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PII: S0967-0645(16)30406-4
DOI: http://dx.doi.org/10.1016/j.dsr2.2016.12.010
Reference: DSRII4179

To appear in: *Deep-Sea Research Part II*
Accepted date: 16

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Keywords: Seamount, Pelagic Ecology, Oceanography, South West Indian Ridge

Abstract

The seamounts of the southern Indian Ocean remain some of the most poorly studied globally and yet have been subject to deep-sea fishing fleets for decades and may face new exploitation through mining of seabed massive sulphides in the future. As an attempt to redress the knowledge deficit on deep-sea benthic and pelagic communities associated mainly with the seamounts of the South West Indian Ridge two cruises were undertaken to explore the pelagic and benthic ecology in 2009 and 2011 respectively. In this volume are presented studies on pelagic ecosystems around six seamounts, five on the South West Indian Ridge, including Atlantis Bank, Sapmer Seamount, Middle of What Seamount, Melville Bank and Coral Seamount and one un-named seamount on the Madagascar Ridge. In this paper, existing knowledge on the seamounts of the southwestern Indian Ocean is presented to provide context for the studies presented in this volume. An account of the overall aims, approaches and methods used primarily on the 2009 cruise are presented including metadata associated with sampling and some of the limitations of the study. Sampling during this cruise included physical oceanographic measurements, multibeam bathymetry, biological acoustics, and net sampling of phytoplankton, macrozooplankton and micronekton / nekton. The studies that follow reveal new data on the physical oceanography of this dynamic region of the oceans, and the important influence of water masses on the pelagic ecology associated with the seamounts of the South West Indian Ridge. New information on the pelagic fauna of the region fills an important biogeographic gap for the mid- to high-latitudes of the ocean of the southern hemisphere.

1. Introduction

The waters around southern Africa are rich in seamounts. Vema Seamount, for example, was the site of one of the first modern investigations of seamount biology (Simpson and Heydorn, 1965). The waters of the Southeast Atlantic form one of the world's major eastern boundary current upwelling systems and host several significant ranges of seamounts including the Southern Mid-Atlantic Ridge, the Walvis Ridge, the Vavilov Ridge, the Aghulas Ridge and a number of more isolated seamounts (e.g. Vema Seamount) and rise features (e.g. Meteor Rise; see Fig. 1; SEAFO Scientific Committee, 2006; Clark *et al*., 2007; Bensch *et al*., 2008). The southern Indian Ocean also hosts significant submarine features including the Madagascar Ridge, the Mozambique Ridge and the South West Indian Ridge (SWIR), the last of which forms part of the global mid-ocean ridge system. Seamount ecosystems of both the Southeast Atlantic and South West Indian Oceans lie outside the main geographic foci of seamount research (North Atlantic, South West Pacific and North Pacific; Rogers *et al*., 2007), and basic information on species presence, biogeography and ecology are lacking. This is not the case for geological studies where the SWIR and Atlantis Seamount have received considerable research effort directed at understanding the tectonics of ultraslow-spreading ridges (e.g. Dick *et al*., 2003). Recent exploration has also resulted in the identification of hydrothermal plumes along the SWIR (e.g. Bach et al., 2002) and the location of the first hydrothermal vent ecosystem (Tao et al., 2012; 2014).

Despite the lack of understanding of the ecology of seamounts around southern Africa, exploitation of the biological resources of these ecosystems has taken place for nearly 40 years. These fisheries were pioneered in the 1970s by the Soviet distant-water fishing fleet, which at the time was one of the largest in the world (Romanov, 2003). In the Southeast Atlantic, the Vavilov and Walvis Ridges were targeted for alfonsino (*Beryx splendens* and possibly *Beryx decadactylus*), cardinal fish (*Epigonus denticulatus*) and pelagic armourhead or boarfish (*Pseudopentaceros richardsoni*) (Clark *et al*., 2007). In the South West Indian Ocean, the Soviet fleet targeted redbait (*Emmelichthys nitidus*) and rubyfish (*Plagiogeneion rubiginosus*) with catches peaking about 1980 and then decreasing to the mid-1980s (Clark *et al*., 2007). Fishing then switched to alfonsino in the 1990s as new seamounts were exploited. Some exploratory trawling was also carried out on the Madagascar Ridge and South West Indian Ocean Ridge by French vessels in the 1970s and 1980s, particularly targeting Walter's Shoals and Sapmer Bank (Collette and Parin, 1991). In the 1990s and early 2000s new fisheries developed in both regions. In the Southeast Atlantic, both within the Namibian economic exclusive zone (EEZ) and in the high seas, along the Walvis Ridge, these fisheries targeted orange roughy (*Hoplostethus atlanticus*). In the southern Indian Ocean, a major fishery developed on the high seas, along the South West Indian Ocean Ridge, targeting orange roughy, black cardinal fish (*Epigonus telescopus*), pelagic armourhead, oreos (Oreosomatidae) and alfonsino (Clark *et al*., 2007). In both cases, fisheries were characterised by a very rapid expansion of fishing effort followed by a collapse in catches (Boyer *et al*., 2001; Branch, 2001; Clark *et al*., 2007). In the South West Indian Ocean, fishing shifted to the Madagascar Plateau, Mozambique Ridge and Mid-Indian Ocean Ridge, targeting alfonsino and rubyfish (Clark *et al*., 2007).

The rapid depletion of deep-sea fisheries is cause for significant international concern and is incompatible with current international law and agreements related to management of fisheries (Rogers & Gianni, 2010). In the Southeast Atlantic, within the Namibian EEZ, rapid depletion of stocks of orange roughy reflected both the inherent vulnerability of the species to overexploitation, a lack of understanding of its biology and responses to fishing pressure (Boyer *et al*., 2001; Branch, 2001; Morato and Clark, 2007). On the high seas, particularly in the South West Indian Ocean and high seas areas of the Southeast Atlantic, deep-sea fisheries developed without assessment of stock size, sustainable levels of exploitation or any other form of management (Lack *et al*., 2003). In the South West Indian Ocean, the result of this was a rapid decline in fisheries, particularly for orange roughy within the space of a few years (1999 – 2003; Lack *et al*., 2003).

Over recent years it has also become clear that the main method used in fishing deep-water species, bottom trawling, is associated with significant damage to benthic ecosystems, particularly communities formed by deep-water corals, sponges and other attached fauna that provide habitat for other marine species. Observations of significant adverse impacts of fishing on deep-water coral communities have been reported from the northeastern and northwestern Atlantic and the northeastern and southwestern Pacific (Stone, 2006; Stone & Shotwell, 2007; Waller et al., 2007; Althaus et al., 2009; Williams et al., 2010). Such ecosystems have a poor capacity for recovery, as habitat-forming corals have slow growth rates, especially some Antipatharia and Octocorallia (Roark *et al*. 2006, 2009), and the coral habitat itself may have taken thousands of years to develop (Hall-Spencer *et al*., 2002). In some areas impacted by trawling, there have been observations of the occurrence on the seabed of small stylasterid corals and solitary Scleractinia as well as some octocoral species and urchins. These animals may not represent recovery of communities but rather are the elements of seamount communities that are resistant to trawling impacts, which live in refugia, or which live in refugia and subsequently spread to areas impacted by trawling (Clark and Rowden, 2009; Williams et al., 2010). In many cases, little or no recovery of pre-fishing seabed ecosystems have been observed even years after fishing impacts (Waller *et al*., 2007; Althaus et al., 2009; Williams et al., 2010). Seamount ecosystems are now also recognised as biological hotspots, sometimes with a higher biomass and diversity of benthic species than adjacent continental slope regions (Rowden et al., 2010) or communities with a distinct structure (McClain et al., 2009, 2010), although this is certainly not always the case

(Howell et al., 2010). They can also attract significant concentrations of ocean predators such as cephalopods, tunas, billfish, sharks, turtles, birds, pinnipeds, and cetaceans (Clarke, 2007, Holland and Grubbs, 2007; Litvinov, 2007; Kaschner, 2007; Santos et al., 2007; Thompson, 2007). The impacts of deep-water fisheries on such animals, through both direct impacts (by-catch of predators) and indirect impacts (disturbance and food-web effects), have not been resolved.

In the Southeast Atlantic, deep-sea fisheries on the high seas have now come under the regulation of a new regional fisheries management organisation (RFMO), the South-East Atlantic Fisheries Organisation (SEAFO). This RFMO has established total allowable catches (TACs) in its regulatory area for deep-sea species including orange roughy, alfonsino, pelagic armourhead, Patagonian toothfish and deep-sea red crab (SEAFO Scientific Committee, 2008). SEAFO have also undertaken measures to protect vulnerable marine ecosystems including: the closure of seamounts to fishing; the instruction of observers to collect data on by-catch of habitat-forming deep-sea species; support of scientific research on benthic ecosystems in the area; adoption of “move-on” rules when habitat-forming species are encountered by fishing vessels and the banning of gillnets in the SEAFO Regulatory Area.

In the southern Indian Ocean, an RFMO, the Southwest Indian Ocean Fisheries Commission (SWIOFC), was established in 2004, but focuses on the management of shallow-water fisheries, although some member states are investigating deep-water fisheries within their Exclusive Economic Zones (e.g. Mauritius or Mauritian dependencies on the Nazareth and St Brandon Banks; SWIOFC, 2009). In 2006, the South Indian Ocean Fisheries Agreement (SIOFA) was opened but ratification of this agreement was delayed until June, 2012. As this delay progressed it caused sufficient concern amongst several of the deep-water fishing companies in the area that in 2006 they formed an association to promote technical, research and conservation activities to furnish a future RFMO with data required for management of deep-water fisheries in the region (Shotton, 2006). This association is known as the Southern Indian Ocean Deepwater Fisher's Association (SIODFA). One of the first actions of this industry body was to declare a number of voluntary benthic protected areas (BPAs) in the South West Indian Ocean, including two seamounts, Coral Seamount and the Atlantis Bank, on the SWIR and part of Walter's Shoals, on the Madagascar Ridge (Shotton, 2006). These BPAs were established under a number of criteria, including scientific interest in the sites (e.g. Atlantis Bank) and the presence of fauna indicative of the presence of vulnerable marine ecosystems such as cold-water coral communities (e.g. Coral Seamount; Shotton, 2006). Coral Seamount and Atlantis Bank were subsequently accepted as Ecologically and Biologically Significant Areas (EBSAs) under the Convention on Biological Diversity (see link to Southern Indian Ocean at: https://www.cbd.int/ebsa/ebsas). In addition, SIODFA declared two additional BPAs, one in an area north of Walters Shoal (The Banana) and the other, part of Middle of What Seamount where significant areas of intact coral habitat were observed as part of the current project (SIODFA, 2013). SIOFA finally entered into force in June, 2012 with member states including: Australia, Cook Islands, the European Union, Mauritius and the Seychelles (http://www.fao.org/fishery/rfb/siofa/en).

To improve scientific understanding of the ecosystems and fisheries associated with the seamounts of the SWIR and to enhance the establishment of sustainable, ecosystem-based management of fisheries within the high seas of the southern Indian Ocean, a new project was established. This was funded by the Global Environment Facility (GEF) of the World Bank, the Natural Environment Research Council (NERC) of the U.K. and the United Nations Development Programme (UNDP) through the Agulhas and Somali Current Large Marine Ecosystems project (ASCLME). The project, *Applying an ecosystem-based approach to fisheries management: focus on seamounts in the Southern Indian Ocean* (GEF Project ID 3657), was coordinated and supported by the International Union for the Conservation of

Nature (IUCN), UNDP and the Fisheries and Agricultural Organisation of the UN (FAO). The Southern Indian Ocean Seamounts Project ran from 2009 to 2012 and involved participation by scientists from the United Kingdom, South Africa, Reunion, Madagascar and Mauritius, and by representatives of the fishing industry, mainly through SIODFA. The scientific effort in this project was focused on two cruises, the first, described here, which took place in November and December, 2009, was aimed at improving understanding of the pelagic ecosystem in the South West Indian Ocean and the interaction between the pelagic environment and both fished and unfished seamounts on the SWIR and the Madagascar Ridge. In November to December 2011, a second cruise focused on surveying the benthic ecosystems associated with the same seamounts took place. This second cruise also included physical oceanographic measurements and sampling of seawater for nutrient and microbiological analyses of the water column which is detailed in this volume (Djurhuus et al., this issue). In this paper the aims of this research project are outlined and the strategy and methods used in the first cruise on the R/V *Dr Fridtjof Nansen* are described.

2. Strategy and Approach

2.1 The Environmental Setting of the Seamounts

The SWIR separates the African and Antarctic Plates and has an ultra-slow spreading rate (full rate of 16 mm per year; Sauter *et al*., 2002). It extends approximately 7700 km from the Rodriguez Triple Junction to close to Bouvet Island in the Southern Ocean (Sauter and Cannat, 2010). The ridge is characterised by a very deep (>5000 m in places) and rough mid-axial valley and is cut by a series of north – south running transform faults (Münch *et al*., 2001), such as the Atlantis II and Novara transform faults that lie either side of Atlantis Bank

(Coogan *et al*., 2004). Near Marion Island/Prince Edward Island the ridge splits into two, one branch continuing as the SWIR and coming in to close proximity to the Mid-Atlantic Ridge at the Bouvet Triple Junction, the other forming the Madagascar Ridge. West of Bouvet Island in the Sub-Antarctic the SWIR terminates at the junction of the Bouvet Fracture Zone and the Spiess Ridge (Ligi et al., 1999; Fig. 1).

The Madagascar Ridge extends southwards from the microcontinent of Madagascar for about 1130 km (Fig. 1). The minimum depth is about 15 m on the summit of Walter's Shoals, which is located roughly 400 nautical miles (nm; approx. 720 km) south of Madagascar and 600 nautical miles east of South Africa, and has an estimated area of 400 km^2 shallower than the 500 m depth isobath (Groeneveld *et al*., 2006). This large and shallow seamount is covered, at its shallowest depths, with rhodoliths, formed predominantly by the calcareous algae *Mesophyllum syrphetodes* and *Tenarea tessellata* (Collette and Parin, 1991), and coral (Romanov, 2003). The slopes of the Shoals are reported to be steep. Other seamounts along the Madagascar Ridge are reported to have summit depths between 84 m to 1100 m (Romanov, 2003).

The SWIR and Madagascar Ridge lie in a region of the southern Indian Ocean dominated by a Sub-Tropical Anticyclonic Gyre (Demopolous *et al*., 2003; Sultan *et al*., 2007; Fig. 2). Topographic constraints exerted by the Madagascar Ridge and SWIR forces the separation of three small anticyclonic cells within the Sub-Tropical Anticyclonic Gyre, two to the east of the Madagascar Ridge and one between the Madagascar Ridge and South Africa (Sultan *et al*., 2007). The western boundary of the Sub-Tropical Anticyclonic Gyre is associated with a strong southward transport of water (~55 Sv) associated with the Agulhas Current. This current retroflects eastwards between 16^o and 20^{o}E to become the Agulhas Return Current (Lutjeharms and Van Ballegooyen, 1988; Fig. 2). Through the region of the present investigation, the southern boundary of the Agulhas Return Current is marked by the

Agulhas Front that lies to the north of the Sub-Tropical Front, to the south of which lies the Antarctic Circumpolar Current (ACC; Read *et al*., 2000; Fig. 2). The Agulhas Front has the steepest density gradient of any in the Southern Ocean, is narrow, with an average width of only 96 km, has a temperature of 21^{o}C – 15.7^{o}C, is optically clear, nutrient impoverished and is limited to about 40^{o}S (Read *et al*., 2000). The Agulhas Front can compress close to the Sub-Tropical Front so the two can be difficult to distinguish (Read and Pollard, 1993). The proximity of the Agulhas Return Current and the Sub-Tropical Front can lead to extreme temperature gradients (up to 1^{o}C per km; Read *et al*., 2000).

The Sub-Tropical Front forms the poleward boundary of warm salty water from the South Atlantic sub-tropical gyre (Read *et al*., 2000). It has mean latitude of 41^{o}40'S (Lutjeharms and Valentine, 1984), although its north-south position varies considerably. It is associated with a marked change in temperature of up to 7^{o}C and in salinity of up to 0.5‰ (Lutjeharms, 1985; Whitworth and Nowlin, 1987; Lutjeharms *et al*., 1993). It is a surface feature associated with the upper 300 m of the water column and its position and shape are influenced by bottom topography (Weeks and Shillington, 1996).

Below the surface water layers, in the regions to the north of the front, Sub-Antarctic Mode Water is located at the thermocline. This water is ventilated in the Southern Ocean, north of the Sub-Antarctic Front, and is associated with a maximum in oxygen. It moves with the subtropical gyre (McDonagh *et al*., 2008). This water mass is found down to about 500 m depth, in the vicinity of the SWIR. Below it occurs Antarctic Intermediate Water, which is also ventilated in the Southern Ocean, and is identified by a salinity minimum (McDonagh *et al*., 2008). This water reaches to about 1500 m depth around the SWIR. Underlying this water mass is Upper Deep Water which comprises mainly Indian deep water. It flows south and forms part of the Indian Ocean overturning circulation (Fig. 2). It exhibits an oxygen minimum, and high levels of inorganic nutrients (McDonagh *et al*., 2008), and penetrates to about 2000 m depth.

The deep-water circulation of the region is quite different to the shallow circulation. Between 2000 and 3500 m depth, modified North Atlantic Deep Water (NADW) flows into the Indian Ocean (McDonagh *et al*., 2008) along the African continental slope, up through the Mozambique Channel and around the southern SWIR and Del Cano Rise (Van Aken *et al*., 2004; Fig. 2). In the northwestern part of the region, the NADW flows up along the eastern slope of the Madagascar Ridge and then over the Ridge at about 35^{o}S. An additional flow comes through the SWIR via the Discovery Fracture Zone in the south (Van Aken *et al*., 2004; Fig. 2). This water eventually forms Circumpolar Deep Water (McDonagh *et al*., 2008).

Below this, the flow of Antarctic Bottom Water into the Indian Ocean is controlled by the SWIR. The main flow, from the Enderby Basin into the Aghulas Basin, is between 20^{o} and 30^{o}E, probably via deep channels (>4000 m depth) in the ridge (Boswell and Smythe-Wright, 2002). This water continues to flow northwards between the gap between the Agulhas Plateau and SWIR and then onto the Mozambique Channel. Another branch crosses the ridge at 35-36^{o}S through the Prince Edward Fracture Zone whilst a third branch passes along the southern flank of the Del Cano Rise (Boswell and Smythe-Wright, 2002).

Overall, the SWIR is set within an area where the Agulhas Return Current, the Sub-Tropical Front and the Sub-Antarctic Front, farther to the south (Fig. 2), create one of the most energetic and important hydrographic regions of the world (Read *et al*., 2000). The seamounts of the SWIR lie within an area of complex biogeochemistry, phytoplankton composition and productivity associated with the transition from sub-tropical conditions to sub-Antarctic (Bathmann *et al*., 2000) whilst those on the Madagascar Ridge lie within the Sub-Tropical Anticyclonic Gyre.

The Sub-Tropical/Sub-Antarctic Front has been associated with elevated concentrations of phytoplankton and zooplankton compared to the seas to the north and south (Froneman *et al*., 1998) and has been identified as a region important in carbon sequestration in the oceans (Llido *et al*., 2005). At the front, peak chlorophyll concentrations of >1 µg l^{-1} have been recorded with microphytoplankton making up a significant proportion (~10%) to total chlorophyll. Outside this region, with the exception of the Sub-Antarctic Front, chlorophyll concentrations have been measured at <0.9 µg l^{-1} and the nano- and picophytoplankton assemblages may be dominant (Froneman *et al*., 1998). It is thought that the accumulation of phytoplankton cells at the front, stability of the water column and availability of nutrients, especially iron may all contribute to elevated chlorophyll measurements (Lutjeharms *et al*., 1985; Weeks and Shillington, 1996; Froneman *et al*., 1998). The enhanced primary productivity of the Sub-Tropical Convergence Zone occurs in intermittent pulses in spring and summer (Llido *et al*., 2005). Species diversity of microphytoplankton may also peak at the Sub-Tropical Convergence as a result of mixing of species from different water masses and unique biochemical conditions which lead to a unique planktonic community that is poorly characterised, especially in regions away from continents (Froneman *et al*., 1998; Barange *et al*., 1998; Longhurst, 1998; Richoux and Froneman, 2009). Recent stable-isotope studies have also demonstrated that planktonic food webs undergo significant changes across the sub-tropical convergence in response to differing availability of phytoplankton and smaller zooplankton size classes (Richoux and Froneman, 2009). Thus, the seamounts along the SWIR are likely to be in contrasting productivity regimes depending on their proximity to the Sub-Tropical Convergence and the Sub-Antarctic Front. Advection of surface production to the benthos of seamounts will depend on the depth of the seamount summit and the current regimes around seamounts (Rowden *et al*., 2005; White *et al*., 2007). The Sub-Tropical Convergence is also thought to represent a major biogeographic boundary in the Southern Indian Ocean dividing two distinct faunal provinces of pelagic biota (Vierros *et al*., 2009).

Data on the diversity of biological communities of the southern Indian Ocean up to the 2009 cruise were sparse. More studies have been undertaken on Walter's Shoal than on the SWIR, probably because the former is closer to land than the latter and because of interests in commercial fisheries in the region. The shoal was sampled during the Indian Ocean expedition in 1964 by the R/V *Anton Bruun* and subsequently by the R/V *Vityaz*. These collections included a new endemic sub-species of crinoid, *Comanthus wahlbergi tenuibrachia* (Clark, 1972), prevalent in the shallow-waters of the shoal (Collette & Parin, 1991), and several crustaceans including an endemic species of alpheid shrimp (*Alpheus waltervadi*; Kensley, 1981) and an endemic isopod, *Jaeropsis waltervadi* (Kensley, 1975). Recently, an endemic species of rock lobster, *Palinurus barbarae*, has been described from the shoals following the landing of the species from commercial fishing vessels (Groeneveld *et al*., 2006). Collette and Parin (1991) described the fish fauna from ~400 m depth to the surface on the shoal (summit depth approx. 15 m) and identified 20 species of which several were potentially endemic undescribed species, several were widespread temperate or sub-tropical species and several were Indo-Pacific reef associated species. Biogeographic affinities of elements of the shallow fish fauna with Gough Island, Tristan da Cunha and St Pauls and Amsterdam Islands (West Wind Drift Islands) were identified, particularly in the occurrence of species such as *Helicolenus mouchezi*, *Trachurus longimannus* and *Serranus novemcinctus* (Collette and Parin, 1991). Others are found in Australia and New Zealand (*Acantholatris monodactylus, Lepidoperca coatsii, Nelabrichthys ornatus*). *Helicolenus mouchezi* and possibly several other species from Walter's Shoal also occur on the SWIR. The implication is that the Sub-Tropical Anticyclonic Gyre and Antarctic Circumpolar Current and/or other westerly flowing currents have assisted in transoceanic dispersal of these species, with islands and seamounts acting as stepping stones. Russian exploration of the Madagascar Ridge in the search of fisheries resources identified: dories (Oreosomatidae), sharks, *Alepocephalus* sp., *Beryx* sp., Macrouridae, Moridae, *Plagiogeneion rubiginosum*, *Polyprion americanus*, *Polyprion oxygeneios*, *Pseudopentaceros richardsoni*, scabbard fish, Scorpaenidae, *Trachurus longimannus*, tuna and members of the family Uranoscopidae.

