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Physical, biogeochemical, and microbial characteristics of sediment samples from the Chatham Rise and Challenger Plateau

Scott Nodder
Els Maas
David Bowden
Conrad Pilditch

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Scott Nodder[1]
Els Maas[1]
David Bowden[1]
Conrad Pilditch[2]

[1]NIWA
Private Bag 14901
Wellington 6241

[2]Department of Biological Sciences
University of Waikato
Private Bag 3105
Hamilton 3240

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EXECUTIVE SUMMARY

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This report presents data from analyses of seabed sediment samples collected during two Ocean Survey 20/20 voyages to the Chatham Rise and Challenger Plateau in 2007 (TAN0705 and TAN0707, respectively). Sediment samples were collected by multicorer and by pipe dredges attached to the epibenthic sled and beam trawl. Sediment grain-size, composition, microbial abundance and biomass analyses were carried out under Ministry of Fisheries project ZBD2007-01, with input from earlier OS 20/20 projects.

The main results are summarised as follows.

- On the Chatham Rise, high mud contents (50–70%, less than 63 µm, silt and clay) occurred on the western and south-central parts, whereas high sand and gravel (60–less than 90%, greater than 63 µm) contents were found on the northeastern flank around the Chatham Islands and on Mernoo Bank.

- On the Challenger Plateau, sediments on the crest of the plateau were dominantly sandy (60–90%), with muddy sediments (20–more than 90%) increasing with depth towards the southwest, northeast, and southeast flanks, and on the Taranaki continental slope.

- Calcium carbonate contents were consistently high (80–more than 90%) across the Challenger Plateau with lower values on the NW Nelson (40–80%) and Taranaki (20–40%) slopes. On the Chatham Rise, highest values were to the east around the Chatham Islands, and along the northern flank, with high values at Mernoo Bank. On the southern flanks of Chatham rise, values were relatively low (20–40%).

- Total organic matter (TOM) content ranged from about 1% to 5% of total sediment weight on both the Chatham Rise and Challenger Plateau, but values were consistently low over central areas of the Challenger Plateau. Values were more variable across the Chatham Rise, with a trend for higher values to the north and west of the area.

- Phytopigments (chlorophyll *a* and phaeopigments) reflect the most labile part of the organic material accumulating in sediments. Levels were highest across the western part of the Chatham Rise and at one site to the east of the Chatham Islands (~0.05–0.1 µg chlorophyll *a* per gram dry weight sediment). In contrast, over most of the Challenger Plateau, phytopigments were absent or present at very low levels (typically <0.01 µg chlorophyll *a* per gram dry weight sediment).

- Mean SCOC rates on the Challenger Plateau were typically lower than on the Chatham Rise (~60 to ~180 µmol O_2 m^{-2} h^{-1} and ~80 to ~280 µmol O_2 m^{-2} h^{-1} respectively). Highest values on the Chatham Rise tended to be at the shallower sites (less than 500 m water depth). The highest SCOC value from either the rise or the plateau study areas, however, was on the Taranaki slope (470±80 µmol O_2 m^{-2} h^{-1}). These data can not be reproduced without the permission of Dr C.A. Pilditch (University of Waikato).

- Bacterial abundance ranged from 2.12 x 10^8 cells per gram dry weight sediment to 4.32 x 10^9 cells per gram dry weight sediment. There was no clear difference in bacterial numbers between the Chatham Rise and Challenger Plateau, although the highest abundance values were recorded on the Challenger Plateau. The highest value from both sampling areas was from the northwest flank of the Challenger Plateau.

- Bacterial biomass, determined using an assumed carbon (C) content per cell, ranged from 4.07 to 26.11 µg C per dry weight sediment on the Chatham Rise, compared with 6.49 to 85.57 µg C per dry weight sediment on the Challenger Plateau. There was no difference in bacterial biomass between the two sampling areas using this technique. The highest amount of microbial carbon biomass was estimated at the deepest site on the northwest flank of the Challenger Plateau.

- Conversely, using the biovolume, or size, of cells, the carbon biomass estimates ranged between 11.66 and 808.90 µg C per gram dry weight sediment, which is between 2.5 and 9.5 times more than the biomass estimate using cell numbers. Biovolume estimates are potentially more accurate in estimating the amount of carbon at each site as this method takes into account cell size. This is an important consideration, especially as it is apparent that the size of bacteria cells on the Challenger Plateau was in general larger than those on the Chatham Rise (1.1 - 1.4 μm^3, down to 0.4 μm^3 cf. 0.4–0.7 μm^3, up to 1.2 μm^3, respectively).

- Exo-enzyme activities are indicative of the processes taking place in the sediments. Five different enzymes were measured: proteases (breakdown of protein), lipases (lipids), chitinases (chitin), β-glucosidase or cellulases (cellulose), and phosphatases (involved in inorganic phosphate recycling). Chitinase and cellulase activity were highest on the Chatham Rise. Phosphatase activity (less than 1.9 µM per minute per gram C) was also high on the rise and on the NW Nelson slope. Very little or no chitinase, cellulose, or phosphatase activity was detected in the Challenger Plateau samples.

- The enzyme data indicate that, although high bacterial cell numbers, and therefore high microbial carbon biomass, are found on the Challenger Plateau, it does not appear that these bacteria are particularly active since very little exo-enzyme activity is apparent. In comparison, on the Chatham Rise, relatively high activity was observed for relatively low bacterial biomass.

1. INTRODUCTION

1.1 Ocean Survey 20/20 Chatham-Challenger project

In November 2004, Cabinet agreed to establish Ocean Survey 20/20 (OS 20/20) as a 15 year project with the following vision:

"Complete by 2020 an ocean survey that will provide New Zealand with the knowledge of its ocean territory to:

- *demonstrate our stewardship and exercise our sovereign rights;*
- *conserve, protect, manage and sustainably utilise our ocean resources; and*
- *facilitate safe navigation and enjoyment of the oceans around New Zealand."*

The Chatham-Challenger Hydrographic, Biodiversity and Sea-bed Habitats Project was identified by Cabinet as the priority OS 20/20 project for 2006–07. The Ministry of Fisheries (MFish), Land Information New Zealand (LINZ), Department of Conservation (DoC), and NIWA were the main drivers in the conceptual development of the project.

The overall purpose of the Chatham/Challenger Project is to map and compare the distribution of seabed habitats and biological diversity across the Chatham Rise and the Challenger Plateau. These areas are in contrasting oceanographic environments and are subjected to different levels of anthropogenic disturbance from fisheries. The Chatham Rise lies under waters with high biological productivity and supports intensive fisheries, whereas the Challenger Plateau has lower productivity and is subject to lower levels of fishing.

The overall objectives were developed by MFish, DoC, LINZ, and NIWA and agreed by the OS 20/20 Chief Executive Group for the Chatham-Challenger Biodiversity and Seabed Habitat 2006/07 Oceans 2020 Project.

1. To determine the distribution of bottom habitats and biodiversity on the seabed in depths of 200 to 1200 m (i.e., fishable depths) on the Chatham Rise and Challenger Plateau.
2. To develop the utility of the Marine Environment Classification system as a proxy for habitat types and biodiversity distribution, and to further develop habitat mapping techniques.
3. To assess the influence of bottom trawling as a broad-scale driver of sea-bed biodiversity.

Three voyages were undertaken through 2006 and 2007 to complete the field sampling phase of the Chatham-Challenger project. The first voyage conducted multibeam swath mapping of pre-selected transects across the Chatham Rise and Challenger Plateau (TAN0610, August 2006). These transects were then targeted for biodiversity and habitat studies on two subsequent voyages (TAN0705 to Chatham Rise in March-April 2007 and TAN0707 to Challenger Plateau in May-June 2007).

1.2 Sampling design for seabed habitats and biodiversity

The two-voyage programme to sample the benthic habitats was completed successfully in 2007. Sampling design was developed on the basis of a multivariate statistical classification using the K-means method with the Calinski-Harabasz stopping statistic (Legendre et al. 2002). In this classification, available oceanographic environmental data layers and parameters from the multibeam transects sampled during voyage TAN0610 were combined. This classification procedure was run separately for the two regions and identified eight environmental clusters on the Chatham Rise and nine clusters on the Challenger Plateau (Figure 1). These clusters defined the strata for the subsequent benthic sampling programme. The sampling sites and sampling effort per site were then allocated evenly across strata in each region, with randomisation within strata. The number of strata on the Challenger Plateau was subsequently reduced to five, using the next lowest peak in the Calinski-Harabasz criterion, to enable adequate sampling density across all strata in the time available.

In order to characterise habitats, and to quantify sediment composition and biological assemblages across a size range from bacteria to megafauna, samples were collected using a range of equipment including cameras, epibenthic sleds, sediment corers, and trawls. Time constraints dictated that not all sampling gear types could be deployed at all sites. Thus, a hierarchy of site types was defined: 'A' sites, at which all gear types were deployed; 'B' sites at which the Deep-Towed Imaging System (DTIS) and the epibenthic sled were deployed and 'C' sites, at which only the DTIS was deployed. In practice, it was possible to deploy both the DTIS and the epibenthic sled at all 'C' sites, and thus in many instances they are the same as 'B' sites for analysis. In this and subsequent reports, however, the nomenclature from the planning stage has been retained to allow direct reference to the original samples. A further modification, made possible by favourable conditions at sea, was the addition of a number of extra sites which were not included in the original sampling design. These were designated as 'D' sites and were included in areas where there were reasons to believe that more detailed coverage would be of use to the objectives of the project. On the northeast Chatham Rise, 11 'D' sites were targeted in the orange roughy spawning box, where two transects with DTIS, multicorer, and beam trawl sampling were undertaken. One transect was in an area of relatively low fishing intensity (D20-24, Figure 1), the other (Sites D13-18, Figure 1) in an area of high fishing intensity.

A total of 100 sites were sampled on the Chatham Rise, and 49 on the Challenger Plateau (Figure 1). These totals include 29 and 9 extra 'D' sites, respectively (Table 1).

Table 1: Total number of sites sampled on the Chatham Rise and Challenger Plateau during TAN0705 and TAN0707, respectively. Categories denote the intensity of sampling at each site, see text for details.

Site category	Chatham Rise	Challenger Plateau
A	11	5
B	37	14
C	23	21
D	29	9
Total	100	49

1.3 Sediment samples

Sediment samples were collected primarily to characterise the physical and chemical properties of the sediment, to estimate bacterial biomass, and to characterise meio- and macro-infaunal assemblages. These sample collections and analyses were undertaken as part of MFish project ZBD2006-04, LINZ project LIN06304, DoC project DOC08306, and NIWA Capability Fund project CRFD073. Subsequently, NIWA tendered for and was awarded a MFish contract (ZBD2007-01A) that included analysis of the sediment samples to characterise their physical and chemical properties (Objective 7) and to measure the bacterial biomass in surficial sediments (Objective 8) on the Chatham Rise and Challenger Plateau. Here, we report results from Specific Objectives 7 and 8 of MFish project ZBD200701: the physical and chemical properties, and microbial community characteristics of the Chatham Rise and Challenger Plateau sediment samples.

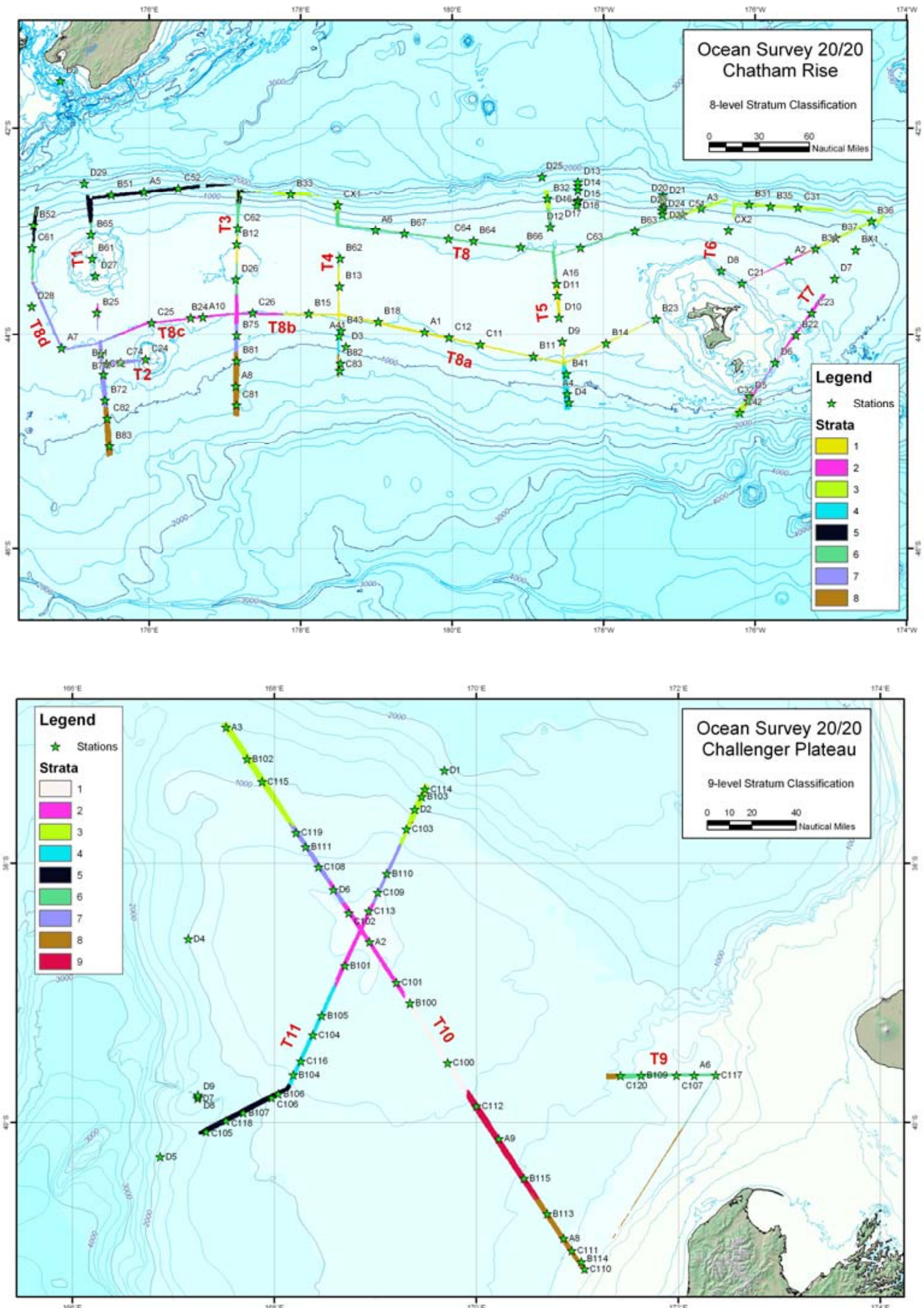

Figure 1: OS 20/20 *a priori* strata and actual sampling sites on the Chatham Rise (TAN0705, top) and Challenger Plateau (TAN0707, bottom). Note the 9 planned strata shown here for the Challenger Plateau were amalgamated into 5 strata before sampling during TAN0707. Red 'T' prefix numbers identify multibeam transects conducted during TAN0610.

