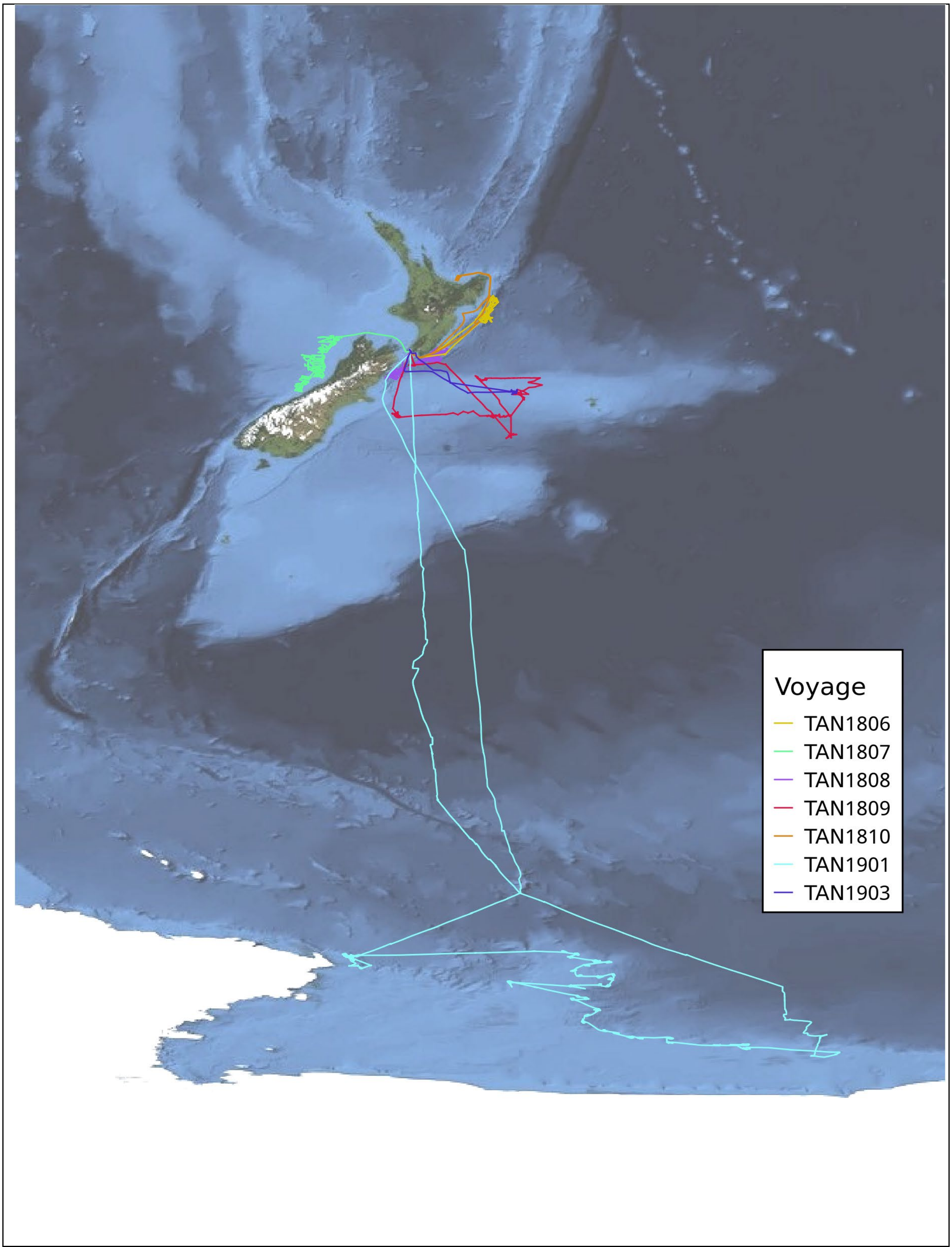
RV Tangaroa Summary Voyages 2018/19

1 July 2018 to 30 June 2019

Strategic Science Investment Fund



Voyages Completed 1 July 2018 to 30 June 2019			
2018/19	**Project**	**Lead**	**TR Group Awarded Days**
NIWA	Quantative Ocean-column Identification (QUOI).	Geoffroy Lamarche	21
NIWA/MPI	Trials of dual frequency acoustic optical systems.	Richard O'Driscoll	4
GNS Science	Gas hydrate reservoirs and seafloor seepage.	Gareth Crutchley	28
GNS Science	Hikurangi Seafloor Geodesy (HOBITSS IV).	Laura Wallace	14
NIWA/Marsden	Mesozooplankton trophic variability in a changing ocean – Chatham Rise.	Moira Decima	32
Collaboration	TAN1901 Antarctica Voyage	Richard O'Driscoll	46
NIWA	TAN 1903 Resilience of deep-sea benthic fauna to disturbance	Malcolm Clark	21

Summary of Voyages

TAN1806: Quantitative ocean-column imaging (QUOI) using hydroacoustic - Bay of Plenty
Date: 3– 22 July 2018
Lead Organisation: NIWA
Funding: NIWA SSIF; RSNZ
Collaboration: University of Tasmania
Voyage Leaders: Geoffroy Lamarche

Background

Detecting liquid or gaseous features in the ocean is generating considerable interest in the geoscience community because of their potentially high economic values (oil & gas, mining, freshwater), their significance for environmental management (oil/gas leakage, biodiversity mapping, greenhouse gas monitoring) and, in New Zealand, for identifying features with cultural or traditional values. Analysis of the acoustic energy backscattered by such features in the water column is still the most reliable, accessible and technologically advanced way to develop quantitative methods of analysis of such features. Identifying and characterising flares and plumes from acoustic backscatter data is difficult however, due to (1) the often very weak contrast of acoustic impedance between scatterers and sea-water (e.g. freshwater); (2) the transient and dynamic behaviour of the scatterers; and (3) the complexity of the physics involved in marine acoustic signal analysis in this dynamic environment.

The research undertaken during this voyage is part of NIWA's Marine Geological Processes and Resources programme, and a milestone of the Royal Society of New Zealand's Catalyst:Seeding project "Building Capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data". The research was undertaken by a consortium of internationally recognised experts brought together for the project (marine acoustics, geophysics, spatial analysis and ocean environment expertise), from New Zealand (NIWA, University of Auckland), France (CNRS/Uni Rennes, IFREMER), Australia (IMAS), the USA (CCOM-UNH) and Germany (GEOMAR).

The aim of the TAN1806-QUOI voyage (Quantitative Ocean-Column Imaging using hydroacoustic sources) conducted from *RV Tangaroa* was to enhance our capability to acoustically detect and characterise liquid and gaseous targets in the ocean water column. The voyage took place between 3 and 22 July 2018. The science party consisted of 20 scientists and students from the consortium organisations as well as students from the University of Auckland, the University of Tasmania, the University of New Hampshire and the Ecole Nationale Supérieure des Technologies Avancées.

The 20-day voyage covered ca. 3640 km (1970 NM) from Wellington to the Bay of Plenty and back to Wellington (figure 1). The large part of the voyage took place in the Bay of Plenty with 13 days spent over the Calypso Hydrothermal Vent Field, ca. 15 km SW of Whakaari-White Island volcano. Numerous hydrothermal vents have been identified in the past over the region through acoustic flares and visual observation and the location therefore provided an excellent opportunity to develop our experiments. Heavy weather (i.e. with wind greater than 30 knots) impacted the deployment of equipment over two periods of 48 and 24 hours. During these times, data was acquired but quality was compromised.

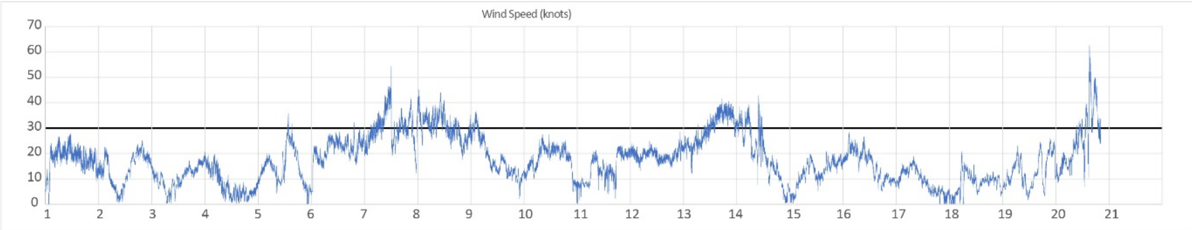


Figure 1 - Winds during TAN1806

The voyage collected ca. 4.6 Tb of acoustic data and video recording of gas bubble and liquid seepages at the seafloor. Pioneering deployments of multiple synchronous echosounders, including 30 kHz and 200 kHz multibeam, 6 single-beam two of which were deployed on the seafloor to ensonify bubble streams horizontally enabled us to generate images of gas bubble streams on echograms. Other innovative experiments included (1) data acquisition using a high echosounder swath overlap to enable the study of angular backscatter response in both seafloor and water-column data; (2) the deployment on the seafloor of a "bubble maker" from the University New Hampshire. This tool enabled us to control bubble rates and sizes, and therefore provided a mean to calibrate the acoustic data; (3) the mounting of a split-beam echosounder on a swivelling device deployed from the vessel moonpool to ensonify the bubble streams are a wide range of angle (-70° to 70°). This provide data that will be use to study the change in the acoustic response from bubbles depending on the angle of incidence of the acoustic wave. We also collected 31 sediment samples and 43 water samples that required 111 gear deployments using a van Veen Grab; towed video camera, CTD and an Acoustic Optical System. These data provide critical ground truthing information to validate any model generated from the echo-sounder data.

Several experiments were developed during the voyage to achieve our objectives:

i. **Echosounders calibration.** Both Split-Beam EchoSounder (SBES) and MultiBeam EchoSounder (MBES) were either calibrated or cross calibrated at the beginning of the voyage. This was critical for quantitative use of acoustic signals.
ii. **High swath overlap MBES coverage** over the Calypso Hydrothermal Vent Field using both 30 kHz (EM302) and 200 kHz (EM 2040) MBES. A large overlap of the swath footprint was generated to enable us to study the backscatter response as a function of the incidence of the acoustic wave on the seafloor and in the water-column data, as well as artefacts inherent to sound wave propagation in the water.
iii. **Multi-sensor data acquisition.** Over specific flares and a synthetic bubble maker. This included a multi-angle (5° increment) and multi-frequency backscatter, high swath overlap coverage and the use of a 200 kHz SBES mounted on a pan&tilt swivelling device beneath the vessel's hull. The bubble maker enabled control of the bubble size and rate.
iv. **Passive acoustic monitoring** was attempted using a hydrophone deployed for 6 days, to "listen" to the ocean background noise.
v. **Ground truthing** samples and video footage was undertaken using a towed video camera.

