characterisation of the local reef where they live (50 m2), we no longer need to tag specific corals as we can relocate them from the 3D maps.

We will build models to represent the population dynamics of black corals from different locations in Doubtful Sound (where the Meridian data is available). We will then use these models to model changes to black coral populations under different recruitment/mortality/impact scenarios.

**Connectivity patterns between coral populations**

A previous study on *A. fiordensis* detected genetic structure (i.e, distinct black coral populations) among populations at scales of 10-15 km (Miller, 1997), although the data showed greater differentiation within fiords compared to between fiords. Miller (1997) proposed this unusual pattern was the result of a population that has not yet reached equilibrium due to a combination of the effects of recent colonisation, asexual reproduction, and the potential longevity of individual coral genotypes. However, this earlier study was conducted using allozyme genetic markers, which are no longer used due to difficulties in isolating the impacts of selection on genetic patterns and limited ability in some cases to resolve population structure. As genetic connectivity can be used to inform population resilience by identifying source and sink populations, and isolated populations, this project component will investigate the population genetic structure of *A. fiordensis* using Genome-Wide SNPs. Single nucleotide polymorphisms (SNPs) represent the most abundant type of variation in DNA sequences among individuals in a population (Bossart and Pashley Prowell, 1998; Vignal et al., 2002). They can occur in coding and non-coding regions and therefore it is possible to use them to investigate not only genetic structure (using neutral SNPs) but also adaptive variation in populations (using SNPs under selection) (Morin et al., 2004).

We will map a Whole Genome Sequence (WGS) for *A. fiordensis* and subsequently identify a panel of SNP markers, which will be used to assess the levels of connectivity and gene flow within and across fiords and between different depths. We will also use these markers (outlier SNPs) to detect any evidence for local adaptation of populations and how environmental gradients in the fiords or possibly fisheries impacts are driving the genetic structure (Hoey et al., 2016; Holland et al., 2020). Understanding vertical connectivity is also important as it will provide information on whether deeper black coral populations can potentially replenish shallower populations (or vice versa) if they are impacted by some external stressor.

*Antipathella fiordensis* samples will be collected across Doubtful, Dusky and Breaksea Sounds to assess within and between fiord connectivity. Sampling locations will be distributed along the fiords from the inner part to the most outward part of the fiords (where commercial fishing is conducted) and separated at different spatial scales from 1 km to 100s km. We plan (depending on the final sequencing depth required) to characterise a total of 10 sampling sites across the fiords. Shallow populations will be sampled at all sites, while both shallow (between 0-20 m) and deep populations (70-100 m) will be sampled at 2 sites to assess vertical connectivity.

Small colony fragments will be collected from 20-25 individuals of *A. fiordensis* along a transect of 50 m. Specimens from shallower populations will be collected by SCUBA diving while deep colonies will be collected using a ROV (a trail has already been made). Upon collection, the

specimens will be preserved in DESS and stored at 4°C. We have been trialing several different DNA extraction kits to get very high-quality DNA for WGS. Samples will be sequenced on the Illumina platform. Sequences will then be compared against the reference genome and between individuals of different populations to identify genomic variants (e.g., SNPs) throughout the genome. Further detailed methodology will provided in a future report.

## Results and discussion

### Fisheries impacts

We have already found loose pots both within commercially and non-commercially fished areas, and the locations of these pots are shown in Figure 5. These were mostly found below 25 m, and in all but one case no longer had more than 2-3 m of rope attached. It is not possible to determine when these pots were placed on the seafloor, although the pots observed in the inner waters of the fiords are likely to have been in place since at least 2005 when commercial fishing ceased in these areas.