2. MATERIALS AND METHODS

2.1 Sediment sampling

Sediment samples were collected by two methods: (1) a 'deep-ocean multicorer' (Ocean Instruments MC-800A), and (2) pipe samplers attached to the epibenthic sled and beam trawl. The multicorer recovers multiple, simultaneous, undisturbed cores (10 cm diameter and up to 70 cm depth) complete with overlying water column, from soft sediments. Because the apparatus does not disturb the sediment, precise sampling of different depth horizons within the cores, as well as the overlying water, is possible. In contrast, pipe samplers attached to the epibenthic sled and beam trawl are mounted horizontally and collect sediment as the gear is dragged across the seabed. They may also be subject to winnowing as the apparatus is lifted through the water column. Samples are, therefore, highly disturbed and may represent an accumulation of sediment types across a wide area.

At each 'A' site, if suitable substrata were present, two multicorer deployments and two epibenthic sled deployments were made. At 'B' and 'C' sites, a single epibenthic sled or beam trawl tow was made. One multicorer core at each 'A' site was used for sediment analyses, with three cores used for bacterial analyses.

2.2 Sediment physical and chemical properties

Surficial sediment samples collected using the multicorer were sectioned at 0.5 cm intervals down to 10 cm, and 1 cm intervals below this depth, and stored frozen (-80 °C) in zip-lock plastic bags. Grain-size parameters were measured from oven-dried subsamples by sieving (sand and gravel fractions: less than 500 µm, 250–500 µm, 125–250 µm, 63–125 µm) and by Sedigraph techniques (silt and clay fractions: less than 63 µm), down to 5 cm for each core.

Total organic matter (TOM) was estimated by loss-on-ignition (500 °C for 4 hours) from samples from the top 1 cm at multicorer 'A' site deployments and on bulk sediment samples from the pipe samplers attached to the epibenthic sleds where there was sufficient material for analysis. Calcium carbonate content was measured on the same samples by a CO_2 vacuum-gasometric method with ±1% accuracy. Before these analyses, subsamples for total chlorophyll *a* and phaeopigments pigment analysis were taken from the frozen 0–0.5 and 0.5–1 cm multicore and surface epibenthic sled samples and re-frozen until analysis. Pigment concentrations were determined by standard spectrofluorometric techniques after freeze-drying, to determine moisture content, and extraction of the dried sample in 90% acetone.

Analyses for particulate organic carbon (POC) and total nitrogen (TN) content are also in progress, funded under project DOC08306. At the time of this report (April 2010) these analyses are about 50% complete and are not reported here.

2.3 Sediment Community Oxygen Consumption (SCOC)

Because multicorer samples are relatively undisturbed and preserve the sediment-water interface where much of the microbial activity occurs, they can be used to measure the overall rate of consumption of oxygen by sediment faunal communities. This rate can be interpreted as a relative measure of the amount of biological activity in the sediments at each site; higher oxygen consumption indicating higher levels of biological respiration. During TAN0705 and TAN0707, Sediment Community Oxygen Consumption (SCOC) incubation experiments were conducted at all 'A' sites on the Chatham Rise and Challenger Plateau where multicore samples were recovered. This work is part of a larger study coordinated by Dr Conrad Pilditch, University of Waikato and funded entirely by the University of Waikato and the Coasts & Oceans OBI. Although this work is not part of the reporting requirements for project ZBD2007-01, with the permission of Dr. Pilditch, we present initial results from the sediment respiration study here.

For the incubations, sediment from the multicorer sampling tube, complete with overlying water, was extruded with minimal disturbance into a sealed incubation core. This was then incubated in the dark at ambient seabed water temperatures. Oxygen levels in the overlying water were monitored over several hours until oxygen concentrations were 10–15% below the starting concentration. From the decline in dissolved oxygen concentration over time, SCOC rate can be determined in µmoles of oxygen consumed by the sediment fauna, per square metre of sediment, per hour.

2.4 Bacterial biomass estimation

At all 'A' sites, except A05 and A04, sediment samples for bacterial abundance and enzyme activity measurements were collected from three multicorer cores. Only two cores were sampled at A05, and no sediment samples were recovered at A04. For each sample, the top layer of the sediment was aseptically removed, placed in a sterile 50 ml falcon tube and frozen at -20 ºC for subsequent analysis.

Bacterial numbers were estimated using a method recently developed by Drs Yuki Morono and Fumio Inagaki at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Kochi Core Centre, Kochi, Japan. The method incorporates rapid, automated image analysis algorithms and has several principal advantages over conventional acridine orange staining techniques, namely: (1) frozen samples can be used, and (2) the process can largely be automated, resulting in considerable saving of time and improvements in the consistency of bacterial counts. Briefly, sediment samples were processed as follows. To fix bacterial cells, a measured amount (about 1 g) of frozen sediment from each sample was thawed in 5 ml of 4% paraformaldehyde in phosphate buffered saline (PBS) for 1 hour at room temperature. After washing twice with 5 ml PBS, the sediments were then resuspended in a 5 ml volume of 1:1 of ethanol (99.5%) and PBS. A 50 µl subsample was then treated with 1% hydrofluoric acid in 3% NaCl for 20 minutes at room temperature. The reaction was stopped with a solution containing 1 M TRIS-HCl (pH 8.0), 0.125 M $CaCl_2$ in 25% methanol and sonicated for 1 minute (20 volts) on ice. A subsample of the sonicated sediments was then filtered onto a 25 mm 0.2 µm polycarbonate filter. The filters were cut into quarters and one quarter was mounted on a microscope slide with mounting fluid containing the SYBR Green stain (Molecular Probes Inc, USA). The slides were placed on an Olympus BX81 fluorescence microscope with a motorised stage. One hundred and forty randomly distributed fields of view from each sample were captured automatically as digital image files and these were then processed using an image analysis algorithm developed by JAMSTEC that records the total number of bacteria per view and the maximum radius of each individual bacterium. These values were then used to calculate estimates for the mean, and confidence limits of: (1) the number of bacterial cells, and (2) the biovolume of bacteria per gram dry weight of the original sediment. Bacterial abundance values were converted to mg carbon per g dry weight of sediment using the conversion factor $19.8 \pm 0.8 \times 10^{-15}$ g C (femtograms, fg) per cell (Lee & Fuhrman 1987) and biovolume values were converted to µg carbon per gram dry weight sediment using the conversion factor 1.3×10^{-13} g C per μm^3 (Van Veen & Eldor 1979, Bakken & Olsen 1987).

2.5 Exo-enzyme activity

Exo-enzyme activity at each site was measured using either 4-methylumbelliferone (MUF) or 4-methyl-coumarinyl-7-amide (MCA) fluorogenic substrates by the method described by Hoppe (1993). Aminopeptidase (protease), β-glucosidase (cellulase), phosphatase, chitinase, and lipase activities were measured using the following fluorogenic substrate analogues (all obtained from Sigma, Australia); Leu-MCA (L-leucine-7-amino-4-methylcoumarin), MUF-β-glucosidase (4-methylumbelliferyl β-D-glucopyranoside), MUF-phosphate (4-methylumbelliferyl phosphate), MUF-chitin (4-methylumbelliferyl N-acetyl-β-D-glucosaminide), and MUF-lipid (4-methylumbelliferyl oleate), respectively. All substrates and the two fluorophores (MUF and MCA) were dissolved in 1% 2-methoxyethanol (Sigma, Australia) to 1.6 mM for the substrates and 200 µM for the fluorophores. Sediment slurries were prepared by weighing a known amount (about 2–3 g) of each sample into a vial and adding 3 ml of sterile PBS (Oxoid), vortexing the samples, and freezing the sample until analysis. The samples were thawed, 200 µl aliquots were pipetted in triplicate into 96 black well plates, and substrates were added to these samples to give a final concentration of 39 µM of each substrate. In addition, control enzymes were added in duplicate to wells containing the corresponding substrate to check for activity. A range of concentrations (0 µm to 50 µM) of the fluorophore (either MUF or MCA) was also measured so that the amount of fluorescence detected could be converted into µM fluorophore. The 96 well plates, were incubated in a fluorescent plate reader (Turner BioSystems Inc., USA) at 15 ºC for 6 hours and the fluorescence was measured (excitation 365 nm and emission 410–460 nm) every 5 minutes. The amount of fluorescence produced by each sample was converted to µM of fluorophore and the data were graphed to allow the V_{max} (maximum velocity of enzyme hydrolysis) for each sample and for each enzyme to be calculated in µM fluorescence produced per minute per millilitre of slurry. These values were then converted to µM per minute per gram dry weight of sediment and finally converted to µM per minute per microgram C using the amount of carbon calculated using the bacterial numbers estimated above (Hoppe 1993).

3. RESULTS AND DISCUSSION

3.1 Sediment physical and chemical properties

Surficial sediment data for all sites are presented in Appendix 1.

3.1.1 Grain-size distributions

Highest sand (greater than 63 µm) percentages were generally found in a large area to the northwest of and around the Chatham Islands as well as a localised area on Mernoo Bank (77–96% sand) (Figures 2 and 3). High sand contents were observed along the entire High Intensity Fishing Gradient transect (D20-D24) and the uppermost part of the adjacent Low Intensity transect (D17-18) and immediately adjacent to (B23) and due east of Chatham Island (B22, C23), with values over 93%. The southwestern, northwestern, and central-southern upper slopes of the rise were characterised by moderately low sand values (less than 25%), and correspondingly had high mud contents. The deepest parts of the southern extents of transects T1 and T2 across the western Chatham Rise had moderate sand percentages (about 20–34%), compared to more easterly sites on transects T4, T5, and T7 where sand contents of 70–78% were observed. The coarsest fraction (over 500 µm, medium sand to gravel) generally contained less than 1%, but on several occasions was found to be greater than 10%, specifically on Mernoo Bank (B61, 48%), the southern end of transect T5 (A4, 37–50%), east of the Chatham Islands (D5 – 28%, C23 – 44%) and due north of Chatham Island (B31, 83%).

On the Challenger Plateau, sediments on the crest were generally moderate to highly sandy (59–93%) with the lowest values observed at the northern end of transect T11 (11–28%) (Figures 2 and 3). The lowest values on the survey were found on transect T6 off the Taranaki slope (6–16% sand) and at B115 (14%) on transect T10. The northwestern end of transect T10 became sandier with increasing depth (more than 50%) as also observed at the opposite end of the same transect on the NW Nelson slope (about 80% sand). In comparison, the deeper parts of transect T11 became less sandy (more muddy) with values falling to between 11 and 28% sand to the northeast and 24 and 32% to the southwest. In general, the coarsest fraction (more than 500 µm, medium sand to gravel) was less than 1%, with higher values observed at A2 (2–4%), A3 (about 1%) and only a few other localised sites (Figure 2).

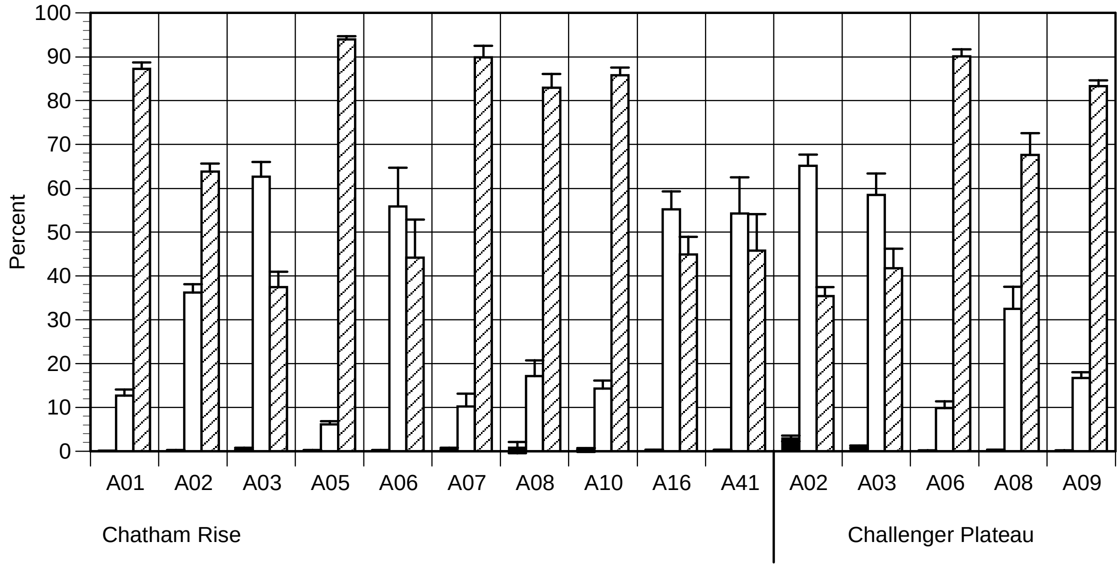

Figure 2: Summary of mean grain-size distributions for the top 5 cm at the "A" sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). The black solid bars represent the proportion of the sediment sample >500 µm in diameter (medium sand to gravel sediment classes), the open bar, %sand and gravel (>63 µm) and the bars with the diagonal stripes, %mud (silt and clay, <63 µm). Error bars are 1 standard deviation, n = 6-14.