Vereshchaka (1995) summarised several investigations on the macrozooplankton occurring on slopes and seamounts in the Indian Ocean. The paper lists a large number of taxa as occurring on Walter's Shoal and identified that species fall into two distinct group, those that were associated mainly with the water column and decrease in numbers towards the seabed, and those that are associated with the seabed. The latter group fall into several categories including: animals that are found near the seabed at night but disappear by day, presumably because they migrate to benthic habitats during daylight hours; animals found well above the seabed by night and descend to the seabed by day; larval animals which are found mainly over areas of seabed inhabited by adults (Vereshchaka, 1995).

Investigations of high seas areas of the Indian Ocean for fisheries resources were undertaken by Soviet research vessels and exploratory fishing vessels from the 1960s to 1998. Whilst detailed information is not available, the following species were identified as being present on the SWIR: *Alepocephalus* spp., *Antimora rostrata*, *Beryx splendens*, *Beryx decadactylus*, *Centrolophus niger*, Chauliodontidae, *Dissostichus eleginoides*, *Electrona carlsbergi*, *Epigonus* spp., Gonostomatidae, *Helicolenus mouchezi*, *Hyperoglyphe antarctica*, *Lepidopus caudatus*, *Macrourus carinatus*, Myctophidae, *Nemadactylus macropterus*, *Neocyttus rhomboidalis*, *Notothenia squamifrons*, *Plageogeneion rubiginosum*, *Polyprion americanus*, *Polyprion oxygeneios*, *Promethichthys prometheus*, *Pseudopentaceros richardsoni*, rays, *Ruvettus pretiosus* , *Schedophilus huttoni*, *Schedophilus maculatus*, *Schedophilus velaini*, sharks, *Trachurus longimannus* (Romanov, 2003). A more extensive species list is given in Romanov (2003) but this list is for all the seamounts sampled in the Indian Ocean from 1969-1998. It was noted that seamounts on the SWIR showed a marked variation in the fish present. For example, pelagic armourhead, *Pseudopentaceros richardsoni*, was almost exclusively caught on Seamount 690 (Romanov, 2003), which corresponds in position to Atlantis Seamount. Some of the species listed, such as *Dissostichus eliginoides* and *Electrona carlsbergi* are exclusively Antarctic/Sub-Antarctic.

Geological investigations have reported lobsters, crabs, sharks, sea fans, siphonophores, sponges and other benthic organisms on Atlantis Bank on the South West Indian Ocean Ridge (Dick, 1998). A single paper on ROV investigations reported the presence of crow shark (*Etmopterus pusillus*), orange roughy (*Hoplostethus atlanticus*) and warty oreo (*Allocyttus verrucosus*) all of which exhibited specific depths distributions (Lindsey *et al*., 2000). Other species observed included several putative species of bellows fish (*Centriscops* spp.), cutthroat eels (*Synaphobranchus* spp), rattail fish (*Coryphaenoides* spp., and possibly *Hymenocephalus* or *Ventrifossa*), attenuated spider fish (*Bathypterois atricolor*), a chimaera, tadpole whiptail (*Squalogadus modificatus*), a halosaur (*Alvodrandia* spp.), a morid cod (*Lepidion capensis*), several perciform fish (Haemulidae) and false cat sharks (*Pseudotriakis microdon*; Lindsey *et al*., 2000). Several benthopelagic or benthic shrimps were observed including *Hepomadus* sp., *Nematocarcinus* spp., and c.f. *Acanthephyra*, as well as sergestids and swarms of euphausiids above the seamount (Lindsey *et al*., 2000). Cirrate octopuses and squid were also observed as well as a pelagic holothurian. One of the photographs in the paper shows bellows fish in amongst colonies of Antipatharia and Octocorallia (Lindsey *et al*., 2000).

As with invertebrates and fish, knowledge of the distribution of aquatic predators, including cetaceans and birds, are sparse in the region. There have been sightings of concentrations of humpback whales in the vicinity of Walter's Shoal (e.g. Collette and Parin, 1991; Shotton, 2006), suggesting that it may be an important migratory area between high latitude feeding grounds and low latitude breeding grounds off Madagascar (Findley, 2009). There are also reports of pilot whales, humpback whales and sperm whales in the areas where deep-water fishing takes place in the southern Indian Ocean although it is not clear precisely where these were observed (Shotton, 2006).

Shotton (2006) reported that sightings of birds are rare in the areas of fishing, and these were rarely seen north of 35^{o}S. White chinned petrels (*Procellaria aequinoctialis*) had been reported as occurring in areas of deep-water fishing and cape pigeons (*Daption capense*) and sooty shearwaters (*Puffinus griseus*) were reported as being observed from fishing vessels (Shotton, 2006). Bird observations taken from a cruise between La Réunion, Crozet, Kerguelen, St. Paul, Amsterdam Islands, and Perth, Western Australia identified 51 species of birds from over 15,000 sightings (Hyrenbach *et al*., 2007). During this cruise the density of birds increased significantly across the Sub-Tropical Convergence from 2.4 birds km^{-2} in sub-tropical waters to 23.8 birds km^{-2} in sub-Antarctic waters. The taxonomic composition of birds also differed markedly in the 3 areas with prions (*Pachyptila* spp.) accounting for 57% of all sub-Antarctic birds, wedge-tailed shearwaters (*Puffinus pacificus*) accounting for 46% of all subtropical birds, and Indian Ocean yellow-nosed albatross (*Thallasarche carteri*) accounting for 32% of all birds in the sub-tropical convergence zone (Hyrenbach *et al*., 2007). Given that this cruise transited part of the SWIR it would seem likely that significant numbers of seabirds are present in the vicinity of the seamounts, particularly in the more southerly areas.

2.2 The aims of the project

The Southern Indian Ocean Seamounts Project focused on a number of scientific questions of relevance to management of deep-sea fisheries in the region. In the context of the R/V *Dr Fridtjof Nansen* Cruise the key questions included:

- What is driving the seamount fisheries (energy supply to the seamount ecosystems)?
- What are the pelagic communities of southern Indian Ocean seamounts like and how diverse are they (global importance, biogeography)?
- What influence do the seamounts of the SWIR exert on the pelagic ecosystem?
- What are the impacts of the past and current deep-sea fishing activities on seamount ecosystems?
- Could the BPAs actually benefit fishing?
- Which seamounts should be fully protected because of their high ecological value, and which others can remain open to fishing subject to regulations to prevent significant adverse impacts to marine biodiversity?

Such a range of questions demanded a multidisciplinary scientific approach addressing aspects of geology, physical oceanography, pelagic ecology, and observations of aquatic predators.

2.3 Geographic scope of studies

Five seamounts were selected for investigation along the SWIR (Table 1, Fig. 1 & 2). These seamounts included both features that were designated as BPAs by SIODFA and those that remained unprotected but still subject to fishing. The seamounts were located north of the Sub-Tropical Convergence and to the south in sub-Antarctic waters, and they represented a range of morphologies and summit depths from ~90 m to 1000 m (see Table 1, Figs. 1, 2). In addition, a seamount to the north of Walter's Shoals was identified from the Gebco bathymetry database as a comparative site on the Madagascar Ridge, to be investigated, should time allow on the cruise. This site was surveyed and found to have a summit depth much deeper than indicated by the Gebco bathymetry (Table 1). In addition, four non-seamount locations were selected for study as a comparison to seamount stations, three to the north of the Sub-Tropical Convergence Zone and one to the south (Table 1). Two CTD sections with phytoplankton sampling were also taken across the Sub-Tropical Convergence to investigate the structure of the water column and changes in fluorescence, chlorophyll, and the phytoplankton community across the complex frontal systems lying above the SWIR (Fig. 2; see below).

2.4 Sampling strategy

In order to achieve a quasi-synoptic picture of the pelagic ecosystems along the SWIR a combination of sampling strategies were employed on the R/V Dr *Fridtjof Nansen*. This involved (a) continuous observations along the ships track and (b) point observations at predetermined stations at the seamounts, non-seamount sites and CTD sections. Because of the limitations of operating with a single cruise across such a large section of ridge, sampling was restricted to the upper 1500 m of the water column. This was because of time constraints and also because the influence of the deep-scattering layer of diurnally migrating organisms was likely to have most influence in this depth range. Regardless of logistical constraints, the effective operation of much of the equipment used during the surveys (e.g. split-beam acoustics, net monitors etc.) was restricted to depths of less than 1200 m anyway.

2.4.1. Continuous observations

Continuous observations were undertaken as the vessel was underway to achieve several aims:

- To document the large-scale changes in the physical environment
- To map the vertical and horizontal distribution in biological backscatter down to 1000 m depth.
- To map the density and diversity of aquatic predators (birds and cetaceans) along the cruise track and on stations associated with, or not associated with seamounts.

The sampling equipment used included:

Split beam echosounders

Acoustic data were collected using a calibrated Simrad EK60 split-beam scientific echosounder (Kongsberg Maritime AS, Horten, Norway) operating at 18, 38, 120 and 200 kHz. The transducer array was mounted on the drop keel of R/V *Dr Fridtjof Nansen* at a deployed depth of 8.0 m. The EK60 was operated in synchronisation with a vessel mounted ADCP and a bottom-mapping multibeam echosounder, with the EK60 38 kHz transducer setting the master ping rate. Pings were transmitted with a pulse duration of 1024 ms. Acoustic signals were digitised and processed with Simrad ER60 software (Kongsberg Maritime AS, Horten, Norway) and logged in a raw format for post processing. Acoustic data quality was monitored in real-time using the ER60 software and near real-time using Echoview software (Myriax Pty Ltd. Hobart, Tasmania, Australia).

Transducer parameters were estimated by calibration following the procedures of Foote *et al.* (1987). The most recent calibration was conducted by the *Nansen's* technical staff on 14th June 2009 at Baia dos Elefantes, Angola (13°13'S 12°44'E) at a bottom depth of 32 m (T. Mørk, personal communication).

A copper calibration sphere (diameter 64 mm) was used for the 18 kHz sounder, a copper sphere (diameter 60 mm) was used for the 38 kHz sounder and a tungsten carbide sphere (diameter 38.1 mm) was used for the 120 and 200 kHz sounders. Theoretical target strengths for those spheres were adjusted to the speed of sound as calculated from local water temperature and salinity (c=1518 ms^{-1}). Parameter estimates are given in Appendix 1.

Acoustic Doppler Current Profiler (ADCP)

A hull-mounted ADCP was used to record current sheer throughout the cruise. The instrument was an RDI Ocean Surveyor 150 kHz model, system serial number 1533 and transducer 3067 running vmDAS version 1.44 with 30° beam angle. Transmissions were synchronised with the other acoustic equipment on board (EM710, EK60), such that the ADCP was triggered by the 38 kHz transducer of the EK60 to ping, before it transmitted. This led to a lower data rate than the instrument is capable of but it provided good data over the top 300-400 m of the water column for most of the cruise.

The instrument was configured with one hundred 8 m bins, 8 m blank beyond transmit and zero transducer depth. Bin depths were corrected during processing using the RDI formula:

Central depth of first bin = blank distance (WF) + 0.5 * (bin size + xmt length + lag)

where the blank distance = 10 m, bin size = 8 m, xmt length = 8 m and lag = 0.74 m. Together with the vessel's draft of 5.5 m, an estimated first bin depth of 24 m was applied. Individual pings were internally corrected for ship's heading using the 1 second NMEA input from the Seatex Seapath 200. Data were averaged internally over 3 minutes (STA) and 20 minutes (LTA). During the cruise, the 3-minute averages were read into pstar, corrected for ship's velocity and plotted for the acoustic grids, CTD yoyo's and transects. No calibration for misalignment angle was attempted during the cruise. The first acoustic survey (event 2) provided coherent data (i.e. no divergence between the lines of the grid) indicating that any misalignment angle must be small.

The Seatex Seapath 200 (S/N 2261) integrated navigation sensor of the R/V Dr *Fridtjof Nansen* provided real-time heading, attitude, position and velocity. These were obtained by integrating the signals from an inertial measurement unit (MRU 5) and two GPS antennae. The Seatex MRU 5 incorporated 3-axis sensors to measure linear acceleration and angular rate and the output was processed in the Seapath processing unit using a Kalman filter to produce roll, pitch, heave and velocity measurements. Roll, pitch and heading were passed to the vessel's ADCP in NMEA format.

Thermosalinograph

Surface measurements of temperature, salinity and fluorescence were made using a Seabird SBE 21 SeaCat thermosalinograph. Data were presented as 1 minute averages in the daily cnv files. Meteorological measurements were provided, although no air pressure was recorded in the data files.

Weather recording system

Meteorological data logged from the Norwegian Meteorological Institute (DNMI) meteorological station included air temperature, humidity, air pressure, wind direction and speed, and sea surface temperature (SST). All data were averaged by unit distance sailed (1 nm). The incoming irradiance or PAR (photosynthetic irradiance) had been removed from the meteorological system and so these data were not available.

Cruise log system

Cruise data were logged using the NANSIS Survey Information System for logging, editing and analysis of biological and environmental data from marine research surveys (available at - http://www.imr.no/forskning/bistandsarbeid/nansis/nansis/en)..

The key features of this software are:

- Main database: Postgres SQL for safe storage of data and linking with other databases;
- Track log module: for logging and visualization of continuously recorded data, weather stations, GPS and echosounder data;
- Bridge log module: vessel activity diary;
- Nansis main window for work with survey data including:
    - Initialization of new surveys
    - Data punching modules for data collected during research surveys
    - Reporting system of collected data
    - Scripting module and Nansis Post Processing
- Nansis Map tool: data visualization and biomass estimation;
- Nansis briefcase: transfer of data between two databases;
- Spread sheet like export facilities to link up with other analytical and map software;
- Nansis help menu for installation and use of all modules in the system

Multibeam echosounder

Surveys of the entire cruise track and of seamount bathymetry were undertaken using a SIMRAD EM710 70 – 100 kHz multibeam echosounder (Kongsberg Maritime AS, Horten, Norway). This is a high-resolution seabed mapping system which, on the R/V *Dr Fridtjof Nansen* is logged onto the Olex navigation system (Olex AS, Pirsenteret N-7462, Trondheim, Norway). The minimum acquisition depth is from less than 3 m below its transducers, and the maximum acquisition depth is approximately 2000 m, although somewhat dependent upon array size. Across-track coverage (swath width) is up to 5.5 times water depth, to a maximum of more than 2000 m and the depth resolution is 1cm (Kongsberg Maritime). The transmit fan is divided into three sectors to maximize range capability, but also to suppress interference from multiples of strong bottom echoes. The sectors are transmitted sequentially within each ping, and use distinct frequencies or waveforms. All acoustic instruments used during the cruise were triggered by the 38 kHz signal from the SIMRAD EK60. Timing of each instrument can be finely adjusted on the vessel to avoid interference between instruments if the vessel is, for example, operating in shallow water. The model on the R/V *Dr Fridtjof Nansen* is a 1 x 2^o model which generates 128 beams/200 soundings per ping. Following collection of raw data for each seamount, data were filtered to remove obvious bad pings (echos that are much higher or lower than background).

Predator observations

During the entire mission, two observers (EB, PP) surveyed marine birds and mammals. Observations were made from the unenclosed bridge of the vessel *Dr Fridtjof Nansen* during daylight hours while the vessel cruised at speeds around 10 knots. Following the transect methods (Tasker et al., 1984), a 300 m strip-width transect band was used, with the two observers surveying each sides of the vessel (i.e. 600 m band). Censuses were continuous, all individuals or groups being identified at the lowest possible taxonomic level. The observer on watch estimated the number of seabirds in the flock, all taxa combined. If more than one taxon was present, percent composition of each species in the flock was also estimated. The behaviour of each bird (sitting, flying, feeding, ship following) and the presence of surface-dwelling fishes or mammals were recorded. Photography was also taken during each transect in order to help determination of species identifications. Also, when the ship was stopped, many observations were made opportunistically in order to complete the seabird sightings but were not taken into account for the density analysis (presence only).

During the cruise, two types of census were undertaken:

1) Transects between seamount stations (see Table 2 for surveyed transects)

2) On the seamounts, four transects were selected along the 10 nm grids for acoustic surveys, representing 24 km² surveying per station (see Table 2 for seamounts surveyed).
The results of these surveys are not presented in this volume.

2.4.2 Point sampling at seamount and non-seamount stations

Hypotheses relating to what drives the biological communities of seamounts fall into two main categories, (a) enhanced primary productivity or (b) trophic focusing (Rogers, 1994; Genin, 2004; Genin and Dower, 2007). Enhanced primary production is theoretically possible if current – topography interactions lead to upwelling of nutrient rich deep water around a seamount, or enhance the stability or mixing of the water column above a seamount (White *et al*., 2007). Typically, this form of enhancement of primary production was thought to be possible where the presence of a Taylor column or cone was generated by the flow of water past the summit of a shallow seamount (Rogers, 1994; Clark et al., 2010). However, observations of long lasting elevated levels of plankton over seamounts are rare (Genin & Dower, 2007), with the best example probably being the Northwest Georgia Rise, in the South Atlantic. Here, a Taylor Column, a warm-core anticyclonic circulation, is frequently generated enhancing primary productivity above the bank (Meredith et al., 2003). However, the presence of this feature is influenced by the strength of the Southern Antarctic Circumpolar Current Front and it cannot be regarded as permanent (Meredith et al., 2003). Tidal forcing may be an alternative mechanism that can generate rectified flows above seamounts. Tidally forced circulation can generate anticyclonic flow above seamounts and a cold, dense dome over the seamount similar to a Taylor column (White et al., 2007). Tidally-driven phenomena such as anticyclonic vorticity, the formation of trapped or internal waves can be important in current acceleration and turbulent mixing, influencing the distribution of suspension feeding benthic communities (Clark et al., 2010).

Trophic focusing may occur through a variety of mechanisms, including the trapping of the diurnally migrating elements of the deep-scattering layer (topographic blockage), asymmetric flow acceleration on the flanks or summits of seamounts leading to enhanced horizontal flux of organic material (phytoplankton, zooplankton) across a seamount or advection of such material from the far field (White *et al*., 2007). There are also potential links in benthic and pelagic food webs that may enhance productivity in fish populations around seamounts (Pitcher and Bulman, 2007). Investigations of the diet of benthopelagic fish on Seine Seamount (summit depth ~ 170 m), in the North Atlantic Ocean, indicated that they relied on pelagic food sources but that these were mainly non-migrating or weakly migrating zooplankton (mainly copepods; Hirch and Christiansen, 2010). This suggests that diurnally migrating zooplankton and micronekton were not an important component of the diet of seamount-associated benthopelagic fish as would be expected with the topographic blockage hypothesis (Hirch and Christiansen, 2010).

Ascertaining which physical and biological processes may be in operation at the seamounts of the SWIR required a combination of observations relating to geomorphology of the seamounts, oceanography, acoustics, and biology, the latter ranging from analyses of phytoplankton communities and particulate organic carbon to net sampling of zooplankton, micronekton and fish communities. Each seamount was mapped, a stratified acoustic survey of the deep scattering layers undertaken and at least one CTD transect taken across the seamount to analyse general structure of the water column and currents. A 24-hour CTD yo-yo was also undertaken on the flanks or summit of each seamount to analyse tidal effects on the hydrographic structure including the identification of upwelling events or generation of internal wave features. Biological sampling was aimed at assessing the possibilities of enhanced primary production around seamounts and for ground-truthing of acoustic surveys as well as studies associated with biodiversity of pelagic communities. This sampling included the use of a large pelagic trawl (Åkra trawl) capable of sampling large size-classes of fish (up to >1m in length) for studies associated with trophic focusing on the target seamounts. Non-seamount stations did not require detailed CTD observations through transects or CTD yo-yos whilst CTD sections involved only measurements associated with oceanography and phytoplankton studies (Table 3). The location of each seamount and non-seamount station is listed in Table 1, the location of CTD section stations are listed in Table 2.

Biological net sampling

Phytoplankton net

An 80 μm ring net (Fig. 3) was deployed vertically to below the Deep Chlorophyll Maximum (DCM) and winched up to the surface at 0.5 ms^{-1}. The contents of the cod-end were washed into a 250 ml honey jar containing 2% Lugols solution and stored for later analyses. Stations are recorded on Table 2.

Multinet mesozooplankton sampler

Mesozooplankton samples were collected with Hydrobios MultiNet MiDi zooplankton sampler that takes up to five discrete samples at predefined depths while measuring the water flow through the net (Fig. 4). The Multinet has a 50×50 cm mouth opening and 180 μm mesh size and was fished obliquely to take samples from 5 depth strata (Falkenhaug 2007; Hosia *et* *al*. 2008; Wenneck *et al*. 2008). While the ship was steaming at 0.3-0.5 m.s^{-1} the Multinet was lowered to a maximum of 200 m. Nets were then triggered at the selected depth intervals. Net changing was controlled by down-wire link from a Net Command Unit. The volume of water filtered was measured by Hydrobios Electronic Flowmeters situated internally and externally on the net frame and was between 8 and 200 m^3 per net. Nominal depth intervals alternated between two sets of standards deployments: Stratified/Biogeographic and Fmax.

Upon recovery of the multinet samples were rinsed into the cod end and thoroughly washed into a sieve with a 180 μm mesh. The contents of the sieve were then washed into a sample jar using a water bottle filled with ambient seawater retrieved from the cod-ends and split into two fractions using a Folsom splitter (Sell & Evans, 1982). One fraction was preserved on 95% ethanol for genetic analysis and the other was preserved on 4% borax- buffered formaldehyde. We visually inspected multinet samples for diversity and bio-volume estimates.

For DCM studies, samples were washed through a 180μm sieve and fixed in 4% borax-buffered formaldehyde. Sample jars were placed in a black plastic boxes for 24 hours. After 24 hours, the approximate volume of zooplankton in each sample was recorded using a ruler (in mm) and the data were entered into a log. The main types of zooplankton observed in each sample were also identified and recorded. Thereafter, the samples were placed back into the black boxes for storage and for further laboratory analysis subsequent to the cruise.

Bongo nets

A bongo net with 375μm and 500μm mesh nets was deployed at all stations (Fig. 5). Three replicate samples from day time and night time hauls were treated in different ways. For one net out of three, the 375µm net was carefully washed through 1mm and 64µm sieves. Thereafter each zooplankton size-fractioned sample was placed into a blue opaque vile and dried in an oven at 50°C. The sample from the 500µm net was washed into a 180 ml honey jar and immediately preserved in 4% buffered formaldehyde for analyses of fish larvae.

For the second net the 500 and 350µm nets were washed through 1mm and 64µm sieves and were immediately preserved in 10% seawater formaldehyde. In the final net the 500µm net codend was removed and the mesozooplankton were preserved in formalin for subsequent taxonomical analysis. Samples from the 375µm net cod-end were removed and preserved on ethanol for subsequent genetic analysis of species diversity.