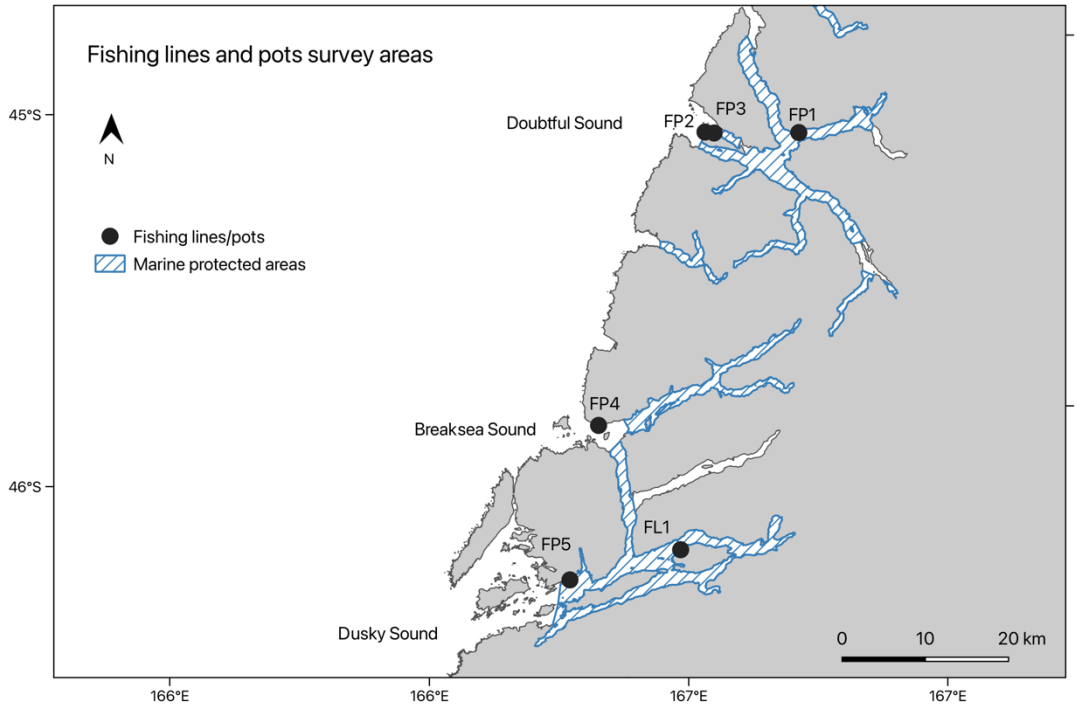


**Figure 5.** Locations of 'loose' cray pots found during SCUBA and ROV surveys between Jan and May 2023 based on visiting nine locations.

## Distribution patterns

We have collected abundance data from nine shallow water populations so far (Figure 6), although no data has yet been collected from deeper video footage. The general trend we have been observing is an increase in coral abundance from the inner to the outer parts of the fiords. However, our size data (Figure 5), suggests those corals in the inner parts of the fiords are much larger than those in the outer areas. Our initial observations suggest that recruitment rates are greater towards the outer parts of the fiords as we see many very small corals. However, we have not yet explored possible reasons for these differences. We plan to compare our data with early data collected by Ken Grange.