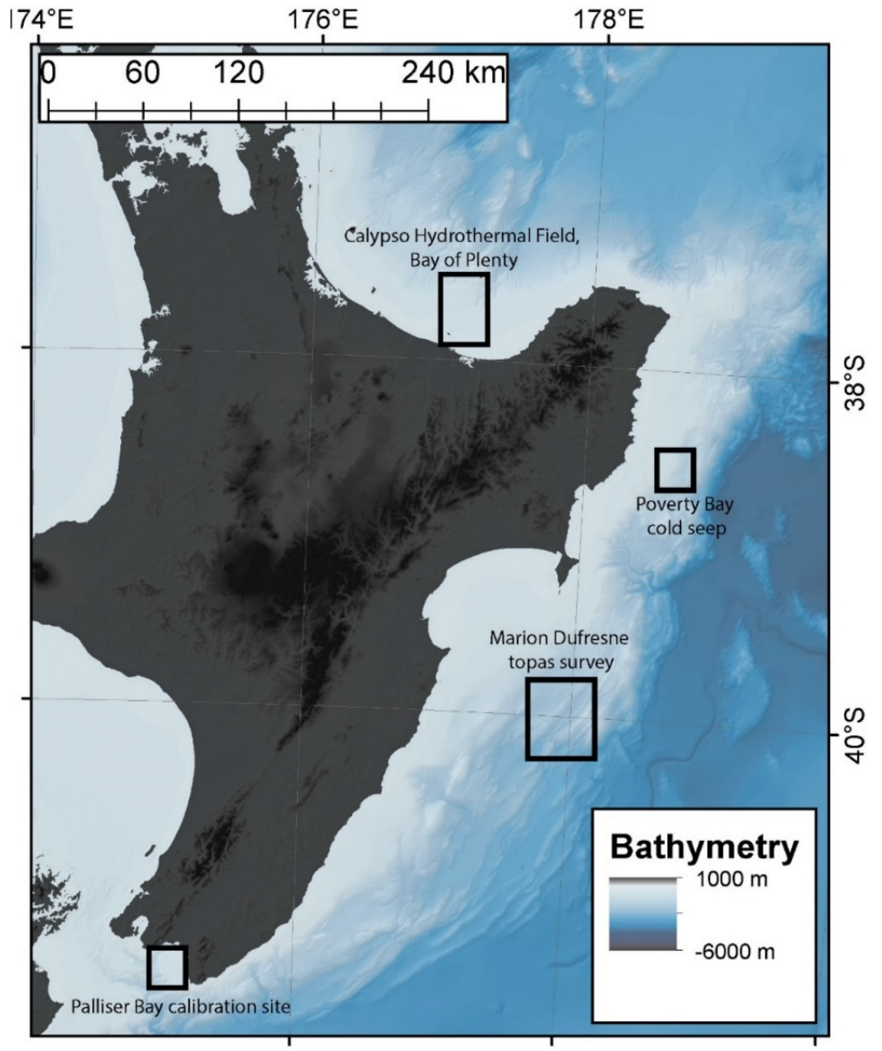


Figure 2 - the four areas of surveying during TAN1806-QUOI

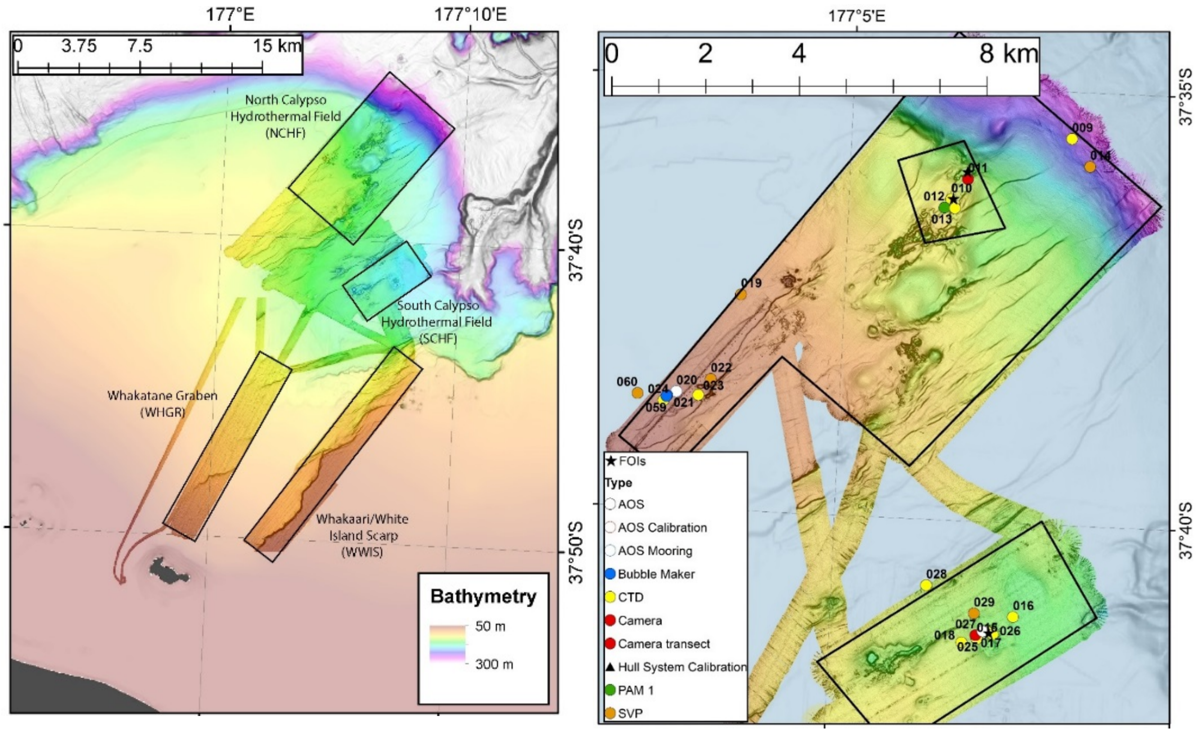


Figure 3 - Survey in the Bay of Plenty and location of all stations (right)

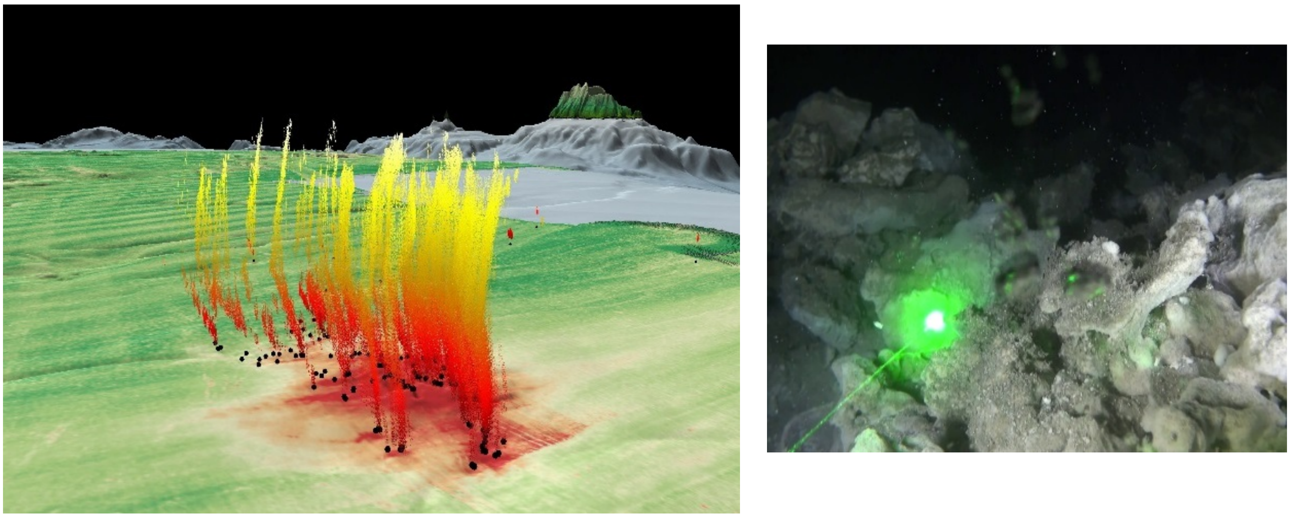


Figure 4 - Left: Perspective view of the Calypso Hydrothermal Vent Field with acoustic flares generated by gas bubbles backscattered acoustic echos. Right: bubble escaping from the seafloor in the Calypso Hydrothermal vent field

Preliminary results and significance

Our survey proved exceptionally successful and demonstrated the potential to differentiate methane and CO_2 bubbles in the water column. A result thought impossible up until now. The most interesting observations from split-beam echosounder data have been the very different frequency responses on flares, both using the Acoustic-Optical System (AOS) and the hull system (Figure 5). Acoustic Optical System deployments on mega-flares have provided us with opportunity to make repetitive, robust and systematic measurements, showing good potential for the use of acoustic for characterization of bubble size and bubble density estimation. Some observations show distinct frequency responses from over a single seep, providing means to study size-distribution of bubbles, and possibly their composition.

Preliminary analysis shows promising results, with frequency responses on flares behaving as expected, telling us that there is potential to use those data for qualitative analysis and potentially flux estimations of various gases.

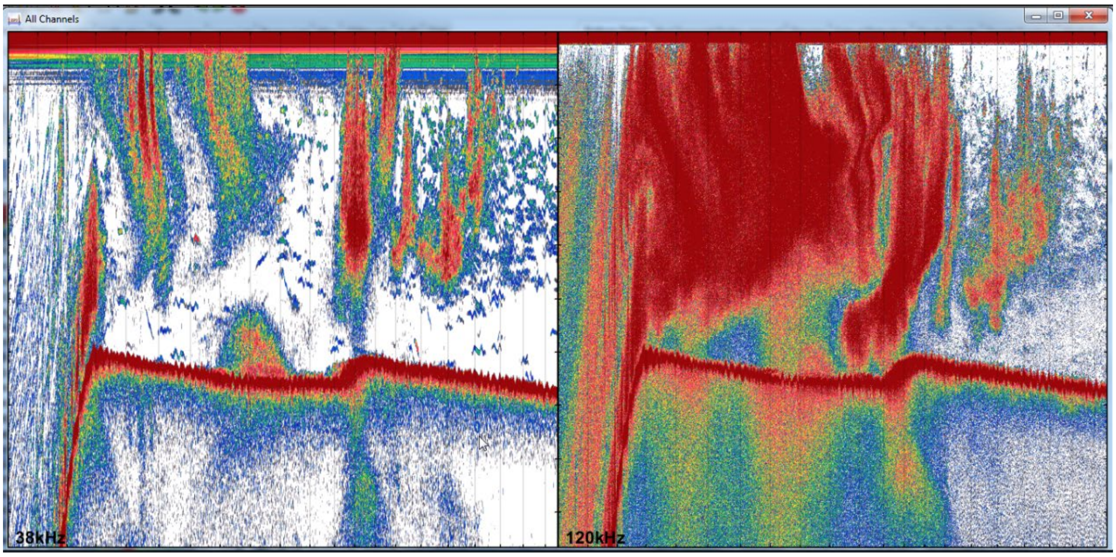


Figure 5 - Echograms over a flare at 38kHz (left) and 120kHz(right), showing very different responses

The deployment of the synthetic bubble maker enabled us to ensonify and image individual bubbles at varying depth and using varying frequencies. The frequency-modulated acoustic response of single targets can be extracted from these data and with the application of calibration offsets target strength can be calculated. The mean target strength of bubbles from both sets of deployment data appears to be approximately -55 dB (bubbles between 80-85 m). Preliminary modelling of the acoustic data suggests that the radii of these bubbles are between 1.5 and 2.0 mm.

The very high overlap of the swath seafloor footprint provided a way to study the angular response of seafloor backscatter, and compare the EM2040 (200 kHz) and EM300 (30 kHz) datasets. While most of the backscatter mosaics from the EM2040 and EM302 are similar, two locations (Figure 5) show contrasting backscatter responses from both systems. These areas have a strong intensities at 30kHz and weak intensities at 200kHz. These data will be used to classify the seafloor based on a set of backscatter angular responses.

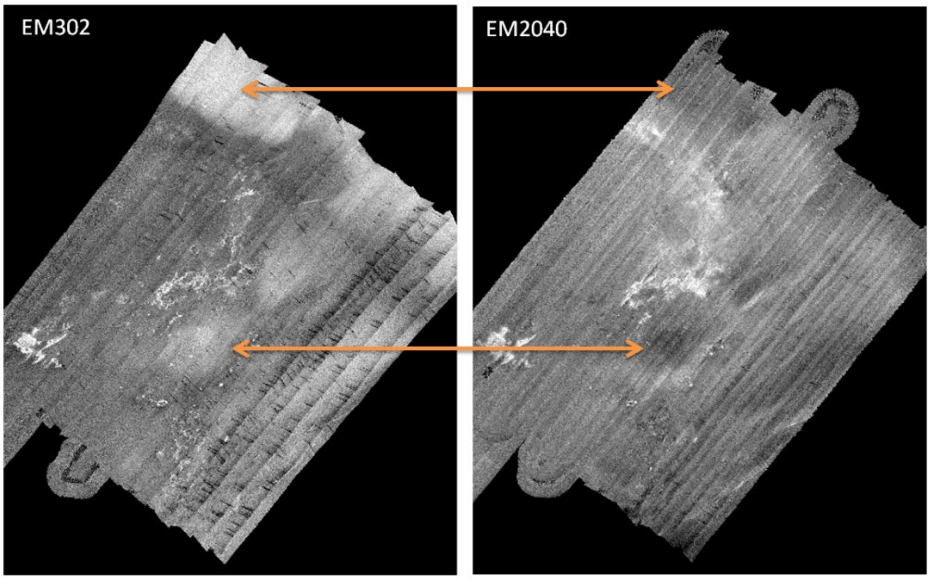


Figure 6 - seafloor backscatter from 2 echosounder acquired with a 95% swath overlap.

