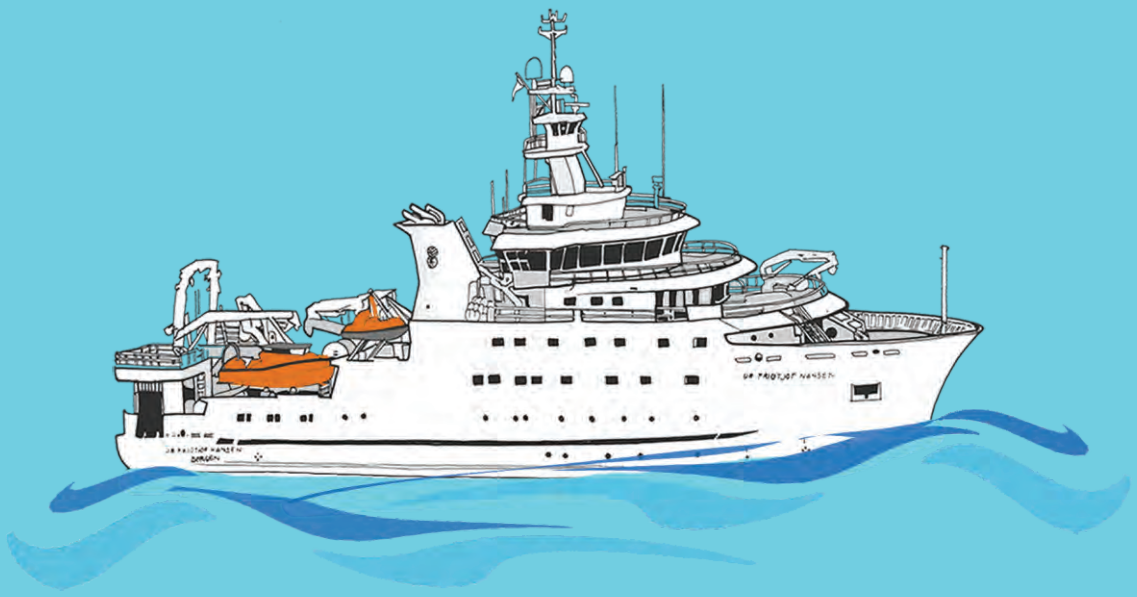
NORAD-FAO PROGRAMME
GCP/GLO/690/NOR

CRUISE REPORTS *DR FRIDTJOF NANSEN*
EAF-Nansen/CR/2018/6



REGIONAL RESOURCES AND ECOSYSTEM SURVEY IN THE INDIAN OCEAN

LEG 2.1. CHARACTERIZING ECOSYSTEMS AND MORPHOLOGY OF THE SAYA DE MALHA BANK AND NAZARETH BANK

Seychelles and Mauritius

3 May – 4 June 2018

Ministry of Defence and Rodrigues, Mauritius
Ministry of Housing and Lands, Mauritius
Mauritius Oceanography Institute, Mauritius
P.P. Shirshov Institute of Oceanology, Russia
University of the Western Cape, South Africa
Seychelles National Parks Authority, Seychelles
Seychelles Fishing Authority, Seychelles
University of Seychelles, Seychelles
University of Mauritius, Mauritius
Albion Fisheries Research Centre, Mauritius

Institute of Marine Research
Bergen, Norway

The EAF-Nansen Programme

The EAF-Nansen Programme "Supporting the application of the Ecosystem Approach to Fisheries Management considering climate and pollution impacts" (GCP/GLO/690/NOR) aims to further strengthen the knowledge base and the overall institutional capacity for the implementation of the Ecosystem Approach to Fisheries (EAF) in developing countries, with additional attention to the impact of climate variability and change, pollution and other anthropogenic stressors.

The programme, that started implementation in May 2017, builds on earlier phases, and is governed by an agreement between the Food and Agriculture Organization of the United Nations (FAO), the Institute of Marine Research (IMR), Norway and the Norwegian Agency for Development Cooperation (Norad). The three pillars of the new programme area: Science, Fisheries management, and Capacity development. A new state of the art research vessel, *Dr Fridtjof Nansen* is an integral part of the programme. A science plan, covering 11 research themes, guides the programme scientific work.

The programme works in partnership with countries, regional organizations, other UN agencies as well as other partner projects and institutions.

Le Programme EAF-Nansen

Le Programme EAF-Nansen "Appuyer la mise en œuvre de l'approche écosystémique de la gestion des pêches en tenant compte des impacts du climat et de la pollution" (GCP/GLO/690/NOR), vise à renforcer la base de connaissances et les capacités institutionnelles pour la mise en œuvre de l'approche écosystémique des pêches (AEP) dans les pays en développement, en accordant une attention particulière aux effets de la variabilité et du changement climatique, de la pollution et d'autres facteurs de stress anthropiques.

Le programme, qui a débuté en mai 2017, s'appuie sur les phases précédentes et est régi par un protocole d'accord entre l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO), l'Institut de recherche marine (IMR) de Norvège et l'Agence norvégienne de Coopération au développement (Norad). Les trois piliers du nouveau programme sont : la science, l'aménagement des pêches et le développement des capacités. Un navire de recherche à la pointe de la technologie, le nouveau *Dr Fridtjof Nansen*, fait partie intégrante du programme. Un plan scientifique, couvrant 11 thèmes de recherche, guide les travaux scientifiques du programme.

Le programme travaille en partenariat avec les pays, les organisations régionales, d'autres agences des Nations Unies ainsi que d'autres projets et institutions partenaires.

Bergstad, O.A., Bissessur, D., Sauba, K., Rama, J., Coopen, P., Oozeeraully, Y., Seeboruth, S., Audit-Manna, A., Nicolas, A., Reetoo, N., Tabachnick, K., Kuyper, D., Gendron, G., Hollanda, S., Melanie, R., Souffre, A., Harlay, J., Bhagooli, R., Soondur, M., Ramah, S, Caussy, L, Ensrud, T.M., Olsen, M., Høines, Å.S., 2018. Regional Resources and Ecosystem Survey in the Indian Ocean, Leg 2.1. Characterizing ecosystems and morphology of the Saya de Malha Bank and Nazareth Bank, 3 May - 4 June 2018. NORAD-FAO PROGRAMME GCP/GLO/690/NOR, CRUISE REPORTS *DR FRIDTJOF NANSEN*, EAF-Nansen/CR/2018/6.

CRUISE REPORTS *DR FRIDTJOF NANSEN*

SURVEY OF REGIONAL RESOURCES AND ECOSYSTEM OF THE INDIAN OCEAN

LEG 2.1: CHARACTERIZING ECOSYSTEMS AND MORPHOLOGY OF THE SAYA DE MALHA BANK AND NAZARETH BANK

Seychelles and Mauritius

3 May – 3 June 2018

By

OA Bergstad[1], D Bissessur[2], K Sauba[2], J Rama[2], P Coopen[2], Y Oozeeraully[2], S Seeboruth[3], A Audit-Manna[4], A Nicolas[4], N Reetoo[4], K Tabachnick[5], D Kuyper[6], G Gendron[7], S Hollanda[8], R Melanie[8], A Souffre[8], J Harlay[9], R Bhagooli[10], M. Soondur[10], S Ramah[11], L Caussy[11], TM Ensrud[1], M Olsen[1], ÅS Høines[1].

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Institute of Marine Research
Bergen, 2020

CONTENTS

EXECUTIVE SUMMARY

The cruise described in this report originated as a proposal entitled "Characterizing the Marine Ecosystem and Morphology of the Saya de Malha Bank" submitted to the EAF-Nansen Programme in February 2017 by the Department for Continental Shelf, Maritime Zones Administration & Exploration, Prime Minister's Office, Mauritius. To that was added limited studies within the Mauritius EEZ in the northwestern corner of the Saya de Malha, and on the Nazareth Bank.

The overriding general aim of this present research vessel (R/V) *Dr Fridtjof Nansen* cruise was to characterize the marine ecosystem and morphology of the Saya de Malha Bank. An additional task, to be included should time be available, was to investigate a specific subarea of Nazareth Bank upon request from Mauritius.

Sampling using the full complement of technologies of the R/V *Dr Fridtjof Nansen* facilitated investigations of the following aspects:

- Geomorphology, benthic habitats and benthos (Multibeam sounder mapping in subareas and along pre-determined transects, habitat and benthos studies emphasising sandy subareas and subareas with macroalgae, seagrass, and coral)
- Fish and crustacean resources (density mapping with acoustic and optical technologies, midwater trawl sampling)
- Physical and chemical oceanography, including current measurements.

In addition, sampling in support of studies with wider geographical scope conducted on other surveys under the EAF-Nansen Programme were included, e.g. tissue sampling for genetics, contaminants, mammal recording, recording of microplastics and litter.

The cruise report contains provisional results pending results of ongoing post-processing of data and material to be published in the future.

CHAPTER 1. INTRODUCTION

1.1 Objectives

In March 2011, the United Nations Commission on the Limits of the Continental Shelf (CLCS) adopted recommendations confirming the entitlement of the Republic of the Seychelles and the Republic of Mauritius to an area of extended continental shelf, as contained in a joint submission by the two States in respect of the Mascarene Plateau region (CLCS, 2011). Mauritius and Seychelles have in 2012 agreed to the establishment of Joint Management Area (JMA) in which the two States exercise sovereign rights jointly for the purposes of exploring the continental shelf and exploiting its natural resources.

There are significant economic opportunities for both Mauritius and Seychelles from future development in the JMA. Both States agree that these opportunities need to be realized in a sustainable and strategic manner. In order to better understand the potential marine resources and sensitivity of the area, it is essential to conduct marine scientific research to survey the oceanography and biota of both the water column and underlying seafloor.

The cruise described in this report originated as a proposal entitled "Characterizing the Marine Ecosystem and Morphology of the Saya de Malha Bank" submitted to the EAF-Nansen Programme in February 2017 by the Department for Continental Shelf, Maritime Zones Administration & Exploration, Prime Minister's Office, Mauritius. To that was added limited studies within the Mauritius EEZ in the northwestern corner of the Saya de Malha, and on the Nazareth Bank.

The overriding general aim of this present R/V *Dr Fridtjof Nansen* cruise was to characterize the marine ecosystem and morphology of the Saya de Malha Bank. An additional task, to be included should time be available, was to investigate a specific subarea of Nazareth Bank upon request from Mauritius. The objectives were further described in an agreed Sailing Order appended to the MoUs between the FAO and the Joint Management Area Commission, and the FAO and Mauritius.

Sampling using the full complement of technologies of the R/V *Dr Fridtjof Nansen* would facilitate investigations of the following aspects:

- Geomorphology, benthic habitats and benthos (Multibeam sounder mapping in subareas and along pre-determined transects, habitat and benthos studies emphasising sandy subareas and subareas with macroalgae, seagrass, and coral)
- Fish and crustacean resources (density mapping with acoustic and optical technologies, emphasising commercial and toxic species)
- Physical and chemical oceanography, including current measurements (onboard measurements)

In addition, sampling in support of studies with wider geographical scope conducted on other surveys under the EAF-Nansen Programme would be included, e.g. tissue sampling for genetics, contaminants, mammal recording, recording of microplastics and litter.

Key Questions to be addressed were the following:

1. Geomorphology, benthic habitats and benthos.

Coarse maps of the bathymetry and substrates were generated from previous surveys. The technologies available on R/V *Dr Fridtjof Nansen* facilitate more detailed and accurate mapping that will be useful as baselines for further scientific studies and assessments related to industrial developments. The approaches would be to use single- and multibeam acoustics and the sub-bottom profiler to map geomorphology in selected subareas and along pre-determined transects, and use the video-assisted multisampler (VAMS) to collect grab samples and HD videos for benthos studies. Benthos studies will be focused on soft-bottom substrates as well as along upper slopes where coral cover is expected. The minimum depths would be 10 m and maximum around 2000 m.

2. Fish and crustacean resources.

The level of knowledge of pelagic and benthic fisheries resources (actual and potential) is unsatisfactory in the Joint Management Area, and basic identification and density mapping is needed along with studies of key species-specific biological traits and population structure. To enhance knowledge on the aspects, the approach was to:

- collect information on the abundance and distribution (also by size) of main pelagic species using acoustic methods and midwater trawling.
- collect information on the abundance and distribution of the main demersal species using video sampling and, if necessary, bottom trawl sampling.
- collect data on the species composition of fishes and habitat association based on video observations and trawl sampling.
- collect voucher specimens, morphometric data and tissue samples for systematics of a wide range of species.
- collect tissue samples for population genetics studies of fishes regarded as harvestable resources.
- collect for targeted harvestable fish species, data for studying the biology (size, age, sex, maturity data) and the population structure (size- and age-structure). This will require sampling of otoliths for age determination.

3. Physical, chemical and biological oceanography.

The environmental setting of the biota, including harvestable resources, was poorly known and the aim was to characterize the physical and chemical properties, as well as pelagic primary productivity, of the waters in the survey area. Data collected in the study area would feed into databases for the Indian Ocean as a whole. The approach would be:

- Along transects and at pre-determined locations record physico-chemical environmental conditions (temperature, salinity, oxygen, chlorophyll, nutrients and pH).
- To record current profiles and characterize circulation patterns based on the ship’s ADCPs (acoustic-doppler current profilers).

4. Occurrence of large epipelagic fish (tuna and tuna-like species, sharks), mammals, turtles and seabirds.

The area is a habitat for a range of large animals, including mammals and birds. These would be recorded when sighted and sightings would be recorded in standardized manners.

5. Record occurrence of debris (litter on the surface and seabed).

This is a standard task on all DFN surveys and would be carried out by recording surface litter as well as litter occurring in trawl samples and on videos at the seabed.

6. Record occurrence of microplastics.

The cruise was an integrated element of the three-pillar science plan of the EAF-Nansen Programme and would serve many of the themes under that plan (Figure 1.1):

- Related to Theme 1: Biology of main target resources, including maturity information by size and age, and mortality estimates.
- Related to Theme 2: First estimates of abundance and distribution of main pelagic resources. Ecology of main pelagic species (occurrence in relation to oceanographic conditions and geomorphology).
- Related to Theme 3: Records of unexploited pelagic resources in all depth zones.
- Related to Theme 4: Visual census and trawl samples of demersal resources, the assemblages they are members of, and their habitats.
- Related to Theme 6: Abundance and occurrence of marine debris and microplastics in the pelagic zones and on the seabed.
- Related to Theme 7: Enhanced baseline information on bathymetry, geomorphology and distribution and quality of benthic habitats and their biota.
- Related to Theme 8: Tissue samples of fish and harvested crustaceans are to be collected for post-cruise analyses of contaminants relevant for assessments of ‘food safety’.
- Related to Themes 9-11: New information on physical and chemical oceanographic conditions, including pH measurements. Enhanced information on primary productivity in pelagic zone from an area where *in situ* observations are scarce. Baseline information on habitats and communities in the pelagic and demersal zones, hence an improved basis for characterizing ecosystem structure and deriving conceptual system models for future studies.

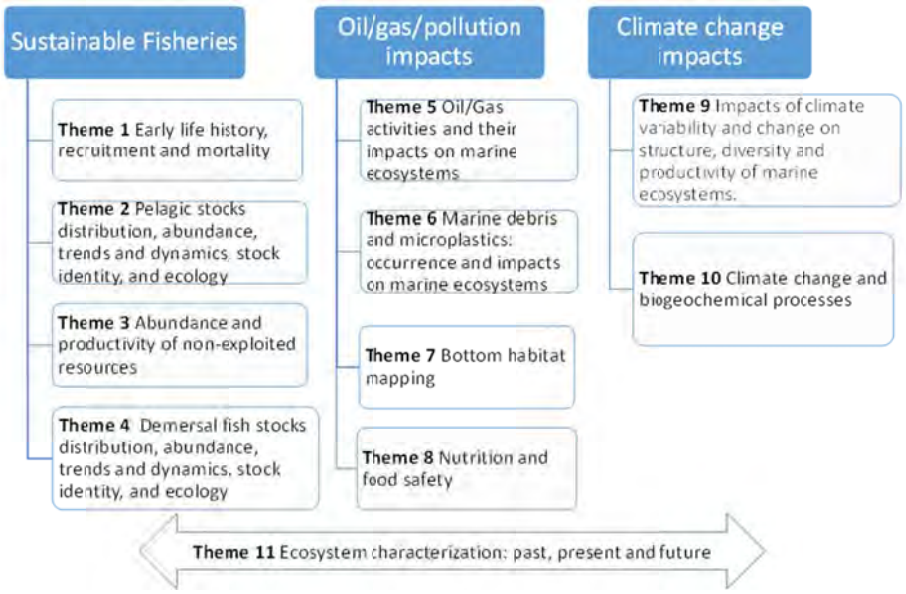

Figure 1.1. Main pillars and research themes of the EAF-Nansen Programme.