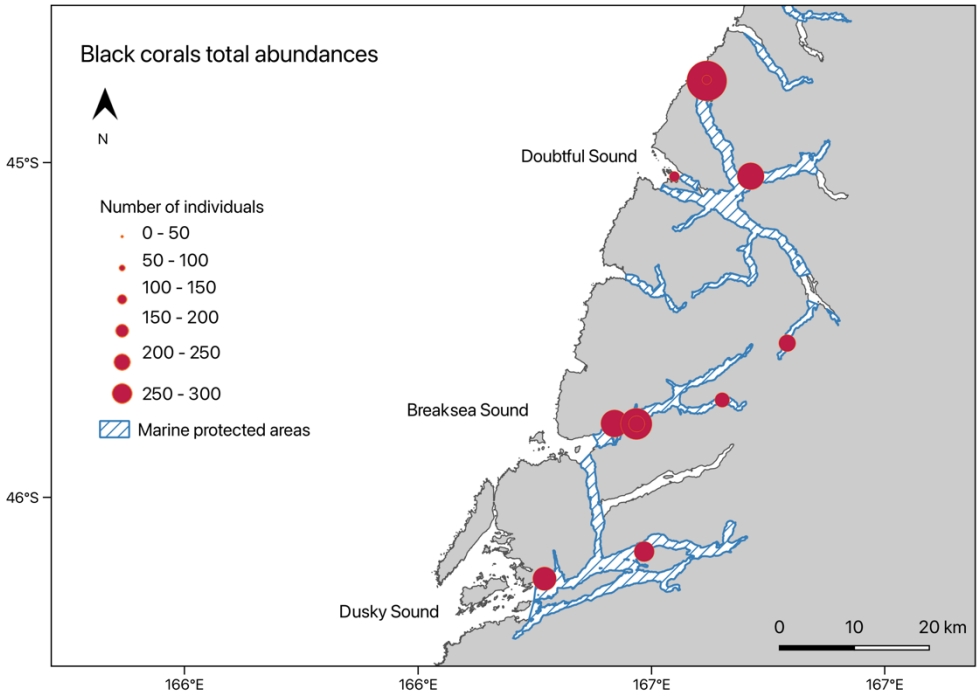


**Figure 6**. The abundance of black corals at 15 m, based on 3 x 20 m transects at each location.

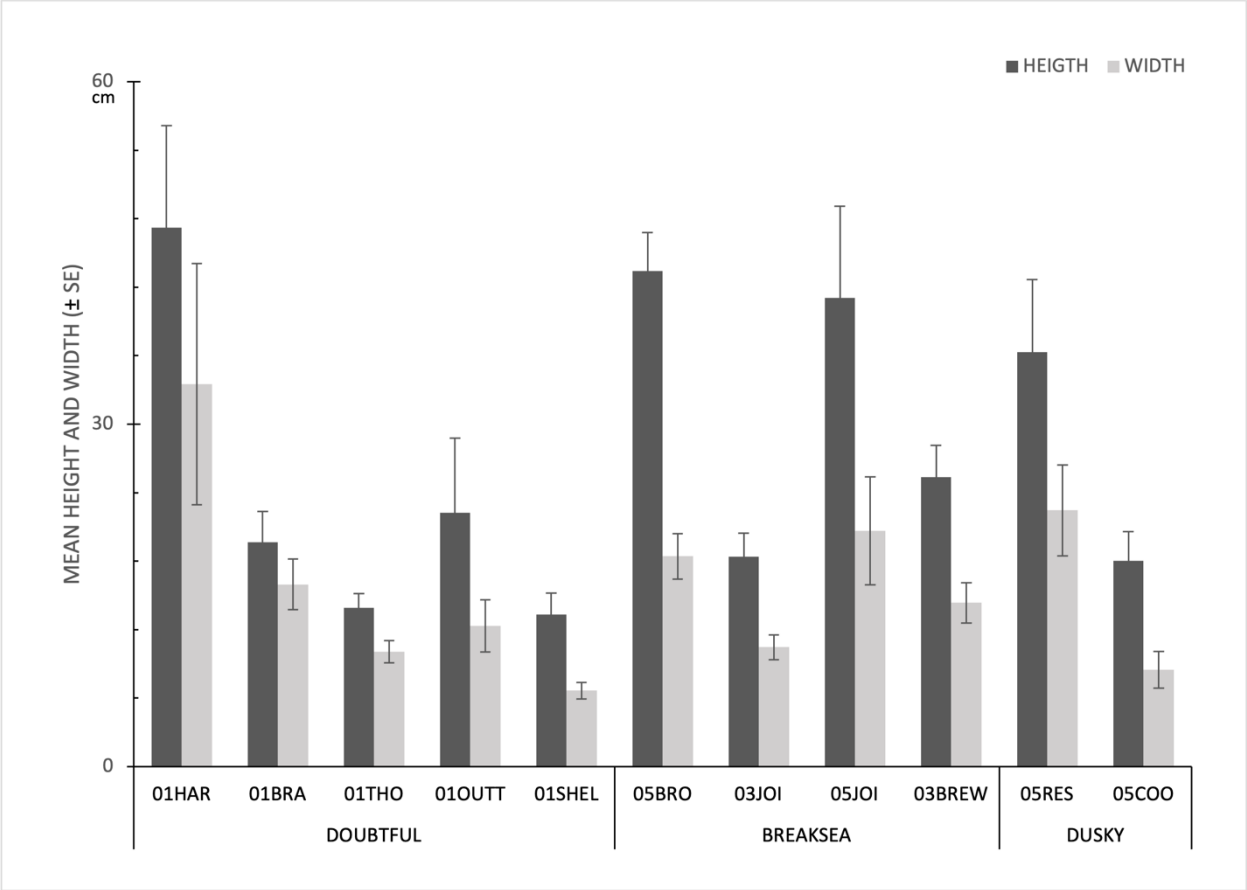


Figure 7. Mean height and width (cm) of black coral across three Fiords. Location codes are shown in Figure 3 and 4, and are arrange from outer to inner fiord locations from left to right.

**Population models**

While some progress has been made in conceptual model development, we are