The towed video camera provided by the University of Tasmania provided invaluable non-invasive sampling alternative to sediment sampling. The quality of imagery acquired by the towed camera depended largely on the sea conditions and water clarity. A range of probes were also mounted on the camera. High quality images of gas and liquid seepages were obtained (Figure 3 right) which combined with the acoustic data will provide critical ground truthing data.

Funding

The science NIWA conducted onboard *RV Tangaroa* was funded by the Ministry of Business, Innovation and Employment's Strategic Science Investment Fund (SSIF).

This work was also partly funded and certainly initiated thanks to the Royal Society of New Zealand Catalyst Seeding fund for a project entitled "Building capability for in situ quantitative characterisation of the ocean water column using acoustic multibeam backscatter data."

Vanessa Lucieer was supported by the Marine Biodiversity Hub through funding from the Australian Government's National Environmental Science Programme and the University of Tasmania. Amy Nau was supported by the University of Tasmania and CSIRO Quantitative Marine Science Program. Erica Spain is supported by the Australian Research Council's Special Research Initiative for Antarctic Gateway Partnership (Project ID SR140300001).

Support for the University of New Hampshire's participation was provided by the US National Science Foundation grant #1352301 and by the UNH Centre for Coastal and Ocean Mapping.

Ifremer's contribution was conducted within the framework of the Underwater Acoustics R&D program R703-06. We wish to acknowledge Dr Xavier Lurton who was the director of R703-06 at the time of the voyage, and who greatly supported this project.

TAN1807: Testing of a multi frequency Acoustic Optical System (AOS)
West Coast South Island
Date: 31 July to 6 August (TRG Days 13 to 16 August)
Lead Organisation: NIWA
Science Funding: MPI
Voyage Leader: Richard O'Driscoll

Background:

NIWA has developed a dual-frequency Acoustic Optical System (AOS) and received Ministry of Business Innovation and Employment (MBIE) funding to add 4 days to the 2018 West Coast South Island trawl survey for testing of this technology) as a tool to estimate abundance of New Zealand commercial fish species.

Dual frequency acoustic systems have been used in the to improve species discrimination on schools containing an assemblage of species (Ryan & Kloser 2016) and are now required by the Ministry for Primary Industries (MPI) for research surveys of orange roughy. Currently the only such system available in New Zealand is owned by Sealord and operated by CSIRO.

NIWA has strategically invested in the development of its own dual-frequency AOS over the past three years. This incorporates the latest Simrad EK80 broadband acoustic technology with 38 and 120 kHz transducers. The system has been tank tested however required extensive trials at sea to determine its operating ranges, signal-to-noise ratio, reliability, and suitability for use in surveys of New Zealand deepwater species.

This testing further allowed us to produce an acoustic abundance estimate of hoki on the WCSI consistent with those obtained in 1998–2013. This will help inform management of the NZ western hoki stock in Feb-Mar 2019. The AOS will be used on future surveys to estimate abundance of NZ fish stock, with its next used planned for southern blue whiting in August-September 2019.

There were 13 deployments of NIWA's new dual frequency broadband acoustic optical system (AOS) (Figure 1). After resolving issues due to acoustic interference from the net monitor, we were able to collect high quality acoustic data at 38 and 120 kHz with the AOS mounted in the hoki trawl towed in midwater (e.g., Figure 2).

Figure 1: Picture of NIWA AOS mounted in the hoki trawl being deployed from *Tangaroa*.

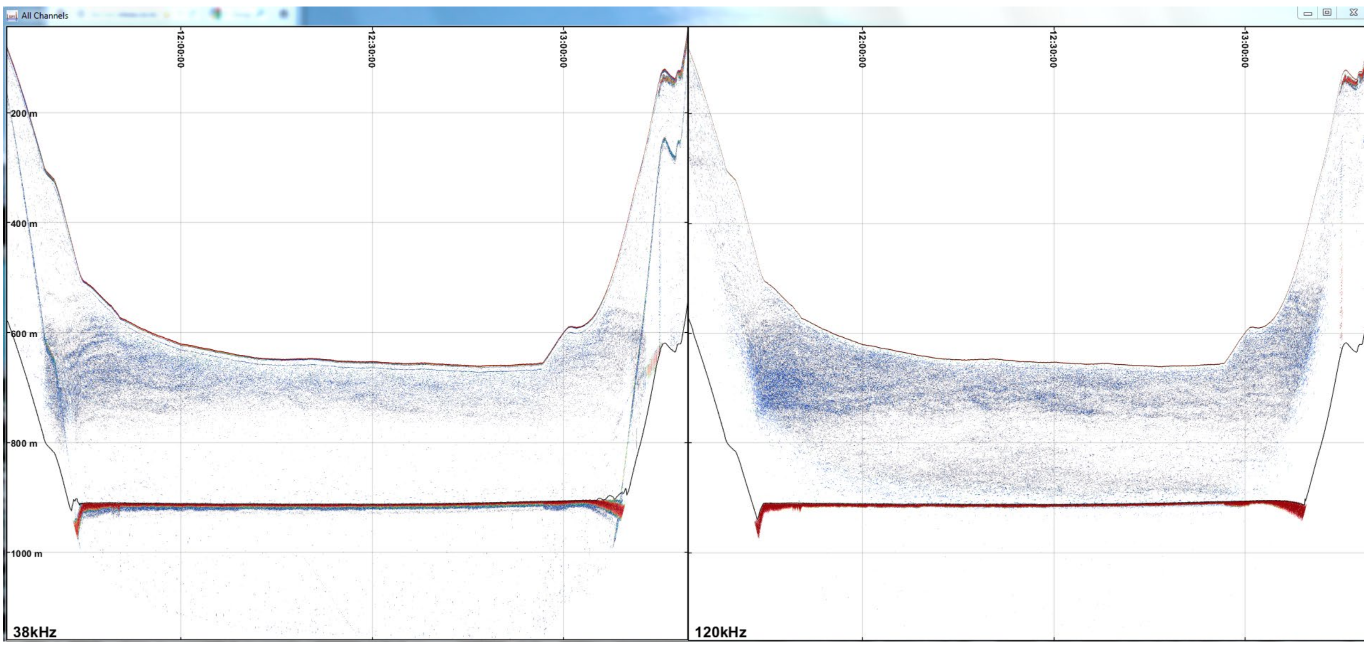


Figure 2: Examples of AOS echograms at 38 kHz (left panel) and 120 kHz (right panel). AOS is deployed at about 650 m depth over a seabed depth of 950 m. Both frequencies show clean (noise-free) data to over 300 m range.

Weather and Breakdown:
There were no days lost to either breakdown or inclement weather.

Papers
Fisheries Assessment Report in preparation due for publication in 2019:
O'Driscoll, R.L.; Ballara, S.L. (2018). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2018 (TAN1807). New Zealand Fisheries Assessment Report 20XX/xx. xx p.

TAN1808: Gas Hydrate Systems of the Southern Hikurangi Margin, Aotearoa, New Zealand
East Coast North Island
Date: 8 September to 5 October 2018
Lead Organisation: GNS Science
Funding: MBIE (Endeavour funded programme)
Voyage Leader: Gareth Crutchley
Background:

In 2017, the New Zealand Ministry for Business, Innovation and Employment funded a five-year research programme entitled "Economic Opportunities and Environmental Implications of Energy Extraction from Gas Hydrates". The acronym for this programme is HYDEE. The HYDEE programme poses two high-level questions that are essential to address if New Zealand is to consider the extraction of gas from gas hydrates for the purposes of energy supply. These questions are: 1. Will feasible hydrocarbon production scenarios, either directly from gas hydrates or through gas hydrates, significantly impact seafloor stability, ecology or ocean biogeochemistry? and 2. What are the likely socioeconomic implications of gas hydrate production in New Zealand? These two high-level questions are being addressed via four core Research Aims (RAs):

(RA1.1) Determine New Zealand-specific frameworks (geological and economic) for energy production from (and through) gas hydrates;

(RA1.2) Predict the geo-mechanical responses at the seafloor and wellbore induced by production drilling;

(RA1.3) Investigate the impact that changes in seafloor stability and/or methane flux could have on marine ecosystems; and

(RA1.4) Incorporate Vision Mātauranga and deliberative community engagement into gas hydrate science to explore potential for growth of Māori economies and broad socioeconomic implications of resource extraction.

TAN1808 was the first research voyage to be funded under the HYDEE research programme. Data collected during TAN1808 are helping us to address RAs 1.1, 1.2 and 1.3.

TAN1808 was focused primarily on the collection of geophysical datasets that help characterise the way in which gas hydrates are forming in the deforming wedge of the Hikurangi subduction margin. The voyage enabled the characterisation of methane seepage through the seafloor, submarine slope stability and marine biodiversity, which are all related to the underlying gas hydrate system. The voyage objectives were to:

1. Collect 2D seismic reflection data to map out sub-surface gas hydrate accumulations.

2. Characterise methane escape at the seafloor and into the water column using EM302 multibeam echo-sounder technology.

3. Image small-scale fluid flow and sedimentary processes using TOPAS single-beam echo-sounder technology.

4. Deploy seafloor sampling equipment to collect samples that are representative of seafloor lithologies and the sediments that host gas hydrates.

5. Collect targeted sediment samples that can be used to characterise the microbiology at the seafloor above gas hydrate accumulations.

The survey:

The survey was centred around the southern end of New Zealand's Hikurangi margin, in locations off the coast of Wairarapa down to offshore Kaikoura. Thanks to good weather conditions for the bulk of the voyage and excellent support from the captain and crew of *RV Tangaroa*, we were able to successfully meet all objectives of the voyage and collect more data than we anticipated.

Geophysical operations (multi-channel seismics, and multibeam and Topas acoustics):

The majority of the voyage was spent collecting multi-channel seismic data with NIWA's 2D seismic system. The system worked excellently for the duration of the voyage and we collected data at five key study sites in the area off the coast of Wairarapa (Figure 1) and off the coast of Kaikoura / Marlborough (Figure 2). In total, we spent almost 390 hours (~16 days) collecting seismic reflection data. While collecting these seismic data, we also collected multibeam bathymetry and water column data to characterise the seafloor and methane escape into the water column. The vessels' Topas single beam echo-sounder was also in operation during all seismic activities, providing high-resolution imaging of the upper ~100 m of the sediment column. The hydro-acoustic methods enabled us to identify a total of 93 active methane seep sites during the voyage; most of these were imaged at least twice during different crossings, and several were at locations where seep sites were previously unknown.

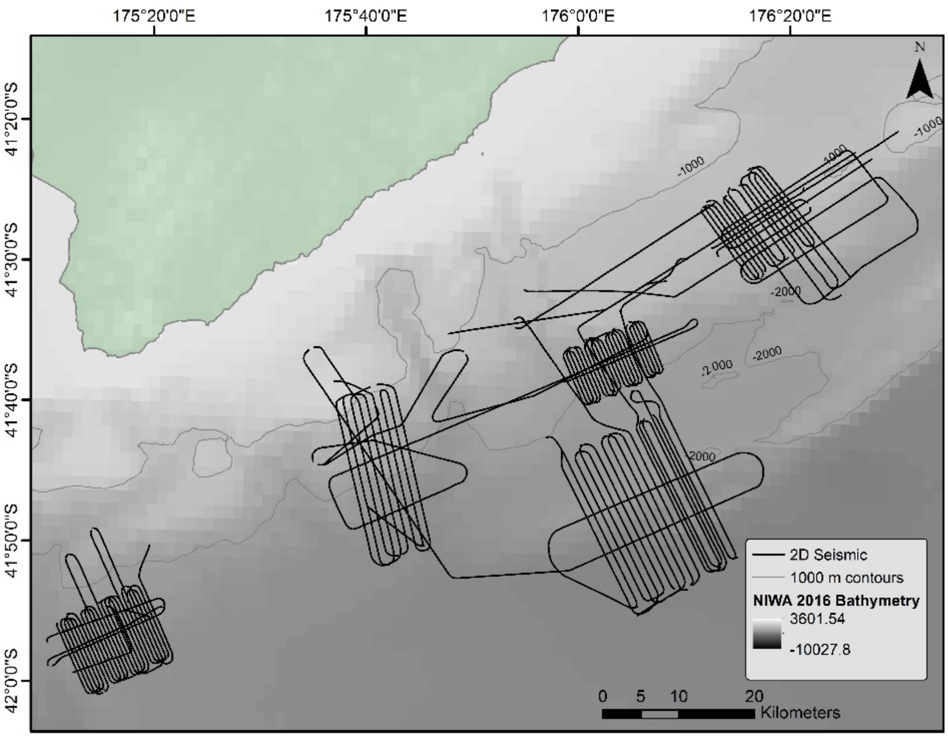


Figure 1. Distribution of collected 2D seismic data off the southern end of the Wairarapa region, North Island.