The cruise thus had a dual purpose of serving the regional interests as requested, and contributing to the EAF-Nansen Programme science activity. Outcomes would be derived by co-operative operations at sea and in post-cruise activities involving participating parties and scientists.

1.2 Participation

The scientific party, led by the principal investigator Dr Odd Aksel Bergstad from Norway and co-lead Dr Dass Bissessur from Mauritius, comprised appointed scientists from Mauritius and the Seychelles, as well as guest scientists from the Russian Federation and South Africa (Table 1.1). In addition, Norway provided a complement of scientists and technicians, including an engineer from the engineering firm Argus Remote Systems ASA, and a trainee from the University of Bergen.

The non-Norwegian contingent was split into seven teams with specific responsibilities for overseeing sampling and reporting on specific topics:

1: Physical oceanography
2: Geomorphology and benthic substrates
3: Chemical oceanography and phytoplankton
4: Zooplankton
5: Pelagic and demersal fish
6: Benthos
7: Mammals, birds and turtles

Many participants had multiple interests and participated in the work of several teams, whenever possible.

The Norwegian contingent conducted training and supported all teams, and dedicated engineers operated specific instruments (e.g. the vehicle used for video recording and benthic sampling).

Table 1.1 Scientific party on the Cruise 2018406 of the R/V *Dr Fridtjof Nansen* (for details on affiliations, see authorship list on front page).

Participant	**Role and team membership**	**Institution**	**Country**
Bergstad, Odd Aksel	Principal investigator, cruise leader	IMR	Norway
Bissessur, Dass	Co-lead, Team 2	CSMZAE	MRU
Coopen, Priscilla	Team 1	CSMZAE	MRU
Oozeeraully, Yuneeda	Team 1	CSMZAE	MRU
Rama, Jemima	Team 1	CSMZA	MRU
Sauba, Keshav	Team 3	CSMZAE	MRU
Seeboruth, Sattiabaryth	Team 2	MHL (Hydrogr. Unit)	MRU
Nicolas, Arnaud	Team 2	MOI	MRU
Audit-Manna, Anishta	Team 5	MOI	MRU
Reetoo, Namrata	Team 6	MOI	MRU
Ramah, Sundy	Team 6	MOE – Fisheries Div	MRU
Caussy, Luvna	Team 5	MOE – Fisheries Div	MRU
Bhagooli, Ranjeet	Team 4	UoM	MRU
Soondur, Mouneshwar	Team 3	UoM	MRU
Melanie, Rodney	Tem 5 and 6	SFA	SEY
Hollanda, Stephanie	Team 5	SFA	SEY
Souffre, Andrew	Team 1	SFA	SEY
Harlay, Jerome	Team 3	UNISEY	SEY
Gendron, Gilberte	Team 6 and 7	SNPA	SEY
Kuyper, Drikus	Team 4	UWC	South Africa
Tabachnick, Konstantin	Team 6	Shirshov Inst. Oceanology	Russia
Høines, Åge Sigurd	Scientist, acoustics	IMR	Norway
Ensrud, Tor Magne	Technician, biology and sampling	IMR	Norway
Olsen, Magne	Technician, biology and sampling	IMR	Norway
Vågenes, Jan Arne	Electronics and ROV engineer	IMR	Norway
Landa, Geir	Electronics engineer	IMR	Norway
Nygård Larsen, Sindre	Electronics and ROV engineer	IMR	Norway

Participant	Role and team membership	Institution	Country
Loven, Kenneth	ROV engineer	Argus Remote Systems ASA	Norway
Vågenes, Patrick	ROV Technician, trainee	Univ. Bergen	Norway

1.3 Narrative

Following a pre-survey meeting on the 2nd of May, embarkation of the scientific party on the 3rd of May, and an official morning event on the 4th of May, the vessel departed from Victoria, the Seychelles, on the 4th of May at 13:00 hours local time (UTC+4 hours). The course was set for the northwestern corner of the Saya de Malha Bank, and instruments were switched to logging mode when leaving the Seychelles EEZ and entering international waters on 6th of May.

With few adjustments, the subsequent part of the cruise was conducted in accordance with the plan described in the Sailing Order and with the details agreed upon in the pre-survey meeting. The ship's trajectory and positions of fixed study locations ('superstations') for the period 6-14 May is shown on Figure 1.2 and 1.3. This trajectory, referred to as Leg I, represents the survey requested by the regional authority, expanded in the east-west direction to ensure sampling off the slopes of the bank. Pelagic trawl stations were allocated as shown on Figure 1.2.

In the subsequent period (15-26 May) referred to as Leg II, the work focused on selected sub-areas of the Saya de Malha Bank and adjacent seamounts. In these sub-areas, more intensive sampling of video data was carried out along transects spanning wider depth ranges from 20-1000 m. The video-recorded subareas 33-43, trawl stations and extra oceanography and zooplankton stations taken during that period are shown in Figure 1.4.

On 26th of May, the vessel set course for the Nazareth Bank in the EEZ of Mauritius. The target area on that bank was the southeastern corner, where an acoustic survey, with associated midwater and bottom trawling, was conducted to study fish resources. Underway across the Nazareth Bank from the north, pre-determined locations were studied by video which were mostly shallow areas suspected to have seagrass.

Sampling was concluded on 31st of May after which the ship sailed to Port Louis, Mauritius, where it arrived on the 2nd of June. Following the offloading of instruments and samples, the scientific party from the Seychelles and most Norwegian scientific crew disembarked on 4th of June. An official event was convened on 4th of June, following which all remaining scientists disembarked the vessel.

Only one day of work was lost due to unfavorable weather. The work was interrupted for half a day on 17th of May, the Constitution Day of Norway, when a celebration was organized for all participants.

1.4 Approach

Leg I:

The ship followed a pre-determined trajectory comprising a set of eight East-West transects across the Saya de Malha Bank, with extensions into the adjacent deep ocean (Figures 1.2 and 1.3). Along the entire trajectory, the following instruments ran and monitored data continuously: thermosalinograph (for surface measurements), the single-beam multifrequency echosounder for studying sound-scatterers in the water column, the multibeam echosounders for bathymetry mapping, the sub-bottom profiler, and the hull-mounted acoustic doppler current profiler (ADCP). Team 7 carried out bird, mamma and turtle observations whenever the weather permitted, and the ship was underway between stations.

At pre-selected locations, either of three types of "Superstations" (Table 1.2) with a set of standard operations were carried out: 1) Benthos station, 2) Plankton station, and 3) Hydrographic station. The operations included the following:

> Benthos stations: a CTD cast from surface to near-bottom depth, a deployment of the Video-Assisted MultiSampler (VAMS) including a standard inspection of the seabed by video and 1-4 grab samples of surface sediments (when possible).
>
> Plankton stations: a CTD cast with water sampling for physical, chemical and biological studies, net sampling of phytoplankton and zooplankton, and microplastics. In addition, pump sampling from the surface was conducted at intervals between stations, mainly to supplements surface sampling by plankton nets.
>
> Hydrographic station: a single CTD cast with water sampling.

During Leg I some *ad hoc* midwater trawl tows (Fig. 1.2) were made to obtain fish samples and to identify scattering layers observed on the echograms.

Leg II:

The approach during Leg II deviated somewhat from that outlined in the Sailing Order, primarily because of the increasing familiarity with the geomorphology and conditions of the Saya de Malha generated during Leg I. In the Sailing Order, four large rectangles were selected as potential study areas; however, when having mapped the transects during Leg I, it was decided to reduce the size of such subareas, and rather increase the number. Most sub-areas were placed where bathymetry mapping had already been conducted during Leg I. This reduced the need for time-consuming additional bathymetry mapping, and allowed a greater spread of sampling units along the slopes of the bank and in adjacent locations (seamounts). The result was that nine pre-defined rectangles were visited (Figures 1.4). Three extra locations were added during the cruise, two of which were at seamounts adjacent to the Saya de Malha Bank.

In all the selected locations (working clockwise from the southwest), the VAMS was used in towed transect mode to study substrate, geomorphology, fauna and seabed flora in relation to depth. The operational depth range of the VAMS on this cruise was 20-1000m. The grabs of the vehicle were used for targeted sampling of benthic substrates, animals and plants.

The VAMS could only be used during the day when the dedicated crew was available, and during the night other sampling (additional CTDs, LADCPs, bathymetry mapping, fishing with midwater trawl and pots, zooplankton and pH and alkalinity sampling, Fig. 1.5) and steaming between locations was carried out. The instruments for continuous recording (echosounders, thermosalinograph, ADCP) were run in recording mode throughout Leg II. Bird, mammal and turtle observations continued during most transits between stations. The list of stations is given in Table 1.3.

Nazareth Bank:

The sampling strategy on the Nazareth Bank was determined based on requests from Mauritius, and the emphasis was on fishing areas in the southeastern corner of the bank (Figure 1.6 & 1.7). A grid of transects was laid out for initial bottom mapping and acoustics sampling in that area. It was also requested that the demersal fish fauna would be studied by bottom trawling in that subarea, and stations were located along the grid lines. Other sampling included VAMS studies of probable seagrass locations along the survey line from Saya de Malha to the southeastern Nazareth Bank, and VAMS stations and transects on the plateau in the southeast and off the eastern slope. Stations are listed in Table 1.4.

The instruments for continuous recording (echosounders, thermosalinograph, ADCP) were run in recording mode throughout the Nazareth Bank studies. Bird, mammal and turtle observations continued during transits.

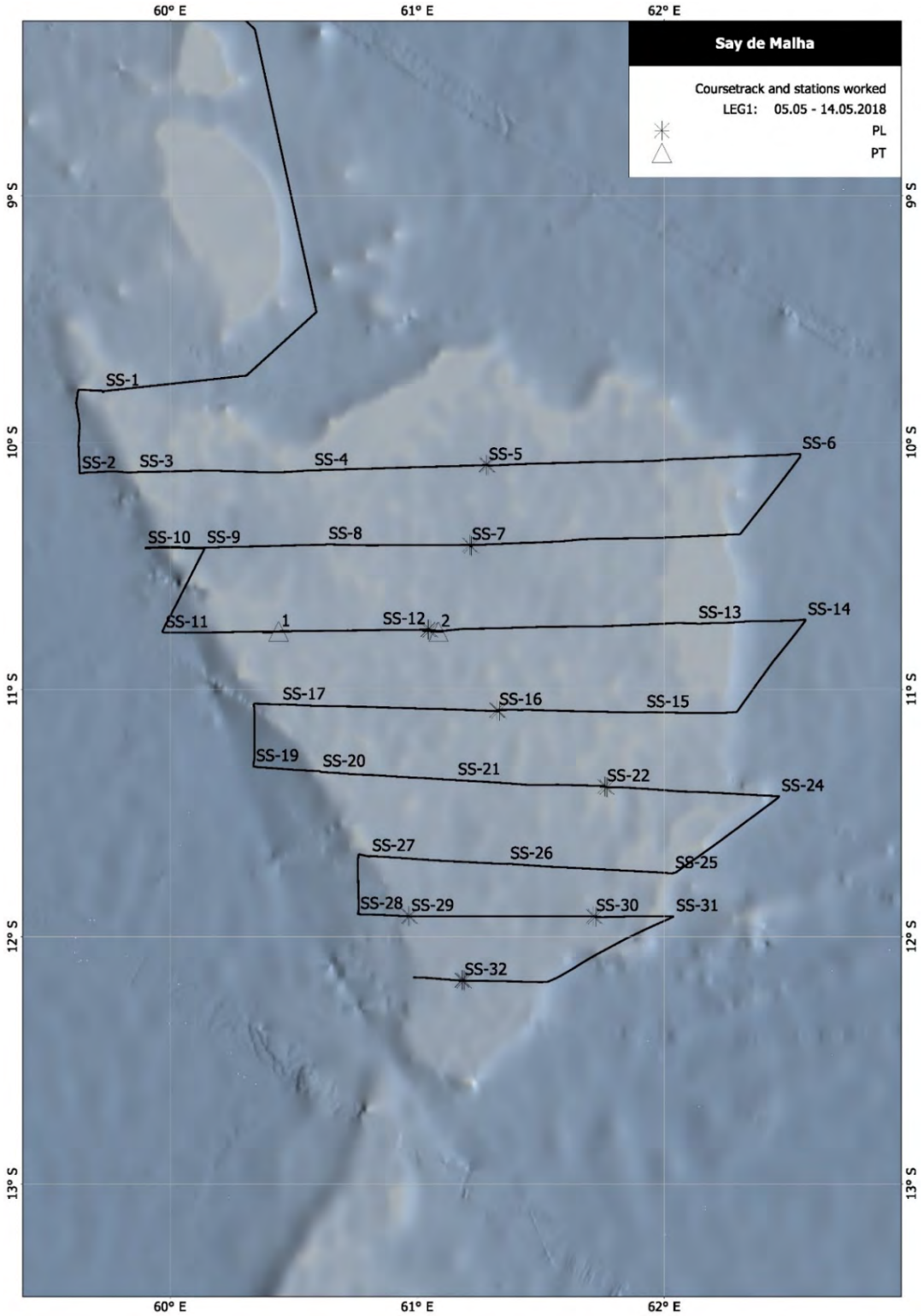

Figure 1.2. Leg I. Trajectory of the vessel and 'Superstations' (SSx). PL-plankton stations, PT-midwater (pelagic) trawl stations. Trawl stations were not associated with pre-determined superstations. See details for trawl stations in Annex III.

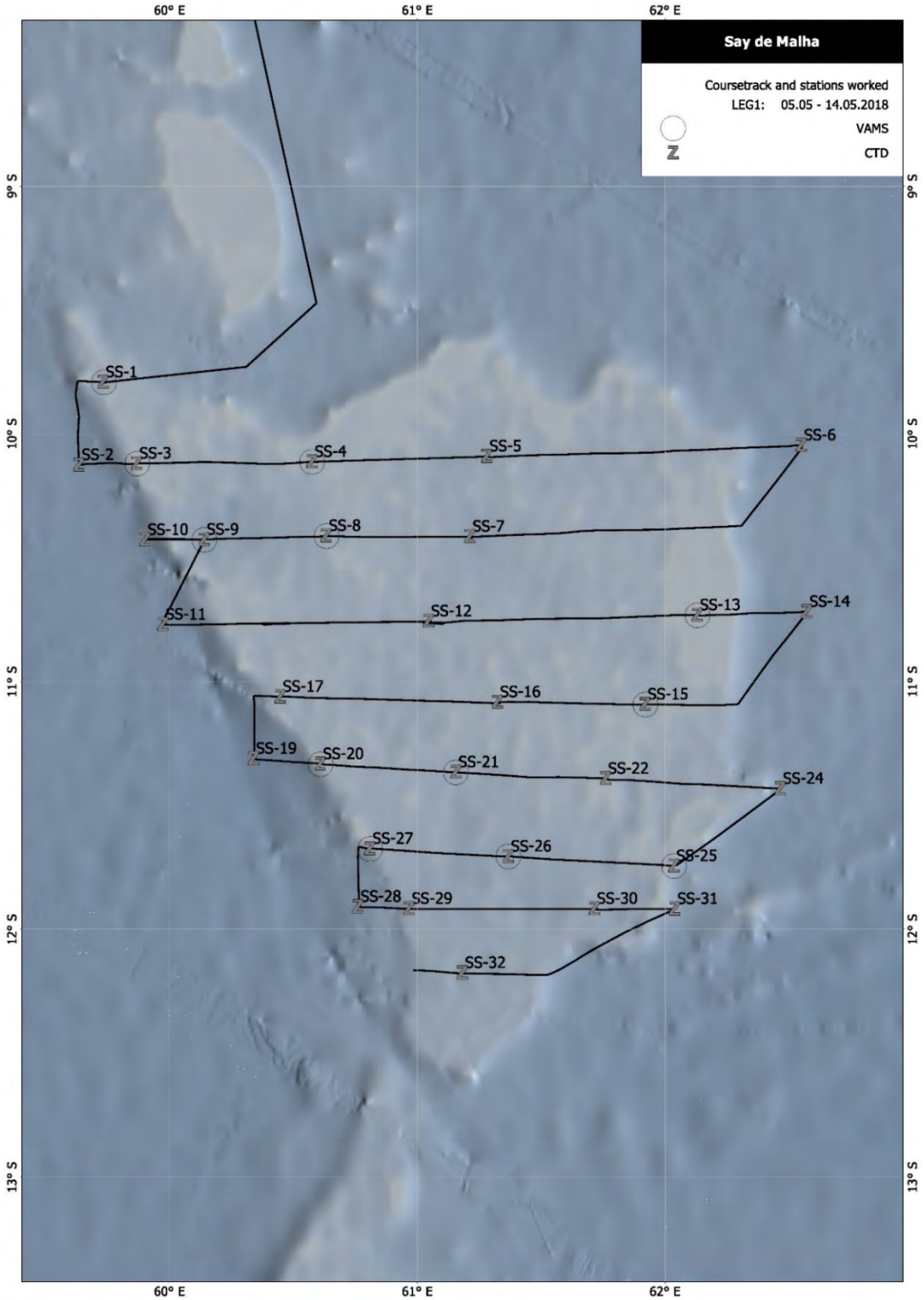

Figure 1.3. Leg I. Trajectory of the vessel and 'Superstations' (SSx). VAMS- benthic station with video and grabs conducted with the video-assisted multisampler, CTD- hydrography station with water sampling. See station details for VAMS stations in Table 1.2.

