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Post Survey Report, RSV Aurora Australis, Marine Science Voyage (2010/11 VMS), January-February 2011

Record

2011/44

GeoCat # 71668

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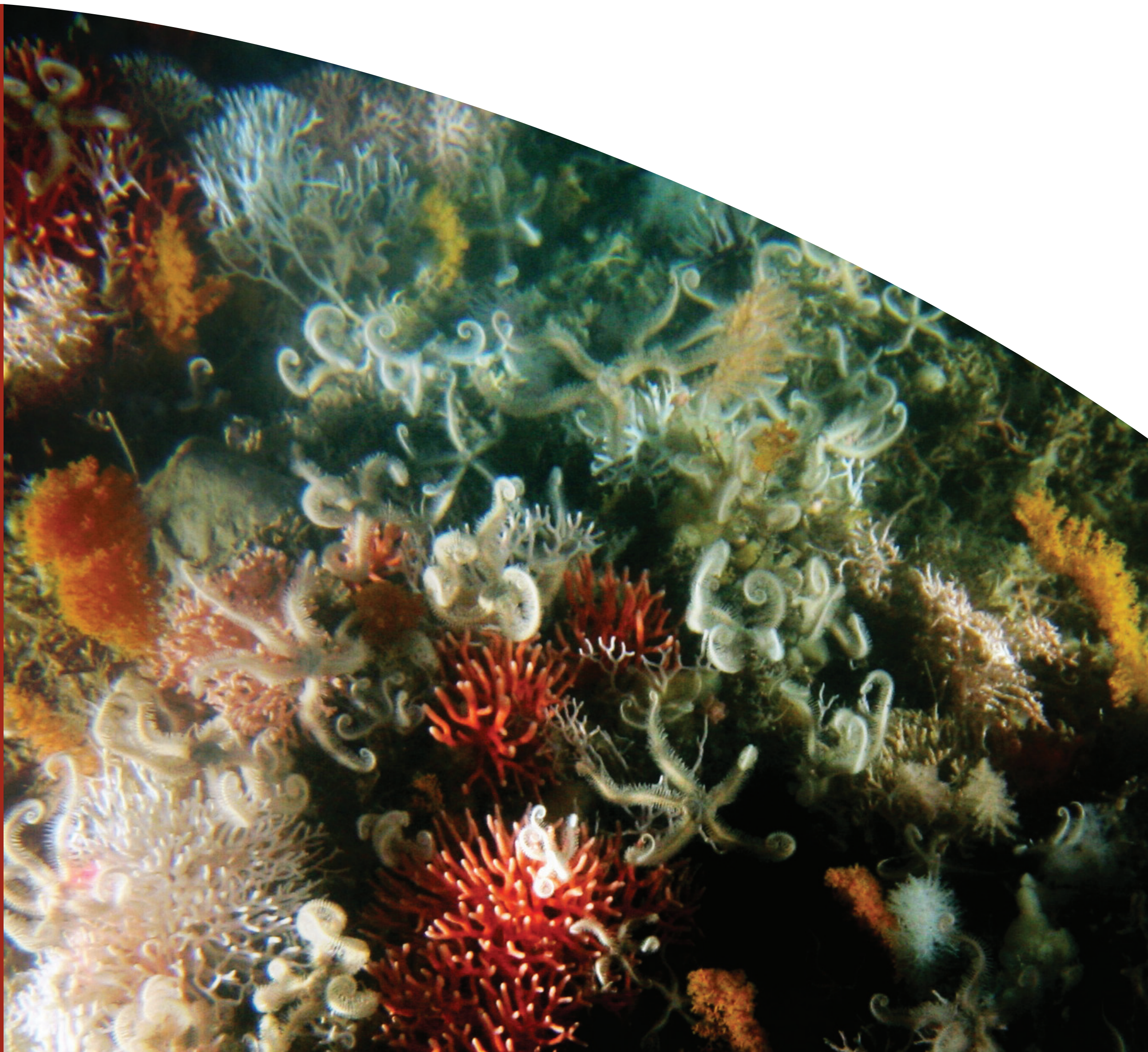

APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

Benthic Community Survey, Mertz Glacier Region, East Antarctica

Post Survey Report, RSV *Aurora Australis*, Marine Science Voyage (2010/11 VMS), January-February 2011

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RECORD 2011/44

By

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ISSN 1448-2177
ISBN 978-1-921954-57-3 (Web)
ISBN 978-1-921954-58-0 (Hardcopy)

GeoCat # 71668

Bibliographic reference: Smith, J. and Riddle, M. 2011. Benthic Community Survey, Mertz Glacier Region, East Antarctica. Post Survey Report, RSV *Aurora Australis*, Marine Science Voyage (2010/11 VMS), January-February 2011. Geoscience Australia Record, 2011/44, 33 pp.

Executive Summary

The Marine Science Voyage (2010/11 VMS) to the Mertz Glacier region was a collaborative survey involving scientists from a number of research institutions, working across a number of different projects, with the overall aim of conducting a coordinated and comprehensive study to measure and monitor the impact of the Mertz Glacier calving event on the local and regional environment. The survey took place in January 2011 and enabled the collection of data shortly after the calving event so that physical, chemical and biological changes in response to the new conditions can be monitored over time. As such, data collected on VMS will provide a benchmark for tracking future change in the Mertz Glacier region environment.

Geoscience Australia and the Australian Antarctic Division conducted a benthic community survey during the voyage. The purpose of the benthic community survey was to collect high-resolution still images of the sea floor to address three main objectives:

1. to investigate benthic community composition in the area previously covered by the MGT and to the east, an area previously covered by approximately 30 m of fast ice;
2. to investigate benthic community composition (or lack thereof) in areas of known iceberg scours; and
3. to investigate the lateral extent of hydrocoral communities along the shelf break.

The survey collected over 1800 images of the sea floor on the continental shelf and slope in the Mertz Glacier region, including in the area previously covered by the Mertz Glacier tongue. There were 75 successful camera deployments of which 19 relate directly to objective 1, 10 to objective 2 and 11 to objective 3. There were a further 7 stations where images were of poor quality but may still provide useful information related to objective 3. The remaining stations were sampled opportunistically at stations related to other projects and will be used to provide general benthic information throughout the region.

The benthic images will be examined in detail to provide information on benthic community composition and substrate type. The survey has provided a major new set of data which will greatly enhance the understanding of Antarctic marine biodiversity and the relationship between physical conditions and benthic communities.

Abbreviations

AABW	Antarctic Bottom Water
ALBW	Adélie Land Bottom Water
CEAMARC	Collaborative East Antarctic Marine Census
HSSW	High salinity shelf water
ISW	Ice shelf water
MCDW	Modified circumpolar deep water
MGT	Mertz Glacier Tongue
VMS	Marine Science Voyage

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1. Introduction

The physical and chemical impacts of climate change on Antarctica and the Southern Ocean are becoming increasingly evident and of concern. Ocean circulation patterns, ice sheet decay (and its impact on sea level rise), ocean carbon uptake (and subsequent acidification) and biological productivity are all likely to be impacted (IPCC, 2007; AAD, 2011). Understanding these processes is vital for predicting climate and environmental changes and their impacts.

The Mertz Glacier region of Antarctica plays an important role in the global ocean over-turning circulation and is one of the few places in the ocean where dense, salty water forms at the surface and sinks to the deep ocean. Polynyas in the region (areas of open-water or low sea ice concentration) produce about 25% of the Antarctic Bottom Water, and this sinking of dense water drives the deep over-turning circulation of the global ocean, carrying oxygen and nutrients to depth in all ocean basins (Young *et al.*, 2010).

In February 2010, a dramatic event changed the geography of the Mertz Glacier region. A massive iceberg designated B09B collided with the Mertz Glacier Tongue (MGT) – a section of the glacier that protruded about 100 km from the Antarctic coastline in George V Land, East Antarctica. The collision precipitated the calving of the glacier tongue, producing a new massive iceberg, C28, measuring 78 km long and between 33 and 39 km wide. This calving event removed about 80% of the tongue, leaving only a 20 km-long stub (Figure 1). Following the calving event in February 2010, the newly formed iceberg C28 drifted west and in April 2010, it collided with a submerged bank and split into several sections. By the end of April, the sections had drifted across the edge of the continental shelf into deeper water. Iceberg B09B remained in position about 50 km north-east of the remaining MGT (Young *et al.*, 2010).

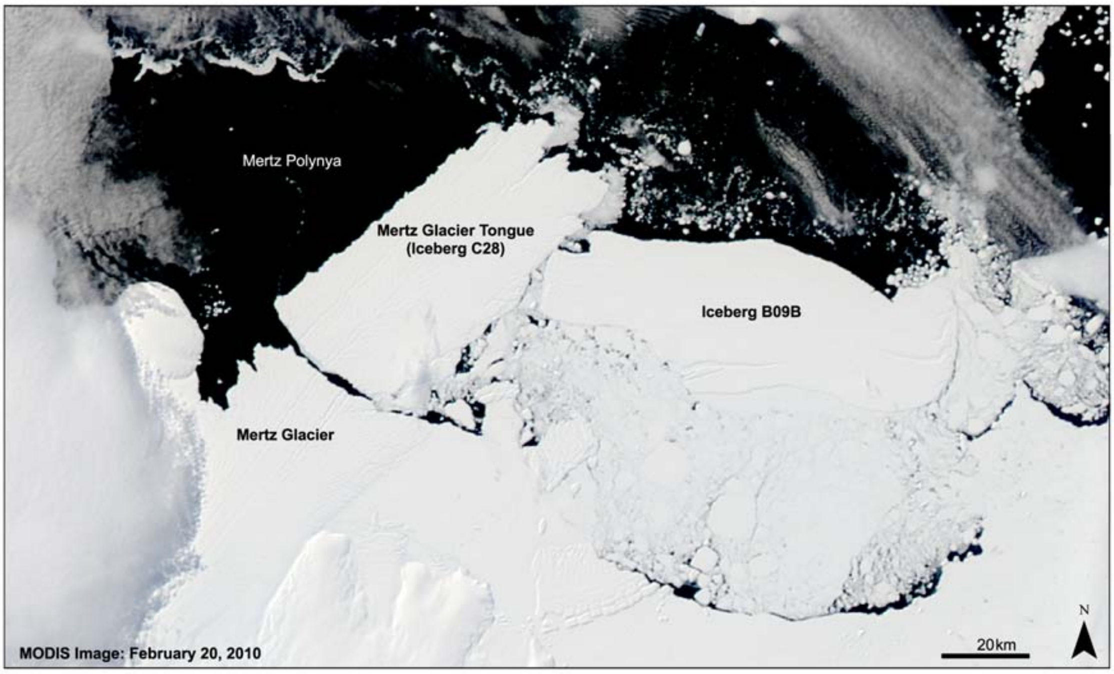

Figure 1: *Calving of the Mertz Glacier Tongue following the collision of iceberg B09B. The newly formed iceberg is designated C28. MODIS image courtesy NASA/GSFC, Rapid Response Team* http://earthobservatory.nasa.gov/IOTD/view.php?id=42819

The calving of the MGT and the shift of large icebergs in the area changed the geography of the region and is likely to have a profound, but largely unknown, impact on the oceanography of the region, particularly on the formation of dense bottom water. These physical changes are likely to have flow-on effects on ocean circulation patterns, sea ice production and biological productivity. Given the key role played by icebergs and floating glacier tongues in air-sea-ice interaction processes in the Ninnis–Mertz Glacier region, any medium-to-long-term change in their distribution and size will lead to complex changes in these processes (Massom, 2003).

2. The Mertz Glacier Region

The Mertz Glacier is located in George V Land (the region east of 142°E), adjacent to Terre Adélie, in East Antarctica (Figure 2). The region has been the focus of numerous geological, oceanographic and biological expeditions and is relatively well studied compared to other regions in East Antarctica (Barnes and Lien, 1988; Eittreim *et al.*, 1995; Brancolini and Harris, 2000; Beaman and Harris, 2005; Presti *et al.*, 2005; Caburlotto *et al.*, 2006; De Santis *et al.*, 2007; Donda *et al.*, 2007; Beaman and O'Brien, 2009; Expedition 318 Scientists, 2010; Beaman *et al.*, 2011).