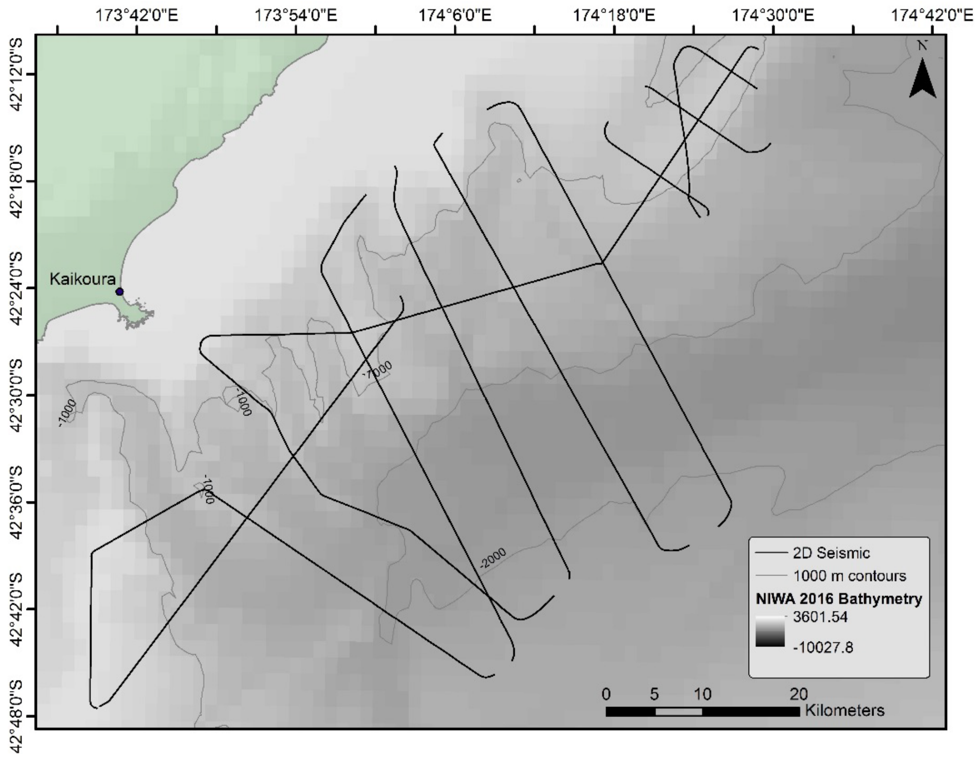


Figure 2. Distribution of collected 2D seismic data off the Marlborough and Kaikoura region, South Island.

Seafloor sampling:

We carried out seafloor sampling at ~50 locations during the voyage, using a combination of gravity coring, grab sampling and rock dredging (Figure 3). For most of the voyage, the Van Veen Grab was the preferred method for obtaining targeted and intact samples of the seafloor, but the gravity corer was also used earlier in the voyage for sampling. The rock dredge was used for targeting outcropping lithologies at the seafloor that would have been too hard (e.g. boulders and well-lithified sediments) to sample with the Van Veen Grab.

Figure 3. Left: Short gravity corer (1.6 m long barrel). Middle: Van Veen Grab. Right: Rock dredge.

The seafloor sampling was used for a few different objectives. Samples were taken strategically at various locations where we collected seismic data to ground truth multibeam backscatter data so that maps of seafloor lithology can be generated. Additionally, we collected sediment at active methane seeps and control sites for microbiology sampling. The primary purpose of microbiological sampling on this voyage was to provide material for on-shore incubation experiments. As part of the broader characterization of ecological responses to possible future gas hydrate production, it is necessary to understand how the ability of microbial communities in sediments at methane seep sites above gas hydrate deposits might be affected by changes in environmental conditions as a result of commercial gas production. These include (but are not limited to) alterations in methane flow rates; alterations in oxygen penetration into the sediment; and alterations in seawater pH. We also collected sediment samples with the rock dredge to characterise reservoir lithologies for gas hydrate formation.

Breakdown / downtime / weather days:

Over the duration of the voyage, we lost approximately 12-24 hours due to rough seas. We were able to use part of this lost time to do some acoustic surveying, so in total we probably only had about 12 hours where we could not collect any data due to weather.

We experienced very few equipment breakdowns. Seismic acquisition systems are always susceptible to breakdowns, but we probably lost less than ~12 hours (from a total of almost 390 hours of surveying) to equipment issues with the 2D seismic system. This lost time was related to electrical leakage in the system.

National relevance:

The data collected during this programme are relevant for assessing the potential for gas hydrates to represent a form of energy in the future. Although offshore hydrocarbon exploration has been ceased by the current government, methane hydrates have the potential to represent a low carbon alternative to other fossil fuels. Making the transition to a low carbon energy economy may involve the use of gas hydrates as an energy resource, but it is not clear what the environmental implications would be. This voyage provided important information for assessing environmental impacts of methane hydrate production, ranging from seafloor stability to marine biology impacts.

Data collected during this project also has important relevance for understanding tectonic processes and earthquake hazards in New Zealand. For example, data have already been used to support a U.S.-led voyage (January 2019) that is exploring how fluid flow on the Hikurangi margin is related to deep tectonic processes.

The voyage also provided baseline data for a follow-up voyage in this research programme that will investigate marine ecology systems around gas hydrate reservoirs.

Data usage:

Geoscience data collected during this voyage will be made available to MBIE as soon as they are available, in agreement with plans made for data dissemination in the MBIE-funded programme. Geophysical data are already being analysed and will form the basis of peer-reviewed research publications. Microbiology data are being analysed and will also be published in a peer-reviewed journal.

Outreach:

A blog of our activities was published online, at this location:

http://jithillman.wixsite.com/geomarine/single-post/2018/10/09/Hydrates-on-the-Hikurangi

TAN1809: Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSSV)
Dates: 6-18 October, 2010
Lead Organisation: GNS Science
Funding: MBIE Endeavour
Voyage Leader: Dan Barker and Laura Wallace (GNS Science)

BACKGROUND

The Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) is a rolling offshore seismic and geodetic experiment that explores the relationship between slow slip events, tectonic tremor, and earthquakes along the offshore Hikurangi subduction zone. The Hikurangi subduction zone is New Zealand's largest and fastest moving plate boundary fault, and it has potential to produce the largest earthquakes and tsunami in New Zealand. However, we currently have very little understanding of the earthquake and tsunami potential of the offshore part of the plate boundary. To better understand the hazard posed by the Hikurangi subduction zone, we have mounted a series of rolling seafloor instrument deployments to monitor slow slip events, earthquakes, and locking (stress build-up) on the offshore plate boundary. The current phase of rolling deployments will continue through 2020 as part of an MBIE Endeavour funded project "Diagnosing the peril posed by the Hikurangi subduction zone: New Zealand's largest plate boundary fault. (HSM)". The project is a collaboration between institutions in New Zealand, Japan and the United States, using instruments belonging to GNS Science, University of Texas, Columbia University, Scripps Institute for Oceanography, University of Tokyo, University of Kyoto, and Tohoku University.

The objectives of TAN1809 were to undertake seafloor geodetic and seismic instrument deployments, recoveries, and surveys offshore the Gisborne, Mahia, and Wairarapa coasts. Overall, we retrieved 9 instruments (deployed in 2017), and deployed 29 more instruments. Previous HOBITSS voyages have focused on the northern Hikurangi subduction zone offshore Gisborne, and TAN1809 is the first one to expand our subduction zone monitoring deployments to offshore Hawkes Bay, and as far south as the Wairarapa. The seafloor geodetic aims involve using bottom pressure recorders (BPRs) to determine the cm-level vertical movement (upward or downward) of the seafloor during slow slip events (e.g., Wallace et al., 2016), as well as to deploy two new precision transponder arrays to monitor cm-level horizontal tectonic movements of the seafloor (using GPS-Acoustic techniques; e.g., Gagnon et al., 2005) near the Hikurangi Trench. We also surveyed an existing seafloor transponder array offshore Gisborne using GPS-Acoustic methods. Ocean bottom seismometers (OBS) were deployed to characterize the distribution of offshore earthquakes. Together these diverse instruments will reveal the relationship between seismicity, slow slip events, and the occurrence of locking (stress build-up) on our largest plate boundary fault. Data from the seafloor monitoring instruments will also complement subseafloor monitoring instruments installed in two International Ocean Discovery Program boreholes offshore Gisborne. Next generation seafloor instruments (developed by Lamont Doherty Earth Observatory, Columbia University) that combine pressure and seismic sensors (POBs) were also deployed to test their effectiveness. Victoria University of Wellington (VUW) is also involved in the project, and we had three participants from VUW, including Professor Martha Savage, and two PhD students who will be working on the data as part of their thesis research. The offshore Gisborne to Hawkes bay region was targeted due to the large and frequent slow slip events that occur there. Offshore Wairarapa and Hawkes bay were targeted for GPS-Acoustic array deployments to determine the degree of locking near the Hikurangi Trench, which is currently unknown, and has important implications for the tsunami hazard posed by the subduction zone.

ACTIVITIES UNDERTAKEN ON THE VOYAGE

9 Bottom Pressure Recorders (BPRs) were recovered during the voyage (see Figure 1). These BPRs were deployed in June 2017 (on TAN1705), and recorded data for over a year, offshore Mahia and Gisborne. TAN1809 scientists and their collaborators are in the process of analyzing the BPR data for vertical seafloor deformation, recording of vertical ground motion due to earthquakes, and evidence for tsunami events that occurred during the deployment. Of particular interest during this period is an unusual tsunami generated by a volcanic episode in the Kermadecs (https://www.geonet.org.nz/news/1dkgstDSguqSgS2GAQum0K) on 8 December 2017, that was recorded on the BPR instruments that we recovered. Although no large slow slip events occurred during the 2017/2018 deployment, we are currently analysing the data to see if there is any evidence for seafloor uplift during a few small slow slip events that occurred during the deployment period (recorded on GeoNet GPS stations). We are also using the BPR data to improve the offshore seismicity locations (due to high rate sampling at some of the sites, the pressure data can be used as a vertical component seismometer), and to better characterize the oceanographic noise characteristics that may influence the bottom pressure recorder measurements to enable better isolation of SSE signals.

Figure 2 shows the locations of instrument deployments that took place on TAN1809. 15 BPRs were deployed offshore Gisborne and Hawkes Bay with the aim to investigate the occurrence and distribution of slow slip events on the offshore northern and central Hikurangi subduction zone. 5 OBS were deployed offshore Gisborne, within the IODP drilling transect, and will complement the borehole observatory measurements, and enable evaluation of seismicity that occurs during the frequent slow slip events there. We also deployed 3 POBS (combined pressure, seismology, tilt instruments), and two GPS-Acoustic arrays (each consisting of 3 precision transponders). The two new GPS-A transponder arrays will be surveyed with a Waveglider in January of 2019, using NIWA's Ikatere, and will be surveyed at least once per year for the next 5-10 years. In all, 9 instrument retrievals and 29 instrument deployments took place during TAN1809. A GPS-A survey of a transponder array offshore Gisborne was also undertaken for 20.5 hours, which will result in a position for the array accurate to within a few cm. We will be recovering the BPRs POBS, and OBS on an R/V Tangaroa voyage scheduled for November 2019. We will download the data at that point, and then redeploy most of the instruments in November 2019 for an additional 1-2 years.

