

2008 ASCLME SURVEY NO. 3

Preliminary cruise report No 7/2008

7 October – 16 November 2008

by

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1. INTRODUCTION

Despite the success of the Shoals of Capricorn Marine Programme (New et al., 2007) surprisingly little is known of the ecology of the Mascarene Plateau. A key aim of the five-year ASCLME project is to develop a series of well coordinated research cruises aimed at gathering baseline information on the oceanography and ecology of the main marine ecosystems of the western Indian Ocean region. Although the ASCLME focuses on the Agulhas and Somalia Current ecosystems it was decided that a detailed survey of the Mascarene Plateau would be required to study the complex nature of the SEC upstream of both LMES. Through cooperation with the EAF-Nansen programme of FAO a pelagic fish component has been included in the surveys, thus covering the wider ecosystem. Due to resources limitations and time constraints it was not possible to include benthos and demersal resources into the investigations.

This survey is the third survey of the GEF funded “Agulhas and Somali Current Large Marine Ecosystem” (ASCLME) project.

The previous “Dr. Fridtjof Nansen” visited the Seychelles in 1978 and did a combined acoustic and demersal survey with some oceanography and plankton sampling. For 30 years this have been the baseline study as regards the fish resources of the Seychelles. The present survey thus represent an update of this baseline with increased effort on physical and biological oceanography, using modern methods.

The main objective of fisheries surveys in the 1980s was to find new resources. Today, when most of the world’s fish resources are located, and in many instances overexploited, the main focus is not on finding new resources, but to monitor the ecosystem and ensure that resource exploitation does not exceed the carrying capacity of the system. Hence an ecosystem approach - a holistic approach encompassing not only the targeted fishery species but the entire physical, chemical and biological environment - to the management of marine resources, is advocated.

This new baseline will enable Mauritius and the Seychelles within the region to monitor subsequent changes in the resources and in the environment. This is especially important today as we are in a crucial period of global warming with likely heavy impact on the coastal areas over time. The new EAF-Nansen (Ecosystem Approach to Fisheries) project with the full backup from the FAO and other UN agencies such as UNEP and the IOC will assist the coastal states in the SW Indian Ocean in following up on this important task in the years to come.

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1.1 Aims and Objectives

Following discussion between the ASCLME and EAF-Nansen projects, the following aims and objectives were decided for the survey.

Aims

- To establish a baseline for the ecosystem of the Mascarene Plateau.
- To establish for the very first time the physical, chemical and biological characteristics of the East Madagascar Current system as a whole, its bifurcation and with special regard to its influence on the ecosystem of the adjacent continental shelf. This current system (including shelf) is one of the least known systems of the world ocean; physically, chemically and biologically (Lutjeharms, 2006). The cruise has been planned to establish a baseline for all three of these disciplines, albeit a once off. It is planned to deploy current meters for long-term monitoring at a later stage to

overcome this shortcoming. The ecosystem baseline assessment is expected to be completed with a special survey on the demersal fauna, (fish and benthos) next year.

Objectives

1. To carry out the first multi-disciplinary cruise that encompasses the whole of the Mascarene Plateau and the adjacent basin.
2. To establish the distribution of organisms on a number of trophic levels and how these are affected by the reigning current system.
3. To establish, as far as possible, the productivity, biodiversity and biomass of the pelagic ecosystem.
4. To establish the interaction of the local currents and the ecosystem over the Mascarene Plateau.
5. To determine the nature of the South Equatorial Current as a driving force for the marine ecosystem of the Mascarene Plateau.
6. To investigate demersal fish species diversity.
7. To fulfil the data management agreement contained in Appendix A.

Key Questions

1. What is the influence of the South Equatorial Current on the waters and ecosystem over the Mascarene Plateau?
2. In what way is the flow of the South Equatorial Current affected by the gaps in the Mascarene Plateau?
3. Is the Mascarene Plateau characterised by an increased diversity in habitats and biota?
4. What are the main components in the Mascarene Plateau pelagic ecosystem, its distribution and abundance?
5. What are the biodiversity of the pelagic ecosystem, and the main fauna of the demersal fish community?
6. Can the Mascarene Plateau be considered a Large Marine Ecosystem on its own?

1.2 Participation

A total of 19 scientists and technicians participated in the survey. The full list of the participants and their affiliations is given in Table 1.

Table 1: List of cruise participants and their affiliations for Leg 3 (Mauritius – Seychelles).

Field	Names	Affiliation & nationality
Cruise Leader	Tore Strømme	IMR, Norwegian
Cruise Leader (Local)	Isabelle Ansorge	UCT, South African
Oceanography	Marek Ostrowski	IMR, Norway
Oceanography	Helena Francourt	SCMRT, Seychellois
Oceanography	Ramchandur Vimal	OMI, Mauritian
Nutrients & phytoplankton	Thomas Bornman	ACEP, South African
Zooplankton	Riaan Cedras	UWC, South African
Zooplankton	Kim Bernard	SAEON, South African
Isotopes & genetics	Sven Kaehler	RU, German
Isotopes & genetics	Jackie Hill	RU, Canadian
ASCLME trainee	Vikash Muibodhe	MOI, Mauritian
Fish	Denis Tweddle	SAIAB, British
Fish	Rodney Govinden	SFA, Seychellois
Fish	Vincent Lucas	SFA, Seychellois
Fish/Scientific watch	Michelle Etienne	SCMRT, Seychellois
Whale Watcher	Morgane Perri	MT, France
Technician, quality control	Oddgeir Alvheim	IMR, Norwegian
Instrument Chief	Tore Mørk	IMR, Norwegian
Technician, acoustic system	Ole Sverre Fossheim	IMR, Norwegian

ASCLME: Agulhas Somali Current Large Marine Ecosystem
 IMR: Institute of Marine Research
 UCT: University of Cape Town
 SCMRT: Seychelles Centre for Marine Research & Technology
 SFA: Seychelles Fishing Authority
 RU: Rhodes University
 SAIAB: South African Institute for Aquatic Biodiversity
 SAEON: South African Earth Observation Network
 MT: Megaptera
 MOI: Mauritius Oceanographic Institute

1.3 Narrative

The complete survey track with environment and biological stations are shown in **Figure 1**. The “Dr Fridtjof Nansen” left Port Louis in the evening of 8 October. Work started with completing 2 hydrographic transects remaining of the previous survey coverage around the island Mauritius, **Figure 1**. Work proceeded northwards with acoustic transects covering the shoals on the channel between Mauritius and Nazareth Bank.

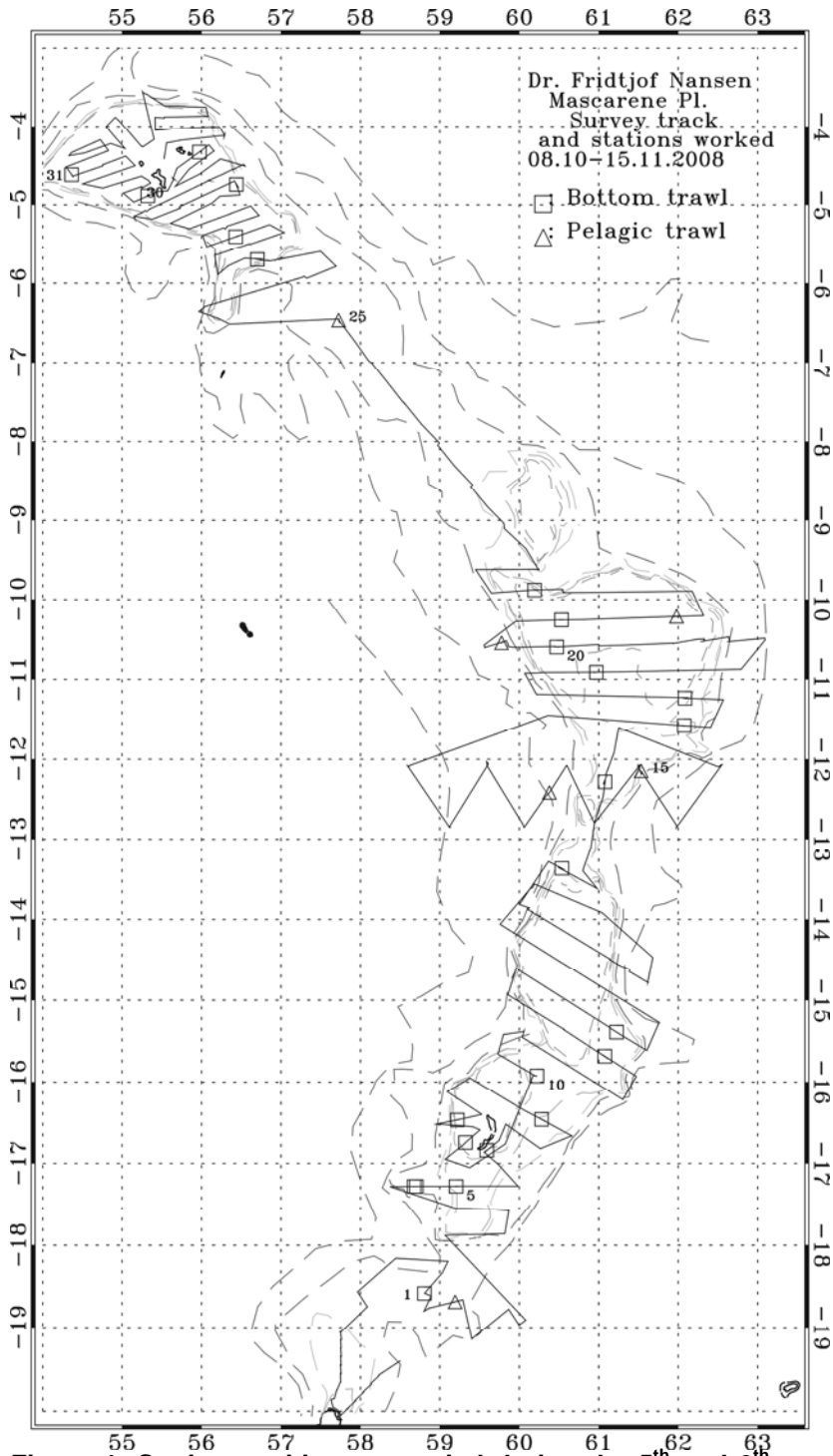


Figure 1: Station positions occupied during the 5th and 6th transects of Leg 2. The 1000m isobath is shown.

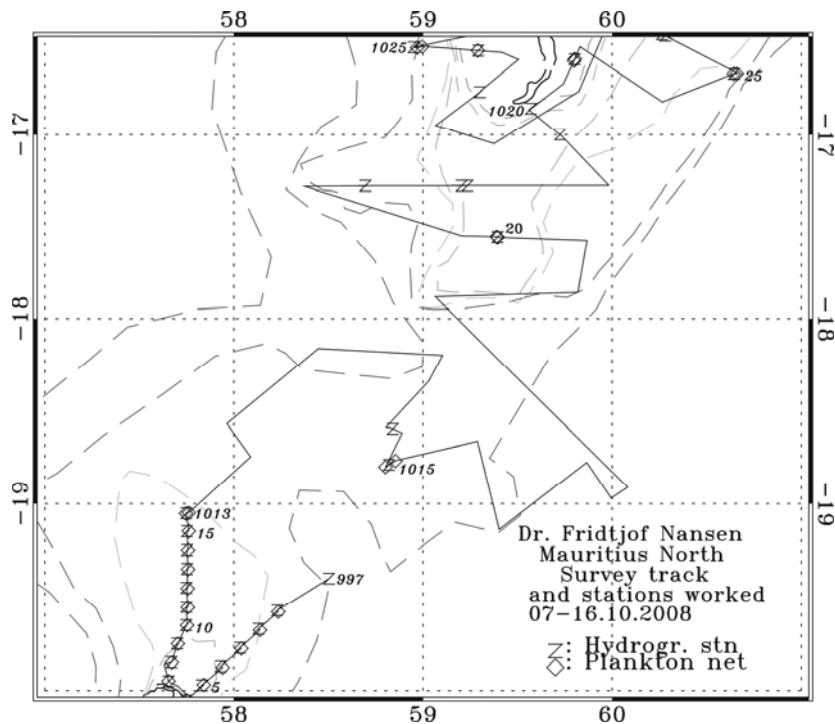


Figure 2: Map showing the location of CTD stations occupied between the Mauritius and Nazareth Banks. The black line represents the 1000 m isobath and the red line indicates the ships track.

The Nazareth Bank was covered in the period 12 – 23 October (Figure 3). Acoustic transects were laid out perpendicular to the main axis of the plateau, with a transect distance of 20nm. Predetermined environment stations were sampled along the axis of the plateau. In a meeting between the scientists it was decided to lay out one reference transect with CTD, Bongo and Multinet on each of the main banks of the Mascarene (Nazareth, Saya del Mahla and Seychelles Bank) in order to better analyse east-west gradients, the influence of the banks as a barrier and possible lifting of nutrients into the photosynthetic zone on the plateau or at the fringes. Bottom trawls for sampling of fish diversity were carried out when suitable bottom for trawling was located. CTD-casts were taken on each of these locations.

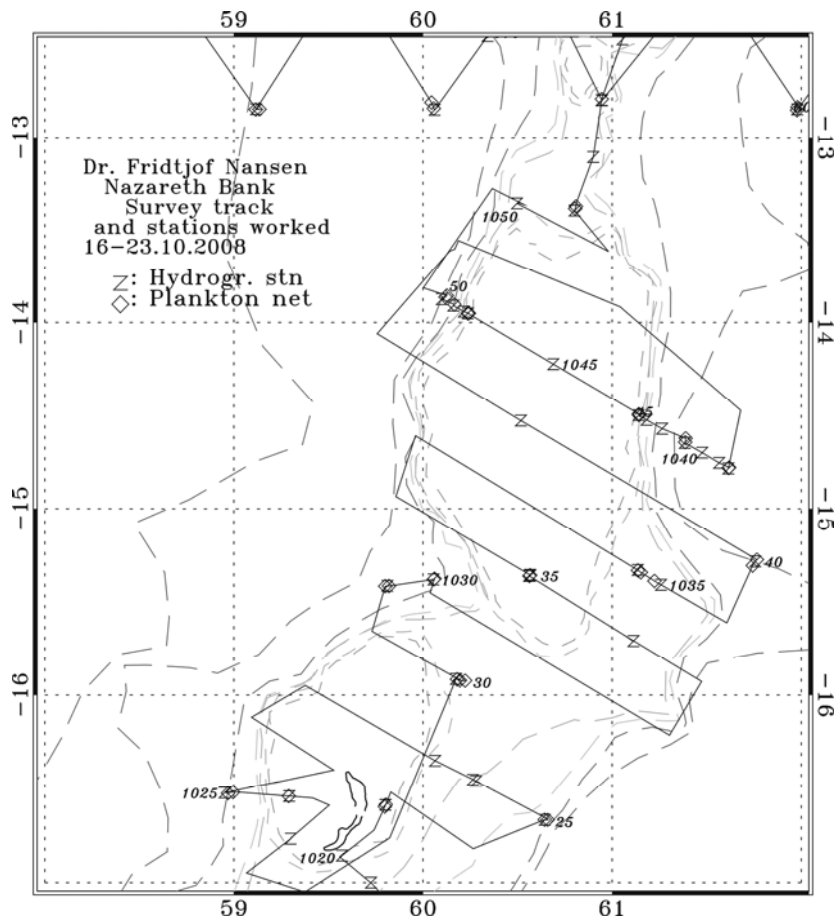


Figure 3: Map showing the location of CTD stations occupied during the Nazareth Bank section of Leg 3. Green dots represent CTD stations 1038-1049, which were occupied during a single high resolution transect from east to west. The black line denotes the 1000 m isobath and the red line indicates the ships track.

A special survey of the channel area between the Nazareth and Saya de Malha Banks and eastwards into the Mascarene Basin was carried out in the period 24-27 October (Figure 4). Recent investigations suggest that approximately 50% of the South Equatorial Current, blocked by the shallow bathymetry of the Mascarene Plateau, is channeled through this narrow gap. The aim of the special survey was to obtain a more detailed picture of the influence this region has on the throughflow of the SEC and the affect this gap could have on productivity downstream into the surface waters in the basin (Figure 15), possibly also holding previous undetected pelagic resources.

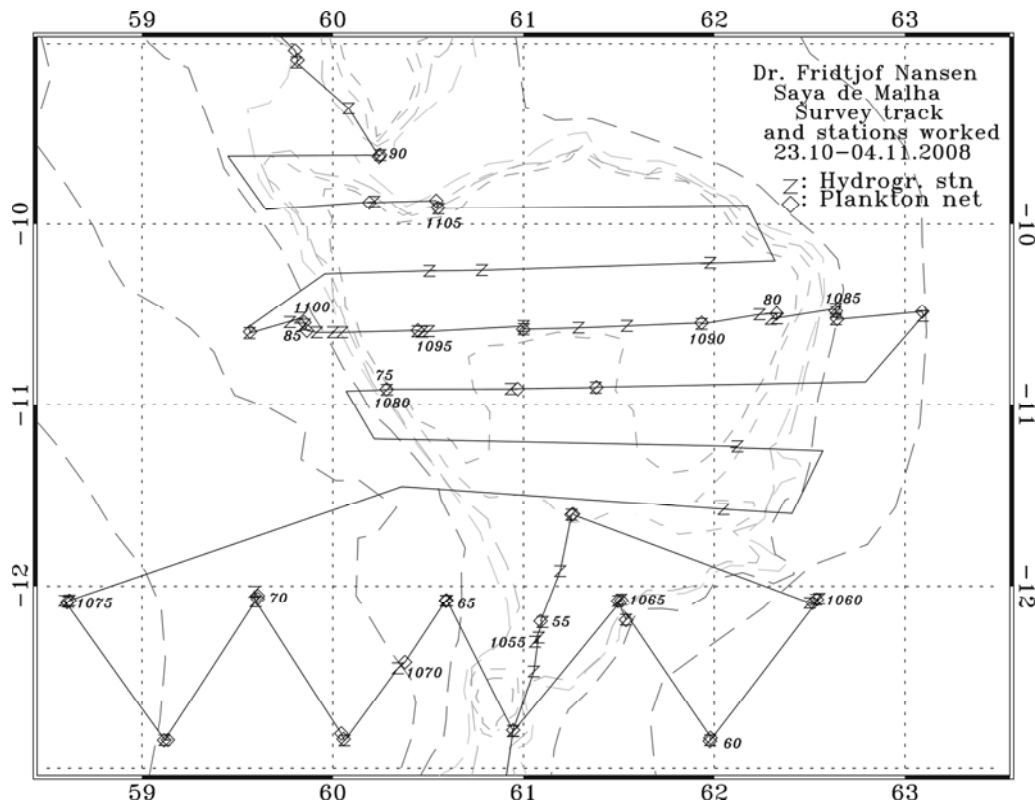


Figure 4: Detailed map showing the location of both CTD and XBT stations occupied in the deep (~1000 m) channel between the Nazareth Bank in the south and the broad Saya de Malha Bank in the north. The black line denotes the 1000 m isobath and the red line indicates the ships track.