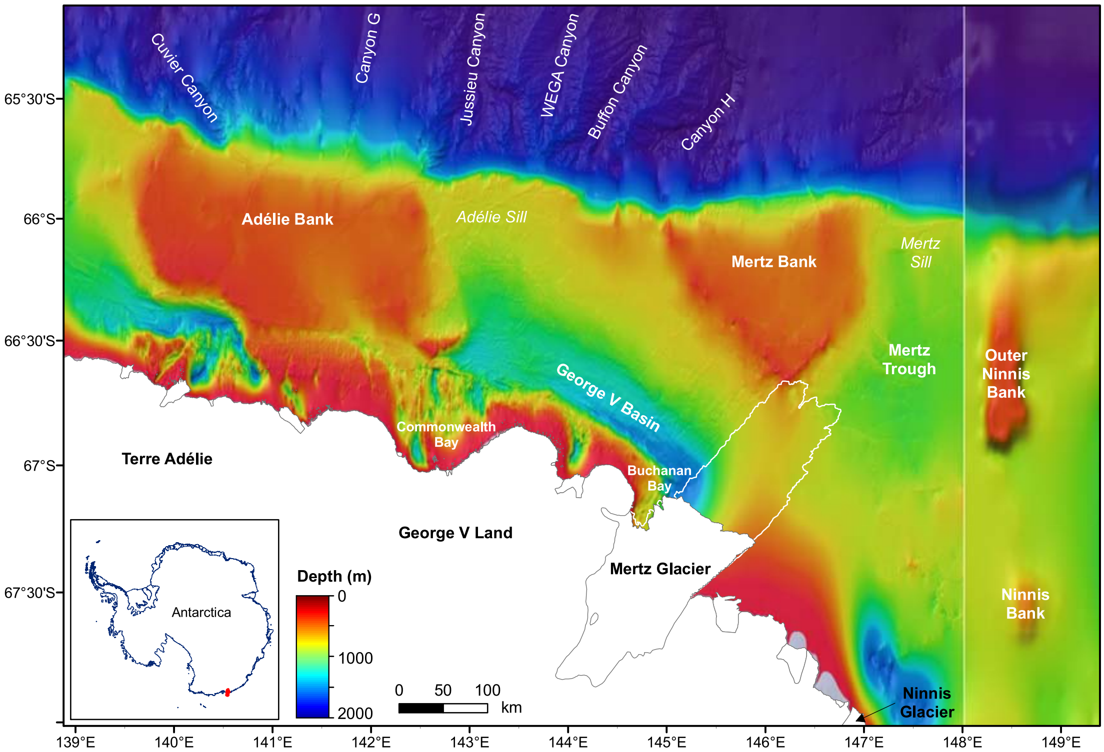

***Figure 2**: The location and seafloor morphology of George V Land and Terre Adélie shelves. The previous extent of the Mertz Glacier Tongue, as of January 2008, is also shown. The bathymetry west of 148°E is from the 250 m grid (Beaman et al., 2011), and east of 148°E is from the GEBCO 1-min grid, version 2.0 (**http://www.gebco.net**).*

The George V Land and Terre Adélie shelves are deep with an average depth along the shelf break of 500 m (Post *et al.*, 2011). The seafloor morphology of the area consists of shoals, grooves, ice gouges and depressions shaped by glacial ice and icebergs (McMullen *et al.*, 2006). The main bathymetric features of the shelf are George V Basin, Mertz Trough and the Adélie, Mertz and Ninnis Banks. The inner shelf is cut by a complex series of deep depressions and small glacial basins. George V Basin (sometimes referred to as the Adélie Depression or the Mertz-Ninnis

Trough) reaches depths of 1300 m adjacent to the MGT. The basin axis trends parallel to the coast, shoaling gently to depths of about 800 m, before swinging north towards a U-shaped sill (referred to as the Adélie Sill) connecting the basin to the shelf break at a depth of approximately 450 m (Beaman and O'Brien, 2009). George V Basin is bounded to the west by the large Adélie Bank and to the north-east by the smaller Mertz Bank, which have mean depths of approximately 200–250m.

The shallower Mertz Trough (sometimes referred to as the Mertz Depression), is located to the north-east of the MGT and to the east of the Mertz Bank, covering an area of about 5000 km^2 (McMullen *et al.*, 2006). The Mertz Trough shows evidence of glacial deposition in the form of streamlined elongated ridges or glacial lineations and grounding line wedges (McMullen *et al.*, 2006). The Mertz Trough leads to the Mertz Sill, approximately 600 m deep, between 147°E and 148°E (Williams *et al.*, 2010). Further east lie two smaller banks, referred to here as the Ninnis Bank (after Domack and Anderson, 1983) and outer Ninnis Bank (after Massom, 2003), which have minimum depths of approximately 300 and 200 m, respectively. Large submarine canyons cut the continental slope, with several canyons (Cuvier, Jussieu and Channel H) reaching the shelf break (Caburlotto *et al.*, 2006; Post *et al.*, 2011).

The Mertz Glacier drains approximately 83,000 km^2 of the East Antarctic Ice Sheet (Rignot, 2002) and advances at a rate of ~1 km $year^{-1}$ (Wendler *et al.*, 1996; Frezzotti *et al.*, 1998). Satellite imagery dating back to the 1970s has been used to determine the changes in ice conditions over the last 35 years (e.g. Frezzotti *et al.*, 1998; Massom, 2003; Massom *et al.*, 2010). A comparison of satellite images from March 2010 and March 2011 reveal the glacier tongue has advanced over 2 km since the calving event (data not published).

Sea-ice begins to form in the region in mid-March but can break out until July due to strong and frequent katabatic winds (Gutt *et al.*, 2007). In spring, it usually breaks out by late November. The floating MGT had a large area of multi-year fast ice attached to its eastern edge from the mid-1970s (Massom *et al.*, 2010). The area of fast ice expanded and retreated over several decades, with a maximum extent in 2002, and a significant reduction since then. During winter, annual fast ice expands across a broad area to the east of the MGT.

The region is a major iceberg “trap”, not only for locally-produced bergs but also those drifting in from the east (Frezzotti *et al.*, 1998; Massom, 2003). Many icebergs have a long residence time in the region, e.g. ~20 years in the case of bergs calved from the Ninnis Glacier from the early 1980s. Icebergs sourced from the Ross Ice Shelf, the Ninnis Glacier and the Cook Ice Shelf are advected westwards into the region (Massom, 2003) and ground readily on the relatively shallow margins of George V Shelf, including the Mertz, Adélie and Ninnis Banks. Icebergs from the Ross and Cook Ice Shelves have average keel depths of 255 and 386 m, respectively (Dowdeswell and Bamber, 2007), while the estimated thickness of icebergs calved from the Ninnis Glacier in the early 1980s is approximately 240 m (Frezzotti *et al.*, 1998). Larger, deeper icebergs also pass through the region and iceberg scours have been found to depths of at least 500 m on Mertz Bank (Barnes and Lien, 1988). As a result of their long residence time in the region, icebergs have a profound and long-term impact on regional sea-ice extent, concentration, thickness distribution, drift patterns and ice production (and thus brine rejection) rates, directly to the east of the Mertz Glacier and indirectly to the west (Massom, 2003).

Iceberg B09B, which calved from the Ross Ice Shelf in 1987, grounded on the Ninnis Bank in 1992 (Massom, 2003) and remained in approximately the same position until late 2008 when it slowly started moving west. During this time, and until the iceberg rotated in late 2009, there was a recurring and persistent polynya on its lee (western) side. The northern extent of the annual fast ice to the east of the MGT varies each season but, until recent years, was generally limited by the polynya on the lee side of B09B.

The occurrence of the Mertz Polynya, an area of ice-free water, dominates the oceanography of George V Shelf (Post *et al.*, 2011). The polynya is sustained by strong and persistent katabatic winds that flow across Buchanan Bay, producing rapid rates of sea-ice formation and removal in the nearshore zone (Massom *et al.*, 2001). The presence of the MGT blocks the inflow of ice to the region, helping to keep the region ice-free. Sustained sea-ice production between April and September in the polynya region increases shelf water salinity and density (Williams *et al.*, 2008), forming high salinity shelf water (HSSW) (Bindoff *et al.*, 2000). Upwelling of modified circumpolar deep water (MCDW) onto the shelf between November and March via the Adélie Sill, combined with the input of cool, fresh ice shelf water (ISW), plays an important role in the formation of Adélie Land Bottom Water (ALBW), a major source of Antarctic Bottom Water (AABW) (Rintoul, 1998; Bindoff *et al.*, 2000; Williams *et al.*, 2008). MCDW is relatively warm and therefore provides extra heat that promotes melting of sea-ice in the polynya region, enhancing the overall size of the polynya (Rintoul, 1998). Furthermore, MCDW increases the salinity of the shelf waters and mixing between HSSW and MCDW raises the salinity of the shelf waters to the point where it is dense enough to spill over the Adélie Sill as ALBW. ALBW is found along the continental slope west of the Adélie Sill (Figure 3). The current size and role of the polynya is unclear given the recent calving of the MGT.

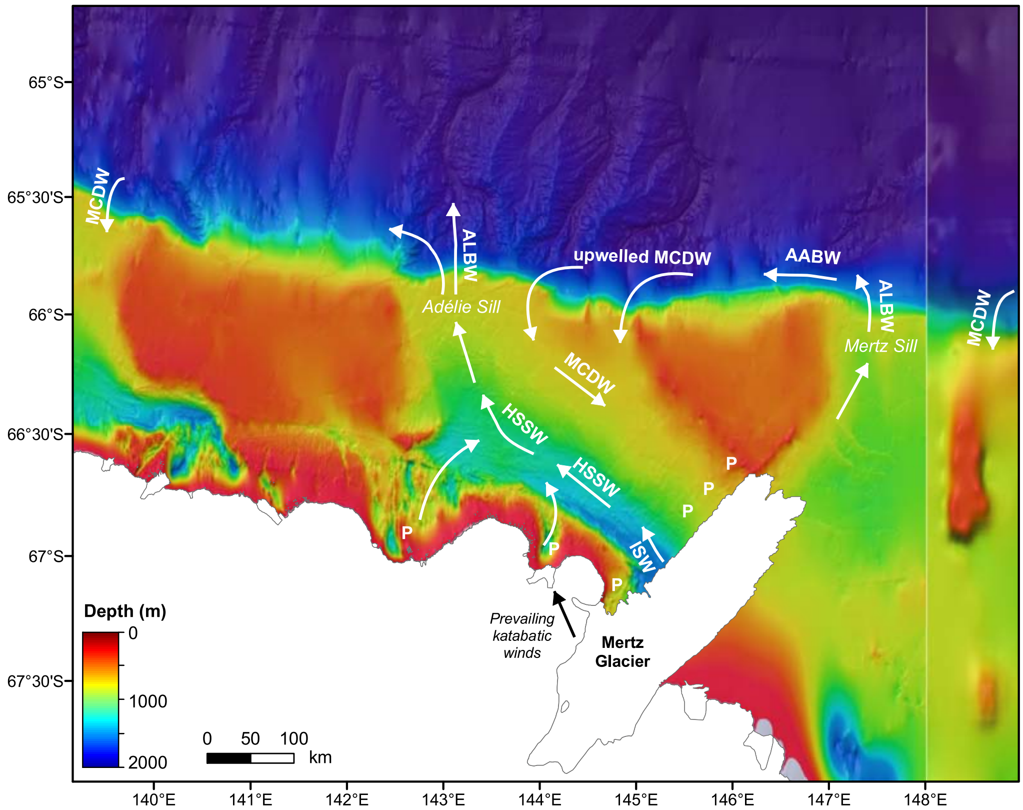

Figure 3*: Oceanographic regime of George V shelf based on Rintoul (1998), Williams et al. (2010) and Bindoff et al. (2000). Bathymetric grid from Beaman et al. (2011) and GEBCO (****http://www.gebco.net****). HSSW is high salinity shelf water, MCDW is modified circumpolar deep water, ALBW is Adélie Land Bottom Water, AABW is Antarctic Bottom Water, ISW is ice shelf water. P marks the Mertz polynya along the coast and western edge of the Mertz Glacier tongue.*

Polynyas are regions of enhanced biological production as the ice-free waters allow light to reach the surface ocean and stimulate primary production thereby supporting a relatively long growing season (Arrigo and Van Dijken, 2003). These waters therefore have high productivity compared to shelf areas with extensive sea-ice cover (Post *et al.*, 2011). The area around the glacier is one of the 'biological hotspots' of the Antarctic and Southern Ocean ecosystem (Gutt *et al.*, 2010) with the high biological productivity attracting whales, penguins and seals to feed on plankton in one of the few areas not covered by ice in the Antarctic winter.

3. Marine Science Voyage (2010/11 VMS)

The Marine Science Voyage (2010/11 VMS) to the Mertz Glacier region was conducted on board the Australian Antarctic research vessel *Aurora Australis* from 4 January to 6 February 2011 (Figure 4). Scientific activities on the voyage included sampling along the WOCE/CLIVAR SR3 repeat transect (140°E) in the Southern Ocean from Tasmania to Antarctica, as well as on the Antarctic shelf and slope in the Mertz Glacier region. The Voyage collected data for a number of science projects (details in Appendix 1) including physical and chemical oceanography, primary production and benthic ecology. The science party and crew are listed in Appendix 2. A voyage narrative describing daily activities is available at:
http://its-app3.aad.gov.au/proms/public/schedules/voyage_sitreps.cfm?season=1011&voyage_no=MS

The main objectives of the VMS were to (Rintoul, 2011):

1. measure changes in water mass properties and inventories throughout the full ocean depth between Australia and Antarctica along 140°E (the CLIVAR/WOCE repeat section SR3)
2. estimate the transport of mass, heat and other properties south of Australia, and to compare the results to previous occupations of the SR3 line and other sections in the Australian sector
3. deploy moorings near the Adélie Depression (142-145°E) to monitor changes in the properties and flow of Adélie Land Bottom Water
4. detect changes in bottom water formation as a result of the calving of the glacier tongue, by comparing measurements in the deep basins on the continental shelf to earlier measurements from this area
5. measure ocean circulation and water mass properties in the region formerly occupied by the MGT and in areas further east that are now accessible for the first time
6. document changes to benthic communities in areas that might be affected by the calving event

The following activities were achieved during the marine science voyage:

- 149 conductivity-temperature-depth (CTD) casts with Niskin sampling bottles
- 93 benthic camera deployments
- 4 Argo deployments (temperature/salinity profiling floats)
- 1 continuous plankton recorder deployment
- 3 oceanographic mooring deployments
- 23 Fast Repetition Rate Fluorometer (FRRF) deployments
- 8 Rectangular Mid-water Trawls (RMTs)
- 16 water samples for metagenomic and metaproteomic analysis
- 3 surface dip nets to collect living pteropods