We note that no time was lost on the voyage due to mechanical issues or adverse weather.

OUTCOMES OF THESE VOYAGES FOR NEW ZEALAND

The overall goals of these seafloor observations of activity on the Hikurangi plate boundary is to reveal modern plate tectonic movements and earthquake activity on the offshore, and potentially most hazardous portion of the plate boundary. Our results will eventually feed in to the National Seismic Hazard and National Tsunami Hazard models, to underpin meaningful assessments of hazard, risk and potential losses due to great (M > 8) earthquakes on the Hikurangi margin. Increased certainty in such assessments will enable development of robust, data-supported strategies to mitigate the hazards. . Importantly, our results will provide underpinning data needed by a variety of Natural Hazards Research Platform and Resilience to Nature's Challenges projects. Better hazard and risk assessment will inform decision making by asset and insurance managers, improve evaluation of risks to coastal communities, and help guide engineering practices to enhance hazard mitigation.

One of the other main goals of this project is to develop completely new, New Zealand-based capability in the frontier field of seafloor geodesy. Doing this will greatly expand our ability to investigate our largest offshore earthquake and tsunami hazards. Prior to now, there has been no capability in New

Zealand to deploy seafloor instruments for monitoring earthquakes and tectonic motions, so this work fills a critical need.

PUBLICATIONS FROM PREVIOUS HOBITSS VOYAGES:

There are several publications stemming from the rolling HOBITSS deployments that began in 2014 (and many more publications are in the pipeline). These include:

Muramoto, T., Y. Ito, D. Inazu, L.M. Wallace, R. Hino, S. Suzuki et al. (2019), Seafloor crustal deformation on ocean bottom pressure records with nontidal variability corrections: Application to Hikurangi margin, New Zealand, ***Geophys. Res. Lett***., 46, doi.org/10.1029/2018GL80830.

Williams, C. A., & Wallace, L. M. (2018). The impact of realistic elastic properties on inversions of shallow subduction interface slow slip events using seafloor geodetic data. ***Geophysical Research Letters***, *45*. https://doi.org/10.1029/2018GL078042

Todd, E. K., Schwartz, S. Y., Mochizuki, K., Wallace, L. M., Sheehan, A. F., Webb, S.C., et al. (2018). Earthquakes and tremor linked to seamount subduction during shallow slow slip at the Hikurangi Margin, New Zealand. ***Journal of Geophysical Research: Solid Earth***, *123*, 6769–6783. https://doi.org/10.1029/2018JB016136

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Wallace, L.M., S. C. Webb, Y. Ito, K. Mochizuki, R. Hino, S. Henrys, S. Schwartz, A. Sheehan, 2016, Slow slip near the trench at the Hikurangi subduction zone, ***Science,*** 352(6286), 701-704, doi: 10.1126/science.aaf2349.

MEDIA COVERAGE AND OUTREACH

VUW PhD students Katie Woods and Wei-Wei Wang wrote blogs about the voyage that were posted on the East Coast LAB website (www.eastcoastlab.org.nz) with help from Kate Boersen at East Coast LAB. GNS Science and East Coast Lab issued two press releases, at the beginning and end of the voyage, which resulted in quite a bit of media coverage of the voyage and the results. The most significant of these was a TV3 news, which broadcast footage of the equipment loading on October 6, and an interview with Laura Wallace (GNS Science) and Ted Koczynski (Columbia University), about the voyage.

Links to a selection of the media coverage is below:

https://www.newshub.co.nz/home/new-zealand/2018/10/scientist-aim-to-predict-new-zealand-s-next-big-earthquake.html https://www.newshub.co.nz/home/new-zealand/2018/10/quake-measuring-devices-placed-on-the-hikurangi-fault.html

https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12149398

https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12139572

https://i.stuff.co.nz/timaru-herald/news/national/107790194/Scientists-deploy-latest-round-of-earthquake-monitoring-equipment-off-NZs-east-coast

https://www.radionz.co.nz/news/national/368065/scientists-to-monitor-nz-s-largest-fault-line

http://gisborneherald.co.nz/localnews/3734444-135/more-tools-to-record-earths-rumbles

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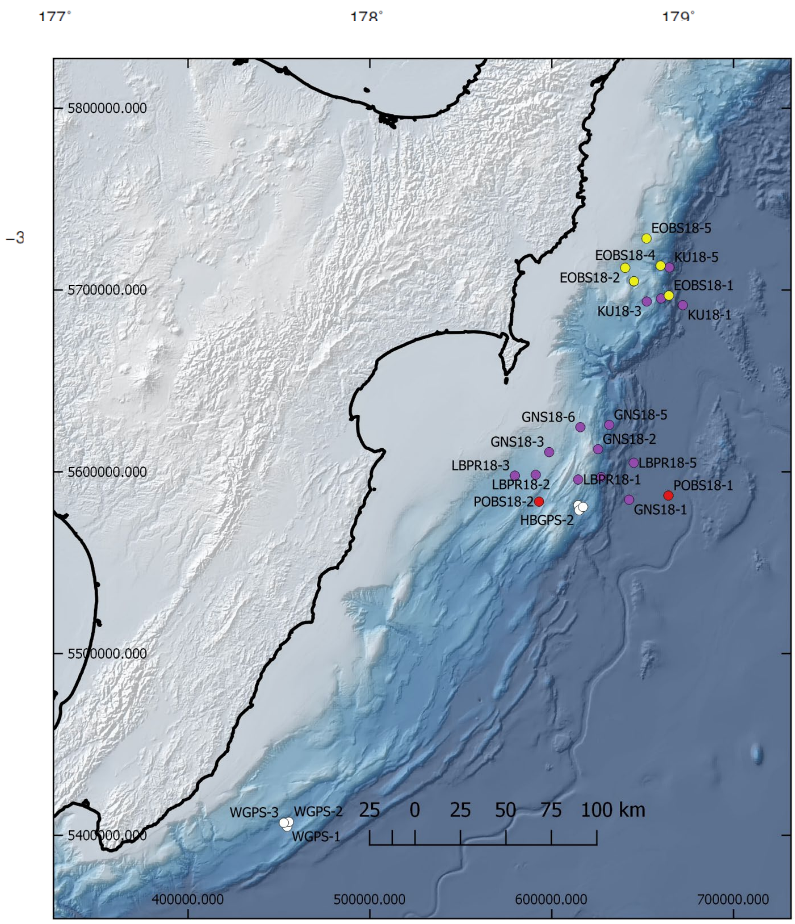
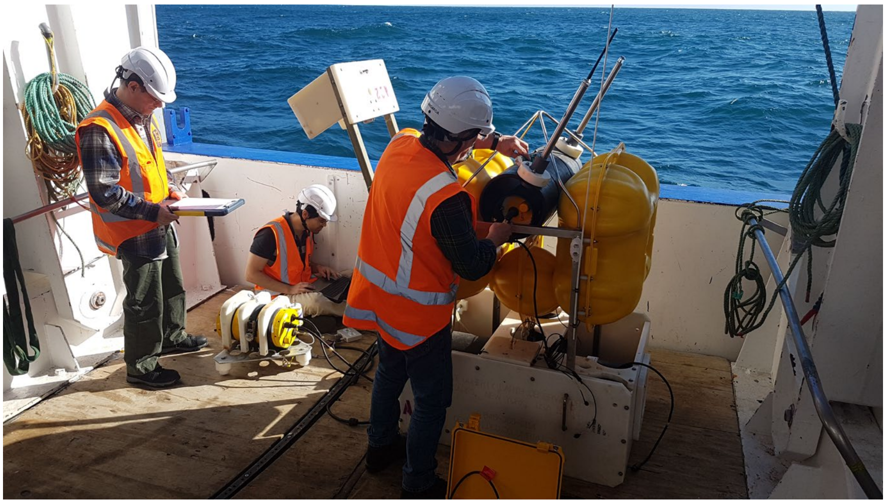


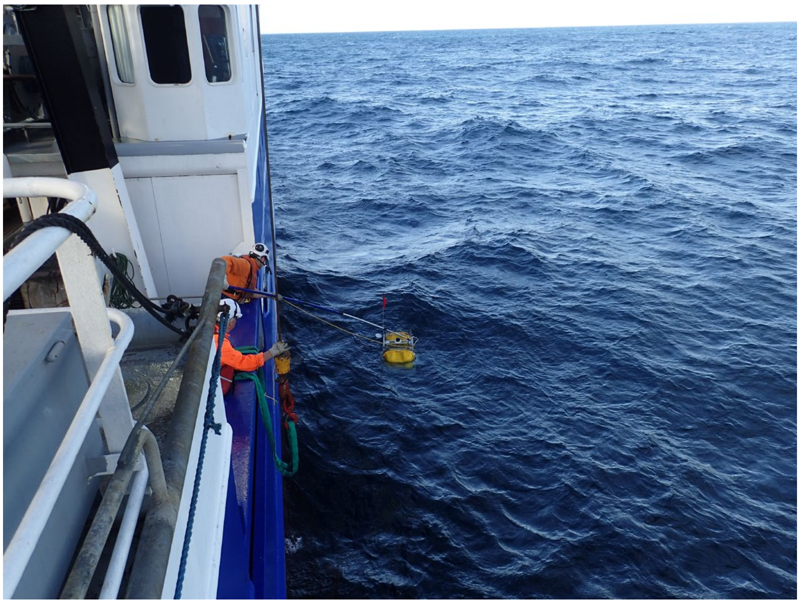
Bottom Pressure recorders deployed during TAN1705 and recovered on TAN1809.

Map of OBS (yellow) BPRs (purple), POBS (red), and GPS-Acoustic arrays white) deployed offshore the North Island's east coast during TAN1809.



The team from Columbia University prepares an instrument with both an Absolute Pressure Gauge and an Ocean Bottom Seismometer (POBS) for deployment

Photo: Neville Palmer, GNS Science



An Absolute Pressure Gauge being retrieved after one year on the seafloor.

Photo: Neville Palmer, GNS Science

The deployment system for the GPS-Acoustic transponders being lowered over the cutaway.

Photo: Neville Palmer, GNS Science

Preparing the seafloor instruments at GNS Science prior to the voyage

Photo: Neville Palmer, GNS Science

TAN1810: SALP Particle expOrt and Ocean Productivity (SalpPOOP)
Date: October 21-November 21, 2018
Lead Organization: NIWA
Funding: NIWA SSIF, Marden Fund, National Science Foundation (NSF, US)
Voyage Leader: Moira Décima

BACKGROUND

Salps are known to play unique and important roles in marine ecosystems, in particular when they form large and/or dense blooms (Alldredge & Madin, 1982, Andersen, 1998, Deibel, 1998, Madin *et al.*, 2006). Studying the biogeochemical impacts of salps blooms, including the details of their alteration of phyto-, bacterio- and microzoo- plankton communities, has been difficulted by the inability of predicting the time and place of their occurrence. However, anecdotal observations, past evidence from other oceanographic voyages, and the habitat of salp-specialist fishes such as smooth, black and spiky oreo - located on both northern and southern flanks of the Chatham Rise east of New Zealand (Forman *et al.*, 2016) – suggest that salps are frequent occurrences in these New Zealand waters. These aggregations have been reported extensively in the area of the Chatham Rise, a bathymetric feature running eastwards ca. 1000km from the east coast of New Zealand, between 42.5 - 45°S, rising up from depths of 3000 to about 350 at the middle of the Rise, and is one of New Zealand's most productive fishing grounds (Bull *et al.*, 2001). It is over this submarine ridge that subtropical (ST) and subantarctic (SA) waters meet, leading to the complex oceanography that forms the Subtropical front (STF). The mixing of these two water masses results in enhanced phytoplankton biomass across the frontal region which spans the width of the Chatham Rise (Pinkerton, 2013), with a phytoplankton community dominated by pico-sized cells, and moderate mesozooplankton standing stocks that rely heavily on microzooplankton as a their main diet (Bradford-Grieve *et al.*, 1998, Zeldis, 2001). The planktonic food-web has thus generally been characterized as microbial, with tight growth-grazing coupling processes (Bradford-Grieve *et al.*, 1999, Hall *et al.*, 2004).