Double-warp fish trawl (Åkra trawl)

Two pelagic Åkra trawls were used for fishing. The larger net, a Flytetrål 152 MSK x 3200mm, with a 20m net mouth opening, was used for most trawls (Fig. 6). The smaller net, with a 10m net mouth opening, was used for faster trawl attempts targeting what were believed to be aggregations of larger fish mainly at dawn. Both nets were fitted to a 24mm trawl wire which was paid out to 2.5 x the target fishing depth. Both nets used two Tuberin combi trawl doors of 1750kg each. Trawling was undertaken between 2 to 3 knots vessel speed.

The Åkra trawl net was fitted with a multisampler for the first deployment. The first three trawls undertaken at Station 2 (all labelled as Event 7) were made using this apparatus. Damage to the multisampler which occurred during recovery of these first trawls meant that it could not be used in successive trawls. Though specific sampling depths were targeted during all trawls the net mouth remained open for the duration of fishing. Incidental catches made during deployment to and recovery from the target depths could therefore not be avoided. This catch was minimised by a quick recovery speed once the nets had been hauled from the target fishing depth.

Prior to each trawl, ice-trays for sorting and sample labels were prepared. Each label had a unique number although they were not used in a consecutive order. Upon arrival on deck the cod end was immediately emptied into large plastic tubs. Particularly large or interesting samples and samples in very good-condition were removed for photography and the rest of the catch emptied into large trays of ice (the fish sorting area was open to the deck and ambient air temperature could be high). A small amount of seawater was added to each tray to prevent the samples freezing to the ice. The catch was largely sorted into fish, cephalopod, crustacean, gelatinous zooplankton, and other abundant invertebrate groups.

Fish which could not be immediately identified were photographed and stored in formalin. If a second specimen was available, it was stored in ethanol for later genetic analysis. Juvenile and larval stages of fish and crustaceans were preserved in ethanol. All other fish were identified, measured for total length and standard length and frozen in individual zip-lock bags. Very large fish were stored in black bin liners. Additional head length and pre-anal fin length measurements were taken for grenadiers. All large fish were weighed. Labels were fixed to large fish by tying on a loop of string through the mouth and gill slits. Labels were tied around the mantle-arm join or around an individual arm of large cephalopods. All other frozen samples were stored in individual zip lock bags with labels inserted. Formalin and ethanol-stored samples were contained in individual buckets, jars or bottles, with labels inserted.

Crustaceans were identified and species diversity was recorded before weighing and fixing in bulk. All other invertebrates were sorted into broad categories and weighed and fixed in bulk. Fractions of every group were fixed in formalin and ethanol, respectively, and an attempt was made to ensure that representatives of every putative species were included in each fraction. For the first 26 trawls (up to and including trawl 26: station 8, event 13) myctophids were individually labelled and frozen after measuring. From trawl 27 (station 8, event 17) onwards myctophids were individually measured but stored together in one container of ethanol with one sample number per trawl. This decision was made based on a shortage of small bags and time constraints during trawl processing. Between 50 and 200 myctophids (in addition to those measured) were taken from each catch and stored in ethanol for later genetic work. Note that the measured myctophids are likely biased towards the larger individuals in each catch.

Small tissue samples were taken from behind the dorsal fin of a subsample of 382 fish by the South African Institute for Aquatic Biodiversity (SAIAB) and stored in ethanol for genetic analysis. Further samples of tissue of both fish and invertebrates were collected for phylogenetic and population genetics studies. Tissue samples from the mantle or arms were collected from large cephalopods and stored in ethanol for genetic analysis. Crustacean and some cephalopod samples were frozen for stable isotope analysis from trawls 23-25, 31, 35, 37, and 38.

Trawls 12 (station 5, event 23), 29 (station 8, event 19) and 40 (station 10, event 29) were recorded in their entirety. All other trawls have a “rest of catch” component labelled, weighed, and split between formalin and ethanol storage. This component is the sieved mixed remains of the catch which were not sorted because of time or logistical constraints. This portion typically represented 0.5 – 1.5kg of the total catch for each trawl. Fish and cephalopod samples were lodged with SAIAB.

Oceanographic instruments

CTD system and Niskin bottles

Conductivity, temperature and pressure data were collected using a SeaBird Electronics SBE 911+ CTD and deck unit, together with an SBE 43 dissolved oxygen sensor and Chelsea Instruments Aquatracka Mk III fluorometer. A 12-way rosette holding twelve 5-litre Niskin bottles was used to collect water samples.

CTD 911+ SBE CTD and deck unit details:

CTD serial no 09P8109-0316

Deck unit serial no 11P8109-0305

Pressure sensor serial no. 53966

Temperature sensor serial no. 4143

Conductivity sensor serial no. 2037

SBE43 dissolved oxygen sensor replaced for station 1398 with serial number 431277

Chelsea instruments Aquatracka Mk III serial number 88/2615/119

12-way rosette with 12 x 5-litre bottles (several of these were lost during the cruise and were replaced by older bottles).

The system worked well throughout the cruise and a total of 423 stations were sampled.
A number of Niskin bottles were lost during bad weather and had to be replaced. The first six bottles were lost on station 1273 and only 9 bottles were available for station 1274 until more could be assembled from spare parts. After this time bottles 11 and 12 regularly leaked or

failed to close. To protect against worn cable, the cable was coiled around the top of the CTD frame several times during the cruise. The CTD termination was re-made after station 1490.

Lowered ADCP

A Teledyne RDI Sentinel “moored” ADCP was attached to the CTD frame and deployed as a lowered instrument during the cruise. This system used an old potting compound with the known problem of breaking up with cyclic pressurisation. However, it was discovered that the holding bar of the CTD frame was distorted under the weight of the ADCP and since no alternative method of deployment could be found, the use of this instrument ceased for the rest of the cruise. Stations with lowered ADCP data were as follows:

1215, 1216 – between Reunion and Atlantis

1342,1343,1344,1345,1346 – Sapmer transect

1384,1385,1386,1387,1388,1389 – Middle of What transect

1390,1391,1392,1393,1394,1395,1396,1397 – STC/SAF transect

Satellite data

Merged sea surface height images and absolute surface velocity estimates were received on a daily basis (data were obtained in real-time from AVISO, http://www.aviso.oceanobs.com/). These provided a low-resolution map of the circulation of the region and proved invaluable in planning the location of sections and “off seamount” surveys. They also allowed tracking of the approximate position of the frontal systems over the SWIR as well as the occurrence of significant eddies and rings within the boundary region between cold and warm waters. Satellite chlorophyll data were obtained in weekly composite maps from the MODIS satellite.

3. Sampling operations

Physical data

Oceanographic measurements

Measurements were undertaken to build-up a picture of the overall structure of water masses and currents both off and on the SWIR. Continuous observations, including surface salinity, temperature and fluorescence along with hull-mounted ADCP, satellite sea-surface height and absolute current measurements and weekly satellite surface chlorophyll estimates, provided a picture of the large-scale distribution of water masses and surface currents as well as proxies for surface productivity. Over each seamount a short, full-depth, CTD transect was undertaken to measure background density gradients and water mass properties (Table 2). In addition, a 24 hour CTD yo-yo was undertaken at or near the seamount crest, in order to provide details of the tidal cycle, inertial oscillations, internal waves and any short-term periodic flow (Table 2). ADCP surveys were undertaken contiguous to the grid-surveys undertaken for multibeam mapping of the seamounts and split-beam acoustic studies of water column biology (see below; Table 3). Overall, these measurements gave a synoptic picture of the occurrence of phenomena such as isopycnal doming over the target seamounts as well as the possibility of detecting tidally-driven rectification or other small-scale oceanographic features (Pollard & Read, 2017; Read & Pollard, 2017). These data were potentially important in interpretation of data obtained through net sampling and acoustic surveys over the target seamount areas.

Multibeam bathymetry

Accurate maps of each target seamount were a pre-requisite to planning of net sampling as well as providing information on the overall shape and complexity of topography potentially important in the interpretation of oceanographic data. On seamount stations multibeam data were collected along ten line transects with a systematic survey design (length = 10nm, inter-transect spacing = 1nm; Table 3). Transect orientation was chosen as a compromise between minimised vessel pitch and bubble entrainment on one hand, which was weather dependent, and maximised seamount coverage on the other. The centre points of the survey grids were chosen arbitrarily within the above constraints. To allow for timing of other sampling operations on the cruise, survey grids were usually separated into two parallel, interlaced grids of 5 transect lines with a 2nm spacing, both parts of the complete grids were usually surveyed within 48 hours. Additional multibeam data were collected while the vessel was underway or completing other operations. Two-dimensional maps of the 6 seamounts are presented in Figures 7-12.

Biological observations

Acoustics

As with measurements for physical oceanographic studies surveys with the split-beam echosounder systems on the R/V *Dr Fridtjof Nansen* were aimed at ascertaining the structure of pelagic communities both on and off the SWIR. The EK60 was running and logging data throughout the cruise, providing acoustic data while the vessel was underway as well as during fishing operations and CTD deployments (albeit of low quality). Over the target seamounts of the SWIR, and also two non-seamount stations (one in sub-tropical waters and one in sub-Antarctic waters), multifrequency acoustic data were also collected along ten line transects with the systematic survey design (length = 10nm, inter-transect spacing = 1nm; Table 3) as described for the multibeam bathymetry surveys. Acoustic grids were surveyed during daytime only, usually from sunrise to mid-day.

Biological oceanography

The Deep Chlorophyll Maximum (DCM) and bottle sample depths were identified on the downcast and Niskin bottles were triggered on the upcast. Fluorescence was measured by an AQUAtracka III (Chelsea Technologies Group Ltd). Two Niskin bottles were triggered at DCM for POM and phytoplankton purposes. Water was collected from five potential depths, i.e. 1) Surface, 2) Below Surface (normally 20 m), 3) Below Surface and above DCM (normally around 40 – 50 m), 4) DCM (can be anywhere from surface to >100 m) and 5) Below DCM (next station below DCM that has a visibly lower fluorescence). Samples were collected for size fractionated chl-a, phytoplankton identification, nutrients and particulate organic matter (POM). Half a litre (500 ml) of water from each of the five (or less depending on the depth of DCM) depths were filtered through a Sartorius filter tower cascade set-up with the following filter paper:

a. Top: 20 µm Nylon Net Millipore filter to collect microphytoplankton

b. Middle: 2 µm Macherey-Nagel filter to collect nanophytoplankton

c. Bottom: 0.7 µm GF/F Whatman filter to collect picophytoplankton

The filter papers were sealed in tin foil, labeled and placed in a -20°C freezer for later analyses. A litre of water were collected from the surface and the DCM Niskin bottle, preserved with 2% Lugols (20 ml) and stored for phytoplankton cell counts.

Nets and trawls

Phytoplankton net

The 80 µm ring net was deployed vertically to below the DCM and winched up to the surface at 0.5 $m.s^{-1}$. At least three casts were undertaken in day and also at night (Table 2).

Bongo net

The bongo was deployed to ~200 m depth and retrieved over ~30 min. A flow meter was mounted inside the mouth of one net and the meter readings before and after each tow, along with the time down, was recorded. Three Bongo net hauls were conducted at day and night at each station to avoid diel vertical migration bias (Table 4). Samples from the three day and three night hauls were preserved in different ways (see above).

Multisampler net

For Stratified/Biogeographic studies the nominal stratified ranges were 250-200, 200-150, 150-100, 100-50 and 50-0 m depths. Single stratified hauls were conducted at all stations during day and night time to avoid diel vertical migration bias (see Table 5 for list of deployments and Appendix B for full list of flow meter readings/deployment times and location).

For DCM studies the fluorescence profile from the CTD cast was used to determine the exact depths at which the nets were triggered, which were as follows: two above DCM, one through DCM, two below DCM (to a maximum of 200m depth). A target of two replicate samples was obtained by day and by night for most sampling stations.

Double-warp fish trawl (Ǻkra trawl)

The pelagic Ǻkra trawl was deployed ideally three times during the day and three during the night. Deployments were at shallow (generally 300-400 m depth), intermediate (600-700 m depth) and deep (900-1100 m) depths, with the depths determined by the position of the deep-scattering layers, the depth of the seamount summit, or other considerations such as weather conditions (Table 6). In most cases, the Flytetrål 152 MSK x 3200 mm was used but for some samples where aggregations of fish were present or where greater mobility of the trawl was required (net deployed close to rugged topography) the smaller net was used. Trawl tows are shown in Fig. 13 along with CTD stations for each seamount.

Problems and assumptions

Opportunities to sample the SWIR are extremely rare and there have been very limited studies of the pelagic ecosystems of the high seas of the South West Indian Ocean. For this project the sampling design was aimed at reaching a balance between obtaining a synoptic picture of large scale variation in oceanography and spatial distribution and abundance of organisms and communities and also identifying the smaller, seamount-scale, variations in physical and biological parameters. This meant a compromise in terms of the scope for obtaining replicate randomised samples for studies of community ecology both on and off seamount stations. The benefit of this approach, however, was that it established baseline information on the biogeography and species diversity associated with the study region. It also allowed us to identify the large-scale processes affecting species composition, abundance and diversity at a range of spatial scales from the influence of water mass, to localised affects arising from, for example, current-topography interactions on biological communities. Clearly there is great scope for more detailed studies of oceanography within this region and the ecology of water column communities around the seamounts of the SWIR to further explore the findings in the present paper and other work associated with the cruise.

The region of the SWIR sampled is extremely exposed to weather systems moving along the Southern Ocean from west to east. Operational considerations, particularly the impacts of weather on sampling operations and transit times between stations meant that there were variations in the timing or positioning of sampling operations leading to a lack of consistency in position and timing of sampling at a range of scales, both between seamounts and also, amongst individual samples taken on seamounts. To some extent, sampling operations, such as net hauls, were determined by physical constraints, such as the depth of the seamount summit or flanks and also by biological observations. For example, Ǻkra trawls were often positioned on the basis of acoustic observations with split-beam echosounders rather than being placed randomly around seamounts at set depth horizons. Such lack of consistency again leads to a synoptic picture of the ecology of the pelagic communities on and off the SWIR and potentially also of the small-scale oceanographic structure associated with individual seamounts. Preliminary examination of oceanographic data between the cruises on the SWIR in 2009 and in 2011 indicate large temporal variation in the oceanography of this region, not surprising given the occurrence of the very complex frontal systems between sub-tropical and sub-Antarctic waters that lie over the ridge (Read and Pollard, 2017; Pollard and Read, 2017).

Any biological sampling using nets and acoustics is biased towards certain types and size-classes of organisms. For nets, mesh size obviously determines what organisms may be retained (Heino et al., 2011). However, water pressure caused by the flow of water through the net will also force or extrude organisms through the net mesh with tow speed being a particularly important factor in the loss of individuals through this process (Sameoto et al., 2000). Delicate organisms, especially small gelatinous zooplankton, are often partially, or completely destroyed in zooplankton nets and therefore not retained or are virtually unrecognisable in catches. Nets, especially fine-meshed phytoplankton or mesozooplankton nets can also become clogged with abundant phytoplankton during blooms or gelatinous zooplankton leading to variation in net retention efficiency between samples (Sameoto et al., 2000). Net avoidance, particularly by larger organisms such as micronektonic or nektonic crustaceans, cephalopods and fish can also be an issue. This depends the size of the net mouth, towing speed and the light conditions (time of day) during which sampling takes place (Sameoto et al., 2000; Heino et al., 2011). Nets also exert a herding effect on animals in that fish will avoid the sides of the net even where the mesh is sufficiently large to allow them to swim through, eventually becoming trapped in smaller mesh at the rear end of the net (Heino et al., 2011). Behavioural effects may also affect net catch as some animals will avoid a net whilst others may be attracted to a net especially where it is causing bioluminescence through mechanical impact of organisms in the water column (Heino et al., 2011). Net feeding is another aspect of behaviour that can influence catch (Heino et al., 2011).

The Ǻkra trawl appeared to be particularly useful for sampling the larger size-fractions of zooplankton, micronekton and nekton with sizes of animals down to ~ 15 mm being captured. The macrozooplankton trawl primarily captured small organisms <5 mm in size. Overall the 10 mm size class of zooplankton and micronekton was probably the least effectively sampled. During sampling large cephalopods and some fish were often found on the outer parts of the Ǻkra trawl, perhaps indicating that they were actually attacking the net or narrowly avoided escape. Similar observations were noted by Heino et al. (2011) for the same equipment in the North Atlantic. Net feeding was also evident for some animals (see Fig. 14). Smaller or delicate organisms were also often heavily damaged in the Ǻkra trawl meaning that identification of specimens was frequently impaired.

Databases and collections

All of the fish samples from the cruise have been lodged with the South African Institute for Aquatic Biodiversity. Crustacean samples analysed in Letessier et al. (2017) are lodged at the Zoology Museum in Oxford.

4. Concluding remarks

The papers published in this issue represent a state change in knowledge of the ecology of the pelagic ecosystems of the South West Indian Ocean. They also provide new information on the interactions between seamounts and the overlying water column. These include observations relevant to understanding small-scale oceanographic phenomena associated with seamounts (e.g. Fig. 15), the influence of water mass and elevated topography on pelagic communities around seamounts and the energetic basis of seamount fisheries. Additionally, geophysical data gathered on the morphology of the target seamounts during both the 2009 (Figs 7-12) and 2011 cruises (the latter not reported here) will advance understanding the biology of seamount ecosystems and the geological processes influencing seamount generation and subsequent erosion. This work is timely both because of the continuing threat posed to seamount ecosystems by deep-sea fisheries but also because of the high likelihood of seabed massive sulphide mining along mid-ocean ridges in the near future. The management of such human activities require detailed information on the ecology of seamounts so that impacts can be predicted and appropriate mitigation measures taken.

Acknowledgements

We wish to thank the Master and crew of the EAF Nansen Project RV *Fridtjof Nansen* cruise 2009 410 and the NERC cruise RRS *James Cook* JC066 for their support during the field work at the Southwest Indian Ridge. We also thank the UK National Marine Facilities staff at NOC for ship board support. Further thanks to the scientists onboard during the two voyages. We also thank Dr Marc Wieland, Dept. of Zoology, University of Oxford for preparation of seamount maps in this paper. This work was funded by the Global Environment Facility Grant through UNDP Project IDGEF3138/PIMS3657 executed by IUCN as the IUCN

Seamounts Project FFEM-SWIO-P00917(http://www.

iucn.org/about/work/programmes/marine/marine_our_work/mar-

ine_governance/gmpp_ocean_governance_projects/seamounts/). It was also supported by NERC Grant NE/F005504/1 Benthic Biodiversity of Seamounts in the Southwest Indian Ocean. Additional funding was provided by the FAO/NORAD EAF Nansen Project and Agulhas and Somali Current LME project. The funders had no roles in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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Tables and Figures

Table 1. Approximate locality of each of the main sampling stations. Seamount station position is taken as that of the shallowest point of the seamount summit. Depth of the seabed around each seamount station is taken as the maximum depth within 10km of the 1000m contour.

Name	Position at shallowest point	Summit depth	Morphology
Off-seamount Station 1	24°48'S, 55°49.3'E	N/A	N/A
Off seamount Station 2	26°56.6'S, 56°14.4'E	N/A	N/A
Off seamount Station 3	29°S, 56°34.5'E	N/A	N/A
Atlantis Bank Station 4	32°42.69'S, 57°16.69'E	690m	Elongate / irregular
Sapmer Bank Station 5	36°48.00'S 52°07.32'E	261m	Irregular
Middle of What Seamount Station 6	37°57.64'S 50°24.67'E	876m	Irregular / elliptical (split)
CTD Section	Start: 39°00'S, 49°30'E End: 41°15'S 49°30'E	N/A	N/A
Off seamount Station 7	41°30'S, 49°30'E	N/A	N/A
Coral Seamount Station 8	41° 24.21'S, 42° 51.33'E	175m	Irregular / rectangular
CTD Section	Start:41°12.85'S 43°00.05'E End: 38°44.95'S 46°22.97'E	N/A	N/A
Melville Bank Station 9	38°28.41'S, 46°45.05'E	91m	Elongate / irregular (two peaks)
Un-named Seamount Station 10	31°37.86'S 42°49.85'E	1249m	Dome-shaped

Off seamount Station 11	31^{o}59.36'S 41^{o}01.75'E	N/A	N/A

Table 2. CTD and townet stations from which water samples were taken giving the date and time (GMT), Nansen CTD station number, position and depth of the CTD at which the first bottle was fired and the location of the station (* indicates where no tow-nets were taken either due to strong winds or lost cod-ends).