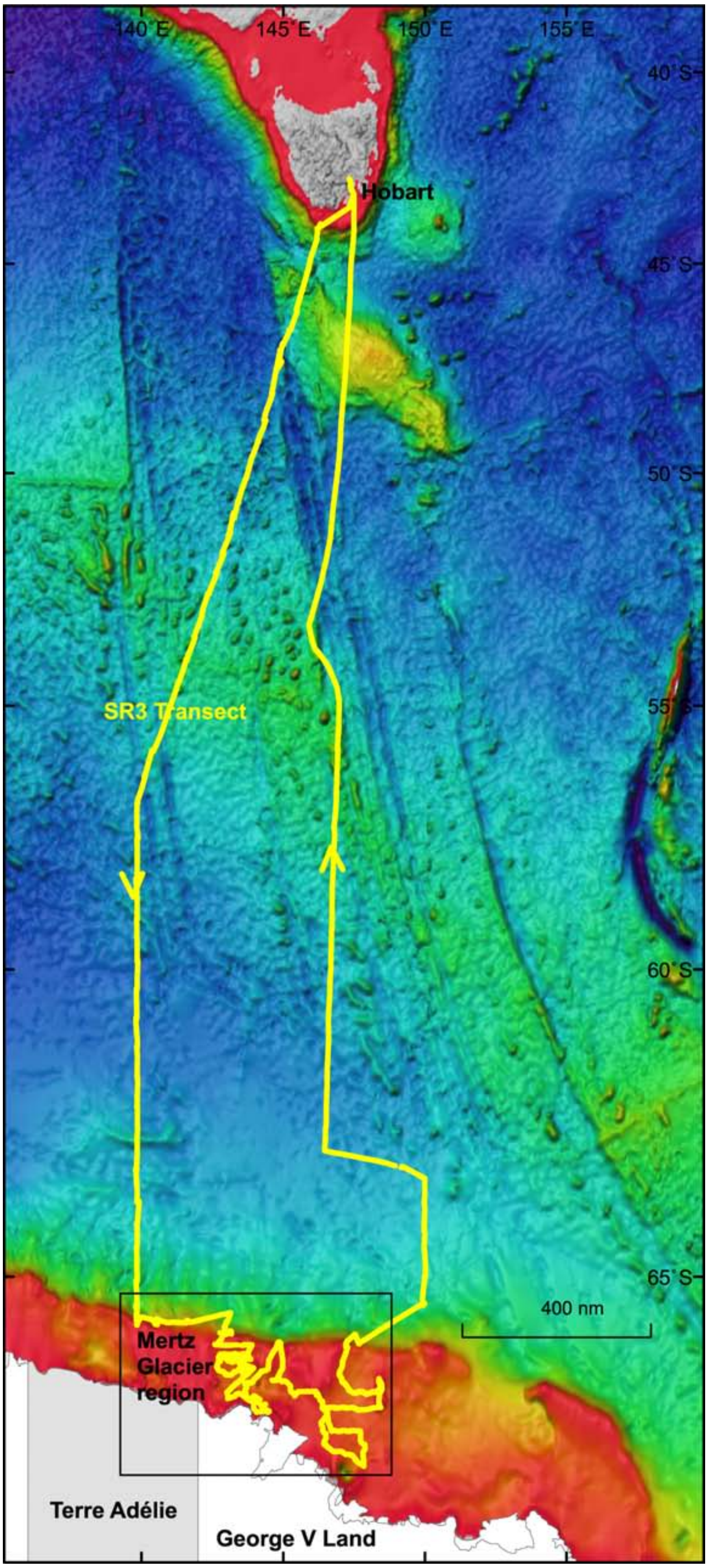

Figure 4: VMS track showing the SR3 transect from Hobart to Antarctica and the Mertz Glacier region (black box) which is the focus of this report.

The voyage provided an opportunity to conduct a coordinated and comprehensive study to measure and monitor the impact of the calving event on the local and regional environment. By collecting data shortly after the calving event, physical, chemical and biological changes in response to the new conditions can be monitored over time. As such, data collected on VMS will provide a benchmark for tracking future change in the Mertz Glacier region environment.

This report will focus only on the Mertz Glacier region component of the voyage (i.e. the SR3 transect is not considered here) and specifically on the benthic community survey (Objective 6) which was conducted by Geoscience Australia and Australian Antarctic Division. Changes to the planktonic communities will have flow-on effects up the food chain, thus making biological surveys of the region both timely and important. The benthic community survey was included as part of AAS Project 2793 (Appendix 1). Information relating to the voyage and other projects can be obtained from the Voyage Leaders Report (Rintoul, 2011) and articles in the *Australian Antarctic Magazine (Issue 20)* (http://www.antarctica.gov.au/about-antarctica/australian-antarctic-magazine/issue-20-2011).

4. Benthic Community Survey Objectives

Underwater video and still-imagery tools are successful groundtruth techniques for recording seabed megabenthos and habitat characteristics, including substrate composition and features. In the Mertz Glacier region, several surveys have utilized these tools. This includes black and white still-images collected during the 2000 WEGA expedition (Brancolini and Harris, 2000; Beaman and Harris, 2005) and several colour still-images from the 2001 NBP0101 expedition (Leventer *et al.*, 2001). More recently, ROV video data were used to differentiate mega-epibenthic diversity within several miles north of the French Antarctic station, Dumont D'Urville (Gutt *et al.*, 2007).

The Collaborative East Antarctic Marine Census (CEAMARC) survey in 2007/08 collected an array of underwater video and still images in addition to physical data such as sedimentary and oceanographic datasets (Beaman and O'Brien, 2009; Post *et al.*, 2011) and is the most comprehensive study to date of benthic community composition and habitats in the Mertz Glacier region. The CEAMARC survey provided a major new dataset to further the understanding of the Antarctic marine biodiversity and the relationship between the physical environment and benthic communities (Beaman and O'Brien, 2009). Nevertheless, a number of research gaps remained. The benthic survey on VMS aimed to address these gaps as outlined below.

The purpose of the benthic community survey was to collect high-resolution still images of the sea floor to address three main objectives:

1. to investigate benthic community composition in the area previously covered by the MGT and to the east, an area previously covered by approximately 30 m of fast ice;
2. to investigate benthic community composition (or lack thereof) in areas of known iceberg scours; and
3. to investigate the lateral extent of hydrocoral communities along the shelf break.

4.1. SUB-ICE-SHELF COMMUNITIES

A widespread habitat in Antarctic waters lies beneath floating ice shelves that cover one-third of Antarctica's continental shelf. This expansive marine setting remains largely unexplored due to inaccessibility. One of the biggest challenges to discovering Antarctica's marine life is to survey the large areas underneath the large floating ice shelves, some being up to several hundreds of metres thick (Gutt *et al.*, 2010). Such sub-ice-shelf ecosystems, where sources of primary phyto-production are severely limited, represent an important coupling zone among ice sheets, the seafloor, and the ocean water column and are diminishing as a consequence of climate change (Domack *et al.*, 2005; Gutt *et al.*, 2011).

Although it has long been recognized that benthic organisms exist under ice shelves, sometimes at substantial distances from the open water, these populations must be sustained by horizontal advection of their primary food source (Clarke *et al.*, 2007; Gutt *et al.*, 2011). In the process of sinking to the seafloor, phytodetritus produced in the euphotic zone undergoes decomposition, and nutritional quality decreases with depth and advection distance (Levin *et al.*, 2001). Therefore, benthic organisms living under ice shelves or tongues do not have the same opportunity for food as in the open ocean where there is a flux of phytoplankton from the surface waters. There are few opportunities to study ecosystems that are able to exist in such situations. Further, little is known about the potential biological impacts of ice shelf collapse.

The CEAMARC survey collected benthic data on the continental shelf and slope between 139°E and 145.5°E (Beaman and O'Brien, 2009) with the eastern extent of the CEAMARC survey area limited by the presence of the MGT. The recent calving of the MGT provided a unique opportunity to examine the deep confines of a sub-ice-shelf setting from a marine perspective. Further, the calving provided an opportunity to access an area where no information on benthic communities currently exists. This study aimed to collect baseline data on benthic community composition and substrate type in this newly exposed area, as well as in the area to the east which has been covered by fast ice for decades (Massom *et al.*, 2010), and to determine whether currents flowing under the floating glacier tongue carried sufficient primary production from adjacent areas to support a high benthic biomass.

4.2. ICEBERG SCOURS

Icebergs play an important role in sediment transport and distribution in this region, and also in sediment reworking by basal scouring (Anderson *et al.*, 1980; Domack and Anderson, 1983). Seafloor disturbance due to iceberg scouring is a common form of disturbance of benthic communities on parts of the Antarctic shelf, at depths typically < 500 m (Barnes and Lien, 1988).

Iceberg scours (both relict and recent) were identified on George V shelf at depths of at least 500 m (Post *et al.*, 2011). Underwater video and still images collected during the CEAMARC survey have shown that benthic communities vary in relation to the relative age of the scours. Recently scoured sections are almost barren, but slightly higher benthic cover along the margins of the scours suggests recent recolonisation from the edges. The benthic communities were similar in areas of relict scours and undisturbed areas (Post *et al.*, 2011). It has been suggested that it takes the benthic community hundreds of years to recover following disturbance from iceberg scours (Gutt, 2000), however, it has not been possible to date the age of these scours. As a result, it is unknown how long recolonisation takes.

Following the calving of the MGT in February 2010, the newly formed iceberg (C28) collided with the Adélie Bank and broke into several sections. This survey aimed to collect baseline information of benthic communities (or lack thereof) in areas of recent scouring, including the point where iceberg C28 collided with the Adélie Bank, and to determine which, if any, benthic organisms have started to recolonise the scoured areas. Understanding how and when recolonisation occurs may assist in better predicting the types of communities that will occur in different areas of the shelf.

4.3. HYDROCORAL COMMUNITIES

Dense hydrocoral-sponge communities were identified on the upper continental slope off George V Land during the 2007/08 CEAMARC voyage (Post *et al.*, 2010). These communities have since been declared Vulnerable Marine Ecosystems (VMEs) by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and are closed to bottom fishing (CCAMLR, 2009a; b).

The richest hydrocoral communities were found below 500 m and in canyons that cut the shelf break and which receive Antarctic Bottom Water from George V Basin. This led to several hypotheses regarding the distribution of the hydrocoral communities and three main factors were identified: 1) their depth in relation to iceberg scouring; 2) the flow of organic-rich bottom waters; and 3) their location at the head of shelf cutting canyons (Post *et al.*, 2010). However, these hypotheses were based on only a few sampling locations.

This survey aimed to test these hypotheses by collecting data from several sites along the continental slope to identify the presence or absence of hydrocoral-sponge communities. Determining the lateral extent of these hydrocoral communities will lead to an increased understanding of the physical processes which control their distribution. This will allow better predictions to be made regarding their distribution and therefore enable protection of these fragile communities on other parts of the Antarctic margin.

5. Benthic Community Survey Methods

Bathymetry information between 138°E and 148°E was derived from a 250-m grid size bathymetric model for George V and Terre Adélie Shelf and adjacent continental slope (Beaman *et al.*, 2011), and between 148°E and 150°E from the General Bathymetric Chart of the Oceans (GEBCO) 1-min grid (The GEBCO One Minute Grid, version 2.0, http://www.gebco.net).

Coastline information was from the Australian Antarctic Territory Coastline 2003 shapefile (Lorenzin, 2001, updated 2010). High-resolution, georeferenced satellite images, including Landsat7 ETM+ and TM (http://landsat.usgs.gov/), MODIS (http://nsidc.org/data/iceshelves_images/) and Envisat ASAR images (www.polarview.org), were collated in the area of interest. All datasets were displayed in ESRI ArcGIS software and used to derive coordinates of potential sampling stations which specifically address the benthic survey objectives.

5.1. IDENTIFICATION OF POTENTIAL STATIONS

5.1.1. Sub-Ice-Shelf Areas

A series of satellite images were digitised and used to map the previous and current extent of the MGT (Table 1). Additionally, information from the literature (e.g. Frezzotti *et al.*, 1998; Massom, 2003; Massom *et al.*, 2010), and satellite imagery dating back to the 1980s was used to determine the changes in ice conditions east of the MGT over the last 35 years. For example, the icescape east of the Mertz in September 2007 is shown in Figure 5. Areas of continuous ice cover, seasonal ice cover and no ice cover were identified in the area between the MGT and 150°E. This information was used on board the ship to navigate to areas known to have been previously under the glacier tongue and fast ice. The benthic photographs collected at stations under the MGT will be examined to determine if the presence of an ice tongue had any influence on benthic community composition.

Table 1: *Satellite images digitised to show the previous and current extent of the MGT*

SATELLITE	DATE ACQUIRED
Landsat TM	02 January 1989
Landsat7 ETM+	25 January 2000
MODIS	8 January 2008
Landsat7 ETM+	3 December 2009
Landsat7 ETM+	6 December 2010