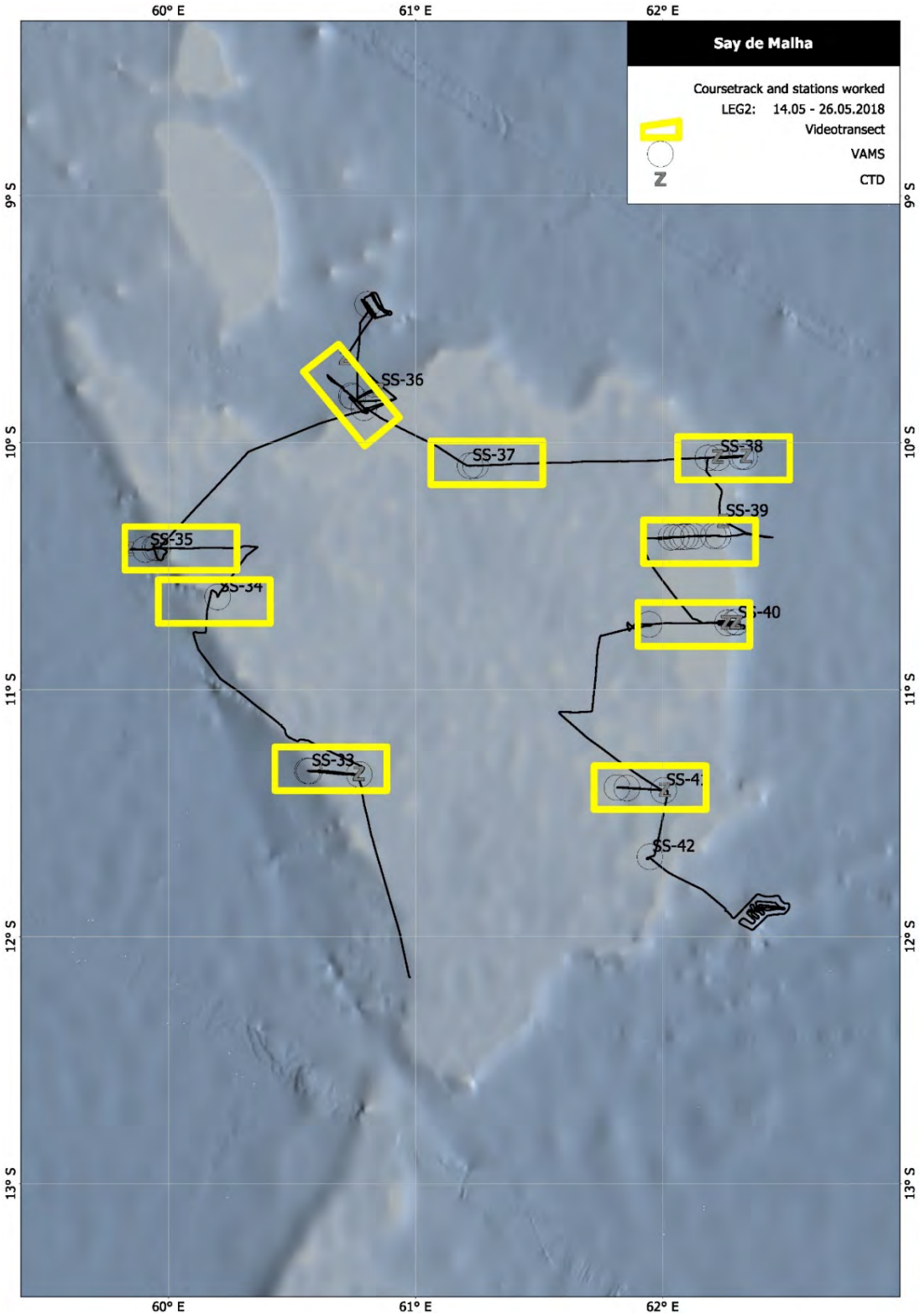

Figure 1.4. Leg II. Trajectory of the vessel and 'Superstations' (SSx). Yellow sub-areas were selected for studies using multiple dives with the video-assisted multisampler (VAMS). CTD – hydrography stations, some also with current measurements by LADCP. See station details in Table 1.3.

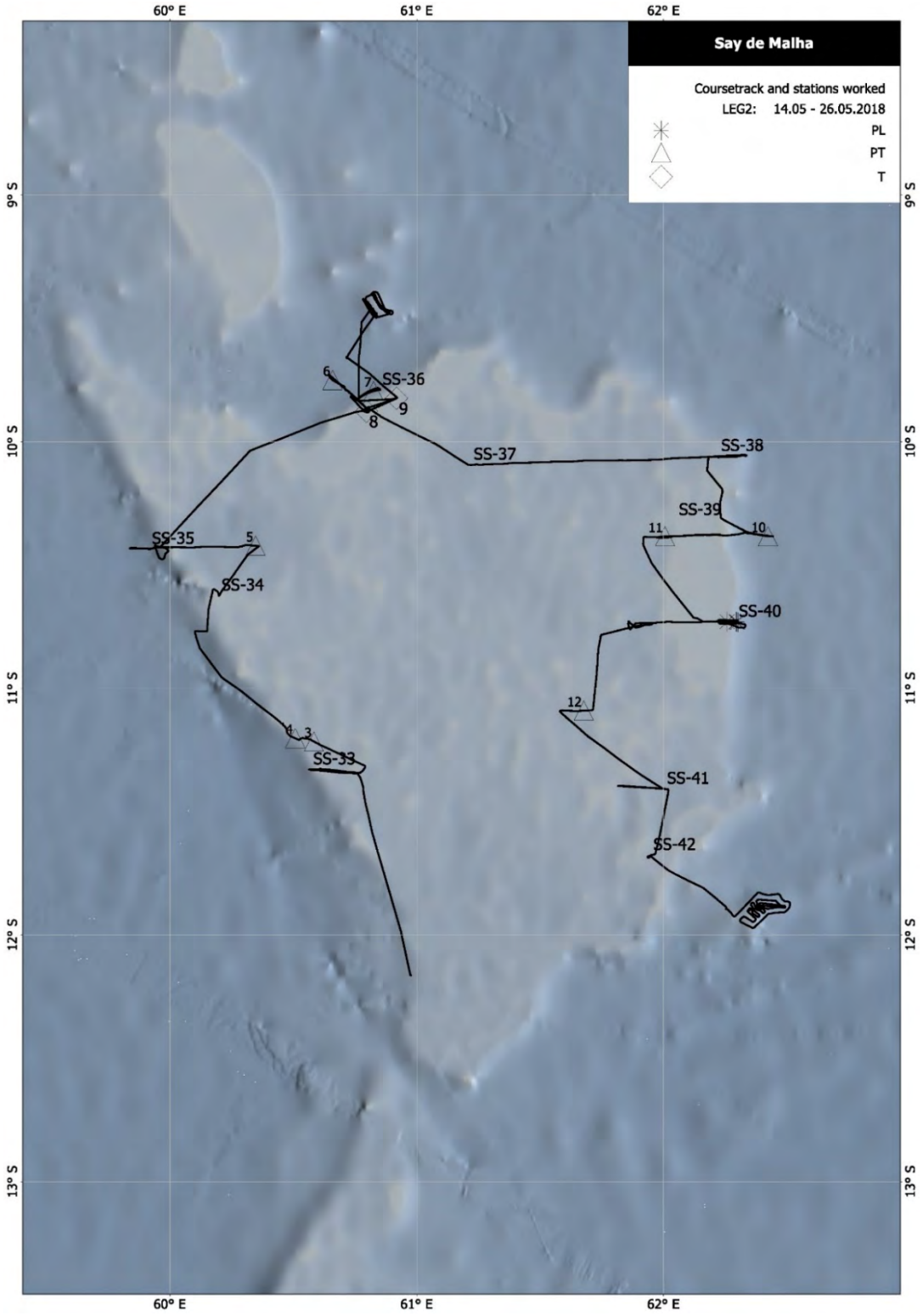

Figure 1.5. Leg II. Trajectory of the vessel and 'Superstations' (SSx). PL-plankton stations, PT-midwater (pelagic) trawl stations (3-7 & 10-12), T-pot sets (St 8&9). These plankton, trawl and pot stations were additional and not associated with pre-determined superstations. See station details for trawls in Annex III.

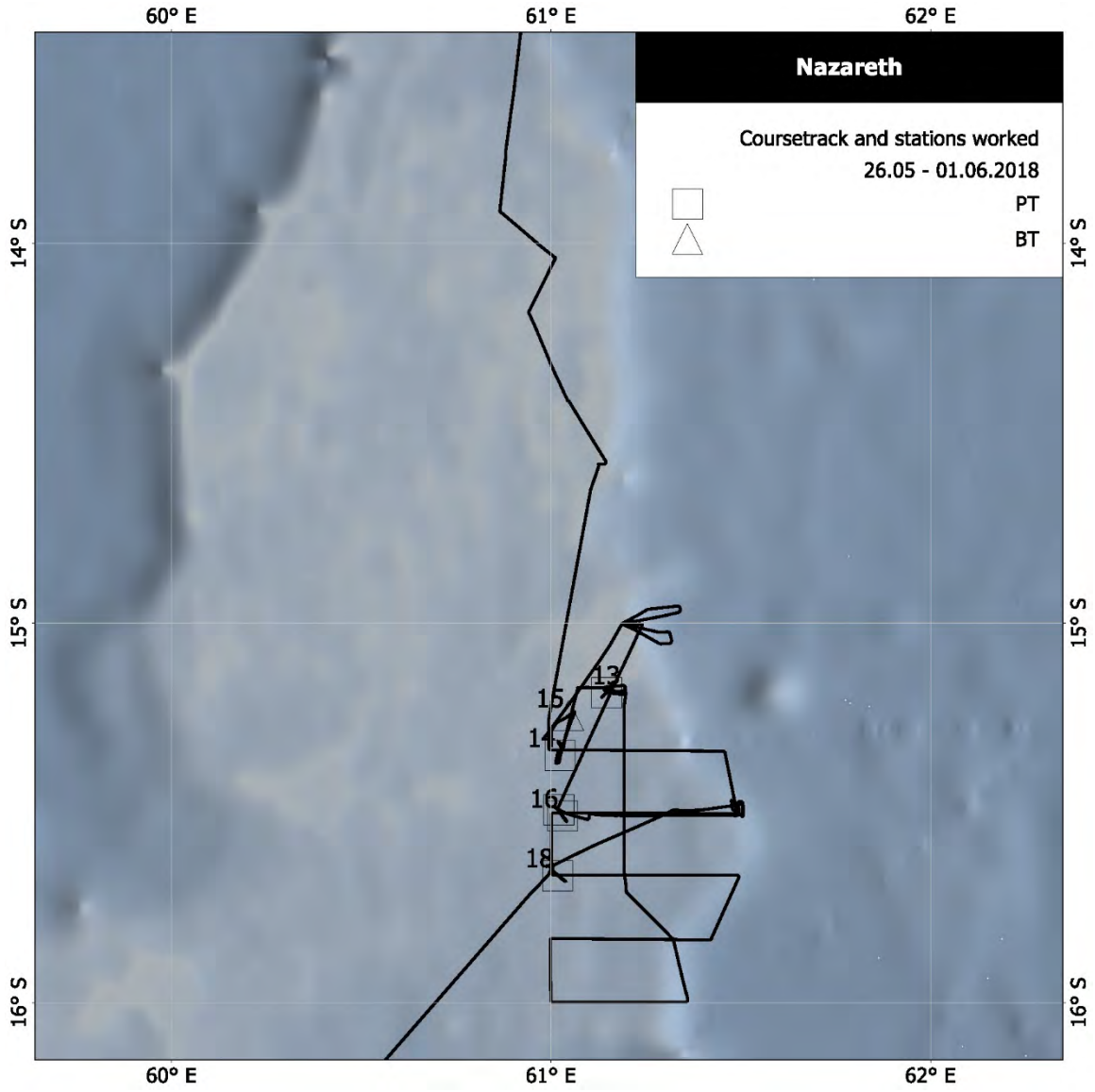

Figure 1.6. Leg II. Trajectory of the vessel on the Nazareth Bank with ‘Superstations’ (SSx). PT-pelagic trawls, BT-bottom trawl stations. See station details in Annex III.

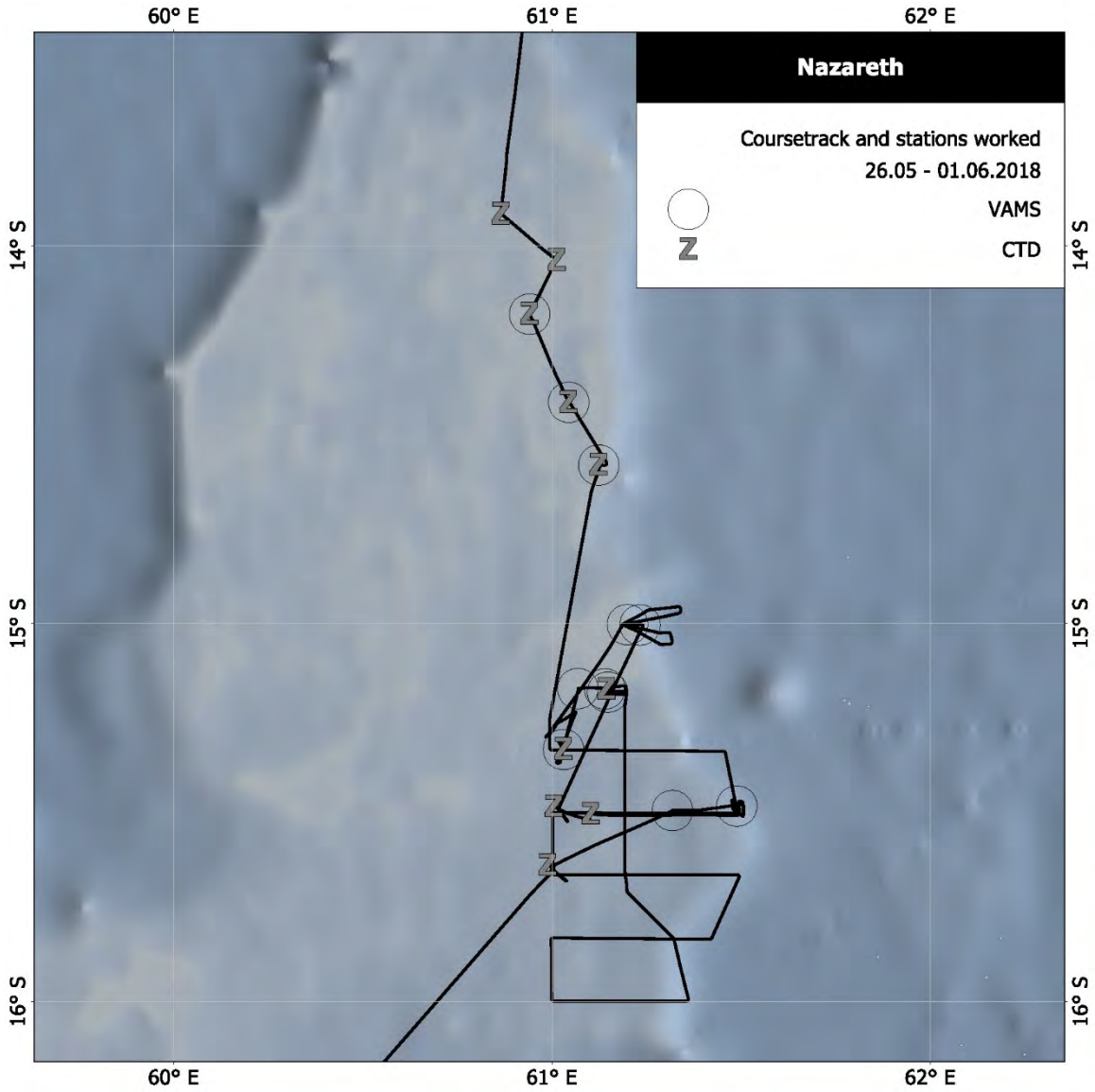

Figure 1.7. Trajectory of the vessel on the Nazareth Bank, with 'Superstations' (SSx). VAMS- video assisted benthic sampler station, CTD – hydrography station, vertical CTD cast. See station details in Table 1.4.

