NIWA
Taihoro Nukurangi

Resilience of deep-sea benthic communities to the effects of sedimentation (ROBES) research webinar

Whakatōrea te pūtaiao, kia kimihia ai e te rangahau tika!

Date: Thursday 30th June 2022
Time: 9:00 am –1 pm
Place: Teams Meeting ***ROBES webinar link*** and email: Jess Moffat Jess.Moffat@niwa.co.nz
NIWA Wellington Main Conference Room (presenters)

AGENDA

Time	**Topic**	**Presenter(s) all NIWA unless otherwise stated**
0900	*Opening Mihi and Karakia from NIWA's Pou Ārahi – Māori Development Leader*	Lee Rauhina-August
0905	*Programme Overview, and context for today's Webinar*	Malcolm Clark (Programme Leader)
0920	*Engagement with Tangata Whenua; opportunity for tangata whenua to respond (tbc)*	Lee Rauhina-August; Tangata whenua partners
0940	*Communication / Stakeholder engagement*	Di Tracey
0945	*Where the data come from: Tangaroa field surveys on the Chatham Rise*	Malcolm Clark et al
1000	*Interannual variability of the subtropical front on Chatham Rise from glider observations*	Charine Collins et al
1015	*Bottom boundary layer responses induced by a benthic disturber*	Joe O'Callaghan et al
1030	Morning tea break	
1045	*Near-bed sediment dynamics and fluxes within the Subtropical Frontal Zone on the Chatham Rise*	Scott Nodder et al
1100	*Sedimentation experiment indicates that macrofauna may be initially resilient to deep-sea mining*	Campbell Murray (now FNZ), Ashley Rowden
1115	*Effects of experimental in situ seabed disturbance on meiofaunal communities of Chatham Rise*	Daniel Leduc et al
1130	*Ship-board seafloor sediment experiments*	Rachel Hale et al
1145	*Can deep sea corals and sponges cope with elevated suspended sediments?*	Vonda Cummings et al
1200	*Concluding remarks: Where to next - future steps*	Malcolm Clark
1215	*Discussion*	
1300	*Closing Mihi and Karakia*	Lee Rauhina-August

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UNIVERSITY OF WELLINGTON

THE EFFECTS OF SEDIMENTATION IN THE DEEP SEA: Resilience Of deep-sea Benthic communities to the Effects of Sedimentation ("ROBES")

PROGRAMME OVERVIEW

Malcolm Clark

NIWA
Taihoro Nukurangi

Climate, Freshwater & Ocean Science

ROBES End-users webinar, 30 June 2022

1

Background

- A large proportion of the offshore deep seas around New Zealand is soft sediment, which can be easily disturbed by human activities
- Impacts on biological communities have been studied in near-shore coastal environments, but little information exists on tolerances of fauna from deeper shelf waters
- Motivation for this work was twofold:
    - interest in offshore mining, uncertainty of the actual effects of sediment plumes on benthos (e.g. EPA decisions for TransTasman Resources and Chatham Rock Phosphate);
    - increased awareness of fisheries impacts (MSC certification of bottom trawl fisheries, e.g. hoki and orange roughy).
- An MBIE 5 year Endeavour project 2016-2021
    - ROBES: Resilience Of deep-sea Benthos to the Effects of Sedimentation

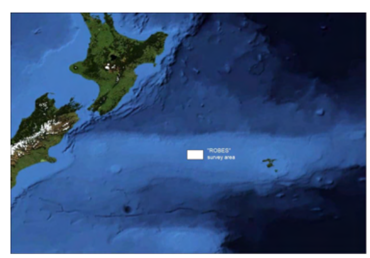
2

Objectives:

- Principal objective
  - to determine impacts of, and measure recovery of benthic communities over time from, sedimentation effects
- Four key questions:
  - Can we determine and quantify effects of settled and suspended sediment from plumes on benthic communities in situ?
  - Are some communities more resilient than others to various levels of particle sizes and concentrations?
  - Can thresholds of acute or sub-lethal levels of sedimentation be defined where impacts upon benthic communities become ‘ecologically significant’?
  - Can impacted benthic communities recover in the short to medium term?

3

The Approach



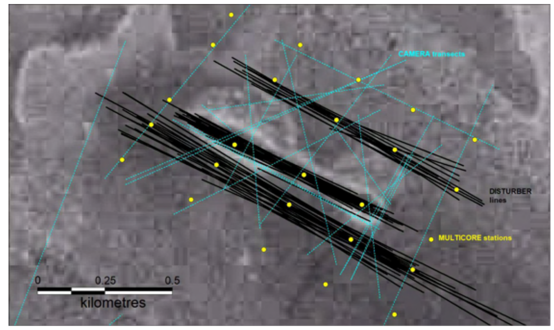
- Two components
- **Field disturbance experiment**
  - Direct physical disturbance, monitor plume, sedimentation rates and composition, biological effects.
  - Three surveys:
    - Survey 1 (2018): baseline, disturbance, monitor
    - Survey 2 and 3 (2019, 2020): monitoring
    - Impacts over days-weeks, 1 year, 2 years
  - Chatham Rise survey area (400-500m)
- **Laboratory sedimentation experiments**
  - coral and sponge species in tanks
  - Manipulate sedimentation from low to high
  - Monitor over weeks to months

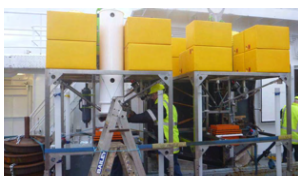
4

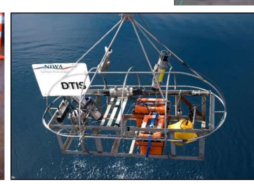
Field survey

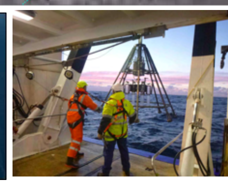
- Disturbance
  - NOAA Benthic Disturber (2018) NIWA “SCIP” (plough) (2019)
  - Multiple transects run, >30 hr periods
  - Area termed “Butterknife
- Monitoring survey
  - Before, After (1 week), After (1 year, some 2 year))
- Oceanography (and water column)
  - Ocean glider, CTD, acoustics, ADCP moorings
- Sedimentation
  - Benthic landers, Sediment trap moorings, multicorer, acoustics
- Biological communities
  - Towed camera, multicorer, beam trawl, sled









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Laboratory-based experiments

- Experiments in NIWA’s Marine Environmental Manipulation Facility (Wellington)
- Live-capture of specimens during voyages (onboard aquaria)
- Two species
  - Knobbly sandpaper sponge (*Ecionemia novaezelandiae*)
  - Stony coral (*Goniocorella dumosa*)
- Treatments
  - Control temperature, pH, water flow; based on in situ environmental data
  - Introduce various suspended sediment concentrations (0, 50, 100, 500 mg/l)
- Measure responses
  - survival
  - metabolism (respiration)
  - feeding activity (clearance rates, particle size)
  - structural damage
  - behaviour (mucous production/opening of valves)



6

Work streams

- Biological community responses
  - Infauna-macrofauna, meiofauna, bacteria (based on multicore samples)
  - Epifauna (largely MEMF experiments)
  - Genetic/microbiome responses to suspended sediment (linked to MEMF experiments)
- Sedimentation experiments
  - Sediment erosion, elutriation, sediment capping data analyses
  - Sediment community respiration analyses
  - DGT sample processing (trace metals)
- Sediment samples
  - Multicorer (pre- & post-disturbance, 3 sites) grain size, physico-chemical characteristics (TOM, water content, CaCo3, POCPN/isotopes, chl/phaeopigments)
  - Benthic lander data (Aquascat, Aqualogger, sediment sample calibration, sediment analyses (as per MUC), ADCP
- Water column dynamics
  - CTD water samples (nutrients, chl/phaeopigments, DIC/alkalinity, Ecotriplet & Aqualogger (DTIS as well))
  - Optics data-glider & CTD (cdom, fluorescence), DIC, DOC, water chemistry
  - Benthic Boundary layer (thickness, stability)-glider data
- Acoustic data
  - MBES and Fisheries sounders multifrequency (pre- and post-disturbance transects)
- Seafloor imagery
  - Natural sedimentation levels
  - Persistence of Disturber marks

7

Presentations today - a range of illustrative results

- Oceanography
  - Variability in Subtropical Front: Charine Collins
  - Benthic Boundary Layer and water column impacts: Joe O'Callaghan
- Sediment dynamics
  - Natural fluxes and disturbance effects: Scott Nodder
- Faunal responses to disturbance
  - Macrofauna: Campbell Murray
  - Meiofauna: Daniel Leduc
- Ship-board sediment experiments
  - Variety of experimental work: Rachel Hale
- Laboratory experimental exposure
  - Coral and sponge sensitivity: Vonda Cummings (Di Tracey and Valeria Mobilia)

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Agenda

Time	Topic	Presenter
0900	Opening Mihi and Karakia	Lee
0905	Programme overview	Malcolm
0920	Engagement with Tangata Whenua	Lee
0940	Communications	Di
0945	Where the data come from	Malcolm
1000	Variability of the SubTropical Front	Charine
1015	Bottom Boundary Layer responses	Joe
1030	Morning tea break	
1045	Near-bed sediment dynamics and fluxes	Scott
1100	Macrofauna responses to impact	Campbell
1115	Meiofauna responses to impact	Daniel
1130	Onboard sediment experiments	Rachel
1145	Laboratory experiments	Di and Valeria
1200	Next steps	Malcolm
1215	Open Discussion	All
1300	Closing Mihi and Karakia	Lee

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ACKNOWLEDGEMENTS

- Funding from the Ministry of Business, Innovation and Employment (contract CO1X1614)
- The support and advice of the project End-User Advisory Group
- Vessel time was provided by MBIE through the Tangaroa Advisory Group

- The ROBES team includes:
  - Biology: Malcolm Clark, Ashley Rowden, Daniel Leduc, Steve George, Rob Stewart, Di Tracey, Alan Hart, Campbell Murray (VUW)
  - Oceanography: Joanne O'Callaghan, Charine Collins, Mark Hadfield, Cliff Law
  - Sedimentology: Scott Nodder, Peter Gerring, Chris Hickey, Chris Eager, Rachel Hale, Conrad Pilditch (UoW), Grace Frontin-Rollett
  - Laboratory experiments: Vonda Cummings, Jenny Beaumont, James Bell (VUW), Valeria Mobilia (VUW), Di Tracey, Neill Barr, Graeme Moss, Jaret Bilewitch, Sarah Seabrook
  - Acoustics: Arne Pallentin, Yoann Ladroit
  - Engagement and Communication: Lee Rauhina-August, Di Tracey

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10

Whakatōrea te pūtaiao, kia kimihia ai e te rangahau tika!
Engagement with Tangata Whenua

Lee Rauhina-August Pou Ārahi – Māori
Development Leader

ROBES End-users Webinar June 30 , 2022

Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi

1

Whakatōrea te pūtaiao, kia kimihia ai e te rangahau tika!
Engagement with Tangata Whenua

Vision Mātauranga potential realised
Engagement & outreach a priority for ROBES
with tangata whenua

He miramira o te kaupapa – highlights of the engagement aspects of the programme

- **continued to disseminate information and liaise with to iwi/ hapū**
  - **- see information flyers (n=12)**
- **organised 3x visits to Wharekauri / Rēkohu / Chatham Islands**
- **iwi participation on *Tangaroa* voyages (Apirana, Cass, Lee)**

2

Hononga – Partnership

- **Lee & Malcolm met with tangata whenua; Hokotehi Moriori Trust, Te Aitanga o ngā uri o Wharekaurii, Ngāti Mutunga o Wharekauri Trust and Ngāi Tahu**
- **ROBES staff visited Wharekauri/Rēkohu in 2019 (Lee, Malcolm) 2020 (Lee, Malcolm Joanne) & 2021 (Lee, Malcolm, Di)**
- **2021 visit presented on the results ROBES plus on other projects – impressive engagement and indication of strong growth in our partnership**
  - **'Crustaceans as Indicators of Marine Environmental Change (CAIME)'**
  - **naming process of two new amphipod species (research also under CAIME)**
  - **MBIE Smart Idea Project 'Using deepsea corals to reconstruct baseline ocean dynamics in NZ waters'**
  - **freshwater project Ngā Motu Tapu o Wharekauri.**
  - **Te Kūwaha and their role of ongoing engagement described at the hui, and various other science topics were raised – fisheries included**
  - **algae and paua sampling**
  - **spoke informally to local Councillors about the research**
  - **NIWA Charts delivered for display in the new Museum**

From these meetings, the project is better able to gauge and understand the viewpoint, share concerns, & discuss opportunities for groups to be involved in the research

3

Ngā pārongo ki te iwi - information to iwi/ hapū

information flyers (n=11) – also see website

Flyer 1 (left) and introduction sheet & Flyer 9 (right) our science-a sheet summarising sediment transport processes

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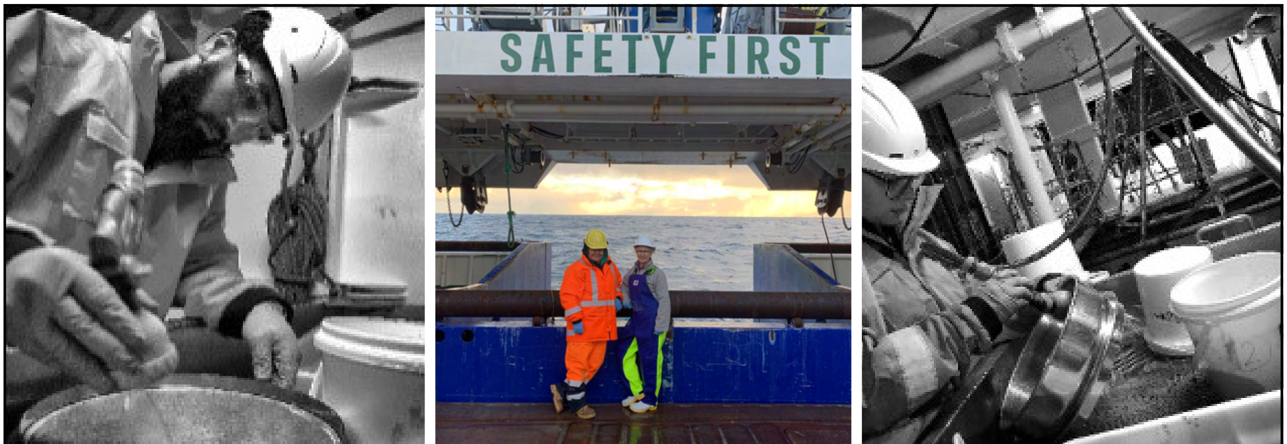


Tangata whenua participation on *Tangaroa* voyages:

Apirana Daymond - Te Aitanga o ngā uri o Wharekauri
Cassidy Solomon - Hokotehi Moriori Trust
NIWA's Pou Ārahi - Lee Rauhina-August

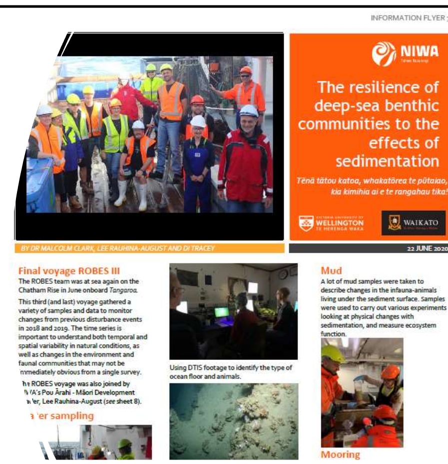
Kia mahitahi ai tātou katoa!

5

Communication / stakeholder engagement and partnerships

He miramira o te kaupapa – highlights of the engagement aspects of the programme

- End user Advisory Group Meetings (advice and feedback on research utility for end-users: Government agencies, Industry, NGOs, Te Kūwaha)
- Produced information flyers (n=12) for dissemination to iwi, hapu – and for website [Sedimentation effects | NIWA]
- Updated website
- RNZ Interview
- Sustainable Seas presentations 2018 & webinar 2021
- Stories for the NIWA Board e.g., Voyages; visit to Rēkohu / Wharekauri / Chatham Is
- Numerous conference papers, NZMSS (n= 2); Deepsea Biology Symposium 2021 (n=2); Geosciences 2020 (n=1); SETAC Australasia (n=1)
- Primary papers (n= 8 +2)


INFORMATION FLYER 7

NIWA

The resilience of deep-sea benthic communities to the effects of sedimentation

Tēnā tātou katoa, whakatōrea te pūtaiao, kia kimihia ai e te rangahau tika!

WELLINGTON TE HERENGA WAKA

WAIKATO

BY DR MALCOLM CLARK, LEE RAUHINA-AUGUST AND DI TRACEY

22 JUNE 2020

Final voyage ROBES III

The ROBES team was at sea again on the Chatham Rise in June onboard *Tangaroa*.

This third (and last) voyage gathered a variety of samples and data to monitor changes from previous disturbance events in 2018 and 2019. The time series is important to understand both temporal and spatial variability in natural conditions, as well as changes in the environment and faunal communities that may not be immediately obvious from a single survey.

The ROBES voyage was also joined by NIWA's Pou Ārahi - Māori Development Leader, Lee Rauhina-August (*see* sheet 8).

Water sampling

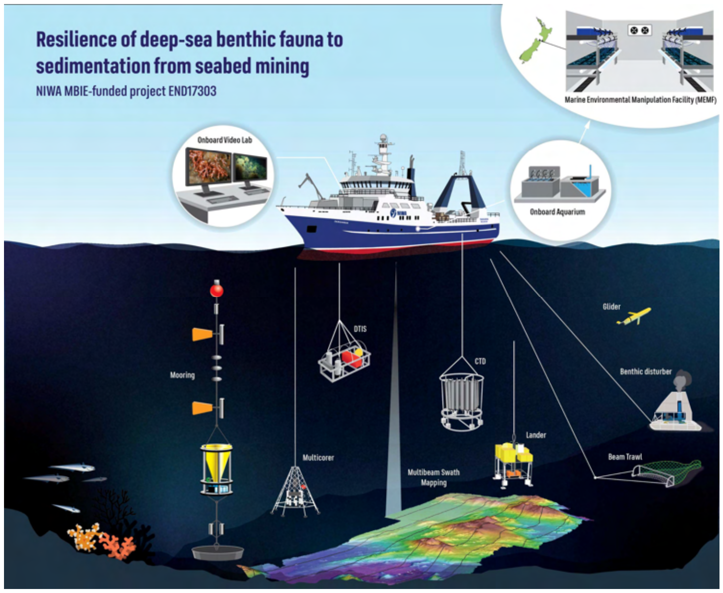
Using DTIS footage to identify the type of ocean floor and animals.

Mud

A lot of mud samples were taken to describe changes in the infauna-animals living under the sediment surface. Samples were used to carry out various experiments looking at physical changes with sedimentation, and measure ecosystem function.

Mooring

6


Resilience of deep-sea benthic fauna to sedimentation from seabed mining
NIWA MBIE-funded project END17303
Marine Environmental Manipulation Facility (MEMF)
Onboard Video Lab
Onboard Aquarium
Glider
DTIS
CTD
Mooring
Benthic disturber
Lander
Multicorer
Beam Trawl
Multibeam Swath Mapping

7

Field surveys on the Chatham Rise: where the data came from

Malcolm Clark, Daniel Leduc, Scott Nodder, Joe O'Callaghan, Ashley Rowden, Craig Stevens, Chris Hickey et al.

Climate, Freshwater & Ocean Science

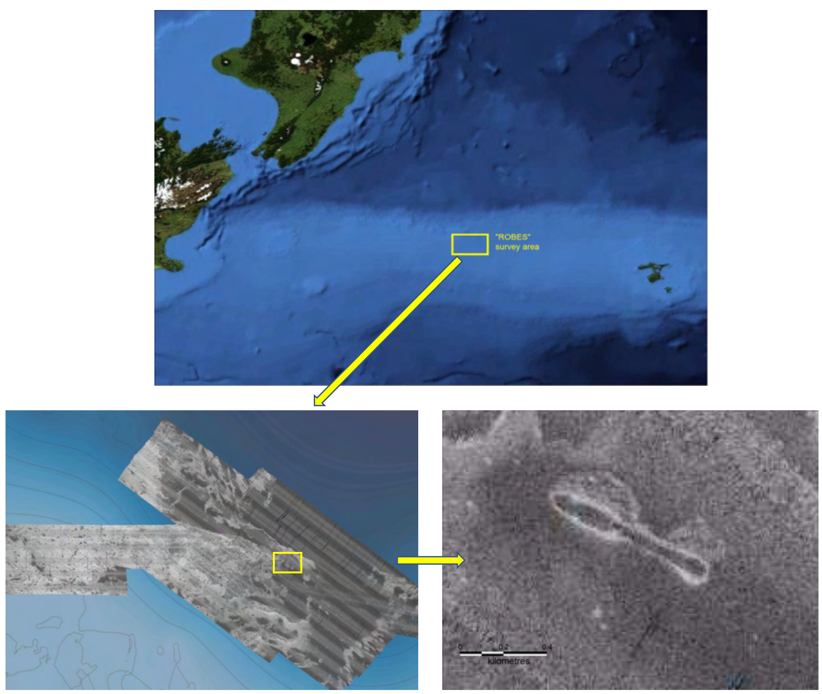
NIWA Taihoro Nukurangi

ROBES End-users webinar, 30 June 2022

1

Survey area

- Chatham Rise
- Relevance for potential phosphorite mining and bottom trawling
- Relatively well-studied so general background information
- Some existing data on coral distribution (main concern for impact)
- Two key areas:
    - Main Disturbance and Monitoring Area
    - Butterknife



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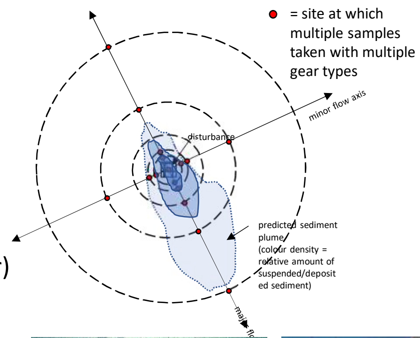
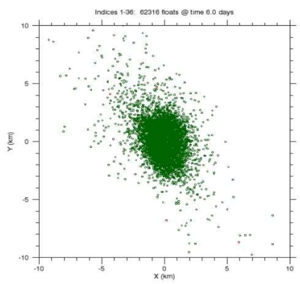
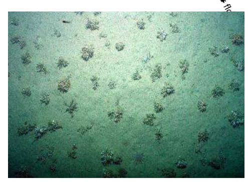
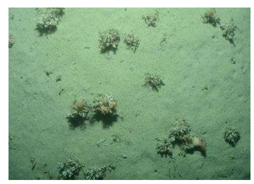
Survey concept

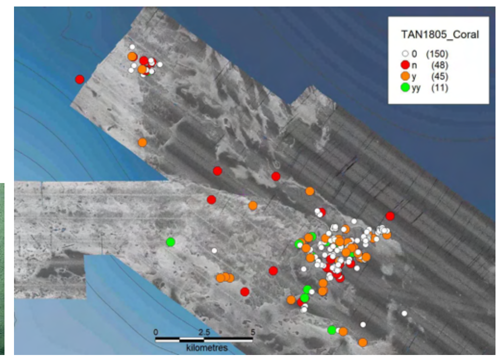
- Disturbance
  - Defined area, soft sediment
- Monitoring survey
  - Before, After (1 week, 1 year, 2 year)
  - Gradient design (linear/concentric)
  - Size and shape informed by prior hydrodynamic modelling
  - Sampling with many different gear types to measure many factors
- Adapted to suit distribution of:
  - Soft sediment (dark backscatter)
  - Coral distribution (target impact taxa)











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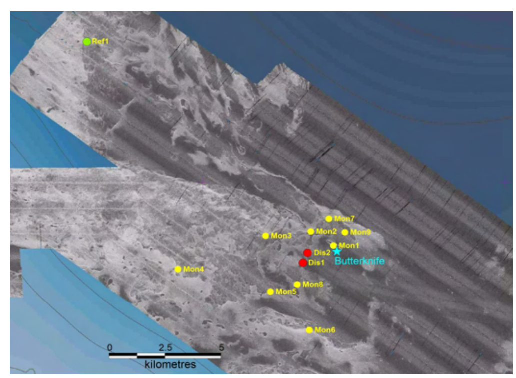
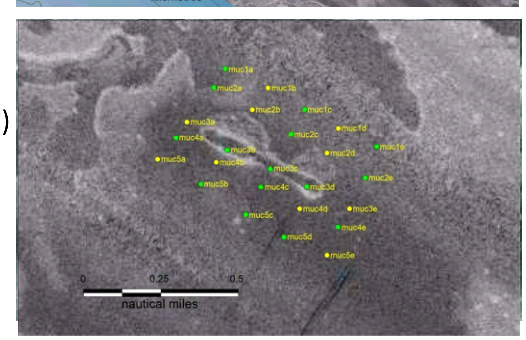
Baseline and Monitoring design