The Saya de Malha Bank was covered in the period 28 October – 4 November with the same survey design as for the Nazareth Bank. Recent studies (New et al., 2007) have indicated that the SEC may act as a boundary separating nutrient rich subtropical waters from nutrient poor tropical water masses. Continued acoustic and environmental stations aimed at assessing whether there was indeed a change in the biogeochemical characteristic of this bank from the Nazareth to the south of the SEC. The east-west reference transect for inter bank comparative analysis were placed close to 10°30'S (Figure 5).

Figure 5: Detailed map showing the location of CTD stations occupied over the broad Saya de Malha Bank. Green dots represent CTD stations 1083-1102, which were occupied during a single high resolution transect from east to west. The black line denotes the 1000 m isobath and the red line indicates the ships track.

The wide channel between the Saya de Malha and Seychelles Bank is also the deepest of the three channels of the Mascarene with depths between 375 and 1763 and was surveyed between 4-7 November, Figure xx. Recent investigations have shown that approximately 25% of the known volume transport associated with the SEC flows through this channel (ref). However, geostrophic velocities (Figure 15) suggests that this channel is one of higher variability than the channels to the south – suggesting that flow through may be represented through mesoscale eddies and/or meanders.

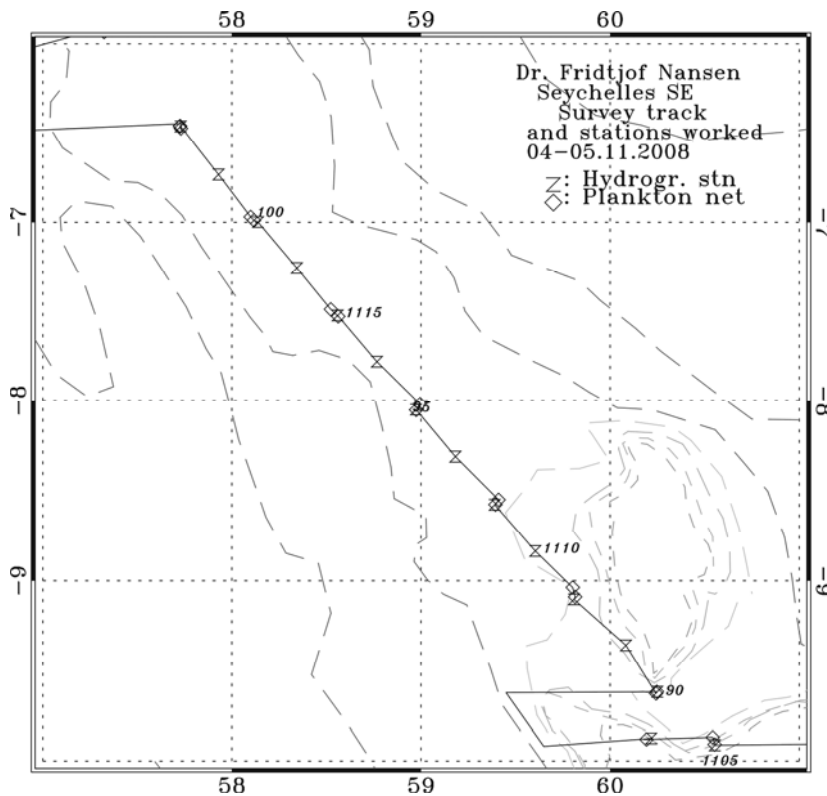


Figure 6: Detailed map showing the location of CTD stations occupied in the deep (~1000 m) channel between the Seychelles and the broad Saya de Malha Bank in the south. The black line denotes the 1000 m isobath and the red line indicates the ships track.

The Seychelles Bank was surveyed in the period 7 - 15 November. Due to many shallow banks and the central islands it was not possible to survey it with the same regular grid as for Nazareth and Saya de Malha. However since there were signs of higher productivity and more fish resources it was decided to increase the sampling density by using an average transect distance of 10nm. The reference transect for inter bank comparative analysis was placed between stations 1130 and 1144 (05°08S, 055°08E and 04°29S, 056°31E - Figure 7). The chain of environment stations running along the axis of the Mascarene was extended into deep waters north of the bank. The survey of the Seychelles Bank was completed with a fixed station north east of the bank to record vertical migration of plankton and fish in connection with the diurnal cycle. The vessel then surveyed towards Port Victoria with the lastest acoustic transect and arrived in port on the late afternoon of 15 November.

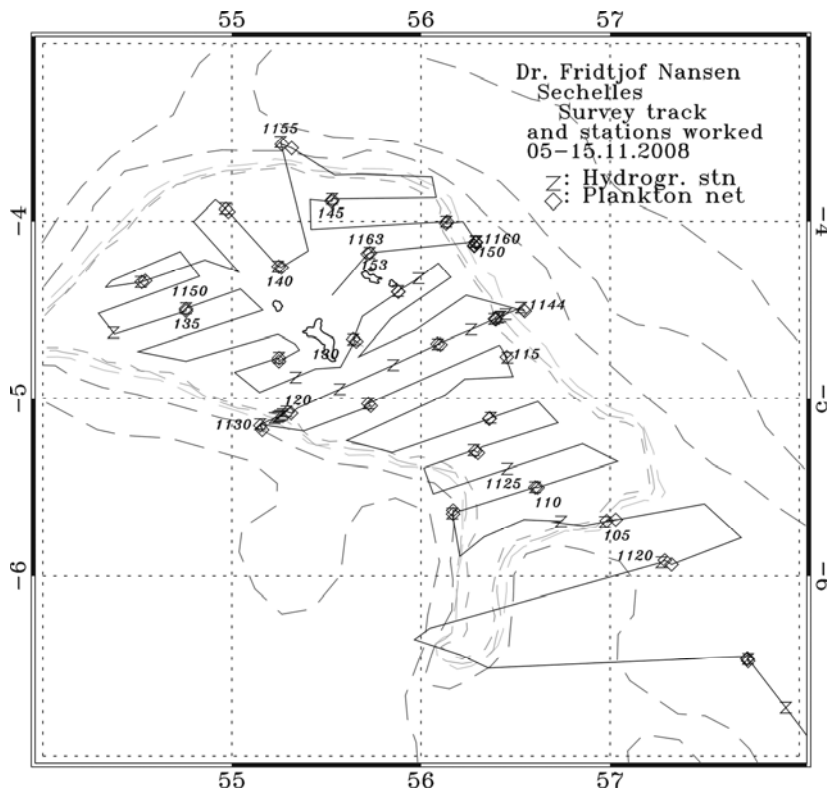


Figure 7: Detailed map showing the location of CTD stations occupied over the broad Seychelles Bank. Green dots represent CTD stations 1130-1144, which were occupied during a single high resolution transect from west to east. The black line denotes the 1000 m isobath and the red line indicates the ship's track. In addition, the yellow triangle represents the position of a fixed station aimed at recording the vertical migration of plankton and fish in connection with the diurnal cycle.

The weather conditions were mostly favourable and did not interfere with the work. A tropical cyclone "ASMA" in the period 18-21 October forced interruption of the survey for two days.

2. METHODS

2.1 Hydrographic Sampling

CTD profiles

A total of 167 CTD stations were conducted along selected hydrographical transects (Figure 10). A Seabird 911 plus CTD plus was used to obtain vertical profiles of temperature, salinity, pressure and oxygen. Real time plotting and logging was carried out using the Seabird Seasave software installed on a PC. The profiles along the Mascarene Plateau and surrounding shelf and slope regions were usually taken down to a few metres above the bottom, whilst offshore, due to instrument restrictions, the maximum sampling depth was 3000 m. Water samples were normally taken at 12 standard depths; 3000, 1500, 1000, 750, 500, 250, 150, f-max, 50, 20, surface (4-5 m) for nutrient analysis as well sensor calibrations of oxygen and salinity. Duplicates were collected only on F-max. Nutrient samples were frozen onboard for analysis on land.

Duplicate oxygen samples were collected from a total of 48 stations (Figure 8). Discrepancies between the titrated oxygen concentration to the oxygen sensor averaged -0.0101

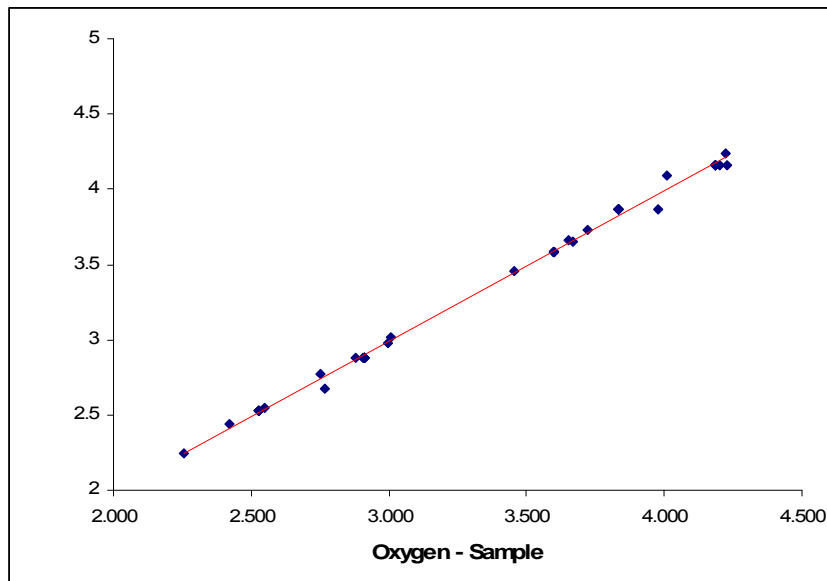


Figure 8: Graph showing differences in oxygen concentrations (ml/l) between the CTD sensor (y-axis) and water sample (x-axis) at 1500 m.

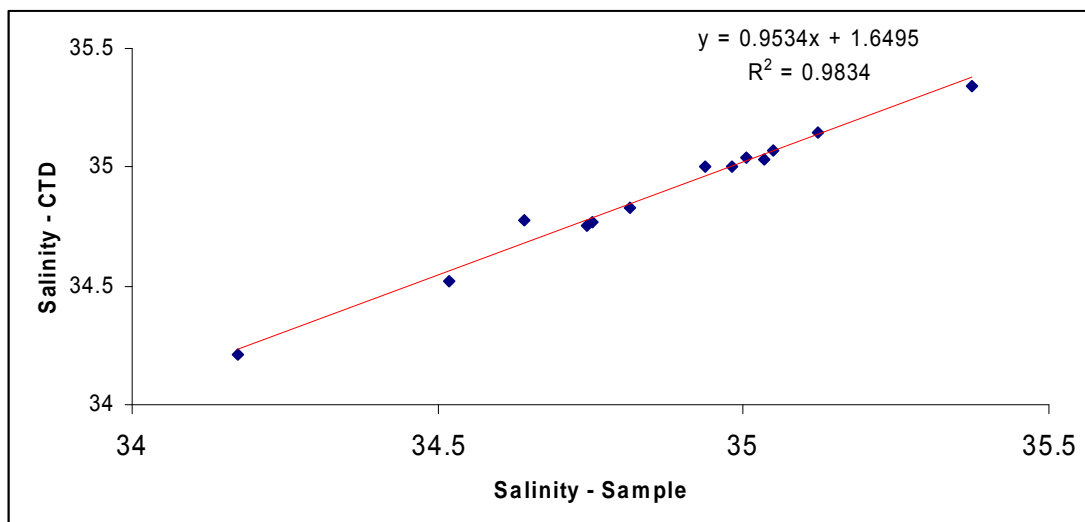


Figure 9: Graph showing differences in salinity between the CTD sensor (y-axis) and water sample (x-axis) at the 2 deepest sample depths.

Salinity samples collected at the 2 deepest depths were analysed using a 8410A Gildline portasal. Salinity calibration with the Portsal salinometer showed a regression factor of 0.9834 (**Figure 9**).

Also attached to the CTD was a Chelsea Mk III Aquatracka fluorometer. It measures chlorophyll a concentration in microgrammes per litre with an uncertainty of 3%. Factory slope and offset remained consistent at 0.921 and -0.02.

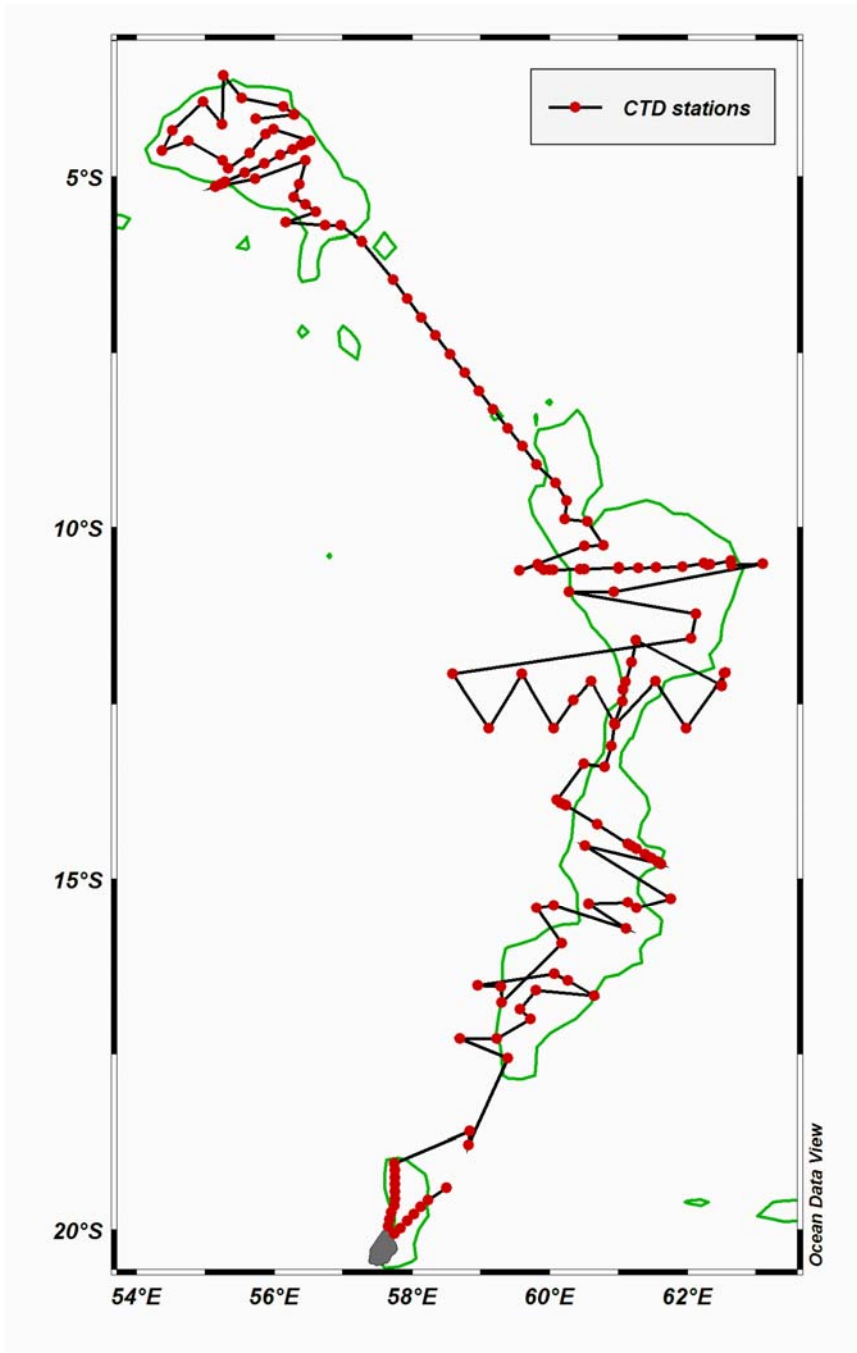


Figure 10: Map showing the distribution of all CTD stations occupied during the survey. The green line represents the 1000 m isobath and the black line the ships track.

XBT

A total of 25 XBT (Expendable Bathythermograph - Table 2) were deployed in the narrow channel separating the Nazareth and Saya de Malha Banks (see Figure 4 – green dots represent all XBT deployments). Sippican Deep Blue XBTs were used and temperature collected to a maximum depth of 760 m. Only a single XBT failed (station 9020) and had to be repeated.