Sample CTD No.	Nansen Stn No.	Date	Time	Position		Depth of bottle 1 (m)	Type
				Latitude	Longitude		
1	1214	13/11/09	14.15	24^{o}48.12'S	055^{o}49.41'E	1500	Off Seamount
2	1215	14/11/09	10.08	26^{o}56.49'S	056^{o}14.32'E	2003	Off Seamount
3	1216	16/11/09	02.18	29^{o}00.06'S	056^{o}34.57'E	2003	Off Seamount
4	1217	17/11/09	08.24	32^{o}42.87'S	057^{o}17.84'E	700	Atlantis Seamount
5	1225	17/11/09	18.58	32^{o}42.68'S	057^{o}16.29'E	737	Atlantis Yo-Yo
6	1239	18/11/09	01.26	32^{o}42.7' S	057^{o}16.26'E	730	Atlantis Yo-Yo
7	1251	18/11/09	07.39	32^{o}42.68'S	057^{o}16.30'E	738	Atlantis Yo-Yo
8	1258	18/11/09	14.28	32^{o}42.67'S	057^{o}16.24'E	739	Atlantis Yo-Yo
9	1269	19/11/09	13.07	32^{o}40.06'S	057^{o}19.66'E	1638	Atlantis Transect
10	1270	19/11/09	15.03	32^{o}41.40'S	057o18.13'E	878	Atlantis Transect
11	1271*	19/11/09	16.19	32^{o}42.01'S	057^{o}17.26'E	712	Atlantis Transect
12	1272	19/11/09	17.19	32^{o}43.28'S	057^{o}15.89'E	715	Atlantis Transect
13	1273	19/11/09	18.18	32^{o}43.88'S	057^{o}15.22'E	999 (Bottle 2)	Atlantis Transect
14	1274	19/11/09	19.35	32^{o}44.72'S	057^{o}14.11'E	2051	Atlantis Transect
15	1275	21/11/09	20.27	36^{o}50.87'S	052^{o}04.88'E	542	Sapmer Seamount
16	1276	22/11/09	15.02	36^{o}50.59'S	052^{o}08.48'E	510	Sapmer Yo-Yo
17	1287	22/11/09	19.45	36^{o}50.60'S	052^{o}08.51'E	508	Sapmer Yo-Yo
18	1305	23/11/09	02.42	36^{o}50.63 S	052^{o}08.53'E	509	Sapmer Yo-Yo
19	1322	23/11/09	08.36	36^{o}50.60'S	052^{o}08.52'E	511	Sapmer Yo-Yo
20	1340	23/11/09	14.37	36^{o}50.58 S	052^{o}08.50 E	508	Sapmer Yo-Yo

21	1341*	24/11/09	10.43	36°52.18'S	052°10.42'E	1985	Sapmer Transect
22	1342	24/11/09	12.31	36°51.23'S	052°09.13'E	879	Sapmer Transect
23	1343	24/11/09	13.42	36°49.63'S	052°07.24'E	441	Sapmer Transect
24	1344	24/11/09	14.24	36°48.96'S	052°06.39'E	328	Sapmer Transect
25	1345	24/11/09	15.03	36°48.17'S	052°05.37'E	960	Sapmer Transect
26	1346	24/11/09	16.08	36°46.63'S	052°03.46'E	2002	Sapmer Transect
27	1347	25/11/09	13.41	37°57.56'S	050°24.79'E	301	MOW Seamount
28	1348	26/11/09	02.49	37°57.42'S	050°24.83'E	960	MOW Yo-Yo
29	1356	26/11/09	08.17	37°57.43'S	050°24.80'E	962	MOW Yo-Yo
30	1363	26/11/09	14.44	37°57.45'S	050°24.84'E	960	MOW Yo-Yo
31	1372	26/11/09	20.20	37°57.41'S	050°24.86'E	970	MOW Yo-Yo
32	1383	27/11/09	02.39	37°57.44'S	050°24.87'E	960	MOW Yo-Yo
33	1384*	27/11/09	16.23	37°55.98'S	050°22.42'E	1481	MOW Transect
34	1385*	27/11/09	17.41	37°57.07'S	050°23.88'E	1214	MOW Transect
35	1386*	27/11/09	18.42	37°58.09'S	050°25.16'E	1071	MOW Transect
36	1387*	27/11/09	19.44	37°58.57'S	050°25.79'E	1171	MOW Transect
37	1388*	27/11/09	20.40	37°58.95'S	050°26.22'E	1449	MOW Transect
38	1389*	27/11/09	22.02	38°00.01'S	050°27.60'E	1676	MOW Transect
39	1390	28/11/09	05.30	38°59.84'S	050°10.95'E	2001	CTD Section 1
40	1391	28/11/09	08.37	39°15.02'S	050°07.48'E	2002	CTD Section 1
41	1392	28/11/09	11.40	39°30.13'S	050°03.45'E	2001	CTD Section 1
42	1393	28/11/09	14.51	39°45.01'S	049°59.56'E	2002	CTD Section 1
43	1394	28/11/09	18.00	40°00.02'S	049°55.58'E	2001	CTD Section 1
44	1395	28/11/09	20.51	40°15.09'S	049°51.62'E	2001	CTD Section 1
45	1396	28/11/09	23.55	40°30.10'S	049°47.45'E	2002	CTD Section 1
46	1397	29/11/09	03.05	40°44.96'S	049°43.14'E	2004	CTD Section 1
47	1398	29/11/09	06.01	40°59.65'S	049°38.82'E	2002	CTD Section 1
48	1399	29/11/09	09.05	41°14.83'S	049°34.53'E	2001	CTD Section 1
49	1400	29/11/09	12.11	41°30.00'S	049°30.04'E	2001	CTD Section 1
50	1401	01/12/09	22.45	41°25.44'S	042°50.82'E	303	Coral Seamount

51	1402	03/12/09	02.58	41°25.35'S	042°50.69'E	802	Coral Yo-Yo
52	1422	03/12/09	08.41	41°25.27'S	042°51.24'E	407	Coral Yo-Yo
53	1443	03/12/09	14.34	41°25.27'S	042°51.19'E	405	Coral Yo-Yo
54	1466	03/12/09	20.45	41°25.29'S	042°51.21'E	400	Coral Yo-Yo
55	1488	04/12/09	02.19	41°25.27'S	042°51.21'E	402	Coral Yo-Yo
56	1490	04/12/09	10.29	41°29.13'S	042°54.01'E	1557	Coral Transect
57	1492	04/12/09	14.21	41°25.71'S	042°52.51'E	566	Coral Transect
58	1493*	04/12/09	15.47	41°24.28'S	042°51.67'E	191	Coral Transect
59	1494*	04/12/09	16.21	41°23.50'S	042°51.26'E	902	Coral Transect
60	1495*	04/12/09	17.23	41°21.23'S	042°50.30'E	1870	Coral Transect
61	1496*	04/12/09	19.40	41°12.18'S	043°00.05'E	1573	CTD Section 2
62	1497*	04/12/09	22.31	40°59.95'S	043°12.34'E	2003	CTD Section 2
63	1498*	05/12/09	01.36	40°48.02'S	043°35.03'E	2003	CTD Section 2
64	1499	05/12/09	04.49	40°36.09'S	043°51.98'E	2002	CTD Section 2
65	1500	05/12/09	08.16	40°23.98'S	044°08.93'E	2001	CTD Section 2
66	1501	05/12/09	11.30	40°12.13'S	044°25.63'E	2003	CTD Section 2
67	1502	05/12/09	14.48	40°00.03'S	044°41.85'E	2004	CTD Section 2
68	1503	05/12/09	18.03	39°48.06'S	044°58.37'E	2001	CTD Section 2
69	1504	05/12/09	21.18	39°36.00'S	045°15.04'E	2003	CTD Section 2
70	1505	06/12/09	00.48	39°23.97'S	045°31.16'E	2002	CTD Section 2
71	1506	06/12/09	04.02	39°11.96'S	045°47.40'E	2000	CTD Section 2
72	1507	06/12/09	07.23	38°55.99'S	046°03.53'E	2002	CTD Section 2
73	1508	06/12/09	10.55	38°44.95'S	046°22.97'E	2003	CTD Section 2
74	1509	06/12/09	14.56	38°31.56'S	046°45.74'E	1862	Melville Transect 1
75	1510	06/12/09	16.28	38°30.17'S	046°45.32'E	1063	Melville Transect 1
76	1511	06/12/09	17.47	38°29.23'S	046°44.98'E	512	Melville Transect 1
77	1512	06/12/09	18.57	38°28.68'S	046°44.75'E	361	Melville Transect 1
78	1513	06/12/09	19.59	38°28.29'S	046°44.67'E	101	Melville Transect 1
79	1514	06/12/09	20.39	38°27.83'S	046°44.42'E	852	Melville Transect 1

80	1515	06/12/09	21.50	38°26.81'S	046°44.03'E	1681	Melville Transect 1
81	1516	08/12/09	18.52	38°28.38'S	046°48.45'E	1258	Melville Transect 2
82	1517	08/12/09	19.57	38°28.51'S	046°47.57'E	751	Melville Transect 2
83	1518	08/12/09	20.42	38°28.36'S	046°46.85'E	550	Melville Transect 2
84	1519	08/12/09	21.34	38°28.24'S	046°45.47'E	106	Melville Transect 2
85	1520	08/12/09	22.02	38°28.27'S	046°44.60'E	109	Melville Transect 2
86	1521	08/12/09	22.33	38°28.33'S	046°43.78'E	550	Melville Transect 2
87	1522	08/12/09	23.16	38°28.67'S	046°42.80'E	420	Melville Transect 2
88	1523	08/12/09	23.53	38°28.66'S	046°42.32'E	430	Melville Transect 2
89	1524	08/12/09	00.37	38°28.33'S	046°41.25'E	1052	Melville Transect 2
90	1525	08/12/09	01.39	38°28.07'S	046°40.60'E	1350	Melville Transect 2
91	1526	09/12/09	09.54	38°28.26'S	046°43.92'E	505	Melville Yo-Yo
92	1545	09/12/09	15.54	38°28.26'S	046°43.93'E	507	Melville Yo-Yo
93	1563	09/12/09	21.38	38°28.28'S	046°43.91'E	510	Melville Yo-Yo
94	1582	10/12/09	03.39	38°28.28'S	046°43.96'E	500	Melville Yo-Yo
95	1600	10/12/09	09.34	38°28.26'S	046°43.94'E	507	Melville Yo-Yo
96	1601	12/12/09	16.24	31°34.33'S	042°45.78'E	301	Madagascar Ridge
97	1602	13/12/09	13.06	31°37.34'S	042°49.17'E	1252	Madagascar Ridge Yo-Yo
98	1611	13/12/09	20.08	31°37.34'S	042°49.19'E	1249	Madagascar Ridge Yo-Yo
99	1618	14/12/09	01.49	31°37.42'S	042°49.13'E	1256	Madagascar Ridge Yo-Yo
100	1624	14/12/09	07.19	31°37.33'S	042°49.39'E	1251	Madagascar Ridge Yo-Yo
101	1628	14/12/09	11.37	31°37.37'S	042°49.17'E	1257	Madagascar Ridge Yo-Yo
102	1629	14/12/09	16.49	31°41.82'S	042°54.72'E	1702	Madagascar Ridge Transect
103	1630*	14/12/09	18.28	31°40.40'S	042°52.90'E	1444	Madagascar Ridge Transect
104	1631*	14/12/09	19.48	31°38.69'S	042°50.93'E	1330	Madagascar Ridge Transect
105	1632*	14/12/09	20.53	31°37.35'S	042°49.15'E	1261	Madagascar Ridge Transect
106	1633*	14/12/09	21.53	31°35.90'S	042°47.53'E	1354	Madagascar Ridge Transect
107	1634*	14/12/09	?	31°34.53'S	042°45.96'E	1469	Madagascar Ridge Transect
108	1635*	15/12/09	00.07	31°33.07'S	042°44.32'E	1887	Madagascar Ridge Transect
109	1636	15/12/09	10.04	31°59.36'S	041°01.75'E	302	Off seamount

Table 3. Acoustic grid survey positions giving date, time, position of the start of each survey, orientation and spacing of survey tracks. Note, most surveys were completed in two separate legs as a result of time constraints imposed by other operations.

Station	**Date (2009)**	**Start of survey (GMT)**	**End of survey (GMT)**	Lat	Long	**Orientation (degrees)**	**Transects**	**Transect length (nautical miles)**
02 Off Ridge North	14/11 15/11	03:27 01:58	09:26 07:53	26^{o}49.36'S 26^{o}50.32'S	56^{o}14.64'E 56^{o}15.74'E	315 315	5 5	10 10
04 Atlantis Bank	17/11 19/11	01:38 02:39	07:40 08:40	32^{o}36.12'S 32^{o}37.12'S	57^{o}17.64'E 57^{o}17.35'E	315 315	5 5	10 10
05 Sapmer Bank	22/11 24/11	01:17 03:24	07:23 09:30	36^{o}51.14'S 36^{o}49.88'S	52^{o}15.09'E 51^{o}59.23'E	315 315	5 5	10.5 10.5
06 Middle of What	25/11 27/11	06:55 04:09	12:54 10:01	37^{o}50.76'S 37^{o}51.60'S	50^{o}23.95'E 50^{o}23.95'E	315 315	5 5	10 10
07 Off-Ridge South	30/11	01:01	11:38	41^{o}34.34'S	49^{o}37.18'E	350	10	10
08 Coral Seamount	2/12 4/12	02:07 03:51	08:04 09:44	41^{o}31.17'S 41^{o}21.70`S	42^{o}49.81'E 42^{o}46.63'E	340 340	5 5	10 10
09 Melville Bank	7/12 9/12	03:46 02:51	16:15 08:43	38^{o}25.01S 38^{o}25.59'S	46^{o}37.96'E 46^{o}37.22'E	345 345	5 5	10 10
10 Madagascar Ridge Seamount	12/12 13/12	10:16 02:42	15:58 08:23	31^{o}38.82'S 31^{o}37.89'S	42^{o}57.41'E 42^{o}57.54'E	315 315	5 5	10 10

Table 4. Bongo net deployments giving Station location date, position of the net at the start of the deployment and position at the end. Flow meter measurements are also given including the flow meter number at the start of deployment and the meter number at the end. The mesh size of the two nets are given along with the methods of preservation for each sample.

Station	Date	Start haul	Stop haul	Position start	Position stop	Start flow	Stop flow	Mesh (µm)	Preservation
2	15/11/09	01.53	02.27	26°50.25’S	26°53.93’S	27173	31981	375	Ethanol
2	15/11/09	01.53	02.27	56°15.79’E	56°11.70’E	4174	11066	500	Formalin
2	15/11/09	02.41	03.19	26°55.69’S	26°57.79’S	31981	39100	375	Ethanol
2	15/11/09	02.41	03.19	56°09.75’E	56°10.50’E	11066	20426	500	Formalin
2	15/11/09	03.28	04.05	26°56.75’S	26°52.58’S	20426	28857	375	Ethanol
2	15/11/09	03.28	04.05	56°11.67’E	56°16.44’E	39100	45318	500	Formalin
2	15/11/09	04.12	04.55	26°52.13’S	26°57.39’S	28857	38198	375	Ethanol
2	15/11/09	04.12	04.55	56°17.37’E	56°14.22’E	45318	51886	500	Formalin
2	15/11/09	16.22	16.50	27°17.74’S	27°22.48’S	38198	44362	375	Ethanol
2	15/11/09	16.22	16.50	56°16.18’E	56°17.11’E	51886	56512	500	Formalin
2	15/11/09	16.57	17.30	27°23.84’S	27°29.48’S	56512	60587	375	Ethanol
2	15/11/09	16.57	17.30	56°17.35’E	56°18.44’E	44362	51595	500	Formalin
4	18/11/09	19.55	20.27	32°43.55’S	32°42.56’S	64534	68229	375	Ethanol
4	18/11/09	19.55	20.27	57°16.05’E	57°15.35’E	58277	62663	500	Formalin
4	18/11/09	21.00	21.32	32°43.30’S	32°43.20’S	68229	72171	375	Ethanol
4	18/11/09	21.00	21.32	57°16.53’E	57°17.87’E	62663	68013	500	Formalin
4	18/11/09	21.35	22.05	32°43.20’S 57°18.00’E	32°43.51’S 57°19.32’E	68013	74378	500	Formalin
4	19/11/09	14.40	15.10	32°40.13’S	32°41.40’S	76659	80193	375	Ethanol
4	19/11/09	14.40	15.10	57°19.70’E	57°18.11’E	74379	78863	500	Formalin
4	19/11/09	15.15	15.50	32°41.39’S	32°41.40’S	80193	89507	375	Ethanol
4	19/11/09	15.15	15.50	57°18.12’E	57°18.15’E	78863	86932	500	Formalin
4	19/11/09	16.00	16.32	32°41.46’S 57°18.13’E	32°41.97’S 57°17.24’E	86932	92643	500	Formalin
5	22/11/09	01.16	01.51	36°51.10’S	36°47.89’S	89756	94331	375	Dried
5	22/11/09	01.16	01.51	52°14.89’E	52°11.99’E	93085	4181	500	Formalin
5	22/11/09	01.55	02.32	36°47.43’S	36°44.53’S	94331	97123	375	Ethanol
5	22/11/09	01.55	02.32	52°11.40’E	52°05.98’E	4181	15624	500	Formalin
5	22/11/09	02.35	03.05	36°44.88’S	36°48.53’S	97123	99376	375	Ethanol
5	22/11/09	02.35	03.05	52°05.56’E	52°09.30’E	15624	21624	500	Formalin
5	24/11/09	21.30	22.10	36°56.64’S	37°00.72’S	99376	2332	375	Dried
5	24/11/09	21.30	22.10	51°52.27’E	51°46.17’E	21631	30210	500	Formalin
5	24/11/09	22.10	22.40	37°00.72’S	37°03.56’S	2332	4676	375	Ethanol
5	24/11/09	22.10	22.40	51°46.17’E	51°41.32’E	30210	36789	500	Formalin
5	24/11/09	22.40	23.15	37°03.56’S	37°07.04’S	4676	6605	375	Ethanol
5	24/11/09	22.40	23.15	51°41.32’E	51°35.76’E	36789	43943	500	Formalin
5	25/11/09	21.05	21.35	37°57.12’S	37°57.06’S	6605	8602	375	Dried
5	25/11/09	21.05	21.35	50°24.54’E	50°26.01’E	43943	51325	500	Formalin
5	25/11/09	21.35	22.02	37°57.06’S	37°57.12’S	8602	10812	375	Ethanol
5	25/11/09	21.35	22.02	50°26.01’E	50°26.89’E	51325	56864	500	Formalin
5	25/11/09	22.02	22.32	37°57.12’S	37°57.22’S	10812	12980	375	Ethanol
5	25/11/09	22.02	22.32	50°26.89’E	50°24.94’E	56864	76619	500	Formalin
6	27/11/09	13.51	14.23	37°57.71’S	37°57.56’S	12980	15968	375	Ethanol
6	27/11/09	13.51	14.23	50°25.81’E	50°25.69’E	61994	70072	500	Formalin
6	27/11/09	14.23	14.58	37°57.56’S	37°57.53’S	15968	19170	375	Dried
6	27/11/09	14.23	14.58	50°25.69’E	50°24.28’E	70072	79781	500	Formalin
6	27/11/09	18.10	18.45	37°57.08’S	37°58.10’S	19170	21681	375	Ethanol
6	27/11/09	18.10	18.45	50°23.96’E	50°25.18’E	79781	85554	500	Formalin
7	29/11/09	18.10	18.47	41°31.09’S	41°30.66’S	21681	24603	375	Ethanol
7	29/11/09	18.10	18.47	49°26.99’E	49°28.44’E	85554	94101	500	Formalin
7	29/11/09	19.55	20.25	41°29.92’S	41°27.55’S	28559	32205	375	Ethanol
7	29/11/09	19.55	20.25	49°231.27’E	49°33.59’E	3533	11434	500	Formalin
7	29/11/09	20.30	21.02	41°27.64’S	41°29.04’S	32205	36270	375	Ethanol
7	29/11/09	20.30	21.02	49°33.39’E	49°31.78’E	11434	20321	500	Formalin
7	30/11/09	17.55	18.25	41°34.73’S	41°34.59’S	38289	41038	375	Ethanol
7	30/11/09	17.55	18.25	48°54.16’E	48°48.37’E	26670	32467	500	Formalin
8	02/12/09	13.25	13.55	41°24.77’S	41°24.39’S	41030	44887	375	Ethanol
8	02/12/09	13.25	13.55	42°57.46’E	42°57.64’E	32480	39906	500	Formalin
8	02/12/09	13.59	14.22	41_{o}24.47’S	41°24.79’S	44887	47272	375	Ethanol
8	02/12/09	13.59	14.22	42°57.34’E	42°56.00’E	39906	45372	500	Formalin

8	02/12/09	14.23	14.58	41°24.80'S	41°25.11'S	47272	50845	375	Dried
8	02/12/09	14.23	14.58	42°55.95'E	42°54.46'E	45372	51749	500	Formalin
8	02/12/09	19.50	20.21	41°25.83'S	41°26.12'S	50845	54545	375	Ethanol
8	02/12/09	19.50	20.21	42°54.61'E	42°52.93'E	51749	59814	500	Formalin
8	02/12/09	20.30	20.55	41°26.23'S	41°26.75'S	54545	58277	375	Ethanol
8	02/12/09	20.30	20.55	42°52.66'E	42°52.37'E	59814	68056	500	Formalin
8	02/12/09	21.03	21.40	41°26.36'S	41°25.04'S	58277	62808	375	Dried
8	02/12/09	21.03	21.40	42°52.17'E	42°54.57'E	68057	77744	500	Formalin
9	08/12/09	08.15	08.45	38°30.58'S	38°30.90'S	62589	67488	375	Ethanol
9	08/12/09	08.15	08.45	46°44.16'E	46°42.75'E	77815	86942	500	Formalin
9	08/12/09	08.50	09.36	38°30.92'S	38°29.75'S	67488	71620	375	Ethanol
9	08/12/09	08.50	09.36	46°42.62'E	46°43.63'E	86942	97309	500	Formalin
9	08/12/09	19.50	20.25	38°28.41'S	38°28.48'S	75355	79195	375	Ethanol
9	08/12/09	19.50	20.25	46°48.32'E	46°47.60'E	5050	15138	500	Formalin
9	08/12/09	20.30	21.05	38°28.52'S	38°28.36'S	79195	82645	375	Ethanol
9	08/12/09	20.30	21.05	46°47.61'E	46°46.96'E	15138	2573	500	Formalin
10	12/12/09	20.42	21.25	31°41.34'S	31°41.22'S	90844	95956	375	Ethanol
10	12/12/09	20.42	21.25	42°51.81'E	42°48.41'E	44838	55394	500	Formalin
10	12/12/09	21.27	21.56	31°41.16'S	31°40.05'S	95956	99326	375	Ethanol
10	12/12/09	21.27	21.56	42°48.49'E	42°49.35'E	55394	63385	500	Formalin
10	13/12/09	13.20	14.10	31°37.37'S	31°37.37'S	99394	3968	375	Ethanol
10	13/12/09	13.20	14.10	42°49.18'E	42°49.18'E	63385	74341	500	Formalin
10	13/12/09	14.12	14.57	31°37.36'S	31°37.37'S	3968	8254	375	Ethanol
10	13/12/09	14.12	14.57	42°49.19'E	42°49.19'E	74341	84309	500	Formalin

Table 5. Multinet deployments giving the Station number, the date, the start time and stop time and start position and stop position for each of five nets for each deployment. Flow meter measurements are also given including the volume of flow through the net and the flow in / out values and flow ratio.