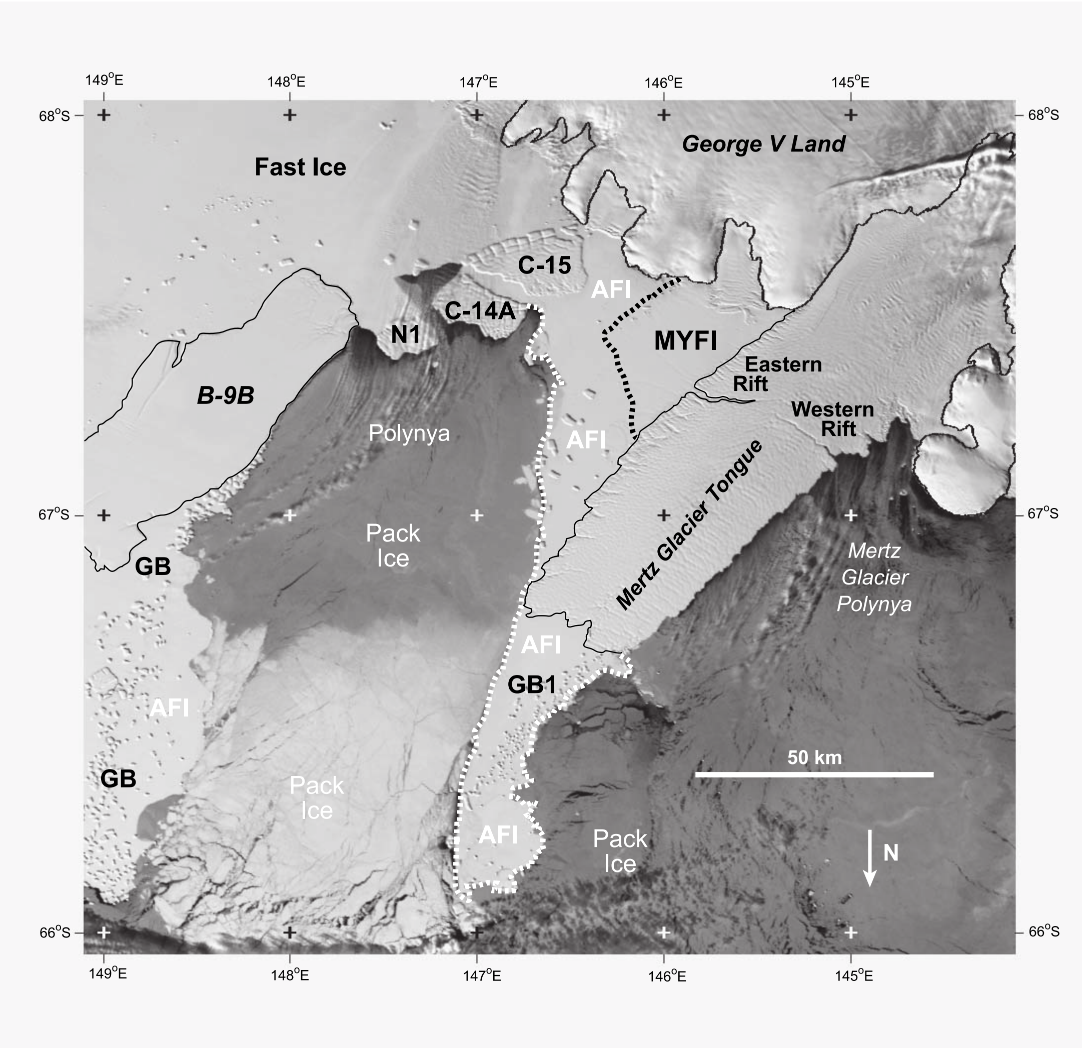

***Figure 5**: Ice conditions east of the Mertz Glacier tongue, as shown in a MODIS visible image from 2 September 2007. The extent of the annual fast ice (AFI), locked onto the eastern margin of the Mertz Glacier Tongue, and multi-year fast ice (MYFI) at this time are shown by the white and black dashed lines, respectively. Grounded bergs (GB) are shown along the eastern flanks of the outer Ninnis Bank and Mertz Bank. Icebergs calved from the Ninnis Glacier in 2000 are marked N1, C-14A and C-15. Figure from Massom et al. (2010).*

5.1.2. Iceberg Scours

Potential scouring sites in the region were located using:

- satellite images to track the movement of large icebergs (C28 and B09B) and to identify regions of small, grounded bergs (e.g. Figure 5);

- estimated iceberg keel depths from the literature (Frezzotti *et al.*, 1998; Dowdeswell and Bamber, 2007) and discussion with experts (Neal Young, pers. comm.); and
- GEBCO and Beaman *et al.* (2011) bathymetry grids.

For example, a series of satellite images from February to April 2010 was used to track the position of iceberg C28. This information, combined with an estimated depth of the iceberg (approx. 400 m, Neal Young pers. comm.) and the bathymetry grid (Beaman *et al.*, 2011), was used to identify potential sites along the eastern flank of Adélie Bank and the western and southern flanks of the Mertz Bank where the MGT and iceberg C28 may have become grounded and scoured the seafloor (Figure 6).

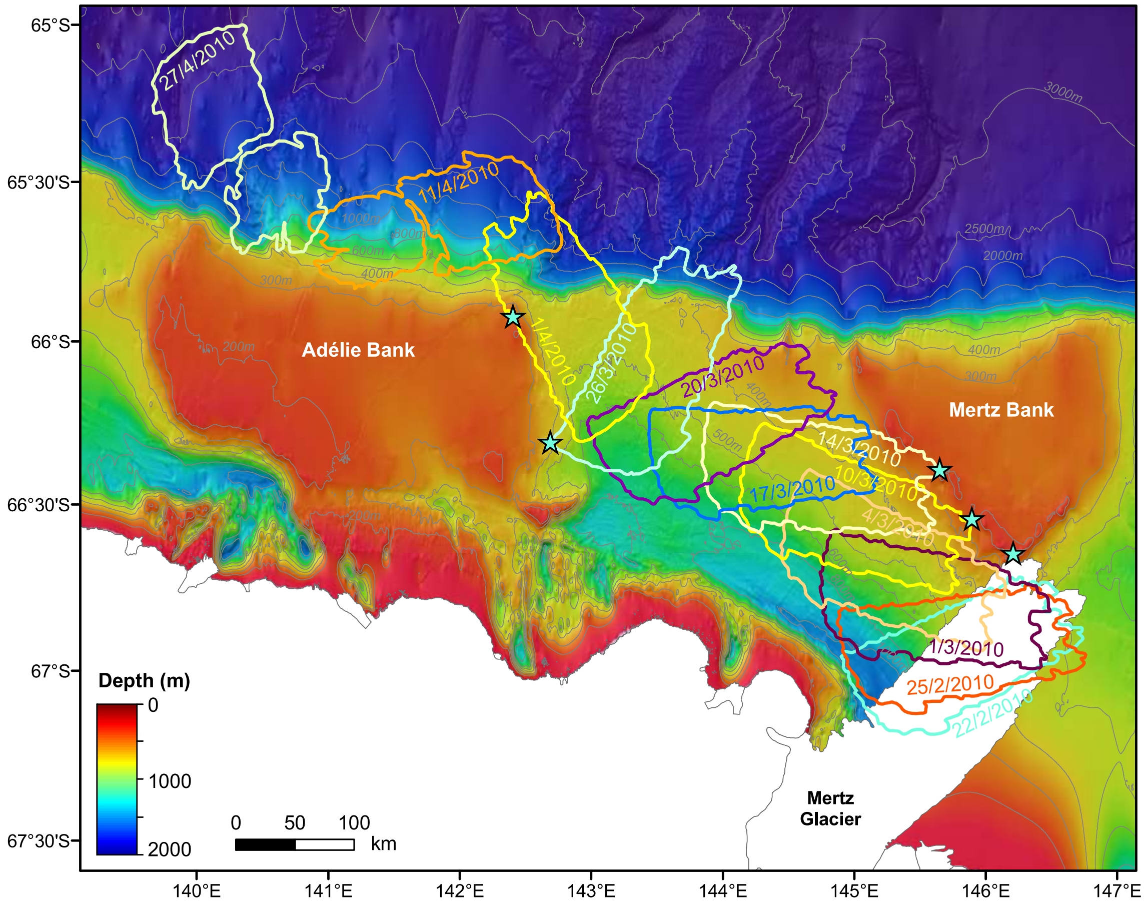

Figure 6: *Map showing the track of iceberg C28 as it moved across George V shelf and the underlying bathymetry. Blue stars indicate potential scour sites. Map courtesy of Alix Post (Geoscience Australia).*

The benthic photographs will be examined for evidence of iceberg scouring, including features such as ice gouges (straight or winding v-shaped furrows) and ice wallows (sub-circular depressions which represent iceberg resting sites).

5.1.3. Hydrocoral Communities

The location of canyons and interfluves on the shelf break were identified using the bathymetry grids. Canyon axes were mapped using contour intervals derived from the 250m bathymetric grid (Phil O'Brien, pers. comm.). Areas along the shelf break receiving dense bottom water outflow were identified from the literature (Rintoul, 1998; Bindoff *et al.*, 2001; Post *et al.*, 2010; Williams *et al.*, 2010).

The stations targeted were within broad areas thought to be receiving, and not receiving, Adélie Land Bottom Water (Figure 7). Additionally, within these areas, stations were chosen to include canyons and interfluves (Figure 8). The benthic photographs collected at stations in canyons and interfluves along the shelf break will be examined to determine the distribution of hydrocoral communities.

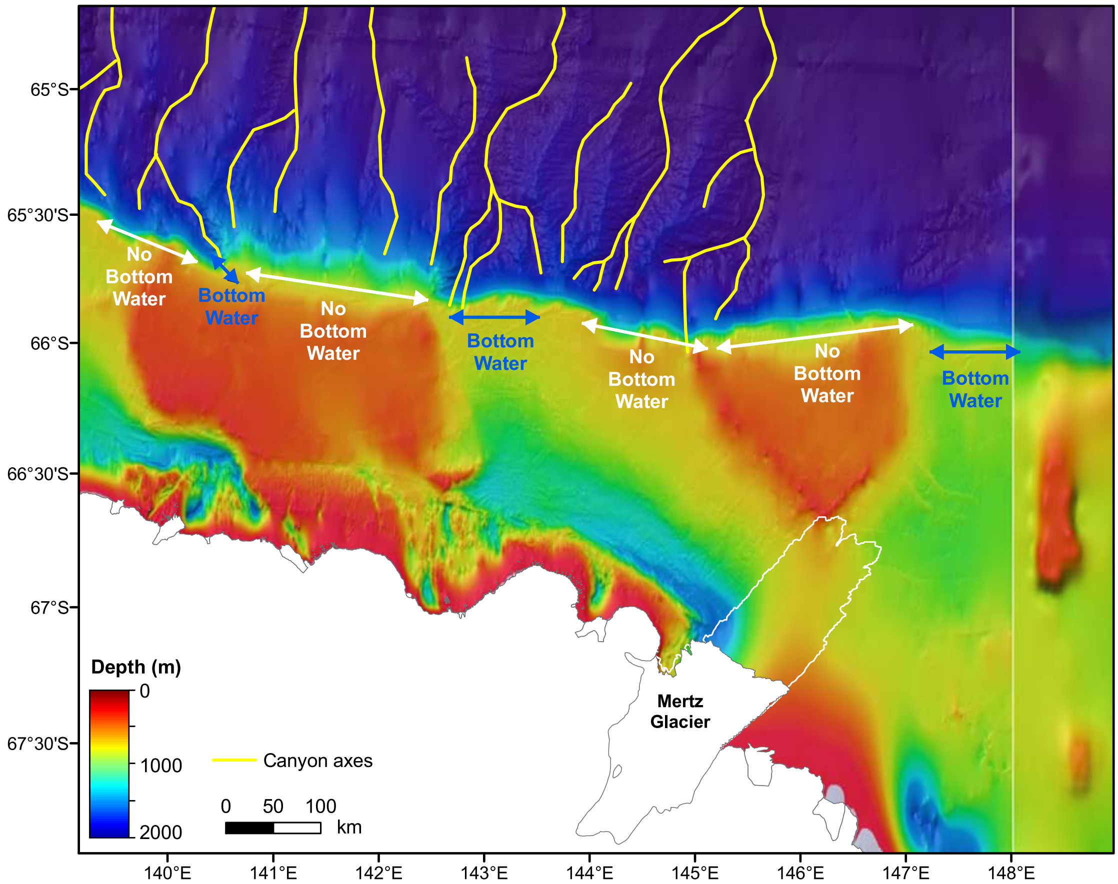

***Figure** 7: Canyon axes along George V slope (Phil O'Brien, pers. comm.), and areas where bottom water spills over the shelf (Rintoul, 1998; Bindoff et al., 2001; Post et al., 2010; Williams et al., 2010).*

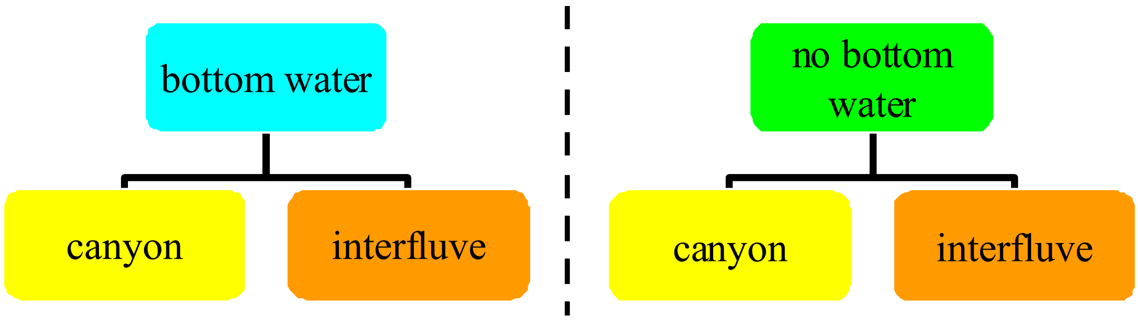

***Figure** 8: Flow chart showing the target areas for hydrocoral communities in areas receiving, and not receiving, bottom water*

5.2. SHIP-BASED ACTIVITIES

Benthic photographs were captured at each station using a Canon EOS 20D SLR 8 megapixel stills camera fitted with a Canon EF 35mm f1.4 L USM lens in a 2500 m-rated flat port anodised aluminium housing. Two Canon 580EX Speedlight strobes were housed in 6000 m-rated stainless steel housings with hemispherical acrylic domes. The camera and strobes were powered with a 28V 2.5Ah cyclone SLA battery pack fitted in the camera housing and connected using Brantner Wetconn series underwater connectors (Figure 9). The results were obtained with 100 ASA and a flash compensation value of +2/3 of a stop. The focus was set manually to 7m and the image was typically exposed at f2.8 and a shutter speed of 1/60 sec. The interval between photos was set to 10 or 15 seconds.

***Figure 9**: A) Canon EOS 20D SLR 8 megapixel stills camera fitted with a Canon EF 35mm f1.4 L USM lens and powered with a 28V 2.5Ah cyclone SLA battery pack. B) Stills camera within the 2500 m-rated flat port anodised aluminium housing. C) Stills camera being removed from the housing which is connected to the strobes using Brantner Wetconn series underwater connectors (thick black cables with red connectors).*

The camera was fitted to either the CTD (conductivity, temperature, depth) frame (Figure 10) or the beam trawl frame (Figure 11) and lowered to the seafloor. Initially the beam trawl frame was used in rough terrain on the shelf edge in order to minimise the risk of damaging the CTD equipment. The position from the seafloor was monitored using an altimeter attached to the frame. The target depth was 4-5 m from the seafloor.