Table 1.2. Leg I. Stations list and numbers. Superstation locations were pre-determined (see SO). Depth ranges are from vessel soundings and may deviate slightly from depth on video overlays.

Super-station	Date	Bottom depth, m	VAMS Dive Number	Dive- time, VAMS, mins	Sediment collected	CTD St.	Water collected	Plankton Station Numbers
1	07.05.2018	135	1	10	x	391		
2	07.05.2018	2347				392	x	
3	08.05.2018	79	2	42	x	393		
4	08.05.2018	31	3	33	x	394		
5	08.05.2018	28				395		1-4
6	09.05.2018	2172				396	x	
7	09.05.2018	68				397		5-9
8	09.05.2018	60	4	66	x	398		
9	10.05.2018	51	5	86	x	400		
10	10.05.2018	1200				399	x	
11	10.05.2018	2129				401	x	
12	10.05.2018	127				402		10-14
13	11.05.2018	29	6	37	x	403		
14	11.05.2018	2123				404	x	
15	11.05.2018	56	7	62	x	405		
16	11.05.2018	120				406		15-19
17	12.05.2018	62				407	x	
18	Orig. loc., not sampled							
19	12.05.2018					408	x	
20	12.05.2018	198	8	50	x	409		
21	12.05.2018	158	9	62	x	410		
22	12.05.2018	106				411		20-24
23	Orig. loc., not sampled							
24	13.05.2018	2068				412	x	
25	13.05.2018	288	10	46	x	413		
26	13.05.2018	250	11	40	x	414		
27	13.05.2018	266	12	42	x	415		
28	13.05.2018	1309				416	x	
29	13.05.2018	326				417		25-29
30	14.05.2018	264				418		30-34
31	14.05.2018	2085				419	x	
32	14.05.2018	285				420		35-39

Table 1.3 Leg II. Stations list. Sediment samples: c=sampled for chemical analyses, b-biol. sample only. Depth ranges are from vessel soundings and may deviate slightly from depths on video overlays.

Super-station	Date	Depth, m	VAMS & Grab st.	Dive duration, mins	Sediment collected	CTD St.	Zoopl. St.	Additional information
33.1	15.05.2018	500-250	13	98				
33.2	15.05.2018	780-500	14	96				
33.3	15.05.2018	81	15	20		421		CTD at 72m
34.1	16.05.2018	750-100	17					750-500m, 400, 300, 300, 200, 100m
34.2	16.05.2018	43	18					
35.1	17.05.2018	1000-750	19	162		422		CTD and LADCP 2000m
35.2	17.05.2018	500	20					
35.3	18.05.2018	400-100	21					
36.1	18.05.2018	1000-850	22					
36.2	19.05.2018	850-38	23		c, b	423		CTD at 110m
	19.05.2018	25			b	424		No VAMS, 3 grabs only. CTD at 1711m
36.3	20.05.2018	23	24	61				
37.1	20.05.2018	42-33	25	63				
37.2	20.05.2018	30	26	60	b			
						425		*Ad hoc* CTD station, 192m
38.1	21.05.2018	1000	27			426		CTD at 1418m
38.2	21.05.2018	500-200	28	109				
38.3	21.05.2018	193-35	29	186				
38.4	21.05.2018	23	30	37	b			
39.1	22.05.2018	67	31	12		427		CTD at 215m
39.2	22.05.2018	53-49	32	64				
39.3	22.05.2018	43	33	16				
39.4	22.05.2018	33	34	38				
39.5	22.05.2018	23	35	54				
39.6	22.05.2018	36	36	51				
39.7	22.05.2018	58,5	37	67	b			
						428	40-43	*Ad hoc* CTD at 506m and two zoopl. stations
40.1	23.05.2018	1000-400	38	130		429		CTD at 1008m
40.2	23.05.2018	412-200	39	81				
40.3	23.05.2018	144-67	40	164	c, b			
						430	44-45	*Ad hoc* CTD at 92m and zoopl. station
40.4	24.05.2018	51-35	41	115		431	46-47	CTD at 570m
41.1	25.05.2018	260-381	42	72	c, b	432		CTD at 380m, «Nansen sinkhole»
41.2	25.05.2018	106	43	25				
41.3	25.05.2018	143	44	28				
42	25.05.2018	46	45	29				
	26.05.2018					433, 434		*Ad hoc* CTD stations at 1719 and 1060m

Table 1.4 Nazareth. Stations list. Sediment samples: c=sampled for chemical analyses, b-biol. sample only. Depth ranges are from vessel soundings and may deviate slightly from depths on video overlays.

Super-station	Date	VAMS & Grab st.	Depth, m	Dive duration, mins	Sediment collected	CTD st.
43	27.05.2018	46	43			435
44	27.05.2018	47	36	52		436
45	27.05.2018	48	60	22		437
46	27.05.2018	49	35	25		438
47	27.05.2018	50	58	31		439
48	29.05.2018	51	215	30		
49	29.05.2018	52	107-173	57	c, b	
50	29.05.2018	53	53	37		440
51	29.05.2018	54	246	26		441
52.1	30.05.2018	55	60-716	339		
52.2	30.05.2018	56	700-1000	91		
	30.05.2018		295			443
53	31.05.2018	57	369-1000	194		
54	31.05.2018	58	269	29		
	31.05.2018		286			444

CHAPTER 2. METHODS

2.1 Underway sampling

2.1.1 Meteorology

Wind direction and speed, air temperature, air pressure, and relative humidity were recorded and logged every 60s with an DNMI (Norwegian Meteorology Institute) weather station.

2.1.2 Sea surface properties

The SBE 21 Seacat Thermosalinograph with the water intake at 4 m depth provided measurements of salinity and temperature every 10s. An attached in-line C3 Turner Design Submersible Fluorometer measured turbidity and chlorophyll-a.

2.1.3 Water Current speed and direction

Two hull-mounted Acoustic Doppler Current Profilers (VMADCP) from RD Instruments ran continuously. The frequency of the VMADCP are 75 and 150 kHz. The system was run in narrow band mode, and data were averaged in 8m vertical bins and stored on files for post-survey processing.

2.2 Fixed hydrographic station sampling

2.2.1 Vertical profiles of temperature, salinity, oxygen, fluorescence, nutrient and currents

Vertical profiles of temperature, salinity, fluorescence, and oxygen were obtained by the Seabird 911 plus probe (CTD). An LADCP attached to the CTD was used to obtain additional current information, at selected stations.

Twelve ten – litre Niskin bottles attached to the CTD rosette were used to collect water at predefined depths. The standard sampling depths were set to: 2000, 1700, 1500, 1200, 1000, 750, 500, 400, 300, 200, 100, 75, 50, 25, and 5m and the standard transects were sampled at 30, 100, 500, 1000 and 2000m.

2.2.2 pH and alkalinity

Seawater samples (250ml) are taken from the Niskin bottles (depth profile) or directly after the thermosalinograph at constant depth of 4m (discrete surface measurements) in borosilicate glass bottles using silicone tubing to reduce air contamination (similar as for oxygen samples) for spectrophotometric pH measurements and total alkalinity through the water column. Samples are collected in parallel and at the same standard depths as for nutrient samples.

pH is determined spectrophotometrically using a Diode array spectrophotometer and a pH sensitive indicator, the sulphonephtalein dye, m-cresol purple in 2 mM solution, as described by Clayton and Byrne, 1993; Chierici *et al*., 1999). Prior to analysis the samples are thermostated to room temperature. Samples are measured in duplicates in a 1cm quartz cuvette. The temperature is measured in the cuvette directly after the sample analysis. Seawater pH is expressed on the seawater total hydrogen ion scale at atmospheric pressure and normalized to a temperature of 25°C (pH_{25}), then computed to *in situ* temperature, salinity and pressure (pH_{tot}).

Total alkalinity was determined in triplicates by automated titration of 50 ml samples by 0.05 M HCl using a Metrohm Titrando 888 and a customized dynamic endpoint titration (DET) program (Metrohm Tiamo). Practically, after an initial addition of 1.700 ml of HCl, the sample is left to equilibrate with ambient carbon dioxide (CO_2) for 15 seconds. The titration re-starts automatically when a stable pH is reached and ends when pH passes the value of 3.2. The total alkalinity (in $\mu mol.l^{-1}$) is determined from the equivalent volume of the titration and converted in $\mu mol.kg_{sw}^{-1}$ using the specific density of seawater at the depth of the point.

All measurements (pH and total alkalinity) are quality checked against Certified Reference Material (CRM 168). The uncertainty was approximately 0.001 in pH and of 3 $\mu mol\ kg^{-1}$ in measurements of total alkalinity. The speciation of the carbonate system is computed (CO2SYS Pelletier *et al.*, 2007) from the two primary variables, total alkalinity and pH_{tot}, using equilibrium constants for the carbonic acid described by (Millero *et al*., 2006). Values of K_{sp} for calcite and aragonite are from Mucci (1983) and that of K_0 from Weiss (1974). Measurements are in compliance with climate quality objective (category 1) for SDG14.3.1 indicators (IOC, 2018; Newton *et al*., 2015).

Sampling of similar data was also made from the water intake to the thermosalinograph.

2.2.3 Nutrient samples

Seawater samples (30 ml) were collected in duplicates from Niskin bottles at pre-defined depths. The samples were in-line filtered through a 0.2 µm syringe filter and kept frozen at -20°C pending analysis. Nutrients will be analyzed at the Mauritius Oceanography Institute (MOI) via automated colorimetric analysis for phosphate, nitrate, nitrite, silicate and ammonia.

In addition, seawater samples were collected for nutrients (nitrate, nitrite, silicate and phosphate) to be analyzed by the Institute of Marine Research. The samples were stored in 20 ml polyethylene bottles, conserved with 0.2 ml chloroform and kept in the dark in a refrigerator.

2.3. Chlorophyll-a, phaeopigments and phytoplankton

Chlorophyll-a was sampled from the water samples collected with the CTD casts.

For chlorophyll-a and phaeopigment measurements, water was collected (263 ml) at the standard depths (as for nutrients). The water was filtered using a 0.7µm filtration system (Munktell glassfiber filters Grade: MGF, vacuum 400 mm Hg) and stored at -20°C until analysis on shore by the Institute of Marine Research. The assay is performed by extraction with 90% acetone followed by centrifugation, and the measurements are taken with a fluorometer (model 10 AU, Turner Designs Inc., Sunnyvale, Ca., USA), according to Welshmeyer (1994) and Jeffrey and Humphrey (1975).

At each plankton-station, qualitative phytoplankton samples were collected with a net (35 cm in diameter and mesh-size of 10 µm), hauled vertically at a speed <0.1 ms-1 from the depth of 30 m to the surface (5 m above bottom at the 30m stations).

2.4 Zooplankton sampling

Zooplankton samples were collected at all plankton stations by vertical tows with a WP2 net (56 cm diameter ring net, mesh size 180 µm). The net was towed vertically at a speed of ~ 0.5 ms^{-1}.

In locations shallower than 30m, a single 25-0m WP2 tow was made. In locations with bottom depth exceeding 30m, two WP2 tows were made:

Bottom depth 100-499 m: First tow – 90-0m, Second tow: 30-0m.

Bottom depth >500m: First tow – 200-0m, Second tow: 30-0m.

Each sample was divided into two equal fractions using a Motoda plankton splitter. One fraction was size-fractioned (2000 microns, 1000 microns and 180 microns) and dried on pre-weighed aluminum dishes and stored for weighing onshore, later to be used for biomass estimation. The other fraction was fixed in 4% borax-buffered seawater solution of formaldehyde for subsequent species identification.

Jellyfish were sampled from pelagic and mesopelagic trawl hauls. When the total catch was considered too big, the entire catch (fish, jellyfish, etc.) was sub-sampled. Thereafter, all jellyfish specimens caught, or representative random samples thereof, if too numerous, were identified to the lowest possible taxon. The jellyfish collected were then measured and weighed.

Jellyfish specimens that were in a good condition were photographed (top and bottom sections). Tissue samples were collected for genetic studies, aimed at determining the species, determining the population structure, and establishing regional and global connectivity. For these genetic studies, a small piece of the oral arm tissue was removed and preserved in 96% ethanol (EtOH) and stored at -20°C. After 24 hours, the 96% EtOH was drained from each sample and then replaced with new 96% EtOH, the sample was then stored at -20°C until analysis.

The rest of the specimen was preserved in 10% formalin. These samples formed part of a greater morphological identification and taxonomic study. In addition to this, jellyfish specimens of a variety of sizes that were in good condition were rinsed with freshwater, individually oven dried at 40°C, and then frozen at -20°C for stable isotope and fatty acid analysis. These specimens were collected to determine the trophic position and ecological role of jellyfish within their ecosystem. All specimens were accompanied by a wet label with identifiable details (station, specimen id, date, species, etc.).

2.5 Fish-eggs and larvae

In all zooplankton samples, all fish eggs and larvae were removed from the total sample, and transferred to vials. The specimens were then preserved in 4% borax buffered formaldehyde.

In addition to collecting specimens from the WP2, eggs and larvae were also obtained from water pumped from the surface and filtered through a plankton net on deck (known as the CUFES sampling). In total, 47 CUFES stations were sampled.

2.6 Microplastics and debris

Microplastics were sampled along the surface waters of eight stations using a Manta Trawl (335µm mesh size). It has a rectangular opening (61cm x 19cm) and fitted with two wings to keep it in balance and at the surface when towing. The Manta Trawl was towed for approximately 15 mins at 1.5 ms^{-1} where prior to and after each trawl the flowmeter reading was recorded. After each trawl the samples were washed into an 180µm sieve and rinsed into a plastic container to be inspected under a dissecting microscope. Samples were inspected for the presence of plastics which were then removed and photographed on a gridded petri dish. All plastics was dried in pre-weighed aluminum trays and stored in a freezer at -20°C. The remaining neuston was rinsed into a 100 ml vial and fixed using 10% formalin for taxonomic studies.

2.7 Bathymetry, geomorphology, seabed substrates and benthos

Seabed mapping (bathymetry) was carried out along pre-determined transects (Leg I), along all transits between stations and in the subareas selected for detailed studies (Leg II and Nazareth Bank). The Multi-Beam Echo Sounders (MBES) ran continuously during the survey except when stopped at sampling stations (see ch. 2.11. for descriptions of instruments). Sub-bottom profiling was also conducted continuously to gather sub-seafloor, imaging of the sediment layers, profile data.

Sediment and other substrate samples were collected with the grabs attached to the Video Assisted Multi Sampler (VAMS) during transect sampling and at selected study sites. The VAMS has five grabs. Habitats will be further characterized following standard procedures using the tethered remotely operated vehicle (ROV) of the VAMS and its HD video camera.

Benthos communities and vegetation data was recorded to facilitate further characterization of observations from video records and grab samples collected at fixed stations (Leg I) and along transects (Leg II) within the rectangular subareas. Initial identification of megabenthos and fish was carried out onboard the vessel, to be followed by land-based post-processing.

Video records were achieved by continuous recording by skilled observers during the VAMS operations. Records were logged with data on time, position, depth, substrate in a dedicated logging software. The videos were revisited after the dives had been completed and overlooked observations were added and erroneous/uncertain records amended.

The VAMS was used in two modes: 1) as a point sampler where the vehicle was deployed at the seabed and only the immediate surroundings explored by the ROV (tether length was approximately 15 m), and 2) in towed mode whereby the vessel towed the vehicle along pre-determined paths at 0.1-0.4 knots while the ROV explored the underlying seabed. Mode 1 was used during Leg I, while most observations during Leg II were made in towed mode along depth transects.