- Two versions of survey evolution
- General area
  - 2018, 2019, 2020
- Butterknife
  - (2018), 2019, 2020
- MON sites (1-8)
  - routine monitoring, within dispersal range
- DIS sites (1-2, plus Butterknife)
  - Sites within disturbance area (2018 BDR, 2019 SCIP)
- REF site (1)
  - Routine monitoring, outside any dispersal
- BUTT grid (25 sites-15 with SCOC)
  - Specific sediment sampling around Butterknife





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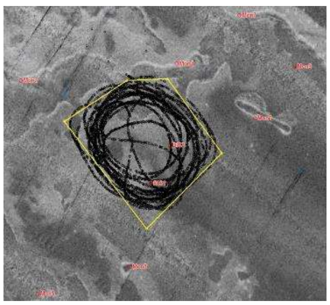
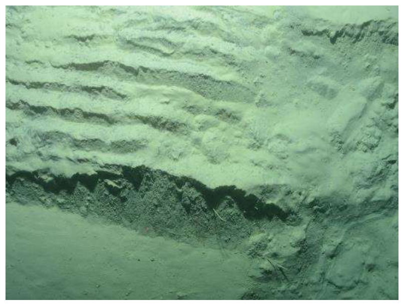
Disturbance

- 2018: NOAA Benthic Disturber
  - Used previously in abyssal plain test-mining areas in 1990s to simulate sediment cloud
  - Sucked up fine muds on surface but not silty sediments >4-5cm
  - Near-bottom currents meant rapid dispersal of cloud, so largely physical disturbance in area run by the Disturber





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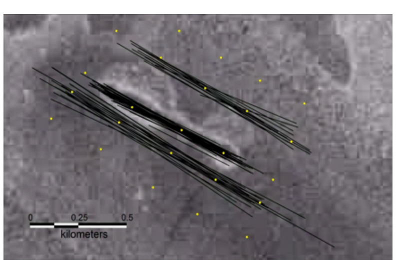
Disturbance (2nd try)

- 2019: NIWA "SCIP" (sediment cloud inducing plough)
  - Tynes, chains, harrow mat (roller damage meant minimal vertical throw)
  - Focussed on Butterknife near known coral thickets
  - Again evidence of fine mud dispersal but limited heavier particle suspension



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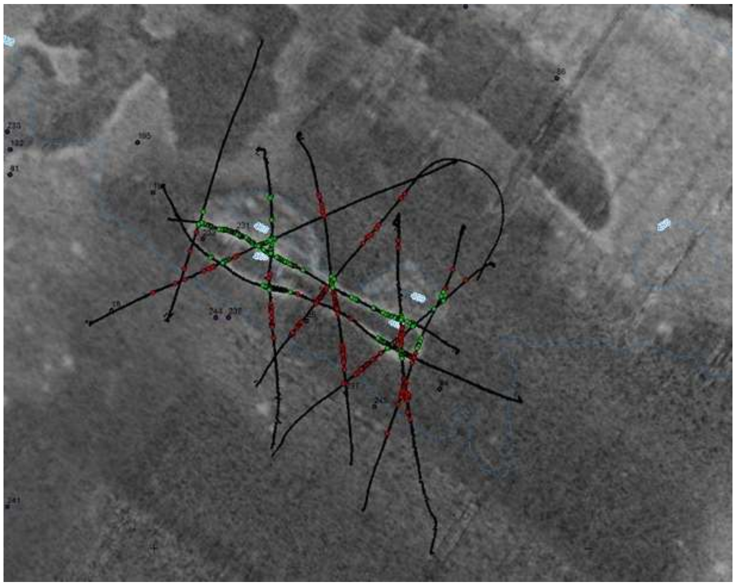
Disturbance (2nd try)

- Clear marks observed on underwater cameras in areas where we towed the SCIP in 2019
  - Green = corals
  - Red = SCIP marks
- No obvious blanketing effect on coral thickets or seabed outside the Disturber paths
  - Limited epifaunal impact analyses
- But a lot of other monitoring of sediment cloud dynamics and direct physical impacts
  - Infaunal impact analyses



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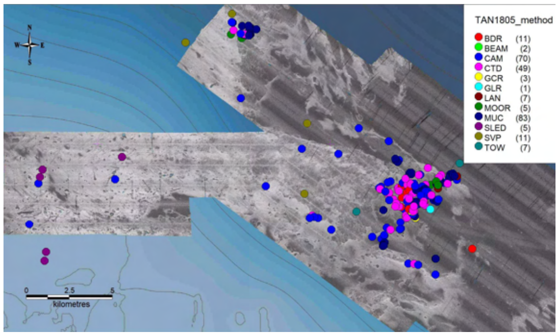
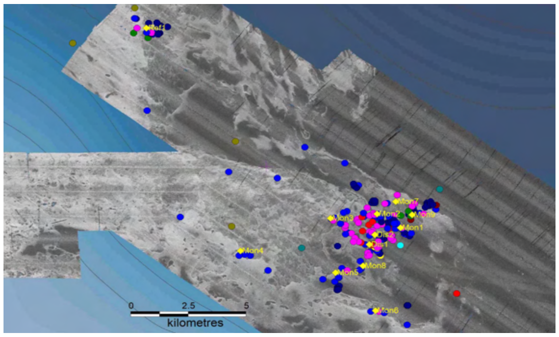
Sampling Distribution

- Initial 2018 survey more exploratory
- Stabilised with core baseline and monitoring sites in late 2018, 2019, 2020.
- Additional sampling for secondary objectives as well.
- Combination of sampling for monitoring impacts, understanding natural variability and dynamics
  - Both spatial and temporal

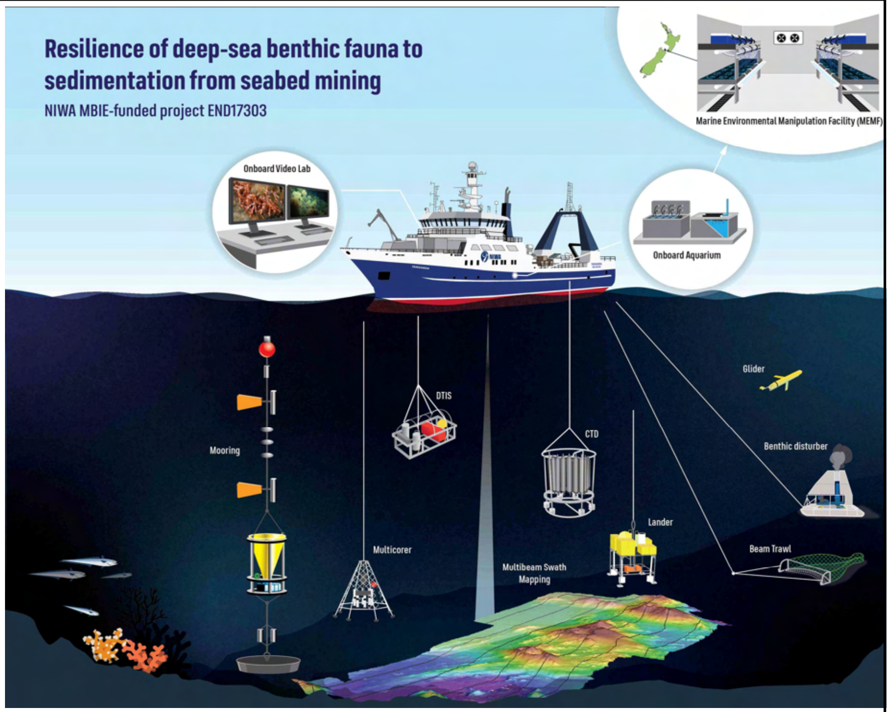




8

Gear used

- Benthic Disturber
- Benthic lander
- Multicorer
- Seamount sled
- Beam trawl
- Moorings
- CTD
- Ocean Glider
- Towed camera (DTIS)
- Live capture aquarium
- Acoustics (ADCP, MBES, Fisheries multifrequency)



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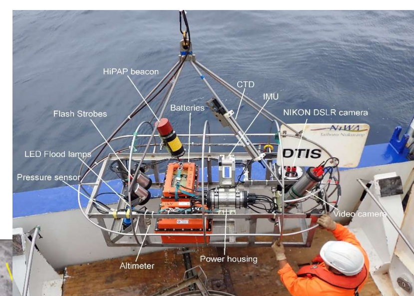
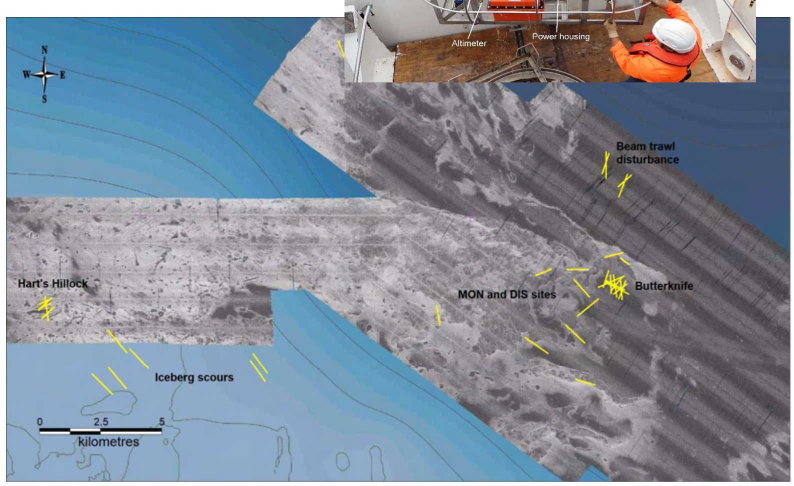
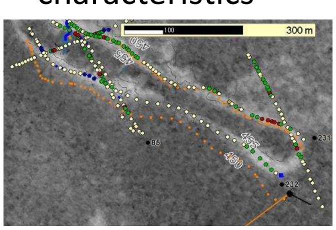
DTIS towed camera system

- All core sites
- Extensive on Butterknife
- Epifaunal composition, distribution, surface seabed characteristics



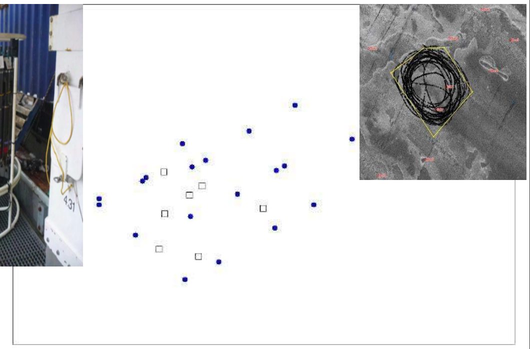


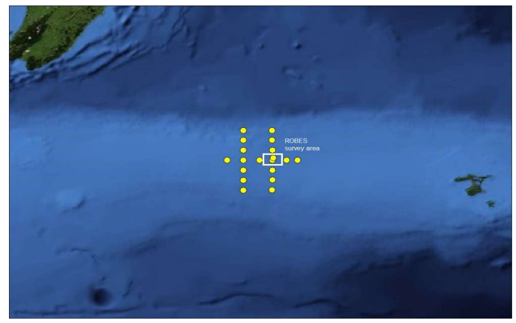


10

CTD: Conductivity-Temperature-Depth

- Monitoring plume
  - After each main disturbance, filled a grid of CTD stations
  - T, S, DO, nutrients, particulates, DIC/DOC, N_2O, CH_4 etc
  - Fine-scale (few km)
- Measuring generic oceanographic conditions
  - broad-scale (10s-100 km)

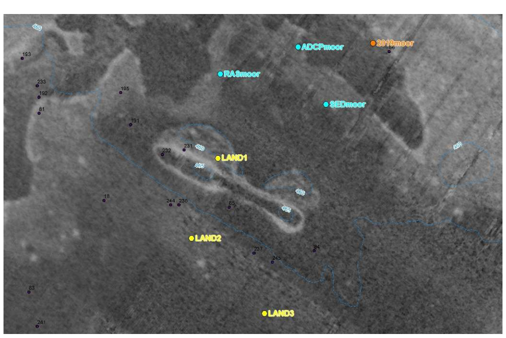


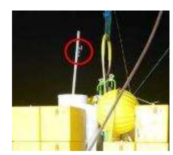


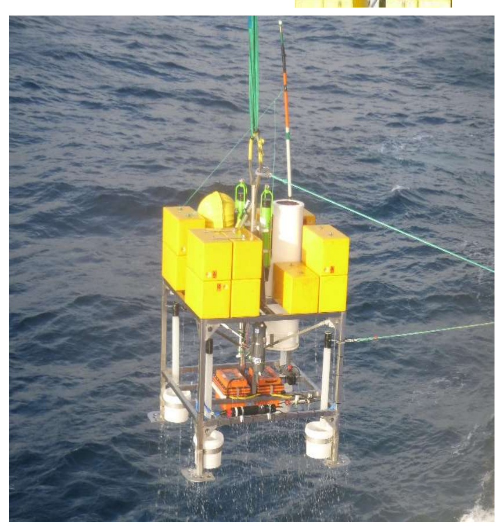
11

Benthic landers

- 3 newly built, christened on 2018 survey
- Camera, sediment trap, CTD, ADCP, turbidity sensors, DGT (Diffusive Gels Thin film-trace metals)
- Deployed around the main disturbance sites in 2018 and **2019**



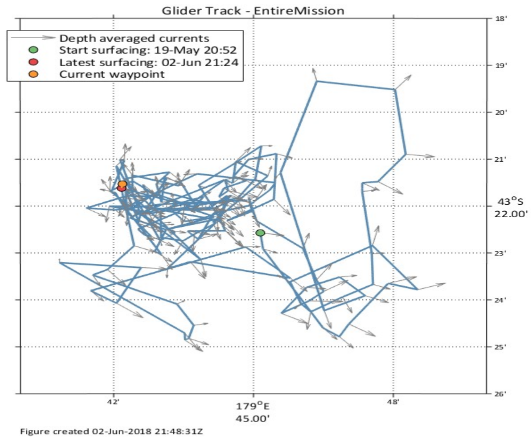




12

Ocean glider

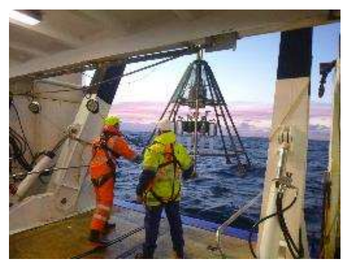
- Autonomous oceanographic measurements
- CTD, chl, DOM, photosynthetic radiation, DO, optical sensors

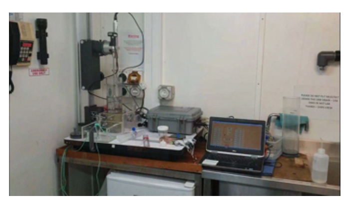


13

Multicorer

- A lot of multicores, at all MON, DIS and REF stations pre- and post disturbance
  - Grain size, POC, chl
  - Macrofauna, meiofauna, bacteria
- Ship-board lab work
  - Biogeochemistry of sediments (DO, pH, redox profiles)
  - Sediment capping by fine sediments-incubation
  - Core fluxes-incubations
  - Elutriates (measure settling rates of fines)
  - Sediment community oxygen consumption (SCOC)
  - Sediment erosion measurement system-sediment transport parameters related to seabed shear stress etc





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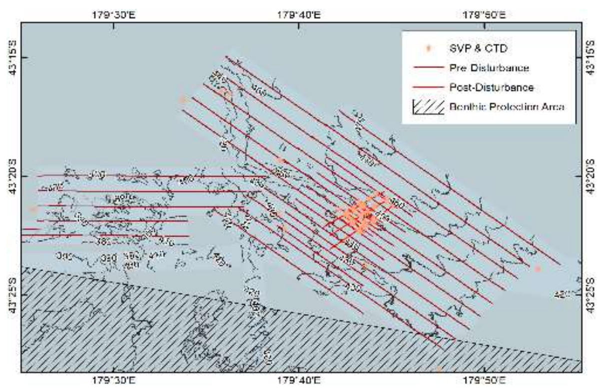
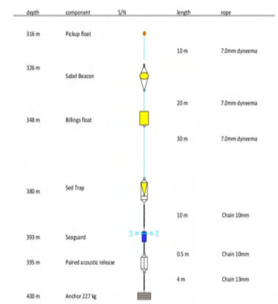
Other gear

- MBES (30kHz) and EK60 fisheries acoustics sounders (18, 38, 70, 120, 200 kHz), TOPAS SBP (2-10 kHz) and ship and glider ADCP
  - Specific ADCP runs before starting first disturbance, and deploying Landers
  - Pre- and post-disturbance transects with MBES and EK60
- Moorings
  - ADCP, Sediment trap, RAS water sampler in 2018-2019
  - 1 & 2 deployed at REF site for 2 weeks, then retrieved and reset with 3 near Disturbance site for 1 year
  - Single mooring (current meter, sediment trap) 2019-2020





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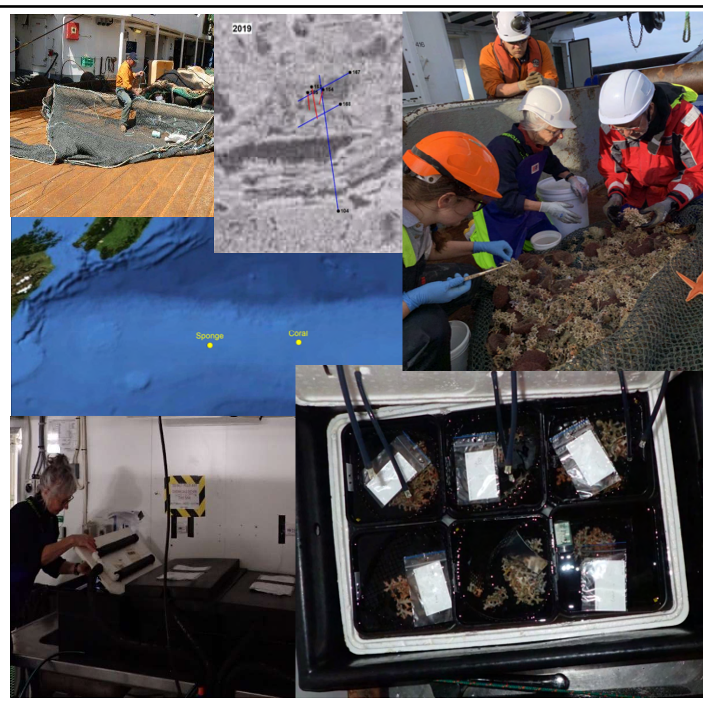
Live collection of fauna

- Beam trawling targeting areas of known sponge (*Ecionemia*) and coral (*Goniocorella*) in 2018, 2019 and 2020
- Night-time, short tows, slow haul
- Rapid transfer to onboard aquarium (maintain in situ temperature, flow rate)
- Subsequent transfer to MEMF



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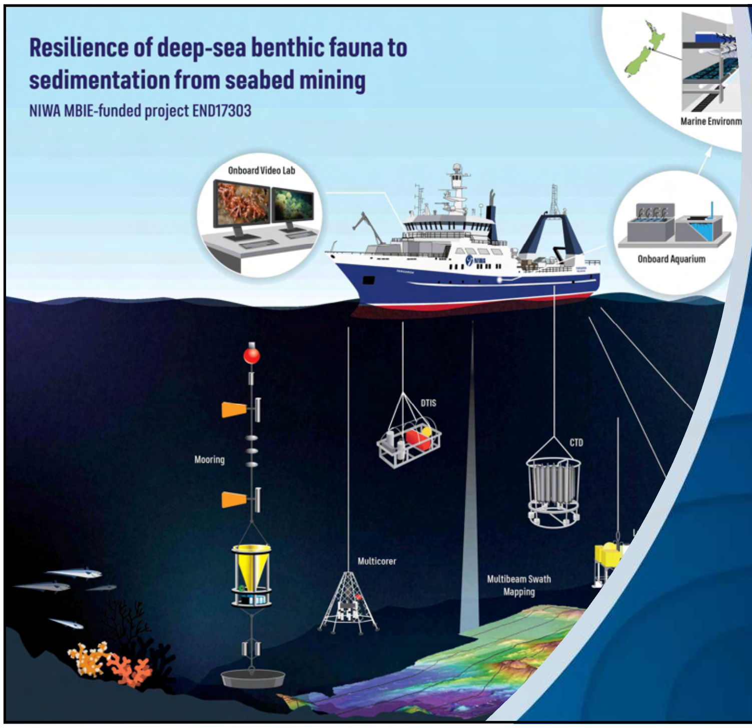

Now to see these data in action

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Interannual variability of the Subtropical Front over Chatham Rise from glider observations

Charine Collins, Joe O'Callaghan, Malcolm Clark, Scott Nodder

ROBES End-users Webinar June 30, 2022

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Ocean fronts

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Ocean fronts

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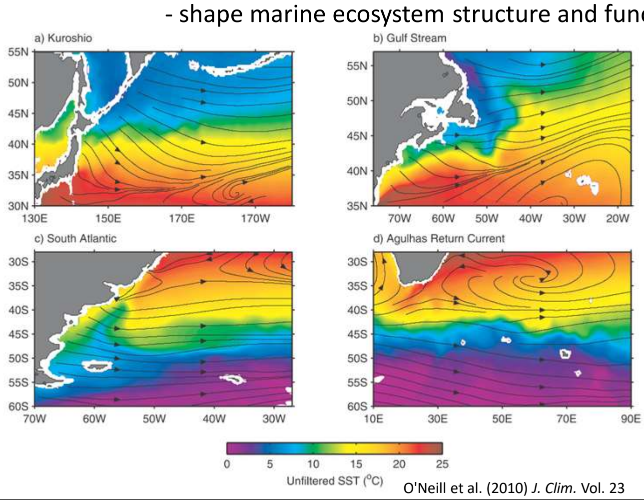
Ocean fronts

Ocean fronts – regions of enhanced horizontal gradients of water properties (e.g. temperature, salinity)
- mark boundary between different bodies of water (i.e. water masses)
- impact physical, chemical and biological environments
- shape marine ecosystem structure and functioning

Water mass: identifiable body of water with common formation history



O'Neill et al. (2010) *J. Clim.* Vol. 23

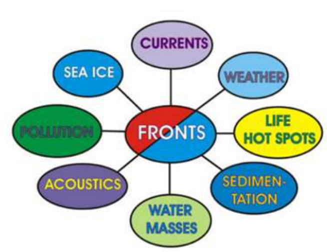
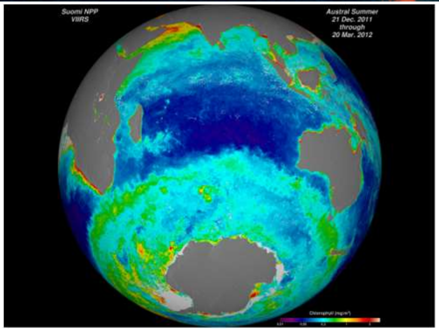


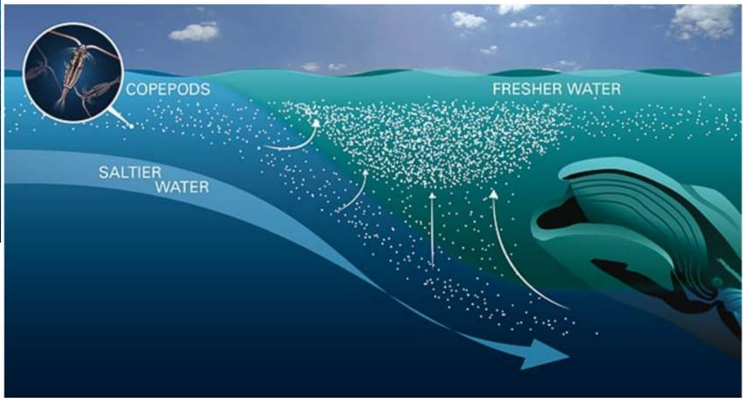
Fig. 1. Impact of oceanic fronts on the oceanic and atmospheric environments (see text for explanation).

Belkin et a. 2009. *Prog. Oceanogr.* Vol. 81

4

Ocean fronts shape marine ecosystems





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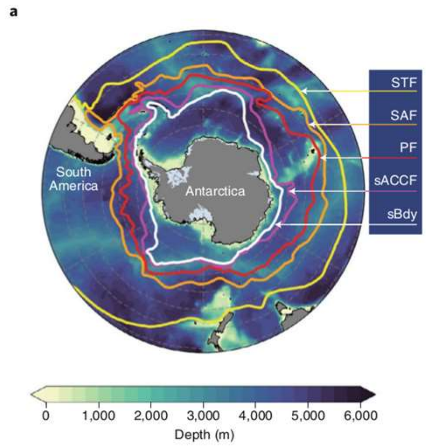
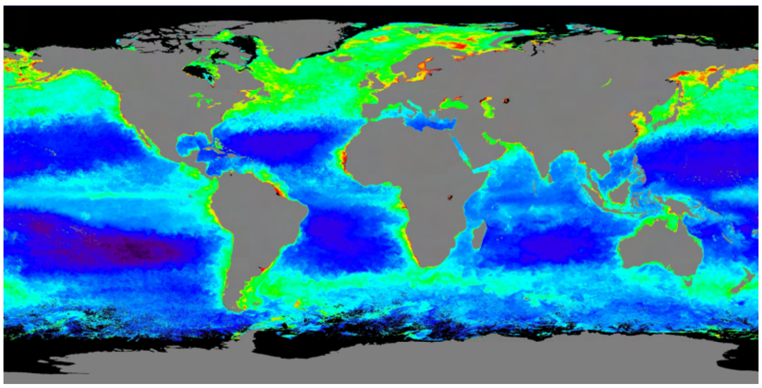
Subtropical front

Encircles the Southern Hemisphere at 35-45°S.