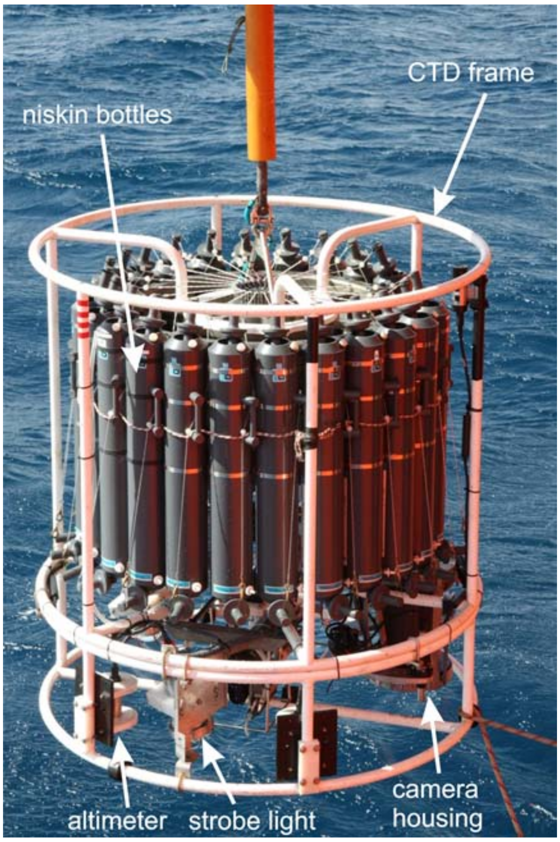

Figure 10: *CTD deployment with the underwater stills camera attached*

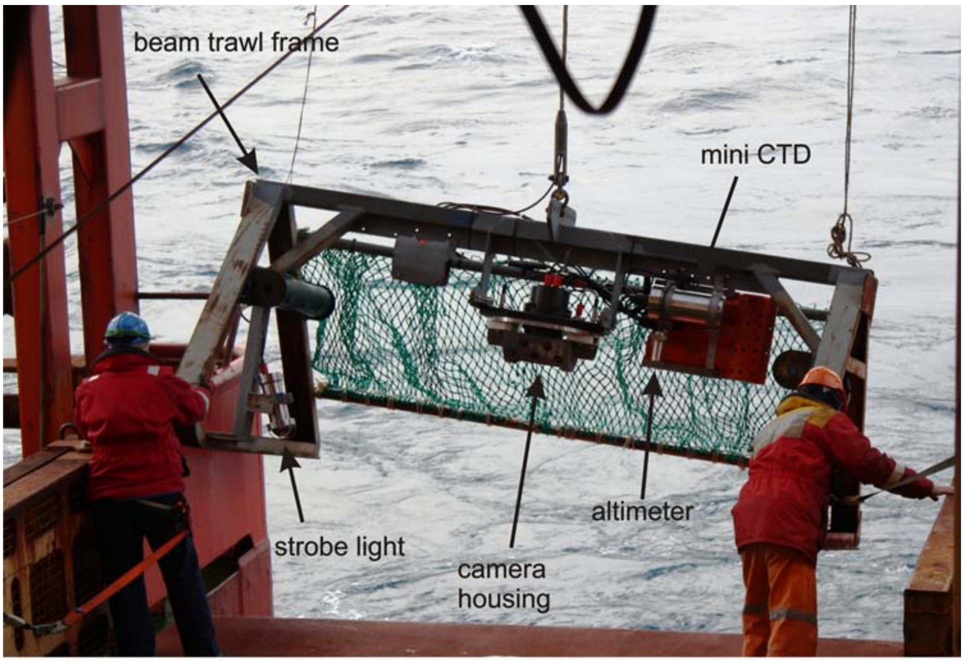

Figure 11: *Deployment of the benthic camera, attached to the beam trawl frame, from the trawl deck of the Aurora Australis*

The altimeter on the beam trawl frame failed and after several attempts to rectify the problem, this system was no longer used. The camera mounted on the CTD frame proved to be a very useful tool for collecting benthic photographs, even over uneven terrain, especially when the seas were calm. When the sea surface roughness increased, it was not possible to hold the frame at a constant depth and the frame had to be held further from the seafloor (approx. 7 m) in order to minimise the risk of damage by hitting the seafloor.

At each station, data was also collected from the CTD, including pressure, conductivity, temperature, salinity, oxygen, fluorescence, irradiance, and transmission. Seawater density, calculated from this dataset, will assist in identifying the presence of dense bottom water at the shelf break sites.

The camera was deployed at 93 stations on the continental shelf and over the shelf break between 139.8°E – 148.5°E and 65.5°S – 67.7°S. At seven sites, the camera was deployed using the beam trawl frame and at the other 86 sites, the camera was deployed using the CTD frame. Following each deployment, the camera was removed from the housing, the batteries recharged, and the photographs downloaded onto a computer and external backup drives in the onboard Photo Lab.

The camera stations were named by:

1. Camera deployment frame (e.g. CTD or beam trawl, BT)
2. Sequence of frame deployments through the survey overall (e.g. CTD53)
3. Instrument (e.g. camera = CAM)
4. Sequence of camera deployments through the survey overall (e.g. first deployment = CAM01, second deployment = CAM02 etc).

For example, BT5_CAM16 is the sixteenth camera deployment of the survey overall, and was the fifth deployment using the beam trawl frame. Similarly, CTD53_CAM01 was the first camera deployment of the survey overall, and was the 53rd deployment of the CTD frame.

During the voyage, iceberg locations and sea ice conditions were monitored using Polar View SAR high-resolution satellite images sent regularly to the ship.

6. Preliminary Results

From the 93 stations, there were 75 successful camera deployments. At 8 of the stations, no photos were collected. This was due to the camera or strobes malfunctioning, the camera being too far from the bottom, or the camera or strobes being in the sediment at the bottom. At a further 10 sites, the photos are considered poor due to the camera being out of focus, the camera being a little too far from the seafloor or because very few photos were captured of the seafloor.

Of the 75 successful deployments where photos were captured, 19 stations relate directly to objective 1 (sub-ice shelf communities), 10 to objective 2 (iceberg scours) and 11 to objective 3 (hydrocoral communities) (Figure 12). There were a further 7 stations directly related to objective 3 which were of poor quality, but which may still be able to provide some useful information on the presence or absence of hydrocorals. The remaining stations were sampled opportunistically at CTD stations related to other projects and were used to gather general benthic information throughout the region.

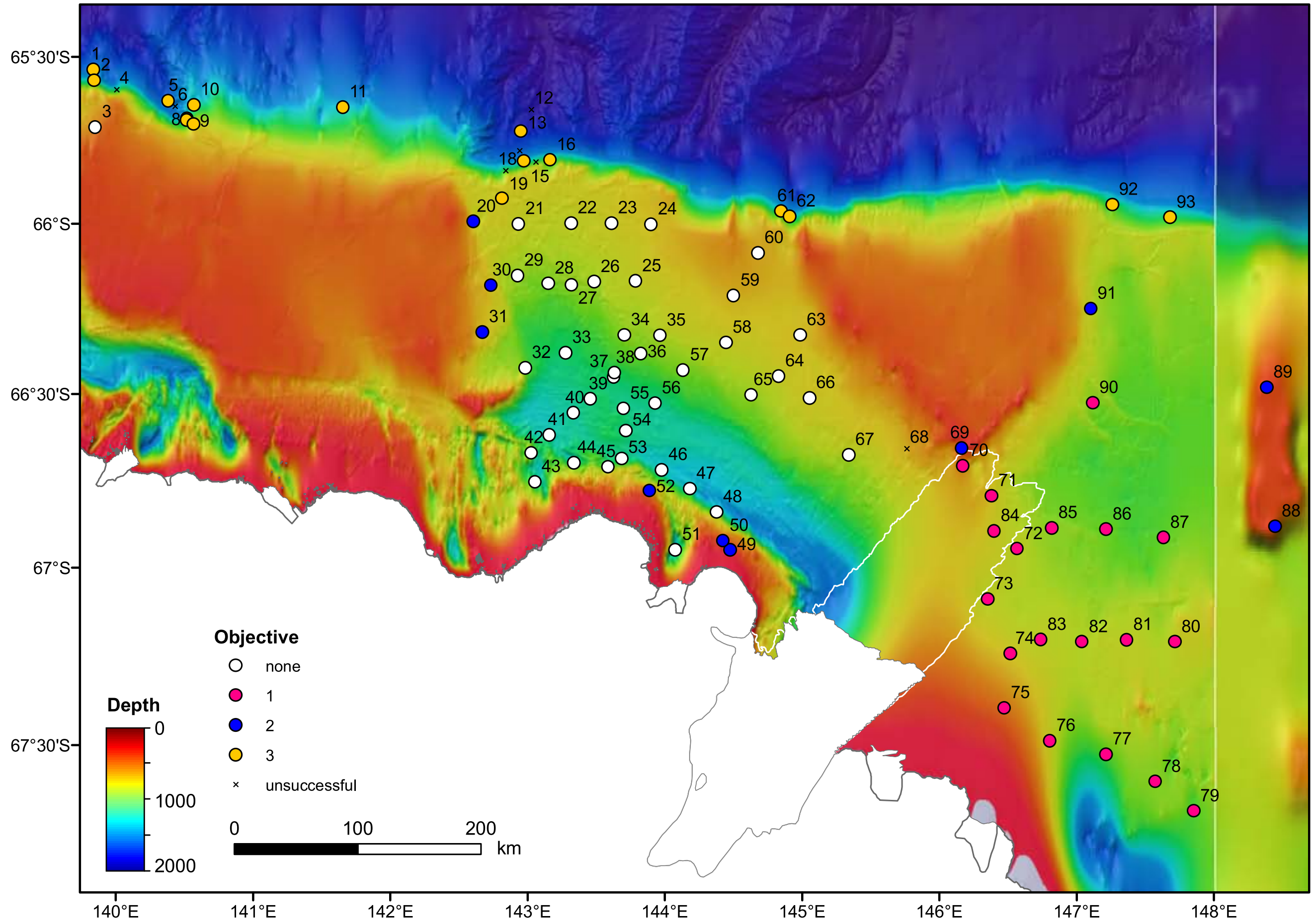

***Figure 12**: Map of camera stations on George V shelf during the Marine Science Voyage (VMS) to the Mertz Glacier region, January 2011. The camera stations relating directly to objective 1 (sub-ice-shelf communities) are shown in pink, objective 2 (iceberg scours) are shown in blue, and objective 3 (hydrocoral distribution) are shown in yellow. Additional camera stations not related to any specific objective are shown in white. Unsuccessful camera deployments are shown as crosses.*

Details of the camera deployments, including the station names, latitude, longitude, depth, quality rating and survey objective, are provided in Appendix 3. Details of the voyage, including the Event log which provides details of each benthic camera deployment are also available at:
http://data.aad.gov.au/aadc/voyages/display_voyage.cfm?voyage_id=555

6.1. SUB-ICE-SHELF COMMUNITIES

Access to potential sampling stations in areas previously under ice (i.e. under the MGT and to the east) was limited by the ice conditions at the time of the voyage. Following the calving of the glacier, iceberg B09B continued to move in a westerly direction across the front of the MGT. During the 12 days spent in the Mertz Glacier region, iceberg B09B was in a stationary position just to the west of the MGT. However, because of the current and wind regime and the size of the iceberg, a large amount of pack ice built up behind B09B, restricting ship access to the region previously covered by the MGT (Figure 13). As a result, the camera was deployed at only three stations in the area previously under the MGT (stations 70, 71 and 84) (Figure 12).

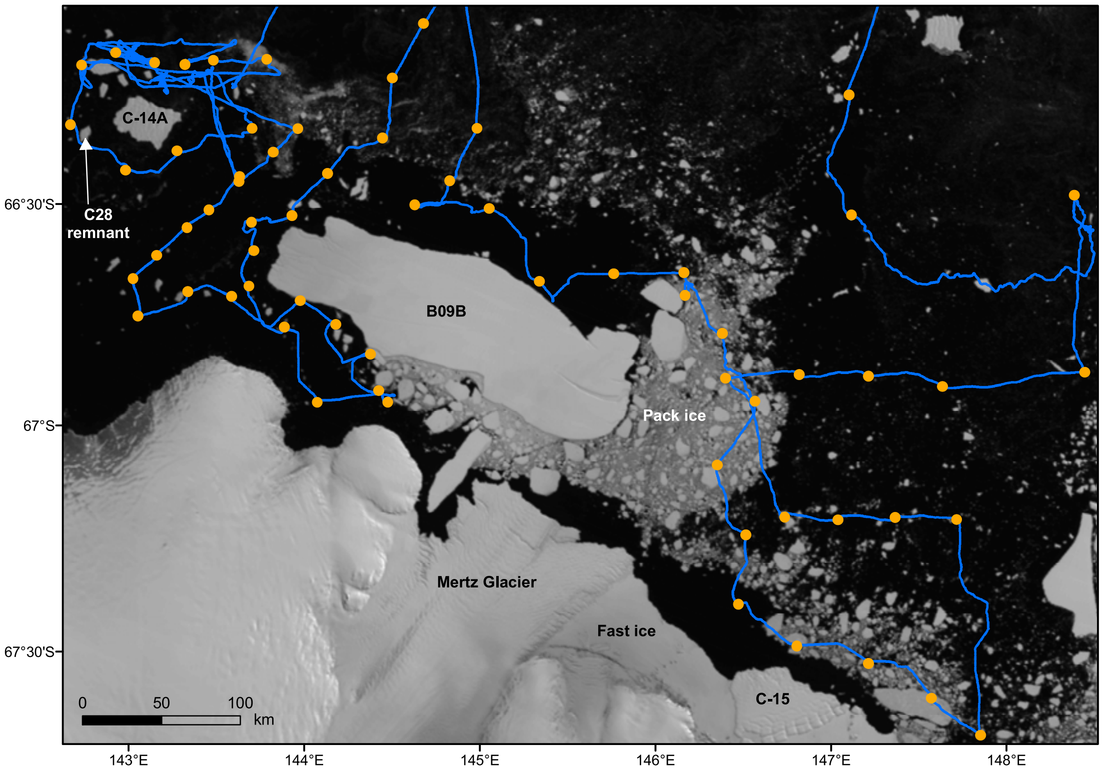

***Figure 13**: Ice conditions, ship track (blue line) and camera stations (orange dots) on George V shelf during the Marine Science Voyage (VMS) in January 2011. The MODIS visible image from 16 January 2011 (**http://nsidc.org/data/iceshelves_images/**) shows the position of iceberg B09B to the west of the Mertz Glacier tongue and the thick pack ice backed up behind it in the area previously covered by the glacier tongue. Icebergs C-14A and C-15 were calved from the Ninnis Glacier in 2000. The fast ice extent to the west of the Mertz Glacier has significantly reduced since the glacier calving.*

It should be noted that the three camera stations (70, 71 and 84) were located close (<20 km) to the edge of where the ice tongue extended prior to its calving. Further, examination of satellite photos shows that the area where these stations are located has been exposed in recent decades. A Landsat TM image from 02 January 1989 shows station 84 lies just beyond the limit of the glacier extent (Figure 14) and so this area has only been covered by the glacier tongue for approximately 20 years.