For seagrass habitat and ecology studies in shallow water, the intention was to use small baited video rigs deployed in selected study sites. This plan could not be pursued since the vehicles were not available and since weather never permitted the use of the small craft.

Sampling of benthic fish and invertebrates with pots fitted with cameras was attempted, but did not produce very useful results.

2.8 Observations of seabirds, turtles and mammals

There is no set marine mammal observation methodology for the EAF Nansen program, therefore the dedicated observers chose to adopt the method designed by the UK Joint Nature Conservation Committee (JNCC) and used in surveys related to efforts to minimize the risk of injury and disturbance to marine mammals from seismic surveys.

During hours of daylight, visual observations were undertaken by two dedicated observers when the ship was steaming and there were no benthos and/or fish samples to process. Observers were equipped with binoculars STEINER navigator pro, 7x50 (on the bridge) and Leica Trinovid, 8x42 (on observation platform), and deck forms (Annex I). Whilst on dedicated watch the 'Effort' data forms were filled out. All visual sightings were logged on the 'Sightings' forms. Additional casual watching was undertaken, however, these hours were not recorded as dedicated 'Effort'.

Visual observations were made from either the bridge (approximately 13.5 m above sea level) or the observation platform (approximately 21.5 m above sea level). Visual observations were carried out using regular 360^0 scans using binoculars and visual scanning with the naked eye. Once a cetacean or any other wildlife was sighted observers used binoculars to quantify group numbers, gain accurate species identification, and determine specific behaviours. Photographs using a Nikon D60 Sigma Lens 70-300mm 1:4 – 5.6 were taken when possible to aid in accurate species identification and provide documentation of visual encounters.

2.9 Biological trawl sampling

Midwater and bottom trawls were used for identifying and sampling organisms observed on echograms from the EK80 multifrequency sounder. Some tows with the midwater trawl were blind trawls conducted to determine if any organisms were present in the water column, despite scarce indications obtained from the echograms. Bottom trawling was prohibited on the Saya de Malha Bank, and only permitted in a small area on the Nazareth Bank. Consequently, all trawls on the Saya de Malha Bank were midwater tows.

The trawl catch was sorted to the lowest possible taxonomic level, and numbers and bulk weight of each taxon recorded.

Length measurements were taken for all species with an Electronic Fish Meter (SCANTROL) connected to a customized data acquisition system (Nansis) running on a Windows PC. The total length of each fish is recorded to the nearest 1 cm below (rounding down to nearest cm).

Tissue from the dorsal part of each fish specimen was excised and frozen at -20°C pending further genetic analysis onshore. All specimens collected for tissue sampling were photo-documented. In a few cases (mostly basket trap specimens), fin clips were also taken for genetic analysis.

Sex and maturity stages were recorded for the first randomly selected 20-30 individuals of target species.

Voucher samples and unidentified specimens were frozen for further onshore processing and curation in a dedicated collection in Mauritius.

2.10 Acoustic sampling

2.10.1 Multi-Beam Echo Sounder and Sub-Bottom Profiler

The R/V *Dr Fridtjof Nansen* is equipped with two Multi Beam Echo Sounders (MBES), Kongsberg EM 710 and EM 302, for seabed mapping and a Kongsberg SBP 300 Sub Bottom Profiler for sub-bottom profiling. The EM 302 is hull mounted whereas the EM 710 is mounted on the drop keel. All three instruments were used during the survey for mapping the seabed and the sub-seafloor.

The operational depths of the EM 710 are 3 to 2000 m and of the EM302 are 10 to 7000 m.

Both MBES can achieve a swath width of 5.5 times the water depth with high resolution and accuracy. Continuous seabed mapping using the EM 302 was carried out throughout the expedition whereas the EM 710 was used only when in water depths less than 1500 m, mainly on the Saya de Malha plateau and on Nazareth Bank where the water depth was often found to be below 100 m.

During the survey, swath coverage and depth range settings were adjusted accordingly to optimize the mapping. The measured sound speed profile was also input in the system when CTD measurements were carried out. Tide correction was not done.

The recorded data was viewed on Seafloor Information System (SIS), Kongsberg real time software designed to be the user interface and the realtime data processing system for its hydrographic instruments, and on Olex, the onboard navigation planning system.

As for sub-bottom profiling, the SBP 300 is an optional extension of the EM 302. It has a very narrow beam. It was run continuously throughout the survey.

The raw data format is ". all" for the MBES data, and SEG Y for the SBP 300 data.

Preliminary bathymetry maps were made onboard to help for the various sampling exercise (VAMS and trawls) and also to map seabed features. The data were output from the Olex system in ascii xyz format. The open source collection software tools Generic Mapping Tools (GMT) was then used to create bathymetry maps. The Olex system outputs xyz data that are partly pre-processed, cleaned and filtered (the exact data processing sequence is not known). These xyz data were gridded using xyz2grd command line tool and then plotted using grdimage command line tool. For convenience, the various parameters were set so as to obtain quick output maps.

However, for better results the original raw data were exported and processed. This would be done onshore during post cruise data processing. Sub-bottom profiling was only viewed on the screen when navigating. The data would be processed onshore.

2.10.2 Single-beam multifrequency sounder

The primary instrument for observing sound-scatterers in the water column was the SIMRAD EK80 Scientific Split Beam Echo Sounders with 18, 38, 70, 120, 200 and 333 kHz transducers mounted in a drop keel.

Raw data from the EK80 (primarily the 38KHz transducer) were treated with the KORONA software to reduce the influence of noise and further scrutinized using the LSSS software to derive backscattering area (S_A) estimates along the entire survey track.

The acoustic backscattering values (S_A) are stored at high resolution in LSSS. After scrutinizing and allocating the values to species or species groups, the values are stored with 10m vertical resolution and 1 nautical mile (n.m.) horizontal resolution. The procedure for allocation by species is normally based on:

- composition in trawl catches (pelagic and demersal hauls)
- the appearance of the echo recordings
- inspection of target strength distributions
- inspection of target frequency responses

Sampling was restricted to the 0-750m depth range. In all areas surveyed there was a dominance of backscattering from small targets (presumably zooplankton), and only seldom did the frequency response suggest occurrence of sound-scattering fish. Total S_A estimates were plotted along survey tracks, but no attempt was made to allocate estimates to specific taxa/scatterer categories, nor to estimate biomass.

CHAPTER 3. RESULTS

3.1 Physical oceanography

CTD

A total of 42 CTD stations were taken along the Saya de Malha bank. The Seabird 911 CTD+ was used to obtain the vertical profiles of temperature, salinity, dissolved oxygen and fluorescence. For this report, data from the sensors t168C for temperature, sal00 for salinity and sbeoxOML/L for dissolved oxygen were used. The descent profiles were considered for analysis and the data were averaged per metre depth. For a better understanding, the bank was divided into 4 regions namely, the northern bank, the southern bank, the eastern slope and the western slope as shown in the Table 3.1.1 below.

ADCP

The ADCP mounted on the ship was used to collect data for currents along transects of the survey. A pre-processing of the data was done using the ADCP live monitor, ADCP-TSG track viewing and subsetting, ADCP current editor and calculator software.

However, during further processing of the ADCP datasets (75 kHz and 150 kHz), erroneous signal from the data was observed. This might be due to the interference with other acoustic instruments operating simultaneously onboard the vessel during acquisition. Therefore, an advanced processing needs to be performed to obtain accurate data.

For this report, the 150kHz ADCP data with a vertical resolution of 8m was used for the preliminary report. This beam frequency only operates to a maximum depth of 400m. Consequently, the section plots displaying current pattern have been restricted to 300m deep using Ocean Data View (ODV) software.

A plot indicating the current direction was also produced along Saya de Malha (Figure 3.1.33) at 50m depth using the ADCP current editor & calculator software.

The results of preliminary pre-processing carried out onboard the vessel for the 150 kHz ADCP data are presented here, indicating current velocity patterns.

Table 3.1.1 Categorisation of CTD stations and their respective bottom depth.

CTD station number	Western slope stations depth (m)	Northern shallow stations depth (m)	Southern shallow stations depth (m)	Eastern slope stations depth (m)
391	120			
392	2230			
393	67			
394		23		
395		26		
396				2003
397		62		
398		56		
399	1157			
400	43			
401	1002			
402		122		
403		22		
404				1004
405		44		
406		100		
407	54			
408	2701			
409	183			
410			151	
411			100	
412				2001
413			101	
414			242	
415			261	
416	1249			
417			310	
418			259	
419				2000
420			281	
421			69	
422	1999			
423		102		
424	1501			
425		182		
426				1401
427		100		
428				501
429				1003
430		81		
431		221		
432			371	

Temperature

A surface temperature of 28°C was observed at all stations with a surface mixed layer varying between 30 and 60m. Station 431 (northern shallow region) and station 415 (southern shallow region) showed the highest variation and temperature drop within the water column by 13°C and 17°C, respectively. For the slope regions, the temperature reached a minimum of 2°C at 2000m deep. The section plot (Figure 3.1.5) demonstrates the change in temperature within the water column.

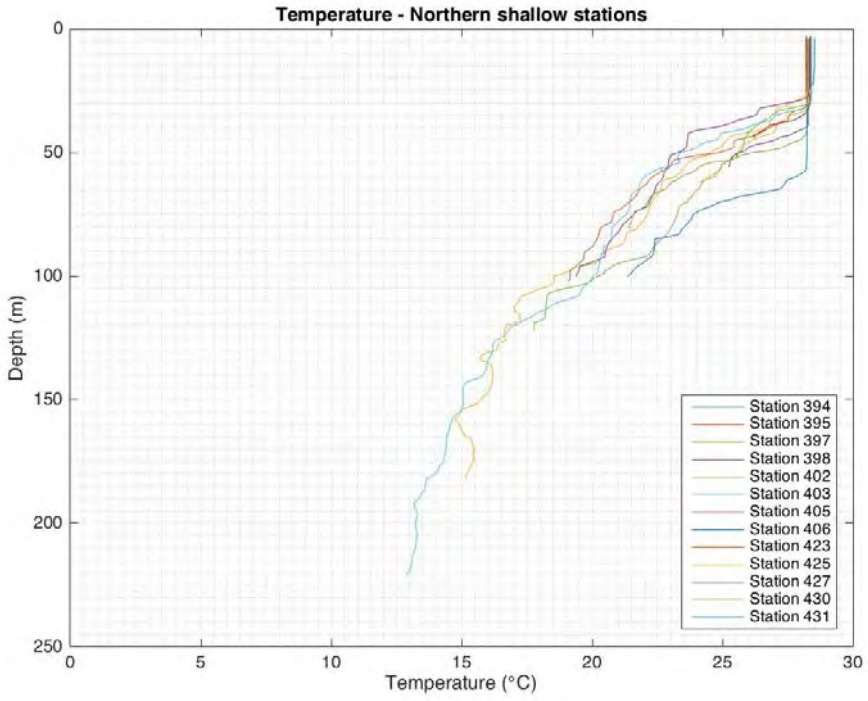

Figure 3.1.1. Temperature (°C) for the Northern shallow stations (394, 395, 397, 398, 402, 403, 405, 406, 423, 425, 427, 430 and 431).

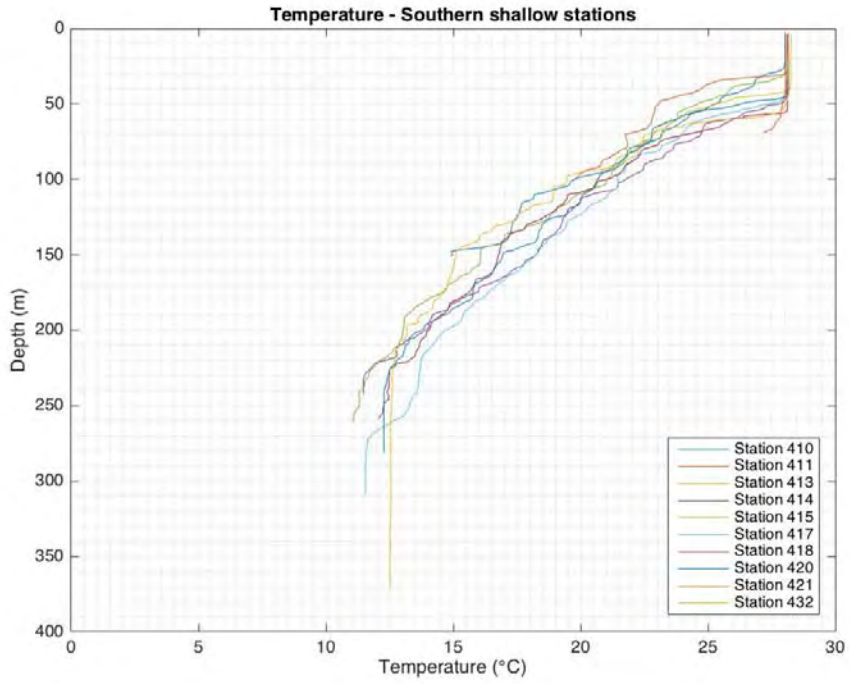

Figure 3.1.2. Temperature (°C) for the Southern shallow stations (410, 411, 413, 414, 415, 417, 418, 420, 421 and 432).

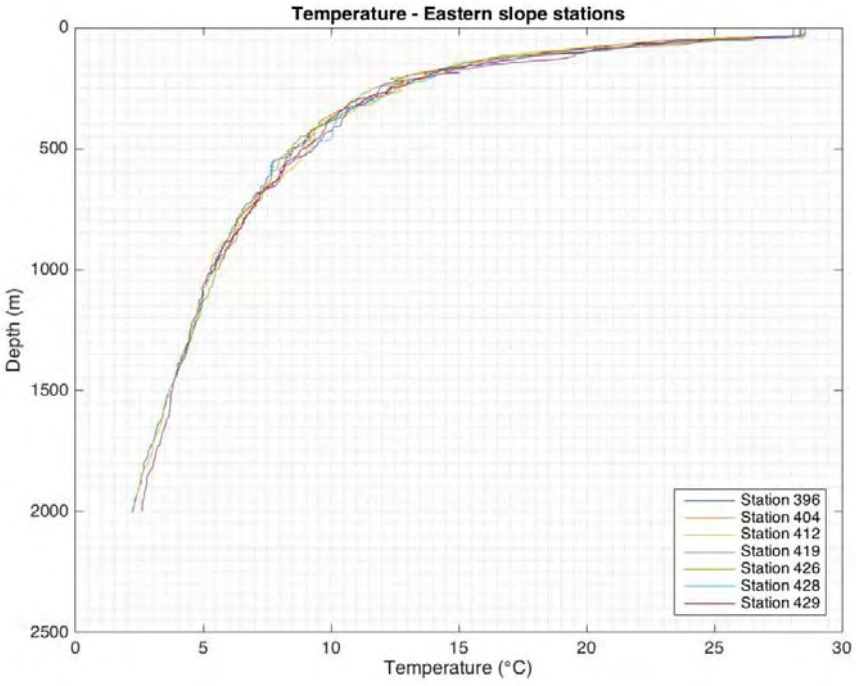

Figure 3.1.3. Temperature (°C) for the Eastern slope stations (396, 404, 412, 419, 425, 428 and 429).

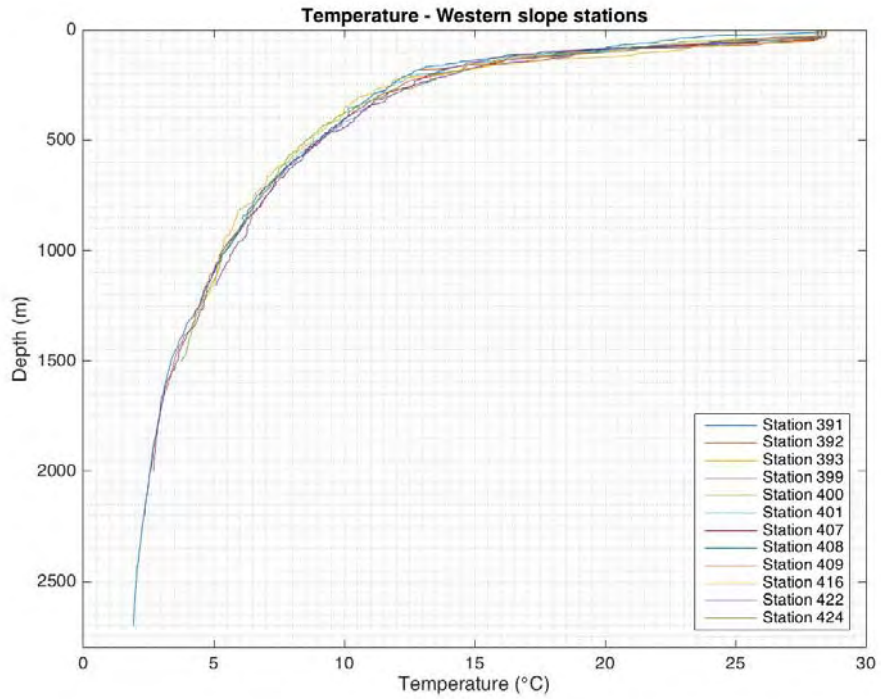

Figure 3.1.4. Temperature (°C) for the Western slope stations (391, 392, 393, 399, 400, 401, 407, 408, 409, 416, 422 and 424).