Station	Date	GMT	Latitude (°S)	Longitude (°E)	Depth (m)
9001	2008/10/23	21:45	13 13.931	060 51.436	760
9002	2008/10/23	23:42	12 57.887	060 55.383	412
9003	2008/10/24	00:25	12 40.010	060 59.550	450
9004	2008/10/24	04:59	12 20.413	061 04.323	271
9005	2008/10/24	10:00	12 06.627	061 07.880	299
9006	2008/10/24	12:26	11 46.004	061 13.268	283
9007	2008/10/24	17:07	11 43.436	061 32.058	245
9008	2008/10/24	19:38	11 51.513	061 52.702	248
9009	2008/10/24	21:40	11 58.083	062 11.088	2300
9010	2008/10/25	06:07	12 20.862	062 19.388	3936
9011	2008/10/25	08:19	12 38.089	062 07.425	3582
9012	2008/10/25	15:25	12 35.160	061 48.952	3454
9013	2008/10/25	17:21	12 19.920	061 38.220	760
9014	2008/10/26	03:16	12 23.476	061 16.701	289
9015	2008/10/26	04:37	12 37.248	061 08.370	1303
9016	2008/10/26	08:21	12 34.462	060 50.295	399
9017	2008/10/26	09:44	12 21.190	060 43.810	1785
9018	2008/10/26	17:52	12 22.562	060 24.521	2427
9019	2008/10/26	20:31	12 36.541	060 14.121	3476
9020*	2008/10/27	03:07	12 37.359	059 55.475	3572
9021	2008/10/27	05:16	12 20.487	059 44.358	3599
9022	2008/10/27	13:07	12 18.747	059 27.190	3821
9023	2008/10/27	15:02	12 35.787	059 16.476	3895
9024	2008/10/27	22:14	12 38.356	058 58.540	4040
9025	2008/10/28	00:15	12 20.906	055 46.524	4143

Table 2: Table showing the deployment position for each XBT. Only 9 out of the 25 stations (36%) were shallower than the maximum sampling cast for a Deep Blue XBT.

Surface Thermosalinograph

The SBE 21 Seacat thermosalinograph was running routinely during the survey, obtaining samples of sea surface salinity and relative temperature and fluorescence (5 m depth) every 10 seconds. An attached in-line Turner Design SCUFA Fluorometer continuously measured Chlorophyll A levels [RFU] at 5 m below the sea surface while underway during the entire cruise. TSG data is extremely high resolution and given the length of the survey it was decided to prevent overloading ODV with excessive data points to reduce the data into a 1:10 resolution i.e. a reading every 100 seconds. This was achieved using the Nantherm software designed by Marek Ostrowski from IMR.

Current speed and direction measurements (ADCP)

The currents along the track were measured by using vessel mounted Acoustic Doppler Current Profiler, (VMADCP), Ocean Surveyor from Teledyne RD Instruments. The unit mounted on R/V Dr. F. Nansen consists of a single transducer using electronic beamforming to produce four beams required to measure current velocity. The unit operates at frequency is 150 kHz and is triggered synchronously with the onboard EK60 echo sounder. The navigation data are provided by the Seapath Differential Global Positioning System (DGPS). The instrument was run continuously in broadband mode shallower than about 150 meter and in narrow band mode in deeper waters. The

practical range of detected currents varied between 200-300 meters, depending on density of scattering layers in the water column. The ping data were averaged in 4 and 8 m vertical bins for the shallow and deep water data, respectively. Spurious data (near bottom, wire interference, etc) were edited using custom designed, prototype software (Marek Ostrowski). The currents were estimated over 5 nautical mile horizontal bins using ping-based data. Only the regions where the vessel speed was more than 6 knots was included in the computations. The raw data, computed currents and quality flags from data editing were stored using the hierarchical data format (HDF5, see www.hdfgroup.org). The quality control of these data is still an ongoing process. In this report we present preliminary results of the horizontal currents at 30 m depth (Figure, 18 and 19).

Meteorological observations

Wind direction and speed, air temperature, air pressure, relative humidity, and sea surface temperature (5 m depth) were logged automatically every 1 min. on an WIMDA meteorological station.

Satellite drifters

Ten satellite drifters were deployed during the Mascarene survey (Figure 11).

ID	Date	GMT	Lat	Lon
70852	10.10.2008	16.31	18 09.664	58 26.850
70848	11.10.2008	04.59	18 20.220	59 01.780
63894	19.10.2008	14.21	17 17.050	61 45.260
63925	21.10.2008	22.10	14 46.604	61 36.437
70851	25.10.2008	07.51	12 04.438	62 32.703
63896	25.10.2008	17.38	12 48.900	61 57.974
63895	25.10.2008	16.25	12 11.164	61 32.265
63897	01.11.2008	00.34	10 34.541	61 17.159
63893	05.11.2008	08.45	07 18.872	58 22.826
63892	05.11.2008	11.45	07 03.062	58 10.816

These surface drifters are drogued at a depth of 18 m and are able to measure surface temperature, velocity and geographic position, which are relayed to ARGOS ground stations. SVP drifters are designed to have a drag area ratio of ~40 (i.e. the ratio of the drag area of the drogue to that of the tether and surface float), which yields a wind slippage of $<1 \text{ cm s}^{-1}$ (Niiler et al., 1995). Satellite tracked drifters have become invaluable tools for studying ocean circulation and provide mixed layer velocity and temperature observations over 5 year periods in all major ocean basins. Data can be obtained from the Drifting Buoy Data Assembly Centre at <http://www.aoml.noaa.gov/phod/dac/> for the SVP drifters.

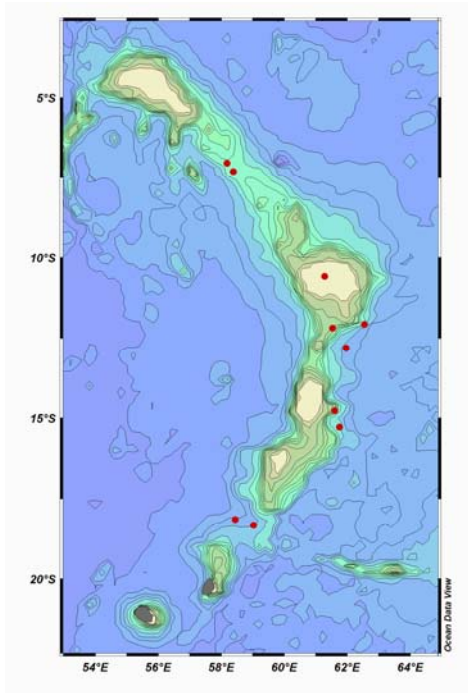


Figure 11: Position of all SVP drifter deployments during the Mascarene survey.

Fluorescence: Chl-a

Water samples were taken from up to 5 depths from Niskin bottles on the CTD rosette, dependant on other hydrographic sampling priorities. An ideal sampling regime was to have a sample from below fMax, one at fMax (maximum fluorescence noted during the CTD downcast), two between fMax and the surface, and one at the surface. Due to the shallow nature of the Mascarene Plateau often (~30 m deep) only 3 or 4 of these depths were available.

500 ml of water from each depth was filtered through a 2.5 cm diameter Whatman GF/F filter. This paper was then placed in a labelled plastic tube and 10 ml of 90% acetone was added; this sample was then stored in a refrigerator for approximately 24 hours. After this 24 hour extraction period, the samples were allowed to warm to room temperature in a dark place and the acetone solution was decanted into a borosilicate glass tube and its fluorescence measured on a Turner Designs Fluorometer, both before and after the addition of one drop of 10% HCl acid. A one minute period was allowed to elapse between the addition of the acid and the subsequent reading being taken. The sensitivity of the machine was adjusted to ensure a mid-scale reading. If the reading was off the scale at minimum sensitivity, the sample was diluted, the dilution factor noted, and a reading taken. 90% acetone blanks at all sensitivities were taken at least once every time the machine was turned on, and the machine was left on for at least 30 min prior to taking any readings. All procedures were performed in subdued light.

Fluorescence readings were converted with the following formula:

$$\text{Chlorophyll a (mg.m}^{-3}\text{/}\mu\text{g.l}^{-1}) = F_D * (T/T-1)*(R_B-R_A)*(v/V)$$

Where:

v = volume of acetone used for extraction (10ml)

V = volume of seawater filtered (500ml)

R_B = fluorescence reading prior to adding acid

R_A = fluorescence reading after adding acid

Acid ratio T = R_B/R_A

T = 2.19

T/T-1 = 1.84

F_D was a calibration factor determined prior to the cruise, dependent on the sensitivity of the fluorometer:

1x sensitivity on Min and 3.16 settings: 25.792

1x sensitivity on 20 and 31.6 settings: 2.7948

100x sensitivity on Min and 3.16 settings: 0.2876

100x sensitivity on 10 and 31.6 settings: could not be determined.

2.2 Multibeam echo sounder for bottom mapping

The EM 710 multibeam echo sounder is a high to very high-resolution seabed mapping system. Acquisition depth is approximately 3 m below the transducers, and the maximum acquisition depth is in practice limited to 1500 m on *Dr. Fridtjof Nansen*. Across track coverage (swath width) is up to 5.5 times water depth and may be limited by the operator either in angle or in swath width without reducing the number of beams. The operating frequencies are between 70 to 100 kHz. There are 128 beams with dynamic focusing employed in the near field. The transmitting fan is divided into three sectors to maximize range capability and to suppress interference from multiples of strong bottom echoes. The sectors are transmitted sequentially within each ping, and use distinct frequencies or waveforms. The along track beam width is 1 degree. Ping rate is set (manually) according to depth. The receiving beam width is 2 degrees.

2.3 Phytoplankton and microzooplankton sampling

At each CTD station, water samples from fMax (maximum fluorescence noted during the CTD downcast) and the surface were taken. An attempt was made to assess flagellate abundance using a Leitz phase contrast microscope by placing one drop of seawater on a slide and placing a coverslip over it and examining. If flagellates were found, an attempt to categorise them into taxa and an estimate of abundance was made (noting the dominant taxa), along with sketches. If no flagellates were apparent in the first drop, a second drop was examined in the same manner.

500ml of water from each of fMax and the Surface Niskin bottles was placed in separate Utermohl settling chambers with 10 ml of prepared formalin solution (equal volume of 40% formaldehyde solution to distilled water with 100 g/l hexamine added). After settling for 24 hours in a fume cupboard, the supernatant layer was drained by slowly separating the baseplate, and the settled plankton remaining in the well were transferred using a glass micropipette into a labelled 50ml dark amber plastic bottle and stored in a plastic bin.

The samples will be analysed on shore for species composition.

Microzooplankton Community Structure

Microzooplankton are defined as phagotrophic organisms that are <200 μm in length. For the sake of operational convenience, the microzooplankton include the pico- and nanozooplankton (0.2-2 and 2-20 μm , respectively) although due to time constraints, we have only focused on the micro- and nanozooplankton (20-200 μm and 2-20 μm , respectively). Microzooplankton are abundant in the surface mixed layer of the oceans, forming a significant stock of organic carbon. Furthermore, microzooplankton have been shown to form a major trophic pathway linking phytoplankton to the higher trophic levels. The study of microzooplankton thus provides important information on the flux of organic carbon in the surface waters.

The methods described in the JGOFS Protocols (JGOFS, 1994) for microzooplankton biomass have been used. Microzooplankton biomass (mg C L^{-1}) is defined as the quantity of microzooplankton organic carbon per unit volume of sea-water. In addition to biomass, the

microzooplankton samples will be identified to the finest taxonomic level possible and counted to give abundance (ind. L⁻¹).

Samples were collected at near surface and at F_{\max} using a Niskin bottle rosette. Microzooplankton samples will be counted and analysed using inverted microscopy. Microzooplankton biomass will be estimated based on appropriate volume to organic carbon ratios obtained from the literature. Heterotrophic nanoplankton will be examined using epifluorescence microscopy.

In addition to the analysis of microzooplankton community structure, trial grazing studies were conducted in order to ascertain the relative importance of microzooplankton as grazers of phytoplankton in the region. Unfortunately, due to time constraints, only 2 dilution and 3 trophic cascading studies were conducted. The dilution experiments were conducted according to (Landry and Hassett, 1982), while the trophic cascading experiments were adapted from (Calbet and Landry, 1999).

Frozen samples from leg 1 were also worked up and prepared/ stored as above

2.4 Zooplankton sampling

Zooplankton 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. The aim was to collect depth-stratified information on the abundance and distribution of zooplankton and to collect zooplankton for genetic analysis. The obliquely-hauled multi-net configuration was 5 nets, fitted with 180 µm mesh. The net was towed obliquely at a speed of 2 - 2.5 knots at five depth strata, from just above the bottom of the surface where deemed possible, and was retrieved at a speed of 0.5 - 1.0 m.s⁻¹. Nets were triggered at either 100 m intervals during deep casts (to a maximum depth of 500 m) or at intervals <20 m during shallow casts (<100 m). The ship's personnel deployed the net at each environmental station except when severe wind prevented deployment. No adjustments to the sampling protocols were made for day or night.

The samples collected were rinsed into the cod end and thoroughly washed into a sieve with a 100 micron mesh. The contents of the sieve were then washed into a sample jar using a water bottle filled with ambient seawater. Labels showing full station details, net number and sampling depth range were placed into the sample jars, which were topped up with 40 ml of 40% formalin. The lids of all sample jars were labelled with station details – including net and station number. The main types of zooplankton observed in each sample were identified and recorded in the log. Any medusa or other obstructions found in plankton samples were fixed and preserved separately (with full labels). Large specimens of other interesting taxa were removed, fixed and preserved separately, with full labels.

Jars were placed in the plastic fish box provided for 24 hours. At the end of each haul, after the samples had been processed, the cod ends were inspected for damage, repaired if necessary, and replaced on the nets. After 24 hours, the approximate volume of zooplankton in each sample was recorded and entered into the logbook. Thereafter, the samples were stored for further analysis on land.

Every 10th zooplankton haul were stored in sample jars filled with 96% ETOH. Samples were labelled and stored in the freezer. After 24 hours, the ETOH was replaced; and then again after a further 48 hours.

Bongos

A bongo net with 180 µm and 375 µm mesh nets was deployed at most environmental stations. The bongo was deployed to 200 m (where possible) and retrieved over 20 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. Tows generally lasted 45 minutes.

The 180 µm sample was immediately drained into a 180 µm sieve and wet weight was determined. Thereafter, the sample was preserved with formaldehyde in 250/500 ml jars (made up to 10% formaline). Jars were labelled and stored for later analysis in Grahamstown.

The 375 µm sample, intended for stable isotope analysis, was serially size-fractionated through 4 mm, 2 mm, 1mm, 500 µm and 280 µm sieves and representative taxa from each size-fraction were collected. In order to quantify the effect of gut clearance on isotope signatures, in some cases, the remaining animals from select size classes were placed into floating cages in filtered seawater (0.7 µm) bounded by 180 µm mesh. Isotope samples were then collected over a number of time series events. All isotope samples were transferred without water into separate labelled Eppendorf vials, pressed against the side of the vials, and then left open in an oven at 50°C for 48 hours before being capped and stored. Labelling was restricted to the outside of the bottle only.

Frozen samples from leg 1 were also worked up and prepared/ stored as above

2.5 Biological fish sampling

The trawl catches were sampled for species composition by weight and number. The deck sampling procedure is described in more detail by Strømme (1992). Length measurements (TL/FL (depending on tail form) and SL, to 0.5 cm below) were taken for the more common species of fisheries interest on stations where caught in reasonable abundance. Few prawns and squid were caught and thus only numbers and weights were recorded, plus basic biological information for those samples kept for study. Basic information recorded at each fishing station, i.e. trawl hauls, is presented in Annex I. Pooled length frequency distributions, raised to catch per hour, of selected species by area are shown in Annex II.

As the Mascarene Plateau is an area that has been subjected to only limited fish surveys in the past, emphasis was placed on ensuring that all fish species caught during the survey were identified as far as possible and good representative samples of all species (particularly those that could not be identified with certainty using the literature available on board) were preserved. Whenever possible, a series of specimens over the size range sampled for each species was pinned out and fins fixed with formalin before storage in 10-15% formalin to ensure that the specimens were in good condition for morphometric measurements for taxonomic study. All fish species were photographed while very fresh to get perfect colour detail to use in the illustrations for the forthcoming book on the fishes of the Western Indian Ocean. The samples were placed in drums of formalin for storage, either separated by trawl number in large perforated ziplock bags or by reference number tied by string to the gills or caudal peduncle, until they are delivered to SAIAB, where they will be transferred to 70% ethanol. Smaller specimens have been stored by trawl number in 2L plastic jars in many cases. Large fish specimens too big to preserve on board were stored in the vessel's freezer until they can be delivered to SAIAB.

At least three individuals of all species taken during the survey were sampled for DNA. Tissues were also taken from three specimens of representative species for isotope analysis. These sampled specimens were measured and pictures taken with labels.

DNA: Muscle tissue was taken from the right side of the fish, or from the ventral in the case of flatfish. This was done in order to keep the left side in good condition for a reference picture (with sample tag). The tissue was removed from below the lateral line on the caudal peduncle after cleaning away skin and scales. Muscle tissue was cut and placed into 1.5 ml Eppendorf tubes containing 95% ethanol and a unique number for identification (e.g. ACEP 08-001). A label with the same identification number used for the DNA tube was attached to the specimens through the mouth and gills for future reference. Fin clips were taken from elasmobranchs for DNA analysis.

Stable Isotope sampling: Muscle tissue was taken from below the lateral line on the tail fin peduncle after cleaning away skin and scales. The tissue sample was placed in a 1.5 ml Eppendorf tube, placed in a 50° C oven and dried with the lid open at this temperature for 48 hours. Permanent markers were used to label the outside of the tube, in addition to a sticky label on the lid. When possible, 3 individuals of the same species from each trawl were sampled. Once dried,

Eppendorf tubes were closed and stored in a “cryobox”. Full cryoboxes were wrapped in clingfilm for moisture protection and stored in a bin for subsequent analysis on shore.