A Landsat ETM+ image from 25 January 2000 shows stations 70 and 71 are just beyond the limit of the glacier tongue extent and so this area has only been covered by the glacier tongue for approximately 10 years (Figure 14). Therefore, the benthic communities found at these stations may not resemble those which have been beneath the ice tongue for much longer time periods, such as those further from the ice edge and closer to the grounding line of the glacier.

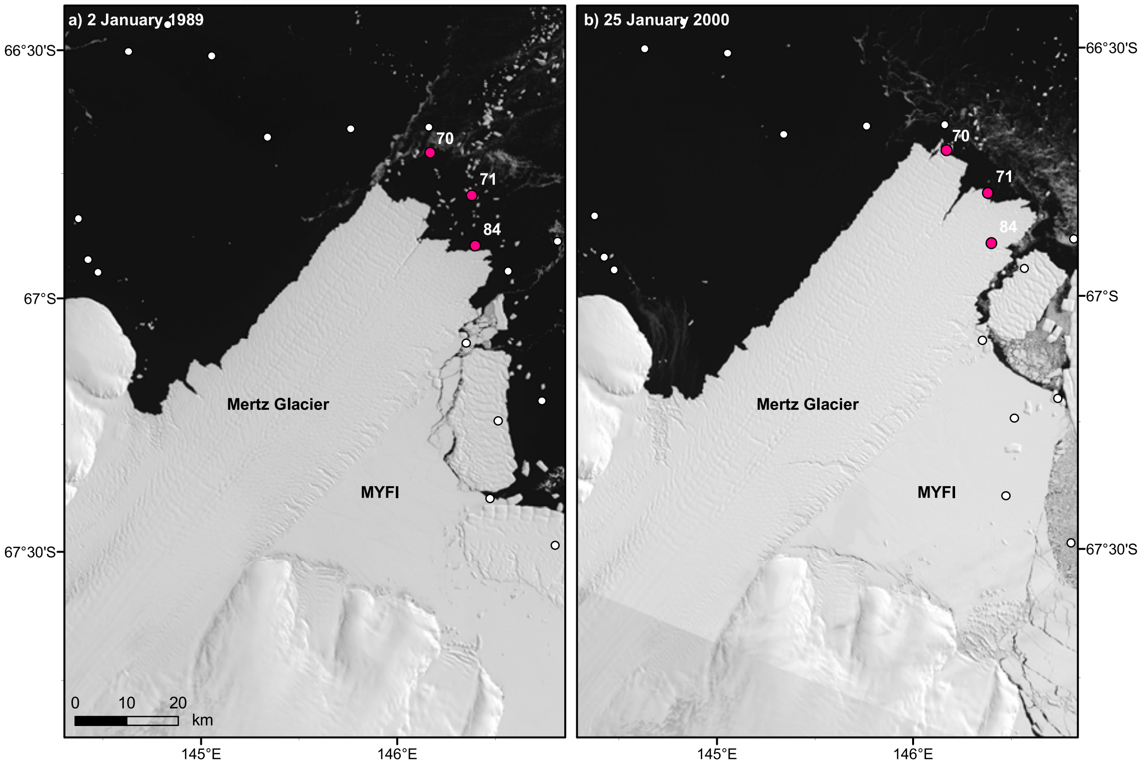

Figure 14: *Location of the three camera stations (70, 71 and 84, in pink) which were under the glacier tongue at the time of calving relative to previous positions of the Mertz Glacier tongue: a) Landsat-5 TM image (Path 082, Row 107) from 2 January 1989, and b) Landsat-7 ETM+ image (Path 082, Row 107) from 25 January 2000. MYFI = multi year fast ice. White dots = other camera stations.*

The camera stations located to the east of the MGT (72-87) have been covered by annual or multi-year fast ice for varying periods of time over the last few decades. Stations 73-75 are located near the area of thick multi-year fast ice (Figure 5) and satellite images and information from the literature (Massom *et al.*, 2010) suggest they were covered year-round by ice for approximately 30 years up until the summer of 2006 when they were exposed. Since then, these stations have been covered by annual fast ice during the winter months but have been exposed during the summer months.

Over the last 30 years, the southern-most camera stations (76-79) and stations adjacent to the area of multi-year fast ice (72 and 83) have typically been covered by annual fast ice each winter but have been exposed during the summer months as the fast ice breaks out.

Stations 80-82 and 85-87 have remained ice-free as they lie within the polynya on the lee side of B09B. These stations have not been covered by ice for any extended periods, however, they may have been occasionally covered by fast ice or pack ice in winter. For example, a MODIS satellite image from 22 October 2005 shows the annual fast ice extended north as far as 66°45’S, covering all camera stations (72-87) in this area (not shown).

In summary, the camera stations east of the Mertz Glacier can be divided into three groups according to the different ice conditions experienced over the past few decades:

1. Stations 73-75 - covered year round by multi-year fast ice from the mid 1970s until 2006, then covered by annual fast ice during winter from 2006 to 2009.
2. Stations 72, 76-79 and 83 - covered each winter by annual fast ice from the mid 1970s until 2009
3. Stations 80-82 and 85-87 - ice-free for the last 30 years

By early 2010, B09B had rotated 90 degrees and drifted west towards the MGT and there was significant break-up of fast ice south of the iceberg. Other smaller icebergs, calved from the Ninnis Glacier in the early 1980s and early 2000 and which had remained in the region east of the MGT, also drifted away at this time. As a result, none of the camera stations east of the Mertz were covered by fast ice during the winter of 2010 and therefore all stations had been ice-free for at least a year prior to the Marine Science Voyage in January 2011.

The benthic photographs collected at stations east of the MGT will be examined to determine if the different ice conditions had any influence on benthic community composition. Initial observations of the photographs indicate low benthic cover in this area (Figure 15).

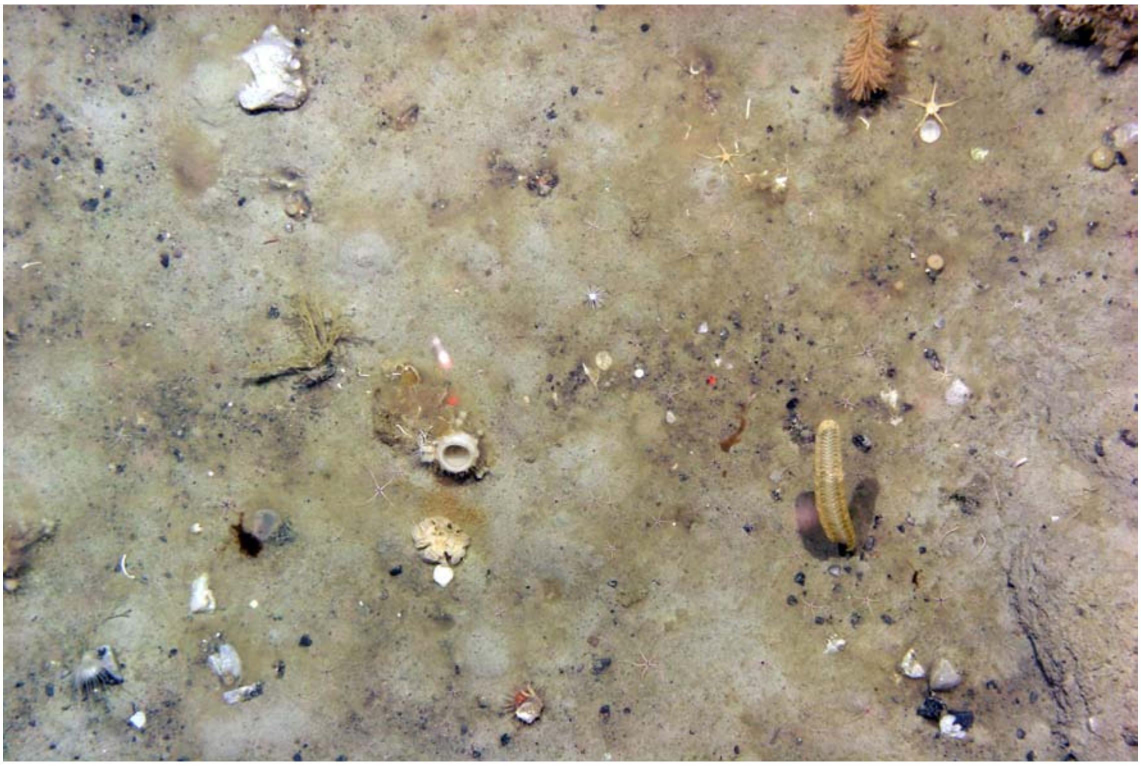

Figure 15: *Underwater image taken at station 84 showing low benthic cover in the area previously under the MGT*

6.2. ICEBERG SCOURING

Initial observations of the benthic photographs indicate there is no evidence of iceberg scouring at the seven stations relating directly to Objective 2. The targeting of stations affected by iceberg scouring proved to be difficult given the nature of the camera system used, the resolution of the satellite and bathymetry data, and the manoeuvrability of the ship.

Camera station 31 is located at the point where C28 grounded and pivoted (Figure 6). The grounding of such a large iceberg was expected to have a significant impact on the seafloor, however, there was no evidence of iceberg scouring at this site. Closer examination of satellite images during and after C28 passed across this area reveals the presence of an iceberg (approx 11 km x 6 km) in the position where C28 pivoted, suggesting a small section of C28 broke off and remained grounded in this position. The iceberg remained in this position for the following year, including during January 2011 when this survey took place (labelled C28 remnant in Figure 13). Station 31 is approximately 7 km from the edge of this iceberg and this iceberg prevented access to the point where C28 grounded and scoured the seafloor. The iceberg has since become ungrounded and moved away from this area, hence the location where the iceberg was grounded (Table 2) represents an important site for future surveys which aim to examine the iceberg scours.

Table 2: *Bounding coordinates for iceberg C28 remnant on the eastern flank of Adélie Bank. This location represents an area to investigate for future surveys examining the impact of iceberg scours.*

LATITUDE	LONGITUDE
-66.332	142.728
-66.322	142.774
-66.342	142.779
-66.359	142.729

Camera station 69 was targeted because it lies on the Mertz Bank where the MGT once extended (Figure 12). It has been suggested that the northern extent of the MGT grounded on the shallow Mertz Bank (Beaman and Harris, 2005). However, benthic photographs show no evidence of iceberg scouring at this site. This station is 174 m deep and it is likely this is greater than the MGT thickness at this point.

Camera station 88 was targeted because small icebergs regularly ground on the outer Ninnis Bank (see Figure 5). Further, as B09B began to move west, it passed over the southern end of outer Ninnis Bank and potentially scoured the bank in the process (Figure 16). However, the benthic photographs show no evidence of iceberg scouring at this site.

Camera stations 49, 50 and 52 were chosen because small icebergs are thought to scour these shallow coastal banks. Additionally, B09B passed through this area and may have scoured these shallow banks as it continued to move west. However, there was no evidence of iceberg scouring at these sites and further examination of georeferenced satellite images reveals it is unlikely B09B scoured this area (Figure 16). Following the survey, B09B continued to move west and on 10 March 2011 it eventually hit a shallow moraine to the south-east of the Adélie Bank. Iceberg B09B has since rotated and begun to break apart. This moraine represents an important site for future surveys which aim to examine the iceberg scours.

The remaining camera stations that were targeted as potential iceberg scouring locations (stations 20, 30, 89 and 91) were sampled opportunistically in shallow waters (<500 m) on the eastern flanks of the Adélie, Mertz and outer Ninnis Banks where icebergs are known to ground. However, benthic photographs at these stations show no evidence of iceberg scouring.