Station	Date	Net	Time Start / Stop	Start Position (Vessel)	End position (Vessel)	Pressure (dbar) Start / Stop	Volume (m^3)	Flow in/ Flow out Start/ Stop	Flow Ratio (%)
2 (PL3)	14/11/09	1	11.27.50 11.30.20	26°56.37'S 56°14.06'E	26°56.31'S 56°13.99'E	250.1 202.9	8	0.3 / 0.3 0.2 / 0.2	100.0 100.0
2 (PL3)	14/11/09	2	11.30.21 11.34.47	26°56.31'S 56°13.99'E	26°56.24'S 56°13.88'E	202.6 151.8	54	0.1 / 0.3 0.7 / 0.3	33.3 233.3
2 (PL3)	14/11/09	3	11.34.48 11.42.51	26°56.24'S 56°13.88'E	26°56.19'S 56°13.77'E	151.6 101.6	224	0.8 / 0.2 2.1 / 1.8	400 116.7
2 (PL3)	14/11/09	4	11.42.52 11.46.26	26°56.19'S 56°13.77'E	26°56.17'S 56°13.75'E	101.3 50.6	101	2.1/ 1.9 1.8 / 1.7	110.5 105.9
2 (PL3)	14/11/09	5	11.46.27 11.49.23	26°56.17'S 56°13.75'E	26°56.20'S 56°13.81'E	50.3 1.5	69	2.0 / 1.8 1.6 / 0.9	111.1 177.8
2 (PL4)	14/11/09	1	12.18.58 12.21.49	26°56.46'S 56°14.72'E	26°56.49'S 56°14.82'E	199.3 151.3	15	0.2 / 0.2 0.1 / 0.3	100.0 33.3
2 (PL4)	14/11/09	2	12.21.50 12.27.55	26°56.49'S 56°14.82'E	26°56.54'S 56°15.03'E	151.3 101.8	123	0.1 / 0.1 1.0 / 1.1	100.0 90.9
2 (PL4)	14/11/09	3	12.27.56 12.33.30	26°56.54'S 56°15.03'E	26°56.58'S 56°15.20'E	101.9 50.7	151	1.1 / 0.8 1.5 / 1.7	137.5 88.2
2 (PL4)	14/11/09	4	12.33.31 12.35.24	26°56.58'S 56°15.20'E	26°56.60'S 56°15.27'E	51.0 25.6	50	1.2 / 1.4 1.7 / 1.6	85.7 106.2

2 (PL4)	14/11/09	5	12.35.25 12.37.03	26°56.60'S 56°15.27'E	26°56.61'S 56°15.34'E	25.6 0.6	42	1.5 / 1.5 1.4 / 0.8	100 175
2 (PL7)	14/11/09	1	19.39.13 19.48.31	26°57.27'S 56°19.24'E	26°57.57'S 56°19.61'E	252.0 202.8	61	0.2 / 0.3 0.8 / 0.1	66.7 800.0
2 (PL7)	14/11/09	2	19.48.32 19.53.20	26°57.57'S 56°19.61'E	26°57.66'S 56°19.50'E	202.1 147.8	90	0.7 / 0.3 1.1 / 1.3	233.3 84.6
2 (PL7)	14/11/09	3	19.53.21 19.56.03	26°57.66'S 56°19.50'E	26°57.69'S 56°19.46'E	147.1 100.2	65	1.1 / 1.3 1.6 / 1.6	84.6 100.0
2 (PL7)	14/11/09	4	19.56.04 19.59.55	26°57.69'S 56°19.46'E	26°57.70'S 56°19.42'E	100.2 50.6	98	1.4 / 1.4 1.8 / 1.7	100.0 105.9
2 (PL7)	14/11/09	5	19.59.56 20.03.14	26°57.70'S 56°19.42'E	26°57.69'S 56°19.39'E	50.6 1.9	75	1.6 / 1.6 1.0 / 1.7	100.0 142.9
2 (PL8)	14/11/09	1	20.26.11 20.29.04	26°57.35'S 56°18.88'E	26°57.25'S 56°18.71'E	201.2 151.9	10	0.2 / 0.3 0.8 / 0.1	66.7 800.0
2 (PL8)	14/11/09	2	20.29.05 20.34.14	26°57.25'S 56°18.71'E	26°57.07'S 56°18.43'E	151.9 101.4	66	0.8 / 0.2 1.2 / 0.1	400.0 1200.0
2 (PL8)	14/11/09	3	20.34.15 20.40.30	26°57.07'S 56°18.43'E	26°56.86'S 56°18.09'E	101.4 51.4	155	1.3 / 0.2 1.2 / 1.3	650.0 92.3
2 (PL8)	14/11/09	4	20.40.31 20.42.18	26°56.86'S 56°18.09'E	26°56.80'S 56°17.99'E	51.3 25.2	41	1.2 / 1.2 1.8 / 1.6	100.0 112.5
2 (PL8)	14/11/09	5	20.42.19 20.43.37	26°56.80'S 56°17.99'E	26°56.74'S 56°17.91'E	24.6 0.6	27	1.8 / 1.6 1.2 / 1.3	112.5 92.3
4 (PL18)	17/11/09	1	08.30.15 08.33.07	32°42.86'S 57°17.82'E	32°42.86'S 57°17.80'E	199.9 155.9	33	0.5 / 0.2 1.1 / 0.3	250.0 366.7
4 (PL18)	17/11/09	2	08.33.08 08.38.32	32°42.86'S 57°17.80'E	32°42.86'S 57°17.76'E	155.2 101.1	121	1.0 / 0.2 1.2 / 1.4	500.0 85.7
4 (PL18)	17/11/09	3	08.38.33 08.43.46	32°42.86'S 57°17.76'E	32°42.88'S 57°17.71'E	101.3 51.9	121	1.0 / 1.2 1.2 / 1.3	83.3 92.3
4 (PL18)	17/11/09	4	08.43.47 08.45.55	32°42.88'S 57°17.71'E	32°42.88'S 57°17.70'E	52.2 25.8	44	1.0 / 1.1 1.2 / 1.3	90.9 92.3
4 (PL18)	17/11/09	5	08.45.56 08.47.49	32°42.88'S 57°17.70'E	32°42.87'S 57°17.71'E	26.1 1.3	50	0.8 / 1.0 1.4 / 1.4	80.0 100.0
4 (PL26)	18/11/09	1	17.17.51 17.22.08	32°44.07'S 57°17.06'E	32°44.16'S 57°16.97'E	201.2 151.1	78	0.5 / 0.7 1.2 / 1.1	71.4 109.1
4 (PL26)	18/11/09	2	17.22.09 17.27.35	32°44.16'S 57°16.97'E	32°44.30'S 57°16.83'E	151.1 100.3	112	1.4 / 1.1 1.2 / 1.0	127.3 120.0
4 (PL26)	18/11/09	3	17.27.36 17.33.04	32°44.30'S 57°16.83'E	32°44.42'S 57°16.70'E	100.2 51.2	108	1.4 / 0.9 0.2 / 0.5	155.6 40.0
4 (PL26)	18/11/09	4	17.33.05 17.35.21	32°44.42'S 57°16.70'E	32°44.46'S 57°16.65'E	51.3 24.9	32	0.7 / 0.7 0.8 / 0.8	100.0 100.0
4 (PL26)	18/11/09	5	17.35.22 17.37.56	32°44.46'S 57°16.65'E	32°44.54'S 57°16.57'E	24.6 1.0	45	1.2 / 0.9 0.5 / 0.8	133.3 62.5
4 (PL27)	18/11/09	1	21.40.16 21.44.34	32°43.22'S 57°18.21'E	32°43.28'S 57°18.43'E	250.6 200.7	72	0.3 / 0.1 1.5 / 1.3	300.0 115.4
4 (PL27)	18/11/09	2	21.44.35 21.48.54	32°43.28'S 57°18.43'E	32°43.32'S 57°18.61'E	200.5 150.1	86	1.3 / 1.1 1.4 / 1.3	118.2 107.7
4 (PL27)	18/11/09	3	21.48.55 21.56.18	32°43.32'S 57°18.61'E	32°43.40'S 57°18.92'E	150.4 100.1	150	0.8 / 0.1 1.7 / 1.6	80.0 106.2
4 (PL27)	18/11/09	4	21.56.19 22.01.49	32°43.40'S 57°18.92'E	32°43.47'S 57°19.19'E	99.8 50.0	151	1.8 / 1.6 2.0 / 1.7	112.5 117.6
4 (PL27)	18/11/09	5	22.01.50 22.06.27	32°43.47'S 57°19.19'E	32°43'53'S 57°19.37'E	49.7 2.1	125	1.8 / 1.7 1.0 / 1.2	105.9 83.3
4 (PL28)	18/11/09	1	22.35.48 22.38.27	32°43.94'S 57°19.47'E	32°43.97'S 57°19.37'E	199.4 150.4	53	1.4 / 0.8 1.2 / 1.1	175.0 109.1
4 (PL28)	18/11/09	2	22.38.28 22.43.05	32°43.97'S 57°19.37'E	32°44.02'S 57°19.14'E	150.1 100.0	90	1.4 / 1.0 0.3 / 0.2	140.0 150.0
4 (PL28)	18/11/09	3	22.43.06 22.50.33	32°44.02'S 57°19.14'E	32°44.13'S 57°18.74'E	100.3 50.8	187	0.8 / 0.5 1.2 / 1.4	160.0 85.7
4 (PL28)	18/11/09	4	22.50.34 22.52.52	32°44.13'S 57°18.74'E	32°44.15'S 57°18.66'E	50.9 24.8	51	1.2 / 1.2 1.4 / 1.5	100.0 93.3
4 (PL28)	18/11/09	5	22.52.53 22.54.52	32°44.15'S 57°18.66'E	32°44.17'S 57°18.58'E	24.9 0.4	44	1.1 / 1.2 1.0 / 1.0	91.7 100.0
4 (PL29)	19/11/09	1	08.26.30 08.30.06	32°48.17'S 57°16.77'E	32°48.59'S 57°16.27'E	251.3 200.6	56	0.8 / 0.1 0.9 / 0.2	800.0 450.0
4 (PL29)	19/11/09	2	08.30.07	32°48.59'S	32°49.32'S	200.7	142	1.0 / 0.2	500.0

			08.36.39	57°16.27’E	57°15.41’E	149.2		1.5 / 1.4	107.1
4 (PL29)	19/11/09	3	08.36.40 08.41.53	32°49.32’S 57°15.41’E	32°48.63’S 57°15.48’E	148.5 100.1	122	1.8 / 1.7 1.2 / 1.4	105.9 85.7
4 (PL29)	19/11/09	4	08.41.54 08.45.30	32°48.63’S 57°15.48’E	32°48.19’S 57°15.56’E	100.3 50.7	87	1.0 / 1.1 1.6 / 1.6	90.9 100.0
4 (PL29)	19/11/09	5	08.45.31 08.48.23	32°48.19’S 57°15.56’E	32°47.75’S 57°15.66’E	50.8 0.0	60	1.3 / 1.4 1.6 / 0.9	92.9 177.8
4 (PL30)	19/11/09	1	09.17.13 09.21.56	32°45.03’S 57°16.32’E	32°44.76’S 57°16.27’E	201.3 150.8	86	0.5 / 0.1 0.9 / 1.0	500.0 90.0
4 (PL30)	19/11/09	2	09.21.57 09.27.09	32°44.76’S 57°16.27’E	32°44.63’S 57°16.16’E	151.1 100.5	94	0.8 / 0.8 0.5 / 0.9	100.0 55.6
4 (PL30)	19/11/09	3	09.27.10 09.31.35	32°44.63’S 57°16.16’E	32°44.52’S 57°15.98’E	101.1 50.8	93	0.3 / 0.5 1.3 / 1.4	60.0 92.9
4 (PL30)	19/11/09	4	09.31.36 09.33.39	32°44.52’S 57°15.98’E	32°44.47’S 57°15.91’E	50.2 25.1	51	1.8 / 1.5 1.6 / 1.6	120.0 100.0
4 (PL30)	19/11/09	5	09.33.40 09.35.20	32°44.47’S 57°15.91’E	32°44.45’S 57°15.87’E	25.0 0.1	40	1.4 / 1.4 1.6 / 1.4	100.0 114.3
5 (PL44)	21/11/09	1	22.16.10 22.19.47	36°47.44’S 52°06.00’E	36°47.29’S 52°06.05’E	200.0 150.2	71	0.7 / 0.1 1.0 / 1.0	700.0 100.0
5 (PL44)	21/11/09	2	22.19.48 22.27.07	36°47.29’S 52°06.05’E	36°47.18’S 52°06.43’E	149.8 101.9	155	1.0 / 1.0 1.0 / 1.1	100.0 90.9
5 (PL44)	21/11/09	3	22.27.08 22.32.26	36°47.18’S 52°06.43’E	36°47.32’S 52°06.66’E	101.4 50.5	112	1.5 / 1.2 1.0 / 1.0	125.0 100.0
5 (PL44)	21/11/09	4	22.32.27 22.34.32	36°47.32’S 52°06.66’E	36°47.42’S 52°06.76’E	50.5 25.1	39	1.2 / 1.0 0.8 / 1.2	120.0 66.7
5 (PL44)	21/11/09	5	22.34.33 22.36.21	36°47.42’S 52°06.76’E	36°47.45’S 52°06.79’E	25.4 1.1	39	0.5 / 0.9 1.6 / 1.4	55.6 114.3
5 (PL45)	21/11/09	1	22.57.13 23.00.43	36°48.02’S 52°07.38’E	36°48.13’S 52°07.50’E	248.4 200.1	71	0.5 / 0.4 1.8 / 1.6	125.0 112.5
5 (PL45)	21/11/09	2	23.00.44 23.05.36	36°48.13’S 52°07.50’E	36°48.27’S 52°07.62’E	199.6 151.1	104	1.8 / 1.6 0.6 / 1.1	112.5 54.5
5 (PL45)	21/11/09	3	23.05.37 23.09.05	36°48.27’S 52°07.62’E	36°48.33’S 52°07.70’E	150.7 100.2	79	1.2 / 1.3 2.1 / 1.4	92.3 150.0
5 (PL45)	21/11/09	4	23.09.06 23.12.31	36°48.33’S 52°07.70’E	36°48.44’S 52°07.80’E	99.5 50.5	83	2.2 / 1.7 1.6 / 1.4	129.4 114.3
5 (PL45)	21/11/09	5	23.12.32 23.15.19	36°48.44’S 52°07.80’E	36°48.49’S 52°07.86’E	50.1 0.2	62	1.8 / 1.5 1.8 / 2.0	120.0 90.0
5 (PL46)	22/11/09	1	11.27.08 11.29.42	36°50.76’S 52°03.39’E	36°50.87’S 52°03.35’E	199.6 149.8	38	1.9 / 1.5 1.4 / 0.3	126.7 466.7
5 (PL46)	22/11/09	2	11.29.43 11.34.58	36°50.87’S 52°03.35’E	36°51.07’S 52°03.28’E	149.6 100.3	108	1.0 / 0.3 1.7 / 1.4	333.3 121.4
5 (PL46)	22/11/09	3	11.34.59 11.40.20	36°51.07’S 52°03.28’E	36°51.27’S 52°03.21’E	100.1 50.3	107	1.5 / 1.5 0.8 / 1.5	100.0 53.3
5 (PL46)	22/11/09	4	11.40.21 11.42.19	36°51.27’S 52°03.21’E	36°51.34’S 52°03.18’E	50.0 25.8	39	1.0 / 1.6 1.0 / 1.0	62.5 100.0
5 (PL46)	22/11/09	5	11.42.20 11.44.07	36°51.34’S 52°03.18’E	36°51.42’S 52°03.16’E	25.6 1.2	39	1.1 / 1.0 1.3 / 1.2	110.0 108.3
5 (PL47)	22/11/09	1	12.05.50 12.08.34	36°52.32’S 52°03.23’E	36°52.45’S 52°03.28’E	250.9 200.2	49	0.9 / 0.8 0.2 / 0.3	112.5 66.7
5 (PL47)	22/11/09	2	12.08.35 12.14.33	36°52.45’S 52°03.28’E	36°52.55’S 52°03.23’E	199.7 150.1	122	0.4 / 0.5 1.6 / 1.5	80.0 106.7
5 (PL47)	22/11/09	3	12.14.34 12.21.14	36°52.55’S 52°03.23’E	36°52.35’S 52°03.27’E	150.2 100.8	140	1.2 / 1.3 1.4 / 1.2	92.3 116.7
5 (PL47)	22/11/09	4	12.21.15 12.26.11	36°52.35’S 52°03.27’E	36°52.17’S 52°03.28’E	100.5 50.4	101	1.6 / 1.3 1.3 / 1.2	123.1 108.3
5 (PL47)	22/11/09	5	12.26.12 12.29.58	36°52.17’S 52°03.28’E	36°52.03’S 52°03.30’E	50.5 0.9	78	1.2 / 1.0 1.0 / 1.3	120 76.9
5 (PL48)	22/11/09	1	12.55.23 12.58.47	36°51.13’S 52°03.39’E	36°50.99’S 52°03.40’E	251.7 199.8	53	1.0 / 1.1 0.5 / 0.8	90.9 62.5
5 (PL48)	22/11/09	2	12.58.48 13.03.05	36°50.99’S 52°03.40’E	36°50.85’S 52°03.43’E	199.7 159.7	88	0.3 / 0.6 1.7 / 1.4	50.0 121.4
5 (PL48)	22/11/09	3	13.03.06 13.05.06	36°50.85’S 52°03.43’E	36°50.78’S 52°03.44’E	159.5 140.0	47	1.6 / 1.4 1.4 / 1.3	114.3 107.7
5 (PL48)	22/11/09	4	13.05.07 13.13.40	36°50.78’S 52°03.44’E	36°50.47’S 52°03.49’E	140.0 49.9	209	1.5 / 1.4 1.7 / 1.5	107.14 113.3

5 (PL48)	22/11/09	5	13.13.41 13.17.54	36°50.47'S 52°03.49'E	36°50.33'S 52°03.51'E	49.4 0.0	86	1.9 / 1.6 1.0 / 1.3	118.7 76.9
5 (PL54)	24/11/09	1	08.52.28 08.59.20	36°47.54'S 52°09.94'E	36°48.34'S 52°10.94'E	201.0 150.2	147	1.2 / 0.3 1.0 / 1.4	400.0 71.4
5 (PL54)	24/11/09	2	08.59.21 09.06.49	36°48.34'S 52°10.94'E	36°49.29'S 52°12.09'E	150.5 101.4	222	1.2 / 1.3 1.3 / 1.6	92.3 81.2
5 (PL54)	24/11/09	3	09.06.50 09.13.35	36°49.29'S 52°12.09'E	36°50.13'S 52°13.08'E	101.6 49.7	221	1.2 / 1.5 1.9 / 2.2	80.0 86.4
5 (PL54)	24/11/09	4	09.13.36 09.15.53	36°50.13'S 52°13.08'E	36°50.37'S 52°13.37'E	49.5 24.4	75	2.1 / 1.9 2.1 / 2.3	110.5 91.3
5 (PL54)	24/11/09	5	09.15.54 09.17.36	36°50.37'S 52°13.37'E	36°50.62'S 52°13.65'E	25.2 0.5	58	2.0 / 1.9 2.1 / 2.3	105.3 91.3
5 (PL61)	24/11/09	1	17.06.28 17.09.46	36°46.65'S 52°03.49'E	36°46.66'S 52°03.46'E	200.1 149.1	53	1.4 / 1.1 1.0 / 1.2	127.3 83.3
5 (PL61)	24/11/09	2	17.09.47 17.14.00	36°46.66'S 52°03.46'E	36°46.67'S 52°03.44'E	149.0 100.3	83	1.2 / 1.1 1.4 / 1.2	109.1 116.7
5 (PL61)	24/11/09	3	17.14.01 17.18.08	36°46.67'S 52°03.44'E	36°46.67'S 52°03.45'E	100.3 50.3	85	1.3 / 1.2 0.8 / 1.0	108.3 80.0
5 (PL61)	24/11/09	4	17.18.09 17.19.51	36°46.67'S 52°03.45'E	36°46.67'S 52°03.45'E	50.5 24.0	35	1.0 / 0.9 1.2 / 1.6	111.1 75.0
5 (PL61)	24/11/09	5	17.19.52 17.22.59	36°46.67'S 52°03.45'E	36°46.67'S 52°03.45'E	24.0 0.2	62	1.0 / 1.2 1.6 / 1.4	83.3 114.3
6 (PL66)	25/11/09	1	13.18.01 13.20.53	38°00.12'S 50°25.53'E	37°59.65'S 50°25.35'E	200.9 150.2	53	0.8 / 0.0 1.2 / 1.3	0.0 92.3
6 (PL66)	25/11/09	2	13.20.54 13.25.16	37°59.65'S 50°25.35'E	37°59.02'S 50°25.16'E	150.0 99.8	100	1.2 / 1.3 1.4 / 1.6	92.3 87.5
6 (PL66)	25/11/09	3	13.25.17 13.29.23	37°59.02'S 50°25.16'E	37°58.38'S 50°25.00'E	99.6 50.5	94	1.4 / 1.4 1.4 / 1.6	100.0 87.5
6 (PL66)	25/11/09	4	13.29.24 13.31.10	37°58.38'S 50°25.00'E	37°58.07'S 50°24.93'E	50.8 25.8	43	1.0 / 1.2 1.4 / 1.2	83.3 116.7
6 (PL66)	25/11/09	5	13.31.11 13.32.35	37°58.07'S 50°24.93'E	37°57.77'S 50°24.90'E	25.3 0.1	33	1.8 / 1.5 1.8 / 1.2	120.0 150.0
6 (PL67)	25/11/09	1	13.53.35 13.56.13	37°57.54'S 50°24.79'E	37°57.53'S 50°24.79'E	249.3 200.6	47	0.3 / 0.0 0.8 / 1.0	0.0 80.0
6 (PL67)	25/11/09	2	13.56.14 14.01.37	37°57.53'S 50°24.79'E	37°57.53'S 50°24.80'E	200.7 149.7	141	0.8 / 0.7 1.8 / 1.6	114.3 112.5
6 (PL67)	25/11/09	3	14.01.38 14.05.26	37°57.53'S 50°24.80'E	37°57.51'S 50°24.79'E	149.5 99.9	109	2.0 / 1.7 2.3 / 2.1	117.6 109.5
6 (PL67)	25/11/09	4	14.05.27 14.08.38	37°57.51'S 50°24.79'E	37°57.51'S 50°24.86'E	99.9 49.5	89	1.7 / 1.8 2.1 / 2.1	94.4 100.0
6 (PL67)	25/11/09	5	14.08.39 14.12.33	37°57.51'S 50°24.86'E	37°57.47'S 50°24.69'E	49.5 0.7	93	1.6 / 1.7 1.8 / 1.6	94.1 112.5
6 (PL68)	25/11/09	1	14.32.29 14.36.06	37°57.23'S 50°24.03'E	37°57.14'S 50°23.91'E	201.3 151.5	64	0.3 / 0.3 0.6 / 0.5	100.0 120.0
6 (PL68)	25/11/09	2	14.36.07 14.41.44	37°57.14'S 50°23.91'E	37°56.99'S 50°23.70'E	151.3 99.4	128	0.8 / 0.7 2.1 / 1.6	114.3 131.2
6 (PL68)	25/11/09	3	14.41.45 14.46.15	37°56.99'S 50°23.70'E	37°56.90'S 50°23.57'E	99.1 50.2	102	1.8 / 1.7 1.6 / 1.4	105.9 114.3
6 (PL68)	25/11/09	4	14.46.16 14.48.19	37°56.90'S 50°23.57'E	37°56.85'S 50°23.51'E	49.8 24.6	44	1.7 / 1.4 1.2 / 1.4	121.4 85.7
6 (PL68)	25/11/09	5	14.48.20 14.51.14	37°56.85'S 50°23.51'E	37°56.78'S 50°23.41'E	24.8 2.0	64	1.0 / 1.2 1.0 / 1.2	83.3 83.3
6 (PL69)	25/11/09	1	15.25.03 15.28.14	37°56.49'S 50°22.49'E	37°56.61'S 50°22.55'E	201.2 148.7	58	0.8 / 0.6 1.4 / 0.9	133.3 155.6
6 (PL69)	25/11/09	2	15.28.15 15.33.11	37°56.61'S 50°22.55'E	37°56.81'S 50°22.65'E	148.4 99.6	106	1.0 / 0.8 1.6 / 1.4	125.0 114.3
6 (PL69)	25/11/09	3	15.33.12 15.37.00	37°56.81'S 50°22.65'E	37°56.97'S 50°22.73'E	99.2 48.8	87	1.6 / 1.5 1.7 / 1.7	106.7 100.0
6 (PL69)	25/11/09	4	15.37.01 15.40.07	37°56.97'S 50°22.73'E	37°57.08'S 50°22.79'E	48.8 25.2	60	1.3 / 1.5 1.1 / 1.0	86.7 110.0
6 (PL69)	25/11/09	5	15.40.08 15.43.36	37°57.08'S 50°22.79'E	37°57.24'S 50°22.87'E	25.4 0.1	71	1.0 / 0.8 1.6 / 1.4	125.0 114.3
6 (PL70)	25/11/09	1	16.03.10 16.07.45	37°57.95'S 50°23.62'E	37°58.14'S 50°23.96'E	250.3 200.7	75	1.1 / 1.0 0.9 / 1.0	110.0 90.0
6 (PL70)	25/11/09	2	16.07.46	37°58.14'S	37°58.28'S	200.9	132	1.1 / 1.0	110.0