For both DNA and stable isotope tissue samples, all equipment used was cleaned between specimens. The working surface used was also wiped clean and dried every time before a new individual was sampled in order to avoid contamination. Only one spreadsheet was used to record DNA, stable isotope sample and voucher specimen data.

Voucher specimens were kept for every species from which DNA and isotopes samples were collected. All specimens were fixed as for the taxonomic collection.

All DNA tissue samples were store in plastic containers by trawl number. All trawl containers with DNA were put in a plastic bucket labelled ASCMLE-LEG3 and kept in the freezer. The name of the person that collected the samples were included in the bucket labels in case questions arise at a later stage.

2.6 Productivity Stations

Primary production stations were conducted along two transects, one through a gap in the plateaux and one across the Saya de Malha bank. Productivity was estimated by the ^{13}C incorporation technique.

Before incubations were initiated, all containers, bottles, filter-funnels etc were acid washed. Water for the experiments was collected by CTD from predefined light-depths that were determined from a light-cast before sampling commenced. The five sampling depths corresponded to 100%, 50%, 25%, 12.5% and 1.25% of surface PAR (at 2m depth). At each sampling depths 10 l of water was collected (i.e. 2x Niskin Bottles). Whenever possible, 24 hr incubation experiments were started and ended during dark hours. Where this was not possible, bottles were kept in the dark (wrapped in black plastic) until the incubation was started and after the incubation (i.e. before filtering). In all cases, incubations were initiated within 30 min of water collection and filtration occurred within 10 min of termination of the experiment.

Exactly 2 l of water was siphoned into each of three Schott bottles from each depth (i.e. three replicates per depth). Bottles were kept in the dark until spiking with 4ml of prediluted $\text{NaH}^{13}\text{CO}_3$ (99 atom% ^{13}C ; 240 μmol per bottle). The concentration of bicarbonate was chosen to represent approx 4-8% of total DIC. Spiking occurred at the incubation chambers. The chambers were covered with Lee neutral density filters that transmitted the above light percentages. Bottles in the incubation chambers were flushed and cooled with surface water from the scientific water supply. Incubations were conducted for 24 hrs.

From the remaining water sample at each light depth, salinity, temperature, pH and alkalinity were determined. These are used to derive the concentration of dissolved inorganic Carbon (DIC) at the start of the incubation (Strickland and Parsons 1968).

After 24 hrs, bottles were removed from the incubation chambers, kept in the dark and immediately filtered in triplicate onto pre-combusted (5 hrs at 480°C) 47 mm GFF filters. GFF filters were then dried at 50°C for 24 hrs and stored in an airtight container for carbon stable isotope analysis back in South Africa.

Nitrate isotopes

1 l water samples were collected in acid cleaned bottles for nitrogen isotope analysis in nitrates. Samples were collected at the surface (2 m), Fmax, 250m and 750m) at pre-selected stations. Samples were frozen after collection for analysis in South Africa.

Isotopes in Particular Organic Matter (POM)

Particulate organic matter collected from the water column reflects primarily phytoplankton (i.e. sources of production). POM was collected from Fmax (5 l) by CTD and the surface (2 m by bucket, 10 l sample size). After collection, water was filtered through precombusted (5 hrs at 480°C) 47 mm GFF filters. Filters were then dried at 50°C for 24 hrs and stored in an airtight container for carbon and nitrogen stable isotope analysis back in South Africa.

Sponge Collection for Pharmaceutical Bioprospecting

Sponges and soft corals were collected from demersal trawls (Table 3) and frozen for subsequent analysis by the marine natural products research group at Rhodes University, South Africa. The samples were photographed and individually bagged before being stored in the blast freezer as -18°C. The photographs will aid the identification of the frozen specimens. A total of 54 samples were collected at 7 stations.

The sponge specimens will be transported frozen to Grahamstown where they will be stored at -20°C in the Chemistry Department at Rhodes University. Small portions of each sponge will be taken as voucher specimens for identification (Dr Toufiek Samaai, Marine and Coastal Management). Another small portion will be lyophilized (freeze dried) and extracted with methanol. The methanol extract will be screened using nuclear magnetic resonance spectroscopy to identify potentially interesting biomolecules (natural products). The extracts will also initially be screened in a number of bioassays in South Africa including anti-malarial assays (Professor Pete Smith, University of Cape Town), anti-cancer assays (Dr Denver Hendricks, University of Cape Town) and at Rhodes for activity against trypanosomiasis (sleeping sickness) and leishmania (a tropical disease common in west and east Africa). The latter two screens are being sent from Rutgers University in the USA as part of the GIBEX (Global Initiative for Bioexploration) "screens to nature" programme. Further screening in other pharmaceutical screens will be contemplated at a later stage. Extracts that show good activity in the primary screens will be subjected to bioassay guided isolation of the natural products responsible for the activity. The chemical structures of the bioactive natural products will be determined using the facilities already in place in the Department of Chemistry, Rhodes University.

Table 3: Positions and Trawl numbers of where sponge samples were collected.

Trawl #	Longitude	Longitude	Depth	Date	GMT	Duration	Samples Collected
6	16 50.4	59 35.4	60	2008/10/13	22:31	14.9	KB001-2; 4-5; 7-8; 010
8	16 28.0	59 13.1	47	2008/10/15	04:28	15.7	KB011-020
13	13 21.9	60 32.1	240	2008/10/23	12:25	30.3	KB021-024
17	11 34.6	62 04.6	47	2008/10/29	05:03	31.5	KB025-036
20	10 35.9	60 28.2	39	2008/11/01	06:41	25.9	KB037-052
24	9 52.8	60 11.5	31	2008/11/03	12:08	27	KB053-055
31	4 37.0	60 11.5	59	2008/11/12	14:28	23.5	KB056-057

2.7 Biomass estimates

Acoustic abundance estimation

A SIMRAD ER 60 Echo sounder was used to survey the water column and the echograms were stored on files. The acoustic biomass estimates were based on the integration technique. The Large Scale Survey System (LSSS) from MAREC was used for integration and allocation of the integrated s_A -values (average area back scattering coefficient in m^2/NM^2). The splitting and allocation of the integrator outputs (s_A -values) was based on a combination of a visual scrutiny of the behaviour pattern as deduced from echo diagrams, LSSS analysis and the catch composition. The mean integrator value in each sampling unit (s_A -values) was divided between the following standard categories/groups of fish: Pel 1 (Clupeoid species), Pel 2 (Carangids, Scombrids, Leiognathids and associated pelagic like barracudas and hairtails), Dem (Demersal species), Meso (Meseopelagic species), Plank (Plankton).

The following target strength (TS) function was applied to convert s_A -values (mean integrator value for a given area) to number of fish by category:

$$TS = 20 \log L - 72 \text{ dB} \quad (1)$$

or in the form

$$C_F = 1.26 \cdot 10^6 \cdot L^{-2} \quad (2)$$

where L is the total length and C_F is the reciprocal back scattering strength, or the so-called fish conversion factor. Generally, in order to split and convert the allocated s_A -values (m^2/NM^2) to fish densities (number per length group per NM^2) the following formula was used.

$$N_i = A \cdot s_A \cdot \frac{P_i}{\sum_{i=1}^n \frac{P_i}{C_{Fi}}} \quad (3)$$

where: N_i = number of fish in length group i

A = area (NM^2) of fish concentration

s_A = mean integrator value (echo density) in area A (m^2/NM^2)

p_i = proportion of fish in length group i in samples from the area

C_{Fi} = fish conversion factor for length group i

$$N = \sum_{i=1}^n N_i \quad (4)$$

Further, the traditional method is to sum the number per length group (N_i) to obtain the total number of fish:

The length distribution of a given species within an area is computed by simple addition of the length frequencies obtained in the pelagic trawl samples within the area. In the case of co-occurrence of target species, the s_A value is split in accordance with length distribution and catch rate in numbers in the trawl catches. Biomass per length group (B_i) is estimated by applying measured weights by length (W_i) when available or theoretical weights (calculated by using condition factors), multiplied with number of fish in the same length group (N_i). The total biomass in each area is obtained by summing the biomass of each length group:

$$B = \sum_{i=1}^n N_i \bar{W}_i \quad (5)$$

The number and biomass per length group in each concentration are then added up to obtain totals for each region.

However, the combination of low s_A value recorded, few PEL1 and PEL2 in the bottom trawl catch and few pelagic trawls made the splitting by length groups unreliable. Therefore, a theoretic mean length of 23 cm was used to convert the s_A values by stratum (Equation 3) to number of fish. Equation 5 was used to convert the number of fish in the defined average length class (23 cm) to total estimated biomasses of PEL1 and PEL2.

A description of the fishing gears used, acoustic instruments and their standard settings is given in Annex III.

2.8 Cetacean Observations

Observations were done between 8h30 and 17h30, with observation periods of 1h30, followed by a 30min break. A 360° survey was done _when the weather conditions permitted.

Every 1h30 the following were recorded: GPS position, sea state (Beaufort's scale), cloud cover, wind speed (in knots) and depth. All this data were recorded again for each sighting.

For each sighting the following were also recorded _ if possible: species, number of individuals (lowest, highest and best estimation), type (calf, juvenile or adult), activity (travelling, resting, socializing, hunting or milling), specific behaviors (e.g.: breaching, bow riding), boat reaction of animal and the sighting cue. Binoculars were use to help during the research.

Mauritius- Nazareth channel: 0 sighting
 Nazareth bank: 1 sighting
 Nazareth – Saya de Malha channel: 2 sightings
 Saya de Malha bank: 0 sighting
 Saya de Malha- Seychelles: 3 sightings
 Seychelles bank: 3 sightings

Very few observations were done during the length of the cruise, only 9 (Table 4).

These results could potentially be explained by:

- It was the end of reproductive season for the migratory species (e.g.: Humpback whales), and the area observed was done on the northern limit of the reproductive area.
- Preliminary results of the measurements (i.e. biomass of phytoplankton, zooplankton, fishes/ macrofauna and birds) also show very low productivity in the Mascarene plateau. These preliminary results could explain the "absence" of sedentary species.

These results need to be put in perspective regarding observation conditions:

- Only one whale-watcher during the entire cruise. The effects of fatigue and the difficulty of covering the entire observation area may have resulted in missed sightings.
- The boat did not change its course to follow a sighted cetacean and consequently species determination was impossible.
- The weather conditions were not ideal for the season, especially at the beginning of the cruise. For example, there was no sea-state under 3 before the 5th of November.

Table 4: Positions of cetacean observations.

N° observation	Date	Specie	GPS position	Number	Depth
G1	13/10/2008	Humpback whales (<i>Megaptera Novaeangliae</i>)	17° 16' 46''S 58° 33' 38'' E	10-15	60 m
G2	25/10/2008	Unidentified large	12° 51'	2 (perhaps	More

		baleen whales	17'' S 61° 58' 47'' E	3)	than 3000 m
G3	26/10/2008	Bottlenose dolphins (<i>Tursiops truncatus</i>)	12° 47' 53'' S 60° 56' 45'' E	Around 30	1000 m
G4	03/11/2008	Like Bryde's whale (<i>Balaenoptera edeni</i>)	09° 51' 11'' S 60° 32' 25'' E	2 (mother and calf)	1300 m
G5	05/11/2008	Like Bryde's whale (<i>Balaenoptera edeni</i>)	06° 59' 55'' S 58° 00' 50'' E	1	1600 m
G6	06/11/2008	Dolphins	06° 12' 23'' S 56° 16' 58'' E	Only 2 saw (by breach)	1000 m
G7	07/11/2008	Common dolphin OR Striped dolphin (<i>Delphinus delphis</i> or <i>Stenella coeruleoalba</i>)	05° 42' 47'' S 56° 48' 45'' E	Only 1 saw (by breach)	40 m
G8	10/11/2008	Bottlenose dolphins (<i>Tursiops truncatus</i>)	04° 32' 19'' S 56° 25' 16'' E	5	60m
G9	11/11/2008	Bottlenose dolphins (<i>Tursiops truncatus</i>)	04° 34' 39'' S 55° 40' 28'' E	3	45 m

OVERVIEW OF STATIONS

Table 5: Number of hydrographic (CTD and XBT), plankton (M and B), pelagic trawl (PT), bottom trawl (BT) stations and drifters during the survey. BT numbers represent both bank and gap region.

Region	CTD	XBT	M	B	PT	BT	Drifter
Mauritius Bank	17		14				
Mauritius – Nazareth Channel	2		1			11	2
Nazareth Bank	35		18				2
Nazareth – Saya de Malha Channel	25	25	10				3
Saya de Malha Bank	30		7			7	1
Saya de Malha – Seychelles Channel	12		7				2
Seychelles Bank	42					6	

3. OCEANOGRAPHIC CONDITIONS

3.1 Background

The Mascarene Plateau, in the South-western Indian Ocean, is a submerged volcanic plateau extending over 2200 km between the Seychelles Bank at 4°S to the island of Mauritius at 20°S (Figure 12).

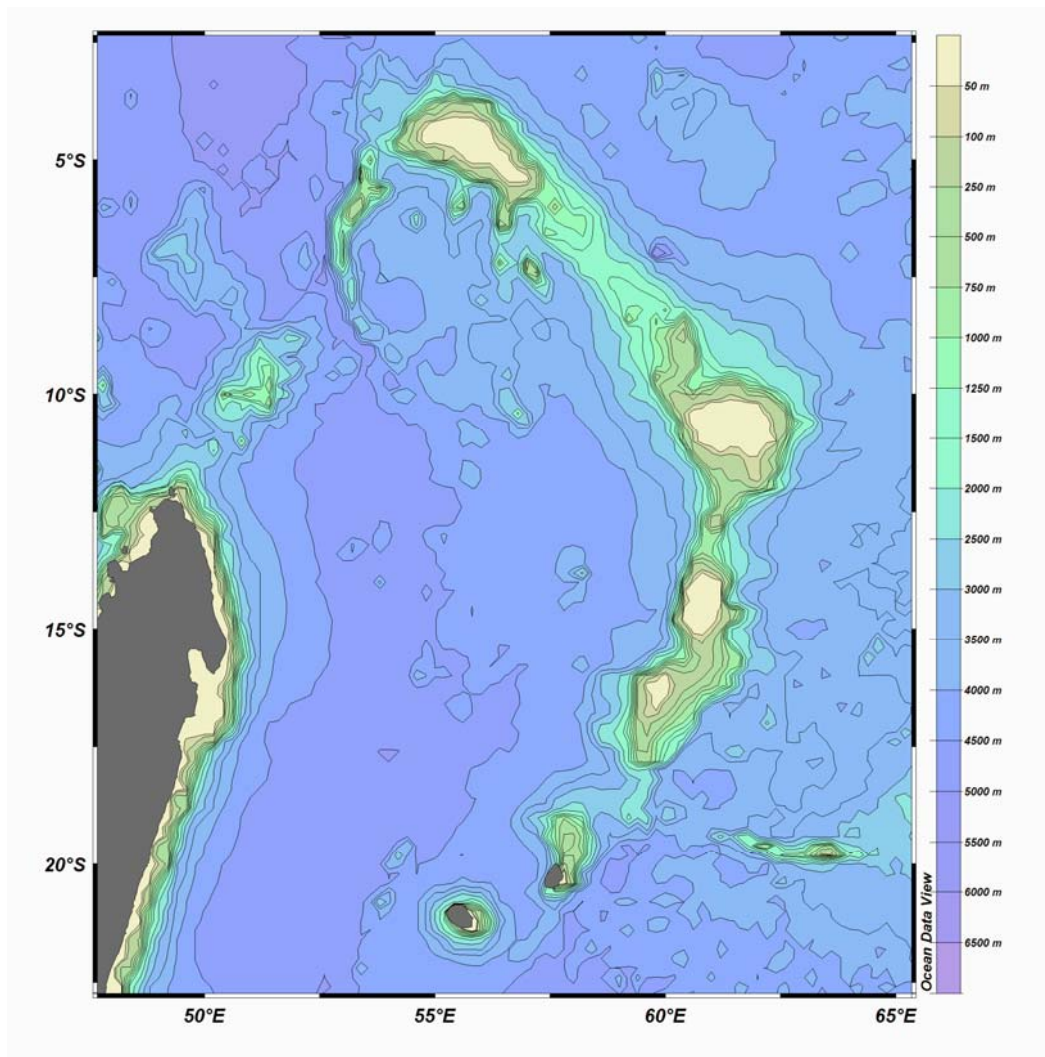


Figure 12: Map showing the location of the Mascarene Plateau. A colour bar highlights isobath readings.

It is a complex bathymetric feature oriented roughly north–south similar to a crescent, covering an area of over 115,000 km² and characterised by a series of islands, banks and shoals which are separated by deep channels (New et al., 2007). The main banks are known as the Seychelles Plateau, the Saya de Malha Bank, the Nazareth Bank and the Cargados-Carajos Bank (Figure 13). These are typically 20-100 m deep coral topped and sometimes break the surface to form small islands (ref).