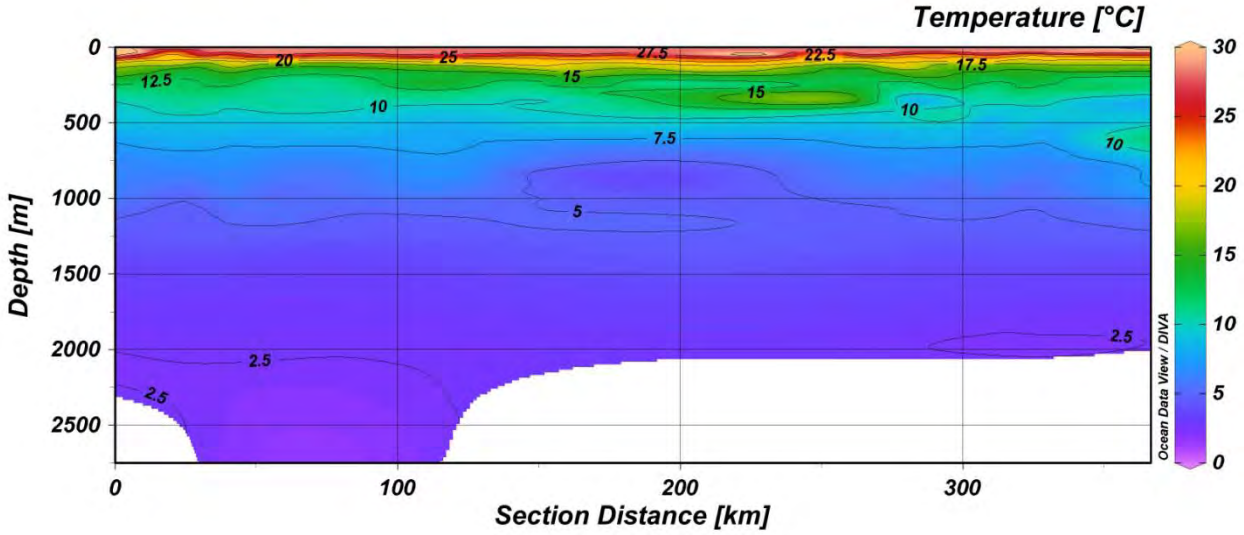

Figure 3.1.5. Section plot of temperature (°C) of the Saya de Malha bank from west (0km) to east (300km).

Salinity

A surface salinity varying from 34.1 PSU to 34.6 PSU can be observed at all the stations which remained constant in the surface mixed layer. Below 50m deep, an increase in salinity can be observed and all four regions showed a peak in salinity (35.4 PSU) at 150m deep. The salinity decreased within the range of 35.1 PSU to 35.26 PSU and 34.94 PSU to 35.06 PSU with depth for the northern and southern shallow regions respectively. For western slope, the salinity decreased gradually until it became constant (34.7 PSU) below a depth of 500m. However, the eastern slope showed another peak at 250m deep with salinity of 35.4 PSU (Figures 3.1.8 and 3.1.10) and it became constant below 500m deep.

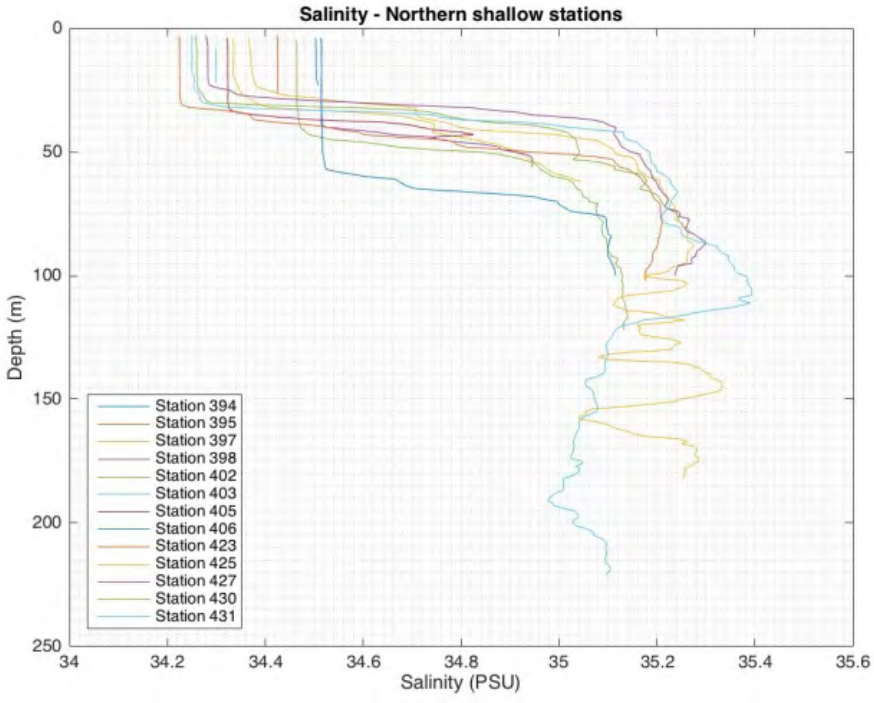

Figure 3.1.6. Salinity (PSU) for the Northern shallow stations (394, 395, 397, 398, 402, 403, 405, 406, 423, 425, 427, 430 and 431).

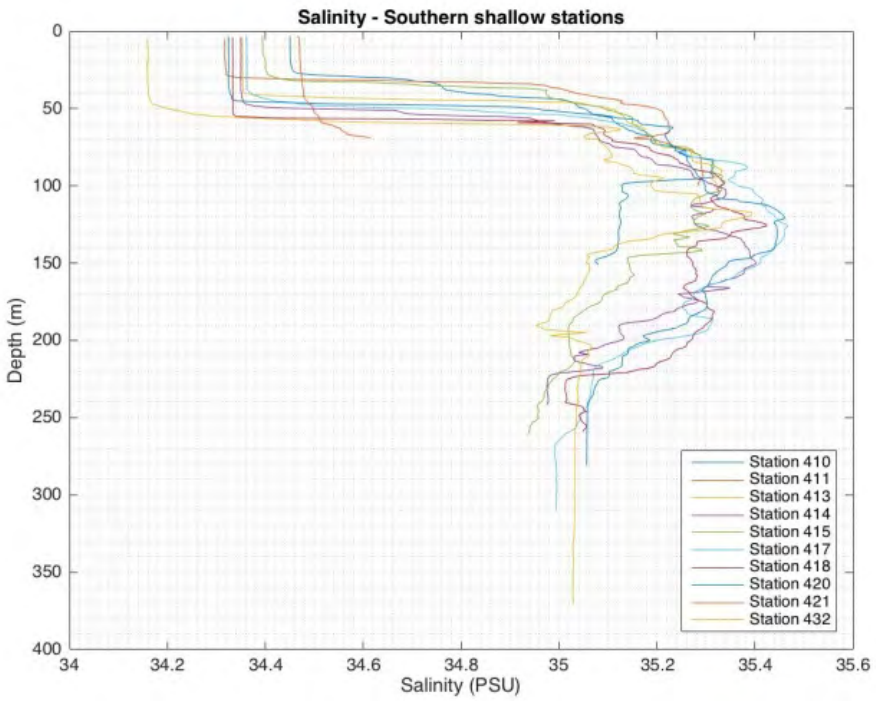

Figure 3.1.7. Salinity (PSU) for the Southern shallow stations (410, 411, 413, 414, 415, 417, 418, 420, 421 and 432).

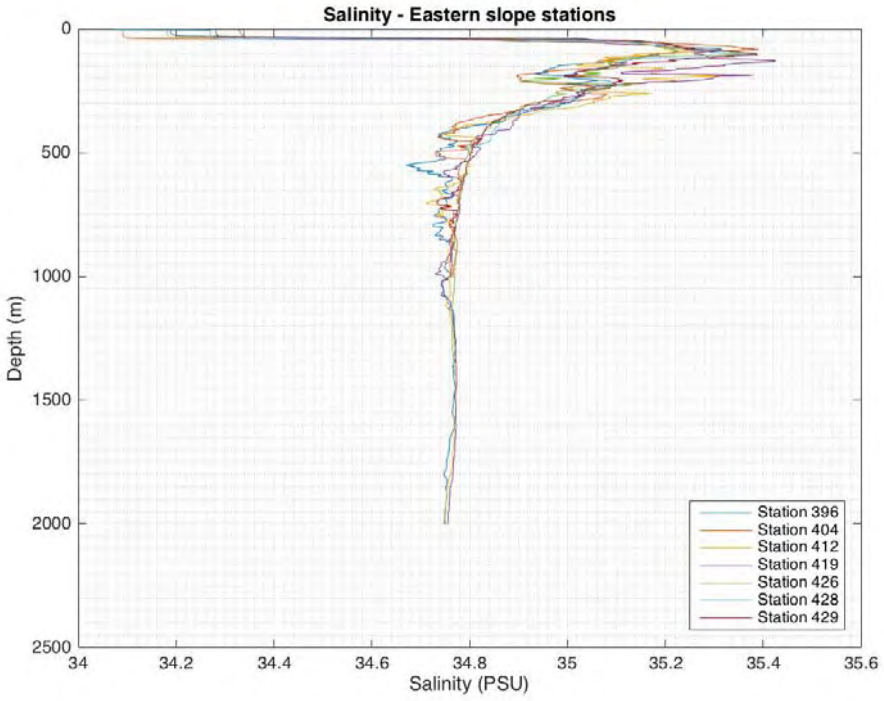

Figure 3.1.8. Salinity (PSU) for the Eastern slope stations (396, 404, 412, 419, 425, 428 and 429).

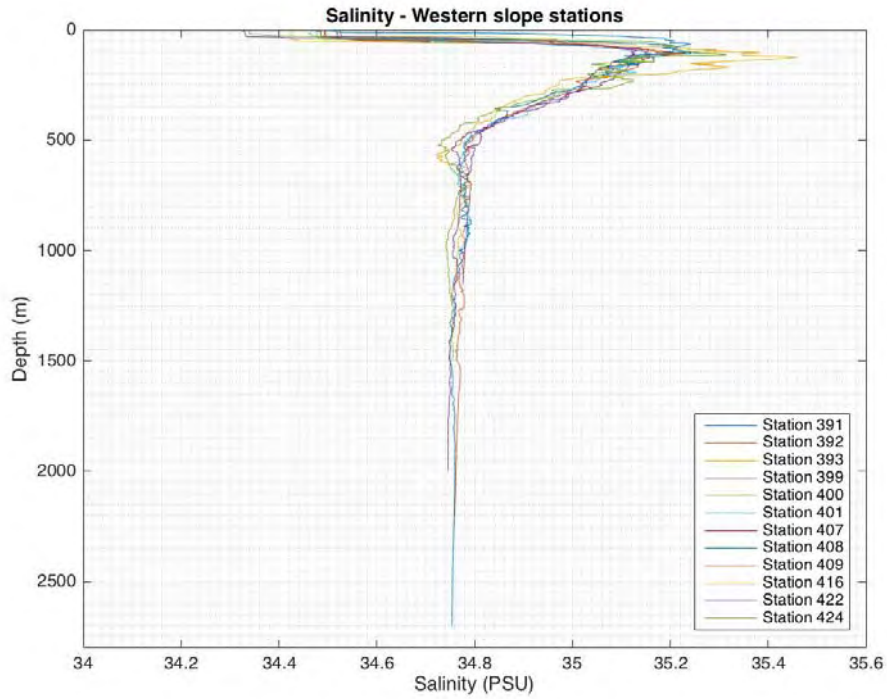

Figure 3.1.9. Salinity (PSU) for the Western slope stations (391, 392, 393, 399, 400, 401, 407, 408, 409, 416, 422 and 424).

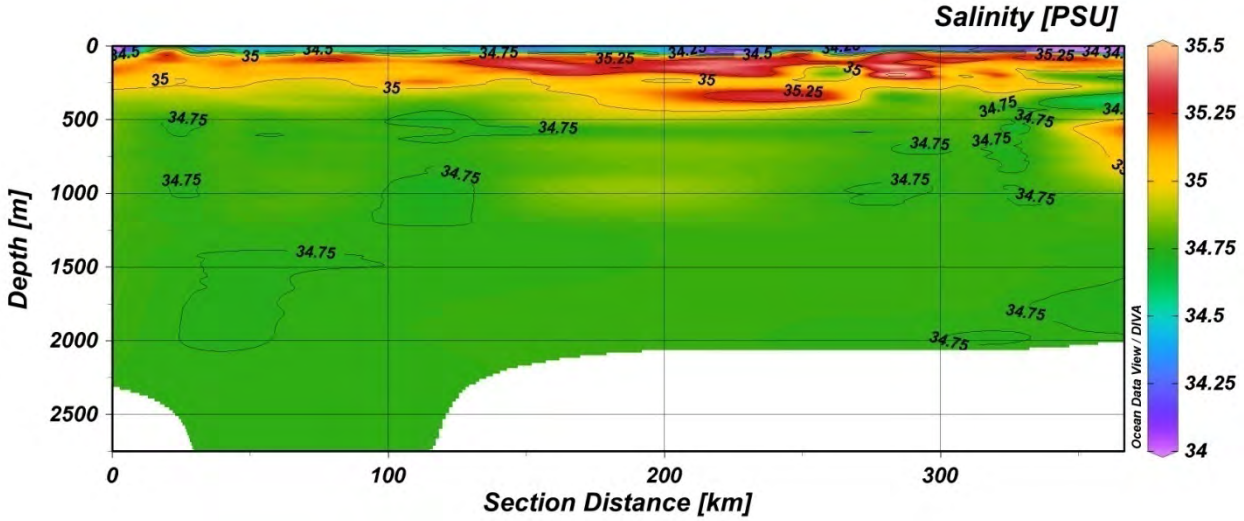

Figure 3.1.10. Section plot of salinity (PSU) of the Saya de Malha bank from west (0km) to east (300km).

Potential Density

The stratification of Saya de Malha bank is shown in Figure 3.1.11. The water column demonstrated a stable stratification, a characterising feature of low latitude regions. The biggest change in potential density occurred at the pycnocline, situated at around 150m depth in this instance. Surface water had a density (1000 + potential density) of approximately 1022kg/m^3 with density decreasing to 1028kg/m^3 at 2000m depth.

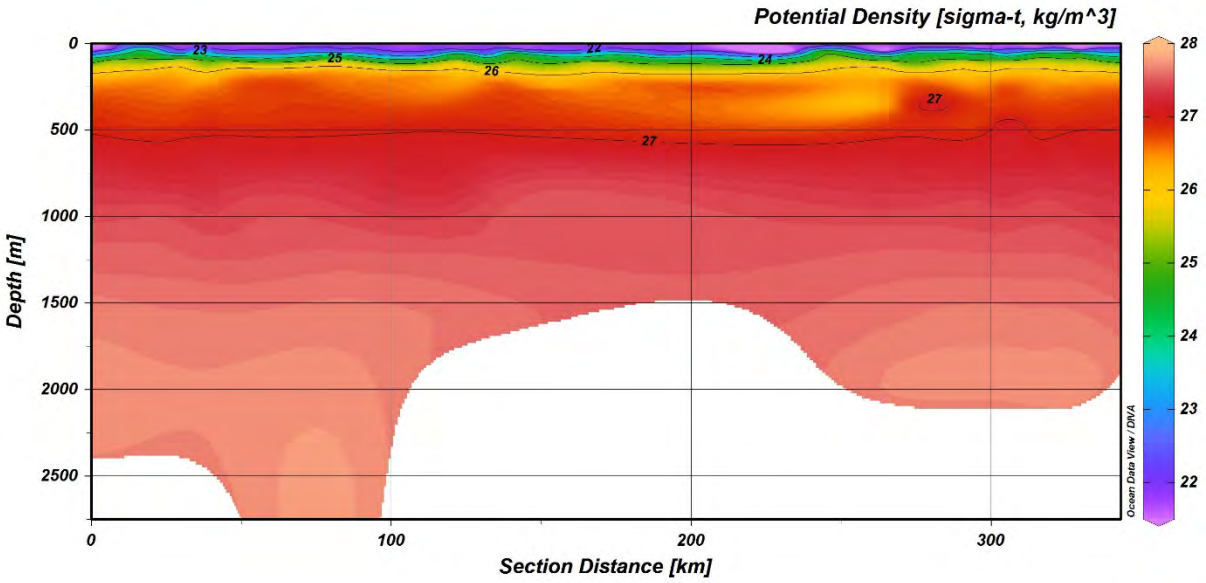

Figure 3.1.11. Section plot of potential density (σ_t; kg/m^3) of the Saya de Malha bank from west (0km) to east (300km).