waiting on data before we can progress this further. We have however, been trialling methods to measure growth rates using 3D photogrammetry and a 3D reconstruction of a single coral is shown in Figure 8. We expect to measure growth using increases in branch lengths, since these 3D models allow very accurate (+/- 0.2 mm) measurements of the corals to be made.

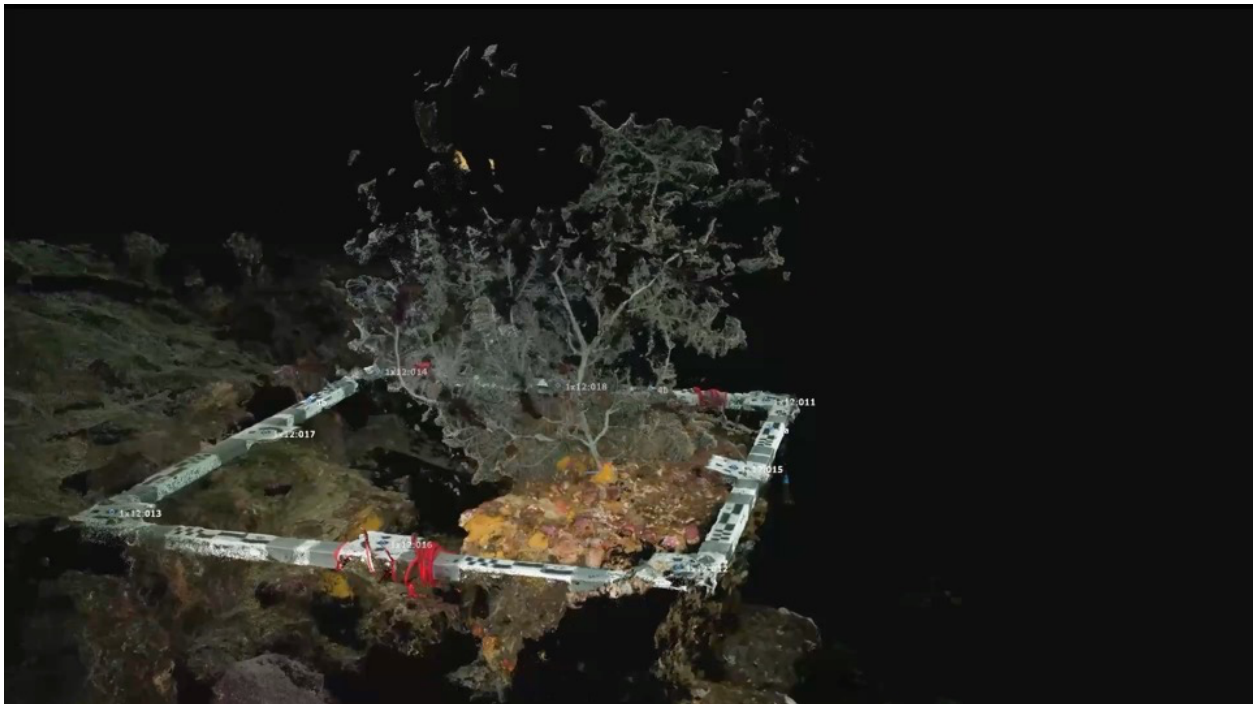

Figure 8. An example of 3D photogrammetry used to recreate a black coral.