The general goal of the voyage was to *assess the carbon flows through the ecosystem and quantify the alteration in the presence of salp blooms, assessing the efficiency of the material transfer up the food-chain or export to depth.* The specific science objectives were:

1) Measure in situ water column rates of growth, grazing and primary production
2) Measure zooplankton community and salp standing stocks and grazing rates
3) Experimentally determine the grazing preferences and faecal pellet production rates of salps
4) Experimentally determine faecal pellet and salp carcass sinking rates
5) Conduct export measurements using ^{238}U:^{234}Th disequilibrium, sediment traps and Labyrinth of Doom collectors.
6) Investigate material reaching the sea-floor with Ocean Instruments MC-800 Multi-corer
7) Investigate microbial planktonic community diversity and production rates
8) Measure bacterial community production and trace gases
9) Investigate virus communities
10) Conduct DMS measurements
11) Experimentally determine copepod and euphausiid prey size-spectra
12) Assess environmental DNA originating from salps
13) Determine OA effects on salp faecal pellets

ALIGNEMENT WITH OTHER RESEARCH

Determining carbon export fluxes and the fate of primary production in different areas of the NZ EEZ is one of the current research goals of the NIWA SSIF programme COOF/PrimProd. Our future goals are to be able to monitor these rates remote sensing, using algorithms based on oceanography and chlorophyll *a*. However, in order to construct these, we need a mechanistic understanding of the regional-specific processes that link primary production to carbon export. These material fluxes feed the benthic and demersal animals living on the Rise, and these must be substantial since the area supports one of the most productive demersal fisheries within the NZ EEZ. The Chatham Rise has additionally been postulated as an area of net absorption of CO_2, but this is based off of a single study (Currie & Hunter, 1998). Significantly more in-depth research is required to quantify the contribution to the global carbon budget, understand the plankton processes that determine the absorption and export of carbon, and characterize the extent to which NZ waters absorbs or emit CO_2 to the atmosphere. Results from these studies will contribute substantially to global efforts currently estimating the amount and rate of change of carbon absorbed by the ocean, which affects both ocean acidification as well as the accumulation of heat in the atmosphere.

This research will also contribute substantially to NZ efforts to model and predict marine good-webs. Estimating energy fluxes among plankton and other components to higher trophic levels are key to understanding potential effects of climate change on fish abundance and distribution. These are also integral to the goals of the COES/FOODWEB programme. Our standing stock and rate measurements will contribute to updating and validating current models of the Chatham Rise food-web, as well as for food-web models of the subtropical and subantarctic regions of the EEZ.

Finally, blooms of gelatinous zooplankton have been linked to warming waters (Brotz *et al.*, 2012, Condon *et al.*, 2012), and even in the New Zealand area the anomalous 2018 year was characterized by high abundances of salp blooms (https://www.stuff.co.nz/environment/101003566/beaches-turning-to-seafood-chowder-under-chronic-summer-heat). With increasingly higher worldwide temperatures (Cheng *et al.*, 2019), the expectation is that the frequency and extent of these blooms will increase, and our study will contribute to predicting the effects of salp blooms on the environment - knowledge that will become increasingly important.

Future publishing plans include a publishing a scientific paper in a high impact journal (i.e. *Science* or *Nature*) in early 2020, and a special edition that we will begin to construct in 2020 including the breath of studies conducted as part of this voyage.

RESULTS OF SCIENCE OPERATIONS

A total of five areas were investigated in detail (Fig. 1). Cycle 1 was conducted southeast of Banks Peninsula, in waters of ~ 1000m depth. The salp community was dominated by the salp *Salpa thompsoni*, and the experimental cycle had a duration of 7 days to ensure all pieces of equipment and experiments were successfully deployed and finalised (see Table 1 for list of equipment and number of total deployments). Initially we envisioned carrying out Cycle 2 in subantarctic areas without salps, but it proved difficult to find a location that was essentially the same as Cycle 1 (subantarctic influenced ~ 1000m depth), without salps. After a series of Bongo tows over the course of 36 hours, we concluded that a new, different community of salps warranted research. Cycle 2 was initiated along the southern flank of the rise, about 110nm east of Cycle 1, for a duration of 5 days. The community was more diverse, with *Pegea confoederata* and *Thetis vagina* contributing notably to salp biovolume and carbon fluxes. We documented the largest *T. vagina* individual yet, exceeding the literature maximum of 30cm by about 1.5cm.

Cycle 3 was carried out in subtropical waters that had negligible salp abundances, which lasted 3 days. We subsequently moved east to look for subtropical waters with high numbers of salps. We carried out 22 Bongo tows over the course of 41 hours, as we searched for a salp bloom in subtropical waters. During these tows, we encountered low and mixed numbers of warm-water species in some areas, including *Salpa fusifomes*, *Thalia democratica*, and *Ihlea maghalanica.* None of these locations had high enough numbers to qualify as a 'Salp cycle'. We concluded our 'Bonga-thon' after we found an interesting area of mixed conditions over the Rise, with warm water at the surface (12°C), a visible salp population of *S. thompsoni*, and we began Cycle 4, which lasted 3 days. Finally, in order to sample subantarctic waters without salps, we headed south again. We stopped on our way to sample where our Cycle 2 (subantarctic with salps) had ended, to investigate the likely duration of the bloom we had studied. After this, we steamed for another ~120nm, and conducted our last experimental cycle (Cycle 5) in subantarctic waters without salp blooms. After a 3-day cycle, we turned around to head back, and stopped at site Hik21, to sample the ocean bottom as part of ongoing monitoring of the effects of the Kaikoura earthquake on the benthic community.

Overall our voyage was extremely successful, as the voyage plan included a high level of uncertainty associated with finding salp blooms within oceanic waters. We sampled a wide array of water column and plankton community parameters, an effort that was aided by the high number of collaborators on this trip. Collaborators for the SalpPOOP voyage were from international institutions, including Florida State University (USA), University of Hawaii (USA), Station Biologique de Roscoff (France), Nanyang Technological University (Singapore), University of British Columbia (Canada), Georgia Technical University (USA), and Otago University (New Zealand).

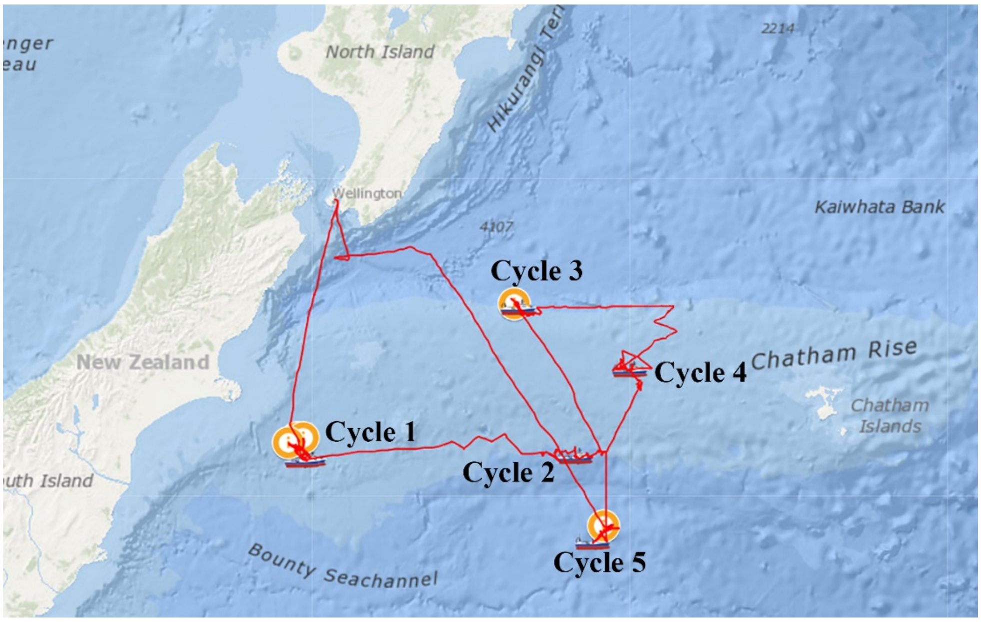


Fig. 1. Locations of each experimental 'Cycle' of TAN1810.

A total of 327 stations were completed, including 123 Bongo casts and 71 CTD casts (Table 1). A total of 35 hours of ship time were lost due to equipment malfunction and weather (Table 2). Whenever possible, equipment deployment order was modified based on weather conditions to maximize sampling.

Instrument type

	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Transit	Total
Baby net	1	2	3	1	2	1	10
Bongo net	23	13	19	13	19	36	123
CPR	-	-	-	-	-	4	4
CTD	22	14	11	12	11	1	71
Drifter array	6	2	3	3	3	N/A	17
Krill net	3	7	2	3	3	4	22
McLane pumps	4	4	4	4	4	-	20
MOCNESS	5	2	2	3	3	-	15
Multicorer	2	1	1	1	1	1	7
Salp net	34	18	4	12	3	4	75
Sediment trap array	-	1	1	1	1	-	4

Table 1. Breakdown of stations by type of equipment deployed, and experimental cycle/ transit.

Breakdown/Downtime/Weather Days

Days/Hrs lost to mechanical breakdown	Days/Hrs Lost to weather
7	28 hours

Table 2. Breakdown of time lost to mechanical breakdown and weather.

MEDIA COVERAGE AND OUTREACH

A blog of the voyage was maintained throughout the course of the expedition, with written updates provided by the voyage leader. These updates covered the sampling scheme, the equipment used, the vessel route, and included ample high-quality footage and photos of the organisms encountered, and science conducted onboard *R. V.* Tangaroa. These were promoted by social media accounts (Instagram, Twitter and Facebook) of both NIWA and the voyage leader, to promote the public outreach. After the conclusion of the voyage, the attention received on social media prompted an interview by Radio NZ's 'Our Changing World' of voyage leader Dr Moira Décima on salp blooms and salp ecology, the *R. V.* Tangaroa science plan, and the species encountered during the trip (https://www.radionz.co.nz/national/programmes/ourchangingworld/audio/2018676118/salps-a-surprising-jelly-like-relative).

Among the science crew were two Sir Peter Blake Ambassadors: Lana Young and Siobhan O'Connor, who did a fantastic job of posting vlogs (video blogs) and helping with video editing for the Unlocking Curious Minds (MBIE) collaboration between NIWA and AUT. As part of this, Leigh School, Goat Island Discovery Centre, Goat Island Dive and Snorkel, the Auckland University App Lab, and NIWA partnered up to produce a mobile app to document salp sightings around New Zealand, which is still in construction (to be launched during March 7th 2019 during New Zealand Seaweek). Prior to the voyage, students were introduced to salps and their biology. For the duration of the voyage, students followed progress through the blog webpage, and sent video questions for the voyage leader to respond. This resulted in 3 accessible and informative videos, which included the students' questions, that explained details of salps and their ecology and the most frequently asked questions (videos available online: https://www.niwa.co.nz/our-science/voyages/tan1810-ocean-vacuum-cleaner). After the voyage, students were shown footage, videos and results by the voyage Leader (Goat Island Discovery Centre, February 12th, 2019), to reinforce knowledge of salp ecology, research in New Zealand and expose young people to careers in STEM. The voyage also inspired the construction of a virtual reality experience by the AUT App lab (to be included as an exhibit in the Goat Island Discovery Centre, to be launched on March 7th 2019 during New Zealand Seaweek), where the public will be able to stand on *R. V.* Tangaroa, explore the trawl deck and sampling equipment, and jump into adjacent waters to experience a virtual salp bloom.

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TAN1901: Ross Sea Environment and Ecosystem Voyage 2019
Ross Sea, Antarctica
Date: 4 January to 18 February 2019
Lead Organisation: NIWA
Funding: MBIE (Endeavour funded Ross-RAMP programme), NIWA, University of Auckland
Voyage Leader: Richard O'Driscoll

Background:

The Ross Sea Environment and Ecosystem Voyage 2019, TAN1901, was the second of two research voyages to the Ross Sea region funded by MBIE for the 2018 and 2019 austral summer seasons. Science content of the voyages was developed by the Tangaroa Antarctic Reference Group, which initiated a call for Expressions of Interest (EOI) in November 2016. Two anchor research themes were selected: physical oceanographic processes, concentrating on the northern continental shelf break of the Ross Sea in 2018; and a seabed and demersal survey concentrating on eastern and north-eastern areas of the continental slope in 2019. Ten EOIs were incorporated into the 2019 voyage, representing research initiatives from

NIWA, the MBIE Endeavour Fund Programme Ross-RAMP, NIWA Strategic Science Investment Fund, and the University of Auckland.