Separates warm, saline Subtropical Water from cooler, less saline Subantarctic water.



Chapman et al. 2020. Nat Clim. Change. Vol 10.



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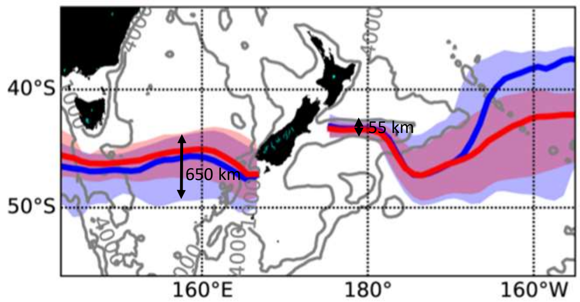
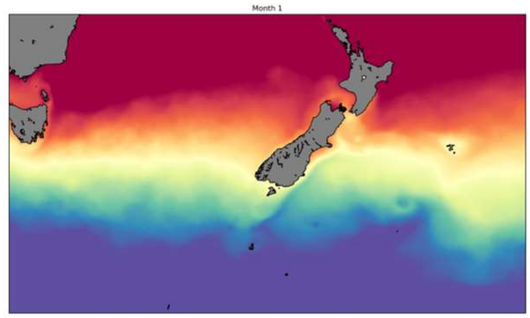
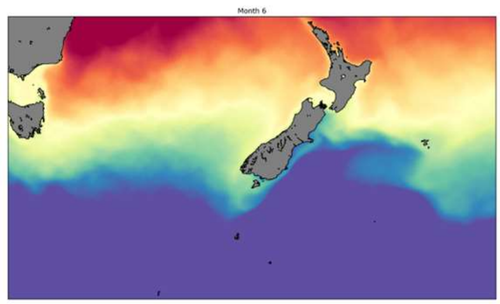
Subtropical front in the Southwest Pacific



Behrens et al. 2021. *J. Geophys. Res. Oceans*. 126





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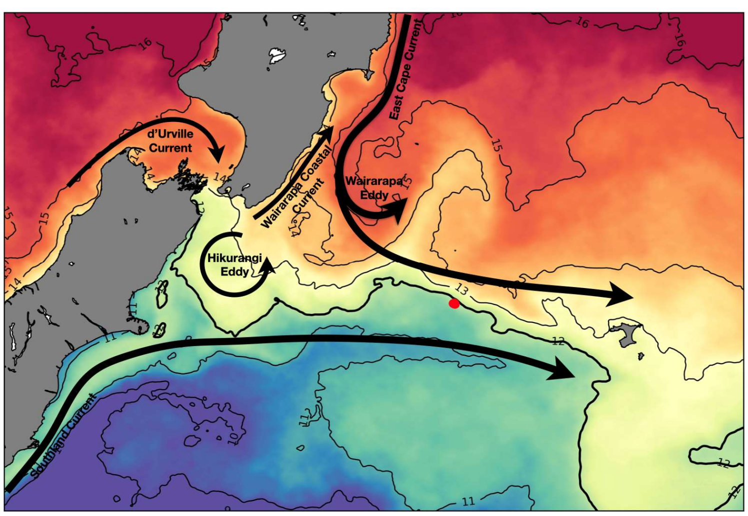
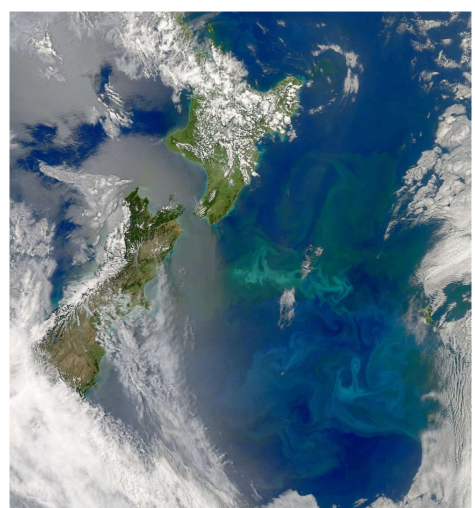
Chatham Rise blocks STF





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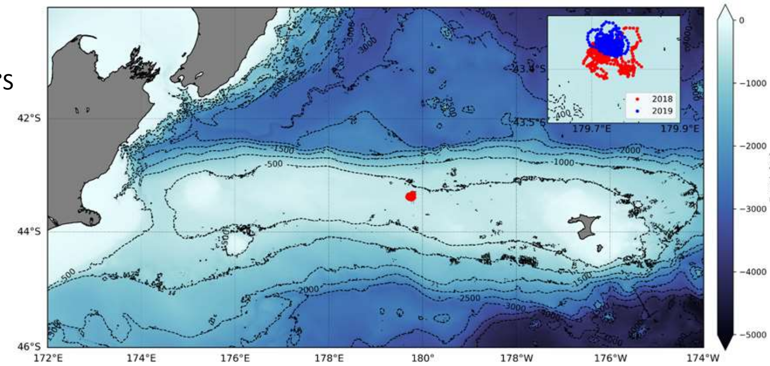
Glider Deployments

2 Glider deployments
- May 2018 (480 profiles)
- June 2019 (381 profiles)

~179.73°E, 43.36°S

Data from gliders
- **Temperature**
- **Salinity**
- **Oxygen**
- **Chlorophyll-a fluorescence**
- CDOM
- Optical backscatter



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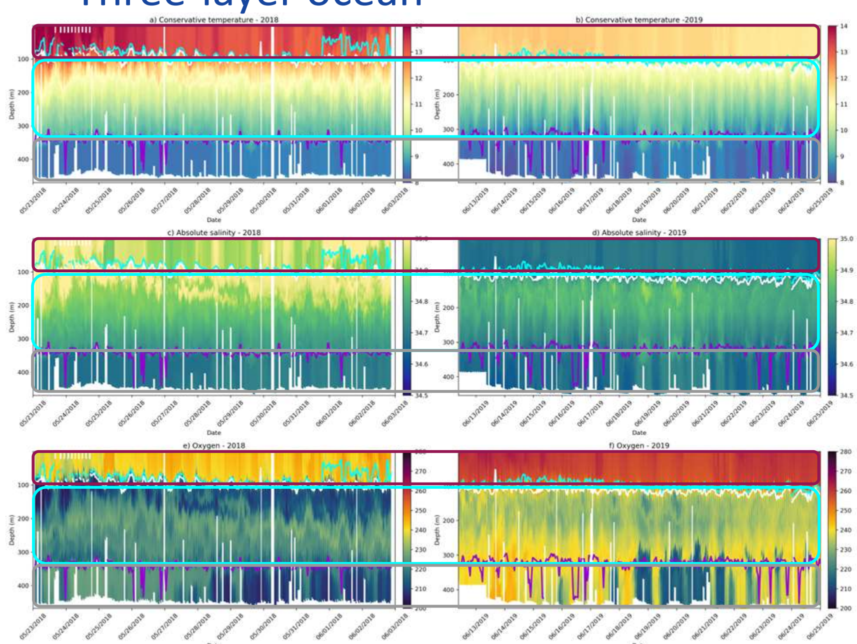
Three-layer ocean

Water column consists of 3 distinct layers:
1. Well-mixed, well-oxygenated, warm surface layer (0 – 100m).

2. Cooler intermediate layer (100 – 300 m).

3. Well-mixed, cold, fresh bottom layer (> 300 m).



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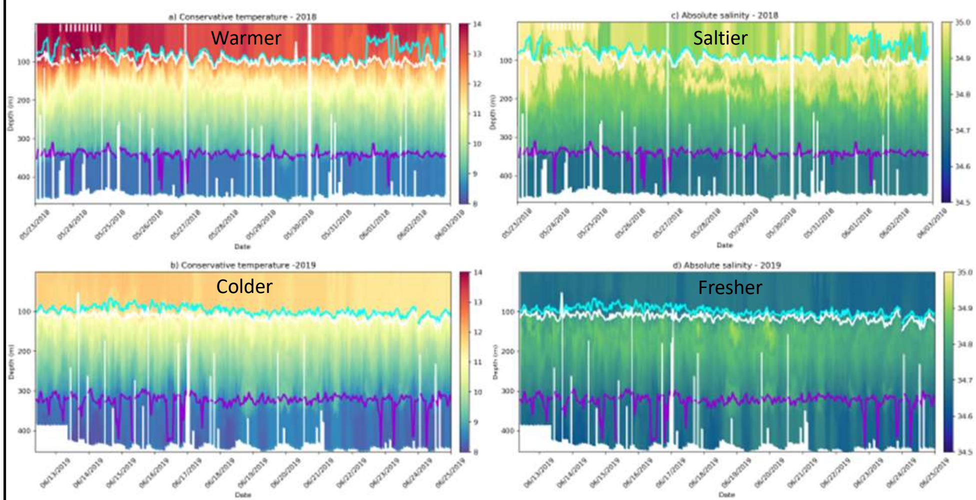
Warmer, saltier surface layer in 2018



Two distinct water masses in upper 100 m:

- 2018 → Subtropical Water (STW)
- 2019 → Subantarctic Water (SAW)

Some north-south migration of the Subtropical Front

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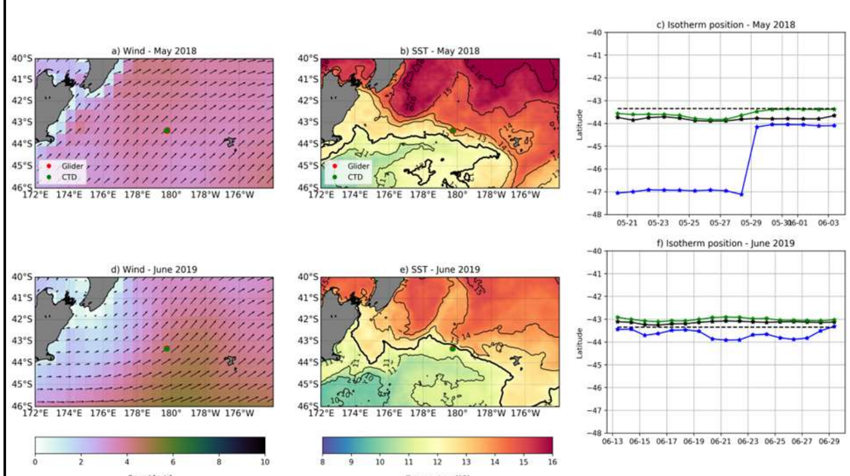
Wind as driving force – Ocean fronts



Japanese 55-year Reanalysis (JRA-55)

Multi-scale Ultra-high Resolution Sea Surface Temperature (MUR-SST)

2018: Weak southwesterly winds allows southward advection of STW

↓

Pushes Subtropical Front southward

2019: Stronger southwesterly winds push SAW northward

↓

Subtropical Front moves northward

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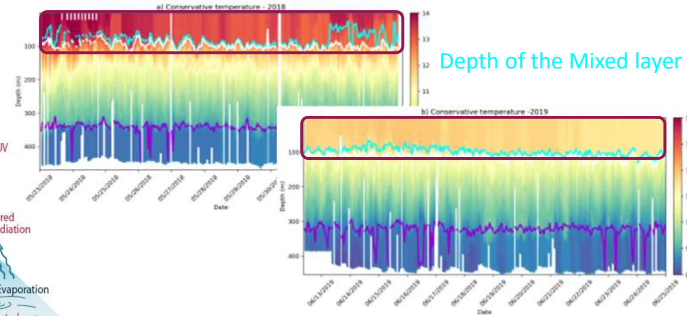
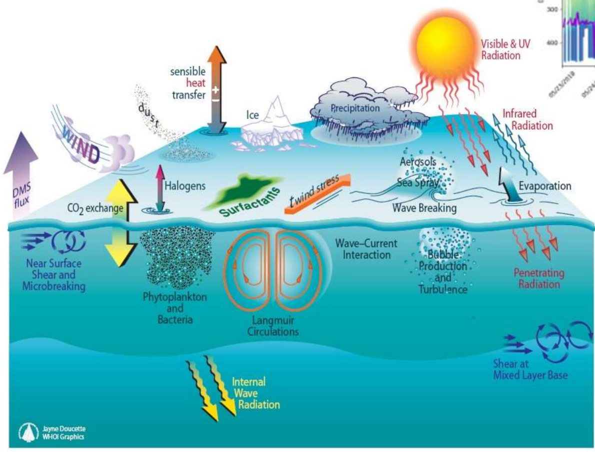
Wind as driving force – Vertical Mixing





Mixed layer – zone where turbulence from surface currents and wind has mixed the water so much that temperature, salinity and other properties are relatively constant throughout the layer.

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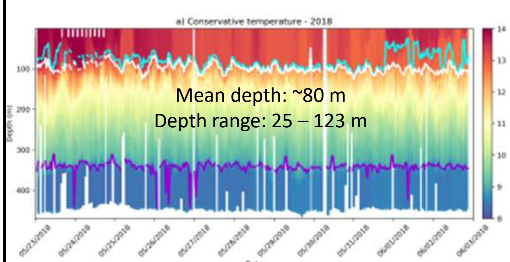
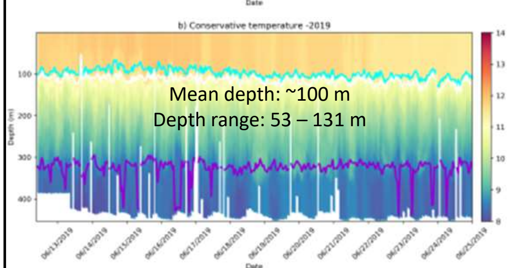
Wind as driving force – Vertical Mixing





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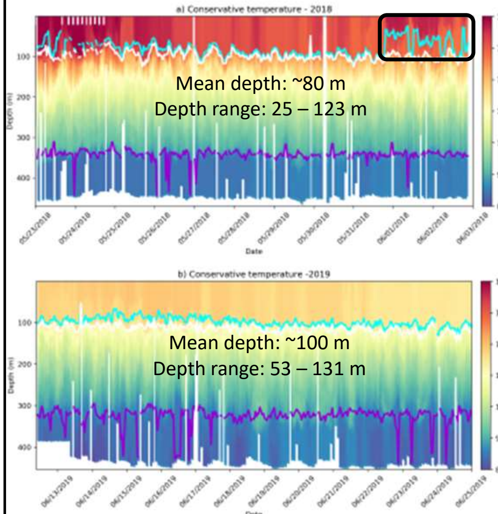
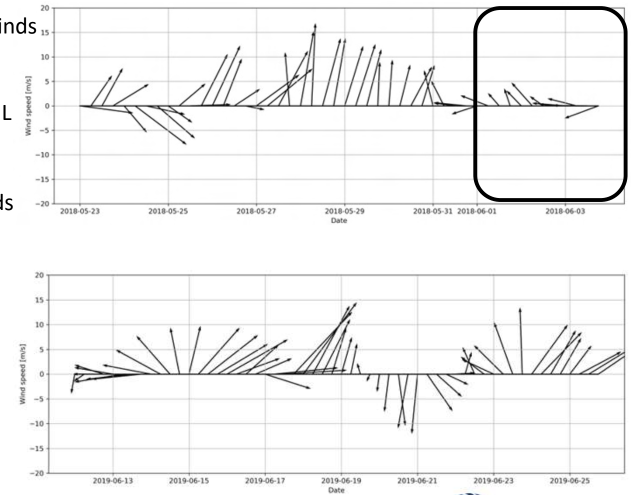
Wind as driving force – Vertical Mixing



Weaker winds
↓
Thinner ML

Strong winds
↓
Deeper ML



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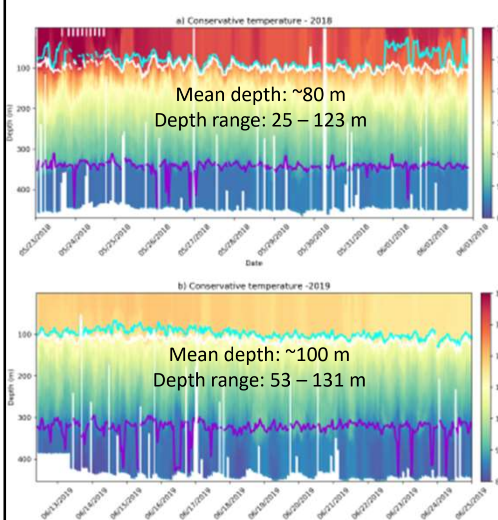
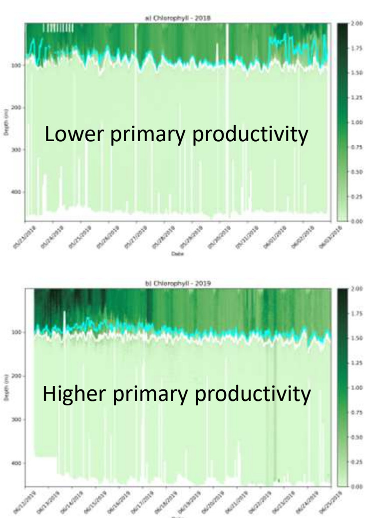
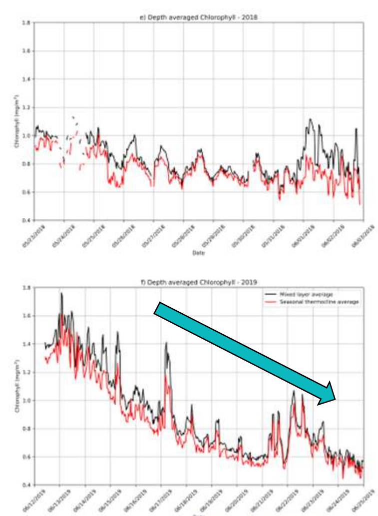
Biological response







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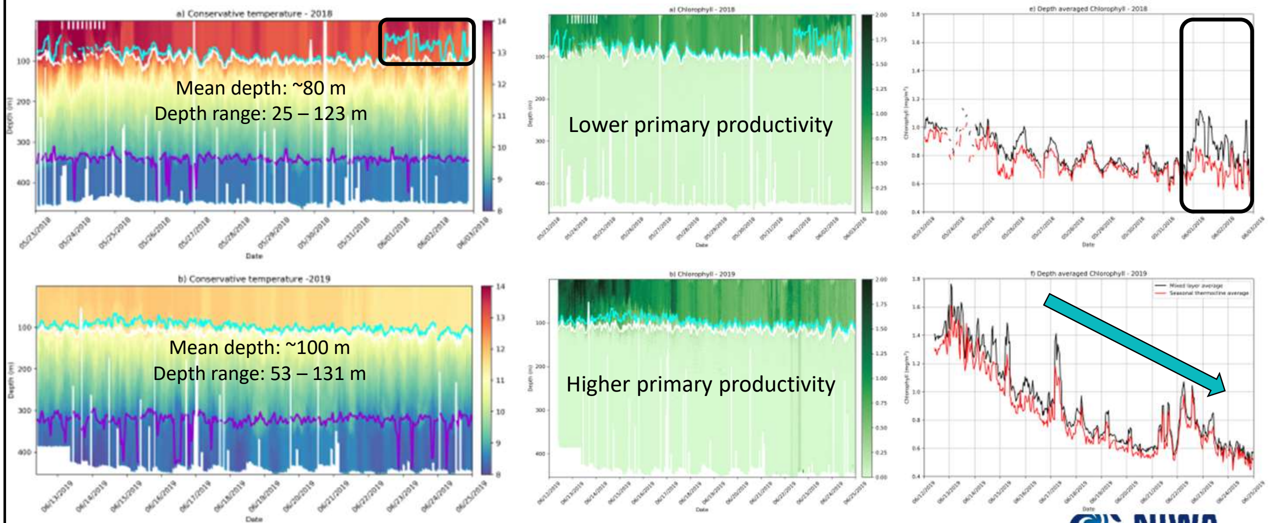
Biological response



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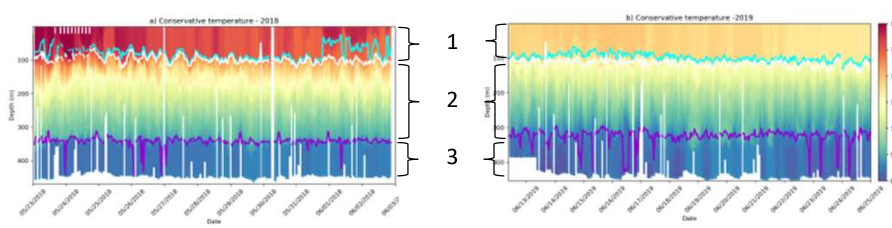
Conclusions

Well-defined Three-layer ocean

1. Well-mixed surface layer
2. Intermediate layer
3. Well-mixed bottom layer



Different water masses dominate the upper 100 m

- 2018 – warm, salty Subtropical Water
- 2019 – colder, fresher Subantarctic Water

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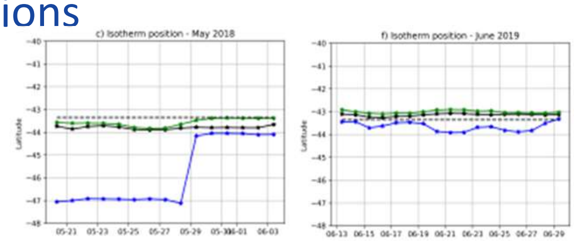
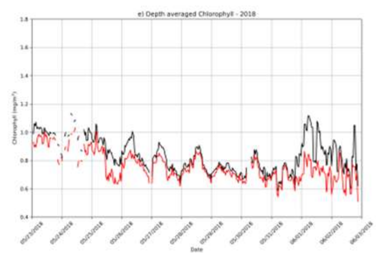
Conclusions

Winds drive variability in the location of STF
- 2018 – Weak southwesterlies → STF further southward
- 2019 – Stronger southwesterlies → STF more northward



Winds drive temporal variability in depth of surface mixed layer
- Stronger winds → deeper mixed layer
- Relaxation of winds → shallower mixed layer

Primary production responds to changes in mixed layer depth



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Thank you

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Water column dynamics induced by benthic plume disturbers

Joe O'Callaghan, Charine Collins, Malcolm Clark, Scott Nodder, Chris Hickey, Daniel Leduc

ROBES End-users Webinar, June 30 2022

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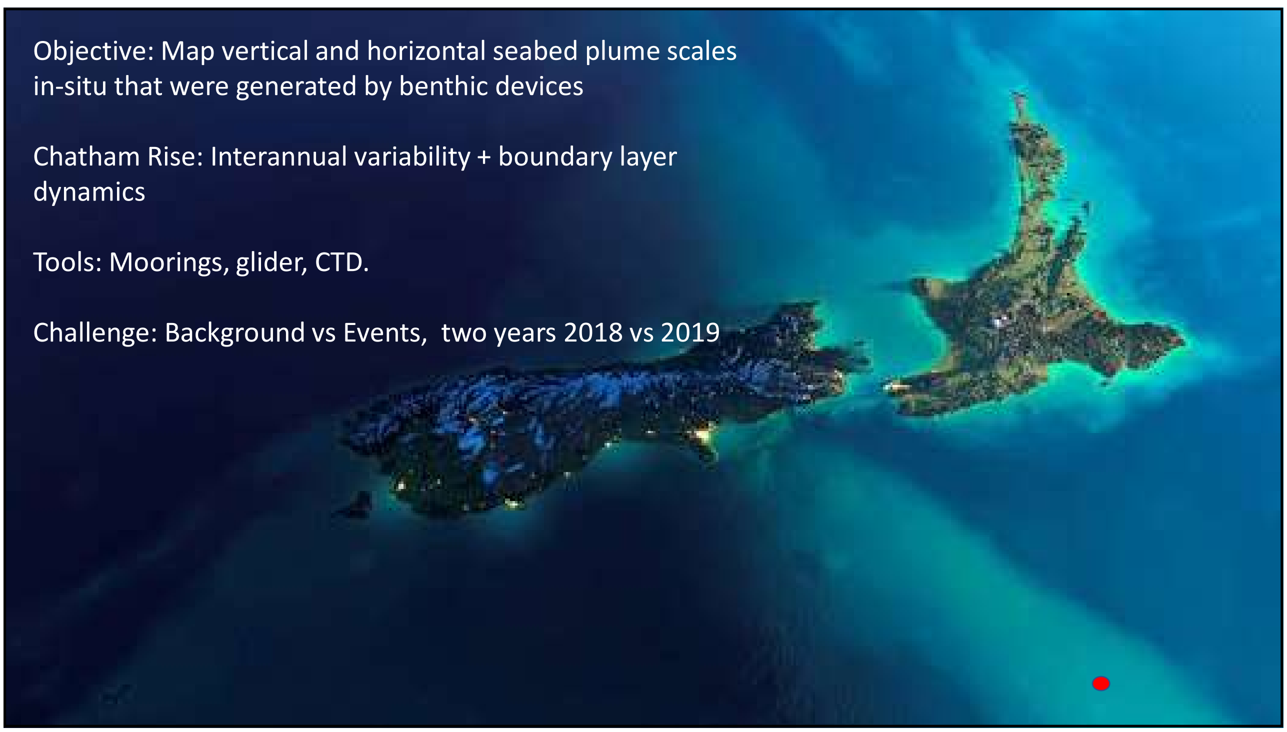
Objective: Map vertical and horizontal seabed plume scales in-situ that were generated by benthic devices

Chatham Rise: Interannual variability + boundary layer dynamics

Tools: Moorings, glider, CTD.