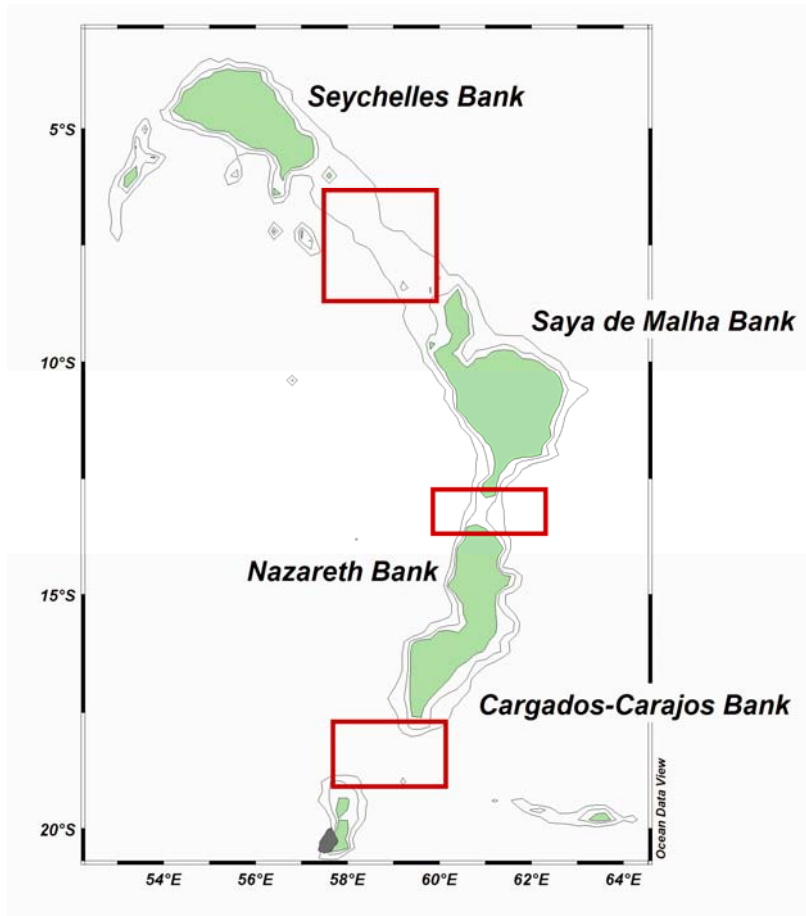


Figure 13: Location of each bank along the Mascarene Plateau. The deep channels separating banks have been highlighted by the red rectangle

On either side of the plateau steep slopes plunge to abyssal depths of 4000m.

The general circulation in this region is dominated by the South Equatorial Current (SEC), a broad current between 10 and 16°S and carrying approximately 50–55 Sv westwards at velocities rarely exceeding 0.3 m s^{-1} . The South Equatorial Current is directly driven by the trade wind belt and forms the westward limb of the large-scale subtropical Indian ocean gyre feeding into both the Agulhas Current system and the East African coastal current (Figure 14). To the north of the SEC lies the eastward flowing counter current known as the South Equatorial Counter Current (SECC).

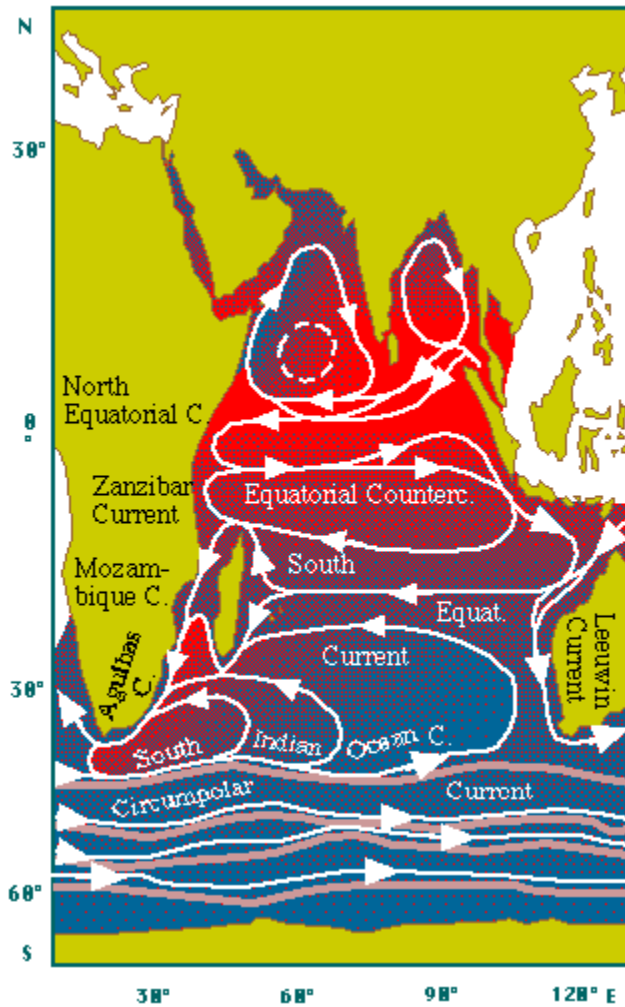


Figure 14: A map showing the general circulation of the Indian Ocean. Note the split in the South Equatorial Current at approx. 60E.

The Plateau's islands, banks and shoals (Figure 12) form a barrier modifying the predominantly westward passage of the South Equatorial Current. Recent studies have shown (ref) that this current, on approaching the Mascarene Plateau branches into a number of tributaries the largest occurring between 12-13°S between the Saya De Malha and Nazareth Banks. Here approximately 50% or 25 Sv of the SEC is forced to flow through the narrow channel separating the Saya De Malha and Nazareth Banks with the remainder of the flow passing in roughly equally volumes around the northern edge of the Saya De Malha Bank (8-9°S) and between Mauritius and the Cargados-Carajos Bank (18-20°S) (Figure 13). The modifying influence of this barrier to the background circulation provides a rare example of an extensive shallow-shelf sea completely detached from land boundaries, and remains an isolated and almost completely unexplored, marine ecosystem.

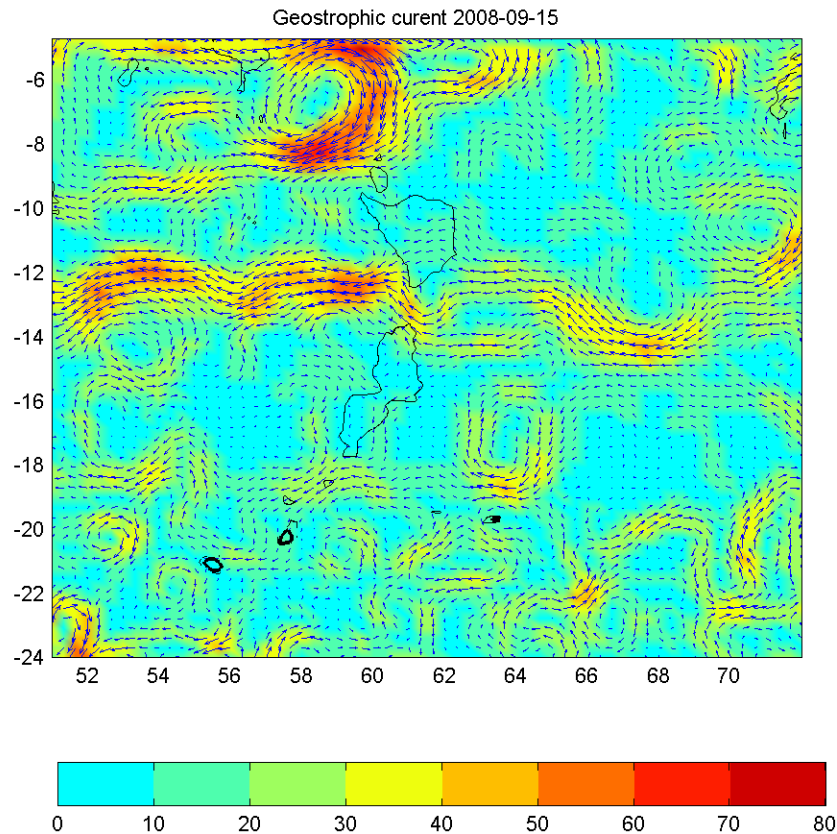


Figure 15: Geostrophic velocity from altimetry data highlighting the circulation in the region of the Mascarene Plateau.

3.2 Results

Past investigations (New et al., 2007) have shown that the overall effect of the Mascarene Plateau on the South Equatorial Current is fourfold:

1. It appears that the SEC is displaced southwards from its mean position of 10°-16°S by the obstruction caused by the shallow bathymetry of the Mascarene Plateau. Upstream of this Plateau the SEC exists as a broad (~650 km in width) shallow (~1000 m in depth) current with speeds averaging 0.30 ms⁻¹.
2. On approaching the Mascarene Plateau the complexity of the bathymetry results in the SEC, identified as a single core jet upstream of the region, to fragment into three distinct branches.
3. Deep channels separating individual banks (Figure 13) act as choke points funneling the flow of the SEC from east to west. Investigations during the Shoals of Capricorn project in 2002 show that downstream of the Plateau the SEC comprises of two cores suggesting that the flow reconstitutes itself, after passing over the Saya de Malha – Nazareth sill.
4. Ekman divergence resulting from the SE trade wind field results in a gradual uplifting of water masses between 15°-5°S as can be seen by the dynamic height for the region. Since nutrients increase with depth, it would be expected that levels would gradually increase with distance north and thus influencing the biological productivity of the surrounding region.
- 5.

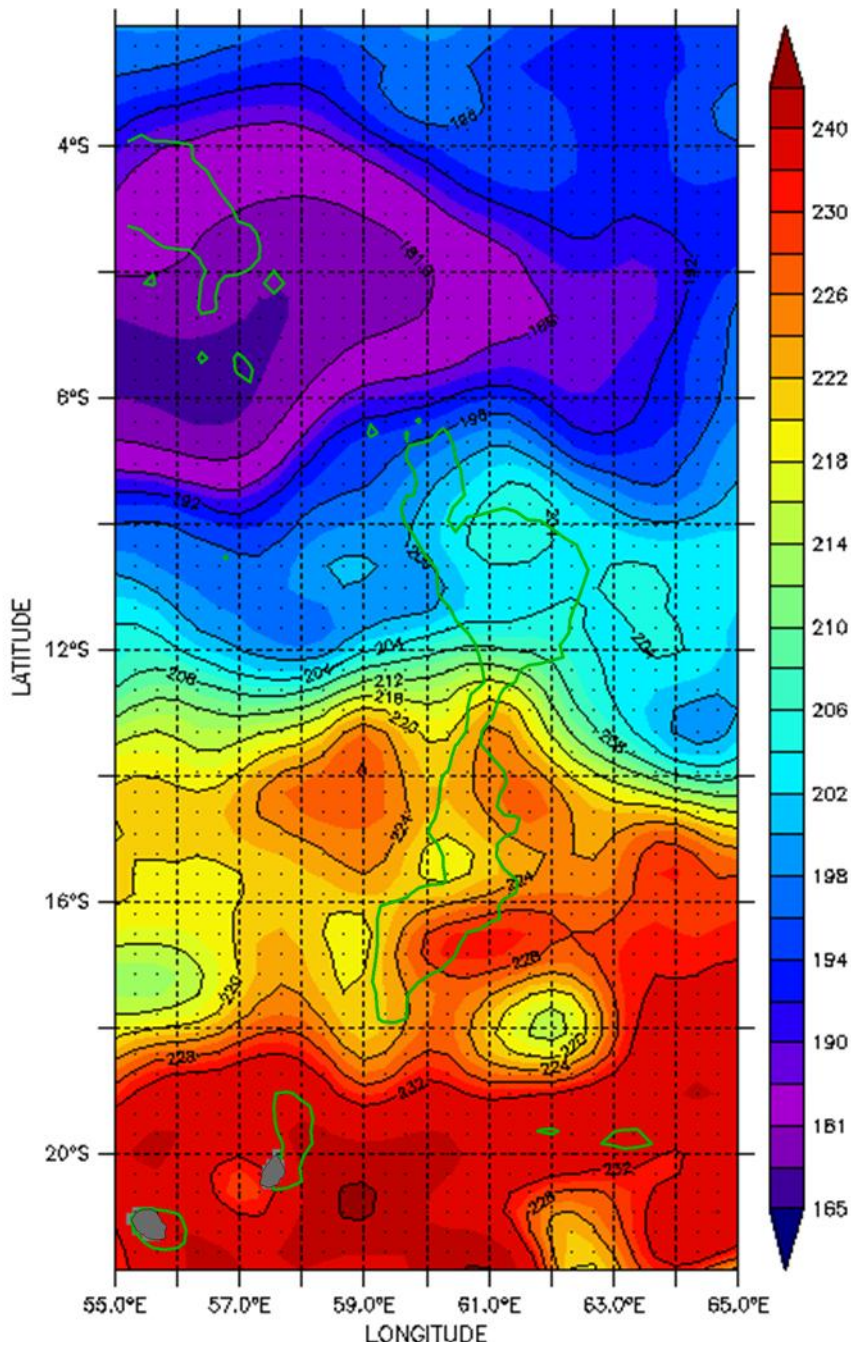


Figure 16: Map showing the change in dynamic height from north to south (165-240 cm). Of interest are the bunching of contours between the Mauritius – Carajos/Nazareth (~19°S) and Nazareth-Saya de Malha (~12°S) gaps as a result of the channeling of SEC. In addition, north of the Seychelles Bank at approx. 4°S dynamic height dips as a result of the eastward flowing SECC.

In agreement with past observations the SEC, during the survey period, existed as 3 separate branches channeled between the deep channels (Figure 13) at 9-8°S, 13°-12°S and 19°-18°S. Velocities exceeded 0.5 ms^{-1} in these channels as can be seen from Figure 17. The net westward geostrophic transport in the SEC on the eastern side of the Mascarene Plateau mirrors the velocity profiles in figure 14. From a total of 56 Sv (New et al., 2007), approx. 23 Sv is constricted between the Saya De Malha and Nazareth Banks near 12–13°S, 10 Sv is diverted around the northern side of the Saya De Malha Bank, and the remaining 25% (~10 Sv) flows southwestwards through the gap between the Cargados Carajos Bank and

Mauritius. New et al., (2007) have suggested that the flow through the Saya de Malha and Nazareth sill forms the northern core of the SEC downstream of the Plateau between 10° -14° S, while the flow passing through the gap south of the Cargados Carajos Bank forms the southern core of the SEC between 16° - 20°S. Finally, the presence of an eastward flow between 6° - 2°S can be related to the position of the eastward flowing South Equatorial Counter Current.

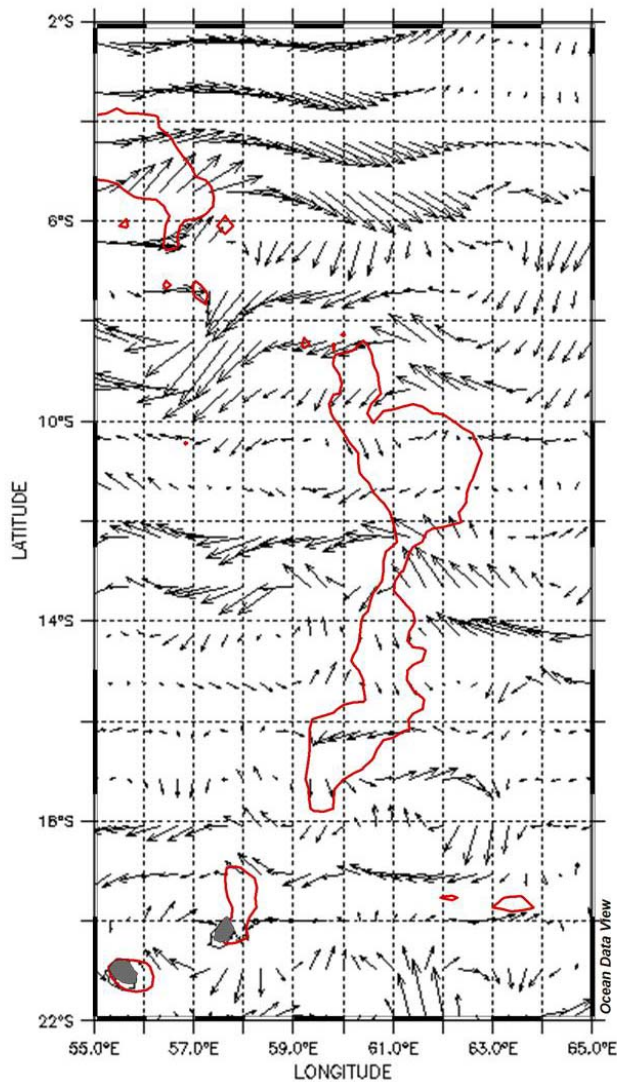


Figure 17: Map of absolute geostrophic velocities ($1\text{cm} = 0.5 \text{ ms}^{-1}$) during the time of the survey. The 1000 m isobath depicting the location of the shallow shoals associated with the Mascarene Plateau is shown in red.

The preliminary ADCP results confirm the general current patterns derived from altimetry. The strongest flow was encountered in the gap between the Nazareth and Saya de Molha Banks with velocities exceeding 0.5 m s^{-1} at 30 m depth (Figure 18). The westward flow is also present across the northern gap, between Saya de Molha and Seychelles. The current reversal related to the SECC over the Seychelles bank is also clearly manifested (Figure 19). The results from southern gap, between Mauritius and Cardagos-Carajos are an exception. The ADCP-derived currents have variable magnitude and direction. A southeastwardly flow accelerates just off Mauritius, which is not resolved in the altimetry data (Figure 17). This suggests that this region may have experienced a period of an mesoscale variability, not well

resolved by the survey sampling grid and not captured on the 1/3 degree altimetry-derived current maps.

Over the shallow banks of Saya de Molha and Nazareth, the currents were typically of the order of $0.1\text{-}0.2\text{ m s}^{-1}$. A stronger current observed over the northern portion of the Nazareth Bank appears to be wind-driven, associated with the strong easterly wind event the survey encountered in this area.