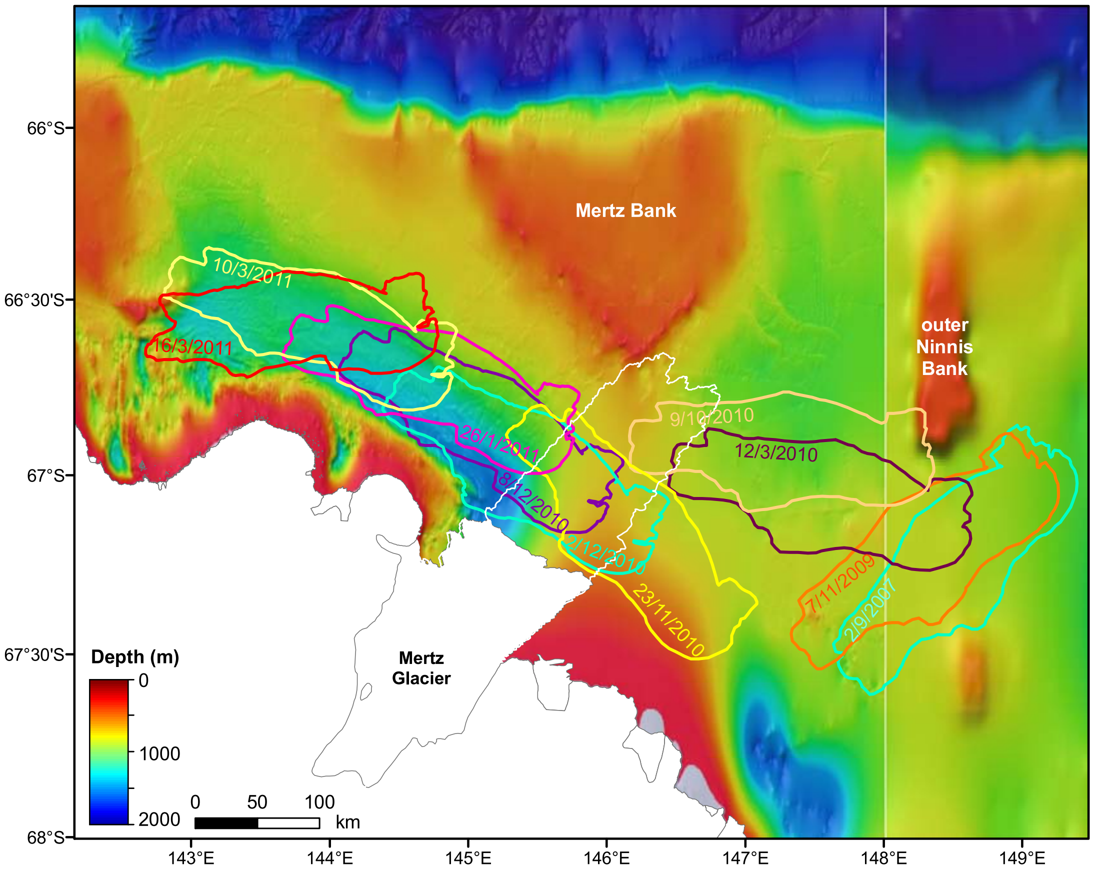

Figure* 16*:* *Map showing the track of iceberg B09B as it moved across George V shelf, and the underlying bathymetry. The position of the Mertz Glacier tongue prior to calving in February 2010 is also shown.

The lack of evidence of iceberg scouring in areas where it was expected is likely due to the localised nature of the camera deployment. It is estimated only several square metres of seafloor was captured with each camera deployment and it is possible there was scouring nearby. Further, individual iceberg scours are often kilometres in length, tens of metres wide and metres deep (Dowdeswell and Bamber, 2007). Therefore, it is possible that some stations were actually within large, relict scours that have been recolonised but the scope of the photographs prevents this information being seen.

Further, the satellite and bathymetry data used to locate possible scour sites is of lower resolution than required for this purpose. In particular, the bathymetric grid is largely interpolated as detailed bathymetry data is not available over much of this area (Beaman *et al.*, 2011). Additionally, the iceberg keel depths were only estimated. An additional factor which affected the ability to target potential scour sites was the lack of manoeuvrability of the ship. Even though coordinates of potential scour sites were provided to the ship crew, it was not always possible to position the ship in the desired location due to the presence of ice and currents which caused the ship to drift. For these reasons, this camera deployment method (i.e. drop camera) is not considered suitable for examining the effects of iceberg scouring on the seafloor. Ideally, transects across scours, preferably those which have been previously identified by multibeam bathymetry or sidescan sonar, are required and a towed video system such as that used during the CEAMARC voyage is better suited to this activity.

There was evidence of iceberg scouring identified at a few stations not specifically related to this objective. For example, at stations 74 (~540 m depth) and 83 (~500 m depth), located east of the MGT, several images show evidence of scouring. At station 74, some images show a linear scrape across the surface (Figure 17A) whilst other photos show fracturing of compacted sediment (Figure 17B), consistent with mechanical stress of the substrate. When disturbed by ice keels, irregular blocks and slabs of compact, overconsolidated mud are ripped loose with angular fracture faces, producing bands of rubbled mud (Reimnitz, 1997). Images from station 84 show a combination of fractured overconsolidated mud covered in a fine sediment layer (Figure 17C); fine sediment with no evidence of fracturing; and piles of rubbled mud (Figure 17D). This suggests the fracturing is relatively old and the station could be on the edge of a scoured area.

These stations are considered too deep for modern iceberg scouring which typically occurs at depths of <500 m. Icebergs may reach deeper due to an increase in draft through iceberg rolling (Polyak, 1997). Post *et al*. (2011) found relict iceberg scours to depths of ~600 m and proposed that these relict scours most likely date from the last glaciation when global sea-level was approximately 120 m lower than the present. The larger depth range of the relict scours may also be caused by the production of icebergs with larger keel depths during major deglaciation or ice-sheet collapse (Dowdeswell and Bamber, 2007).

Figure 17: *Underwater images showing evidence of iceberg scouring (A) a linear scrape across the sediment surface (station 74); (B) fractured compacted sediment (station 74); (C) fractured overconsolidated mud covered in a fine sediment layer (station 83); (D) rubbled mud (station 83).*

6.3. HYDROCORAL COMMUNITIES

Initial observations of the benthic photographs indicate further evidence of dense hydrocoral-sponge communities at some locations along the continental shelf (Figure 18). *Errina* spp., easily identifiable in photos by its distinct pink/orange colour, will be used to determine the presence or absence of hydrocorals at each station. Oceanographic measurements taken during this voyage will be used to determine the presence of Adélie Land Bottom Water across the continental slope, and thus test the hypothesis that dense hydrocoral communities occur in areas of bottom water flow. The distribution of hydrocoral communities in relation to canyons along the shelf break will also be examined.

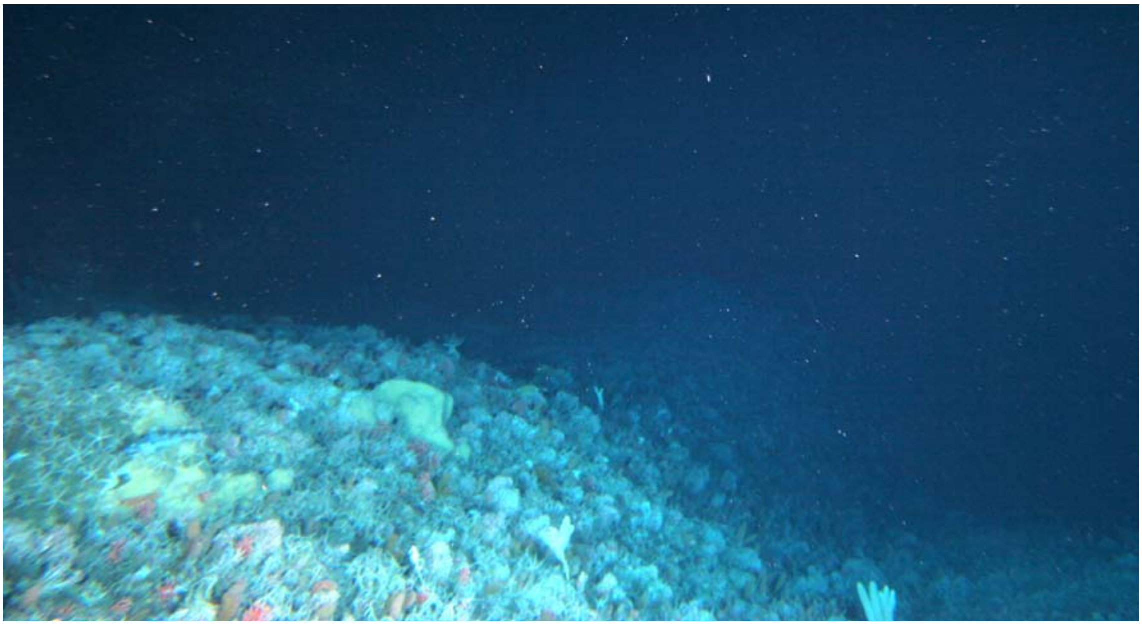

Figure 18: *Underwater image taken during the Marine Science Voyage (2010/11 VMS) showing a dense hydrocoral-sponge community on the continental slope*

The capture of benthic photographs in areas along the continental shelf proved difficult during the voyage due to the problems with the altimeter on the beam trawl frame. As a result, either no photographs, or poor quality photographs were collected at a number of target stations. Further, the bathymetric data along most of the continental slope is not detailed enough to determine whether the camera stations were within canyons or interfluves. Due to the localised nature of the camera deployment system, it is unclear whether the hydrocoral communities are continuous across the slope, or restricted to localised patches. Transects across the continental slope, covering both canyons and interfluves, would be needed to determine the lateral extent of the communities. A towed video system would be better suited to this activity.

7. Conclusions

The Marine Science Voyage (2010/11 VMS) was highly successful in providing new insights into benthic communities and seafloor environments in the Mertz Glacier region. Ongoing interpretation of the data will greatly enhance the understanding of Antarctic marine biodiversity and the relationship between physical conditions and benthic communities. The collection of this data as soon as possible after the calving event was critical and will enable physical, chemical and biological changes in response to the new conditions to be monitored over time.

Acknowledgements

The authors wish to thank Miguel de Salas, Michael Field, Kim Briggs, Penny Purdie and Gerrit Klomp from the Australian Antarctic Division for their assistance in developing, operating, maintaining and deploying the underwater camera system. The authors also thank Captain Murray Doyle and the crew of the RSV *Aurora Australis* for their assistance in collecting the data contained in this report. Thanks also to the voyage leader Steve Rintoul (CSIRO) and the CTD team for their assistance in the instrument room.

Thanks to Alix Post and Phil O'Brien from Geoscience Australia for advice during survey planning and assistance in interpretation of the benthic images. The report was improved by reviews of an earlier draft provided by Alix Post and James Daniell. This report is published with the permission of the Chief Executive Officer, Geoscience Australia.

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Appendix 1: VMS 2010/11 Marine Science Projects

PROJECT NO.	ONBOARD CONTACT	CHIEF INVESTIGATOR	PROJECT TITLE
40	Miguel de Salas	Simon Wright	The role of Antarctic marine protists in trophodynamics and global change and the impact of UV-B on these organisms
472	Dave Watts	Graham Hosie	Continuous plankton recorder survey
1307	Fraser Kennedy	Andrew McMinn	Sea ice primary production off eastern Antarctica for the 2011 season
3046	Will Howard	Will Howard	Southern Ocean Calcareous Zooplankton Response to Ocean Acidification
2519	Esmee van Wijk	Steve Rintoul	Real-time monitoring of upper ocean variability in the Australian region of the Southern Ocean using Argo profiling floats
2793	Steve Rintoul	Steve Rintoul	Observing transport and water mass changes south of Australia (CLIVAR SR3, 140E)
1302	Bronte Tilbrook	Bronte Tilbrook	The carbon cycle in the Australian sector of the Southern Ocean
3145	Tim Williams	Rick Cavicchioli	Monitoring Environmental Health and the Impacts of Climate Change – the Australian Southern-Ocean Genome-Based Microbial Observatory
3225	Harvey Marchant	Harvey Marchant	Parmales: taxonomy and role in the Antarctic marine ecosystem
3175	Karen Barlow	Sally Chambers	ABC Lateline Program

Appendix 2: Scientific Party and Crew

Voyage Management and Support	
Dr Steve Rintoul (CSIRO, ACECRC)	Voyage Leader and Chief Scientist
Dr Fred Olivier (AAD)	Deputy Voyage Leader
Dr Kevin Harmey (AAD)	Antarctic Medical Practitioner
Mr Matt Longmire (AAD)	Supervising Communications Technical Officer
Marine Science Technical Support	
Mr Kim Briggs (AAD)	Marine Electronics
Mr Michael Field (AAD)	Marine Electronics
Ms Penny Prudie (AAD)	Gear Officer
Mr Gerrit Klomp (AAD)	Gear Officer
Mr Ben Walter (RAN)	Hydrographer
Dr Dave Watts (AAD)	Data Officer
Scientific Programs	
CLIVAR SR3, 140E Project and Argo Floats	
Dr Steve Rintoul (CSIRO)	Chief Scientist, Oceanographer
Mr Mark Rosenberg (ACECRC)	Oceanographer
Ms Laura Herraiz Borreguero (CSIRO)	Oceanographer
Dr Beatriz Pena-Molino (CSIRO)	Oceanographer
Mr Miquel Rosell-Fieschi (CSIRO)	Oceanographer
Ms Esmee van Wijk (CSIRO)	Oceanographer
Dr Serguei Sokolov (CSIRO)	Oceanographer
Mr Peter Hughes (CSIRO)	Hydrochemist
Ms Alicia Navidad (CSIRO)	Hydrochemist
Ms Heidi Pethybridge (CSIRO)	Hydrochemist
Ms Sue Reynolds (CSIRO)	Hydrochemist
CO2 Project	
Dr Bronte Tilbrook (CSIRO)	Chemical Oceanographer
Ms Kate Berry (CSIRO)	Biogeochemist
Mr Adam Swadling (CSIRO)	Biogeochemist
Mr Graham Simpkins (UNSW)	Research Student
Benthic Ecology Project	
Dr Jodie Smith (GA)	Geoscientist
Parmales Project	
Dr Harvey Marchant (ANU)	Biologist
Ocean Acidification Project	
Dr Will Howard (ACECRC)	Marine Biologist
Mr Nick Herrald (ACECRC)	Marine Biologist
Mr Antonio Mozqueira (Chief Scientists Office)	Research Scientist
Genomics Project	
Dr Tim Williams (UNSW)	Biologist
Mr David Wilkins (UNSW)	Biologist

Marine Protists Project

Dr Miguel de Salas (AAD)	Research Scientist
Mr Rob Johnson (AAD)	Research Student

Sea Ice Primary Production Project

Mr Fraser Kennedy (IASOS)	Research Student
Ms Laura Smith (IASOS)	Research Student

Media Program

Ms Karen Barlow (ABC)	Film crew
Mr Michael Brooks (ABC)	Film crew

P&O Crew

Cpt Murray Doyle	Master
Robert Darvall	1st Mate
Mike Watson	2nd Mate
Simon Smeaton	3rd Mate
Tom Watson	4th Mate
Paul Rasmussen	Cadet
Paul Dickson	Chief Engineer
Jerzy Przybyiski	1st Engineer
Jarrad Taft	2nd Engineer
Wayne Lindgren	3rd Engineer
Keith Mitchell	Bosun
Matt Finn	Integrated Rating
Nathan Arahanga	Integrated Rating
Murray Dovey	Integrated Rating
Trent Wickham	Integrated Rating
Roger Davis	Integrated Rating
Sean Lawrence	Integrated Rating
Gregory Wight	Integrated Rating
Rose Crosdale	Integrated Rating
Darren Lilly	Integrated Rating
Cassandra Rowes	Chief Caterer
Brooke Saal	Chief Cook
Lynette McLaren	Caterer
Emma Carlos	Cook

Appendix 3: List of Camera Stations

Note: time, latitude, longitude and depth are taken from the camera log sheets and were recorded once the frame reached the seafloor. The voyage event log (http://data.aad.gov.au/aadc/voyages/display_voyage.cfm?voyage_id=555) includes details of the entire deployment, i.e. the start and end times and locations when the frames (CTD or beam trawl) entered and were removed from the water. The objectives column indicates the survey objective each station relates too (see Section 4). The rating column indicates the quality of the images at each site: 1 = good quality, 2 = ok quality, 3 = poor quality or no photos.