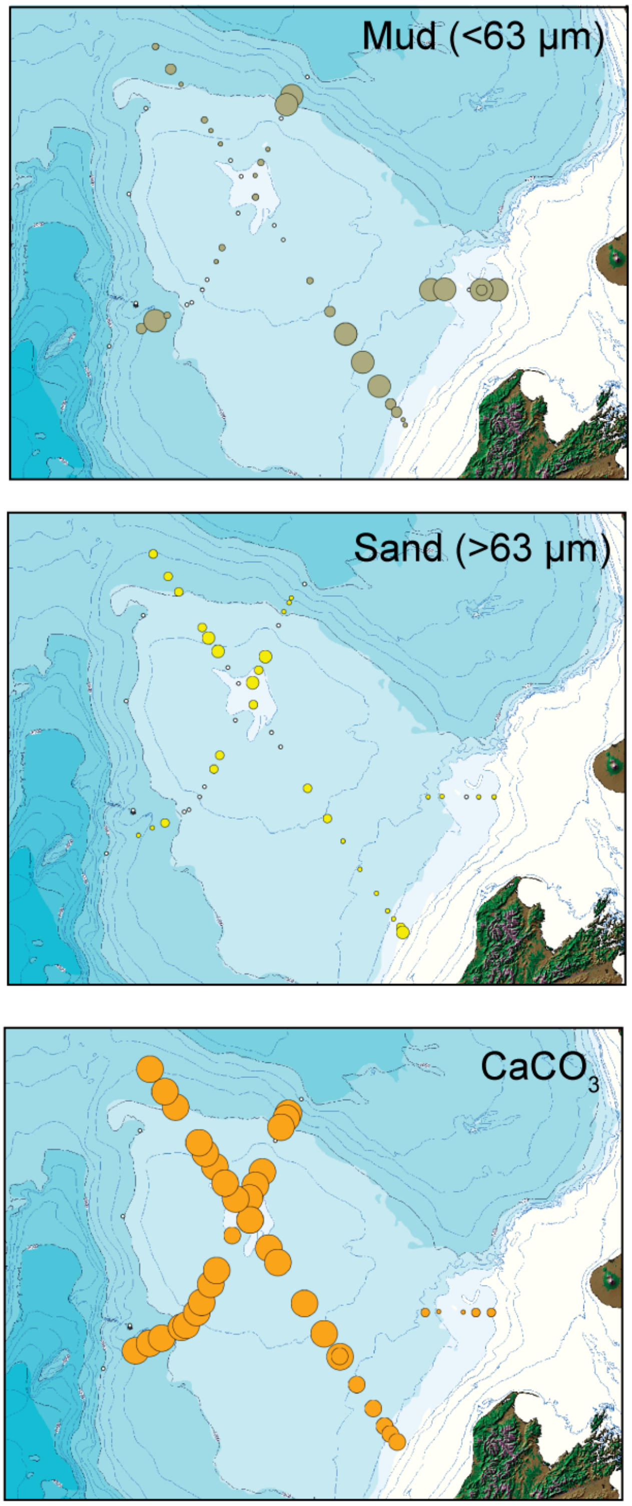

Figure 3: Distribution of relative % mud (top panel), % sand and gravel (middle), and % $CaCO_3$ (bottom) for all OS 20/20 sample sites on the Challenger Plateau during TAN0707. Filled symbols show 4 abundance classes as proportions of the maximum value recorded for each variable across all sites, i.e., small to large: 0-25%, 25-50%, 50-75%, and 75-100% of maximum value. For actual values see Table A1.

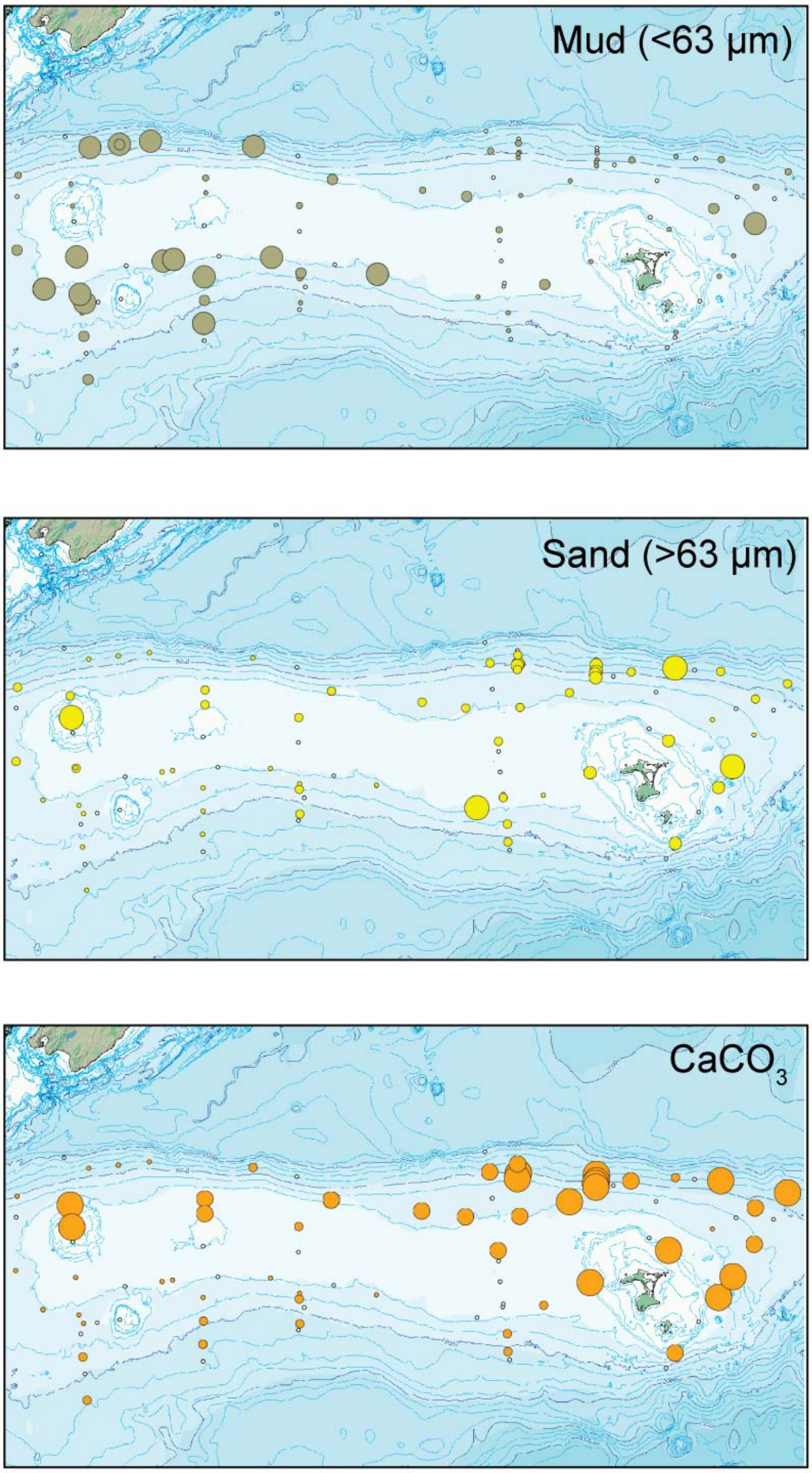

Figure 4: Distribution of relative %mud (top panel), %sand and gravel (middle), and %$CaCO_3$ (bottom) for all OS 20/20 sample sites on the Chatham Rise during TAN0705. Symbol scale same as for Figure 3.

3.1.2 Calcium carbonate

The highest surface calcium carbonate contents on the Chatham Rise were found on the central northern, northeastern and eastern sectors of the rise, reaching values of 60–80%. Moderate values were also observed on the top of the rise across Mernoo and Reserve banks (50–80%) and on the deep southwestern flanks (transects T1 and T3, strata 7–8), with values of 30–40% (Figures 3 and 5).

Very high carbonate values were found across the entire Challenger Plateau (80–90%) with progressively lower contents on the inner end of transect T10 (50–70%) and across all of transect T6 (20–35%) (Figures 4 and 5).

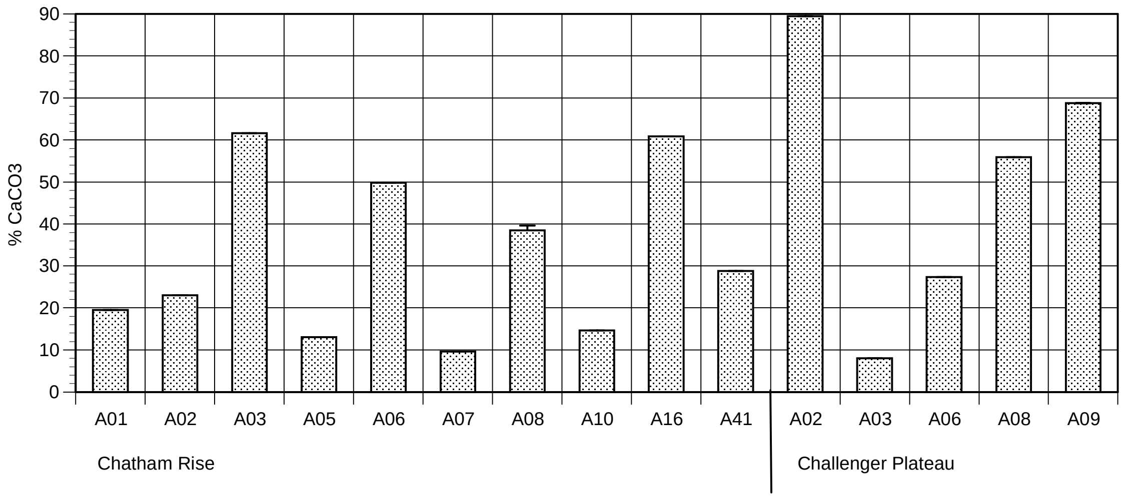

Figure 5: Summary of mean calcium carbonate ($CaCO_3$) contents (in percent) for the "A" sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). Error bars are 1 standard deviation, *n* = 1–4.

3.1.3 Total Organic Matter (TOM)

Total organic matter contents in the surficial sediments of the Chatham Rise varied from 1.0 to 5.4%, and were reasonably consistent across the rise with typical values in the order of 2–3%, regardless of depth (Figures 6 and 8). On several transects there were indications that TOM increased with depth (e.g., T5, northern end: 2.4% (site B66) to 3.8% (B32); southern end: 2.2% (site B41) to 4.2% (A4)), although these types of measurements are often very variable due to the heterogeneity of infaunal biomass and organic matter concentrations in marine sediments (Figures 6 and 8).

Similar values for TOM were observed on the Challenger Plateau, ranging from 0.9 to 5.7%, although in general values were lower in magnitude, typically 1.0–2.5% (Figures 7 and 8).

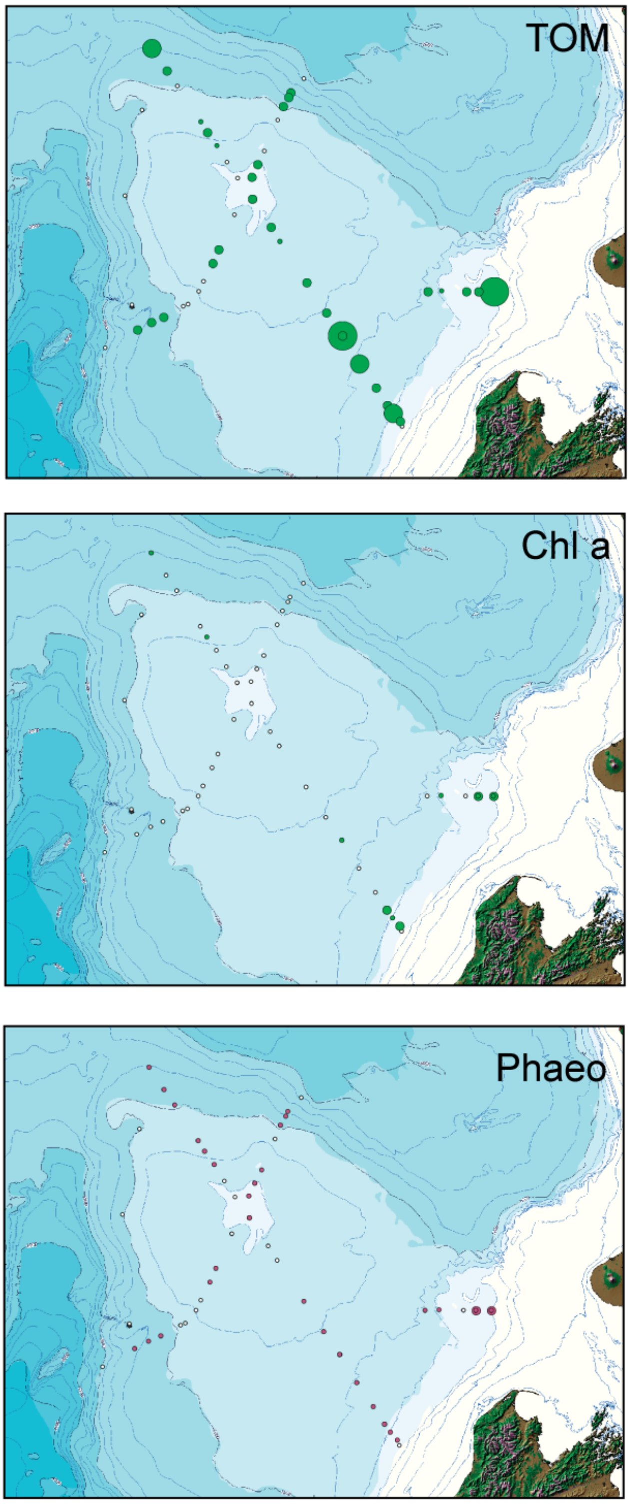

Figure 6: Distribution of relative % total organic matter (TOM) (top panel), chlorophyll *a* content (µg per gram dry weight sediment) (middle), and phaeopigment content (µg per gram dry weight sediment) (bottom) for all OS 20/20 sample sites on the Challenger Plateau during TAN0707. Symbol scale same as for Figure 3.