			16.13.19	50°23.96’E	50°24.37’E	150.7		1.4 / 1.4	100.0
6 (PL70)	25/11/09	3	16.13.20 16.17.03	37°58.28’S 50°24.37’E	37°58.27’S 50°24.58’E	150.4 99.8	91	1.8 / 1.4 1.4 / 1.3	128.6 107.7
6 (PL70)	25/11/09	4	16.17.04 16.21.33	37°58.27’S 50°24.58’E	37°58.09’S 50°24.63’E	100.1 49.7	102	0.9 / 1.0 1.6 / 1.6	90.0 100.0
6 (PL70)	25/11/09	5	16.21.34 16.24.39	37°58.09’S 50°24.63’E	37°57.98’S 50°24.63’E	49.6 0.4	82	1.4 / 1.4 1.8 / 1.8	100.0 100.0
6 (PL71)	25/11/09	1	16.40.38 16.44.38	37°57.41’S 50°24.58’E	37°57.28’S 50°24.55’E	199.5 150.2	60	0.8 / 0.3 0.5 / 0.7	266.7 71.4
6 (PL71)	25/11/09	2	16.44.39 16.49.14	37°57.28’S 50°24.55’E	37°57.15’S 50°24.50’E	150.0 99.9	95	1.2 / 1.0 1.6 / 1.4	120.0 114.3
6 (PL71)	25/11/09	3	16.49.15 16.52.42	37°57.15’S 50°24.50’E	37°57.04’S 50°24.42’E	99.5 49.4	75	1.6 / 1.4 1.5 / 1.4	114.3 107.1
6 (PL71)	25/11/09	4	16.52.43 16.55.04	37°57.04’S 50°24.42’E	37°56.98’S 50°24.38’E	48.8 25.3	48	1.9 / 1.6 0.8 / 1.0	118.75 80.0
6 (PL71)	25/11/09	5	16.55.05 16.56.51	37°56.98’S 50°24.38’E	37°56.91’S 50°24.33’E	25.2 0.7	38	1.0 / 1.0 0.7 / 1.0	100.0 70.0
6 (PL82)	27/11/09	1	11.13.51 11.17.46	37°57.37’S 50°25.99’E	37°57.41’S 50°25.83’E	200.0 150.2	62	1.0 / 0.8 1.0 / 0.8	125.0 125.0
6 (PL82)	27/11/09	2	11.17.47 11.23.51	37°57.41’S 50°25.83’E	37°57.47’S 50°25.61’E	150.2 100.6	109	1.0 / 0.8 1.2 / 1.1	125.0 109.1
6 (PL82)	27/11/09	3	11.23.52 11.28.14	37°57.47’S 50°25.61’E	37°57.51’S 50°25.46’E	100.4 51.0	90	1.3 / 1.2 1.2 / 1.4	108.3 85.7
6 (PL82)	27/11/09	4	11.28.15 11.30.33	37°57.51’S 50°25.46’E	37°57.54’S 50°25.35’E	51.1 25.9	55	1.0 / 1.2 1.3 / 1.3	83.3 100.0
6 (PL82)	27/11/09	5	11.30.34 11.31.59	37°57.54’S 50°25.35’E	37°57.55’S 50°25.32’E	25.3 1.2	39	2.1 / 1.6 1.4 / 0.3	131.2 466.7
7 (PL95)	29/11/09	1	12.40.08 12.41.53	41°29.98’S 49°30.28’E	41°29.97’S 49°30.29’E	199.4 149.4	31	0.6 / 0.3 1.2 / 0.3	200.0 400.0
7 (PL95)	29/11/09	2	12.41.54 12.44.55	41°29.97’S 49°30.29’E	41°29.94’S 49°30.30’E	149.2 100.4	70	1.0 / 0.2 1.3 / 1.4	500.0 92.9
7 (PL95)	29/11/09	3	12.44.56 12.47.49	41°29.94’S 49°30.30’E	41°29.91’S 49°30.34’E	100.6 49.9	63	1.1 / 1.2 1.6 / 1.3	91.7 123.1
7 (PL95)	29/11/09	4	12.47.50 12.48.53	41°29.91’S 49°30.34’E	41°29.91’S 49°30.34’E	49.4 25.0	21	1.6/1.4 1.5 / 1.4	114.3 107.1
7 (PL95)	29/11/09	5	12.48.54 12.49.54	41°29.91’S 49°30.34’E	41°29.90’S 49°30.33’E	24.0 0.4	24	2.1 / 1.7 1.4 / 1.4	123.5 100.0
7 (PL97)	29/11/09	1	13.51.09 13.54.45	41°29.45’S 49°31.31’E	41°29.40’S 49°31.50’E	200.3 150.2	62	0.3 / 0.3 1.4 / 1.2	100.0 116.7
7 (PL97)	29/11/09	2	13.54.46 13.58.30	41°29.40’S 49°31.50’E	41°29.37’S 49°31.64’E	150.3 100.2	80	1.0 / 1.0 1.4 / 1.8	100.0 77.8
7 (PL97)	29/11/09	3	13.58.31 14.02.33	41°29.37’S 49°31.64’E	41°29.33’S 49°31.85’E	100.5 49.9	95	1.0 / 1.3 0.9 / 1.1	76.9 81.8
7 (PL97)	29/11/09	4	14.02.34 14.04.23	41°29.33’S 49°31.85’E	41°29.32’S 49°31.89’E	49.7 25.0	40	1.1 / 1.1 0.8 / 1.0	100.0 80.0
7 (PL97)	29/11/09	5	14.04.24 14.06.32	41°29.32’S 49°31.89’E	41°29.30’S 49°32.01’E	25.0 0.0	44	1.0 / 1.0 1.4 / 1.0	100.0 140.0
7 (PL102)	29/11/09	1	17.20.31 17.27.09	41°30.49’S 49°28.90’E	41°30.59’S 49°28.63’E	200.5 120.3	109	0.5 / 0.3 1.2 / 1.2	166.7 100.0
7 (PL102)	29/11/09	2	17.27.10 17.30.37	41°30.59’S 49°28.63’E	41°30.65’S 49°28.46’E	120.3 81.1	58	1.0 / 1.0 1.2 / 1.0	100.0 120.0
7 (PL102)	29/11/09	3	17.30.38 17.34.14	41°30.65’S 49°28.46’E	41°30.70’S 49°28.33’E	80.4 51.4	65	1.6 / 1.3 0.9 / 0.9	123.1 100.0
7 (PL102)	29/11/09	4	17.34.15 17.38.44	41°30.70’S 49°28.33’E	41°30.77’S 49°28.11’E	51.7 25.9	82	1.0 / 0.8 0.5 / 0.9	125.0 55.6
7 (PL102)	29/11/09	5	17.38.45 17.42.23	41°30.77’S 49°28.11’E	41°30.81’S 49°27.98’E	25.8 0.0	63	1.0 / 0.9 0.5 / 1.3	111.1 38.5
7 (PL103)	29/11/09	1	17.59.28 18.03.52	41°31.04’S 49°27.26’E	41°31.12’S 49°27.05’E	251.1 200.3	67	1.1 / 0.8 1.1 / 1.0	137.5 110.0
7 (PL103)	29/11/09	2	18.03.53 18.09.42	41°31.12’S 49°27.05’E	41°31.09’S 49°26.99’E	200.1 151.2	100	1.1 / 1.0 0.9 / 1.0	110.0 90.0
7 (PL103)	29/11/09	3	18.09.43 18.14.13	41°31.09’S 49°26.99’E	41°31.03’S 49°27.14’E	151.5 100.2	85	0.9 / 0.9 1.4 / 1.4	100.0 100.0
7 (PL103)	29/11/09	4	18.14.14 18.18.43	41°31.03’S 49°27.14’E	41°30.97’S 49°27.34’E	100.0 50.0	94	1.4 / 1.4 0.8 / 1.1	100.0 72.7

7 (PL103)	29/11/09	5	18.18.44 18.22.02	41°30.97’S 49°27.34’E	41°30.93’S 49°27.47’E	50.2 0.0	63	0.8 / 1.0 1.5 / 1.4	80.0 107.1
7 (PL104)	29/11/09	1	18.44.46 18.54.11	41°30.66’S 49°28.44’E	41°30.58’S 49°28.73’E	202.5 80.4	138	1.4 / 1.2 1.0 / 1.1	116.7 90.9
7 (PL104)	29/11/09	2	18.54.12 18.56.24	41°30.58’S 49°28.73’E	41°30.56’S 49°28.81’E	80.3 50.0	45	1.1 / 1.1 1.3 / 1.2	100.0 108.3
7 (PL104)	29/11/09	3	18.56.25 18.59.50	41°30.56’S 49°28.81’E	41°30.52’S 49°28.97’E	49.8 25.0	65	1.4 / 1.2 1.2 / 1.2	116.7 100.0
7 (PL104)	29/11/09	4	18.59.51 19.02.48	41°30.52’S 49°28.97’E	41°30.49’S 49°29.11’E	25.0 0.8	46	1.2 / 1.0 0.9 / 0.8	120.0 112.5
8 (PL108)	01/12/09	1	22.37.59 22.41.44	41°25.36’S 42°51.05’E	41°25.43’S 42°50.82’E	200.7 150.6	75	0.2 / 0.1 1.6 / 1.5	200.0 106.7
8 (PL108)	01/12/09	2	22.41.45 22.46.08	41°25.43’S 42°50.82’E	41°25.45’S 42°50.82’E	150.7 100.9	97	1.3 / 1.4 1.2 / 1.2	92.9 100.0
8 (PL108)	01/12/09	3	22.46.09 22.49.25	41°25.45’S 42°50.82’E	41°25.47’S 42°50.80’E	100.5 50.7	66	1.4 / 1.2 0.8 / 1.0	116.7 80.0
8 (PL108)	01/12/09	4	22.49.26 22.50.38	41°25.47’S 42°50.80’E	41°25.47’S 42°50.81’E	50.6 24.9	23	0.8 / 1.0 1.2 / 1.4	80.0 85.7
8 (PL108)	01/12/09	5	22.50.39 22.51.37	41°25.47’S 42°50.81’E	41°25.48’S 42°50.81’S	24.8 0.0	24	1.1 / 1.2 1.6 / 1.6	91.7 100.0
8 (PL109)	01/12/09	1	23.17.51 23.24.46	41°25.90’S 42°51.21’E	41°26.33’S 42°51.41’E	250.5 200.3	129	0.1 / 0.2 0.3 / 0.5	50.0 60.0
8 (PL109)	01/12/09	2	23.24.47 23.31.06	41°26.33’S 42°51.41’E	41°26.23’S 42°51.69’E	200.4 149.5	169	1.0 / 1.0 2.1 / 2.3	100.0 91.3
8 (PL109)	01/12/09	3	23.31.07 23.35.18	41°26.23’S 42°51.69’E	41°26.16’S 42°51.89’E	149.4 100.5	119	1.8 / 2.0 1.6 / 1.8	90.0 88.9
8 (PL109)	01/12/09	4	23.35.19 23.39.07	41°26.16’S 42°51.89’E	41°26.08’S 42°52.10’E	100.6 50.2	99	1.4 / 1.5 1.2 / 1.4	93.3 85.7
8 (PL109)	01/12/09	5	23.39.08 23.42.18	41°26.08’S 42°52.10’E	41°26.02’S 42°52.22’E	50.1 1.9	78	1.2 / 1.3 1.4 / 0.5	92.3 280
8 (PL110)	02/12/09	1	00.04.10 00.06.42	41°25.62’S 42°53.24’E	41°25.57’S 42°53.43’E	200.4 149.8	56	1.0 / 0.7 1.2 / 1.2	142.9 100.0
8 (PL110)	02/12/09	2	00.06.43 00.11.21	41°25.57’S 42°53.43’E	41°25.48’S 42°53.67’E	149.8 100.8	111	1.2 / 1.2 1.5 / 1.7	100.0 88.2
8 (PL110)	02/12/09	3	00.11.22 00.16.19	41°25.48’S 42°53.67’E	41°25.37’S 42°53.97’E	100.8 50.2	129	1.4 / 1.5 1.2 / 1.4	93.3 85.7
8 (PL110)	02/12/09	4	00.16.20 00.18.02	41°25.37’S 42°53.97’E	41°25.32’S 42°54.08’E	50.4 24.5	42	1.0 / 1.2 1.7 / 1.8	83.3 94.4
8 (PL110)	02/12/09	5	00.18.03 00.19.18	41°25.32’S 42°54.08’E	41°25.30’S 42°54.13’E	24.4 0.7	31	1.6 / 1.6 1.3 / 0.4	100.0 325.0
9 (PL146)	07/12/09	1	21.54.41 22.00.32	38°29.64’S 46°44.33’E	38°29.67’S 46°43.96’E	200.7 148.8	113	0.5 / 0.3 0.1 / 0.5	166.7 20.0
9 (PL146)	07/12/09	2	22.00.33 22.07.27	38°29.67’S 46°43.96’E	38°29.77’S 46°43.73’E	148.7 99.9	172	0.1 / 0.3 1.0 / 1.1	33.3 90.9
9 (PL146)	07/12/09	3	22.07.28 22.11.55	38°29.77’S 46°43.73’E	38°29.89’S 46°43.61’E	99.9 50.9	105	1.4 / 1.2 1.4 / 1.3	116.7 107.7
9 (PL146)	07/12/09	4	22.11.56 22.13.49	38°29.89’S 46°43.61’E	38°29.98’S 46°43.59’E	50.8 25.3	46	1.4 / 1.2 1.5 / 1.4	116.7 107.1
9 (PL146)	07/12/09	5	22.13.50 22.15.18	38°29.98’S 46°43.59’E	38°30.01’S 46°43.58’E	25.4 0.7	37	1.1 / 1.2 1.0 / 1.4	91.7 71.4
9 (PL147)	07/12/09	1	22.49.08 22.55.34	38°30.31’S 46°43.8’E	38°30.12’S 46°44.01’E	250.6 200.7	126	0.7 / 0.3 0.5 / 0.5	233.3 100.0
9 (PL147)	07/12/09	2	22.55.35 23.03.12	38°30.12’S 46°44.01’E	38°29.92’S 46°44.23’E	200.5 150.4	198	1.2 / 1.0 1.8 / 1.8	120.0 100.0
9 (PL147)	07/12/09	3	23.03.13 23.08.32	38°29.92’S 46°44.23’E	38°29.78’S 46°44.44’E	150.8 99.3	125	1.2 / 1.4 2.2 / 2.3	85.7 95.6
9 (PL147)	07/12/09	4	23.08.33 23.12.09	38°29.78’S 46°44.44’E	38°29.69’S 46°44.53’E	99.0 50.7	86	1.7 / 2.0 1.0 / 1.1	85.0 90.9
9 (PL147)	07/12/09	5	23.12.10 23.15.50	38°29.69’S 46°44.53’E	38°29.58’S 46°44.66’E	50.0 1.7	87	1.8 / 1.4 0.6 / 1.2	128.6 50.0
9 (PL148)	07/12/09	1	23.44.11 23.48.29	38°28.87’S 46°45.63’E	38°28.79’S 46°45.79’E	200.4 150.1	65	0.3 / 0.4 0.2 / 0.6	75.0 33.3
9 (PL148)	07/12/09	2	23.48.30 23.53.22	38°28.79’S 46°45.79’E	38°28.72’S 46°46.01’E	150.3 101.5	82	0.5 / 0.7 0.5 / 0.8	71.4 62.5
9	07/12/09	3	23.53.23	38°28.72’S	38°28.67’S	101.9	84	0.6 / 0.7	85.7

(PL148)			23.58.03	46°46.01'E	46°46.22'E	50.1		0.8 / 1.2	66.7
9 (PL148)	08/12/09	4	23.58.04 00.00.17	38°28.67'S 46°46.22'E	38°28.65'S 46°46.30'E	51.3 25.4	47	1.0 / 1.2 1.0 / 1.1	83.3 90.9
9 (PL148)	08/12/09	5	00.00.18 00.02.05	38°28.65'S 46°46.30'E	38°28.62'S 46°46.39'E	26.3 0.2	38	0.9 / 1.0 1.8 / 1.8	90.0 100.0
9 (PL149)	08/12/09	1	02.16.06 02.21.35	38°28.19'S 46°43.95'E	38°28.04'S 46°43.76'E	201.3 149.5	96	1.2 / 1.1 1.4 / 1.6	109.1 87.5
9 (PL149)	08/12/09	2	02.21.36 02.26.36	38°28.04'S 46°43.76'E	38°27.87'S 46°43.51'E	149.4 100.1	128	1.2 / 1.4 2.0 / 2.1	85.7 95.2
9 (PL149)	08/12/09	3	02.26.37 02.30.55	38°27.87'S 46°43.51'E	38°27.76'S 46°43.44'S	99.8 51.4	111	2.0 / 2.1 1.0 / 1.4	95.2 71.4
9 (PL149)	08/12/09	4	02.30.56 02.33.02	38°27.76'S 46°43.44'S	38°27.70'S 46°43.43'E	51.8 25.5	53	1.0 / 1.2 1.2 / 1.5	83.3 80.0
9 (PL149)	08/12/09	5	02.33.03 02.34.42	38°27.70'S 46°43.43'E	38°27.64'S 46°43.43'S	25.9 0.2	43	0.8 / 1.1 1.7 / 1.4	72.7 121.4
9 (PL150)	08/12/09	1	02.55.05 02.58.31	38°28.49'S 46°44.27'E	38°29.07'S 46°44.51'E	251.6 200.4	53	1.0 / 0.9 0.1 / 0.1	111.1 100.0
9 (PL150)	08/12/09	2	02.58.32 03.03.33	38°29.07'S 46°44.51'E	38°29.47'S 46°44.80'E	200.8 149.2	116	0.1 / 0.1 1.8 / 2.0	100.0 90.0
9 (PL150)	08/12/09	3	03.03.34 03.09.01	38°29.47'S 46°44.80'E	38°29.38'S 46°44.98'E	149.5 98.9	137	1.2 / 1.6 2.3 / 2.4	75.0 95.8
9 (PL150)	08/12/09	4	03.09.02 03.12.50	38°29.38'S 46°44.98'E	38°29.31'S 46°45.12'E	98.8 50.8	100	1.8 / 2.1 1.3 / 1.4	85.7 92.9
9 (PL150)	08/12/09	5	03.12.51 03.15.45	38°29.31'S 46°45.12'E	38°29.26'S 46°45.23'E	50.6 1.3	78	1.6 / 1.4 1.8 / 1.9	114.3 94.7
9 (PL151)	08/12/09	1	03.51.47 03.54.51	38°28.67'S 46°46.52'E	38°28.62'S 46°46.62'E	199.8 149.5	53	1.2 / 1.1 0.3 / 0.8	109.1 37.5
9 (PL151)	08/12/09	2	03.54.52 03.59.53	38°28.62'S 46°46.62'E	38°28.54'S 46°46.80'E	149.4 101.4	123	0.6 / 1.0 1.2 / 1.3	60.0 92.3
9 (PL151)	08/12/09	3	03.59.54 04.04.03	38°28.54'S 46°46.80'E	38°28.48'S 46°46.93'E	101.5 50.3	116	1.3 / 1.3 1.4 / 1.4	100.0 100.0
9 (PL151)	08/12/09	4	04.04.04 04.06.36	38°28.48'S 46°46.93'E	38°28.43'S 46°47.03'E	50.0 25.1	65	1.7 / 1.5 1.1 / 1.2	113.3 91.7
9 (PL151)	08/12/09	5	04.06.37 04.09.26	38°28.43'S 46°47.03'E	38°28.40'S 46°47.09'E	25.7 1.5	70	0.8 / 1.1 1.3 / 1.8	72.7 72.2
10 (PL177)	12/12/09	1	18.11.13 18.15.40	31°36.87'S 42°48.64'E	31°37.04'S 42°48.82'E	199.7 151.0	69	1.5 / 1.3 1.0 / 1.0	115.4 100.0
10 (PL177)	12/12/09	2	18.15.41 18.21.36	31°37.04'S 42°48.82'E	31°37.21'S 42°49.01'E	151.0 100.0	128	1.2 / 1.0 1.3 / 1.2	120.0 108.3
10 (PL177)	12/12/09	3	18.21.37 18.26.04	31°37.21'S 42°49.01'E	31°37.35'S 42°49.15'E	99.9 49.2	99	1.4 / 1.2 1.4 / 1.6	116.7 87.5
10 (PL177)	12/12/09	4	18.26.05 18.27.45	31°37.35'S 42°49.15'E	31°37.42'S 42°49.22'E	49.3 24.5	36	1.0 / 1.2 1.7 / 1.6	83.3 106.2
10 (PL177)	12/12/09	5	18.27.46 18.30.07	31°37.42'S 42°49.22'E	31°37.49'S 42°49.29'E	24.4 1.2	45	1.2 / 1.3 1.0 / 1.0	92.3 100.0
10 (PL178)	12/12/09	1	18.47.06 18.50.05	31°38.03'S 42°49.90'E	31°38.13'S 42°50.01'E	250.8 200.1	41	1.1 / 1.0 0.1 / 0.2	110.0 50.0
10 (PL178)	12/12/09	2	18.50.06 18.55.29	31°38.13'S 42°50.01'E	31°38.29'S 42°50.19'E	199.6 150.3	120	0.1 / 0.5 1.4 / 1.5	20.0 93.3
10 (PL178)	12/12/09	3	18.55.30 19.00.20	31°38.29'S 42°50.19'E	31°38.46'S 42°50.38'E	150.3 99.5	106	1.3 / 1.4 1.6 / 1.6	92.9 100.0
10 (PL178)	12/12/09	4	19.00.21 19.04.13	31°38.46'S 42°50.38'E	31°38.60'S 42°50.53'E	99.6 49.7	82	1.1 / 1.3 1.2 / 1.2	84.6 100.0
10 (PL178)	12/12/09	5	19.04.14 19.07.06	31°38.60'S 42°50.53'E	31°38.71'S 42°50.64'E	49.5 0.5	60	1.4 / 1.1 1.2 / 1.0	127.3 120.0
10 (PL179)	12/12/09	1	19.21.14 19.24.40	31°39.24'S 42°51.16'E	31°39.37'S 42°51.30'E	199.9 149.1	53	0.2 / 0.1 1.1 / 1.2	200.0 91.7
10 (PL179)	12/12/09	2	19.24.41 19.28.26	31°39.37'S 42°51.30'E	31°39.47'S 42°51.40'E	148.8 100.5	72	1.2 / 1.2 0.9 / 1.1	100.0 81.8
10 (PL179)	12/12/09	3	19.28.27 19.32.44	31°39.47'S 42°51.40'E	31°39.64'S 42°51.59'E	100.3 51.2	85	1.0 / 1.0 1.0 / 0.9	100.0 111.1
10 (PL179)	12/12/09	4	19.32.45 19.34.47	31°39.64'S 42°51.59'E	31°39.71'S 42°51.67'E	50.9 24.7	45	1.3 / 1.0 1.6 / 1.6	130.0 100.0
10 (PL179)	12/12/09	5	19.34.48 19.36.24	31°39.71'S 42°51.67'E	31°39.74'S 42°51.71'E	24.5 0.1	40	1.4 / 1.4 0.8 / 0.3	100.0 266.7

10 (PL180)	13/12/09	1	07.32.40 07.35.27	31°42.38’S 42°50.12’E	31°42.14’S 42°49.83’E	200.3 150.2	48	1.0 / 0.4 0.8 / 1.0	250.0 80.0
10 (PL180)	13/12/09	2	07.35.28 07.40.01	31°42.14’S 42°49.83’E	31°41.53’S 42°49.13’E	150.2 100.2	94	0.6 / 0.8 1.5 / 1.2	75.0 125.0
10 (PL180)	13/12/09	3	07.40.02 07.44.07	31°41.53’S 42°49.13’E	31°41.04’S 42°48.57’E	99.9 49.6	84	1.6 / 1.3 1.9 / 1.7	123.1 111.8
10 (PL180)	13/12/09	4	07.44.08 07.45.59	31°41.04’S 42°48.57’E	31°40.80’S 42°48.29’E	49.1 24.9	38	1.8 / 1.8 0.8 / 1.2	100.0 66.7
10 (PL180)	13/12/09	5	07.46.00 07.47.28	31°40.80’S 42°48.29’E	31°40.67’S 42°48.15’E	25.1 0.2	31	0.7 / 0.9 1.5 / 1.5	77.8 100.0
10 (PL181)	13/12/09	1	08.10.29 08.14.07	31°37.86’S 42°44.90’E	31°37.35’S 42°44.34’E	250.2 200.6	57	0.3 / 5.0 1.3 / 0.8	6.0 162.5
10 (PL181)	13/12/09	2	08.14.08 08.21.24	31°37.35’S 42°44.34’E	31°36.48’S 42°43.36’E	200.3 150.4	152	1.4 / 0.9 1.3 / 1.2	155.6 108.3
10 (PL181)	13/12/09	3	08.21.25 08.27.45	31°36.48’S 42°43.36’E	31°36.25’S 42°43.48’E	150.3 100.6	137	1.4 / 1.2 1.4 / 1.2	116.7 116.7
10 (PL181)	13/12/09	4	08.27.46 08.33.42	31°36.25’S 42°43.48’E	31°36.24’S 42°43.74’E	100.5 50.7	125	1.4 / 1.2 1.4 / 1.0	116.7 140.0
10 (PL181)	13/12/09	5	08.33.43 08.38.10	31°36.24’S 42°43.74’E	31°36.24’S 42°43.94’E	50.5 0.9	98	1.4 / 1.1 1.0 / 1.0	127.3 100.0

Table 6. Åkra trawl deployments are given including the Nansen Åkra trawl number, the Station Number, the date, the position at the start of the trawl and the position at the end. D = Day trawl; N = Night trawl; Dw = dawn trawl.