Challenge: Background vs Events, two years 2018 vs 2019



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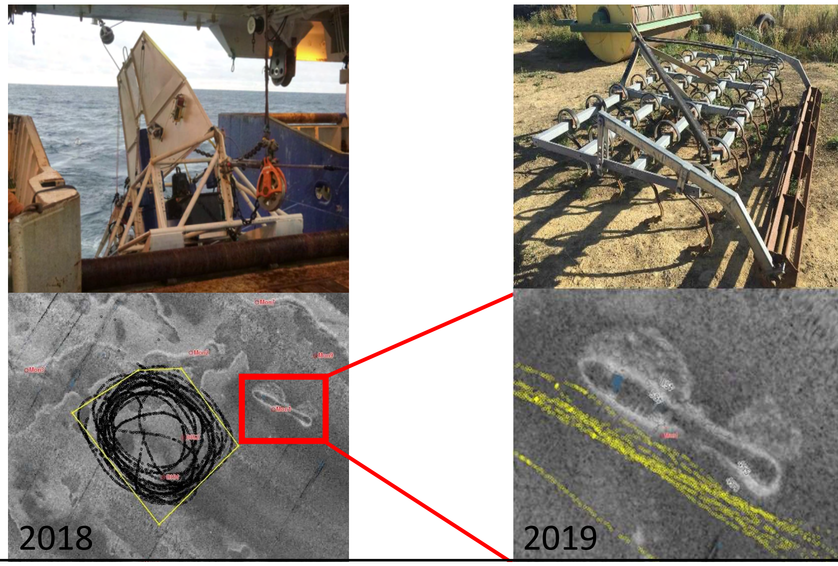
Map vertical and horizontal plume scales



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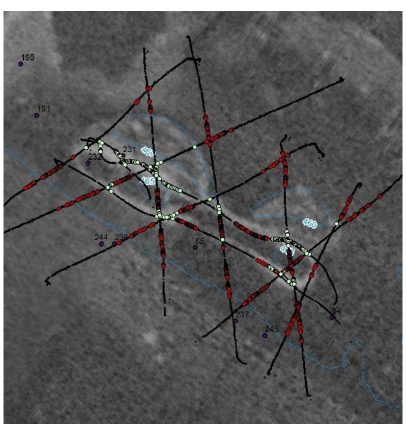
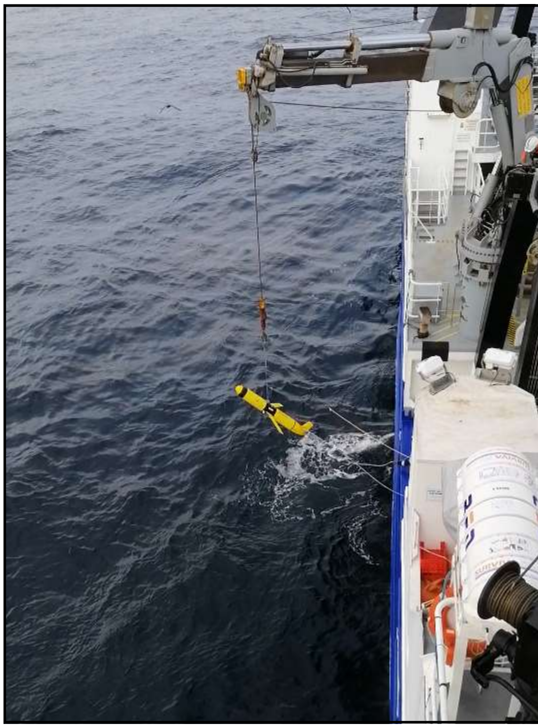
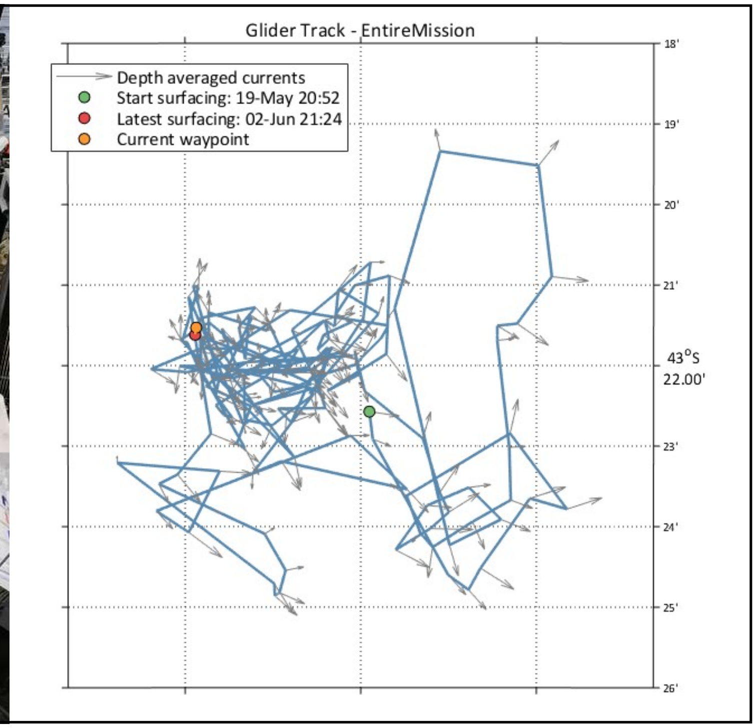


Small-scale plume experiment, 3-4m high, 400m long

Repeat tracks to N, S and Central tracks for 30 h

4





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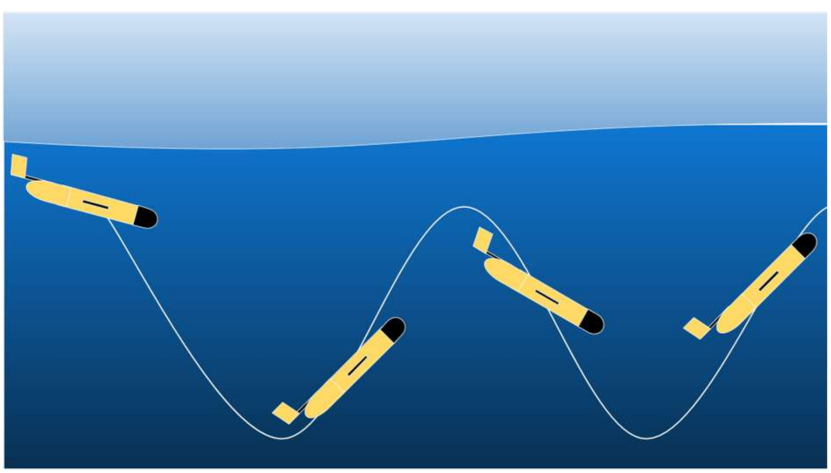
Glider observations on Chatham Rise



High resolution data around benthic disturber

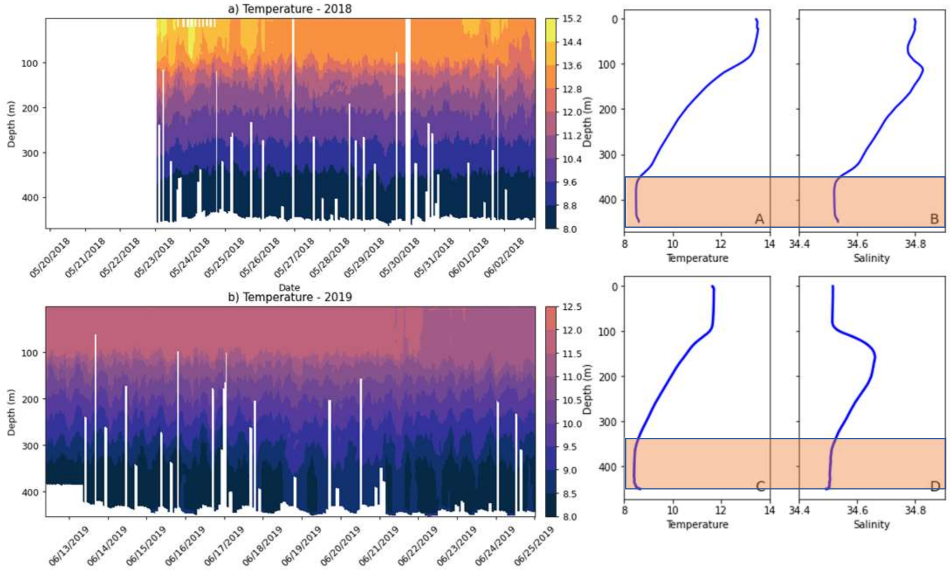
400 profiles per voyage. An order of magnitude more than CTD profiles

Vertical profile 800m and 40mins

Parallel sampling platform so other ship operations can continue

6

Background variability, Chatham Rise



Well-mixed bottom boundary layer

400 glider profiles

2018 BBL = 98m
2019 BBL = 113m

7

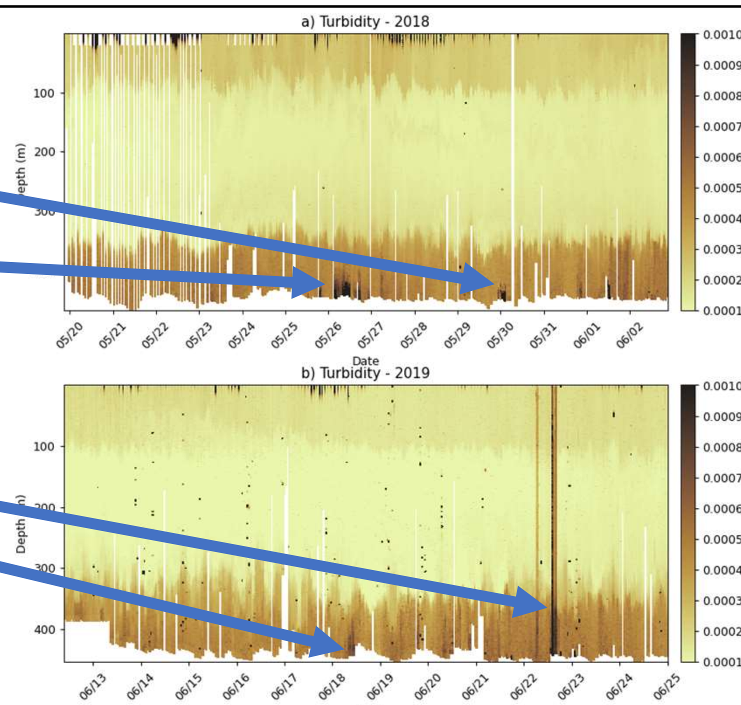
Benthic disturber/SCIP deployments coincided with small plumes detected by glider in both 2018 + 2019

2018 turbidity > 2019

Vertical extent small (10-20m) and short lived

Is the full water turbidity spike real? Yes…? (POC/Nodder)

[“only a small fraction of the sediment went into suspension” Purkiani et al. 2021]



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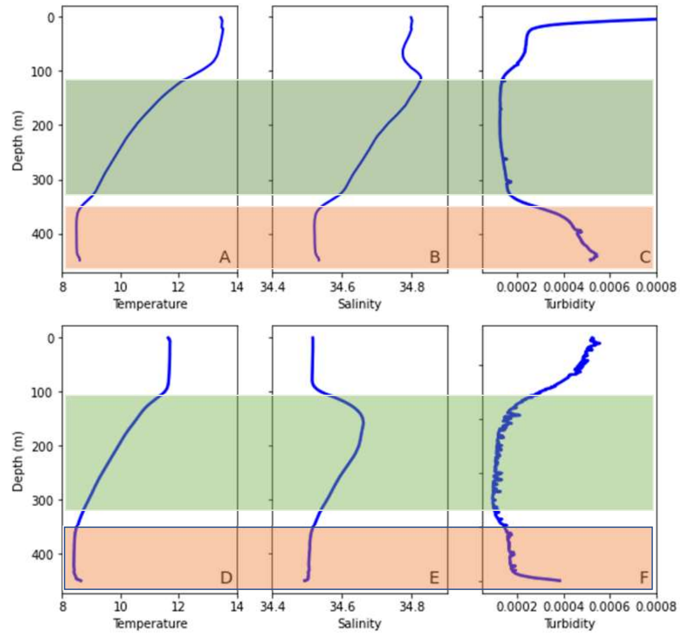


Mid water column (green)

2018: Salinity interleaving dominant below MLD

Turbidity equivalent for 2018 + 2019

Bottom mixed layer (orange)

2018: 97m
2019: 113m

Variability observed in turbidity close to seabed. Retained in 2019 mean profile

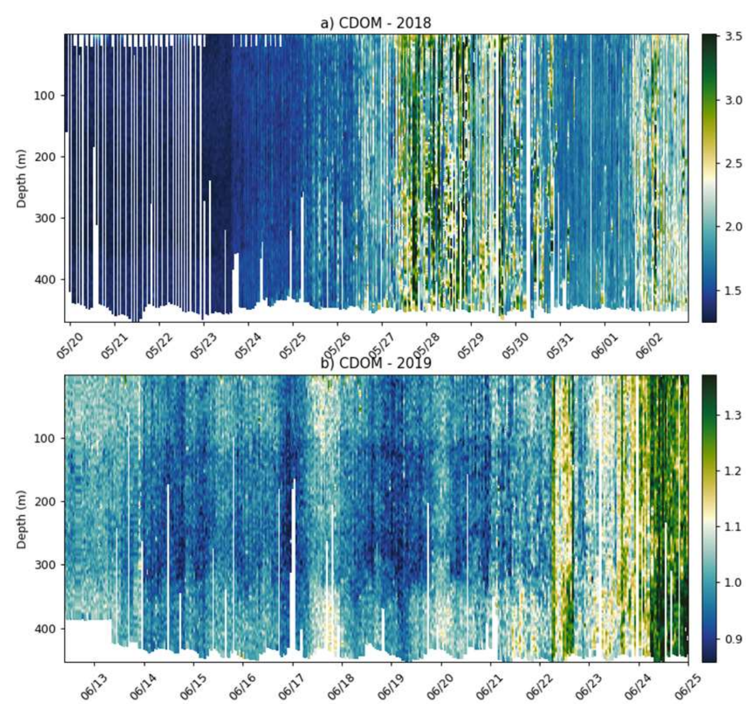
9

CDOM: coloured dissolved organic matter. Often associated with rivers or nearbed sediments

CDOM signals post benthic disturber/SCIP deployments significant in both 2018 + 2019

2018 CDOM > 2019

Vertical extent through water column + not constrained by upper and deep mixed layers



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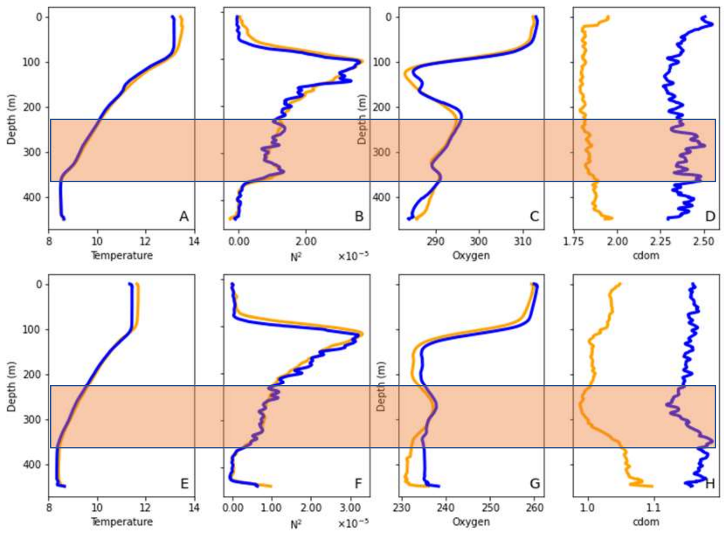
Water column variability during disturbances?



Higher near bed instabilities (N2) in 2019

CDOM + Oxygen, higher background values during 2018

Low (2018) + high (2019) oxygen responses during disturbances events

30% more CDOM during and after disturber experiments (2018)

15-18% more CDOM during and after SCIP experiments (2019)

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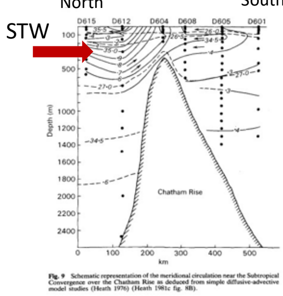
Background Variability

2018

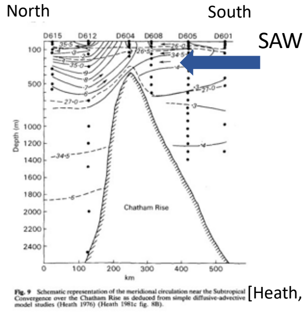


2018 anomalous year. Warm, saline, low O2 STW from N

BBL (mean) = 97 m
Variable thickness, at times <30m

[Heath, 1976]

2019

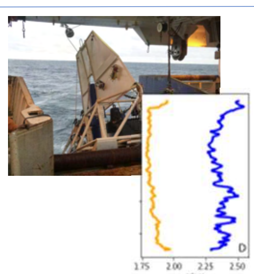


2019, Cold, fresher, higher O2 from S

BBL (mean) = 97 m
Variable thickness, at times <30m

[Heath, 1976]

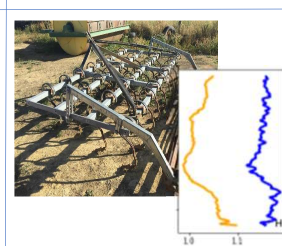
Disturbance Events



Small, detectable near bed plumes 5-20m for short periods

2018 plume/CDOM > 2019

Vertical extent of CDOM spanned 0-400m and increased by 30%



Butterknife feature smaller than 2018 and harder for glider to be virtual mooring

Small plume with SCIP. POC bursts to surface

CDOM increased by 18%. Mixed boundary layer structure in CDOM

Water column dynamic and pelagic responses potentially as large as plumes from seabed disturbances

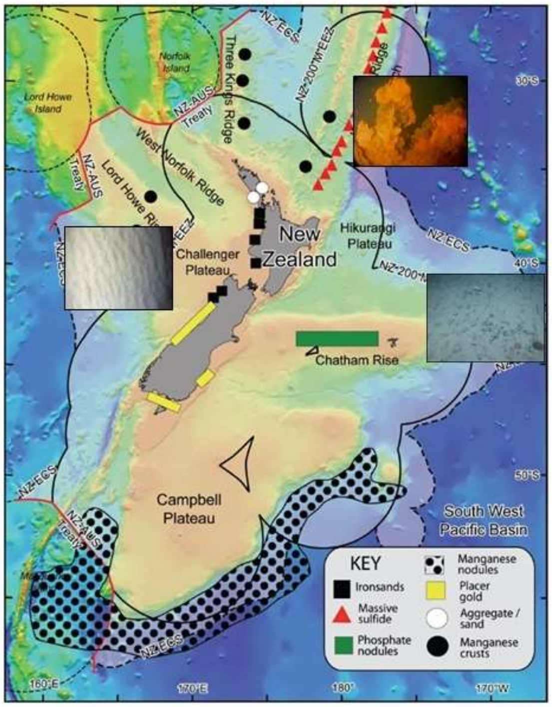
12

13

Summary

- Upper ocean: 2018 Anomalous compared to 2019, 2020. STW on Chatham Rise due to wind stress (lagged effect of 2017/2018 La Nina?)
- Lower ocean: thick boundary layers (97-115m) with 2018 more variable than 2019
- Small plume from benthic disturber and SCIP
- Significant dissolved organic matter response. 32% (2018) and ~20% (2019)
- Impact on pelagic systems potentially larger than near bed sediment plumes from disturber/trawler operations

14



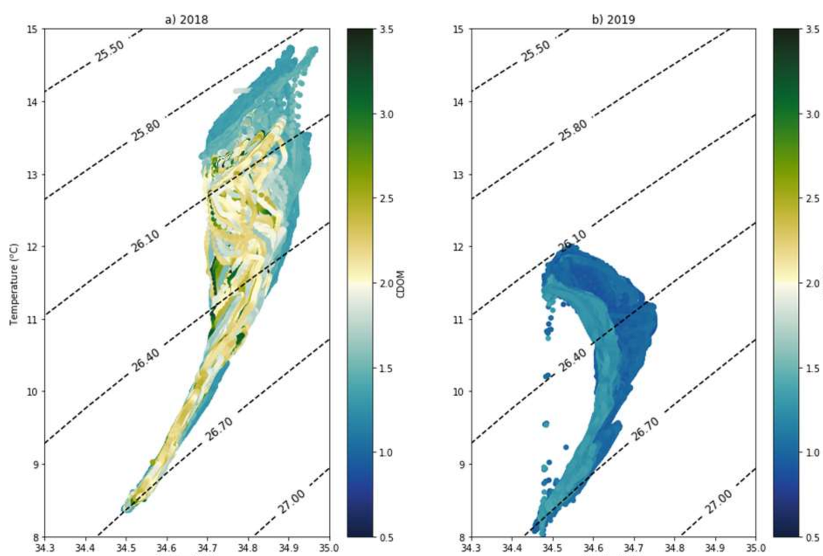
Chatham Rise?