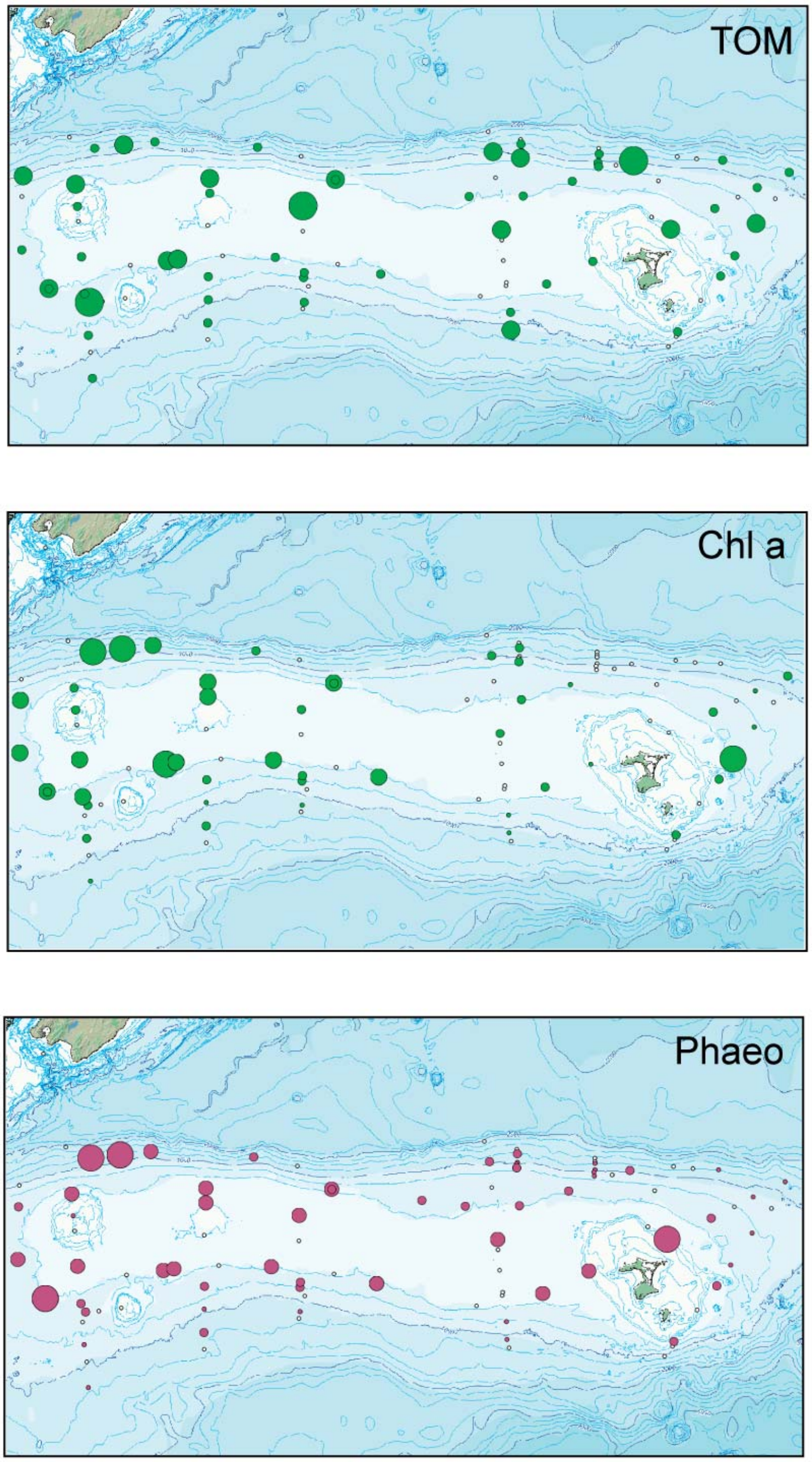

Figure 7: Distribution of relative %total organic matter (TOM) (top panel), chlorophyll *a* content (µg per gram dry weight sediment) (middle), and phaeopigment content (µg per gram dry weight sediment) (bottom) for all OS 20/20 sample sites on the Chatham Rise during TAN0705. Symbol scale same as for Figure 3.

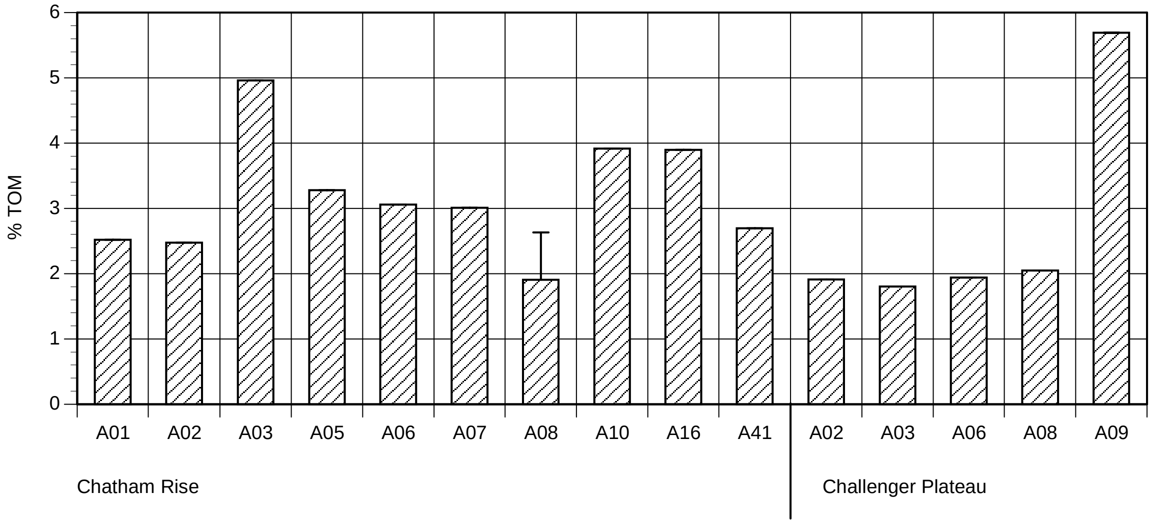

Figure 8: Summary of mean total organic matter (TOM) contents (in percent) for the "A" sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). Error bars are 1 standard deviation, *n* = 1–4.

3.1.4 Sediment pigments

Surficial sediments on the western crest and northwestern and southwestern-central flanks of the Chatham Rise (strata 1–3, 5, and 7) showed elevated levels of chlorophyll *a* (>0.05 µg per gram dry weight sediment), except for the top of Mernoo Bank (Figures 6 and 9). Maximum values were typically 0.08–0.10 µg per gram dry weight sediment, with highest values of about 1.4 observed at B24 (upper flank, southwest Chatham Rise, transect T8c, stratum 7) and an anomalous, isolated measurement at C23 (upper slope, east of the Chatham Islands, transect T7, stratum 2). There was an apparent decrease in chlorophyll content with depth on most transects, although data coverage is sparse, and in some instances upper slope values were lower than those at deeper mid-slope depths (e.g., northern end of T5 - compare B66 – 0.07 µg g^{-1} to B32 – 0.03 µg g^{-1}; Low Impact Fishing transect - D13–D18).

In comparison, chlorophyll *a* concentrations on the Challenger Plateau were, not surprisingly, given the oligotrophic status of the overlying waters, substantially lower than on the Chatham Rise, with values generally below 0.01 µg per gram dry weight sediment. Highest values were found on the inner ends of transect lines, T9 and T10, with values of 0.05–0.06 at A6 (on T9) and about 0.02 at B114 and C110 (on T10) (Figures 7 and 9).

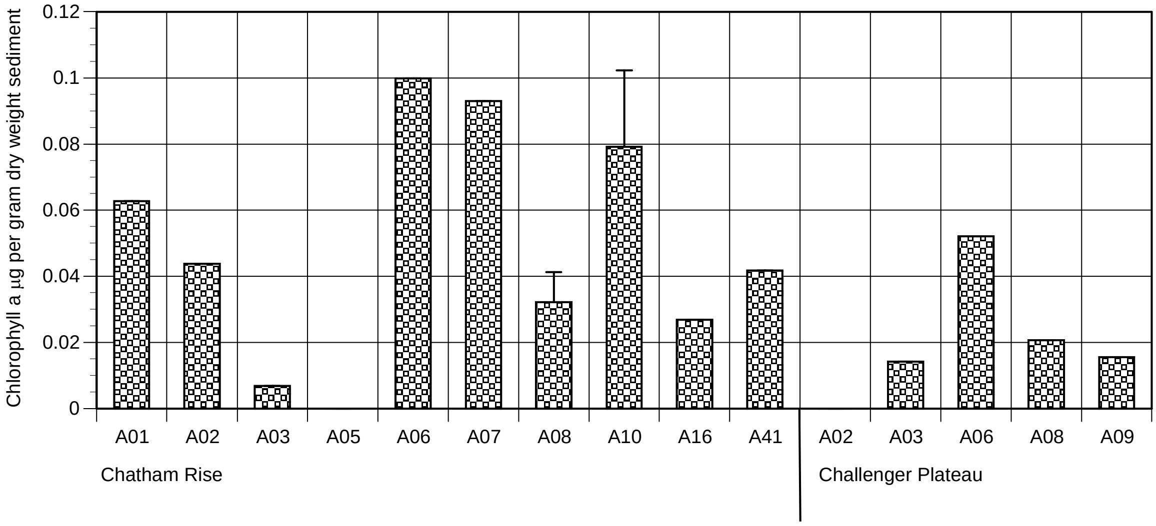

Figure 9: Summary of mean sediment chlorophyll *a* contents (in µg per gram dry weight sediment) for the "A" sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). Error bars are 1 standard deviation, *n* = 1–4.

Similar trends were observed for pigment degradation products (represented by total phaeopigments), with values of over 5 µg per gram dry weight sediment found on the western crest, northwestern, and southwestern-central flanks and on the central crest of the Chatham Rise (Figures 6 and 10). On the Challenger Plateau, phaeopigment concentrations ranged from 0.1 to about 3.0 µg per gram dry weight sediment, with higher values found on the inner ends of transect lines, T9 and T10 (Figures 7 and 10).

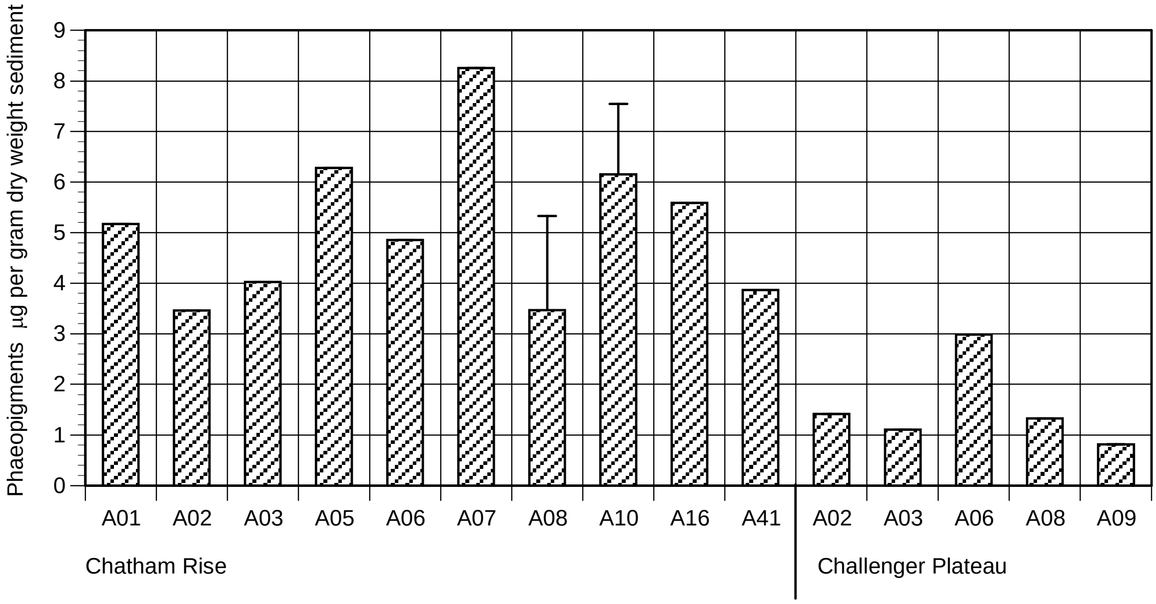

Figure 10: Summary of mean sediment phaeopigment contents (in µg per gram dry weight sediment) for the "A" sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). Error bars are 1 standard deviation, *n* = 1–4.

3.1.5 Sediment Community Oxygen Consumption (SCOC)

SCOC values are presented here as mean values (± 1 standard deviation, in µmol O_2 m^{-2} h^{-1}). Highest values on the Chatham Rise were found on the northwestern and crestal parts of the rise, with the highest average measurements at the shallower sites at about 500 m water depth in strata 6 (A6 – 274±18 µmol O_2 m^{-2} h^{-1}), 2 (A10 – 262±16) and 1 (A1 – 273±73) (Figure 11). The lowest value was found at the shallowest site (A2 – 80±46), but the integrity of these samples may have been compromised by the rough weather encountered during the core incubation period. With the exception of A5, deeper sites tended to have lower SCOC values (i.e., A3, A8 and A41 – 108±12, 141±48 and 194±28, respectively) (Figures 11 and 20).

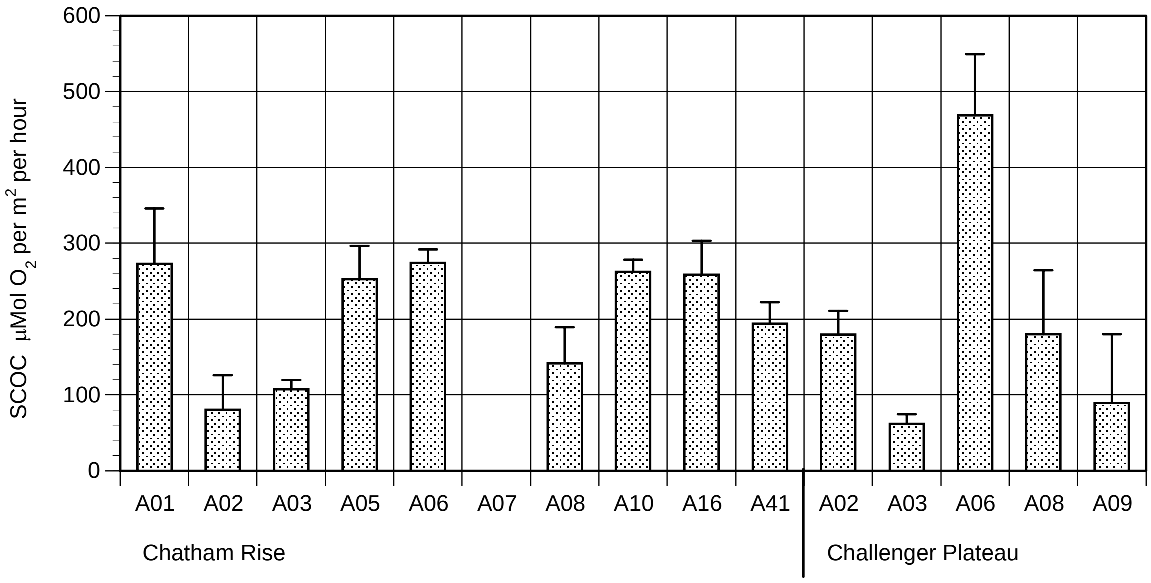

Figure 11: Summary of mean sediment community oxygen consumption (SCOC) (in µmol O_2 m^{-2} h^{-1}) for the 'A' sites on Chatham Rise (left-hand side of figure, TAN0705) and Challenger Plateau (right-hand side of figure, TAN0707). Error bars are 1 standard deviation, *n* = 3–4.