Nansen Trawl Number	Station	Date	Start position	End position	Maximum depth	Day / Night / Dawn
1	2	14/11/09	26°55.85’S 56°11.34’E	26°56.32’S 56°13.80’E	600	D
2	2	14/11/09	26°56.45’S 56°14.22’E	26°56.81’S 56°16.74’E	300	D
3	2	14/11/09	26°56.81’S 56°16.92’E	26°57.17’S 56°19.44’E	50	D
4	2	15/11/09	26°59.15’S 56°14.58’E	26°55.79’S 56°10.80’E	800	D
5	4	17/11/09	32°43.49’S 57°17.82’E	32°42.89’S 57°14.46’E	700	D
6	4	17/11/09	32°43.49’S 57°17.82’E	32°43.31’S 57°13.98’E	400	D
7	4	18/11/09	32°43.61’S 57°17.82’E	32°43.55’S 57°15.72’E	700	N
8	4	18/11/09	32°43.31’S 57°16.44’E	32°43.55’S 57°19.44’E	400	N
9	4	19/11/09	32°44.21’S 57°17.24’E	32°41.57’S 57°17.82’E	740	Dw
10	5	22/11/09	36°51.35’S 52°03.34’E	36°49.13’S 52°03.72’E	750	D
11	5	22/11/09	36°49.61’S 52°03.66’E	36°52.07’S 52°03.18’E	400	D
12	5	23/11/09	36°50.51’S 52°03.36’E	36°48.29’S 53°03.72’E	720	N
13	5	23/11/09	36°48.95’S	36°47.21’S	400	N

			52°04.50'E	52°07.08'E		
14	5	23/11/09	36°47.27'S 52°07.26'E	36°47.27'S 52°07.26'E	500	N
15	5	24/11/09	36°51.65'S 52°03.06'E	36°48.41'S 52°03.96'E	750	Dw
16	6	25/11/09	37°57.29'S 50°22.61'E	37°57.05'S 50°25.85'E	700	N
17	6	25/11/09	37°57.17'S 50°25.25'E	37°57.29'S 50°22.37'E	400	N
18	6	26/11/09	37°57.41'S 50°24.53'E	37°57.47'S 50°26.39'E	930	N
19	6	27/11/09	37°57.35'S 50°24.17'E	37°57.53'S 50°25.55'E	700	D
20	6	27/11/09	37°57.47'S 50°25.37'E	37°57.47'S 50°24.29'E	420	D
21	7	29/11/09	41°28.79'S 49°32.03'E	41°31.07'S 49°29.57'E	700	N
22	7	29/11/09	41°30.59'S 49°30.23'E	41°28.49'S 49°32.51'E	400	N
23	7	30/11/09	41°34.25'S 49°27.00'E	41°32.99'S 49°28.25'E	700	D
24	7	30/11/09	41°33.41'S 49°28.55'E	41°34.07'S 49°27.35'E	400	D
25	8	02/12/09	41°25.61'S 42°55.67'E	41°24.89'S 42°57.17'E	900	D
26	8	02/12/09	41°24.65'S 42°56.51'E	41°25.07'S 42°54.77'E	600	D
27	8	02/12/09	41°25.55'S 42°55.79'E	41°26.15'S 42°52.79'E	900	N
28	8	02/12/09	41°25.13'S 42°54.17'E	41°23.99'S 42°56.63'E	643	N
29	8	03/12/09	41°24.71'S 42°52.19'E	41°24.11'S 42°54.29'E	270	Dw
30	9	07/12/09	38°30.23'S 46°45.53'E	38°31.01'S 46°41.93'E	860	N
31	9	07/12/09	38°28.67'S 46°46.79'E	38°29.69'S 46°43.79'E	480	N
32	9	08/12/09	38°28.49'S 46°46.25'E	38°28.37'S 46°44.21'E	320	Dw
33	9	08/12/09	38°30.29'S 46°45.59'E	38°30.89'S 46°42.65'E	850	D
34	9	08/12/09	38°29.57'S 46°44.57'E	38°28.43'S 46°47.45'E	430	D
35	9	08/12/09	38°27.89'S 46°44.93'E	38°28.49'S 46°42.05'E	560	D
36	10	12/12/09	31°38.45'S 42°49.97'E	31°37.43'S 42°50.39'E	700	N
37	10	12/12/09	31°35.33'S 42°51.59'E	31°34.85'S 42°53.09'E	1100	N
38	10	13/12/09	31°35.75'S 42°52.79'E	31°36.29'S 42°51.53'E	300	N
39	10	14/12/09	31°38.87'S 42°48.77'E	31°39.77'S 42°48.17'E	1100	D
40	10	14/12/09	31°38.69'S 42°48.77'E	31°37.61'S 42°49.67'E	700	D

Figure 1. SW Indian Ocean showing the South West Indian Ridge, Madagascar Ridge and other topographic features. Stars = Islands; Triangles = Positions of sampled seamounts (ATL = Atlantis Bank; SAP = Sapmer Bank; MOW = Middle of What Seamount; MEL = Melville Bank; COR = Coral Seamount; UMR = Un-named Seamount Madagascar Ridge); Circles = Off-Seamount Stations; Lines = CTD Transects. Map generated using GEBCO.

Figure 2 SW Indian Ocean showing the South West Indian Ridge, Madagascar Ridge, other topographic features and major surface water masses and fronts. Stars = Islands; Triangles = Positions of sampled seamounts (ATL = Atlantis Bank; SAP = Sapmer Bank; MOW = Middle of What Seamount; MEL = Melville Bank; COR = Coral Seamount; UMR = Un-named Seamount Madagascar Ridge); Circles = Off-Seamount Stations; Red Lines = CTD Transects; Yellow Lines = Major currents; Pale Blue Lines = Fronts. Map generated using GEBCO.

Figure 3. Phytoplankton net being recovered at night 13/11/2009. Photograph AD Rogers.

Figure 4. Multinet being recovered during the day 14/11/2009. Photograph AD Rogers.

Figure 5. Bongo nets lying on deck, 12/12/2009. Photograph S. Gotheil.

Figure 6. Åkra trawl being recovered onto the rear deck on the evening of 14/11/2009. Large animals such as squid and fish were often caught in the outer panels of the net. Photograph AD Rogers.

Figure 7. 2D map of Atlantis Bank generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

Figure 8. 2D map of Sapmer Bank generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

Figure 9. 2D map of Middle of What Seamount generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

Figure 10. 2D map of Melville Bank generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

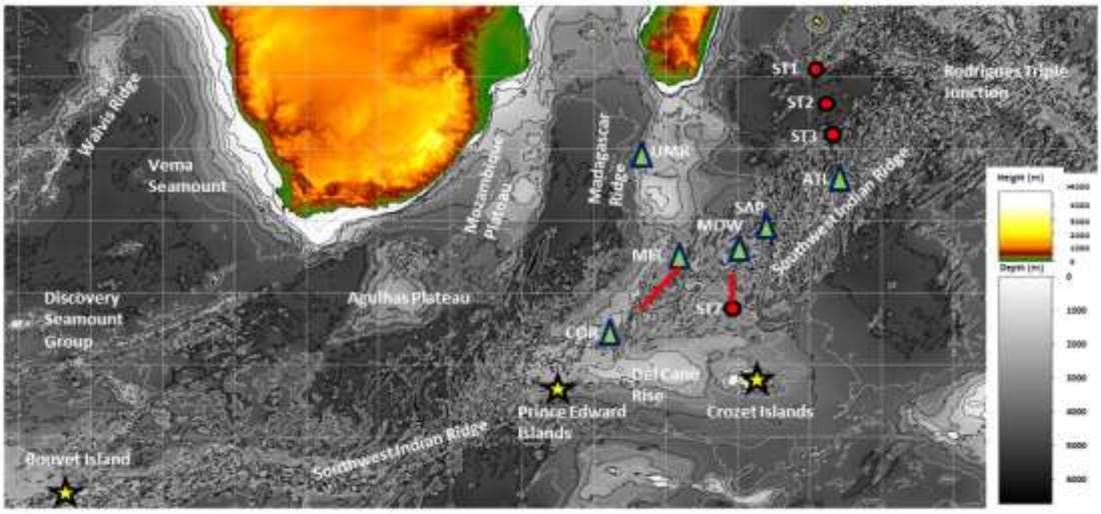
Figure 11. 2D map of Coral Seamount generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

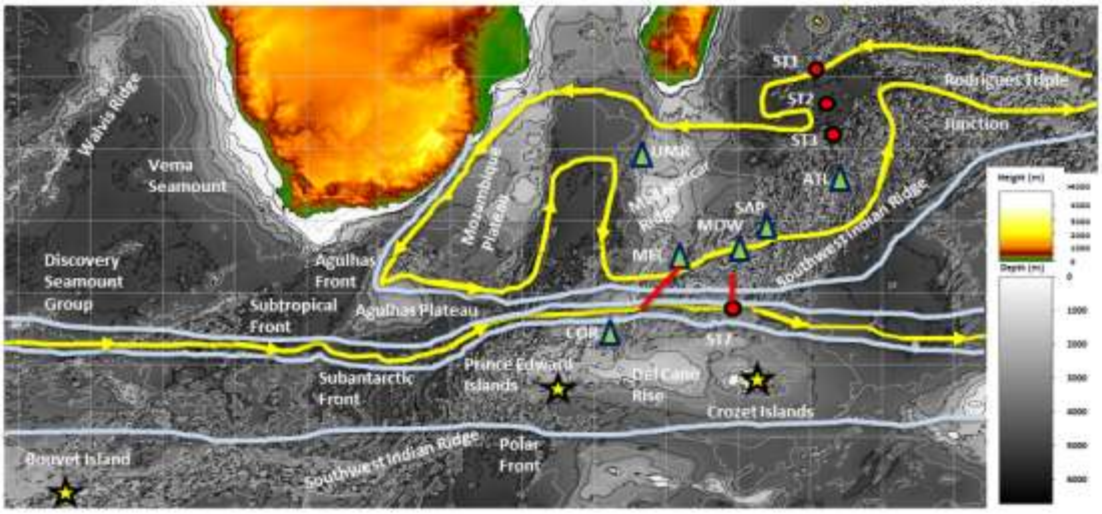
Figure 12. 2D map of Un-named seamount, Madagascar Ridge, generated by multibeam during RV *Fridtjof Nansen* cruise 2009 410. C/O Marc Wieland, University of Oxford, Dept. Zoology.

Figure 13. Composite maps for all seamounts showing positions of CTDs (black circles) and trawls (red lines).

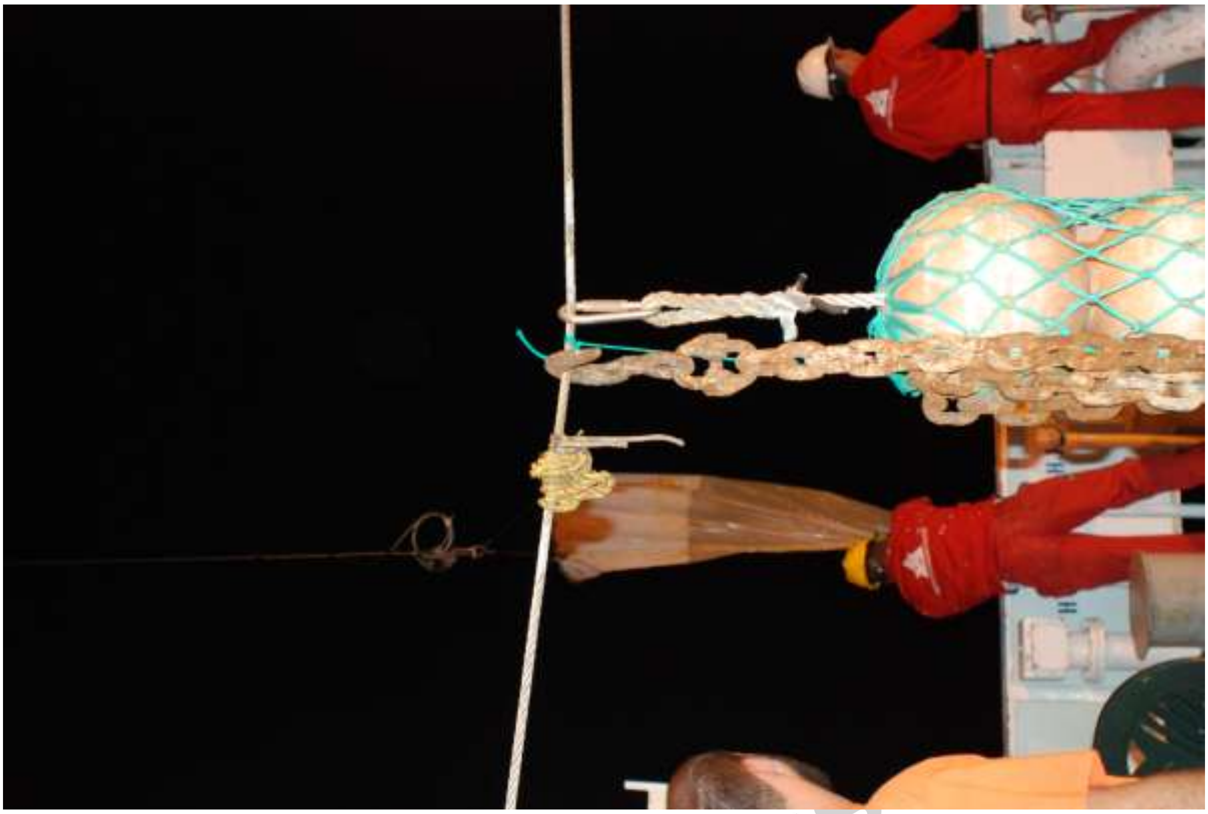
Figure 14. *Etmopterus pusillus* following recovery in Åkra trawl showing evidence of net feeding on squid.

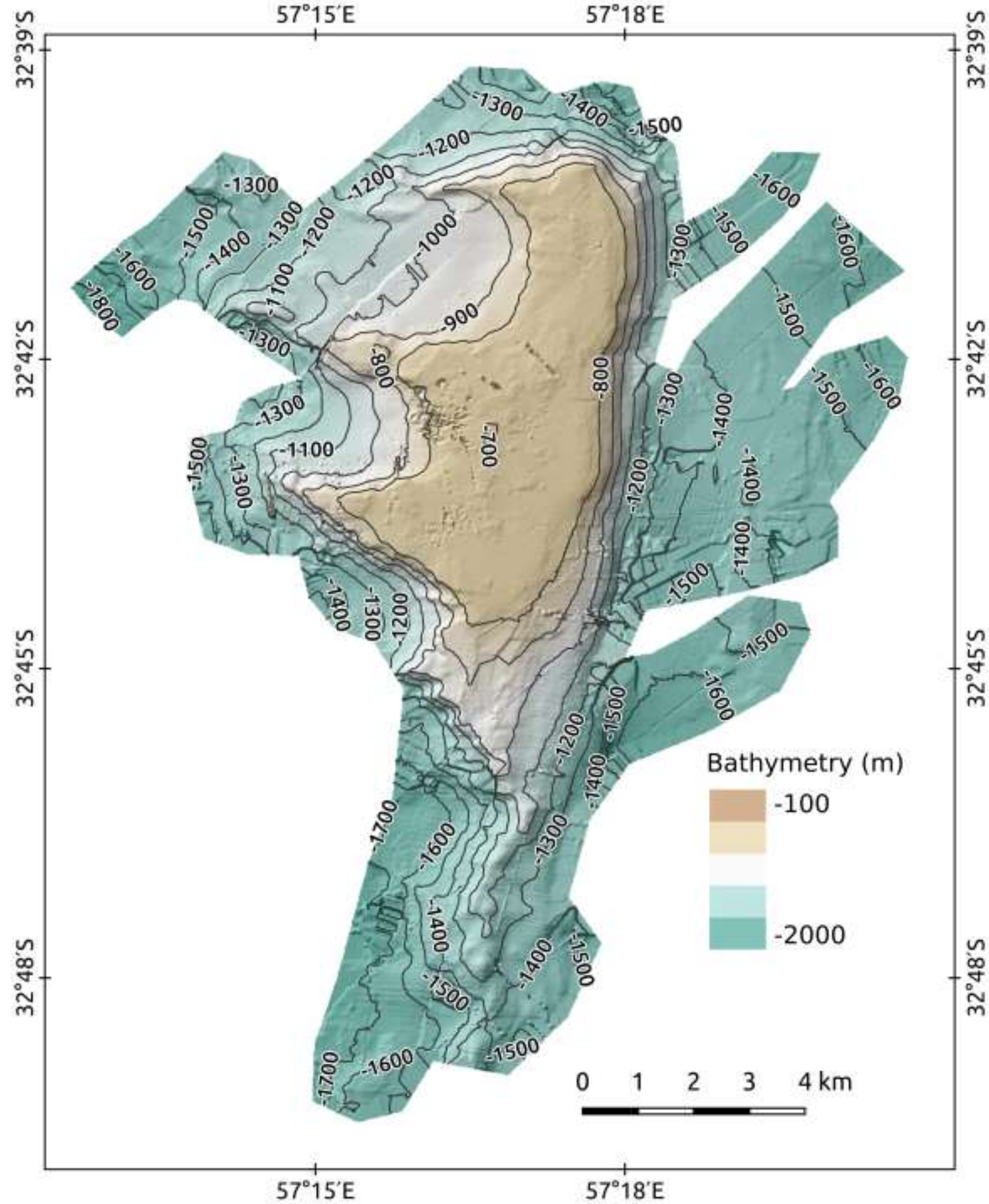
Figure 15. Internal wave detected through acoustic reflection of entrained zooplankton / micronekton detected over un-named seamount on the South West Indian Ridge.