**Connectivity patterns between coral populations**

We have collected shallow water coral samples from four populations for genetic work, and successfully tested our ability to collect deeper water samples with the ROV. We have trialled several DNA extraction methods and expect to begin sequencing for the creation of our WGS by early July.

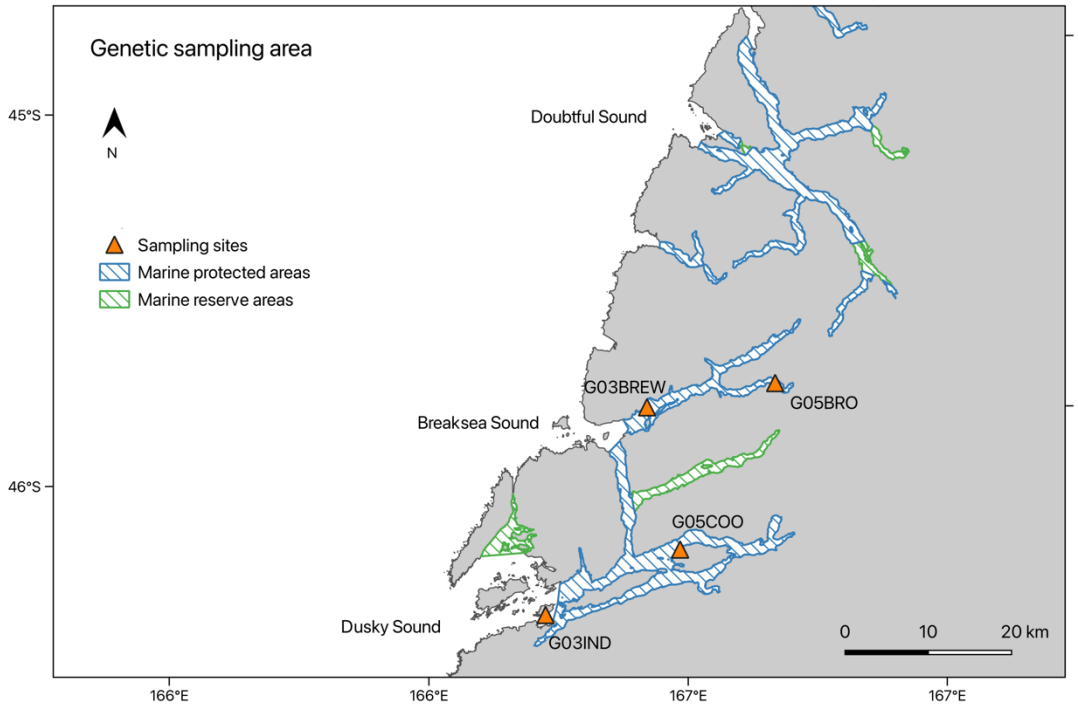


**Figure 9**. Locations where shallow water black coral populations (n=20) have been collected to date for genetic analysis.

## Future plans

We have two further research cruises planned for year two of this project, where will collect all remaining genetic samples (including those from the deep), and complete more deep and shallow water abundance surveys. We also expect to have a full genome sequence available by December 2024, and will begin population analyses as soon as we have our genome complete.

## Acknowledgments

This project is supported by Dr Alice Rogers and Associate Professor Peter Ritchie from Victoria University of Wellington, and Dr Lyndsey Holland from the Department of Conservation. We acknowledge the financial support provided by the Department of Conservation, Victoria University of Wellington and The George Mason Charitable Trust. We are grateful to the crew of the RV Southern Winds, Hannah, Chris and Ross, and particularly Richard Kinsey. We also acknowledge the help and support of Paul and Katherine Mitchell from Fiordland charters and the MV Pembroke. This work was completed as part of the Southern Fiordland Initiative. Finally,

we acknowledge Gabriela Wood, Manon Broadribb, , Valerio Micaroni, Francesca Strano, and Georgia Ryan for help with fieldwork, and Matteo Collina for the 3D photogrammetry work.