Mean SCOC measurements on the Challenger Plateau were typically lower than those on the Chatham Rise, ranging from 60 µmol O_2 m^{-2} h^{-1} at A3 (northwestern T10) to about 180 µmol O_2 m^{-2} h^{-1} at A2 (crest) and A8 (southeastern T11) (Figure 11). The highest SCOC value from either the rise or the plateau study areas, however, was on the Taranaki slope at A6 where the SCOC was estimated to be 470±80 µmol O_2 m^{-2} h^{-1} (Figure 11).

3.2 Bacterial biomass estimation

The bacterial numbers, estimated across all the sites, ranged from 2.12 x 10^8 cells per gram dry weight sediment at site TAN0705 A16 to 4.32 x 10^9 cells per gram dry weight sediment at site TAN0707 A03 (Figures 12–14, Table 2). There was no difference between the two sampling areas in terms of bacterial numbers. Interestingly, the highest cell numbers from both surveys were recorded on the Challenger Plateau at sites A03 and A06. Site A03 (1217 m water depth) is the most northwestern site in the sampling area and site A06 (266 m) is the furthest east site on the Taranaki continental slope (See Figure 1). The highest cell numbers on the Chatham Rise were obtained from sites A02 (644 m) and A10 (478 m); 1.10 x10^9 and 1.32 x 10^9 cells per gram dry weight sediment, respectively (Figures 12 and 14, Table 2). The highest cell numbers were obtained from site A10 located in the southwestern corner of the sampling area (See Figure 1). A previous study had estimated the bacterial numbers on the southern slope of the Chatham Rise on a transect between 41° S and 47° S along 178° 30' E, to be 2.9 x 10^9 cells per gram dry weight sediment at the northern end of the transect, decreasing to 1.2 x 10^9 cells per gram dry weight sediment at the southern end (Nodder et al. 2007).

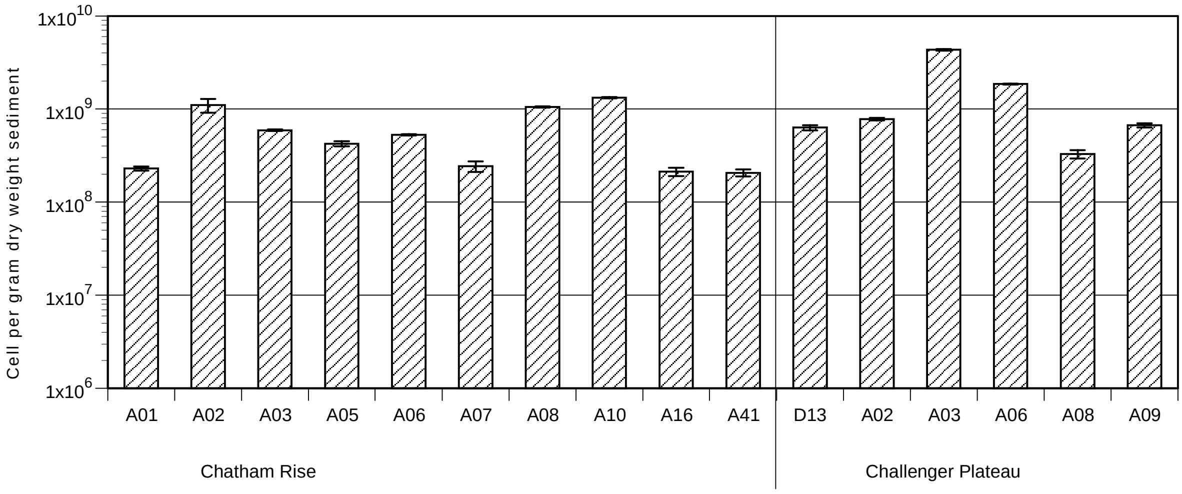

Figure 12: Average bacterial numbers (cells per gram dry weight) at each site across the Chatham Rise (TAN0705) and the Challenger Plateau (TAN0707) (error bars are equal to 1 standard error).

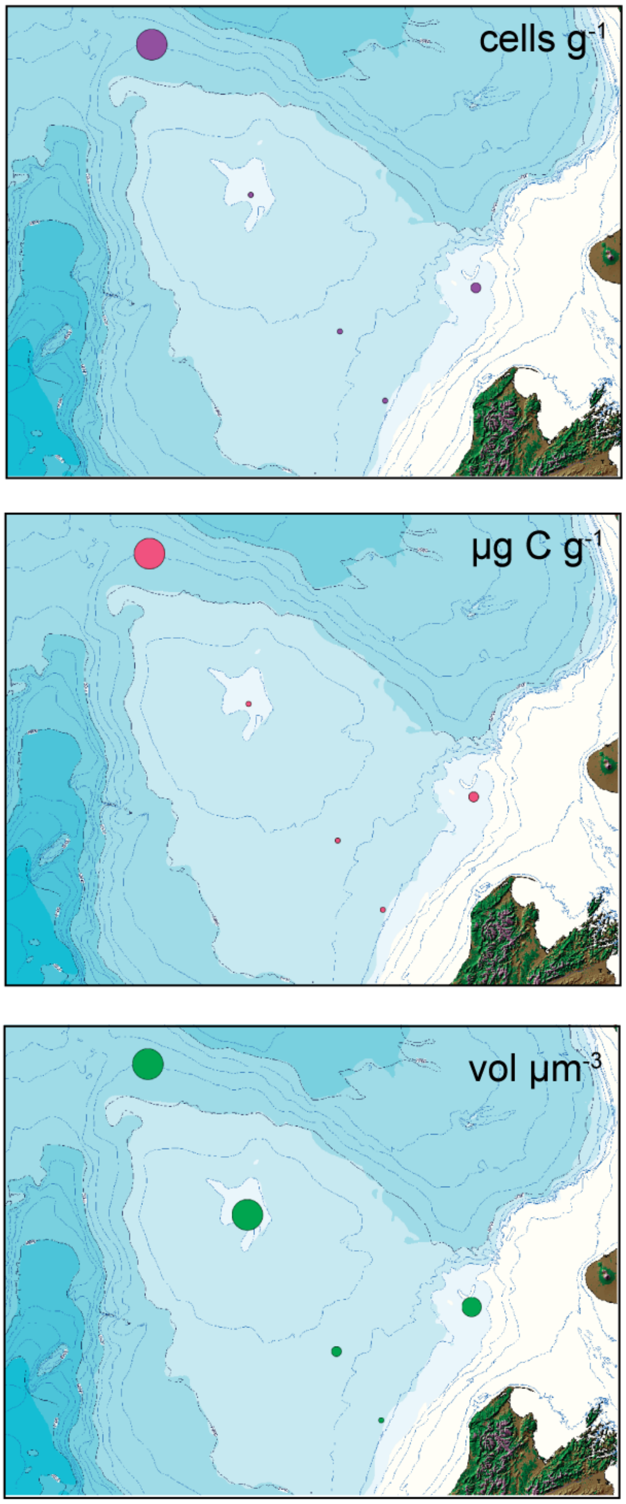

Figure 13: Abundance, biomass, and volume of bacteria: Challenger Plateau. Cells per gram of sediment (top); µg carbon per g of sediment (calculated using cell numbers) (middle); and volume of bacterial cells per µm^3 of sediment (bottom). Symbol scale same as for Figure 3.

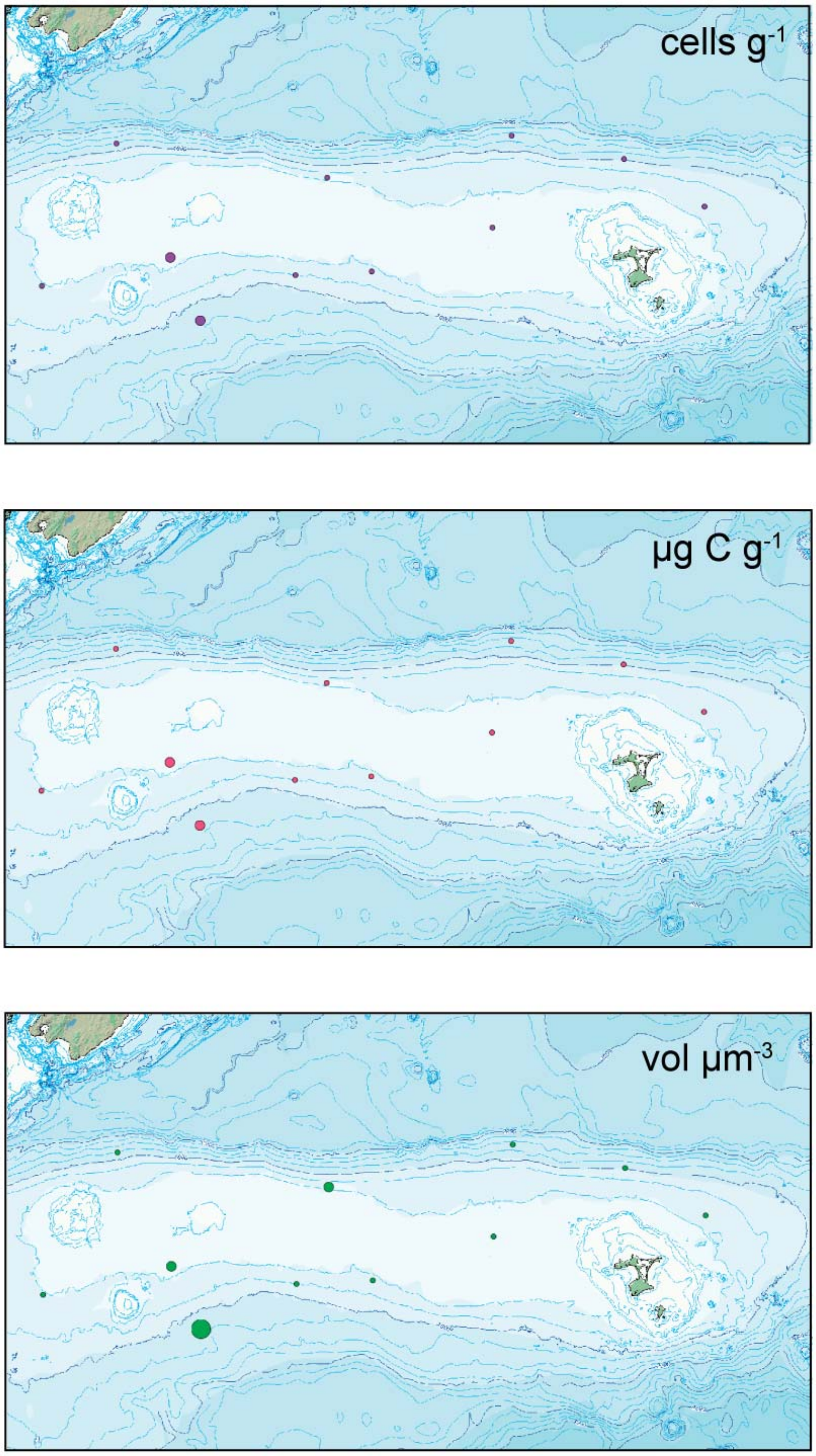

Figure 14: Abundance, biomass, and volume of bacteria: Chatham Rise. Cells per gram of sediment (top); µg carbon per g of sediment (calculated using cell numbers) (middle); and volume of bacterial cells per µm^3 of sediment (bottom). Symbol scale same as for Figure 3.

Table 2: Averages for bacterial cell numbers, µg carbon (C) calculated using cell numbers, average cell size (biovolume) and µg carbon calculated using biovolume for each site across the Chatham Rise (TAN0705) and the Challenger Plateau (TAN0707)

Voyage	Site	Average number of cells per gram dry weight sediment (SE)	µg C per gram dry weight sediment (SE)*	Average biovolume of bacterial cell μm^3 (SE)	µg C per gram dry weight sediment (SE)**
TAN0705	A01	2.30×10^8 ($\pm 1.27 \times 10^7$)	4.56 (±0.25)	0.39 (±0.022)	11.66 (±0.65)
	A02	1.10×10^9 ($\pm 1.83 \times 10^8$)	21.76 (±3.62)	0.52 (±0.015)	74.88 (±2.21)
	A03	5.91×10^8 ($\pm 9.66 \times 10^6$)	11.70 (±0.19)	0.48 (±0.012)	36.58 (±0.94)
	A05	4.24×10^8 ($\pm 2.65 \times 10^7$)	8.40 (±0.52)	0.43 (±0.019)	23.45 (±1.02)
	A06	5.28×10^8 ($\pm 9.23 \times 10^6$)	10.45 (±0.18)	0.73 (±0.018)	50.00 (±1.26)
	A07	2.43×10^8 ($\pm 3.19 \times 10^7$)	4.82 (±0.63)	0.49 (±0.032)	15.43 (±1.01)
	A08	1.05×10^9 ($\pm 1.44 \times 10^7$)	20.75 (±0.29)	1.15 (±0.021)	156.74 (±2.88)
	A10	1.32×10^9 ($\pm 2.31 \times 10^7$)	26.11 (±0.46)	0.75 (±0.021)	128.62 (±3.54)
	A16	2.12×10^8 ($\pm 2.11 \times 10^7$)	4.19 (±0.42)	0.44 (±0.025)	12.14 (±0.70)
	A41	2.06×10^8 ($\pm 1.75 \times 10^7$)	4.07 (±0.35)	0.47 (±0.023)	12.50 (±0.63)
	D13	6.30×10^8 (±4.08 X 107)	12.48 (±0.81)	0.48 (±0.018)	39.18 (±1.46)
TAN0707	A02	7.79×10^8 ($\pm 2.18 \times 10^7$)	15.42 (±0.43)	1.42 (±0.029)	143.42 (±2.93)
	A03	4.32×10^9 ($\pm 8.58 \times 10^7$)	85.57 (±1.70)	1.44 (±0.021)	808.9 (±12.05)
	A06	1.86×10^9 ($\pm 2.30 \times 10^7$)	36.86 (±0.46)	1.06 (±0.020)	256.32 (±4.94)
	A08	3.28×10^8 ($\pm 3.31 \times 10^7$)	6.49 (±0.65)	0.42 (±0.023)	17.99 (±0.97)
	A09	6.69×10^8 ($\pm 3.62 \times 10^7$)	13.24 (±0.72)	0.76 (±0.023)	66.07 (±2.03)

*calculated using cell numbers and 19.8 fg C per cell

**calculated using biovolmes and 1.3×10^{-13} g C per μm^3

The bacterial biomass was estimated at the sites using two conversion factors. The first conversion factor uses only the cell numbers to estimate the amount of carbon, and does not take account of the bacterial cell sizes at each site. Using the first method, the amount of bacterial carbon at the sites ranged between 4.07 and 26.11 µg carbon (C) per dry weight sediment on the Chatham Rise and 6.49 and 85.57 µg C per dry weight sediment on the Challenger Plateau (Table 2, Figures 13 and 14). There was no difference between the two sampling areas, and the maximum amount of carbon estimated was on the Challenger Plateau at site TAN0707 A03 (Table 2). The biovolume of the bacterial cells at each site was calculated to give an estimate of the size of the bacteria at each site. The biovolume of the bacteria ranged between 0.39 and 1.44 μm^3 across all sites (Table 2). The biovolume estimates were converted to µg C per gram dry weight sediment (Table 2). The amount of carbon at the sites using this conversion factor ranged between 11.66 and 808.90 µg C per gram dry weight sediment, which is 2.5 to 9.5 times more than the value estimate using just cell numbers (Table 2). Using the biovolume is potentially a more accurate method for estimating the amount of carbon at each site as it takes into account the cell size. Previous studies (Nodder et al. 2003, 2007) have not taken the biovolume into account when estimating carbon, so the estimates obtained in this study can not be compared with them.