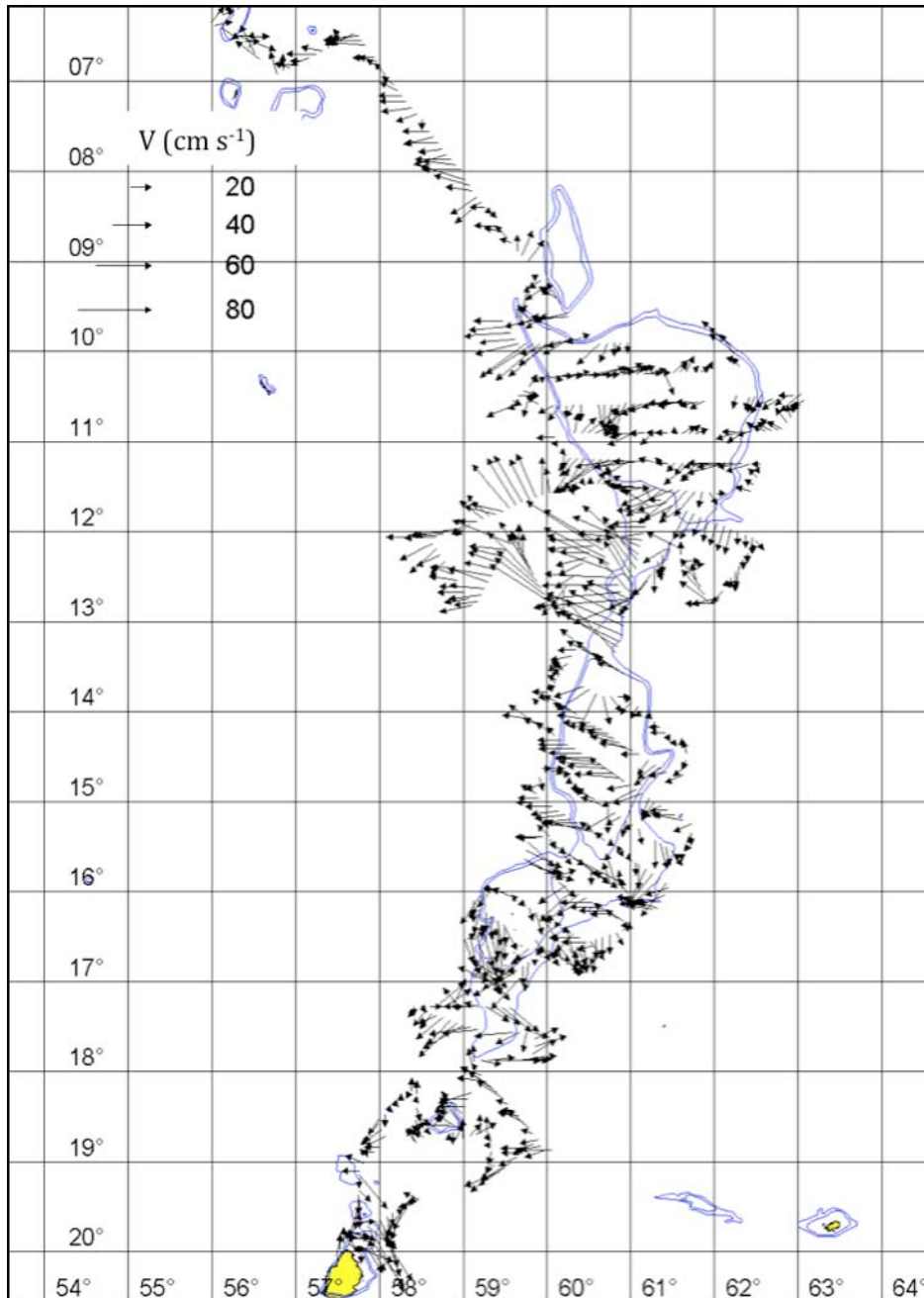


Figure 18: Map of ADCP-derived currents along the survey track at 30 m depth, exclusive of the Seychelles Bank. The vector scale shown in the top-left portion of figure.

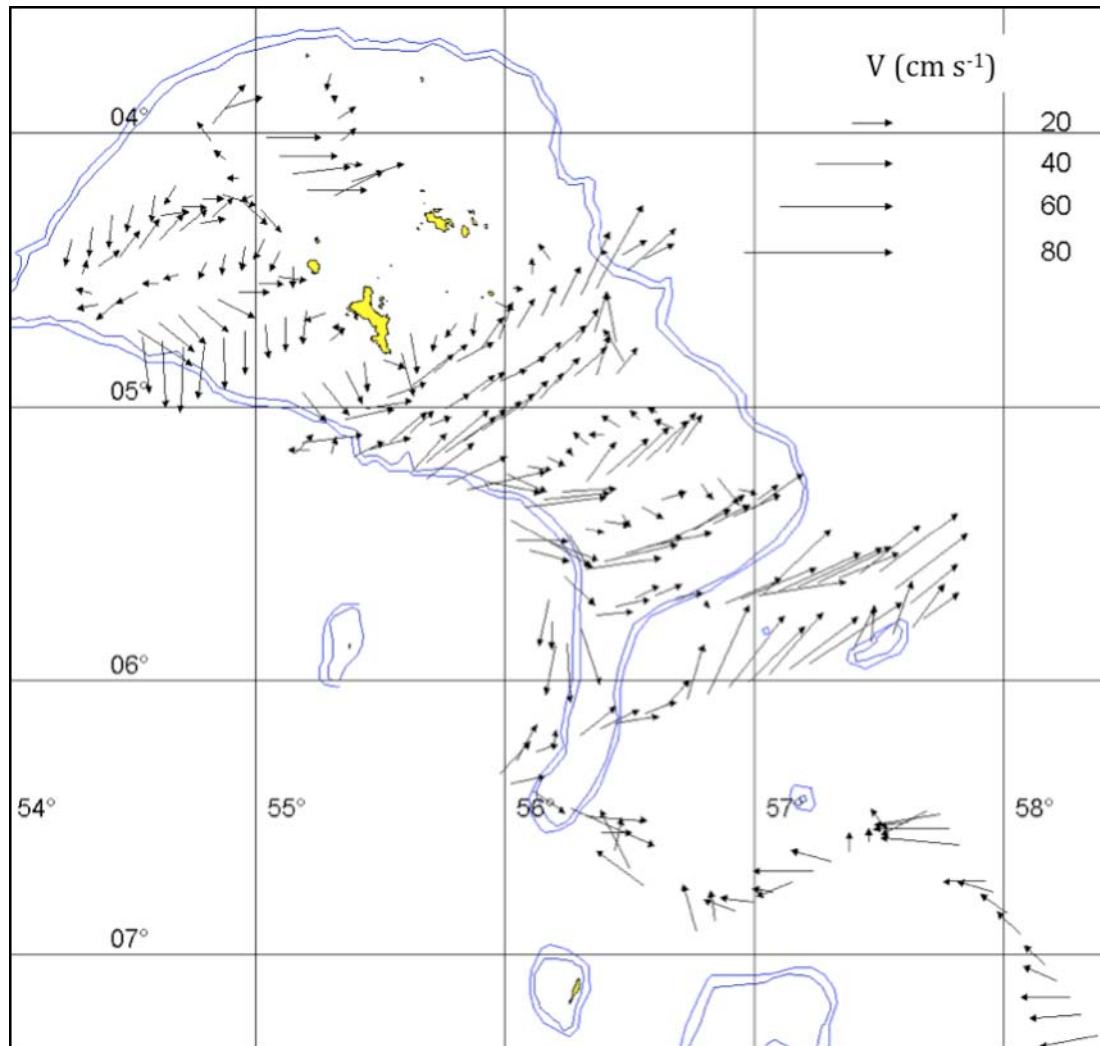


Figure 19: Detailed map of ADCP-derived currents at 30 m depth over the Seychelles Bank. Dataset until November 13, 2008. The vector scale shown in the left-right portion of figure.

Defining the ocean environment of the Mascarene Plateau

New et al. (2007) carried out a detailed study of the water masses in the region of the Mascarene Plateau. From their data it can be seen that there are prominent differences between the northern and southern regions. In contrast there is relatively little difference between water masses found to the east and west of the plateau. Data collected during the Mascarene survey support past investigations and physical-chemical profiles (Figure 20) give further evidence that the SEC acts as a barrier between the north and southern regions. While the SEC dominates the general circulation in the vicinity of the Mascarene Plateau, highly saline surface waters over the Seychelles Bank bear resemblance to Arabian Sea High Salinity Water (ASHSW) and suggest the influence of the eastward flowing South Equatorial Counter Current (SECC) on local water masses. Further support to the close proximity of the SECC in the northern regions of the Mascarene Plateau is given from Figure 17 which highlights the eastward flow north of 4°S as well as the presence of Red Sea Water only in the northern sector of the survey. Furthermore, results collected during this survey provide evidence that the SEC acts as a major conduit for the transport of Indonesian Throughflow Water channeling its passage through the gaps across the Indian Ocean.

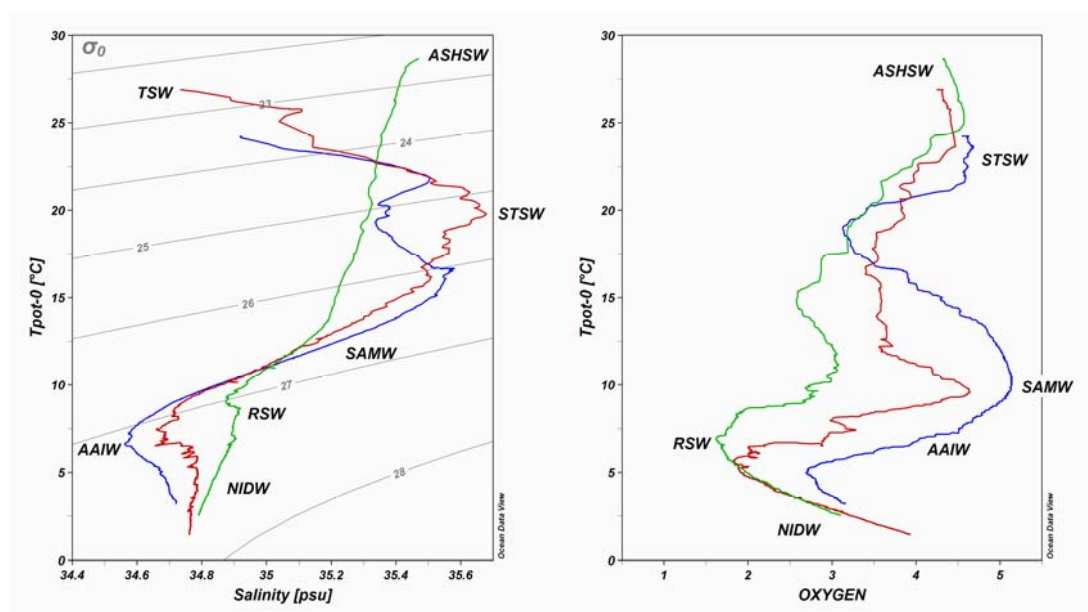


Figure 20: Temperature/Salinity (left panel) and Temperature/Oxygen (right panel) profiles for 3 CTD stations. The green line denotes CTD station 1130, which was occupied at 5°S, red line denotes CTD station 1059 at 12°S and the blue line represents CTD station 997 at ~19°20'S. Difference in their north-south physical/chemical properties is immediately clear.

The following water masses were observed during the cruise:

Tropical Surface Water (TSW) – this is a broad band of fresh water between 4 and 20°S. Salinities are low (34.7 – 34.9) due to the high levels of precipitation in the tropics. During the survey TSW was observed at all stations occupied south of the Seychelles-Saya de Malha gap, further supporting evidence that the SEC influences the distribution of surface water masses. Indeed Figure 22 shows the change in surface properties from CTD station 1109 (9°S) which is predominantly TSW and CTD station 1121 (5°30'S) which is typical of the high salinity characteristic of Arabian Sea High Salinity Water (ASHWS) to the north. ASHSW is highly saline (>35.5) as a result of excess evaporation over precipitation in the Arabian Sea and is swept eastwards across the Indian Ocean by the SECC. A north-south section (Figure 21) along the Mascarene Plateau clearly shows the meridional distribution of the fresher TSW in relation to other water masses. It is clear from the section that the channel separating the Seychelles and Saya de Malha bank acts as a barrier separating fresh TSW from saltier modified ASHSW to the north.

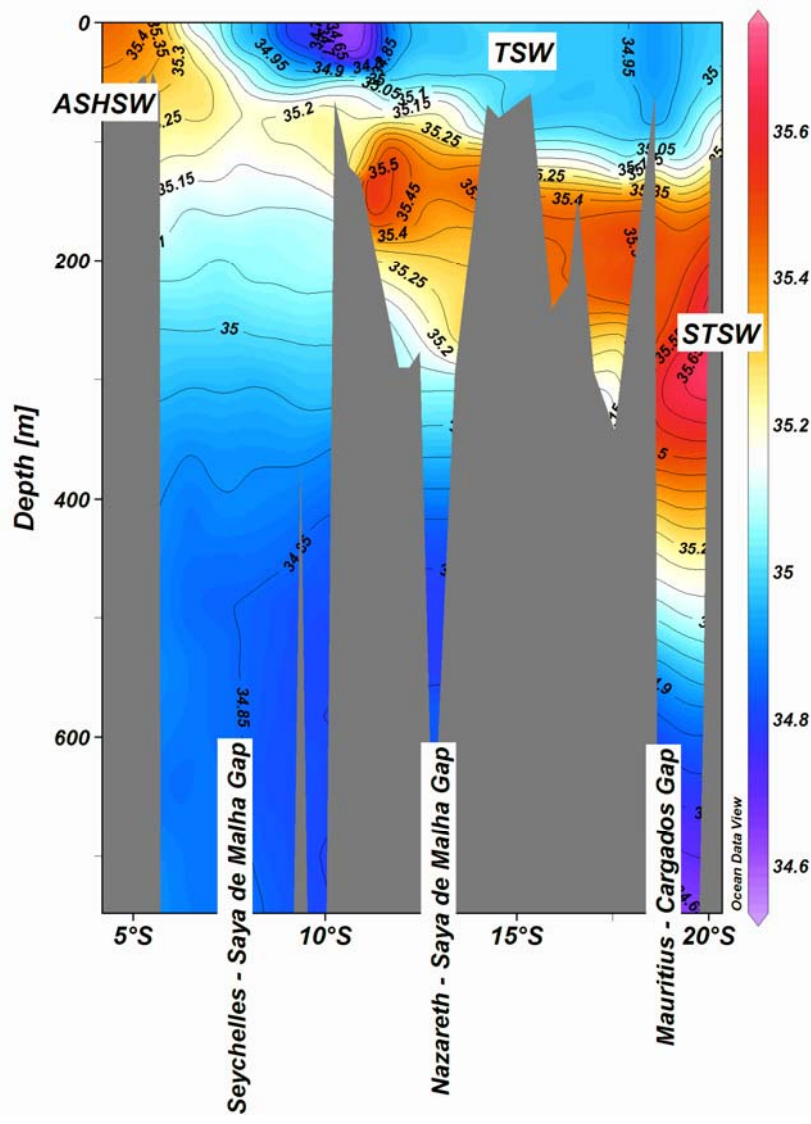


Figure 21: North - south salinity section across the Mascarene Plateau (upper 750 m). Core water masses ASHSW – Arabian Sea High Salinity Water, TSW – Tropical Surface Water, STSW – Subtropical Surface Water have been identified. It is clear that the channel separating the Seychelles-Saya de Malha Banks separates TSW from saltier surface waters in the north.

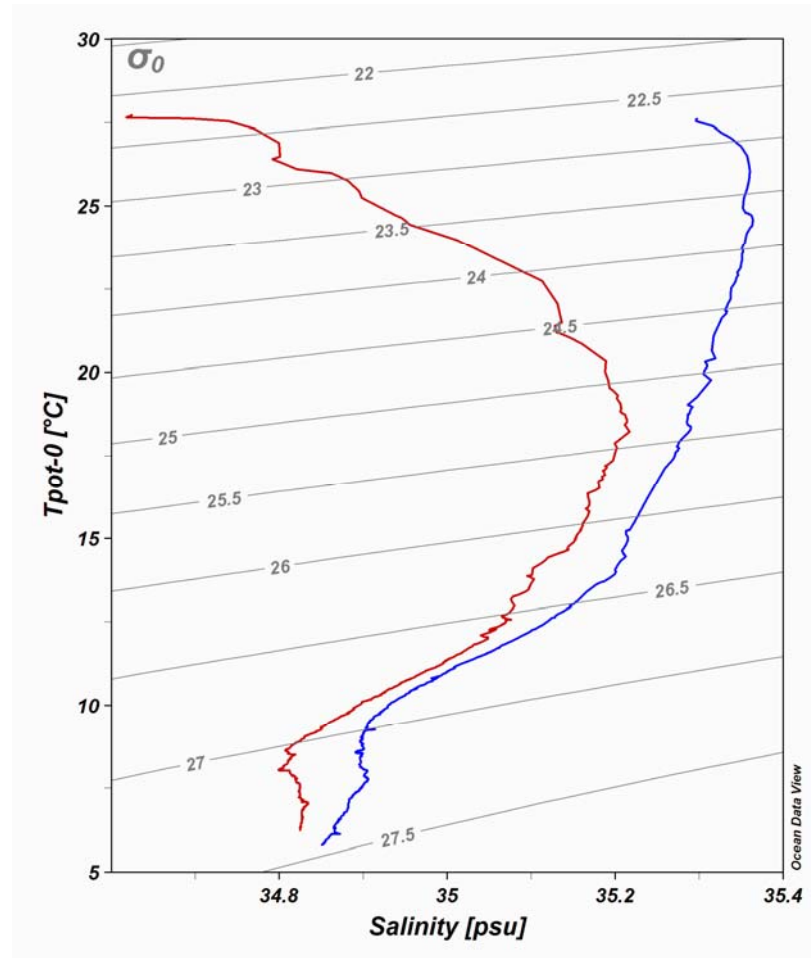


Figure 22: TS profiles for 2 stations occupied on the southern end (red) and northern end (blue) of the Seychelles – Saya de Malha channel

Subtropical Surface Water (STSW) can be found in the subtropical belt between 20°-35°S. STSW displays characteristically high salinity values (>35.4) due to the high levels of evaporation associated with the subtropics. Travelling northwards STSW subducts below the fresher TSW to form a subsurface salinity maximum, which at 18°S is centred at 300m depth (Figure 21). This salinity maximum extends as far north as 14°S, and may be partly carried westward by the SEC (**Error! Reference source not found.**). Immediately below TSW between 100-300m, Song et al. (2004) have identified Indonesian Throughflow water (ITF). An important feature of the Indonesian Throughflow is that because the water in the western equatorial Pacific Ocean has a higher temperature and lower salinity than the water in the Indian Ocean, the Throughflow transports large amounts of relatively warm and fresh water to the Indian Ocean. When the Indonesian Throughflow through Lombok Strait and the Timor passage enters the Indian Ocean it is advected towards Africa within Indian South equatorial current. ITF is slightly more saline (>0.5-0.6 = 35.2) than TSW and in the region of the Mascarene Plateau can be found between 100–250m at 10°S. Carried within the core of the SEC (Figure 23), ITF has been shown to spread across the western boundary of the Indian Ocean, forming a subsurface oxygen minimum of ~2.5 ml/l (Figure 23).