CAM #	STATION NAME	FRAME#	DATE (UTC)	TIME (UTC)	LATITUDE	LONGITUDE	DEPTH	OBJEC #	RATING	COMMENTS
1	CTD53_CAM01	CTD53	18-Jan-11	3:21:10	-65.53870	139.83800	1306	3	2	Photos out of focus
2	CTD54_CAM02	CTD54	18-Jan-11	5:38:00	-65.57167	139.84300	733	3	2	Strobes not firing properly, few useable photos
3	CTD55_CAM03	CTD55	18-Jan-11	9:11:36	-65.71200	139.85083	296		2	Not close enough to seafloor, photos out of focus
4	BT1_CAM04	BT1	18-Jan-11	11:26:40	-65.60067	140.00567	754	3	3	No altimeter, bottom not reached, no photos
5	CTD56_CAM05	CTD56	18-Jan-11	14:03:48	-65.63300	140.38233	1497	3	1	
6	CTD57_CAM06	CTD57	18-Jan-11	16:05:01	-65.65033	140.43200	1131	3	3	Strobes did not work, no photos
7	CTD58_CAM07	CTD58	18-Jan-11	18:08:48	-65.68617	140.52067	833	3	1	
8	BT2_CAM08	BT2	18-Jan-11	20:18:36	-65.69083	140.51700	807	3	2	No altimeter, only one strobe fired, few photos
9	CTD59_CAM09	CTD59	18-Jan-11	22:09:00	-65.70350	140.56650	425	3	1	
10	BT3_CAM10	BT3	19-Jan-11	0:07:15	-65.64500	140.57017	810	3	1	No altimeter
11	BT4_CAM11	BT5	19-Jan-11	6:47:58	-65.65233	141.65483	821	3	1	No altimeter
12	CTD61_CAM12	CTD61	19-Jan-11	15:39:02	-65.66067	143.02733	2385	3	3	Strobes did not work, no photos
13	CTD62_CAM13	CTD62	19-Jan-11	18:23:30	-65.72483	142.95200	2108	3	2	Not close to bottom for long
14	CTD63_CAM14	CTD63	19-Jan-11	21:00:40	-65.78333	142.94317	1451	3	3	Housing problem, no photos
15	CTD64_CAM15	CTD64	19-Jan-11	22:59:39	-65.81367	142.97333	876	3	2	Camera not in focus
16	BT5_CAM16	BT5	20-Jan-11	2:38:15	-65.81017	143.16467	569	3	1	No altimeter

CAM #	STATION NAME	FRAME#	DATE (UTC)	TIME (UTC)	LATITUDE	LONGITUDE	DEPTH	OBJEC	RATING	COMMENTS
17	BT6_CAM17	BT6	20-Jan-11	6:53:24	-65.81733	143.06133	643	3	3	No altimeter, strobes in mud
18	BT7_CAM18	BT7	20-Jan-11	11:05:36	-65.84317	142.84150	594	3	3	No altimeter, strobes in mud
19	CTD66_CAM19	CTD66	20-Jan-11	13:03:29	-65.92433	142.81467	423	3	1	
20	CTD67_CAM20	CTD67	20-Jan-11	14:55:34	-65.99333	142.60567	423	2	1	
21	CTD68_CAM21	CTD68	20-Jan-11	17:01:20	-66.00050	142.93550	456		1	
22	CTD69_CAM22	CTD69	20-Jan-11	19:00:07	-65.99883	143.31833	464		1	
23	CTD70_CAM23	CTD70	20-Jan-11	20:53:48	-65.99850	143.61250	433		1	
24	CTD71_CAM24	CTD71	20-Jan-11	22:40:26	-66.00183	143.90100	396		1	
25	CTD72_CAM25	CTD72	21-Jan-11	13:28:13	-66.16950	143.78800	467		1	
26	CTD73_CAM26	CTD73	21-Jan-11	15:07:50	-66.17167	143.48450	542		1	
27	CTD74_CAM27	CTD74	21-Jan-11	16:29:06	-66.18117	143.32200	553		1	
28	CTD75_CAM28	CTD75	22-Jan-11	0:27:49	-66.17633	143.15067	584		1	
29	CTD76_CAM29	CTD76	22-Jan-11	2:44:14	-66.15350	142.92750	562		1	
30	CTD77_CAM30	CTD77	22-Jan-11	4:37:32	-66.18250	142.73350	408	2	1	
31	CTD78_CAM31	CTD78	22-Jan-11	6:27:54	-66.31950	142.67000	384	2	1	
32	CTD79_CAM32	CTD79	22-Jan-11	8:47:56	-66.42400	142.98417	634		1	
33	CTD80_CAM33	CTD80	22-Jan-11	10:53:56	-66.37983	143.27633	729		1	
34	CTD81_CAM34	CTD81	22-Jan-11	13:30:49	-66.32817	143.70567	562		1	
35	CTD82_CAM35	CTD82	23-Jan-11	11:34:37	-66.32900	143.96467	520		1	
36	CTD83_CAM36	CTD83	23-Jan-11	13:31:16	-66.38233	143.82500	610		1	
37	CTD84_CAM37	CTD84	23-Jan-11	15:17:41	-66.45000	143.62833	730		1	
38	CTD85_CAM38	CTD85	24-Jan-11	4:13:04	-66.43850	143.63300	721		2	Repeat of previous site. Slightly out of focus
39	CTD86_CAM39	CTD86	24-Jan-11	5:58:17	-66.51450	143.45867	776		1	
40	CTD87_CAM40	CTD87	24-Jan-11	7:38:55	-66.55483	143.33367	821		1	
41	CTD88_CAM41	CTD88	24-Jan-11	9:22:51	-66.61833	143.16000	811		1	
42	CTD89_CAM42	CTD89	24-Jan-11	11:09:44	-66.67067	143.02650	650		1	
43	CTD90_CAM43	CTD90	24-Jan-11	12:54:00	-66.75450	143.05450	683		3	Steep site, too far from bottom, no photos
44	CTD91_CAM44	CTD91	24-Jan-11	14:39:55	-66.69950	143.33833	702		1	
45	CTD92_CAM45	CTD92	24-Jan-11	16:30:00	-66.71083	143.58783	586		1	

CAM #	STATION NAME	FRAME#	DATE (UTC)	TIME (UTC)	LATITUDE	LONGITUDE	DEPTH	OBJEC	RATING	COMMENTS
46	CTD93_CAM46	CTD93	24-Jan-11	18:48:11	-66.72017	143.97783	894		1	Too far from bottom
47	CTD94_CAM47	CTD94	24-Jan-11	20:40:20	-66.77383	144.18133	864		1	
48	CTD95_CAM48	CTD95	24-Jan-11	23:15:55	-66.84100	144.37717	759		1	
49	CTD96_CAM49	CTD96	25-Jan-11	1:46:34	-66.94867	144.47733	192	2	1	
50	CTD97_CAM50	CTD97	25-Jan-11	2:59:39	-66.92300	144.42483	189	2	1	
51	CTD98_CAM51	CTD98	25-Jan-11	4:53:37	-66.94900	144.07667	910		2	Deep hole, a little too far from bottom
52	CTD99_CAM52	CTD99	25-Jan-11	7:24:28	-66.77983	143.88800	286	2	1	
53	CTD100_CAM53	CTD100	25-Jan-11	9:21:17	-66.68733	143.68683	769		1	
54	CTD101_CAM54	CTD101	25-Jan-11	11:35:27	-66.60733	143.71483	761		1	
55	CTD102_CAM55	CTD102	25-Jan-11	13:57:45	-66.54250	143.70067	756		1	
56	CTD103_CAM56	CTD103	25-Jan-11	16:28:08	-66.52717	143.93100	782		1	
57	CTD104_CAM57	CTD104	25-Jan-11	18:28:45	-66.43083	144.13433	591		1	
58	CTD105_CAM58	CTD105	25-Jan-11	20:39:55	-66.35017	144.44633	448		1	
59	CTD106_CAM59	CTD106	25-Jan-11	22:38:05	-66.21217	144.50200	385		2	Too far from bottom
60	CTD107_CAM60	CTD107	26-Jan-11	0:15:50	-66.08667	144.67950	358		1	
61	CTD108_CAM61	CTD108	26-Jan-11	2:13:09	-65.96267	144.84767	705	3	1	
62	CTD109_CAM62	CTD109	26-Jan-11	3:51:15	-65.97867	144.91083	561	3	1	
63	CTD110_CAM63	CTD110	26-Jan-11	7:23:56	-66.32800	144.98567	392		1	
64	CTD111_CAM64	CTD111	26-Jan-11	9:05:56	-66.44800	144.83050	460		2	Too far from bottom
65	CTD112_CAM65	CTD112	26-Jan-11	11:02:20	-66.50283	144.63117	535		1	
66	CTD113_CAM66	CTD113	26-Jan-11	13:25:04	-66.51167	145.05467	434		1	
67	CTD114_CAM67	CTD114	26-Jan-11	15:31:45	-66.67667	145.34033	507		1	
68	CTD115_CAM68	CTD115	26-Jan-11	17:58:06	-66.65967	145.76317	381		3	Too far from bottom, no photos
69	CTD116_CAM69	CTD116	26-Jan-11	19:39:25	-66.65683	146.16267	174	2	1	
70	CTD117_CAM70	CTD117	26-Jan-11	20:44:48	-66.70800	146.17033	390	1	1	
71	CTD118_CAM71	CTD118	26-Jan-11	23:15:52	-66.79433	146.38133	416	1	1	
72	CTD119_CAM72	CTD119	27-Jan-11	1:42:33	-66.94617	146.56767	485	1	1	
73	CTD120_CAM73	CTD120	27-Jan-11	3:42:27	-67.08933	146.35283	488	1	1	
74	CTD121_CAM74	CTD121	27-Jan-11	5:59:10	-67.24350	146.51633	537	1	1	

CAM #	STATION NAME	FRAME#	DATE (UTC)	TIME (UTC)	LATITUDE	LONGITUDE	DEPTH	OBJEC	RATING	COMMENTS
75	CTD122_CAM75	CTD122	27-Jan-11	7:57:42	-67.39633	146.47350	624	1	1	
76	CTD123_CAM76	CTD123	27-Jan-11	10:20:15	-67.48817	146.80617	624	1	1	
77	CTD124_CAM77	CTD124	27-Jan-11	12:22:18	-67.52600	147.21333	545	1	1	
78	CTD125_CAM78	CTD125	27-Jan-11	14:29:10	-67.60200	147.57233	585	1	1	
79	CTD126_CAM79	CTD126	27-Jan-11	16:21:45	-67.68317	147.85267	564	1	1	
80	CTD127_CAM80	CTD127	27-Jan-11	20:11:29	-67.21033	147.71583	473	1	1	
81	CTD128_CAM81	CTD128	27-Jan-11	21:47:05	-67.20483	147.36567	457	1	1	
82	CTD129_CAM82	CTD129	27-Jan-11	23:27:15	-67.21050	147.04000	513	1	1	
83	CTD130_CAM83	CTD130	28-Jan-11	0:59:40	-67.20417	146.73833	501	1	1	
84	CTD131_CAM84	CTD131	28-Jan-11	4:16:07	-66.89500	146.40000	419	1	1	
85	CTD132_CAM85	CTD132	28-Jan-11	6:18:12	-66.88667	146.81900	565	1	1	
86	CTD133_CAM86	CTD133	28-Jan-11	8:35:27	-66.89033	147.21433	608	1	1	
87	CTD134_CAM87	CTD134	28-Jan-11	10:40:50	-66.91383	147.63467	621	1	1	
88	CTD135_CAM88	CTD135	28-Jan-11	13:34:37	-66.88200	148.44500	169	2	1	
89	CTD136_CAM89	CTD136	28-Jan-11	17:20:01	-66.48133	148.38583	201	2	1	
90	CTD137_CAM90	CTD137	29-Jan-11	6:32:54	-66.52600	147.11717	580	1	1	
91	CTD138_CAM91	CTD138	29-Jan-11	10:15:12	-66.25100	147.10383	477	2	1	
92	CTD139_CAM92	CTD139	29-Jan-11	13:42:25	-65.94333	147.26117	596	3	1	
93	CTD140_CAM93	CTD140	29-Jan-11	16:35:55	-65.98100	147.68133	629	3	1	