New Zealand marine environment hosts a wide array of natural resources

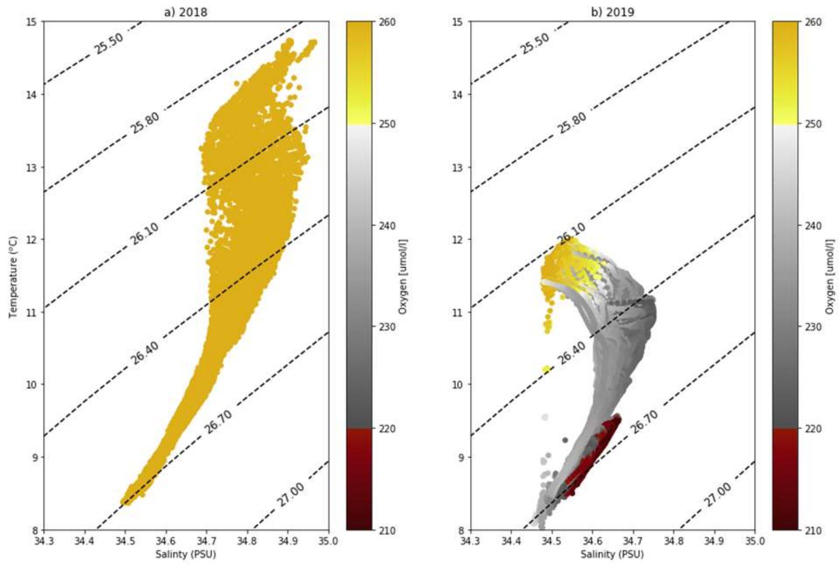
Last 10 years have seen increasing interest in potential seabed mining (both globally and in NZ) to support future green economy

Limited data and understanding of biological response to indirect impacts

15



16


a) 2018
b) 2019
Temperature (°C)
Salinty (PSU)
Oxygen [umol/l]
25.50
25.80
26.10
26.40
26.70
27.00

17

Near-bed sediment dynamics and fluxes within the Subtropical Frontal Zone on the Chatham Rise

S. Nodder[1], C. Eager[2], J. O'Callaghan[1], M. Clark[1], D. Leduc[1], R. Hale[3], A. Rowden[1], C. Hickey[2], P. Gerring[1], O. Price[1], F. Elliott[1], S. Searson[1], W. Quinn[1], S. Deppeler[1], G. Frontin-Rollet[1], R. Ovenden[2]

[1] NIWA Wellington, [2] NIWA Hamilton, [3] NIWA Nelson

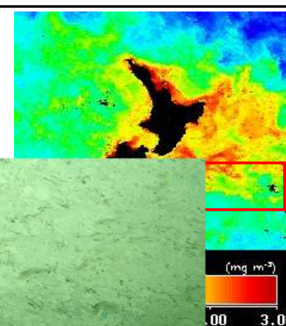
Climate, Freshwater & Ocean Science

ROBES Research Webinar, 30th June 2022

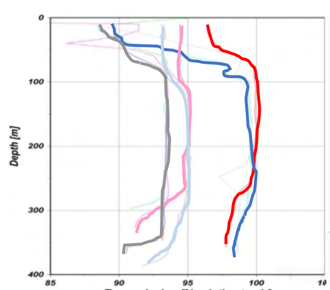
NIWA
Taihoro Nukurangi

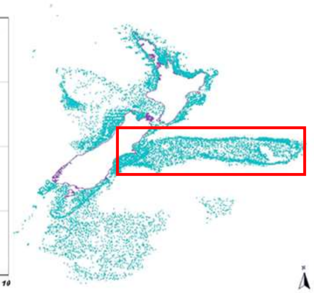
1

Baseline conditions – Chatham Rise



- **Physical oceanography**
  - Dynamic Subtropical Frontal Zone; high productivity
  - Strong currents & tides; vertical & horizontal mixing
- **Sediment properties**
  - ~50% sand/mud
  - Phosphorite nodules
- **Benthic communities – epi- and infauna**
  - Moderate benthic biomass & diversity
  - Encrusting corals & sponges – sensitivity?
- **Particle fluxes – short- & long-term**
  - High near-bed fluxes; high OC deposition
- **High bottom-trawl fishing activity**





2

Tools for measuring near-bed sediment dynamics

Sediment Trap Moorings - BASELINE

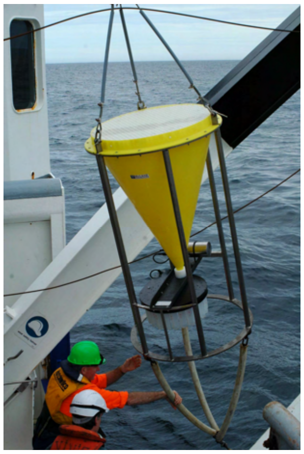


Image credit: E. Maas

Multi-corer – Sediment sampling

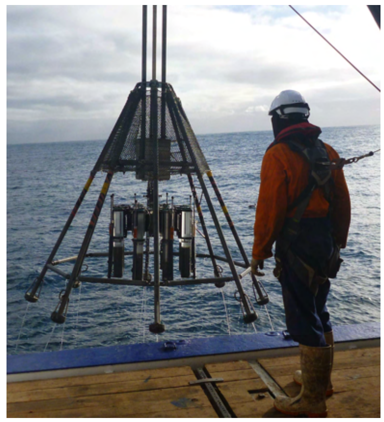


Image credit: S. Deppeler

Benthic Landers – DISTURBANCE EFFECTS

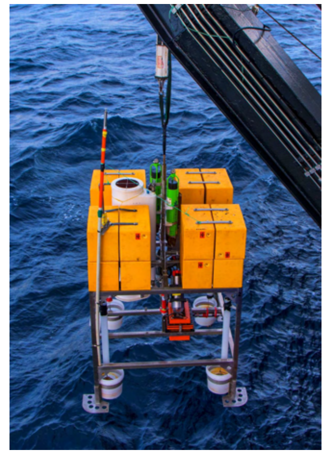
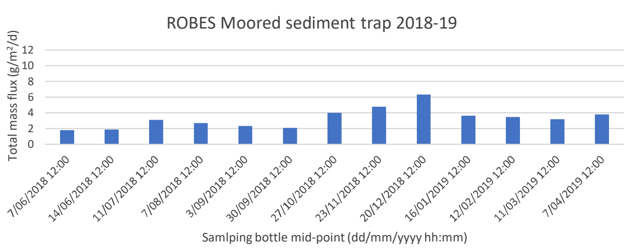
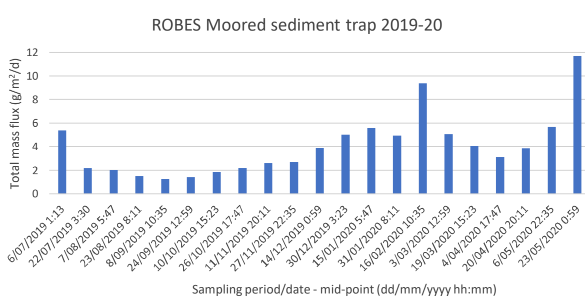


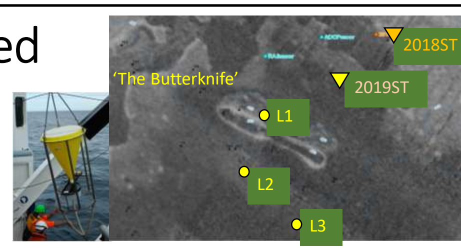
Image credit: A. Shorrock

3

Chatham Rise long-term, near-bed fluxes - BASELINE







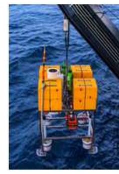
- Annual near-bed fluxes measured on rise crest for 1st time
- 2018-19 < 2019-20
- **Seasonality:** low fluxes in winter-early/mid-spring
- high fluxes in late spring/summer, and late autumn (perhaps 2019-20 only, seasonality subdued in 2018-19?)

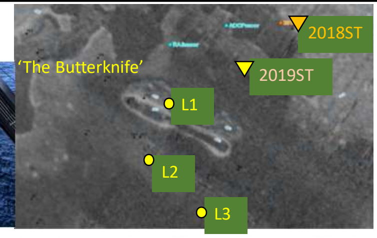
4

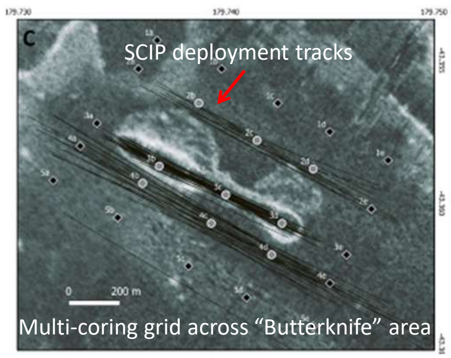
4

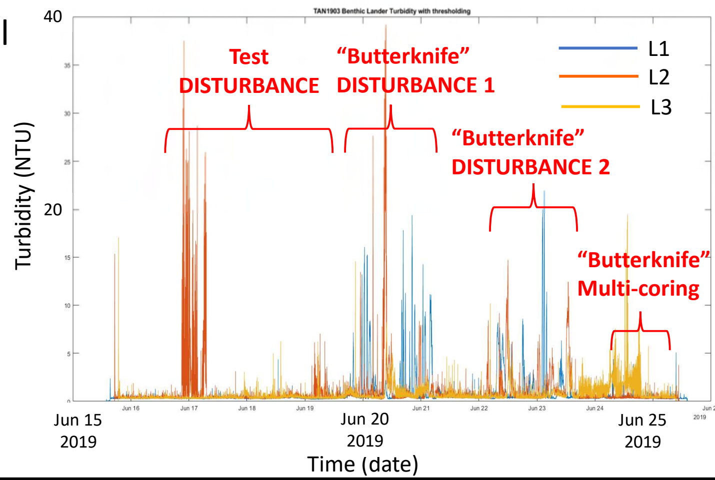
Short-term near-bed processes DISTURBANCE EFFECTS

- Lander data (days to weeks)
- Turbidity (NTU)
- Evidence of effects of physical disturbances?



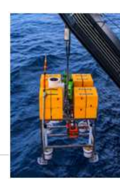


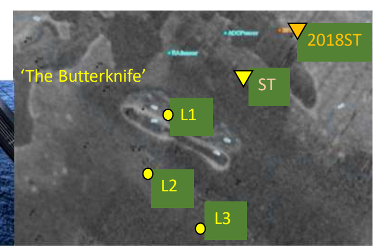


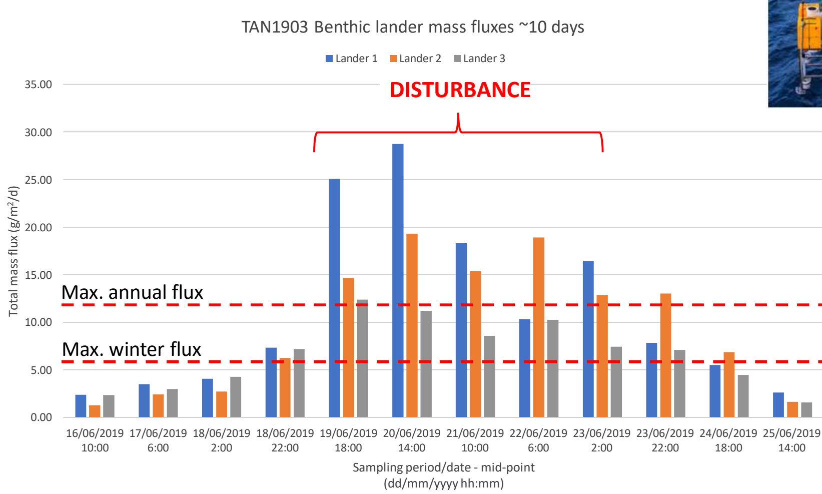


5

Chatham Rise short-term near-bed fluxes DISTURBANCE EFFECTS







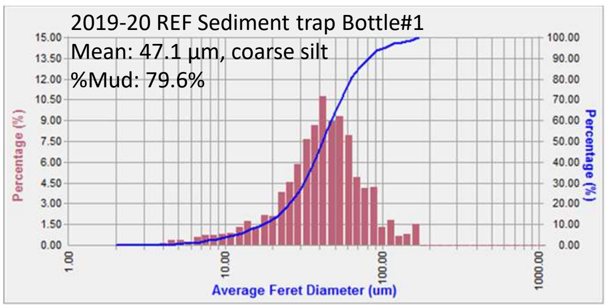
- Pre- & post-disturbance fluxes, relative to "Baseline"
- "Disturbance" fluxes up to 2x higher than annual maximums & seasonal minimums

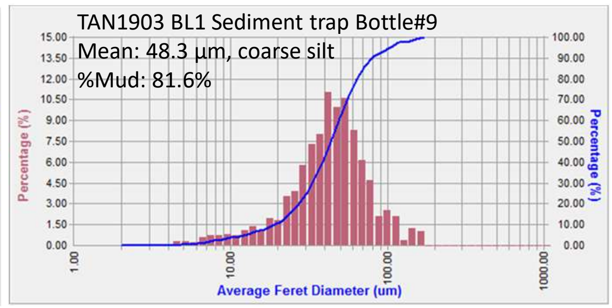
6

6

Near-bed sediment fluxes – physical & biogeochemical characteristics

A. Resuspended cf. surficial sediments – grain-size distributions





cf. Surficial sediments

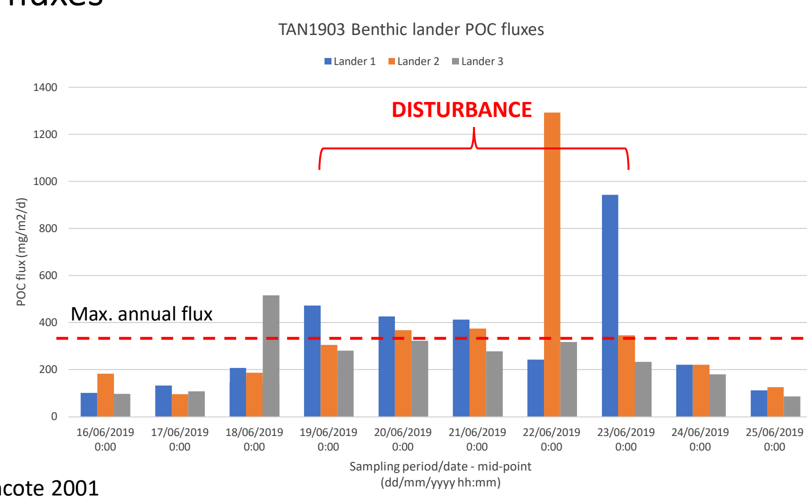
Mean: 67-81 µm, <u>very fine sand</u>, 50-60% mud → partitioning of sediment grains in near-bed flows?

7

Near-bed sediment fluxes – physical & biogeochemical characteristics

B. Chatham Rise POC fluxes

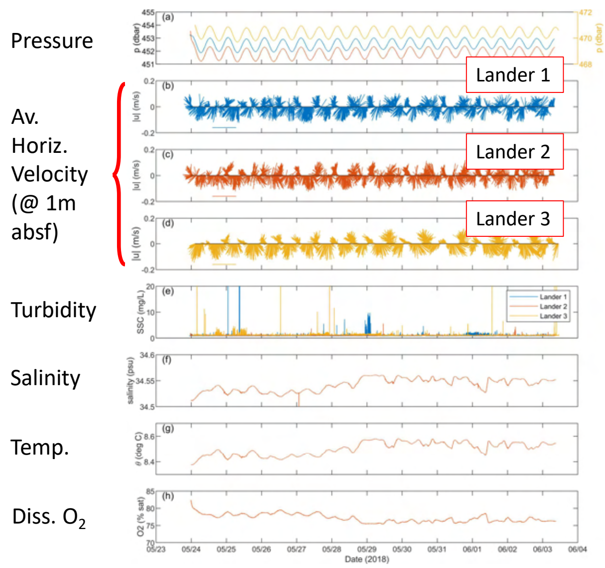
- POC fluxes were an order of magnitude higher than 'off-rise' background pelagic fluxes[1] & similar magnitude to fluxes on Chatham Rise flanks[2]

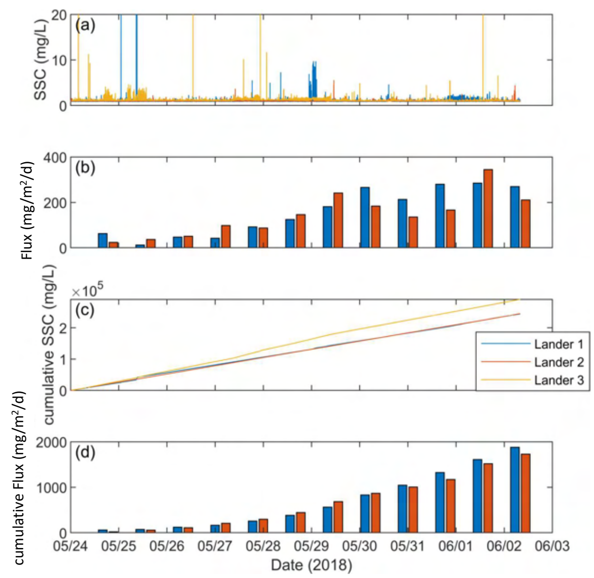


[1] Nodder et al. 2016; [2] Nodder & Northcote 2001

8

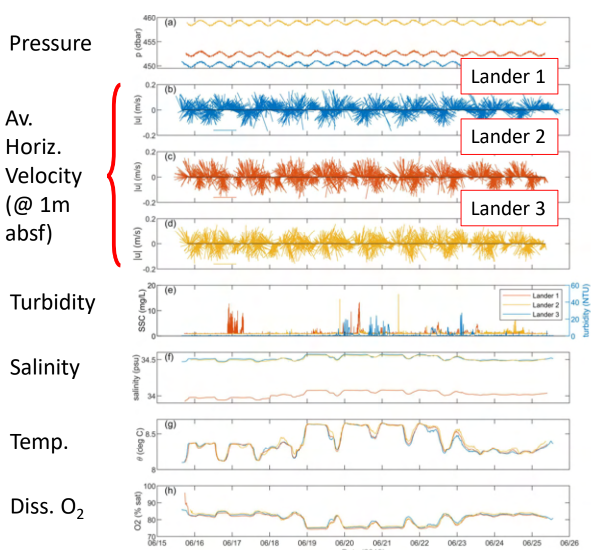
TAN1805 Benthic lander – integrated measurements

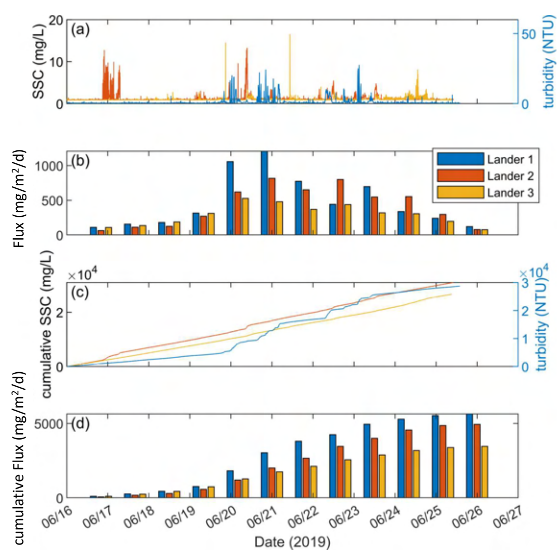




9

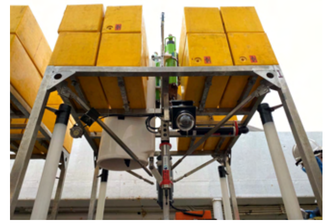
TAN1903 Benthic lander – integrated measurements





10

Summary of lander data (2018, 2019)



- **Pressure**: near-bed tidal oscillations apparent
- **Currents**: variable speeds and directions, related to tides
- **Currents**: max. speeds 10-15 cm/s; in general – 2018 < 2019, related to other physical processes (potentially stronger inertial flows in 2019?)
- **Turbidity**: L1 (proximal) > L2 > L3 (distal) on both voyages; more clear relationships with seabed disturbance activities in 2019
- **Turbidity**: calibrated SSC – max. concentrations 10-15 mg/L; 2018 < 2019
- **Salinity**: variable between sites but uniform; some periodicity apparent in 2018
- **Temperature**: slight incr. over time in 2018 tho’ not variable cf. large, periodic 0-2-0.4°C drops in 2019, peaking mid-deployment for 5 days, corresponding to slight decr. in salinity & incr. in dissolved O_2; related to near-bed advection of different water parcels
- **Particle fluxes**: incr. in relation to seabed disturbances; typically L1 (proximal) > L2 > L3; grain-size distributions partitioned into Mud (resuspended):Sand (bedload) fractions
- **Particle fluxes**: similar to previous estimates on Chatham Rise flanks and wider region; 2018 < 2019

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Conclusions

- Near-bed processes range from diurnal (tides) to seasonal/annual (oceanography/climate) time-scales.
- Physical disturbance of (sandy) Chatham Rise sediments during ROBES did generate a minor sediment muddy plume, esp. in 2019, with marked effects on near-bed sediment fluxes [& on benthic responses – see later talks].
- **BUT** these are at different time- and space-scales cf. proposed future phosphorite mining activities (e.g., max. measured SSC conc^{N} on ROBES = 3-5 mg/l (water bottles), up to 10-15 mg/l (calibrated instrumented turbidity), cf. max. modelled mining SPM 10->100 g/l locally).
- Thus, to characterise the spatio-temporal scales and relationships between physical, biological, chemical and geological processes on Chatham Rise, in relation to future deep-sea mining activities, further research is required.

ACKNOWLEDGEMENTS: Thanks to the scientific crew on the three ROBES voyages (2018-20), Malcolm Clark for his leadership of the project, and the officers, engineers, catering staff and deck crew of RV *Tangaroa*, plus NIWA Vessels Management. Acknowledgements are also given for the funding of the ROBES project by the MBIE Endeavour Fund, NIWA for capital expenditure, especially the development of new benthic lander technology, and the ROBES Technical Advisory Group for their guidance in developing the project’s direction.

12

Effects of experimental in situ seabed disturbance on macrofaunal communities of Chatham Rise

Campbell Murray, Ashley Rowden, Daniel Leduc, Scott Nodder, Rachel Hale, Malcolm Clark

ROBES End-users Webinar June 30, 2022

NIWA
Taihoro Nukurangi

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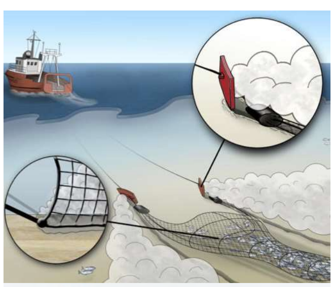
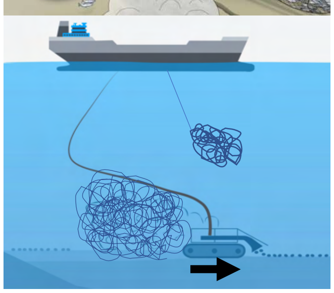
1

The issue: Sedimentation

Bottom trawling and mining





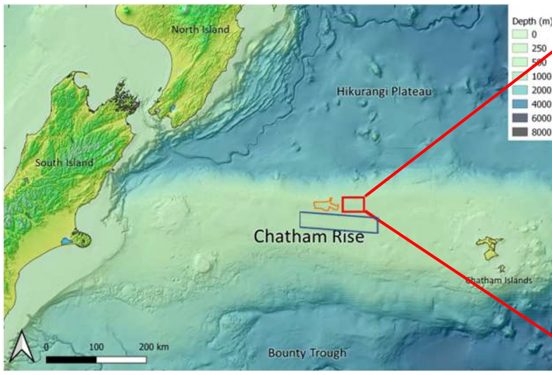
dw.com usgs.gov

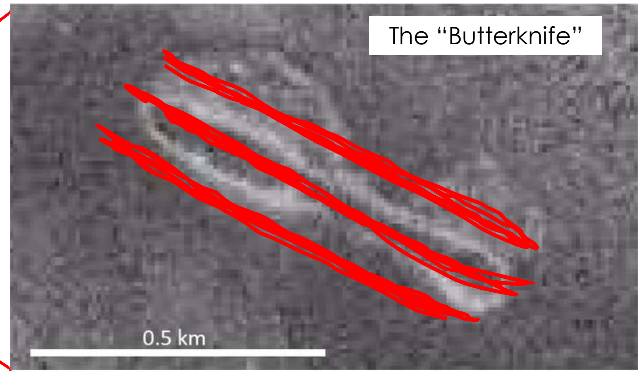
Resilience of benthic communities to the effects of sedimentation ("ROBES")

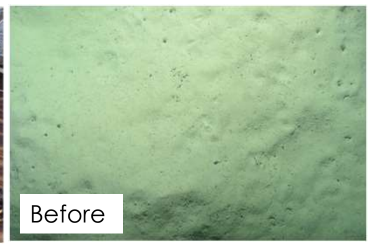
niwa.co.nz

2

Survey area: Chatham Rise







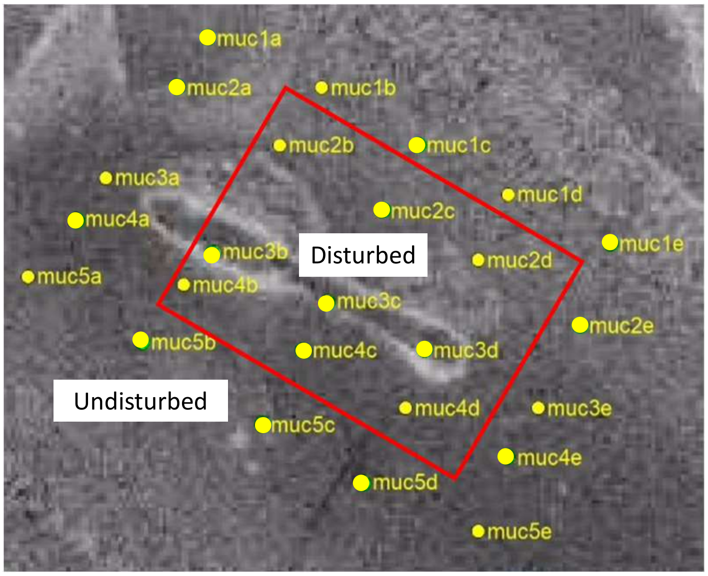
3

Macrofauna

- Multicorer obtained seabed samples which were then washed through a 300-micron sieve. Includes infauna and animals on the seabed.
- Can be more sensitive to disturbance than larger epifauna
- Play a role in nutrient recycling and facilitate bacterial function through bioturbation

4

Multicore sampling design



<u>Treatment</u>

Disturbed – Physically run over/ subjected to sedimentation

Undisturbed – Subjected to low-level sedimentation

<u>Sampling period</u>

(P) Pre-disturbance (June 2019)

(A) Immediately after disturbance (June 2019)

(O) One year after disturbance (June 2020)

5

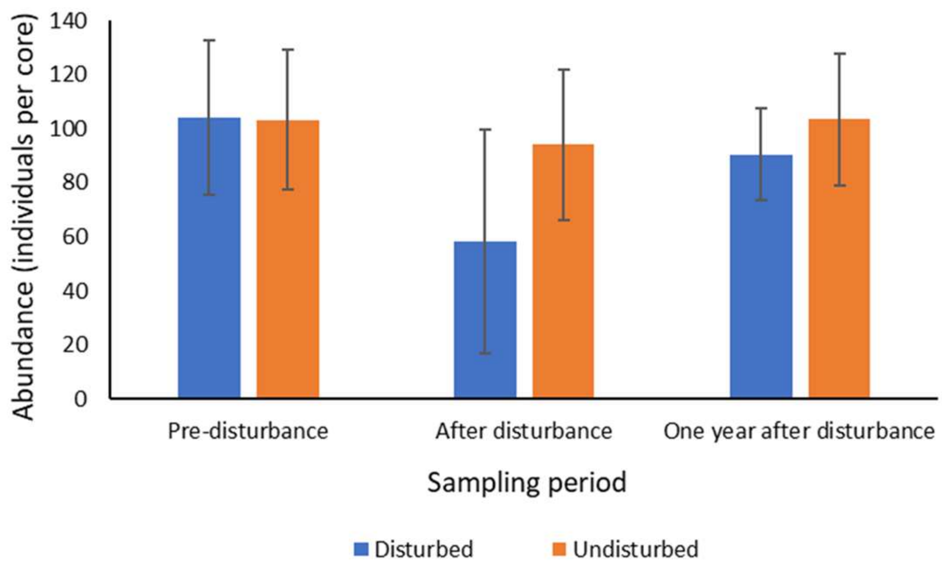
Results: Univariate abundance

Groups (Sampling period)	t	P (perm)
D, U (P)	0.30749	0.7713
D, U (A)	2.5716	**0.0155**
D, U (O)	1.3865	0.1795
Groups (Treatment)	**t**	**P (perm)**
P, A (D)	2.73	**0.0168**
P, O (D)	1.2257	0.2456
A, O (D)	2.1614	**0.0474**
P, A (U)	0.67206	0.5018
P, O (U)	0.30684	0.7657
A, O (U)	1.0068	0.3178