## References


Bossart, J.L., Pashley Prowell, D., 1998. Genetic estimates of population structure and gene flow: Limitations, lessons and new directions. Trends Ecol. Evol. 13, 202–206. https://doi.org/10.1016/S0169-5347(97)01284-6

Freeman, D., Marshall, B., Ahyong, S., Wing, S., Hitchmough, R., 2013. Conservation status of New Zealand marine invertebrates, 2009. N. Z. J. Mar. Freshw. Res. 44, 129–148. https://doi.org/10.1080/00288330.2010.495373

Goldberg, W.M., Taylor, G.T., 1989. Cellular structure and ultrastructure of the black coralAntipathes aperta: 1. Organization of the tentacular epidermis and nervous system. J. Morphol. 202, 239–253. https://doi.org/10.1002/jmor.1052020210

Grange, K.R., 1990. *Antipathes fiordensis* , a new species of black coral (Coelenterata: Antipatharia) from New Zealand. N. Z. J. Zool. 17, 279–282. https://doi.org/10.1080/03014223.1990.10422603

Grange, K. R. and Goldberg, W. M., 1992. Chronology of black coral growth bands: 300 years of environmental history? Proc. Second Int. Temperate Reef Symp., New Zealand: 169-174

Hitt, N.T., Sinclair, D.J., Fallon, S.J., Neil, H.L., Tracey, D.M., Komugabe-Dixson, A. and Marriott, P., 2020. Growth and longevity of New Zealand black corals. *Deep Sea Research Part I: Oceanographic Research Papers*, *162*, p.103298.

Hoey, A.S., Howells, E., Johansen, J.L., Hobbs, J.-P.A., Messmer, V., McCowan, D.M., Wilson, S.K., Pratchett, M.S., 2016. Recent Advances in Understanding the Effects of Climate Change on Coral Reefs. Diversity 8, 12. https://doi.org/10.3390/d8020012

Holland, L.P., Rowden, A.A., Hamilton, J.Z., Clark, M.R., Chiswell, S., Gardner, J., 2020. Genetic connectivity of deep-sea corals in the New Zealand region. Ministry for Primary Industries, Wellington.

Jiang, W., Cornelisen, C., Knight, B., Gibbs, M., 2015. A pattern-oriented model for assessing effects of weather and freshwater discharge on black coral (Antipathes fiordensis) distribution in a fjord. Ecol. Model. 304, 59–68. https://doi.org/10.1016/j.ecolmodel.2015.02.020

Miller, K., 1997. Genetic structure of black coral populations in New Zealand's fiords. Mar. Ecol. Prog. Ser. 161, 123–132. https://doi.org/10.3354/meps161123

Morin, P., Luikart, G., Wayne, R., 2004. Morin PA, Luikart G, Wayne RK. SNPs in ecology, evolution and conservation. Trends Ecol Evol 19: 208-216. Trends Ecol. Evol. 19, 208–216. https://doi.org/10.1016/j.tree.2004.01.009

Opresko, D.M., 2001. Revision of the Antipatharia (Cnidaria: Anthozoa). Part I. Establishment of a new family, Myriopathidae.

Parker, N.R., Mladenov, P.V., Grange, K.R., 1997. Reproductive biology of the antipatharian black coral Antipathes fiordensis in Doubtful Sound, Fiordland, New Zealand. Mar. Biol. 130, 11–22. https://doi.org/10.1007/s002270050220

Vignal, A., Milan, D., SanCristobal, M., Eggen, A., 2002. A review on SNP and other types of molecular markers and their use in animal genetics. Genet. Sel. Evol. 34, 275. https://doi.org/10.1186/1297-9686-34-3-275