The over-arching purpose of this multi-disciplinary research voyage was to increase knowledge about key environmental and biological processes in the Ross Sea region of Antarctica and the Southern Ocean, and thereby improve understanding of ecosystem function and likely responses to future change. The focus was on providing baseline information about the recently established Ross Sea Marine Protected Area (MPA) to allow scientific evaluation of its ecological status, spatial adequacy, and effectiveness. The ten EOIs were consolidated into eight voyage objectives under the themes: 1) demersal fish survey; 2) seabed habitats and fauna; 3) oceanographic moorings; 4) microbial planktonic communities; 5) zooplankton; 6) mesopelagic fish; 7) oceanographic and atmospheric observations; and 8) cetacean ecology.

Forty people were on board: 21 science staff and 19 NIWA Vessels crew, the latter including the medical doctor, Jenny Visser and ice navigator, Peter Sandison. The science staff included scientists from China, Italy and France.

Weather and sea conditions were favourable during the voyage and the survey area was largely free of ice. This allowed the voyage to follow the survey plan, and most of the work planned across the eight research objectives was completed (see summary below).

The survey:

The voyage track is shown in Figure 1. A summary of gear deployments is shown in Table 1.

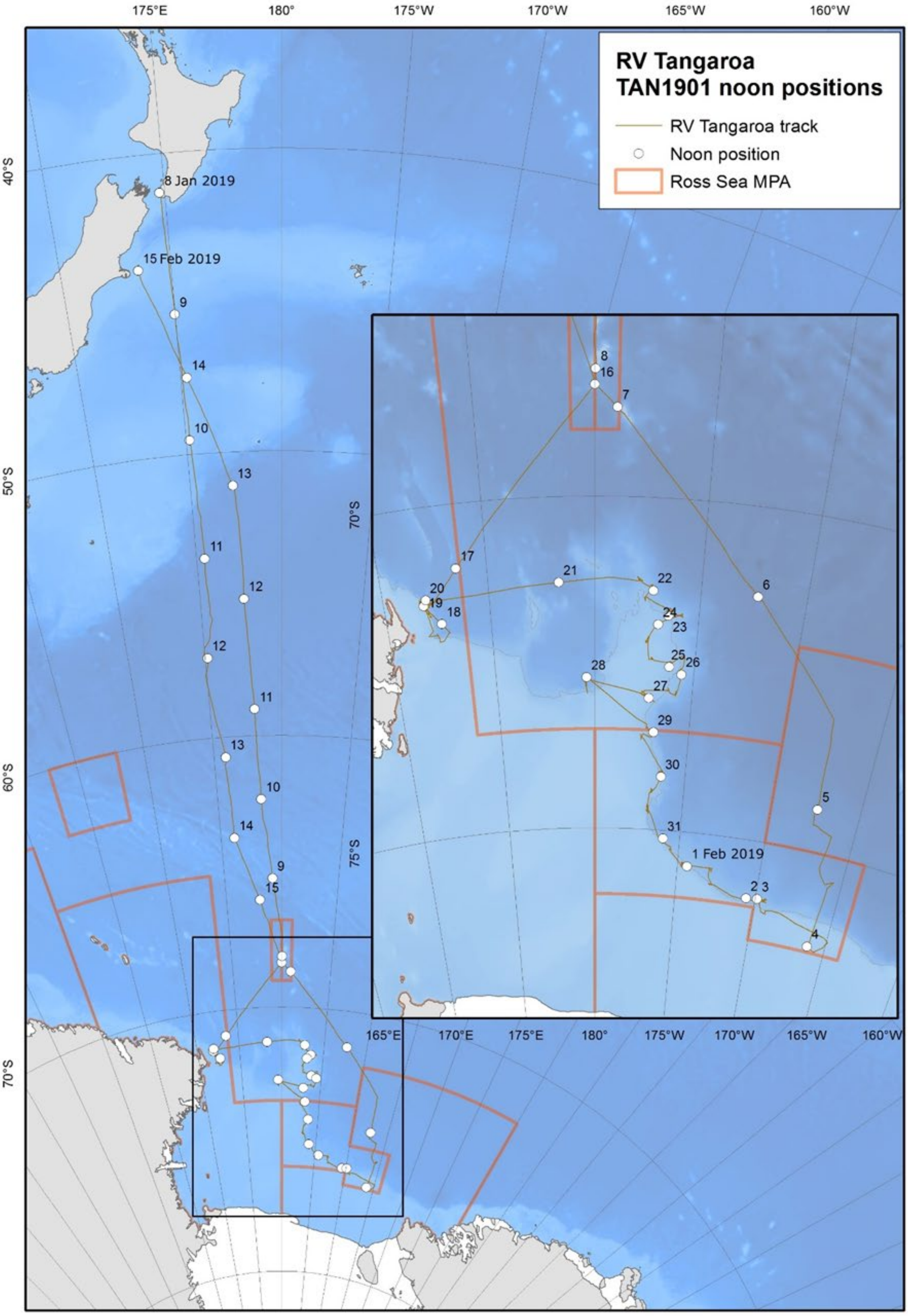


Figure 1: TAN1901 Voyage track, showing daily noon positions. Numbers represent the date (January going south, February going north).

Table 1: Summary of scientific gear deployments by start date. Gear types: ARGO, core ARGO buoy; BB, 'baby Bongo' plankton net; BONG, Bongo plankton net; BT, bottom trawl; CAL, acoustic calibration; CPR, continuous plankton recorder; CTD, conductivity temperature depth profile; DEEP, deep ARGO buoy; DTIS, deep towed imaging system; MOOR, mooring; MWT, midwater trawl; WAVE, wave buoy; SVP, sound velocity probe; SVPB, Global Drifter Programme SVP-B buoy.

Date start	ARGO	BB	BONG	BT	CAL	CPR	CTD	DEEP	DTIS	MOOR	MWT	WAVE	SVP	SVPB
8-Jan						1								
9-Jan						1								1
10-Jan			1			1	1					1		1
11-Jan	1					1	1	1				1		2
12-Jan	2							4						2
13-Jan	2	1	1			1	1				1	1		2
14-Jan	2		1			1	1			1				2
15-Jan	3	1	1				1				2	1		
16-Jan			1			1	1			1	1			
17-Jan		1	1		1		1							
18-Jan			1				2		1				1	
19-Jan		1	1				1		2	2	1			
20-Jan			1			1	1		1	1	1			
21-Jan		1	1				1				1			
22-Jan			1	2			1		3					
23-Jan		1	1	2			1		2					
24-Jan			1	2			1		2		1			
25-Jan		1	1	2			1		4					
26-Jan			3	2			1		2					
27-Jan		1	2	1			1		2		1			
28-Jan			3			1	2		1	1	2			
29-Jan		1	3	3			1		2					
30-Jan			3	2			1		2					
31-Jan		1	3				1		3		1			
1-Feb			3	3			1		3					
2-Feb		1	3	1			1		2					
3-Feb			1	3			1		1					
4-Feb		1	2				1		1		1			
5-Feb			3				1							
6-Feb			3			1	1							
7-Feb		1	2				1							
8-Feb	1		1			1	1		1		2			
9-Feb	1	1	3				2				1			
10-Feb			1				1				2			
Total	**12**	**14**	**53**	**23**	**1**	**11**	**34**	**5**	**35**	**6**	**18**	**4**	**1**	**10**

Demersal fish survey: Demersal trawls were carried out at 23 random sites in 6 strata at depths of 600-1500 m on the western Iselin Bank and eastern Ross Sea slope. The biological catch of 1056.5 kg was made up of 89 species or species groups, including 42 fish species. The main species in the catch by weight were grenadiers (rattails), jellyfish, toothfish, icefish, glacial squid, violet cod, and silverfish. Several rare or unusual fish species were caught and preserved for identification. Detailed biological information was collected from 1559 individual fish. Catch rates of the grenadier *Macruorus caml* were highest in 600-1000 m strata. There was a depth segregation between *M. caml* and *M. whitsoni*, with the latter more abundant deeper than 1100 m. Four Antarctic toothfish were caught, of which three large specimens were tagged and released alive.

Seabed Habitats and Fauna: Bathymetric mapping using multibeam acoustics, and seabed photographic transects using a towed video and still image camera system, were completed at 33 sites: 4 at the shelf break off Cape Adare; 27 in the 6 demersal fish slope strata; 1 on the south-eastern continental shelf, and 1 on Scott C seamount. In total, 33 h 38 min of seabed video and 8,116 still images were captured.

Moorings: Six of the seven moorings deployed in 2018 were recovered. The passive acoustic mooring on Scott Seamount (A2) failed to release and was not recovered. Six moorings were re-deployed. Four moorings were re-deployed at their original locations but two were changed: the physical oceanography mooring (P3) was moved to a position offshore of the other physical moorings off Cape Adare (P1 and P2), and the passive acoustic mooring (A3) was moved from the eastern Iselin Bank to the western Iselin Bank. The active acoustic mooring (A4) was not re-deployed as a cable fault meant that the mission plan could not be sent to the instrument.

Microbial Planktonic Communities: an extensive suite of measurements and experiments to characterise microbial community composition and function was conducted throughout the voyage, based on samples from daily CTD rosette casts (n = 31), plankton net tows (n = 14) and the vessel's underway seawater system. Experiments included on-board productivity and grazing studies. A novel research focus was on the role of Rhizaria in oceanic silicon and carbon cycles.

Zooplankton: A Continuous Plankton Recorder was deployed during transits to and from the Ross Sea, and from west to east from Cape Adare to Iselin Bank. Daily bongo plankton net tows to 200 m depth (n = 31) were coupled to daily CTD rosette casts. The MOCNESS net was not operational during the voyage due to a microprocessor failure, so additional bongo net deployments were made to 500 m (n = 14) and 1000 m (n = 9). Samples were preserved for gut pigment analysis (grazing rates), species identification, biomass estimation, and isotope studies.

Mesopelagic Fauna: Multi-frequency fisheries acoustic echosounders were run at all times during the voyage. Eighteen midwater trawls were carried out for specimen collection or mark identification. Five different mark types were targeted. The midwater catch of 856.1 kg was made up of 46 species or species groups, including 28 fish species. The main species in the catch by weight were jellyfish, myctophids, Antarctic krill, and grenadiers. Species diversity decreased with increasing latitude.

Oceanographic and Atmospheric Observations: Underway water sampling provided continuous spatial coverage of physical and biological parameters from surface waters. Carbon dioxide in air and seawater was also measured continuously, and 20 flask samples were collected. Bio-optical properties were measured on samples from the underway system and CTD, and sea surface water colour was monitored during daylight hours at one-minute intervals over the entire voyage using hyperspectral sensors and a 360° camera. Thirty-one oceanographic drifters were deployed during the voyage: 12 core Argo floats; 5 deep Argo floats; 10 Global Drifter Programme SVP-B buoys, and 4 New Zealand Defence Technology Agency wave buoys. Two of the deep Argo buoys were faulty, and one was recovered on the transit north.

Cetacean Studies: No dedicated marine mammal watches were conducted during the voyage. However, science staff assisted vessel officers in recording opportunistic sightings made from the bridge. The most commonly observed were minke whales (18 groups, best estimate total of 76 individuals), humpback whales (8 groups, total of 17 individuals), and killer whales (3 groups, total of 80 individuals). Two groups of blue whales and fin whales were also observed, along with two further sightings of larger baleen whales that could not be further identified. A single sighting was made of a sperm whale. Photos of dorsal fins (mainly of minke whales) and flukes (3 humpback whales) were taken for identification.

Breakdown / downtime / weather days:

Favourable weather and sea conditions were encountered for much of the voyage and no significant time was lost. The study area was largely free of sea-ice, except close to Cape Adare and on the south-eastern slope. This enabled most of the work planned across the eight research objectives to be completed. Work undertaken and preliminary results are summarised below.