Testing for a difference in total abundance between groups

6

Results: Univariate abundance



7

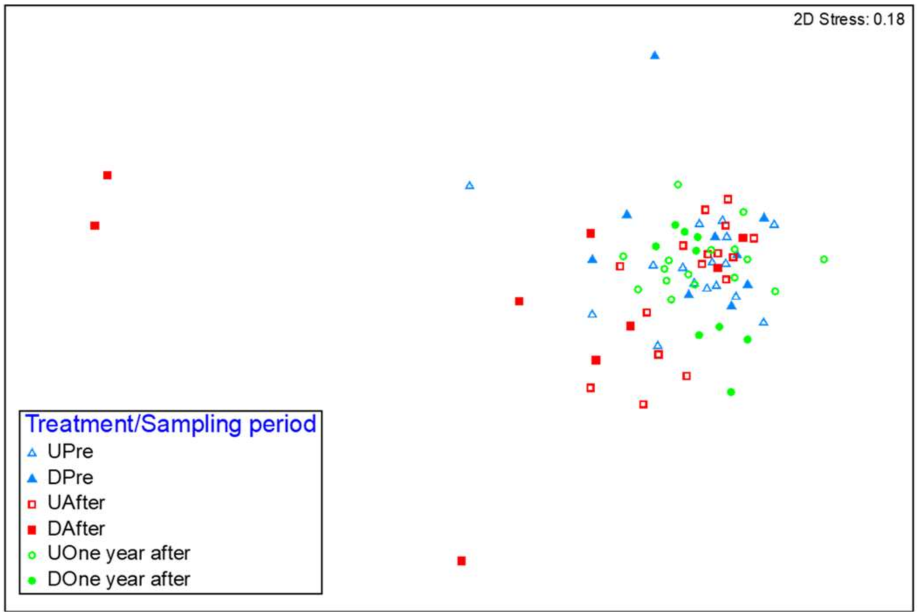
Results: Multivariate abundance

Groups	Treatment level	t	P (perm)
P, A	D	1.8108	**0.0118**
P, O	D	1.2686	0.1035
A, O	D	1.8382	**0.0097**
P, A	U	1.4572	**0.0259**
P, O	U	0.79958	0.7744
A, O	U	1.3072	0.0842

Testing for a difference in community structure between groups

8

Results: Multivariate abundance



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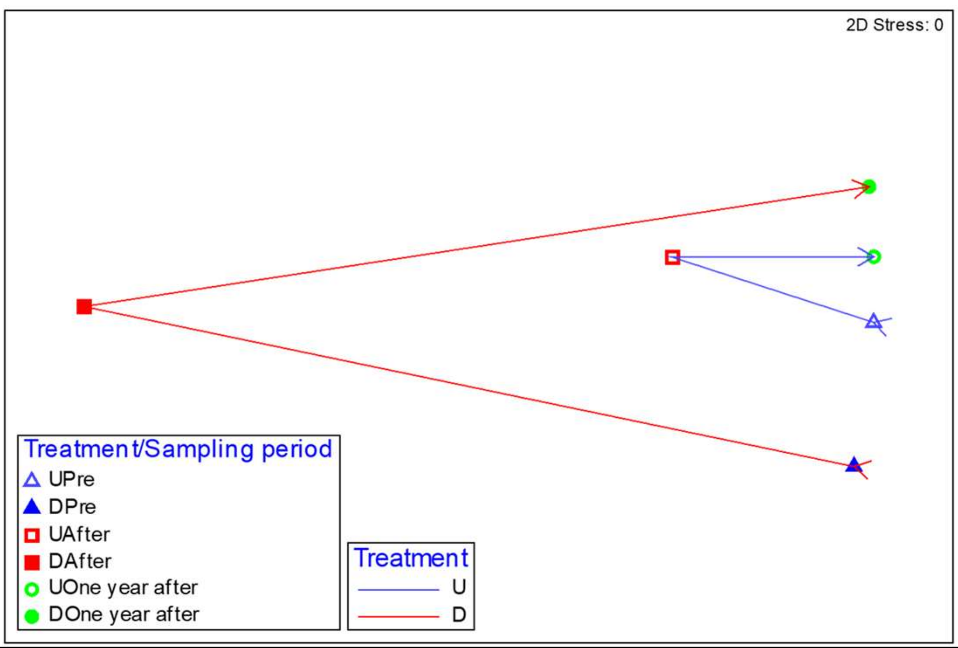
Results: Multivariate abundance



10

Average abundance (indivs. per core) in undisturbed sites

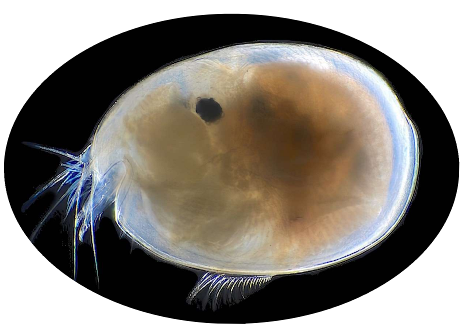
		Before		Immediately after	Contribution % to total
	Polychaetes	59.4	↓	50.1	10.24 %
	Bivalves	2.9	↑	3.8	8.89 %
	Sipunculans	1.3	↓	0.8	7.86 %
	Tanaids	5.4	↑	6	7.55 %
	Amphipods	7.1	↓	4.7	7.5 %

Avg dissimilarity = 25.12

11

Discriminating taxa (dissimilarity/SD >1.3)

Ostracods (seed shrimp)



- Other studies have found ostracods to be excellent bioindicators of changes in environmental variables, such as bottom grain sizes, salinity, temperature, pH, dissolved oxygen and hydraulic conditions

Difference between	Dissimilarity/SD
Undisturbed and disturbed (after disturbance)	1.51
Predisturbance and after disturbance (in undisturbed area)	1.32
Predisturbance and after disturbance (in disturbed area)	1.49
After and one year after disturbance (in disturbed area)	1.49

12

Conclusions

- Macrofauna appear to be resilient to the disturbance caused by SCIP
- Impacts are more pronounced in physically disturbed areas than in adjacent areas
- Only subtle changes to community structure were observed in the undisturbed area (Sedimentation disturbance)
- Future research is needed to assess the impact of repeated or prolonged disturbance on macrofaunal communities

13

14

Effects of experimental seabed disturbance on meiofaunal communities of Chatham Rise

Daniel Leduc, Campbell Murray, Ashley Rowden, Scott Nodder,
Rachel Hale, Malcolm Clark

ROBES End-users Webinar June 30, 2022

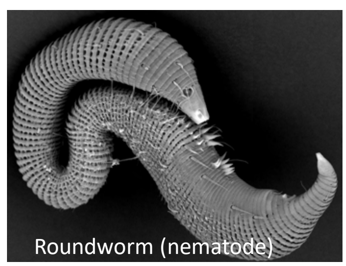
Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi

1

Meiofauna – what are they?

- Similar to macrofauna, i.e., animals living in the seabed but microscopic, about 1 mm or less in length
- Consists of distinct invertebrate groups, dominated by roundworms (nematodes)
- Widespread, from beaches to the deepest ocean
- Highly abundant, about 1 million individuals per m^2 on continental slope


Roundworm (nematode)


Copepod crustacean


Gastrotrich


Crustacean larva (nauplius)

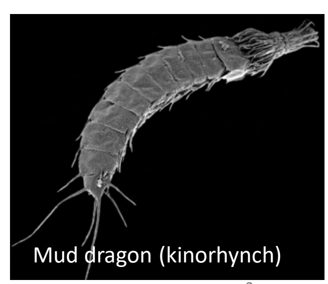

Mud dragon (kinorhynch)

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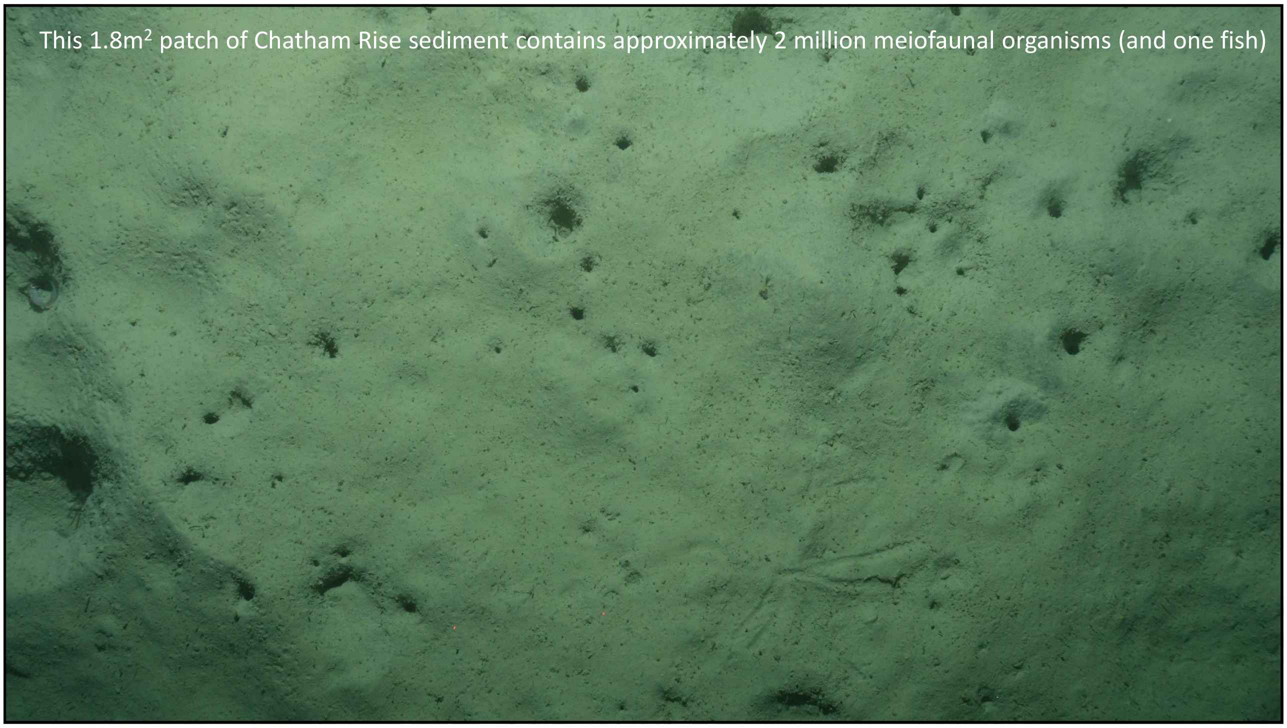
Image credits: Brandão, S.N.; Karanovic, I. (2021). World Ostracoda Database. Accessed at http://www.marinespecies.org/ostracoda on 2021-03-02. doi:10.14284/364; Martin Sorensen, Natural History Museum of Denmark, Denmark; Hidetaka Nomaki, JAMSTEC, Japan; Jisu Yeom, Hanyang University, South Korea; Daniel Leduc, NIWA, New Zealand

2

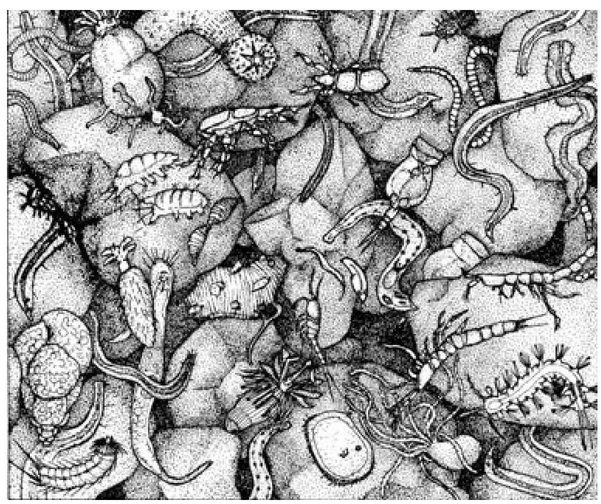
2



3

Meiofauna – what do they do?

- By constantly moving and feeding in the sediment, meiofauna speed up the decomposition of organic matter and help release nutrients back into the water column
- A healthy meiofauna community helps maintain seabed ecosystem function



Meiofauna among the sand grains

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4

4

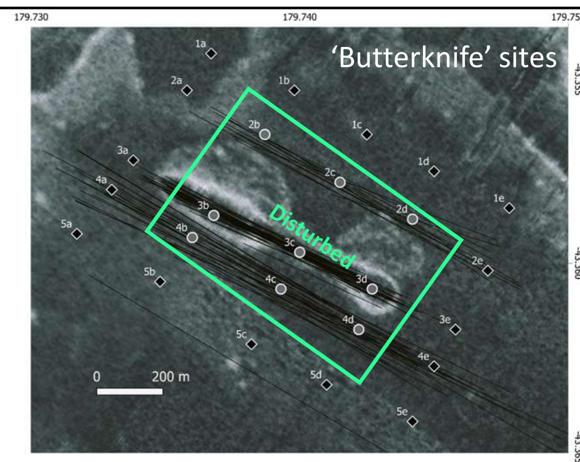
Are meiofauna vulnerable?

- Meiofauna considered more resilient to physical disturbance than larger organisms due to small size and high turnover rate
- Impacts on seabed meiofauna from experimental disturbance range from positive to long-term (decades) negative effects
- Little information on meiofauna in deep-sea ecosystems

Roundworm from Chatham Rise (*Pselionema*)

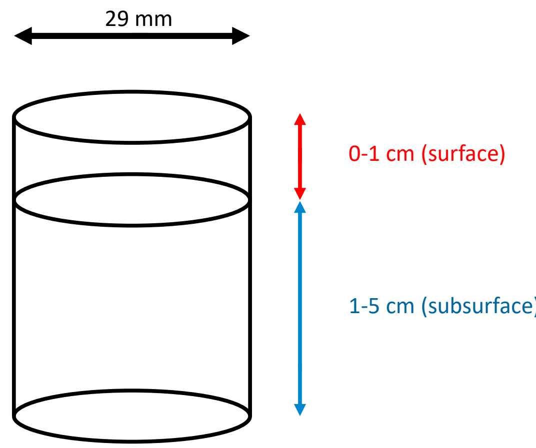
ROBES disturbance experiment 2019 & 2020

- ‘Butterknife’ feature, 450 m depth
- Grid of 5 x 5 sites, central 9 sites disturbed by SCIP, 16 sites on periphery undisturbed
- Sites sampled pre-disturbance, immediately after disturbance, and one year post-disturbance using multicorer
- Reference site also sampled, 15km north-west of Butterknife



Sampling

- Meiofauna samples were obtained using a small core of diameter 29 mm
- Cores were sliced into surface (0-1 cm) and subsurface (1-5 cm) layers because these usually contain different meiofauna



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Sediment characteristics

- Sediment characteristics important for meiofauna
- Physical characteristics (grain size, porosity)
- Food availability (organic matter, pigments, carbon and nitrogen content)
- Food quality (carbon to nitrogen ratio, chlorophyll *a* to phaeopigment ratio)

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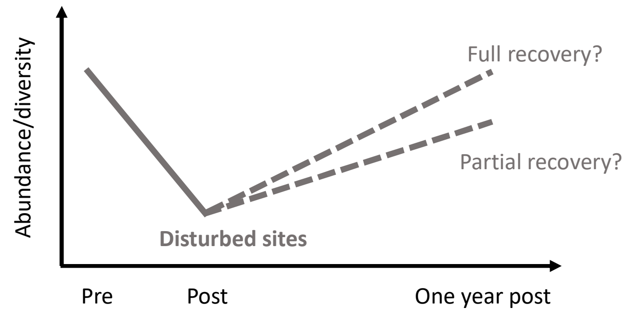
Predicted response

- We predicted a decline in meiofauna abundance/diversity at the disturbed sites immediately post-disturbance, followed by partial to full recovery one year later



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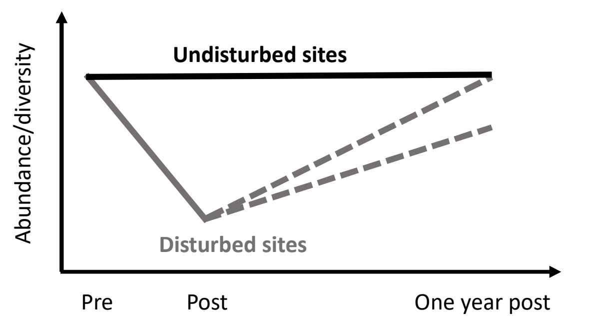
Predicted response

- We predicted a decline in meiofauna abundance/diversity immediately post-disturbance, followed by partial to full recovery one year later
- We predicted no change for the undisturbed sites



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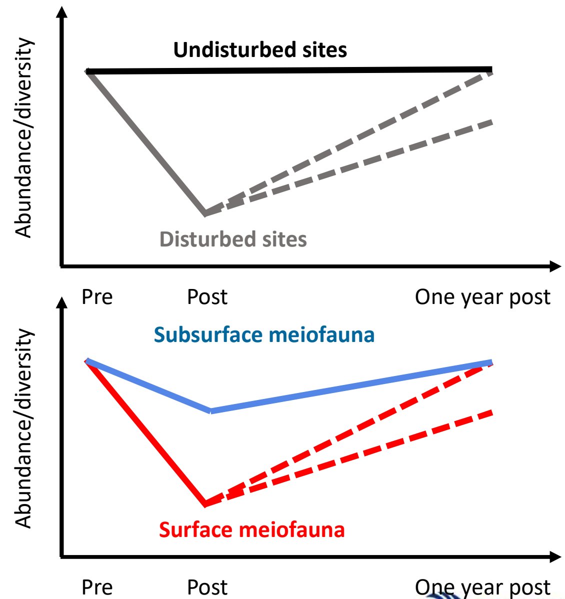
10

Predicted response

- We predicted a decline in meiofauna abundance/diversity immediately post-disturbance, followed by partial to full recovery one year later
- We predicted no change for the undisturbed sites
- At the disturbed sites, we predicted a more pronounced decline in surface (0-1 cm)than subsurface meiofauna (1-5 cm) abundance/diversity immediately post-disturbance, followed by partial to full recovery one year later
- Sediment characteristics were expected to show similar pattern overall



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Results - Sediment characteristics

- No change at reference site between 2019 and 2020

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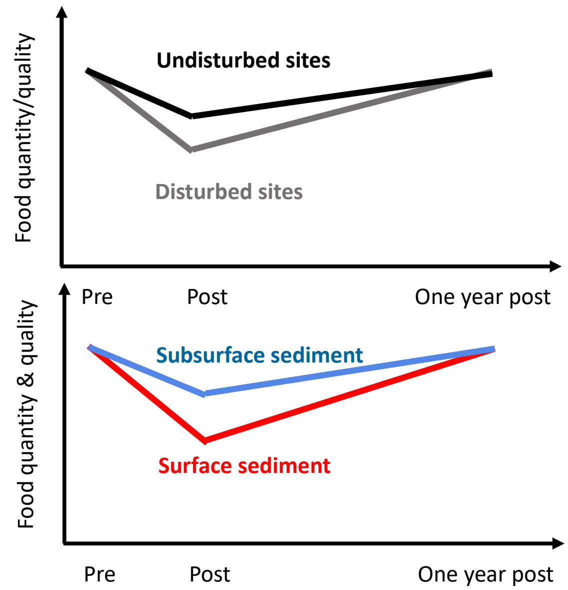
Results - Sediment characteristics

- No change at reference site between 2019 and 2020
- At Butterknife sites, food quantity and quality both decreased immediately after disturbance, most markedly at disturbed sites and in surface (0-1 cm) sediment layer, then returned to pre-disturbance levels one year later
- No change in grain size or porosity

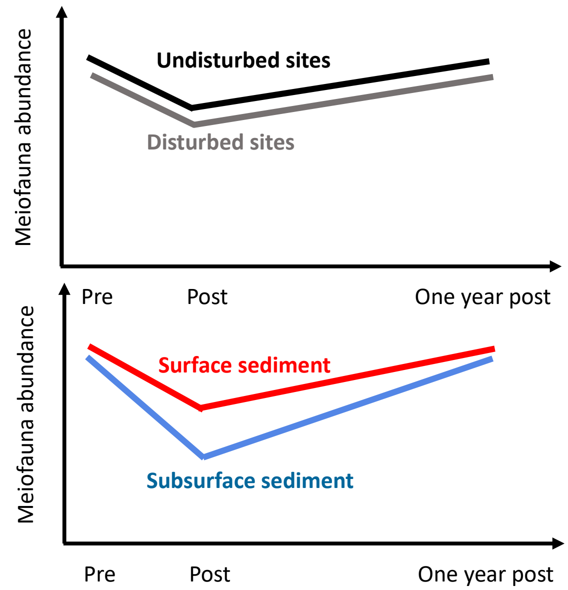


Results - Meiofauna abundance and diversity

- Little change at reference site between 2019 and 2020 (slight increase in abundance of 0-1 cm layer)

Results - Meiofauna abundance and diversity

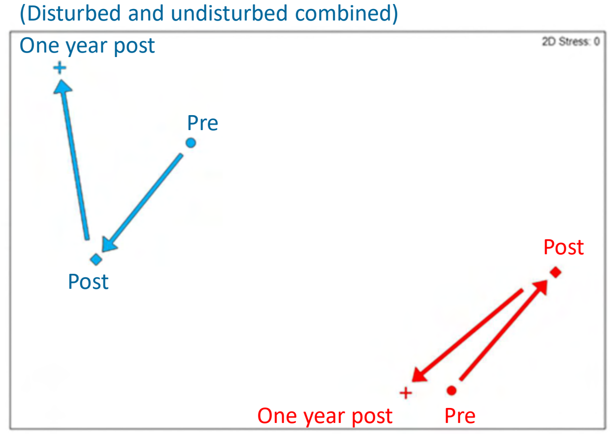
- Limited change in meiofauna abundance at both disturbed and undisturbed sites (and no change in diversity anywhere)
- More pronounced decrease in abundance in subsurface than surface layer (opposite of what was expected) immediately after disturbance, followed by return to pre-disturbance levels one year after



Results - Meiofauna community structure

- No difference between disturbed and undisturbed sites (unexpected!)
- Surface and subsurface consistently different (as expected)
- Surface and subsurface meiofauna affected by disturbance, with decreased abundance of main groups (roundworms, copepods, mud dragons)
- One year later, subsurface meiofauna recovered more slowly than surface meiofauna, mainly because copepod abundance still lower than pre-disturbance
- Recovery of meiofaunal community between 2019 and 2020 was linked to increased food quantity and quality in the sediment

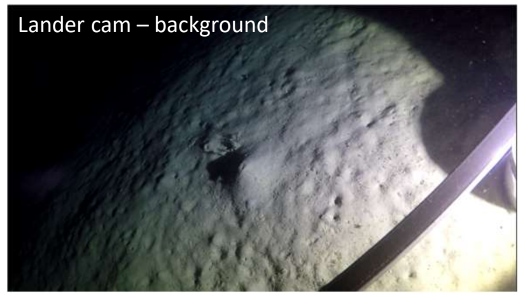
Subsurface layer
(Disturbed and undisturbed combined)

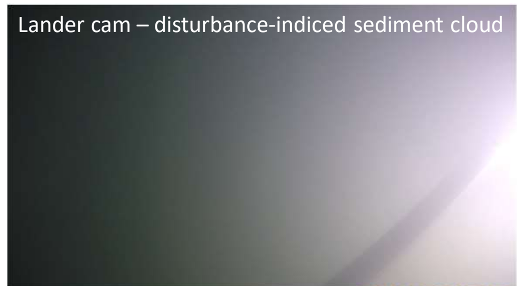


Surface layer
(Disturbed and undisturbed combined)

Conclusion 1

- Contrary to our expectation, meiofauna at disturbed and undisturbed sites showed the same short-term response to the experimental disturbance
- Reduced meiofaunal abundance immediately post-disturbance may be due to resuspension of top >1cm sediment and meiofauna as a result of mechanical disturbance and locally-induced currents
- Resuspended meiofauna may have drifted away due to currents while heavier sediment particles may have settled in vicinity of Butterknife
- Direct mortality and burial also possible. But no clear sign of freshly deposited sediment layer in cores.