3.3 Exo-enzyme activity

Exo-enzyme activities measured at each site are indicative of the processes taking place in the sediments. Five different enzymes were measured: proteases (breakdown of protein), lipases (breakdown of lipids), chitinases (breakdown of chitin), cellulases (breakdown of cellulose), and phosphatases (involved in inorganic phosphate recycling). Three cores from each site were analysed in triplicate and averages for the sites were calculated. At two sites on the Chatham Rise, TAN0705 A16 and A41, the variation between the cores was substantial, resulting in large standard errors (Figures 15 and 16). Chitinase and cellulose activity were highest at Chatham Rise sites TAN0705 A01, A16 and A41 (Figures 15, 16, and 20). Phosphatase activity (less than 1.9 µM per minute per microgram C) was also high at these sites and at Chatham Rise TAN0705 A08. Very little or no chitinase, cellulose, or phosphatase activity was detected in the Challenger Plateau samples (Figures 15, 16, 17, and 19). Protease activity was detected at five sites on the Chatham Rise (A01, A05, A07, A16, and A41) and two sites (A08 and A09) on the Challenger Plateau (Figures 15, 16, 17, and 18). Lipase activity was low at all sites, with only one site on the Challenger Plateau, TAN0707 A09, and one site on the Chatham Rise, TAN0705 A01, showing any activity. The enzyme data indicates that, although high cell numbers and therefore carbon were detected on the Challenger Plateau, it does not appear that these bacteria are active as very little exo-enzyme activity was detected compared to the sites on the Chatham Rise, which had relatively few bacteria, but relatively high activity.

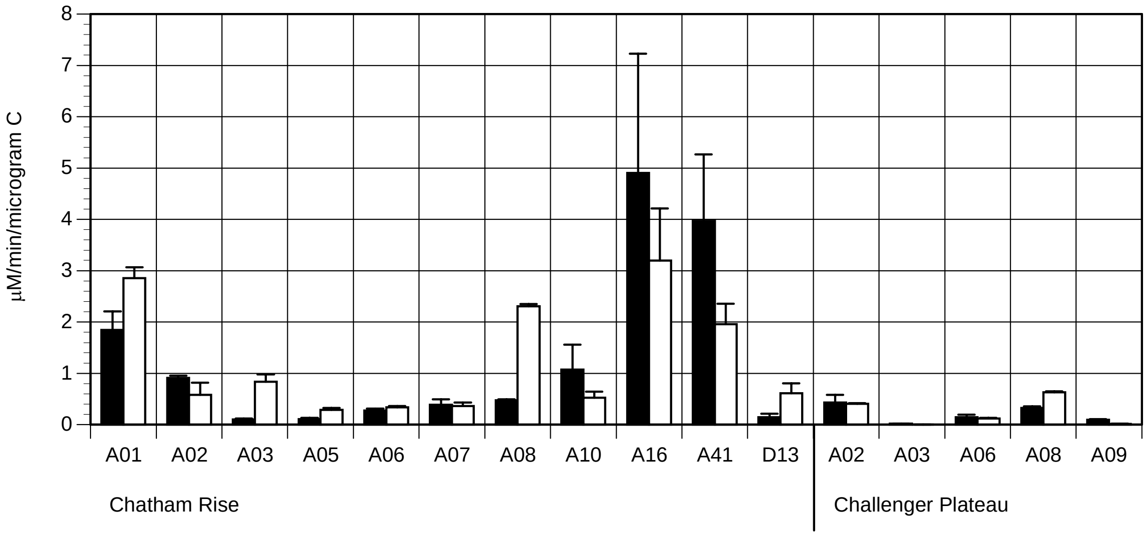

Figure 15: Average exo-enzyme activity at each station across the Chatham Rise (TAN0705) and the Challenger Plateau (TAN0707), chitinase (■) and phosphatase (□) in µM per minute per microgram carbon (error bars are equal to one standard error).

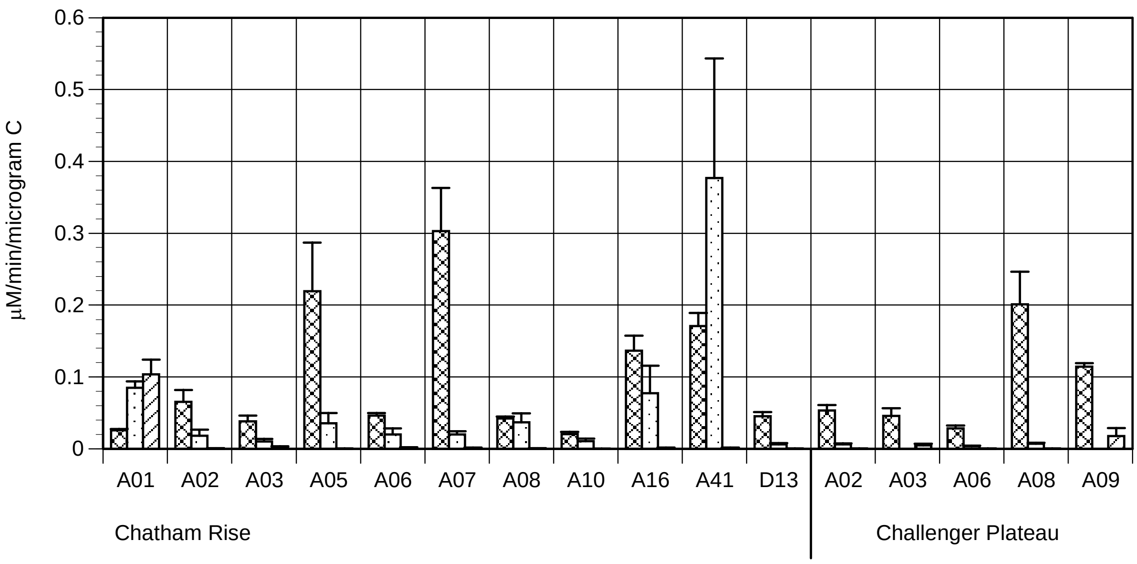

Figure 16: Average exo-enzyme activity at each station across the Chatham Rise (TAN0705) and the Challenger Plateau (TAN0707), protease ( ), cellulase ( ) and lipase ( ) in µM per minute per microgram carbon (error bars are equal to one standard error).

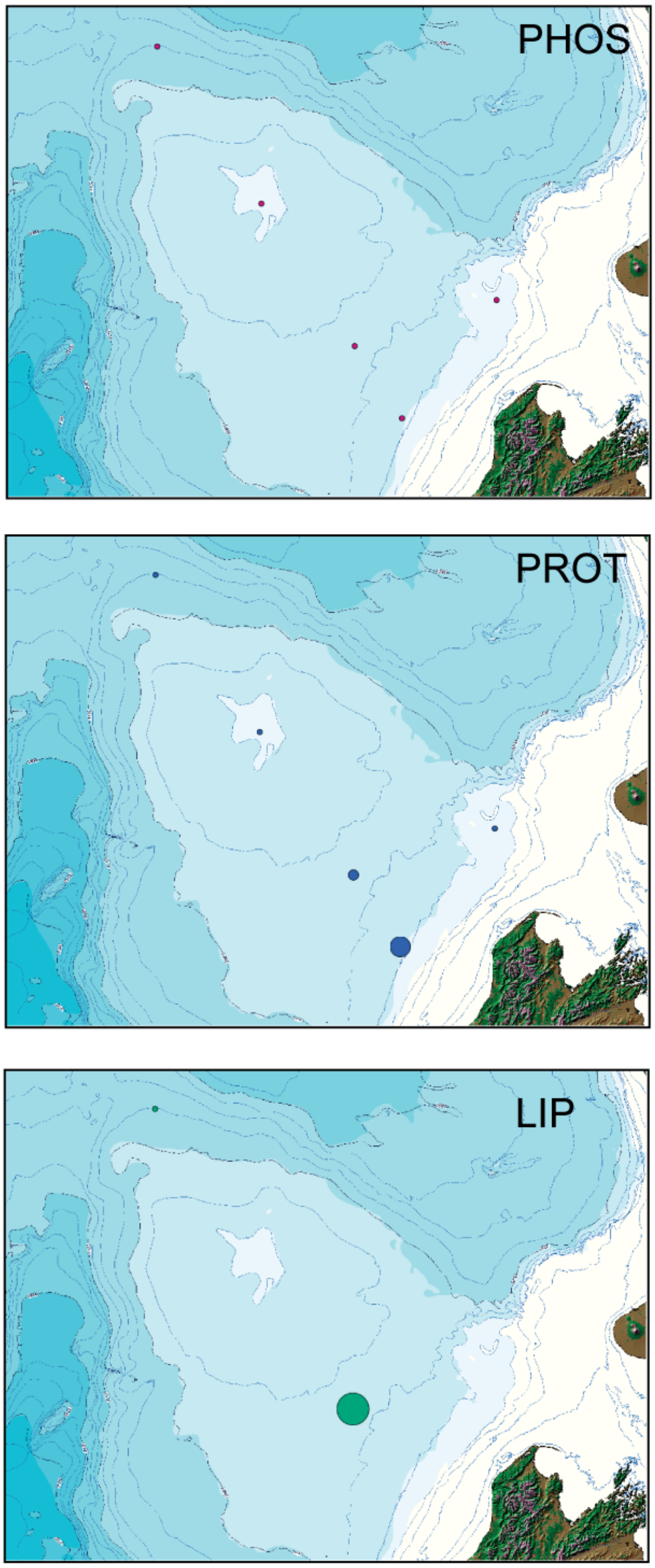

Figure 17: Relative bacterial enzyme activity in µM per minute per microgram carbon: Challenger Plateau. PHOS, phosphatase (top); PROT, protease (middle); LIP, lipase (bottom). Symbol scale same as for Figure 3.

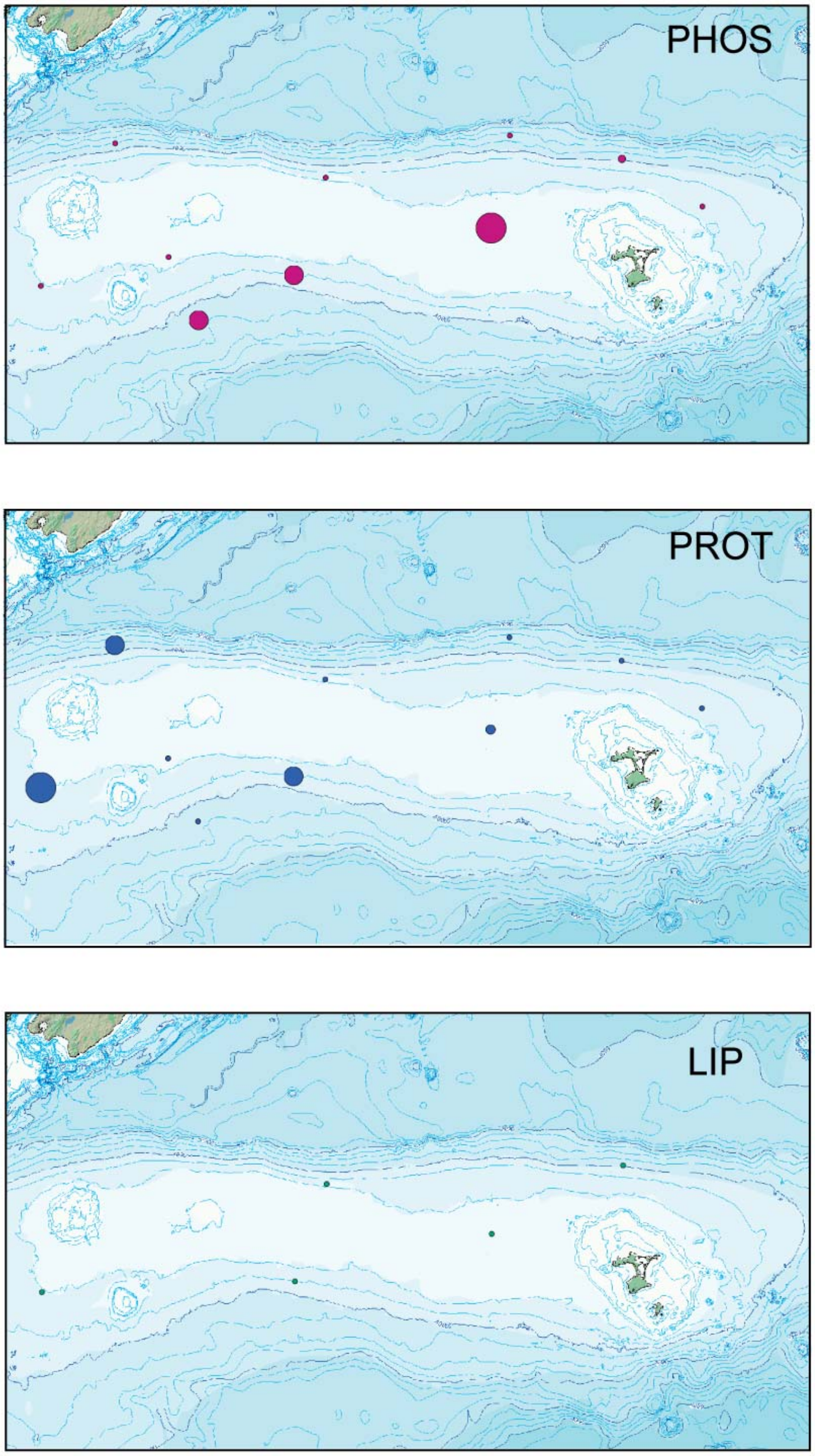

Figure 18: Relative bacterial enzyme activity in µM per minute per microgram carbon: Chatham Rise. PHOS, phosphatase (top); PROT, protease (middle); LIP, lipase (bottom). Symbol scale same as for Figure 3.