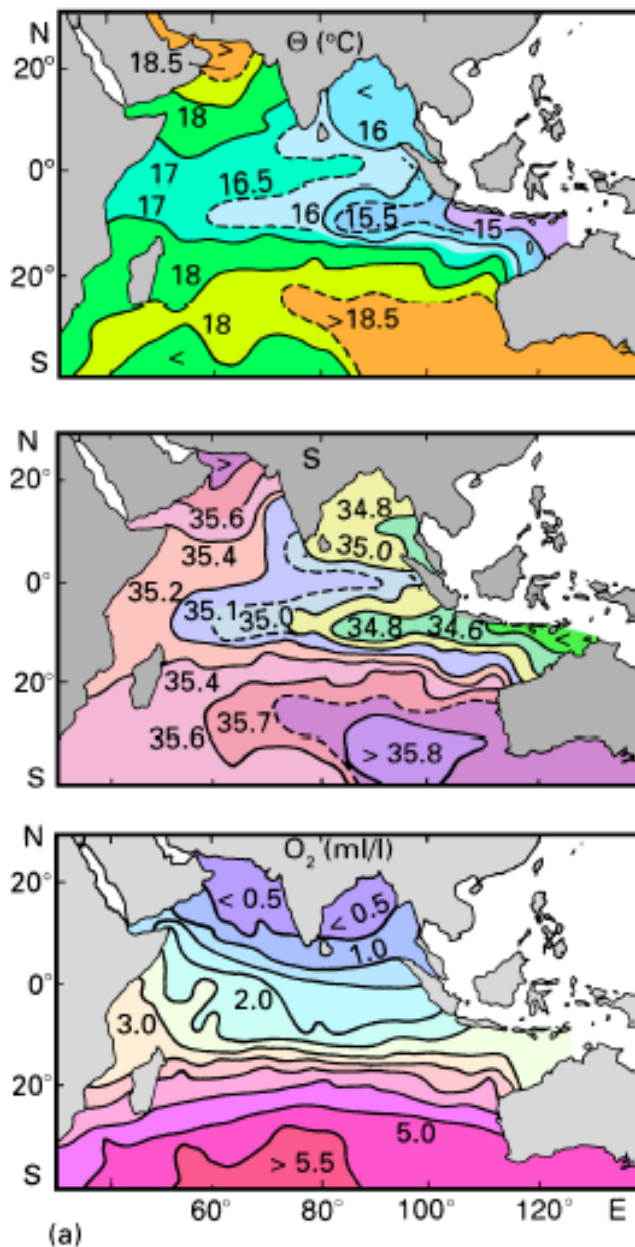


Figure 23: Map showing clearly the movement of Indonesian Throughflow water (ITF) across the Indian ocean between 100-150 m. Panels represent upper – temperature, middle – salinity and lower – dissolved oxygen.

During the survey evidence of ITF was identified by its subsurface oxygen minimum in each of the deep channels separating the shallow shoals of the Mascarene Plateau further supporting suggestions that SEC is the main conduit for ITF's advection across the Indian Ocean.

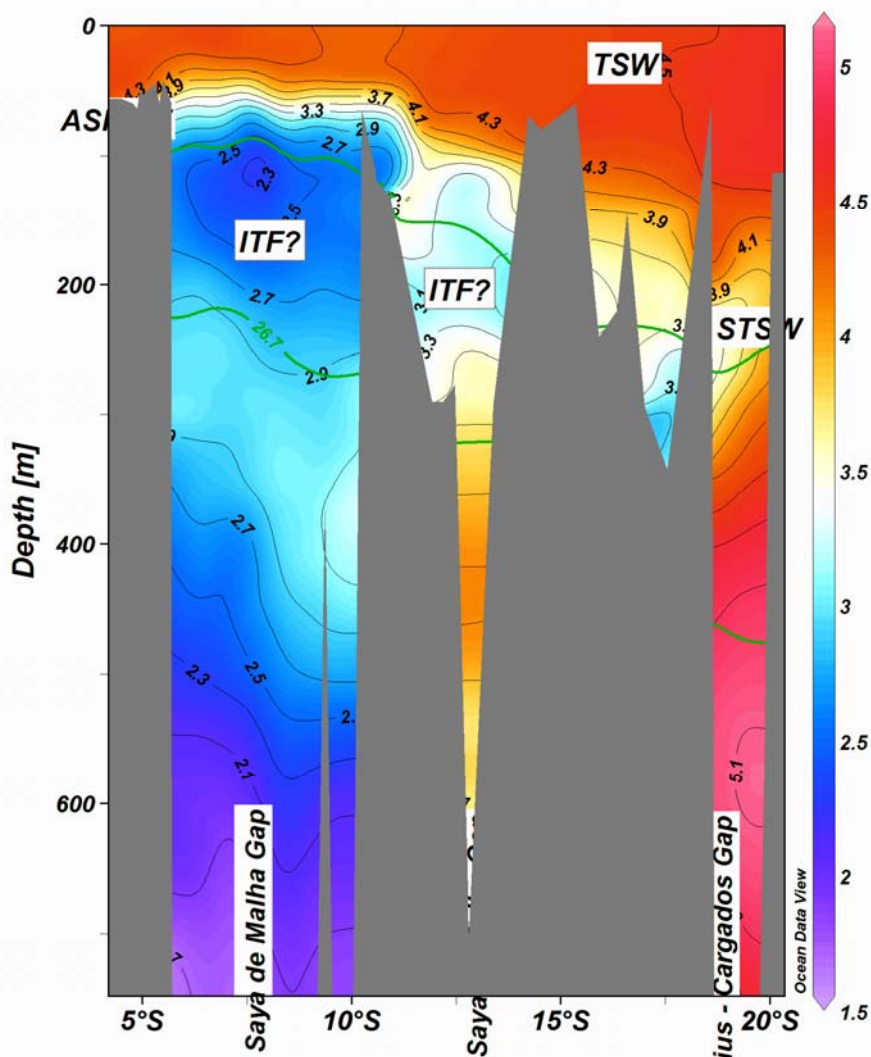


Figure 24: North - south oxygen section (upper 750 m) across the Mascarene Plateau. The location of core water masses have been highlighted. A tongue of subsurface oxygen minimum characteristic of ITF is seen to extend southwards. The density boundaries associated with ITF are shown in green.

Sub-Antarctic Mode Water (SAMW) – this water mass is formed between 35° and 45°S as a result of deep winter mixing, and subducted northwards in the subtropical gyre recirculation (McCartney, 1982). SAMW is characterized by a temperature range between 8°–15°C, salinities and an oxygen maximum >4.5 ml/l. High oxygen concentrations (>5 ml/l) characteristic of SAMW were only observed in the southern part of the survey between the Mauritius and Carajos Banks along centred at density 26.85 kg/m³.

Antarctic Intermediate Water (AAIW) is characterised by a salinity minimum between 800–1500m (<34.6) and oxygen levels >3.5 ml/l. AAIW originates in the Southeast Pacific (McCartney, 1982) and in the South Atlantic (Piola and Gordon, 1989), and appears to enter the South Indian Ocean in its southeastern region (Fine, 1993). Higher salinity Red Sea Water (RSW) occupies approximately the same depth and density range as the AAIW (Figure 20), but in contrast to AAIW has a much lower oxygen content (<2 ml/l) and higher salinities >34.85. Beal et al. (2000) show that the primary spreading route for the RSW is, from its

origins in the Red Sea, southwards along the western boundary of the Indian Ocean to at least 20°S, AAIW and RSW are easily identified in the TS profiles of the stations occupied during the survey with RSW found only in the northern section of the survey (10°S).

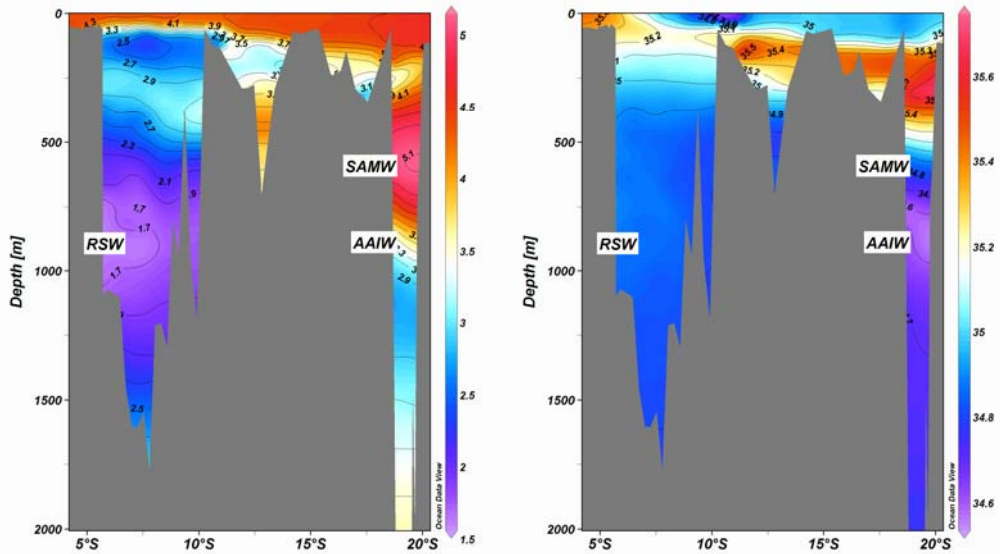


Figure 25: Full depth north - south oxygen (left panel) and salinity (right panel) section across the Mascarene Plateau. The separation of deeper water masses is clear with Red Sea Water restricted north of 10°S and Subantarctic Mode Water and Antarctic Intermediate Water observed in the south.

In contrast a number of stations (Figure 5) were occupied along an east-west transect in order to determine the influence the Mascarene Plateau may have as a barrier to the advection of water masses (Figure 26). Of interest is the degree of similarity within station pairs i.e. east and west, while distinct differences between station pairs i.e. north-south are observed, again suggesting the role the SEC plays in separating the northern tropical region from the south.

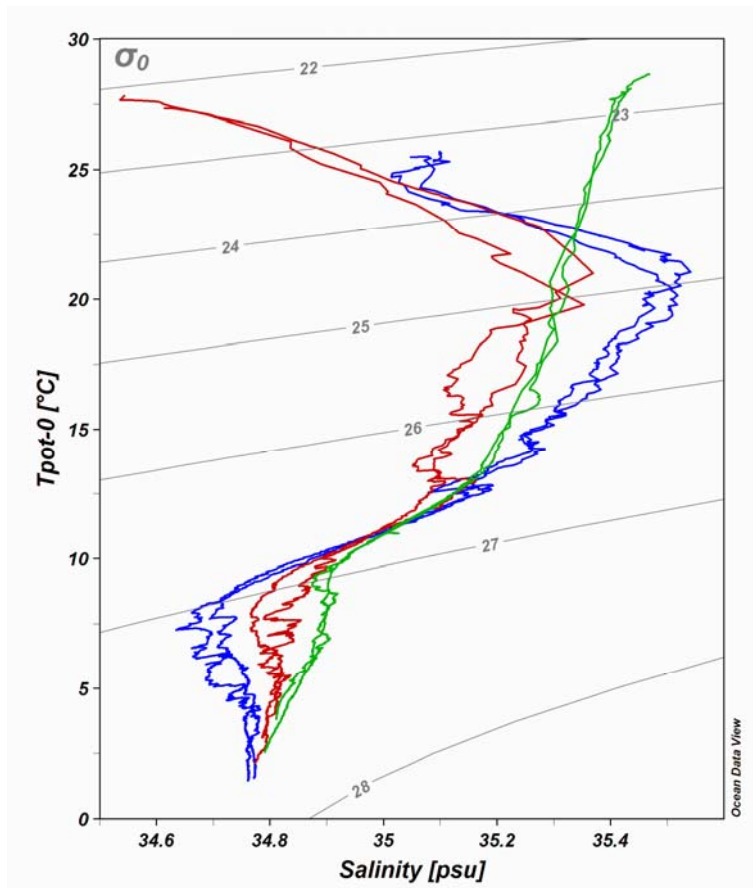


Figure 26: TS profiles of station pairs occupied along east-west transects during the survey. Blue denotes CTD stations 1038 and 1049 occupied across the Nazareth Bank, Red denotes CTD stations 1084 and 1099 occupied across the Saya de Malha Bank and green represents CTD stations 1130 and 1144 occupied across the Seychelles Bank.

The overall effect of the Mascarene Plateau is to split the SEC into separate cores centered near 12 and 18°S. Once passed the Plateau it seems likely that these 2 cores continue westwards towards the Madagascar coast at 50°E and there form the North East and South East Madagascar Currents. The SEC has been shown to divide the southern water masses (STSW and AAIW) from the northern water masses (ASHSW and RSW), at the same time as sweeping these water masses across the Mascarene Plateau (New et al., 2007). In addition, the SEC acts as a main conduit for the westward advection of ITF water across the Indian Ocean bringing with it its subsurface oxygen and salinity characteristics. An interesting circulation exists over the Seychelles Bank, its character influenced by both the SEC flowing westwards to the south and the eastward flowing SECC. The influence the SECC has in bringing eastwards highly saline surface waters originating from the Arabian Gulf as well as RSW intermediate water needs to be further investigated.

FIELD RESULTS FROM PHYTOPLANKTON SAMPLING

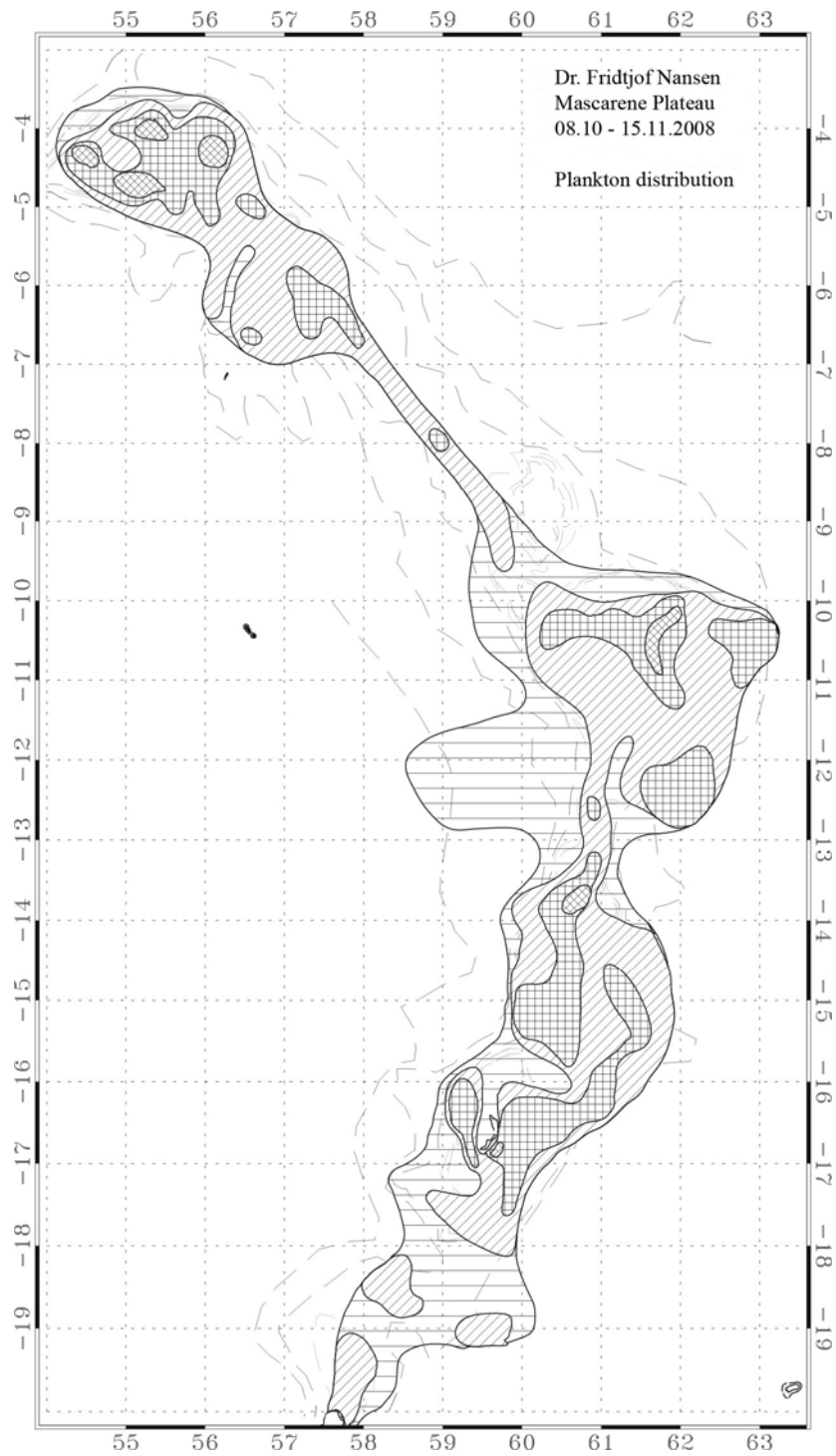
Distribution of chlorophyll by depth from point samples