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Conclusion 2

- Also contrary to our expectations, the surface meiofauna was not more strongly impacted by the disturbance than the subsurface community – both similarly affected
- Unlike surface meiofauna, the subsurface meiofauna community still had not recovered to pre-disturbance state one year after disturbance (copepods)
- Meiofaunal taxa inhabiting subsurface layer are less easily dispersed by currents, which may result in slower recolonisation?
- Increased food supply from 2019 to 2020 is another factor which may have promoted meiofauna recovery

Copepods appear more sensitive to disturbance? (Female with eggs)

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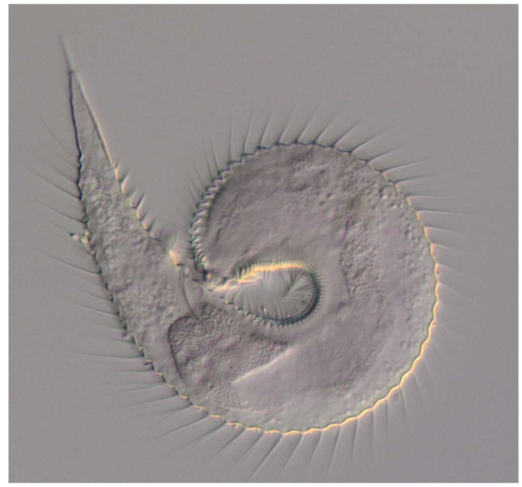
Image credits: Jisu Yeom, Hanyang University, South Korea

18

Implications

- Chatham Rise meiofauna are negatively impacted by a relatively small-scale, one-off disturbance
- Recovery may take longer than a year for subsurface meiofauna
- Reduced meiofaunal abundance may compromise health of seabed ecosystem and provision of ecosystem services



Chatham rise roundworm with cuticle spines (*Greeffiella*)

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Ngā mihi

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Ship-board seafloor sediment experiments

Rachel Hale et al…….

Apirana Daymond, Campbell Murray, Cassidy Solomon, Chris Eager, Chris Hickey, Daniel Leduc, Lee Rauhina-August, Rima Browne, Rob Stewart, Scott Nodder, Steve George….and more

ROBES End-users Webinar June 30, 2022

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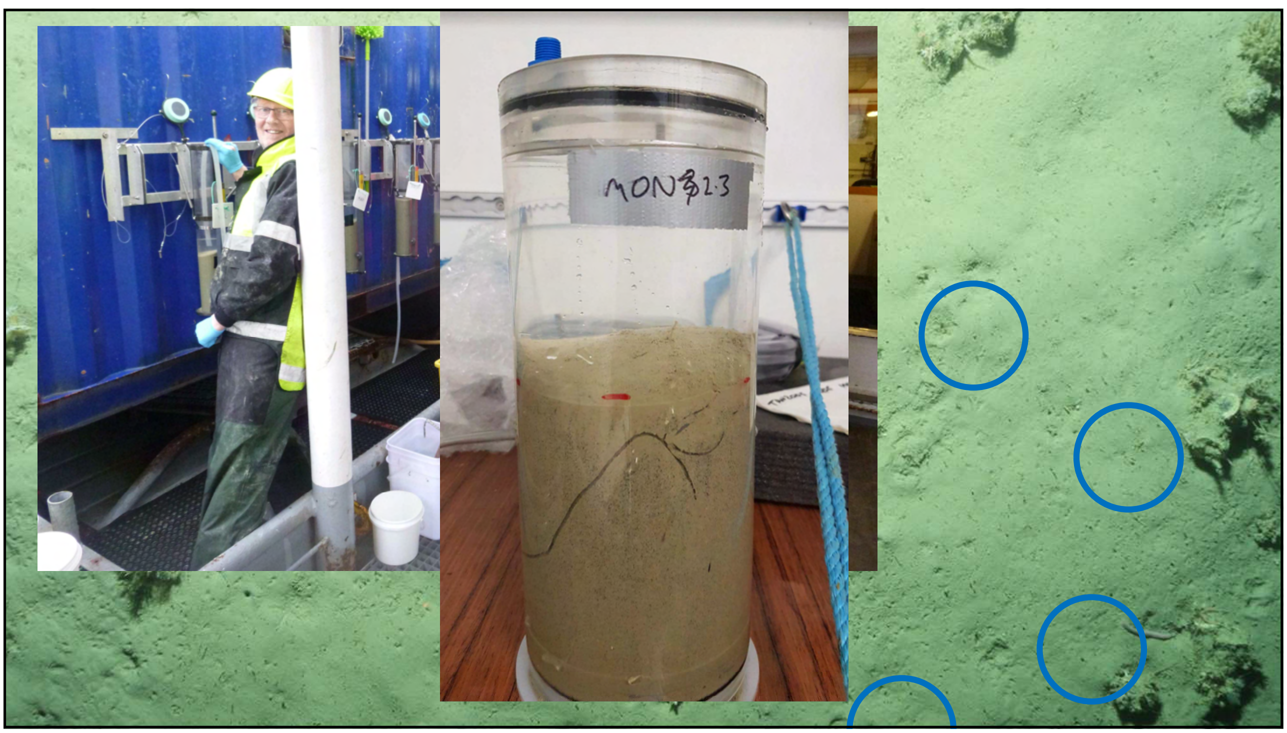

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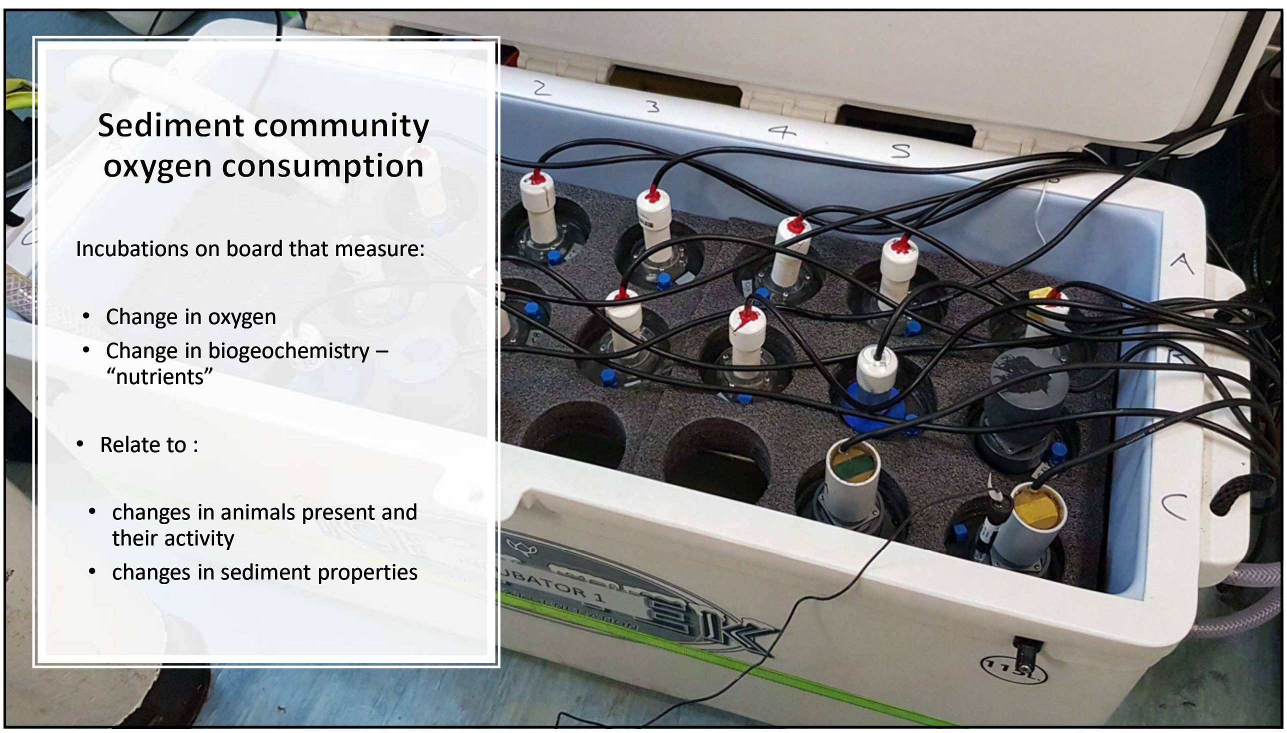
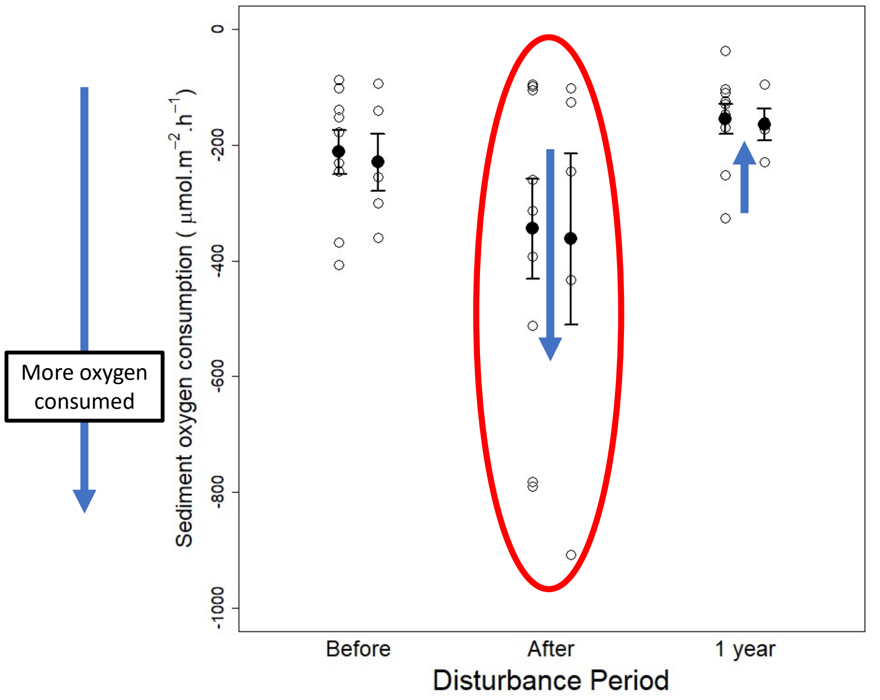
Ship-board seafloor sediment experiments
1. Sediment community oxygen consumption
2. Sediment capping experiment
3. Simulated on-board disturbance – tumbler and EROMES

3

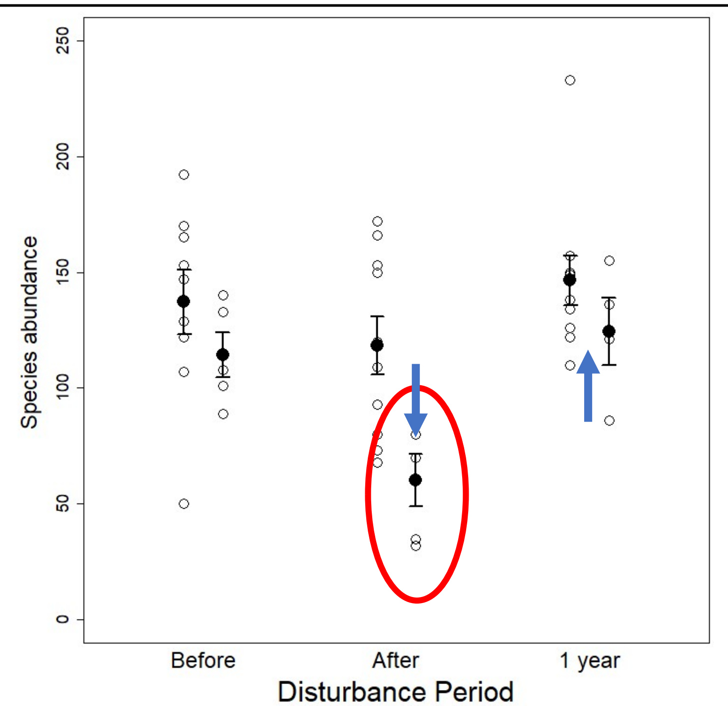

Sediment community oxygen consumption
Incubations on board that measure:
• Change in oxygen
• Change in biogeochemistry – "nutrients"
• Relate to :
• changes in animals present and their activity
• changes in sediment properties

4



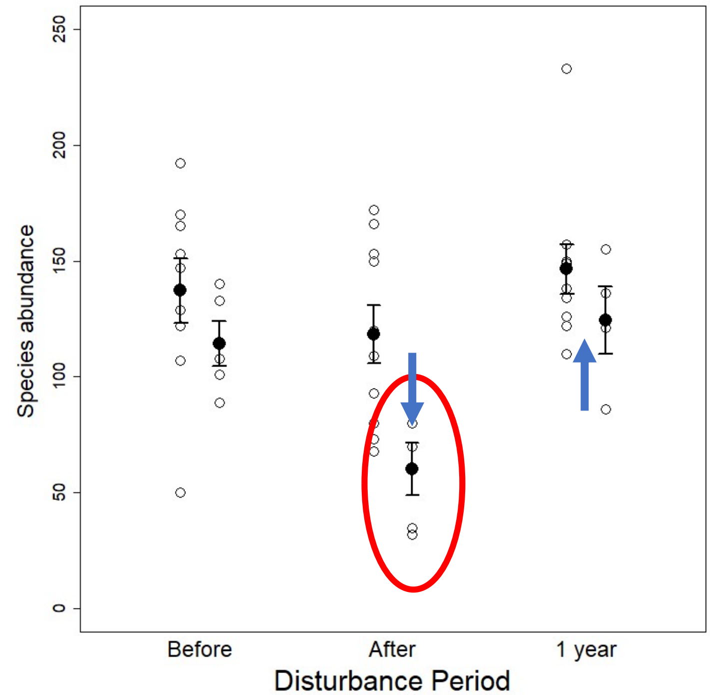
- Immediately post-disturbance sediment community oxygen consumption increases
- Across both directly disturbed and indirectly disturbed locations
- Then returns to pre-disturbance levels one year later.

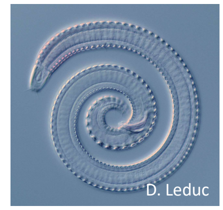
5



Spatial variation between central and outer study area, but immediately post-disturbance – directly disturbed communities are affected – lower species abundance, but again returns to pre-disturbance levels one year later.

6





Frutos et al.

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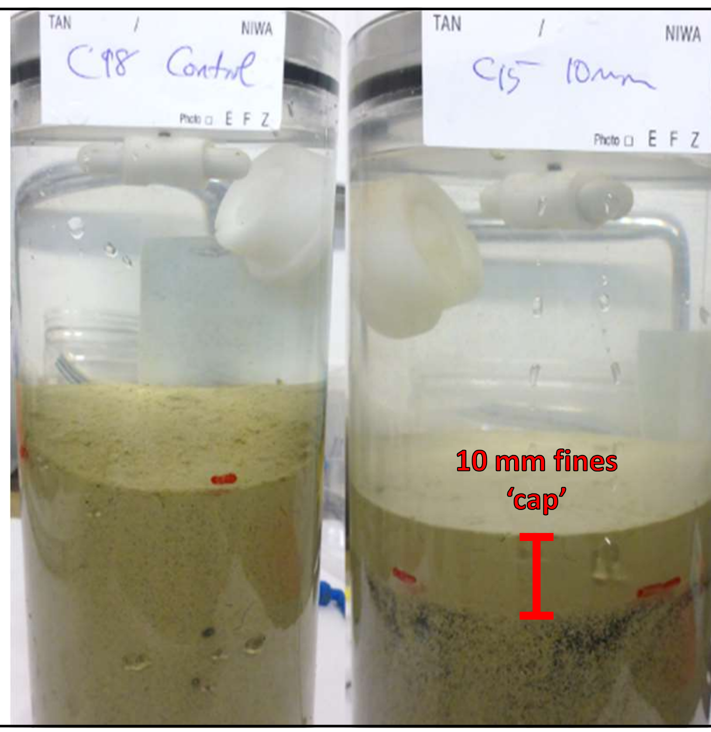
Sediment capping experiment

Incubations on board that measure:

- What is effect of blanketing seabed with fines?
- 5mm, marked reduction in DO penetration
- Development of anoxic sediments



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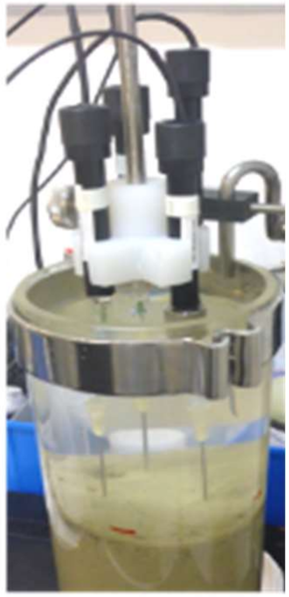
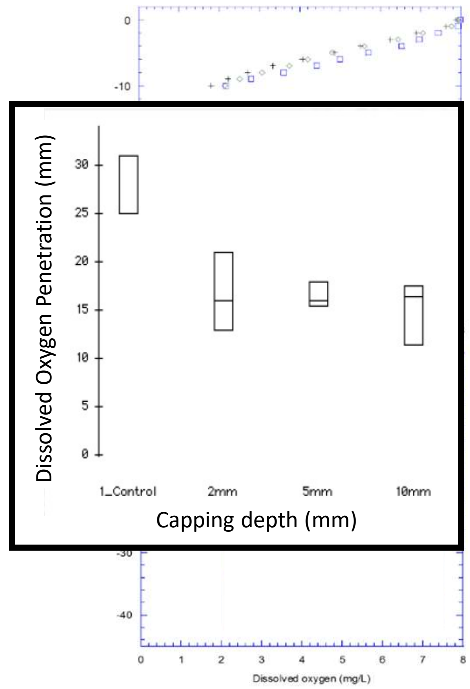
Sediment capping profiling

- marked reduction in seabed oxygen penetration:
  max 40mm to 15mm
- Development of anoxic sediments under cap
- Organisms are most abundant in the top few cm





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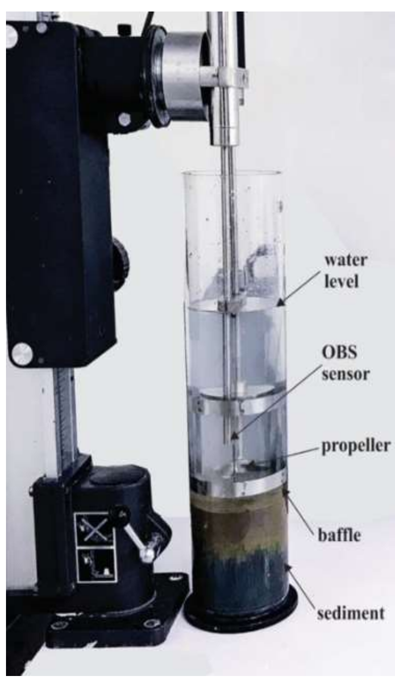
Simulated on-board disturbance

Disturbances on board to examine:

- Surface resuspension – analogous to natural currents/”benthic storm”
- Larger disturbance – complete disruption of surface and deeper layers
- Analyses in progress…



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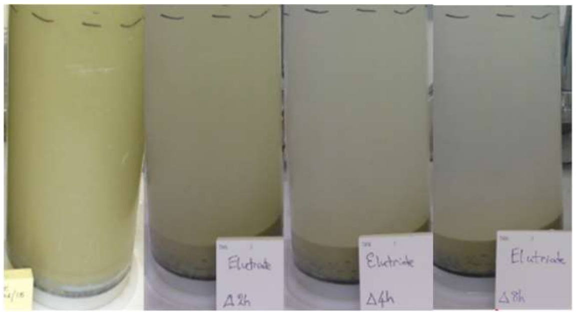
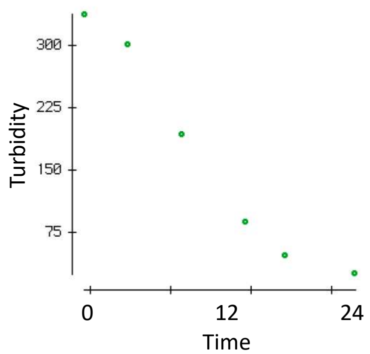
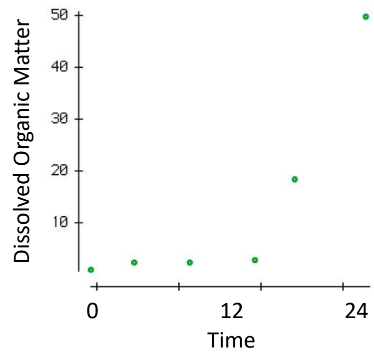


"Elutriate" samples – agitated for 24 hours on the tumbler
-> complete sediment disruption

Measured:
- silty resuspended particles/turbidity
- dissolved oxygen
- dissolved nutrients (carbon, nitrogen, phosphorus, etc.)
- dissolved metals





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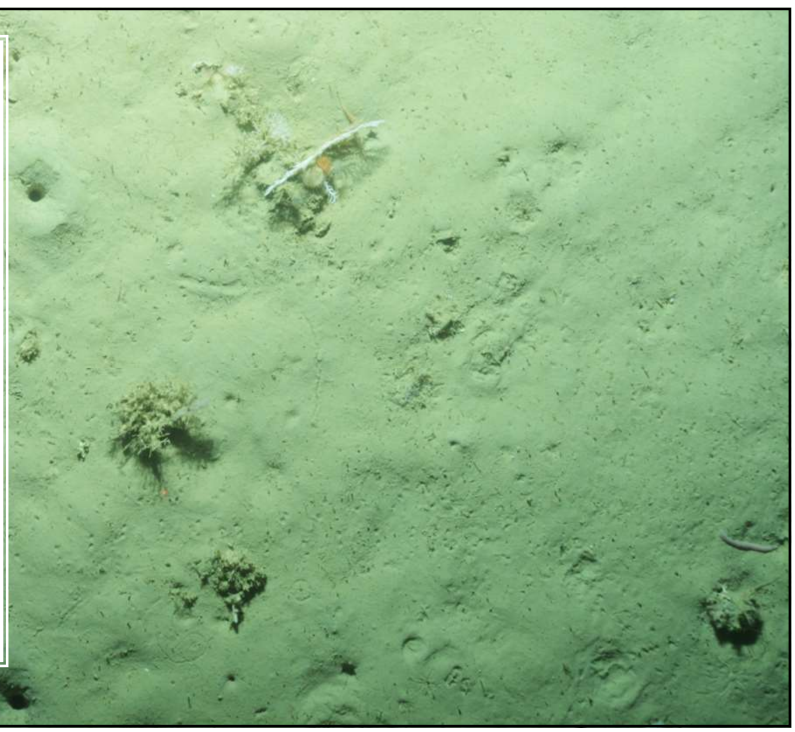
Conclusions

- disruption to multiple aspects of seabed biogeochemistry and ecosystem processes
- Changes in oxygen availability particularly important
- Determining effects of natural and larger disturbance and sedimentation over short- and long- timescales will be crucial to understand and manage effects of mining impacts



12

Can deep sea corals and sponges cope with elevated suspended sediments?

Vonda Cummings, Valeria Mobilia, Di Tracey, Peter Marriott, Jennifer Beaumont, Graeme Moss, Neill Barr, Malcolm Clark (NIWA)
James Bell (VUW)

VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA

ROBES End-users Webinar June 30, 2022

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Background

The generation of sediment plumes by human activities, such as bottom fishing and potential deep-sea mining, poses threats to deep-sea benthic fauna

- Many benthic species have strategies to cope with elevated suspended sediment concentrations (e.g., can stop pumping, expel large sediment particles, produce mucous)
- Relative lack of data for **deep-sea organisms**
- Sessile sponges & corals are abundant and ecologically important species on the Chatham Rise
- **Is there a threshold of suspended** sediment for these groups when impact is serious?

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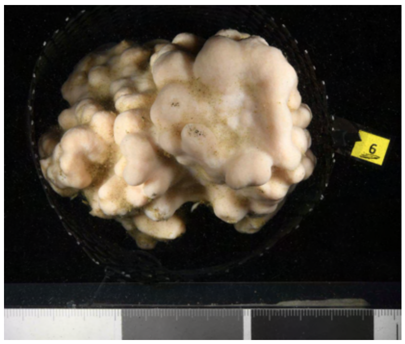
What we did:

Responses of common Chatham Rise sponge and coral species to sediment disturbance?