T-S Profile

Given the stratified nature of the water column, the data points for all stations occupied a large region on the T-S plots. For western and eastern slope stations, the T-S profiles confirmed that the water in the deep section of the water column is relatively homogeneous (Figures 3.1.14 and 3.1.15). The continuous distribution of the data points in the T-S profile for all stations indicates that there was mixing occurring between the upper stratified layer and the bottom well-mixed layer. The bottom water has the same water mass properties as the Antarctic Intermediate Water (salinity between 33.8 PSU and 34.8 PSU and temperature between 2°C and 10°C). Indian Central Water mass properties (salinity between 34.5 PSU and 35.5 PSU and temperature between 8°C and 15°C) can also be seen in the T-S profiles.

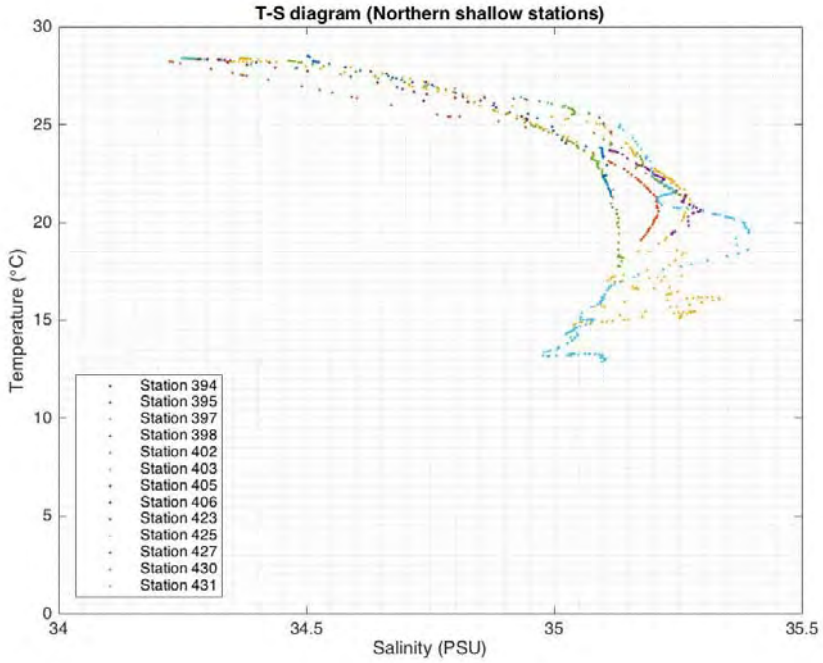

Figure 3.1.12. TS diagram for Northern shallow stations (394, 395, 397, 398, 402, 403, 405, 406, 423, 425, 427, 430 and 431).

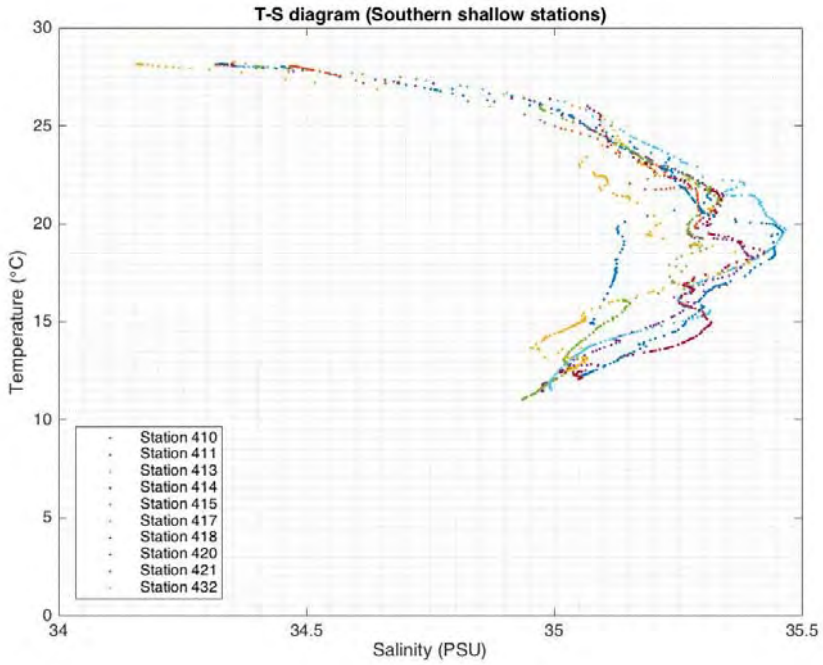

Figure 3.1.13. TS diagram for the Southern shallow stations (410, 411, 413, 414, 415, 417, 418, 420, 421 and 432).

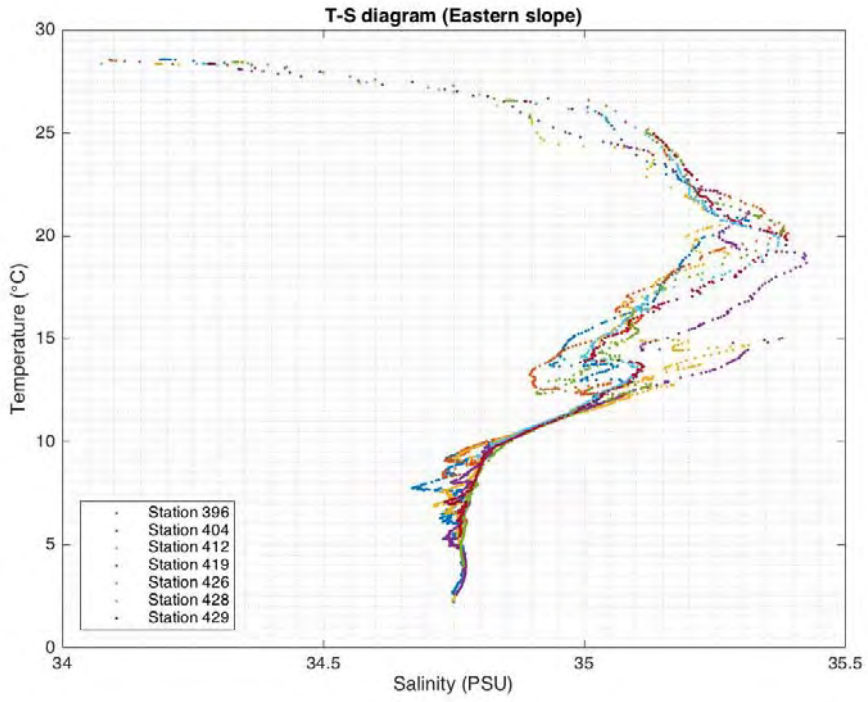

Figure 3.1.14. TS diagram for the Eastern slope stations (396, 404, 412, 419, 425, 428 and 429).

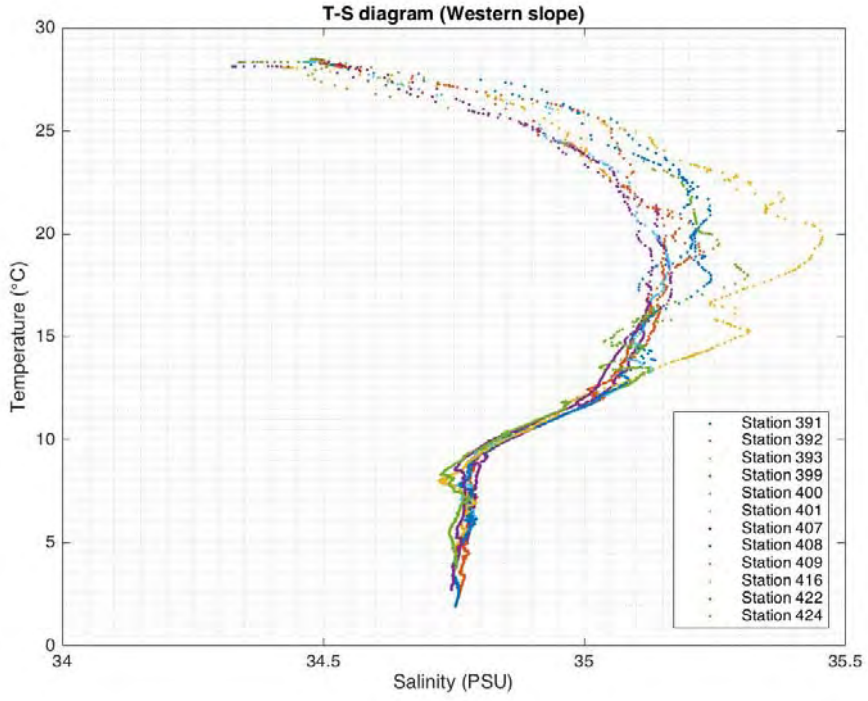

Figure 3.1.15. TS diagram for Western slope stations (391, 392, 393, 399, 400, 401, 407, 408, 409, 416, 422 and 424).

Dissolved Oxygen

The northern and southern shallow regions demonstrated a constant concentration of dissolved oxygen in the surface mixed layer which varied between 30m to 50m deep. The eastern and western slope stations showed a decrease in dissolved oxygen at the surface up to 200m deep. A peak in dissolved oxygen at 400m deep can be observed and then dissolved oxygen gradually decreased to 1000m deep (Figures 3.1.18 and 3.1.19). Below 1000m depth, there was a slight increase in dissolved oxygen with a concentration of 3.5ml/L. The central bank has a relatively higher concentration of dissolved oxygen (5.5ml/L) at 500m deep (Figure 3.1.20).

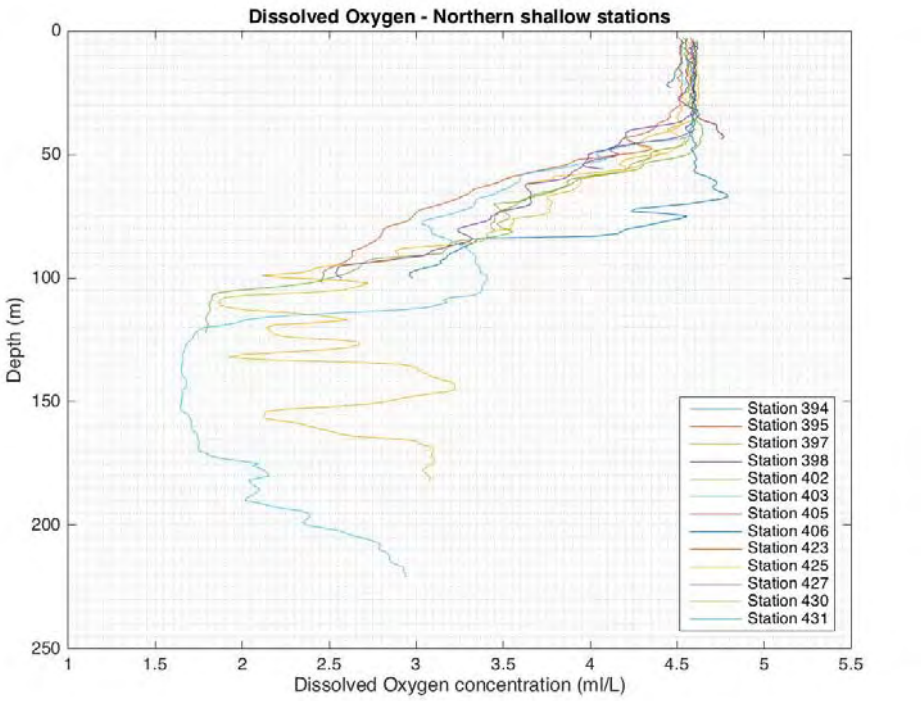

Figure 3.1.16. Dissolved oxygen concentration (ml/L) for the Northern shallow stations (394, 395, 397, 398, 402, 403, 405, 406, 423, 425, 427, 430 and 431).

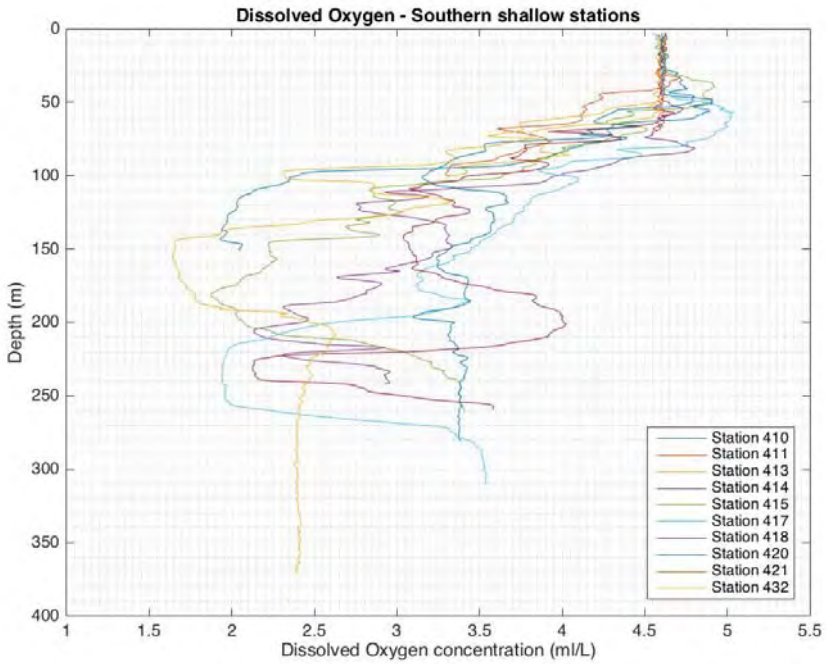

Figure 3.1.17. Dissolved oxygen concentration (ml/L) for the Southern shallow stations (410, 411, 413, 414, 415, 417, 418, 420, 421 and 432).

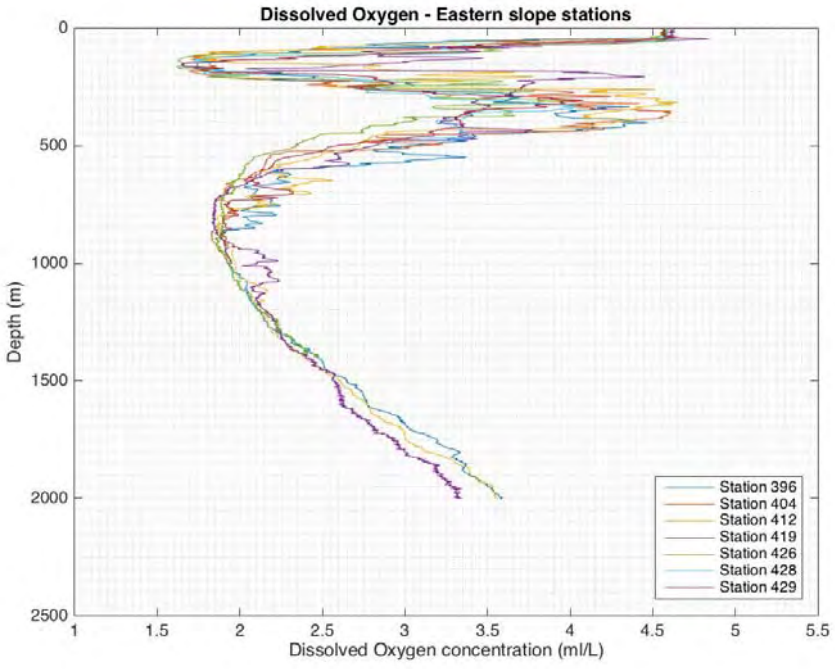

Figure 3.1.18. Dissolved oxygen concentration (ml/L) for the Eastern slope stations (396, 404, 412, 419, 425, 428 and 429).