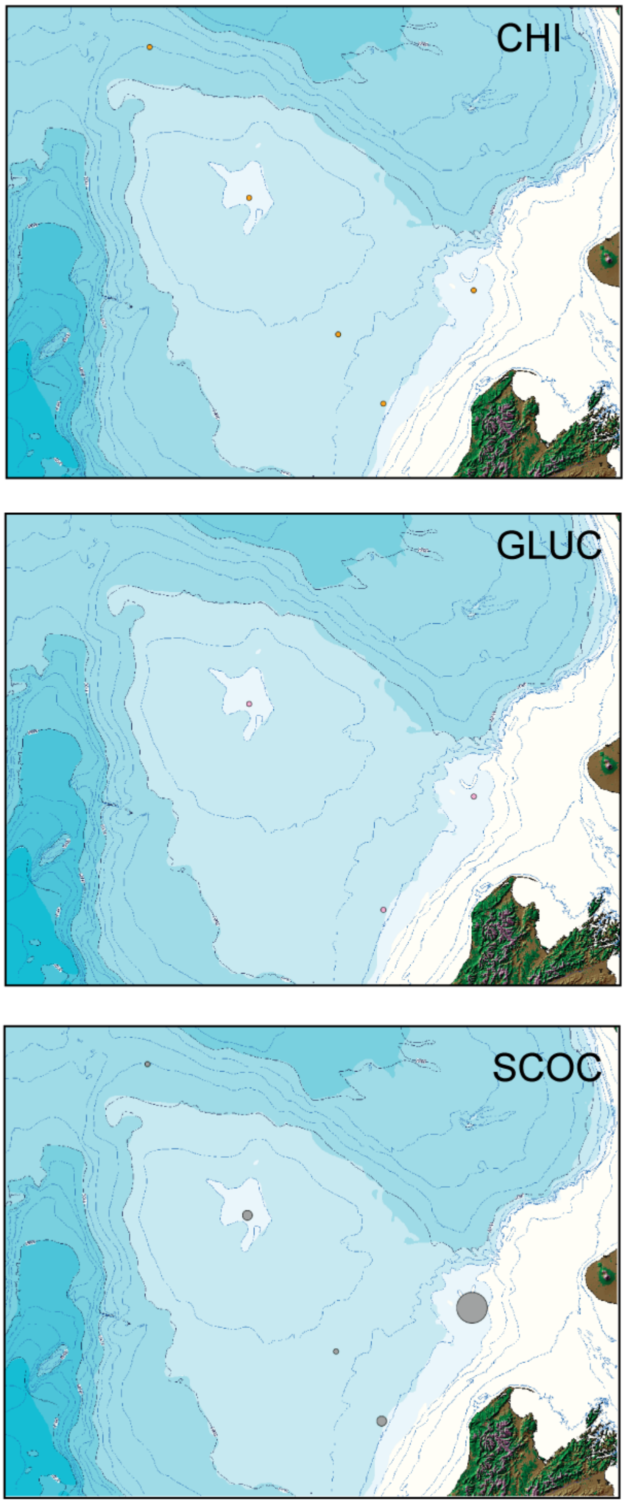

Figure 19: Relative bacterial enzyme activity in µM per minute per microgram carbon and sediment respiration in µmol O_2 m^{-2} h^{-1}: Challenger Plateau. CHI, chitinase (top); GLUC, cellulose (middle); SCOC, total sediment respiration (bottom). Symbol scale same as for Figure 3.

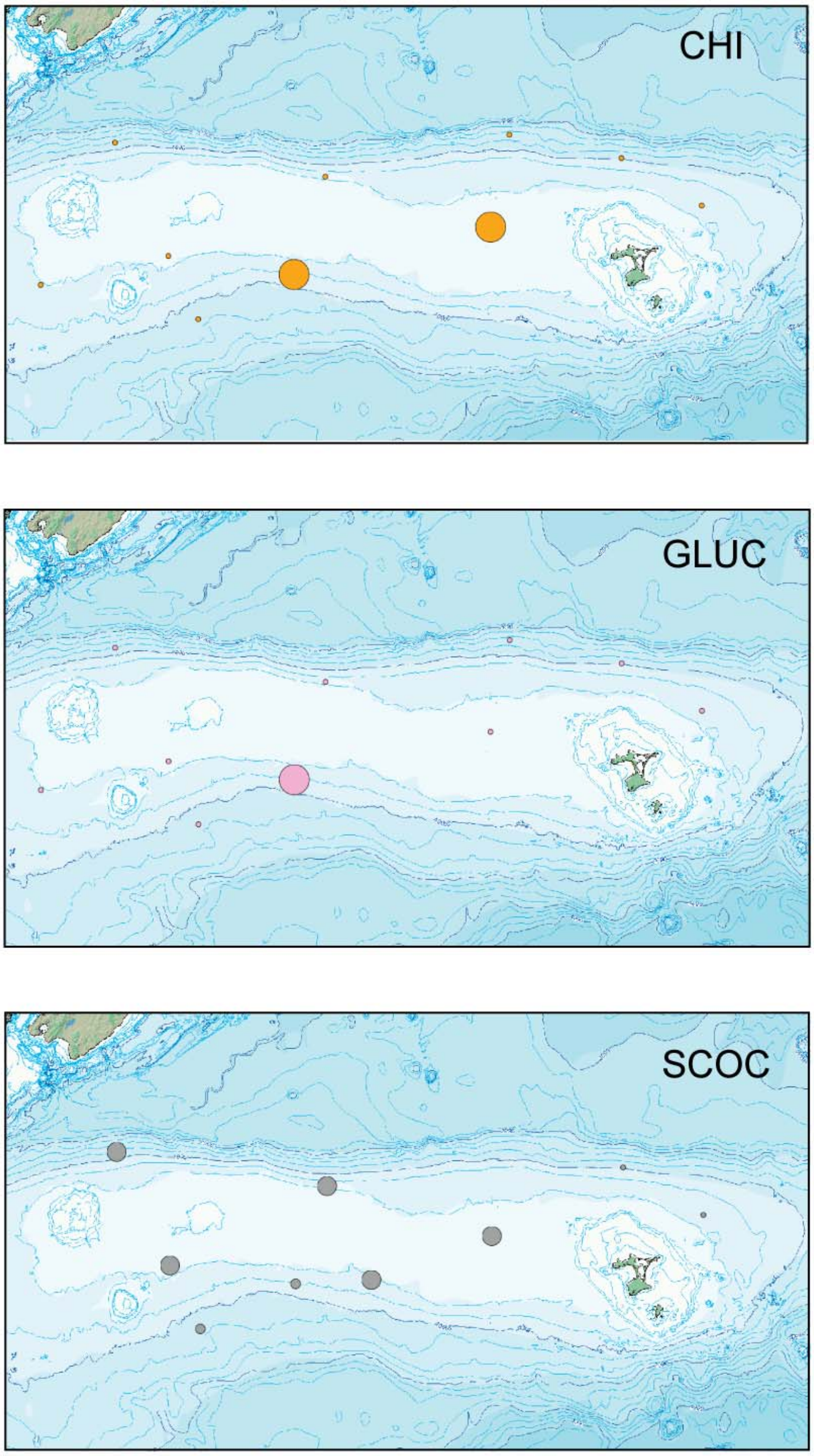

Figure 20: Relative bacterial enzyme activity in µM per minute per microgram carbon and sediment respiration in µmol O_2 m^{-2} h^{-1}: Chatham Rise. CHI, chitinase (top); GLUC, cellulase (middle); SCOC, total sediment respiration (bottom). Symbol scale same as for Figure 3.

4. ACKNOWLEDGMENTS

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6. APPENDIX

Table A1: Grain-size distributions and organic content of sediments – all sites. Grain-size values are given as percentage of total sample in each size class. TOM (total organic matter) and calcium carbonate ($CaCO_3$) as percentages of total sample weight; chlorphyll a (Chla) and phaeopigments (Phaeo) as µg per g dry weight sediment. CM, multicorer; SEL, epibenthic sled; TB, beam trawl; CB, box corer. All multicorer values are from surficial (0-0.5 or 0-1 cm) samples, except for grain-size values, which are averaged over the top 0-5 cm.

					Grain size (µm)											
Voyage	Site	Latitude (-ve = °S)	Longitude (+ve = °E, -ve = °W)	Gear	>500	250-500	125-250	63-125	Sand (>63)	Mud (<63)	Silt (4-63)	Clay (<4)	TOM	$CaCO_3$	Chla	Phaeo
tan0705	A1	-43.979	179.633	CM	0.12	0.33	1.50	8.91	12.72	87.30	72.11	17.02	2.521	19.500	0.063	5.170
tan0705	A1	-43.979	179.633	SEL	0.06	0.26	2.37	10.25	13.00	87.06	71.82	15.24	2.787	20.100	0.101	4.267
tan0705	A10	-43.827	176.704	SEL	0.09	0.68	4.48	12.01	15.30	84.75	66.46	16.31	3.235	13.050	0.081	4.036
tan0705	A10	-43.827	176.704	CM	0.28	0.68	3.39	10.80	14.27	85.82	69.78	14.09	3.915	14.650	0.079	6.155
tan0705	A16	-43.516	-178.617	CM	0.24	2.30	23.65	34.94	55.15	44.91	30.61	8.19	3.896	60.900	0.027	5.589
tan0705	A2	-43.293	-175.545	CM	0.19	8.00	15.96	13.65	36.23	63.82	41.17	20.74	2.475	23.000	0.044	3.460
tan0705	A3	-42.786	-176.715	CM	0.59	19.11	23.44	14.13	62.66	37.48			4.959	61.600	0.007	4.026
tan0705	A4	-44.562	-178.483	SEL	43.35	13.46	27.23	12.83	75.10	11.78	33.66	9.38	3.656	25.350	0.016	1.890
tan0705	A41	-44.017	178.519	CM	0.27	1.46	24.74	20.33	54.26	45.79	44.81	8.28	2.697	28.829	0.042	3.861
tan0705	A5	-42.622	175.926	CM	0.21	0.79	1.55	3.71	6.13	93.92	51.24	42.43	3.279	13.050	0.000	6.280
tan0705	A5	-42.622	175.926	SEL	1.93	8.07	12.05	6.69	30.67	71.26	35.13	36.13	3.830	12.600	0.174	7.092
tan0705	A6	-42.990	178.986	CM	0.19	3.63	34.41	31.57	55.88	44.17			3.057	49.800	0.100	4.856
tan0705	A6	-42.990	178.986	SEL	0.07	1.96	20.92	29.80	50.66	49.38	36.20	11.06	2.777	50.000	0.061	3.251
tan0705	A7	-44.130	174.846	SEL	0.27	0.47	2.32	8.95	12.27	88.00	76.82	11.18	2.365	10.400	0.048	4.437
tan0705	A7	-44.130	174.846	CM	0.41	0.34	1.45	12.16	10.29	89.83	71.96	13.50	3.010	9.650	0.093	8.255
tan0705	A7	-44.130	174.846	CB	3.00	0.23	0.93	7.41	14.57	88.43	78.35	10.08	2.622	10.200	0.069	6.952
tan0705	A8	-44.486	177.141	SEL	0.41	1.98	8.80	10.63	22.24	78.17	50.89	27.28	1.892	40.200	0.017	1.737
tan0705	A8	-44.486	177.141	CM	0.83	1.69	8.41	10.20	17.20	82.95	50.13	25.48	1.908	38.525	0.032	3.469
tan0705	B11	-44.212	-178.923	SEL	57.65	42.20	0.15	0.00	157.64	0.01					0.000	0.000
tan0705	B12	-43.131	177.166	SEL	0.53	11.19	48.73	15.45	76.43	24.10	19.74	4.36	1.843	50.600	0.094	5.293
tan0705	B14	-44.081	-177.971	SEL	0.65	1.48	9.03	16.25	28.06	72.59	60.98	11.61	1.911	37.750	0.066	4.716
tan0705	B15	-43.806	178.115	SEL	0.23	0.51	1.91	10.70	13.57	86.66	71.13	15.51	2.267	16.400	0.075	4.300
tan0705	B17	-44.103	-178.549	SEL	38.56	3.44	0.00	0.00	80.56						0.000	0.000
tan0705	B22	-44.000	-175.462	SEL	9.53	23.06	45.99	15.42	103.52	6.01			2.143	78.900	0.024	2.484