Ecionemia novaezealandiae
knobbly sandpaper sponge



Goniocorella dumosa
stony branching coral

For Methods on sampling the study species at-sea *see Clark_survey* data presentation

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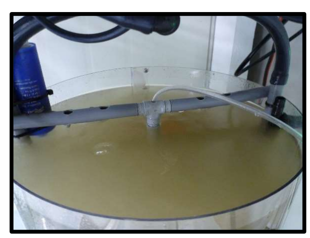
Three laboratory experiments: MEMF

Vortex-based sediment resuspension chambers

- Sediments sourced from the Chatham Rise
- Suspended sediment concentrations informed by field measurements:

  0 mg l^{-1} ← "control" conditions
  50 mg l^{-1}
  100 mg l^{-1}
  500 mg l^{-1}
  (50–500 mg l^{-1}: mining/trawling disturbance)

- T, pH, Water flow reflected *in situ* dark environment



16 chambers, each 28 litres, 4 reps

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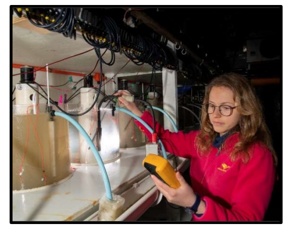
Assessed deep sea sponge/coral responses:

- Survival
- Metabolism (respiration rates)
- Structural damage (sponge tissue necrosis & budding, coral outer tissue damage/polyp health)



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Experiments:

Expt 1: Sponge - Continuous SSC exposure

14 day experiment

Sampled after 1 & 14 days

Expt 2: Coral - Pulsed SSC exposure

4-days SSC : 5-days no SSC (3 pulse cycles)

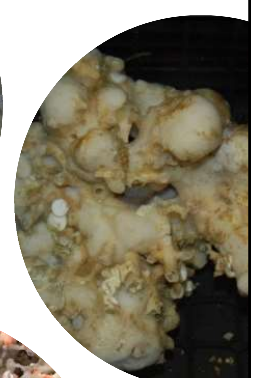
27 day experiment

Sampled after each pulse (T1, T2, T3) and at expt end

Expt 3: Coral - Continuous exposure

28 day experiment

Sampled after 5, 14 & 28 days



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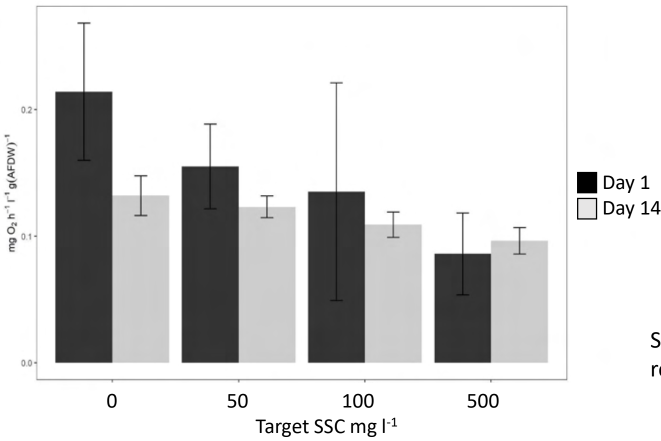
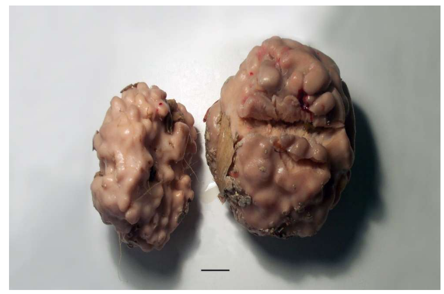
Sponge, continuous SSC:

Respiration rates





Significant effect of SSC treatment on sponge respiration rates ($F_{(3,23)}$ = 3.85, p = 0.0224)

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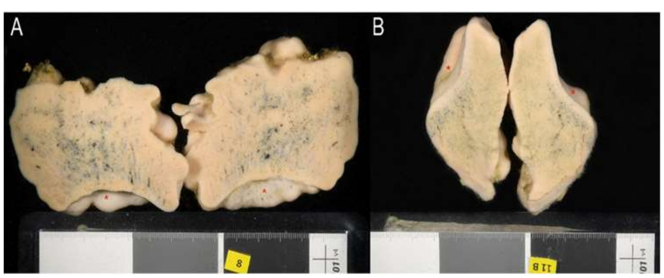
Mobilia et al. (2021). J. Exp Mar. Biol. Ecol. 541

7

Sponge, continuous SSC:

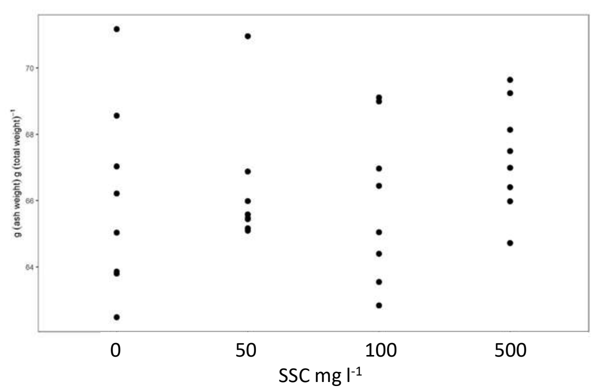
Presence of sediment inside sponge body



Control sponge

100 mg l^{-1} SSC treatment sponge

No difference in the % inorganic content among treatment and control sponges



Mobilia et al. (2021). J. Exp Mar. Biol. Ecol. 541

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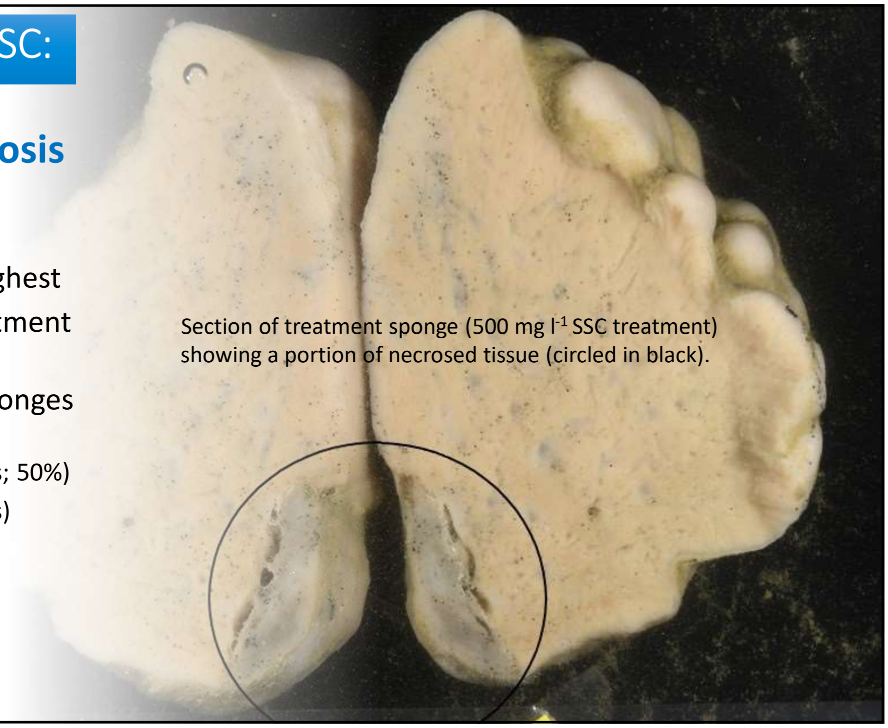
Sponge, continuous SSC:

Survival & necrosis

- One death, in the highest (500 mg l^{-1}) SSC treatment
- Partial necrosis in sponges from:
  500 mg l^{-1} SSC (4 sponges; 50%)
  100 mg l^{-1} SSC (2 sponges)
  0 mg l^{-1} SSC (1 sponge)



Section of treatment sponge (500 mg l^{-1} SSC treatment) showing a portion of necrosed tissue (circled in black).

Mobilia et al. (2021). J. Exp Mar. Biol. Ecol. 541

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Sponge, continuous SSC *Summary:*

- Rapid response to elevated SSCs
- Reduction in respiration rates with elevated SSC, possibly due to decreased pumping activity
- Sediment incorporated in sponge tissue was not correlated with experimental SSC exposure
- Sub-lethal effects observed potentially serious to the health of *E. novaezealandiae* beyond the sediment exposure period

Mobilia et al. (2021). J. Exp Mar. Biol. Ecol. 541

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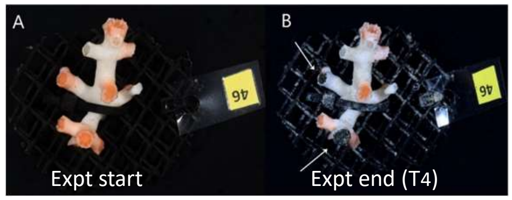
Coral, pulsed SSC:



- 100 % survival of whole coral fragments
- Mortality of some polyps in SSC treatment corals from T_2 onwards (after 2 extended pulses)

4 days SSC, 5 days no SSC (3 pulse cycles)
Sampled after each pulse (T1, T2, T3)
and at expt end (T4)

	T_1				T_2				T_3				T_4			
	SSCs															
	0	**50**	**100**	**500**	**0**	**50**	**100**	**500**	**0**	**50**	**100**	**500**	**0**	**50**	**100**	**500**
Total polyp no.	75	69	59	54	89	81	49	75	48	89	70	62	67	63	58	75
Dead polyp no.	-	-	-	-	-	-	1	2	-	-	-	2	-	1	1	4

Mobilia et al. draft MS

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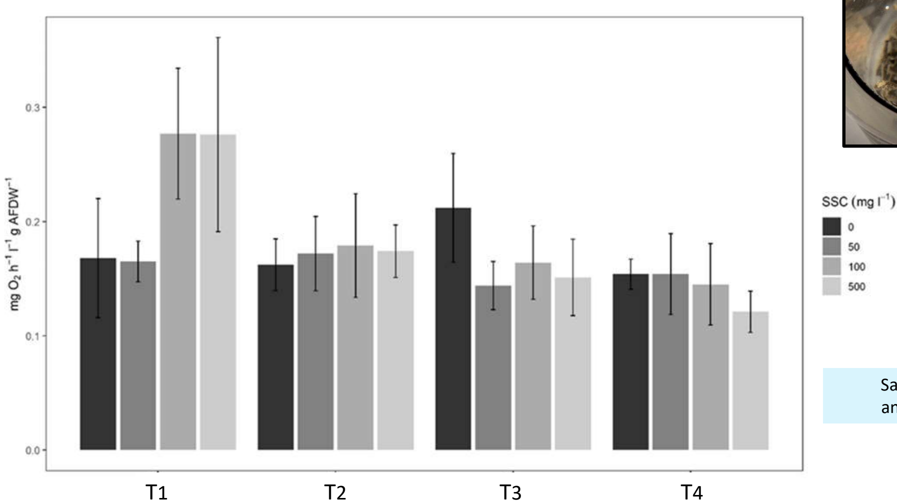
Coral, pulsed SSC:

Respiration rates – not affected



Sampled after each pulse (T1, T2, T3)
and at expt end (T4)

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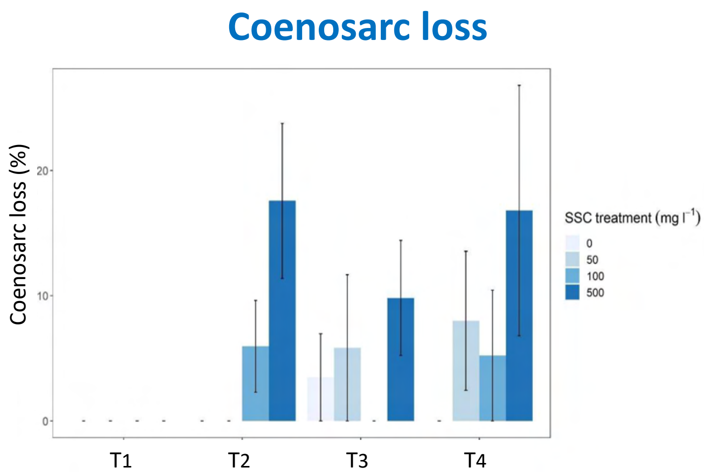
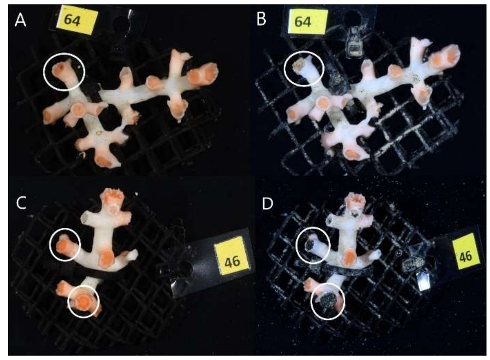
Coral, pulsed SSC:



Percentage of coenosarc loss (%) in each of the suspended sediment concentration (SSC) treatments at each sampling time point (T_1 = 4, T_2 = 13, T_3 = 22, T_4 = 27 days). Bars show mean values ± SE. N = 4.



- Partial coenosarc loss from T_2 onwards, highly variable
- No statistically significant effect of SSC and time on % coenosarc loss

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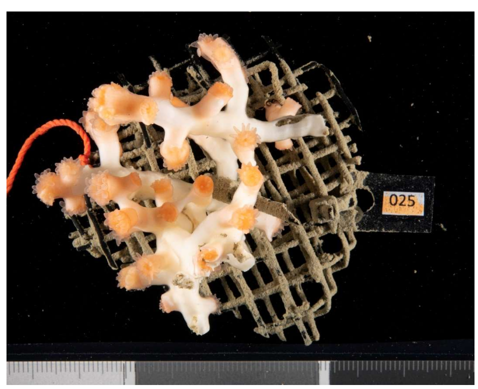
Coral, pulsed SSC *Summary:*

- Total survival and sublethal responses (respiration rates, loss of coenosarc loss) not significantly impacted by elevated SSCs

BUT

- Polyp mortality and coenosarc loss show decline in coral health
- Sublethal effects could be long-lasting: long time needed to recover



Mobilia et al. draft MS

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Coral, continuous SSC:

Expt 3: Continuous SSC,
sampled after 5, 14 & 28 days

- Respiration rates
- Polyp counts/mortality
- Change in polyp and skeletal tissue/coenosarc extent

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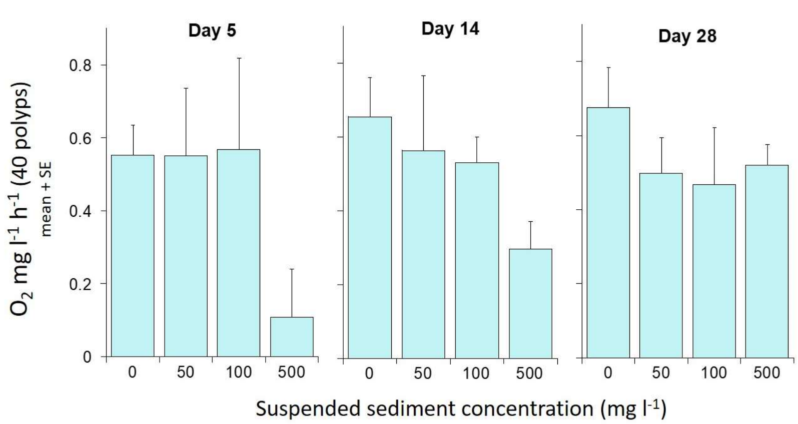
Coral, continuous SSC:

Respiration rates



- on Days 5 and 14 the corals in the 500 mg l^{-1} SSC had reduced respiration rates
- by Day 28 the rates were similar across treatments

→ initial shut-down at 500 mg l^{-1}, but then slow acclimatisation towards end of experiment

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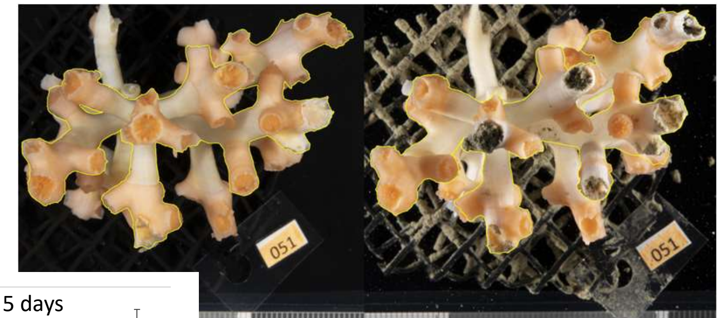
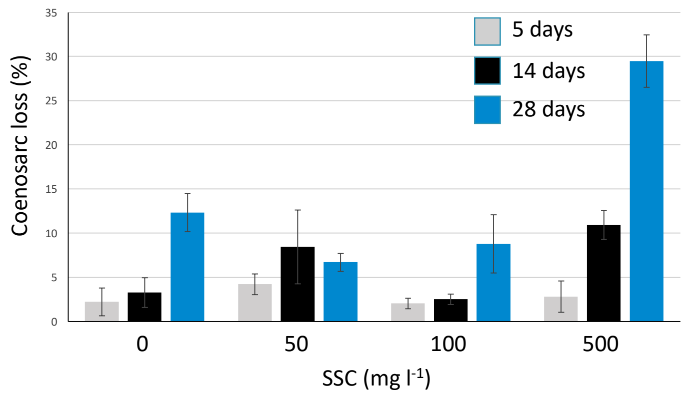
Coral, continuous SSC:

Polyp tissue loss





- Clear tissue loss between start (left) and end (right) photo.
- Marked increase in tissue loss of coral polyps with time especially at 500 mg l^{-1}

Cummings et al. draft MS

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Coral, continuous SSC *Summary:*

- Reduced respiration rates
- Increase in dead polyps over time
- Polyp and skeletal tissue loss increased with SSC and exposure time (esp. at 500 mg l^{-1})

Exciting discovery!
The corals produced larvae during the experiment:
G. dumosa are brooders.

→ Brooders have limited dispersal capability cf. broadcast spawners

Tracey et al. 2022
Beaumont et al. draft MS

Cummings et al. draft MS

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Conclusions

 

- Mortality rates were extremely low for both species
  (occurred at the highest SSC)

- Respiration rates were affected in corals only
  - Immediately reduced in corals in both experiments
    (halved in the highest SSC cf. controls)
  - After 28 days continuous exposure, rates were as for controls

 

- Clear tissue damage in both species, esp. at 500 mg l^{-1}
  (sponge necrosis, polyp tissue loss)

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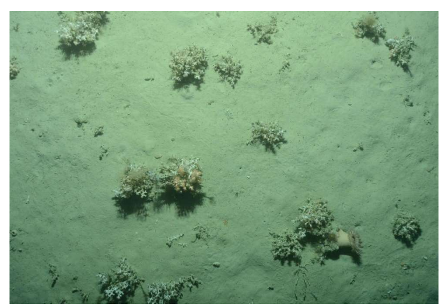
Conclusions



- Sublethal affects are a concern; prolonged exposure to elevated SSCs detrimental to health
  - Implications for reproduction and growth?
  - More studies needed

- Next steps
  - Submit coral papers
  - More explicitly link experimental findings with the other components of the ROBES programme
    (continuous coral experiment)

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Nga mihi

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VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA

NIWA Taihoro Nukurangi

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ROBES: Where to next?

Malcolm Clark

Climate, Freshwater & Ocean Science

ROBES End-users webinar, 30 June 2022

NIWA
Taihoro Nukurangi

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Objectives: a reminder

- Principal objective
  - to determine impacts of, and measure recovery of benthic communities over time from, sedimentation effects

- Four key questions:
  - Can we determine and quantify effects of settled and suspended sediment from plumes on benthic communities in situ?
  - Are some communities more resilient than others to various levels of particle sizes and concentrations?
  - Can thresholds of acute or sub-lethal levels of sedimentation be defined where impacts upon benthic communities become 'ecologically significant'?
  - Can impacted benthic communities recover in the short to medium term?

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General Conclusions

- Programme has collected a huge amount of data across a wide range of environmental factors related to sedimentation and sediment effects-both natural and human-induced
- Highly variable & dynamic environment on Chatham Rise-both spatially and temporally, with communities faced with persistent, occasionally high sediment loading.
- Shallow physical disturbance of sediments generated a minor sediment plume, with marked effects on near-bed sediment fluxes and water column characteristics
- Impact on infauna was clear, but signs of relatively quick "recovery" (within/at 1 year).
- Experimental results more informative for epifauna, showing impacts at high and prolonged suspended sediment levels (100 and 500 mg/l)

- Taken together results can provide a suite of information to assist understanding and management of human activities creating sedimentation in the deep sea.

Work Streams

- Biological community responses
  - Infauna-macrofauna, meiofauna, bacteria (based on multicore samples)
  - Epifauna (largely MEMF experiments)
  - Genetic/microbiome responses to suspended sediment (linked to MEMF experiments)
- Sedimentation experiments
  - Sediment erosion, elutriation, sediment capping data analyses
  - Sediment community respiration analyses
  - DGT sample processing (trace metals)
- Sediment samples
  - Multicorer (pre- & post-disturbance, 3 sites) grain size, physico-chemical characteristics (TOM, water content, CaCo3, POCPN/isotopes, chl/phaeopigments)
  - Benthic lander data (Aquascat, Aqualogger, sediment sample calibration, sediment analyses (as per MUC), ADCP
- Water column dynamics
  - CTD water samples (nutrients, chl/phaeopigments, DIC/alkalinity, Ecotriplet & Aqualogger (DTIS as well))
  - Optics data-glider & CTD (cdom, fluorescence), DIC, DOC, water chemistry
  - Benthic Boundary layer (thickness, stability)-glider data
- Acoustic data
  - MBES and Fisheries sounders multifrequency (pre- and post-disturbance transects)
- Seafloor imagery
  - Natural sedimentation levels
  - Persistence of Disturber marks

Work in progress

- Biological community responses
  - Infauna-macrofauna, meiofauna, bacteria (based on multicore samples)
  - Epifauna (largely MEMF experiments)
  - Genetic/microbiome responses to suspended sediment (linked to MEMF experiments)
- Sedimentation experiments
  - Sediment erosion, elutriation, sediment capping data analyses
  - Sediment community respiration analyses
  - DGT sample processing (trace metals)
- Sediment samples
  - Multicorer (pre- & post-disturbance, 3 sites) grain size, physico-chemical characteristics (TOM, water content, CaCo3, POCPN/isotopes, chl/phaeopigments)
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  - Optics data-glider & CTD (cdom, fluorescence), DIC, DOC, water chemistry
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- Acoustic data
  - MBES and Fisheries sounders multifrequency (pre- and post-disturbance transects)
- Seafloor imagery
  - Natural sedimentation levels
  - Persistence of Disturber marks

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Short-term: Special Issue of ROBES in NZJMarFwRes 2022-2023

- Collins et al. Interannual variability of the Subtropical Front over Chatham Rise from glider observations
- O'Callaghan et al. Bottom boundary layer changes induced by seabed disturbance.
- Nodder et al. Near-bed sediment dynamics and fluxes within the Subtropical Frontal Zone on Chatham Rise crest, and implications for deep-sea bottom trawling and seabed mining
- Leduc et al. Effects of experimental seabed disturbance on meiofaunal communities of Chatham Rise.
- Murray et al. Simulated mining-related sedimentation impacts on the deep-sea macrofauna of the Chatham Rise, New Zealand.
- Hale et al. Changes in seafloor community oxygen consumption rates with seabed disturbance.
- Cummings et al. The effects of suspended sediment on a common stony coral in New Zealand: results of laboratory experiments.
- Hickey, Eager et al. Changes in seabed characteristics from potential disturbance by human activities: results from sediment capping, elutriation and erosion experiments.
- Clark et al. A synthesis of results and evaluation of implications for bottom trawling and seabed mining mitigation and management (editorial)

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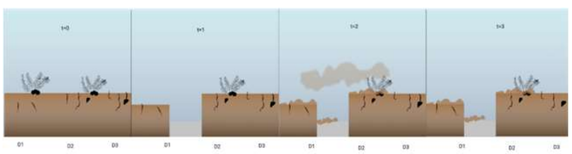
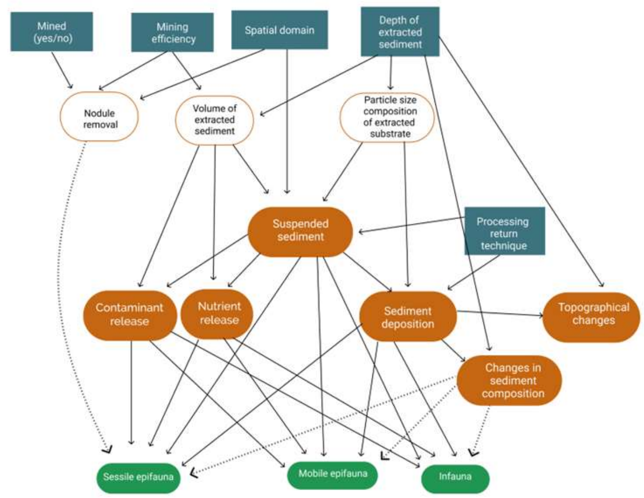
Medium term:
Ecological Risk Assessment: a follow-up

- Post-doctoral Scholar 2022-2023
- Progressing development of an ERA for Chatham Rise (2020)
  - Resilience
  - Recovery
- Based on Bayesian Network modelling
  - Functional groups
  - Expert probabilities of impact
  - Several disturbance scenarios
- Utilise a lot of project data and results





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Longer term:
Resilience and recovery studies

- Baseline and monitoring time series on Chatham Rise
  - Extend for longer-term impact (what haven't we seen with only 2 years monitoring)
  - Recovery trends in infauna (composition and abundance)
  - Adds a medium depth soft sediment environment (volcanoes, canyons, seamounts)
- Associated data from ROBES field surveys
  - BACI disturbance "mini-surveys":
    - beam trawl (corals - DTIS; infauna – multicorer)
    - iceberg scours (DTIS, multicorer) for long-term changes in biodiversity
  - Data awaiting keen students
- Proven methodology now with MEMF
  - Good experimental control for scenario testing
  - Way forward for threshold estimation of epifauna

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Ngā mihi

TIME FOR GENERAL DISCUSSION

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