Walvis Ridge
Vema Seamount
Discovery Seamount Group
Agulhas Front
Mozambique Plateau
Subtropical Front
Agulhas Plateau
Subantarctic Front
Prince Edward Islands
Bouvet Island
Southwest Indian Ridge
Polar Front
Del Cano Rise
Crozet Islands
UMR
Madagascar Ridge
MEL
MDW
SAP
ATL
COR
ST1
ST2
ST3
ST7
Rodrigues Triple Junction
Southwest Indian Ridge

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32°42′S
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-800
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-1100
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-1300
-1400
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-1700
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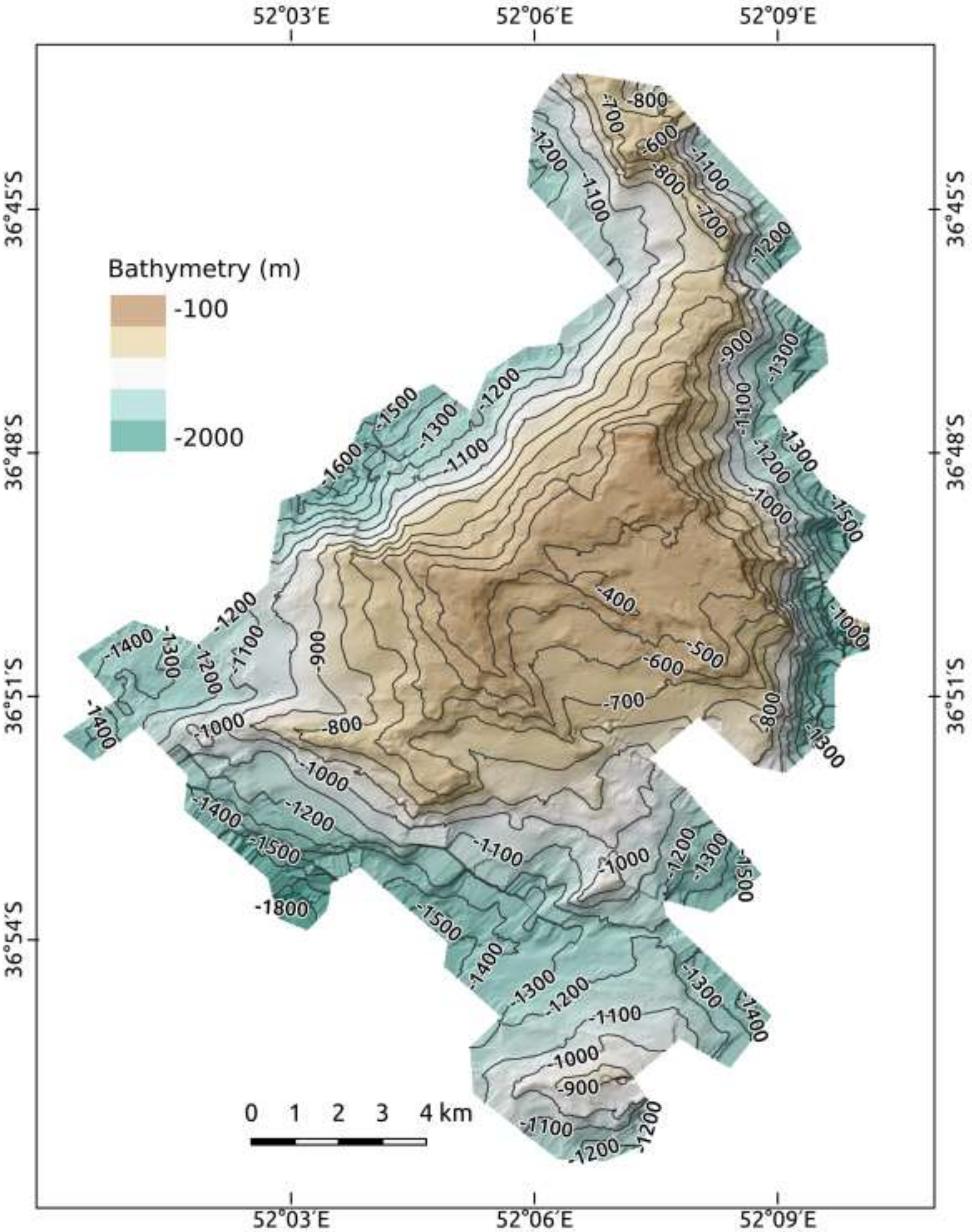
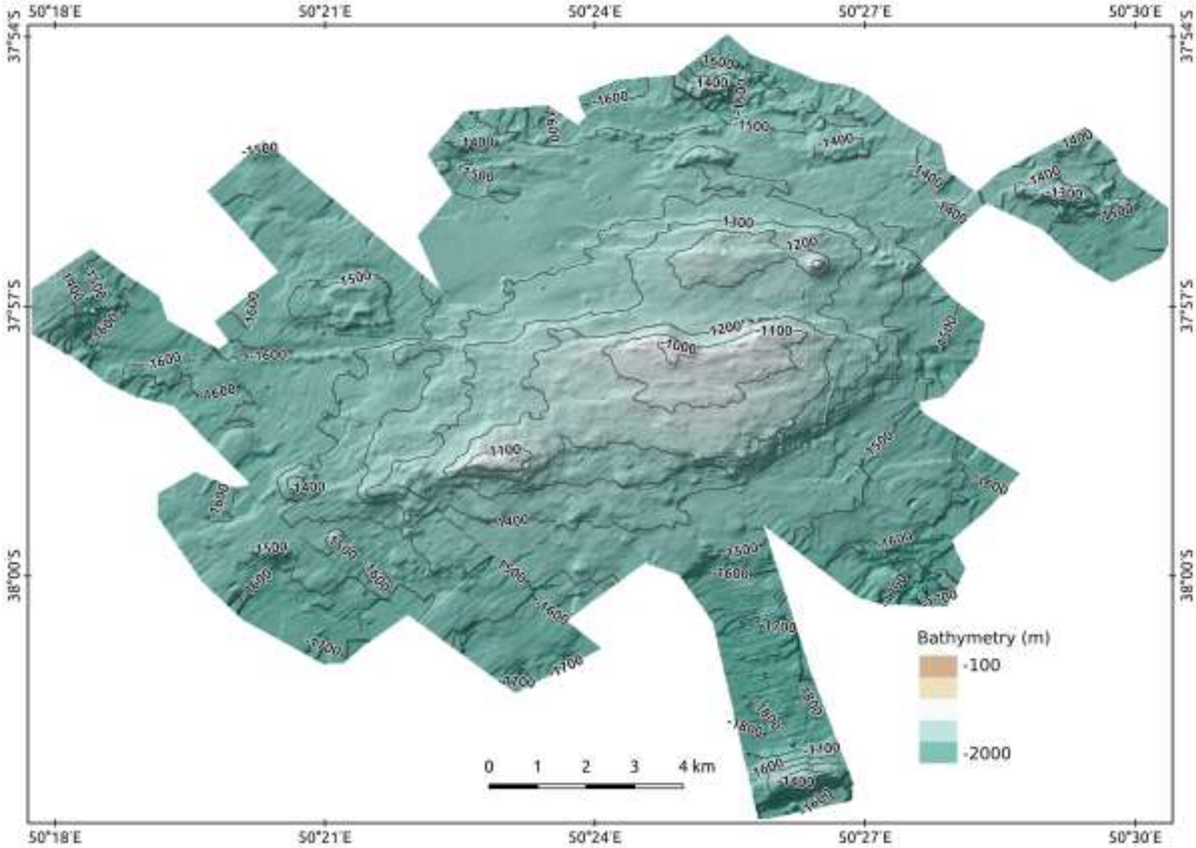
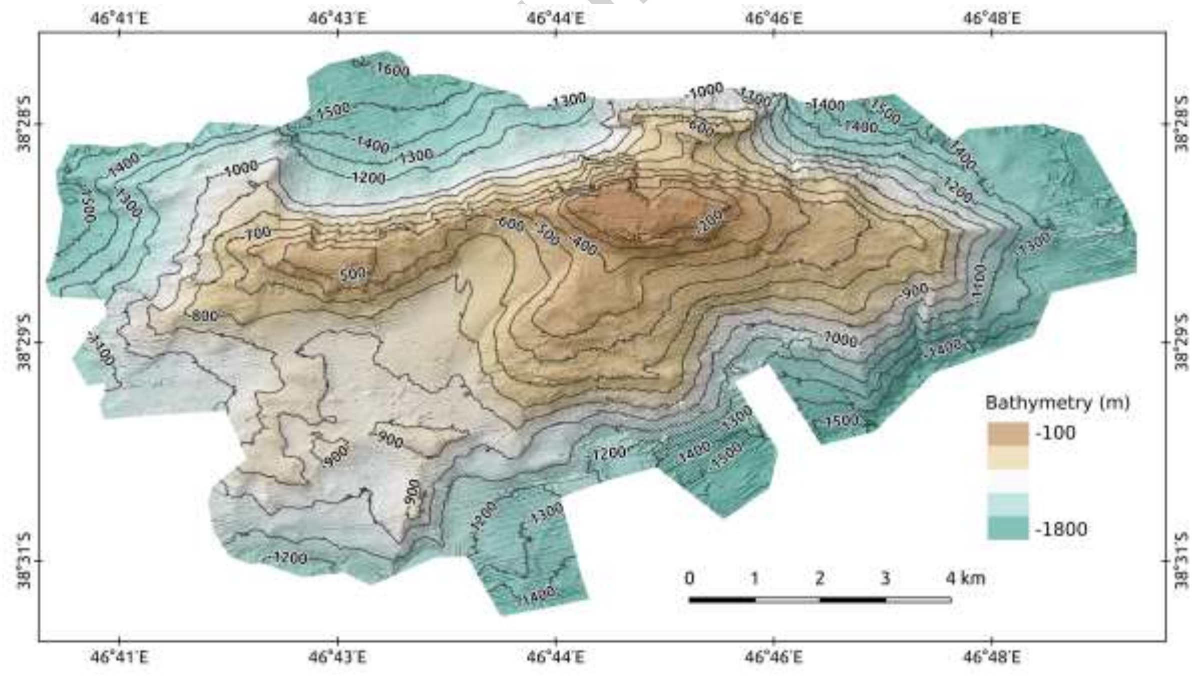
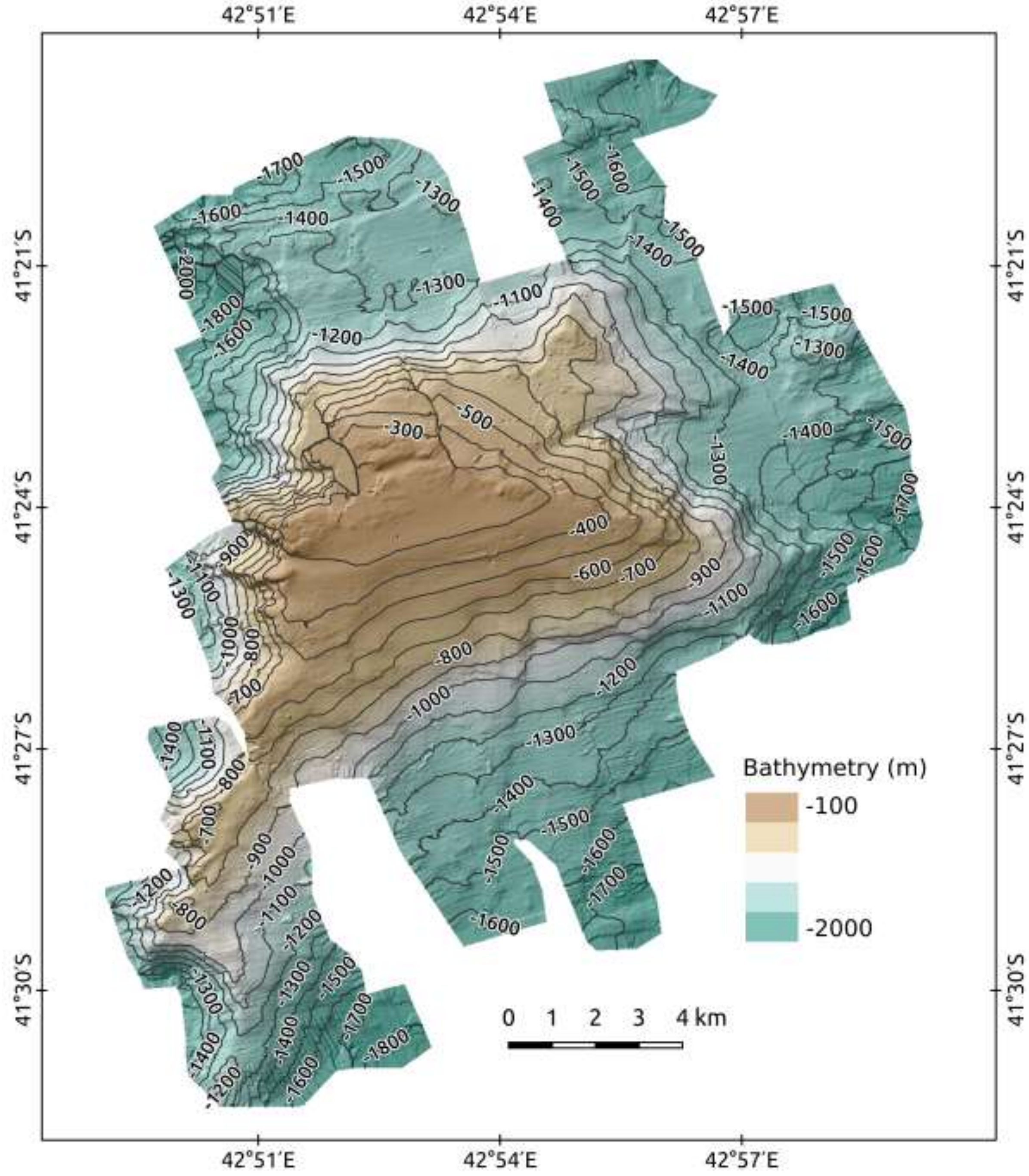
Bathymetry (m)
-100
-2000
0 1 2 3 4 km

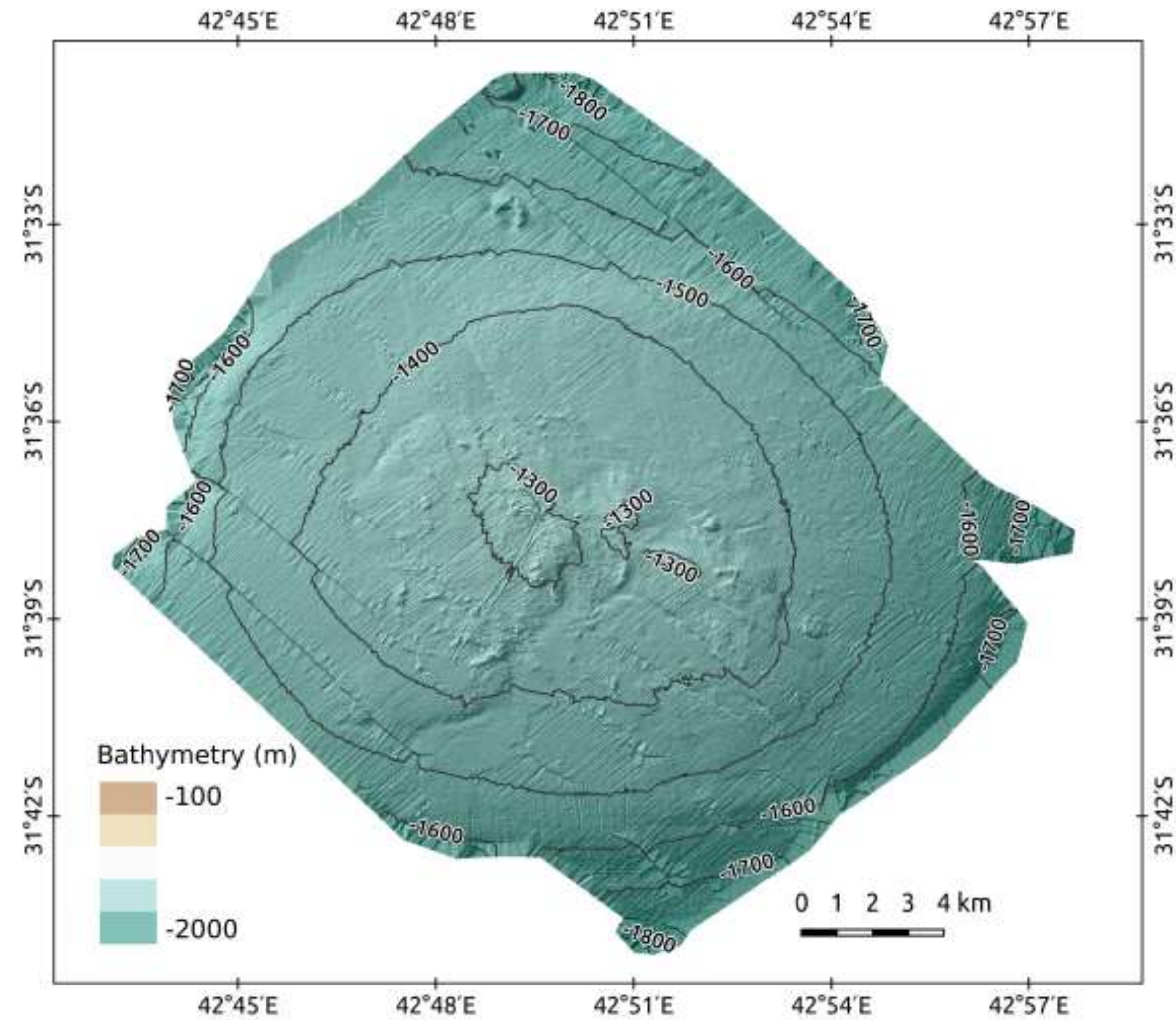

52°03'E
52°06'E
52°09'E
36°45'S
36°48'S
36°51'S
36°54'S
Bathymetry (m)
-100
-2000
0 1 2 3 4 km

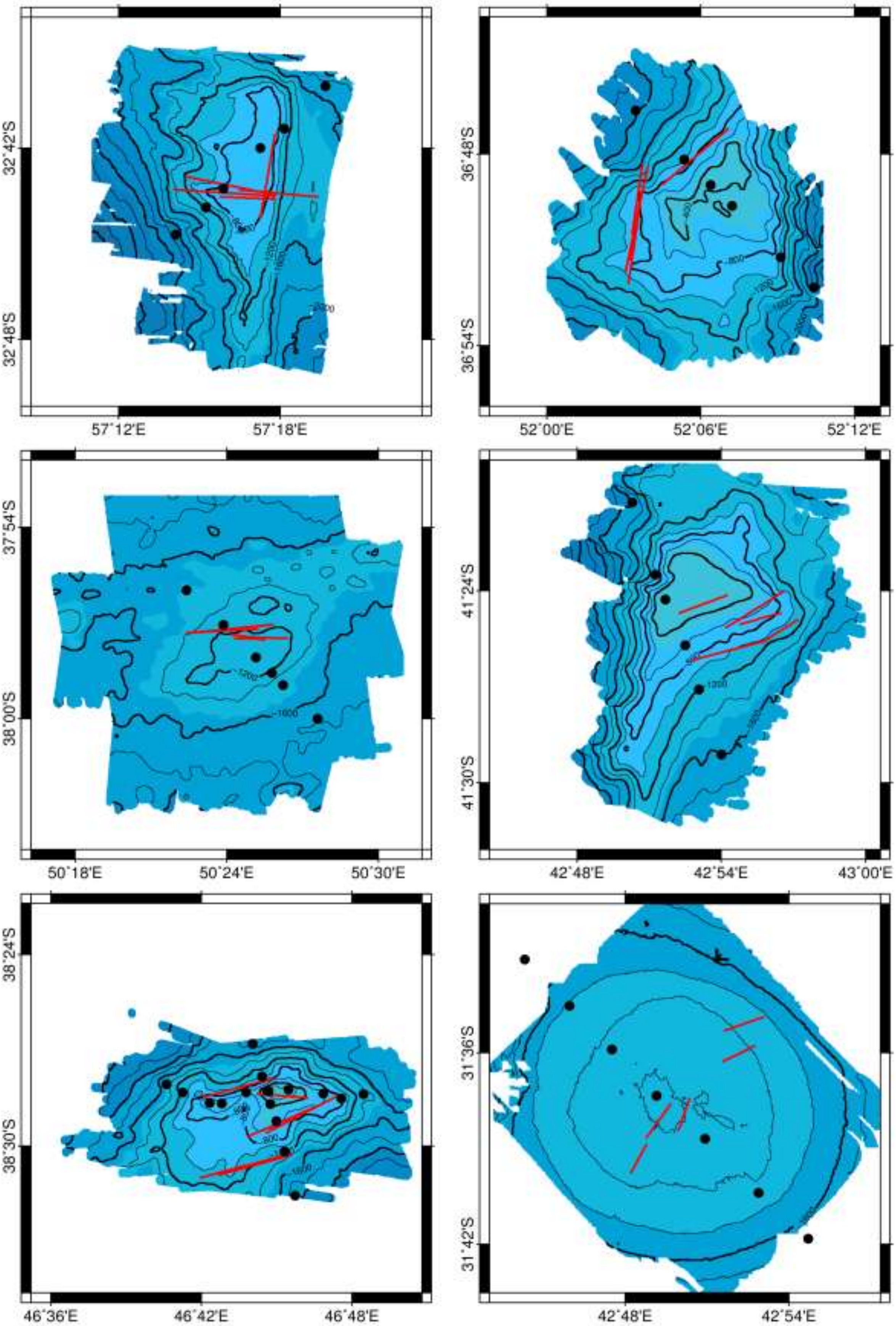

50°18'E
50°21'E
50°24'E
50°27'E
50°30'E
37°54'S
37°57'S
38°00'S
Bathymetry (m)
-100
-2000
0 1 2 3 4 km

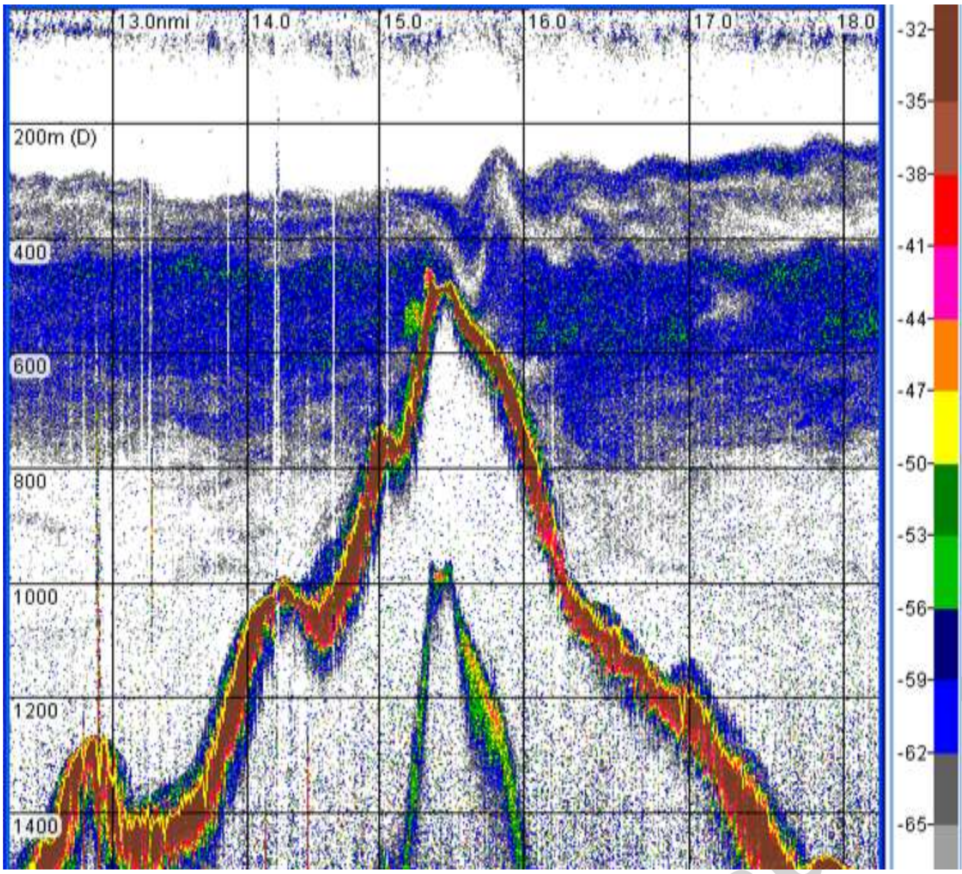

46°41'E
46°43'E
46°44'E
46°46'E
46°48'E
38°28'S
38°29'S
38°31'S
Bathymetry (m)
-100
-1800
0 1 2 3 4 km



42°51′E
42°54′E
42°57′E
41°21′S
41°24′S
41°27′S
41°30′S
Bathymetry (m)
-100
-2000
0 1 2 3 4 km


42°45′E
42°48′E
42°51′E
42°54′E
42°57′E
31°33′S
31°36′S
31°39′S
31°42′S
-1800
-1700
-1600
-1500
-1400
-1300
Bathymetry (m)
-100
-2000
0 1 2 3 4 km


32˚42'S
32˚48'S
57˚12'E
57˚18'E
36˚48'S
36˚54'S
52˚00'E
52˚06'E
52˚12'E
37˚54'S
38˚00'S
50˚18'E
50˚24'E
50˚30'E
41˚24'S
41˚30'S
42˚48'E
42˚54'E
43˚00'E
38˚24'S
38˚30'S
46˚36'E
46˚42'E
46˚48'E
31˚36'S
31˚42'S
42˚48'E
42˚54'E


13.0nmi
14.0
15.0
16.0
17.0
18.0
200m (D)
400
600
800
1000
1200
1400
-32
-35
-38
-41
-44
-47
-50
-53
-56
-59
-62
-65