					Grain size (µm)											
Voyage	Site	Latitude	Longitude	Gear	>500	250-500	125-250	63-125	Sand (>63)	Mud (<63)	Silt (4-63)	Clay (<4)	TOM	$CaCO_3$	Chla	Phaeo
tan0705	B23	-43.847	-177.308	SEL	0.72	2.43	49.33	40.47	93.68	7.04	3.07	3.97	1.732	76.400	0.017	4.336
tan0705	B24	-43.844	176.553	SEL	0.10	0.27	1.86	14.22	16.56	83.54	66.08	17.46	2.906	15.400	0.141	5.553
tan0705	B25	-43.796	175.314	SEL	0.23	4.44	30.18	28.79	63.87	36.36	27.71	8.65	2.570	8.700	0.061	4.019
tan0705	B25	-43.796	175.314	SEL	0.24	1.52	4.89	9.11	15.99	84.25	53.50	30.75	1.812	16.800	0.110	4.134
tan0705	B31	-42.747	-176.083	SEL	83.08	0.67	0.29	0.19	167.31	15.77				32.900	0.000	0.000
tan0705	B32	-42.693	-178.742	SEL	0.30	4.79	20.55	25.78	51.73	48.58	32.93	15.64	3.819	62.300	0.033	2.564
tan0705	B33	-42.645	177.861	SEL	0.44	1.16	8.67	9.79	20.51	79.94	39.25	40.69	2.667	29.700	0.032	2.591
tan0705	B36	-42.912	-174.467	SEL	0.30	18.66	29.09	18.82	67.17	33.13	15.67	17.46	2.326	71.900	0.028	1.708
tan0705	B37	-43.071	-174.934	SEL	0.33	9.78	27.37	29.82	67.63	32.70	22.76	9.94	2.542	67.900	0.011	1.016
tan0705	B41	-44.373	-178.495	SEL	1.13	5.64	49.23	20.15	77.28	23.85	16.07	7.78	2.147	25.200	0.010	1.538
tan0705	B43	-43.964	178.528	SEL	0.17	1.12	22.54	12.53	36.53	63.64	50.21	13.43	2.374	19.500	0.041	2.307
tan0705	B51	-42.655	175.503	SEL	0.01	0.21	0.34	1.51	2.08	97.93	47.79	50.14	2.347	11.700	0.167	7.443
tan0705	B52	-42.949	174.481	SEL	11.58	10.99	29.68	15.42	79.26	32.32	18.13	14.19	3.891	9.700	0.000	0.000
tan0705	B61	-43.269	175.253	SEL	48.18	16.78	30.13	2.96	146.23	1.95			1.741	83.800	0.026	0.768
tan0705	B62	-43.266	178.516	SEL	1.30	4.44	23.77	22.90	53.70	47.60	38.94	8.66	4.545	29.900	0.064	4.474
tan0705	B63	-43.002	-177.598	SEL	0.36	12.19	48.38	17.91	79.20	21.16	16.74	4.42	1.860	70.200	0.017	2.688
tan0705	B64	-43.105	-179.715	SEL	0.35	5.35	30.66	25.24	61.94	38.40	32.64	5.76		59.500	0.007	2.069
tan0705	B65	-43.035	175.236	SEL	0.80	6.45	46.34	24.76	79.16	21.65	13.76	7.88	2.882	74.900	0.044	4.607
tan0705	B66	-43.165	-179.092	SEL	0.36	2.80	18.07	24.14	45.72	54.64	34.37	20.27	2.404	66.400	0.007	2.244
tan0705	B71	-44.276	175.433	SEL	0.32	0.27	0.71	4.51	6.13	94.19	55.57	38.62	5.405	9.300	0.044	2.199
tan0705	B72	-44.612	175.417	SEL	0.41	4.25	11.29	23.01	39.38	61.03	44.73	16.30	2.256	33.000	0.020	1.339
tan0705	B74	-44.184	175.359	SEL	0.14	0.20	0.71	9.32	10.52	89.62	65.87	23.75	2.273	8.700	0.074	3.139
tan0705	B75	-44.006	177.150	SEL	0.06	0.24	5.40	13.35	19.12	80.95	63.78	17.16	2.073	20.000	0.065	2.793
tan0705	B81	-44.248	177.149	SEL	1.74	4.87	11.90	9.25	29.51	72.24	49.05	23.19	2.446	29.000	0.016	1.991
tan0705	B82	-44.274	178.528	SEL	2.11	38.43	31.66	5.90	80.20	21.90			2.651	25.200	0.014	2.012
tan0705	B83	-45.054	175.476	SEL	0.36	9.42	11.58	13.03	34.90	65.23	42.46	23.37	2.422	37.950	0.016	1.674
tan0705	C21	-43.515	-176.175	SEL	1.36	2.16	31.48	50.68	87.05	14.32	11.70	2.62	3.343	73.700	0.000	6.567
tan0705	C23	-43.788	-175.253	SEL	44.00	37.23	14.08	0.85	140.16	3.84			1.754	85.500	0.137	0.796
tan0705	C31	-42.780	-175.429	SEL	0.35	14.65	37.19	20.18	72.73	27.62	18.04	9.58	1.563	70.600	0.006	1.331

					Grain size (μm)											
Voyage	Site	Latitude	Longitude	Gear	>500	250-500	125-250	63-125	Sand (>63)	Mud (<63)	Silt (4-63)	Clay (<4)	TOM	$CaCO_3$	Chla	Phaeo
tan0705	C52	-42.587	176.376	SEL	0.15	0.94	5.64	8.87	15.75	84.40	48.87	35.53	2.397	21.500	0.108	5.147
tan0705	C61	-43.171	174.462	SEL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.094	4.042
tan0705	C62	-42.979	177.168	SEL	0.48	6.07	24.78	31.68	63.48	37.00	30.27	6.73	2.954	52.100	0.075	5.652
tan0705	C63	-43.160	-178.308	SEL	0.16	8.94	42.32	26.05	77.62	22.54	16.25	6.29	2.239	69.900	0.032	2.986
tan0705	D15	-42.612	-178.339	CM	0.19	7.59	28.39	31.61	67.98	32.21	18.78	13.43	2.778	59.900	0.034	2.605
tan0705	D16	-42.707	-178.330	TB	1.28	74.09	14.32	3.23	94.20	7.08			2.290	77.500	0.002	0.252
tan0705	D16	-42.707	-178.330	CM	0.59	64.77	27.43	1.88	95.26	5.33			2.110	71.900	0.004	0.453
tan0705	D17	-42.724	-178.347	TB	0.92	53.66	37.49	2.72	95.71	5.21			1.961	52.000	0.003	0.199
tan0705	D18	-42.762	-178.349	CM	0.16	3.93	53.51	18.92	76.69	23.48	13.36	10.12	3.425	72.400	0.034	3.015
tan0705	D21	-42.713	-177.213	CM	0.75	64.23	26.42	2.20	94.36	6.39			2.020	76.700	0.008	1.424
tan0705	D22	-42.782	-177.210	CM	0.87	45.36	43.93	3.23	94.27	6.60			0.985	76.700	0.004	0.647
tan0705	D23	-42.808	-177.228	CM	0.31	29.30	60.30	4.26	94.48	5.84			2.463	79.600	0.005	0.946
tan0705	D24	-42.847	-177.225	CM	0.15	19.50	67.32	5.80	92.92	7.23			2.151	77.700	0.008	1.195
tan0705	D28	-43.727	174.456	SEL	2.39	0.28	9.88	32.71	47.65	54.74	44.45	10.29	1.799	8.300	0.108	4.235
tan0705	D5	-44.575	-176.079	SEL	28.33	20.91	15.73	11.64	104.95	23.38	17.72	5.66	2.394	65.000	0.044	3.602
tan0705	D7	-43.455	-174.944	SEL	0.12	3.11	5.61	7.43	16.39	83.73	49.23	34.50	3.828	66.600	0.014	0.749
tan0707	A9	-40.126	170.222	CM	0.20	4.76	6.39	6.57	16.71	83.33			5.691	68.750	0.015	0.817
tan0707	A9	-40.126	170.222	SEL	0.33	4.53	6.24	6.70	19.02	81.15	32.67	49.61	2.085	71.150	0.004	0.258
tan0707	A9	-40.126	170.222	TB	0.32	4.53	5.94	6.36	17.45	82.86	30.99	52.95	2.679	68.600	0.006	0.333
tan0707	A2	-38.618	168.943	CM	2.96	20.98	23.62	17.09	65.12	35.48	16.83	18.38	1.911	89.500	0.000	1.418
tan0707	A2	-38.618	168.943	SEL	2.42	17.23	24.70	21.90	69.01	32.20	16.52	16.98	1.916	92.300	0.000	0.990
tan0707	A3	-36.921	167.526	CM	1.02	23.43	23.16	19.20	58.46	41.76	13.71	19.10	1.802	8.000	0.014	1.100
tan0707	A3	-36.921	167.526	SEL	0.67	14.67	18.26	20.82	53.63	46.71	17.51	28.08	3.186	84.650	0.005	0.250
tan0707	A6	-39.646	172.153	CM	0.18				9.85	90.15			1.935	27.400	0.052	2.987
tan0707	A6	-39.646	172.153	SEL	1.76	2.26	3.21	4.62	30.19	71.68	49.61	39.94	2.550	36.850	0.015	0.939
tan0707	A8	-40.881	170.860	CM	0.29	10.97	15.12	11.40	32.47	67.60			2.048	55.950	0.021	1.323
tan0707	A8	-40.881	170.860	SEL	0.30	8.54	15.69	11.14	35.29	64.86	32.38	31.99	2.182	59.850	0.007	0.333
tan0707	B100	-39.091	169.341	SEL									0.935	85.100	0.000	0.000
tan0707	B101	-38.799	168.695	SEL										67.000	0.000	0.000

					Grain size (µm)											
Voyage	Site	Latitude	Longitude	Gear	>500	250-500	125-250	63-125	Sand (>63)	Mud (<63)	Silt (4-63)	Clay (<4)	TOM	$CaCO_3$	Chla	Phaeo
tan0707	B102	-37.176	167.733	SEL	0.54	13.14	16.65	19.91	50.78	49.76	19.11	30.65	2.158	83.600	0.006	0.306
tan0707	B103	-37.480	169.459	SEL	0.23	6.47	7.86	9.32	24.11	76.12	24.05	52.07	2.809	74.400	0.006	0.174
tan0707	B104	-39.641	168.189	SEL	0.00	0.00	0.00	0.00		0.00	0.00	0.00		89.850	0.000	0.000
tan0707	B105	-39.183	168.468	SEL	1.30	13.44	21.46	22.99	60.49	40.81	18.49	22.32	2.479	90.700	0.008	0.507
tan0707	B106	-39.783	168.033	SEL										77.700	0.000	0.000
tan0707	B107	-39.924	167.688	SEL	3.48	31.67	19.57	8.87	67.07	36.41	11.87	24.54	2.679	86.900	0.006	0.398
tan0707	B109	-39.637	171.627	SEL	0.19	2.89	3.27	5.58	12.12	88.07	72.83	15.24	1.379	19.300	0.013	0.718
tan0707	B110	-38.083	169.117	SEL	0.90	37.73	45.88	7.20	92.61	8.29				86.200	0.006	0.550
tan0707	B111	-37.876	168.313	SEL	1.72	51.31	34.53	4.98	94.26	7.46			1.709	87.700	0.010	0.871
tan0707	B113	-40.693	170.695	SEL	0.25	5.71	8.16	8.53	22.91	77.35	39.84	37.51	1.594	62.900	0.006	0.327
tan0707	B114	-41.057	171.040	SEL	1.08	14.61	33.26	29.82	79.86	21.23	14.30	6.92	1.471	47.200	0.022	1.041
tan0707	B115	-40.432	170.465	SEL	0.22	3.88	4.77	5.37	14.47	85.75	29.50	56.25	3.158	63.800	0.004	0.196
tan0707	C100	-39.546	169.715	SEL	1.14	17.30	24.55	19.00	60.15	40.15	18.86	19.08	2.016	90.000	0.006	0.334
tan0707	C101	-38.932	169.207	SEL									1.967	87.300	0.000	0.000
tan0707	C102	-38.387	168.740	SEL										82.400	0.000	0.000
tan0707	C104	-39.333	168.387	SEL	1.26	20.15	32.52	28.32	83.51	17.75	10.28	7.47	1.444	90.400	0.005	0.392
tan0707	C105	-40.065	167.322	SEL	0.75	10.61	11.59	8.95	32.64	68.10	16.55	51.08	1.504	87.600	0.004	0.239
tan0707	C106	-39.809	167.968	SEL										84.900	0.000	0.000
tan0707	C107	-39.646	171.977	SEL									1.639	23.000	0.000	0.000
tan0707	C108	-38.025	168.445	SEL	3.67	24.44	34.30	20.74	86.82	16.85	9.20	7.65	0.926	90.900	0.008	0.677
tan0707	C109	-38.233	169.022	SEL	2.50	19.33	35.95	12.65	72.93	29.56	13.92	15.64	1.869	93.400	0.003	0.495
tan0707	C110	-41.112	171.071	SEL	0.61	9.75	32.54	45.17	88.67	11.93					0.000	0.000
tan0707	C111	-40.971	170.942	SEL	0.34	9.83	12.53	10.99	34.04	66.30	33.22	33.08	3.468	55.000	0.019	0.776
tan0707	C112	-39.877	169.997	SEL	2.04	10.44	15.96	14.87	45.34	56.70	21.49	35.21	2.000	86.150	0.002	0.186
tan0707	C113	-38.378	168.938	SEL	1.80	28.47	38.59	21.19	91.85	9.95	5.34	4.61	2.479	90.400	0.000	0.608
tan0707	C114	-37.423	169.490	SEL	0.30	7.61	9.51	10.74	28.46	71.84	20.26	51.58	2.358	78.300	0.000	0.100
tan0707	C115	-37.351	167.882	SEL	0.93	36.89	34.16	10.59	83.51	17.43	6.64	10.79		85.200	0.005	0.359
tan0707	C116	-39.531	168.258	SEL										84.350	0.000	0.000
tan0707	C117	-39.641	172.372	CM	0.10	1.07	2.37	6.96	9.99	90.03	71.22	18.25	3.279	25.600	0.029	2.546

					Grain size (µm)											
Voyage	Site	Latitude	Longitude	Gear	>500	250-500	125-250	63-125	Sand (>63)	Mud (<63)	Silt (4-63)	Clay (<4)	TOM	$CaCO_3$	Chla	Phaeo
tan0707	C117	-39.641	172.372	SEL	0.39	2.12	4.11	9.68	16.70	83.70	46.70	37.00	4.469	25.700	0.019	1.281
tan0707	C118	-39.984	167.517	SEL	0.20	4.78	8.83	9.76	23.77	76.43	19.18	57.25	1.734	87.900	0.002	0.128
tan0707	C119	-37.754	168.216	SEL	0.39	25.27	35.27	9.43	70.74	29.65	11.00	18.64	1.215	86.700	0.008	0.366
tan0707	C120	-39.646	171.430	SEL	0.07	1.46	2.13	2.51	6.24	93.83	45.23	48.60	2.304	34.600	0.007	0.347
tan0707	D2	-37.581	169.385	SEL	0.28	3.70	3.54	3.40	11.20	89.08	49.88	39.20	2.139	84.700	0.000	0.768
tan0707	D6	-38.209	168.586	SEL										90.000	0.000	0.000