National relevance:

The research is consistent with the New Zealand Antarctic and Southern Ocean science directions and priorities 2010–2020, specifically:

- Aligning with New Zealand's international obligations under CCAMLR (management of Antarctic marine living resources, engagement in ecosystem-based management, enhanced conservation measures);
- New Zealand's objective of establishing a network of marine protected areas in the Ross Sea region (support for the selection and development of marine protected areas);
- Creating larger collaborative programmes of research, especially when undertaking ship-based marine research.
- Improving understanding of Antarctic and Southern Ocean responses to past climate conditions and enhanced modelling of the Antarctic and Southern Ocean impact on, and response to, climate change and variability.

The research objectives specifically address the following priority elements for scientific research and monitoring in support of the Ross Sea MPA (CCAMLR Conservation Measure 91/05 Annex C):

- At-sea surveys or censuses to estimate the distribution and abundance of marine mammals, seabirds, fishes and invertebrates.
- Acoustic surveys to map distribution and abundance of Antarctic silverfish and krill.
- Targeted sampling of Ross Sea shelf and slope communities with focus on middle trophic level organisms.
- Investigate oceanographic drivers of phaeocystis- vs. diatom-dominated production and consequences for higher-level trophic ecosystem function.
- Paired stratified surveys of slope habitats with contrasting local exploitation rates to monitor effects of fishing on Antarctic toothfish and demersal fishes.

- Surveys and sampling to investigate life history hypotheses, biological parameters, ecological relationships and variations in biomass and production of Antarctic krill.
- Meteorological and oceanographic research, including satellite remote sensing, to characterise physical properties and dynamics of phytoplankton and zooplankton.
- Long-term monitoring of benthic ecosystem function.
- Investigate deep bottom water formation (relevant to global oceanic circulation), slope water intrusion and cross-shelf nutrient exchange.

Research will also:

- Demonstrate the commitment of New Zealand to an active science program designed to improve conservation outcomes for Southern Ocean whales.
- Quantify key functional and structural components of the Ross Sea ecosystem that will further develop New Zealand's Ross Sea ecosystem modelling.
- Improve our understanding about how the marine environment and marine food webs may respond to climate change and ocean acidification.
- Build on New Zealand's reputation for research on atmosphere/ocean circulation processes.
- Support long-term monitoring projects that contribute directly to global networks.

Data usage:

A voyage report was submitted to MBIE and MFAT in May 2019. Samples are currently being analysed by research groups in New Zealand, Italy, France, Korea, China, Australia, and the United States. Preliminary results were presented to CCAMLR Ecosystem Monitoring and Management Working Group (EMM) in France in July 2019, to the Antarctica New Zealand conference, and to the general public (including at the launch of the James Cameron: Exploring the Deep Exhibition at Otago Museum). Results will be disseminated through primary publications and research reports to CCAMLR.

Outreach:

A Media Plan was developed by the NIWA Communications and Marketing group, coordinated by Susan Pepperell. Press releases were made in the run-up to the voyage and a media conference was held on 7 January 2019 on the bridge of RV *Tangaroa*. There was no dedicated media berth on the ship but eight voyage updates with accompanying photographs were prepared and uploaded to NIWA by voyage leader Richard O'Driscoll. The NIWA Communications team then promulgated these items via social media (Facebook, Twitter), and the NIWA web-site. A "Critter of the Week" article on a pelagic worm caught in the bongo net was also prepared by Diana Macpherson and distributed via the NIWA Invertebrate Collection Facebook page.

A press release was prepared on completion of the voyage and a selection of images provided. These featured in Water & Atmosphere Magazine and in the Sunday Star Times.

This media strategy was successful, gaining wide exposure and increasing awareness of the voyage, its research, and the wider issues and priorities associated with understanding and managing Antarctic environments and ecosystems.

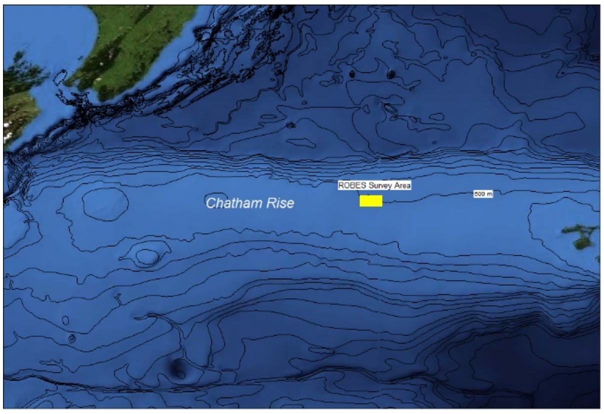
Voyage number: TAN1903
Title: Sedimentation effects-the Resilience Of deep-sea Benthos to the Effects of Sedimentation (ROBES)
Area: Chatham Rise
Period: 9 - 29 June 2019
Lead organization: NIWA
Voyage leader: Malcolm Clark

Background

This voyage was the second of three surveys designed to determine the effects of sedimentation, and the resilience and potential recovery of impacted benthic communities. The first (2018) survey was designed to subject an area of seabed to disturbance that would create a sediment plume. The suspended sediment load created by the disturbance would then be tracked and monitored, by pre- and post-disturbance sampling to determine the effects on faunal community structure at an increasing distance from the impact. The monitoring (post-disturbance survey) was to be repeated in 2019 and 2020 to determine the longer-term resilience and recovery dynamics of disturbed communities. However, because the plume created during the 2018 survey did not blanket epifauna as hoped, the survey this year was a combination of monitoring, and further disturbance.

The survey

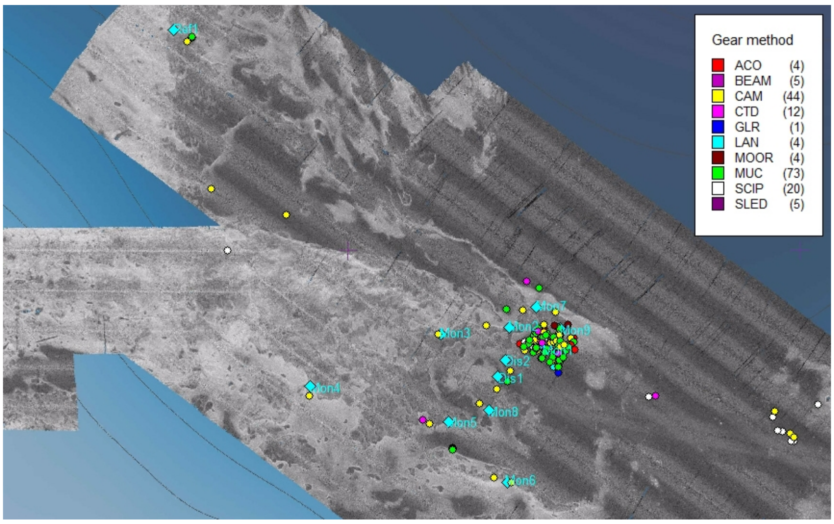
The survey occurred on the central Chatham Rise, north of the Mid-Chatham Benthic Protection Area. It is an area of relatively uniform slope, with no topographic features, but patches of coral communities (dominated by *Goniocorella dumosa*) on exposed rock and cobble substrate.



The location of the survey (left) and an example of a coral-dominated community in the area (right)

The survey was divided into two discrete parts, the first focussed on repeat sampling of sites from 2018, and the second involving a new disturbance of a small area around a feature termed the "butterknife".

Monitoring occurred at 12 of the sites established during the 2018 survey, with towed camera at all, and multicore deployments at seven sites. The distribution of sites, and gear deployments during TAN1903, are shown in the figure below.



Detail of the survey area, showing the 2018 monitoring stations (labelled) and the more clustered distribution of 2019 sampling stations around the Butterknife.

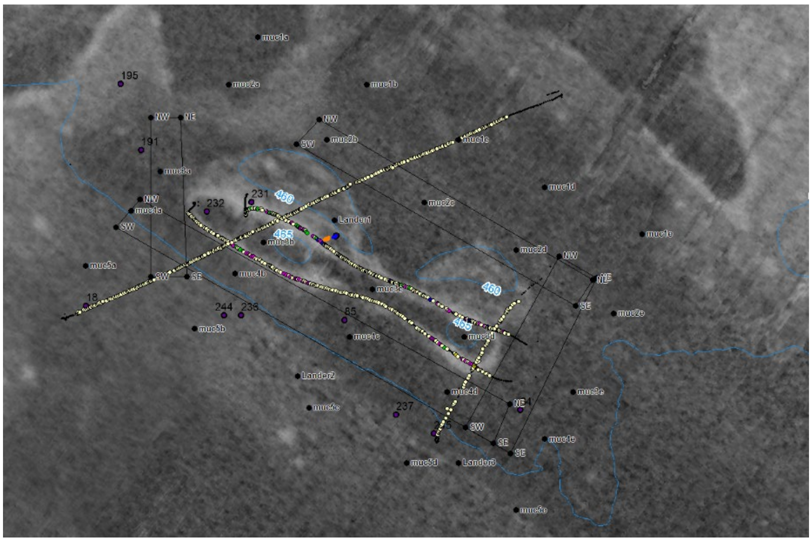
The concentration of stations from this survey was around the “Butterknife”. The intention here was to attempt a more localised disturbance, whereby the disturber would be run close to the rims where there were coral communities, as well as “inside” the feature to allow for tidal flows flushing the sediment cloud in several directions.

The physical disturbance was done with a modified agricultural plough, a 12’ Felxi-tyne named SCIP (Sediment-Cloud-Induction-Plough), with the tynes set to penetrate about 15cm into the sediment, and having a roller (similar to a hand lawn-mower) behind. The latter was damaged, and replaced by a harrow mat. This was observed to create a cloud 1-2 m high.


SCIP on deck, and a shot on the seafloor with the tynes digging into the sediment.

Baseline data were collected on bathymetry, topography, water column characteristics, sediment composition, and faunal community structure and abundance prior to, and post- disturbance. Current flow was assessed using the vessel ADCP, NIWA’s underwater glider, and a moored ADCP. Water column data were collected from a CTD-rosette, multibeam echo-sounder (backscatter), and multi-frequency fisheries acoustics sounders. Several sounder transect surveys were run to map the area of disturbance pre- and post-disturbance, and CTDs were deployed in some locations immediately after disturbance events to sample the cloud. Three benthic landers were deployed downstream of the disturbance site with an array of sensors, including sediment traps. Detailed sediment sampling with the multicorer (supporting onboard respiration experiments as well as sediment profile data), and extensive DTIS towed camera stations were completed.

The plot below shows the backscatter map of the Butterknife feature, with several DTIS track tows along the rims as well as across the feature, and the array of multicorer station sites.



The Butterknife feature. The white dotted lines show observations made during several towed camera runs along the northern and southern rims, as well as across the feature. The black dots show the location of three benthic landers, and a grid of 25 multicorer sites.

Live deep-sea sponges (two species) and corals (one species) were also collected for sedimentation experiments back at the laboratory. Three mooring arrays were recovered, and a single combined sediment trap-current meter mooring redeployed at the end of the survey for a further 12 months to monitor current and sediment dynamics. In total there were 172 gear deployments, comprising multicorer (73), towed camera (44 -2 tests), CTD (12), SCIP disturber (20), landers (4 -1 test), moorings (4), seamount sleds (5), ocean glider (1 continuous), beam trawls (5) and acoustic survey grids (4).

The current flow in the survey area is strong, and although SCIP was run as close as possible to the Butterknife, sediment settlement appeared to be light. The sediments in the cloud appear to disperse rapidly in the relatively fast bottom current conditions. Nevertheless, the complex interaction of multiple gear types and disciplines planned for the survey worked well overall, and the survey has collected a large amount of oceanographic, sedimentological, and biological data for comparison with 2018, and pre-and post-disturbance that will support a wide variety of analyses in coming months.

There was no specific outreach (voyage blogs etc). However, prior to the survey we held a half-day seminar with a wide range of stakeholders, so everyone knew what we were doing during the survey (and agreed with it). Three hui were held with iwi in May, and two participated in the survey itself for capacity-building (Moriori, Te Ataitanga) and were joined by an early career researcher from the Cook Islands Seabed Minerals Authority.