FIELD RESULTS FROM ZOOPLANKTON SAMPLING

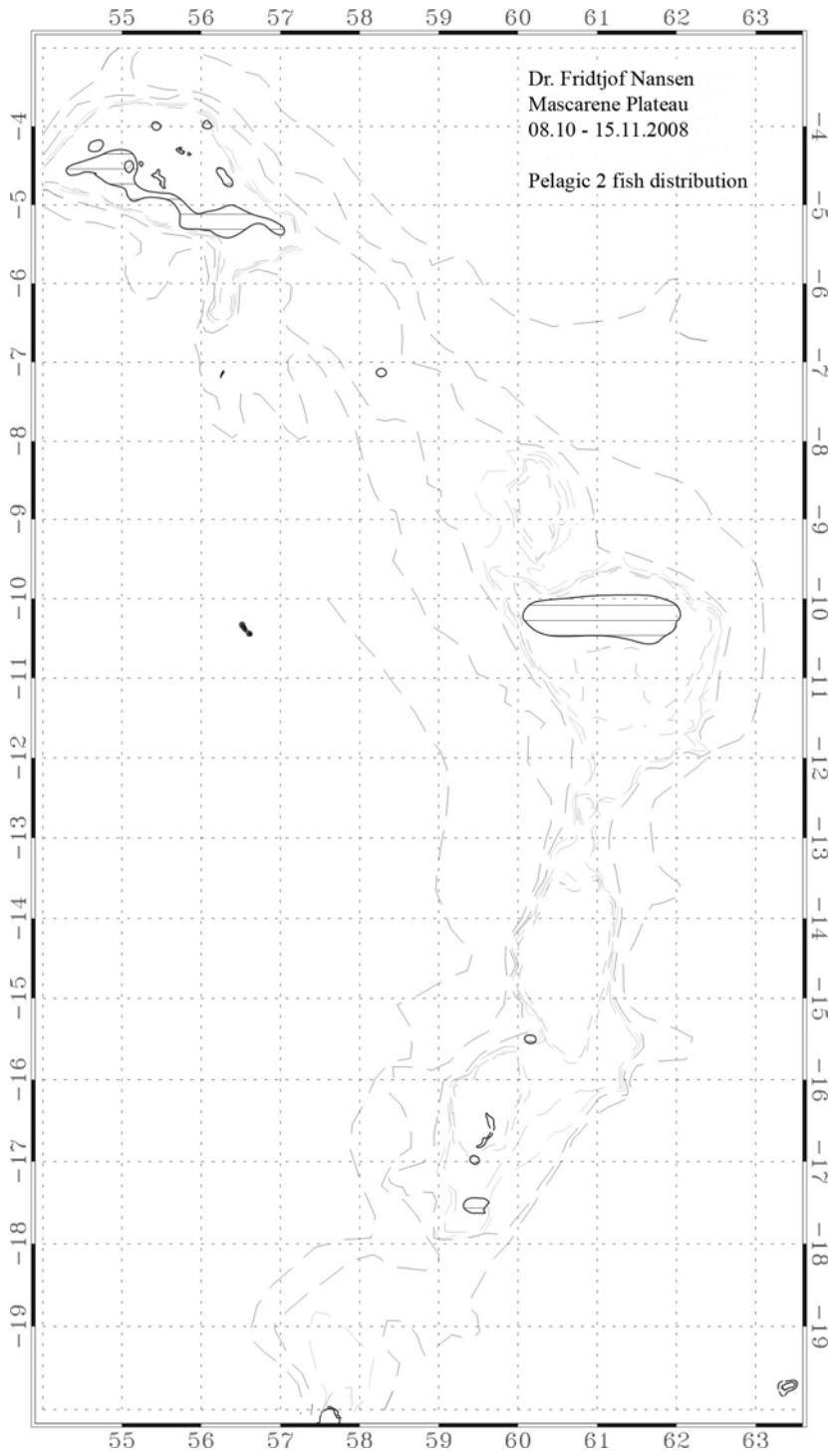
Distribution of biomass (wet weight) from point samples

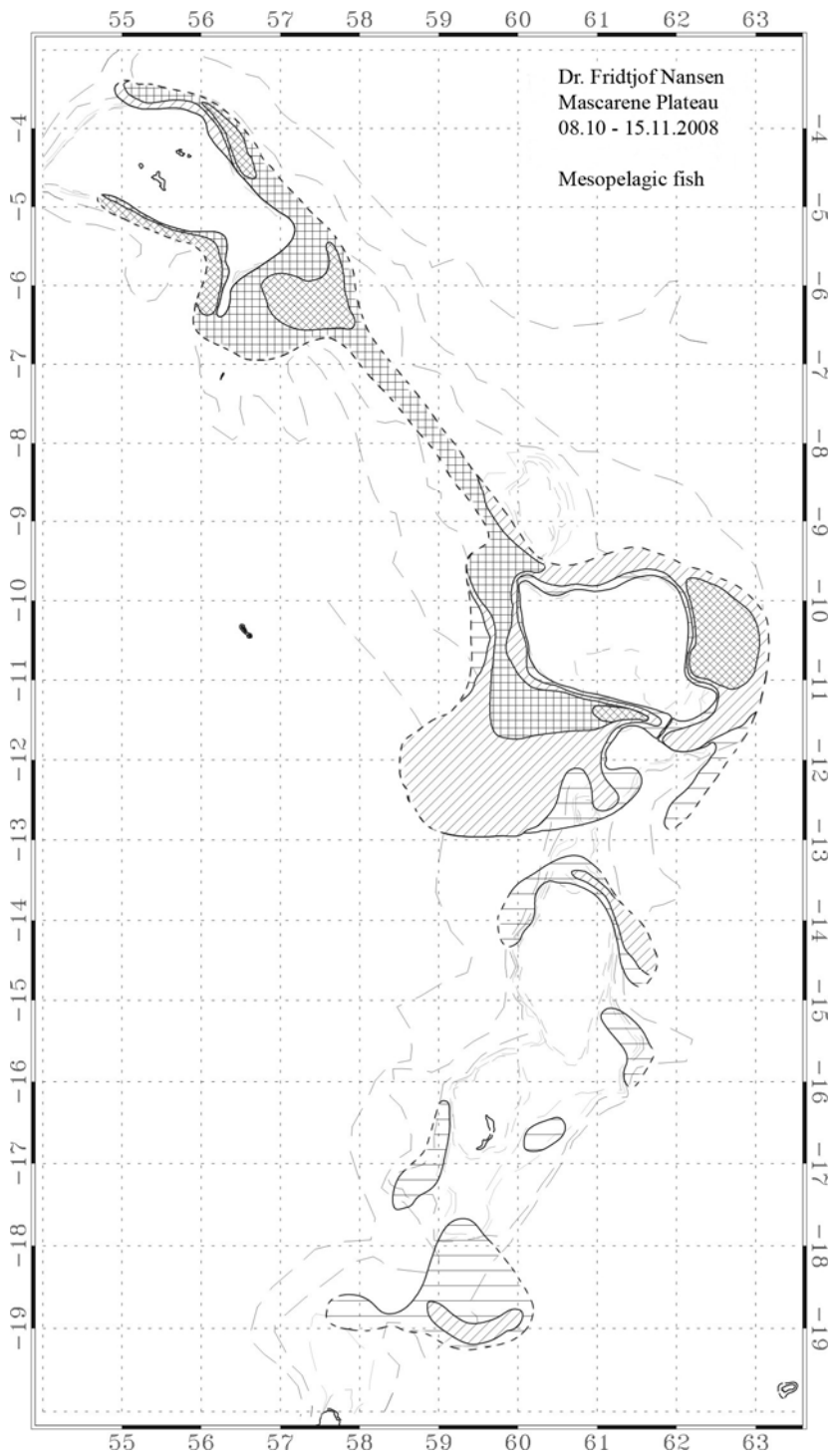
RESULTS OF THE ACOUSTIC SURVEY AND FISHING OPERATIONS

Distribution of plankton from acoustic registrations



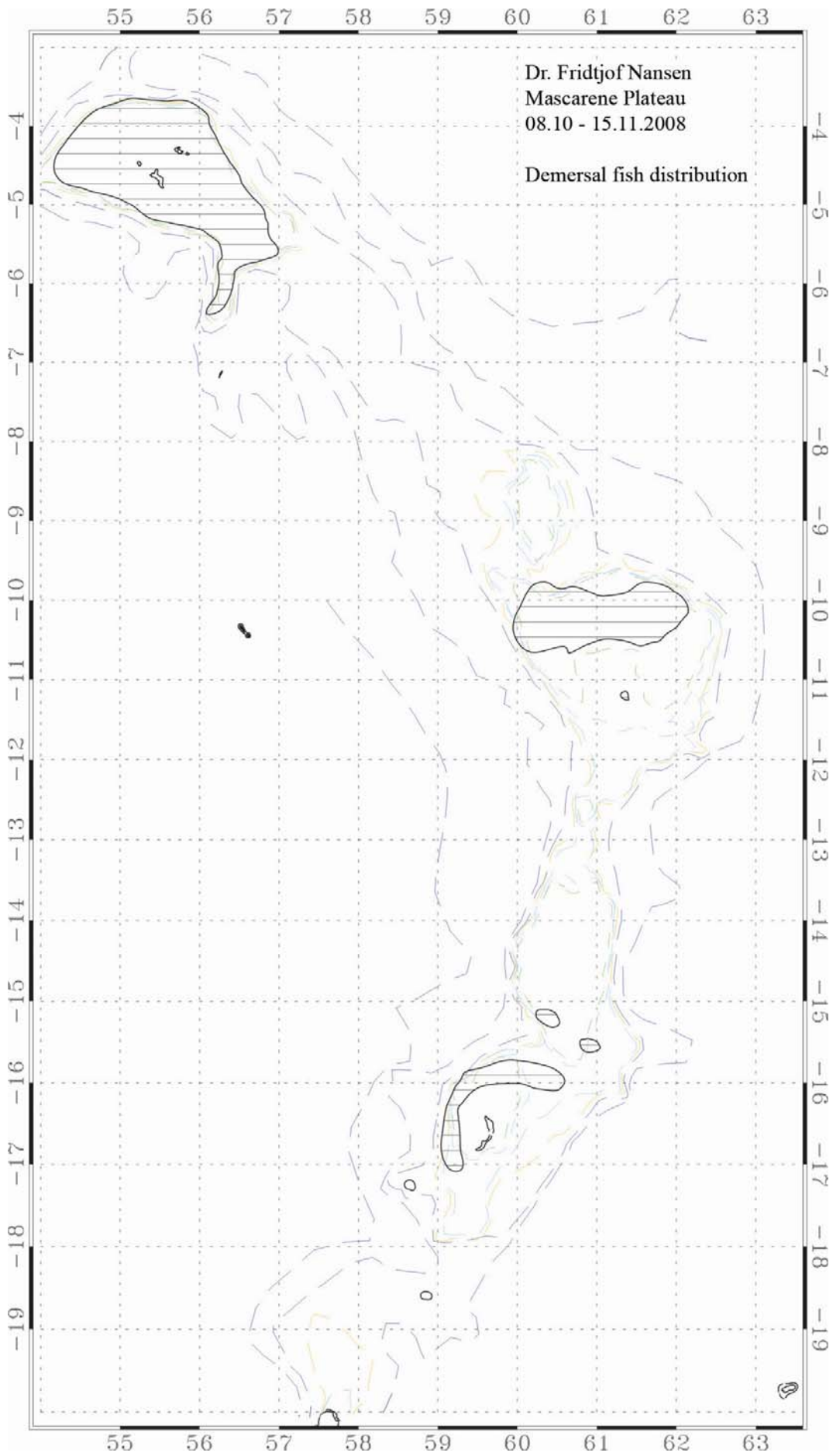
4.1 Pelagic fish distribution and abundance





Distribution of mesopelagic fish

4.2 Distribution of demersal fish from acoustic registrations



4.3 Species diversity from trawl sampling

DNA and isotope collections

A total of xxx tissue samples were collected for DNA analysis, from a provisional total of yyy species (Table zzz). Once the tissue samples are back in SAIAB in Grahamstown their identities will be confirmed by cross-referencing specimens, photos and labeled tissues. Tissue samples will be analysed through the Barcode of Life programme (FISHBOL) in addition to other genetic studies as and when these are conducted in association with taxonomic revisions.

Sven & Jackie to do isotope paragraph

Taxonomy and photography

The collection of reference specimens for all species collected during the survey, and type series for species believed to be undescribed or poorly represented in earlier collections, has resulted in a provisional total of 271 fish species (estimating for duplication of temporary names for the same species in the database) in over 80 families (Table aaa). Most species have been positively identified on board using available reference materials (FishBase on-line, Smith's Sea Fishes, Heemstra & Heemstra's Coastal Fishes of Southern Africa, FAO identification guides for the Western Indian Ocean, FAO species catalogues for various important families, Compagno et al.'s Field Guide to the sharks of the world and the South African guide to sharks and rays, and also various field guides to coral reef fishes in the Indian Ocean). Up-to-date taxonomic names are in the process of being verified using Eschmeyer's on-line 'Catalog of Fishes'.

Photographs have been taken by Oddgeir Alvheim for every species collected, the majority after the fish were pinned out to display the fins properly. These photographs will be used in the preparation of paintings of each species for inclusion in the forthcoming book on the Fishes of the Western Indian Ocean. Examples of these photos shown here include (Plate 1) a selection of photos of species that are either undescribed or are poorly represented in the literature of the fishes of this area. Plate 2 is an example of the photos of all species of one family, in this case the Mullidae, presented together to facilitate identification in future. Plate 3 includes photos of a fairly random selection of species that indicate the quality of photos available for use in the preparation of the new WIO fishes book illustrations.

Biodiversity assessment

While every effort has been made to explore all depths down to 300 m, this proved difficult to achieve in many areas (Table b). In the southern area near Mauritius and on the Nazareth Bank, shallow water stations were impossible to find because of extensive corals, and even in 60 m depth corals were present in most areas, limiting trawling opportunities. The first attempt at 60 m had to be abandoned when corals were encountered shortly after the net was set. In this area it did prove possible to trawl at greater depths and six trawls were made from 214 to 313 m in depth.

In the central part of the Mascarene Plateau, i.e. the Saya de Malha banks, shallower trawls were possible as a result of less extensive corals, and four trawls were made in water less than 50 m deep. Trawls were possible over a wide depth range.

The greatest difficulty in finding suitable trawling ground was on the Seychelles Islands banks, where all trawls were carried out at similar depths in the region of 60 m. In shallower water the bottom was untrawlable as a result of uneven topography and/or coral outcrops. At the edge of the banks, the slopes to deep water are too steep to permit trawling along the depth contours.

The data collected are thus inadequate for any statistical meaningful analysis, the only possible comparison being the four hauls on the Mauritius/Nazareth banks and six on the Seychelles banks between 50 and 70 m depth. Catches were, however, extremely variable, as shown by the very large SDs for the catch data by weight (Table c). Most noteworthy catches came from the last three hauls of

the survey, which yielded catch rates between 484 and 819 kg h⁻¹, and it appears that the northern part of the survey area is more productive than the areas to the south.

Table b. Distribution of demersal trawl stations by depth in the three parts of the Mascarene Plateau.

Depth (m)	Number of ½ hr trawls		
	Nazareth	Saya de Malha	Seychelles
30-50	1	3	
50-70	*4	0	6
70-100	0	1	
100-200	0	2	
200-300+	6	1	

* The 3rd (5 min) and 4th (22 min) trawls are combined as one in this analysis.

Table c. Mean catch rates, with standard deviation, for the trawl hauls shown in Table 1.

Depth (m)	Nazareth		Saya de Malha		Seychelles	
	Mean kg h ⁻¹	SD	Mean kg h ⁻¹	SD	Mean kg h ⁻¹	SD
30-50	62		123	45		
50-70	142	155			338	314
70-100			73			
100-200			51	15		
200-300+	41	23	22			

* The 3rd (5 min) and 4th (22 min) trawls are combined as one in this analysis.

The trawl station data with preliminary species lists are included as Appendix xx to this report. The highest diversity was recorded in the last two trawls of the survey, with 60 and 64 fish species listed. This was remarkable given that the first four trawls on the Seychelles bank at similar depths yielded only 13 to 28 species, while no other trawls during the survey yielded 40 species or more.

These biodiversity data indicate that, although some idea has been obtained of the distribution and abundance of commoner species in the Mascarene area, the survey must be regarded as only providing a preliminary impression of the diversity and abundance of the fishes in the area. The data will be compared with the species list provided in the report on the 1978 survey by the previous RV Dr Fridtjof Nansen, but this will require some research into the literature to take account of taxonomic progress since that survey

In addition to the demersal trawls, six pelagic trawls were conducted at night to investigate the composition of concentrations of organisms revealed in the acoustic survey. Four trawls were in midwater at various depths, while two trawls were carried out in the surface layer. The pelagic trawl catches were investigated and samples collected of the various species in the catch.

Crustaceans and squid in the catches were also recorded. Table 3, sorted by family in alphabetical order). The final species list is uncertain because of a number of informal names used in early trawls that may result in duplication, while close study of the pelagic fauna will undoubtedly increase the number of species, particularly the difficult to distinguish Myctophidae, in the catch.

OTHER OBSERVATIONS

5.1 Marine Mammals

SUMMARY AND CONCLUSIONS

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