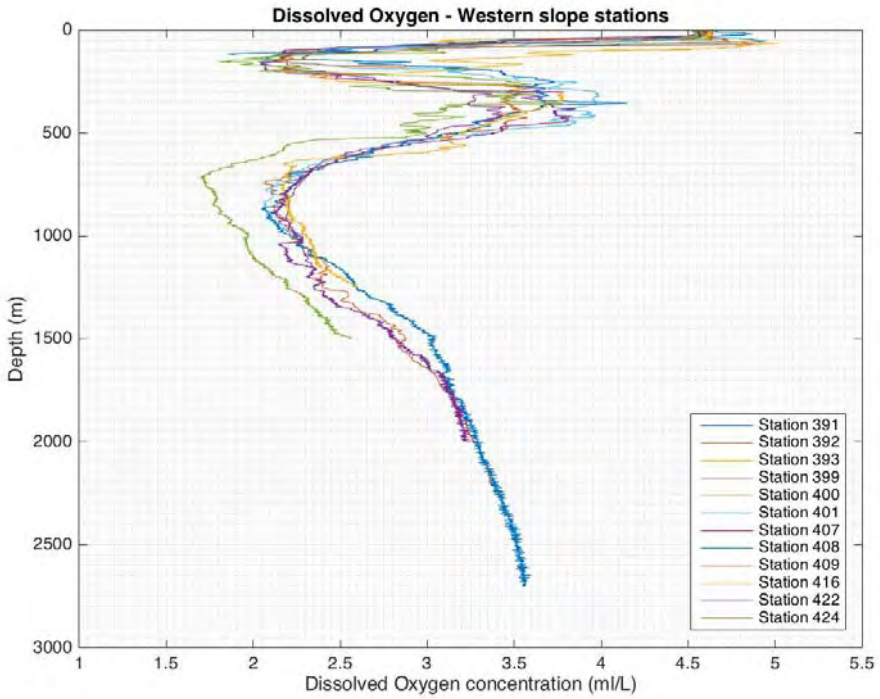

Figure 3.1.19. Dissolved oxygen concentration (ml/L) for the Western slope stations (391, 392, 393, 399, 400, 401, 407, 408, 409, 416, 422 and 424).

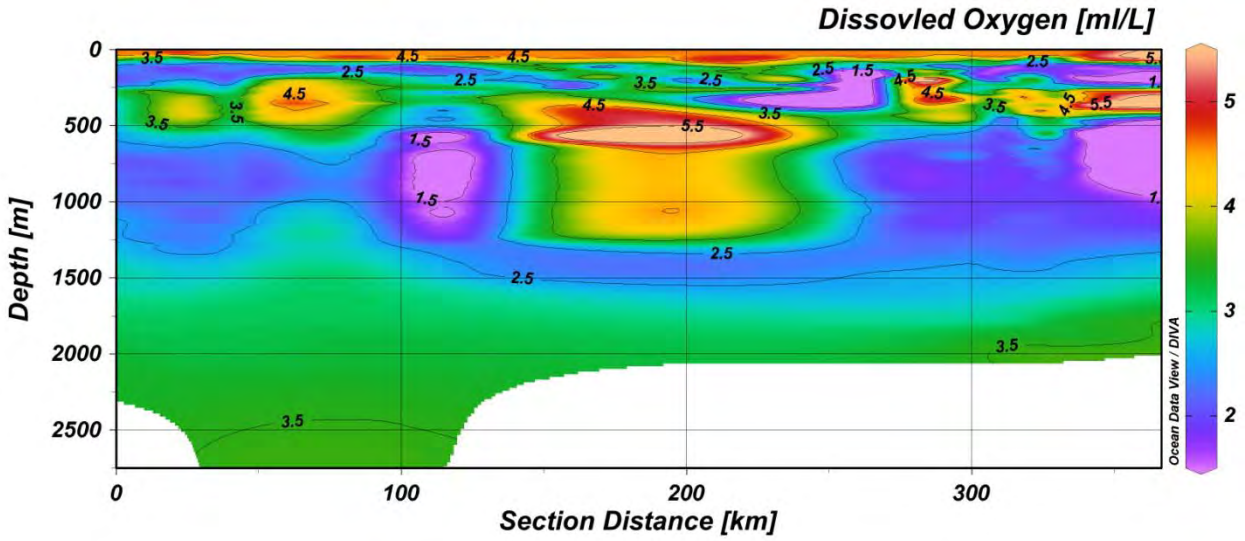

Figure 3.1.20. Section plot of dissolved oxygen concentration (ml/L) of the Saya de Malha bank from west (0km) to east (300km).

Fluorescence

For the four regions, the stations showed a peak in fluorescence, varying between 0.4µg/L and 0.6µg/L between 50m to 100m deep which then decreased with depth. For deep stations, the concentration of fluorescence was not significant below 200m depth (Figures 3.1.23 and 3.1.24). The concentration of fluorescence was higher on the eastern slope of Saya de Malha as compared to the western slope (Figure 3.1.25).

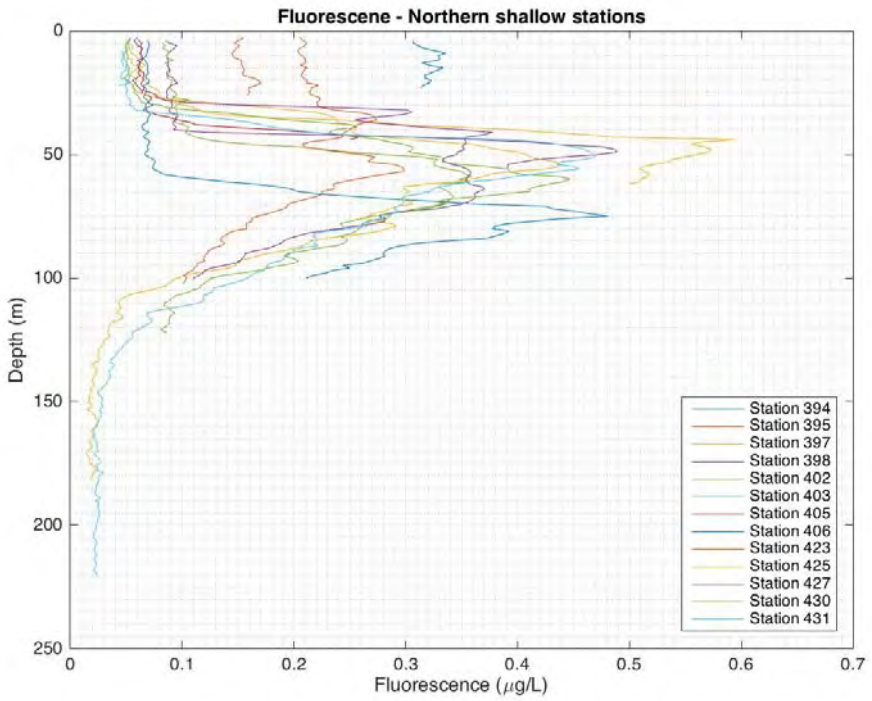

Figure 3.1.21. Fluorescence concentration (µg/L) for the Northern shallow stations (394, 395, 397, 398, 402, 403, 405, 406, 423, 425, 427, 430 and 431).

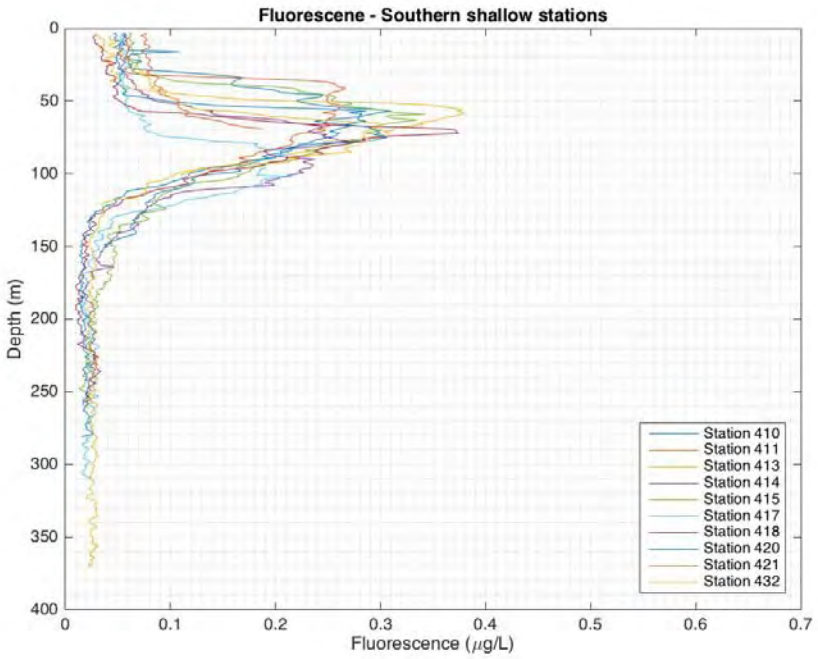

Figure 3.1.22. Fluorescence concentration (µg/L) for the Southern shallow stations (410, 411, 413, 414, 415, 417, 418, 420, 421 and 432).

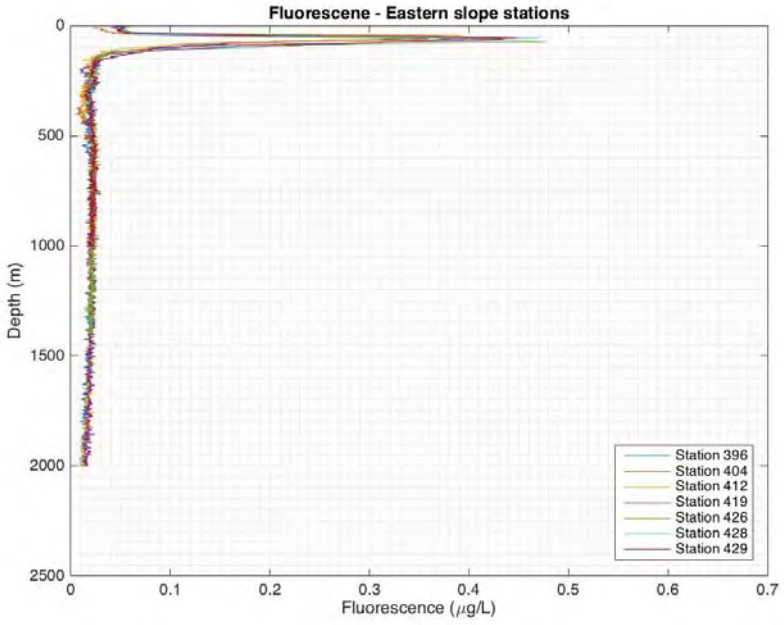

Figure 3.1.23. Fluorescence concentration (µg/L) for the Eastern slope stations (396, 404, 412, 419, 425, 428 and 429).

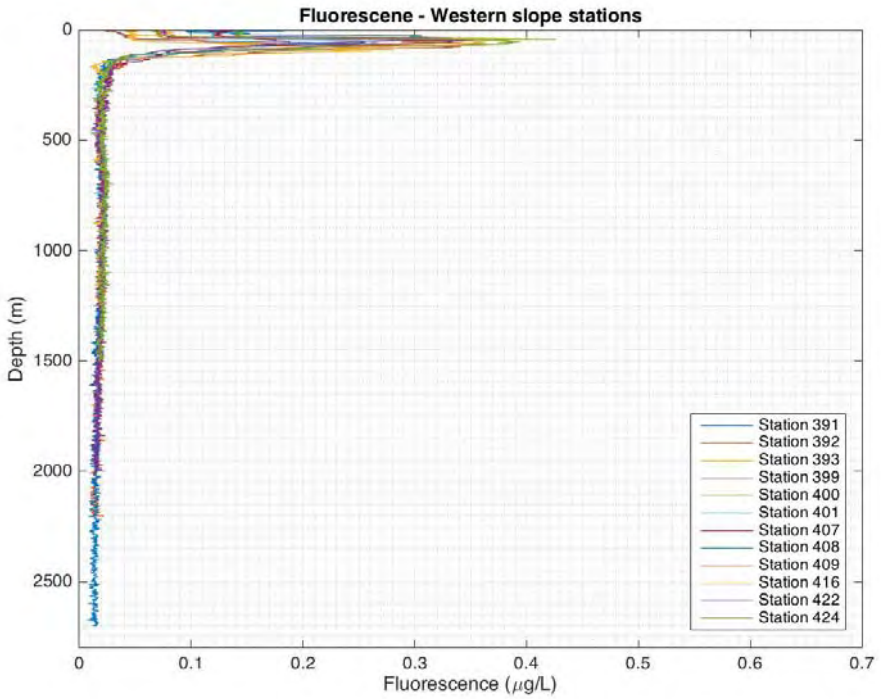

Figure 3.1.24. Fluorescence concentration (µg/L) for the Western slope stations (391, 392, 393, 399, 400, 401, 407, 408, 409, 416, 422 and 424).

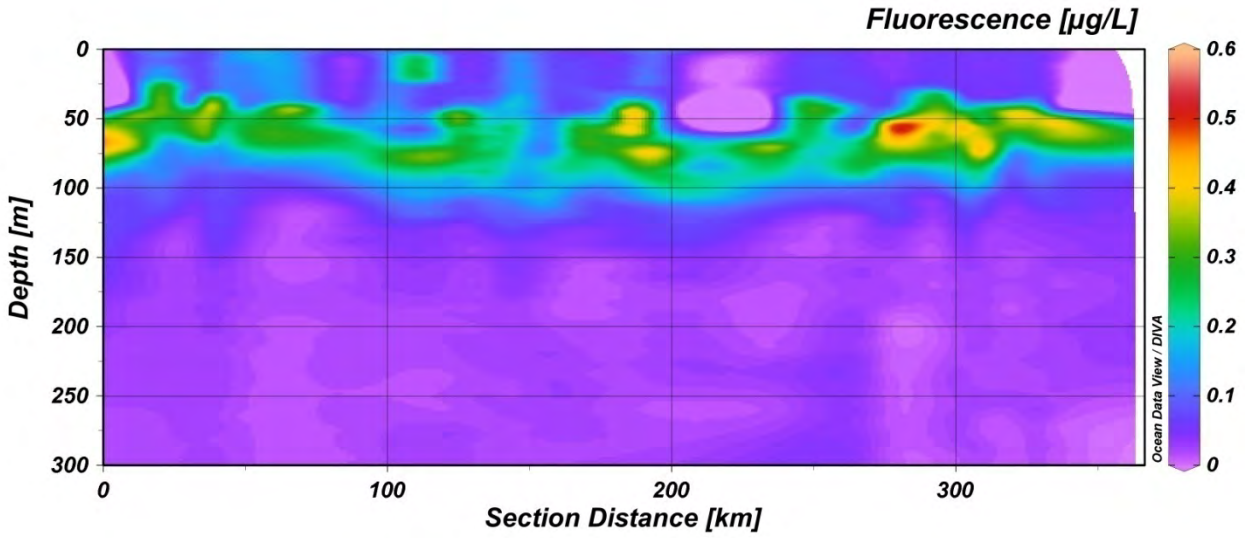

Figure 3.1.25. Section plot of Fluorescence concentration (µg/L) of the Saya de Malha bank from west (0km) to east (300km).

Current Velocity Section

Considering Transect 1 (Figure 3.1.26), the overall zonal velocity was relatively lower than the meridional velocity. For instance, the zonal velocity peaked at 20cm/s on the lee side of the eastern bank while the meridional velocity reached a maximum of 50cm/s. This indicated that the current had a strong northward component which further generated a strong vertical shear at the top of the eastern slope. From Figure 3.1.27, Transect 2 showed a westward current of approximately 10cm/s on the bank. For Transect 3, the strong northward current persisted in the bottom of the eastern slope while the vertical shear was relatively higher in the upper section of the eastern bank. The strong shear may be due to currents moving in the opposite direction (as shown in the meridional velocity plot of Figure 3.1.28 at around 30-40m deep).

A relatively strong south-westward current (westward current of 30cm/s and southward current of 20cm/s) was observed on the eastern slope of the bank in Transect 5. This observation might be due to the sudden change in topography. The width of the bank decreases when moving south and this may cause a change in the current pattern. On the southern tip of Saya de Malha (Transect 7, Figure 3.1.31), there was a strong westward current of 30cm/s. For the last transect (Transect 8, Figure 3.1.32), a strong south-eastward current can be seen over the relatively flat topography.

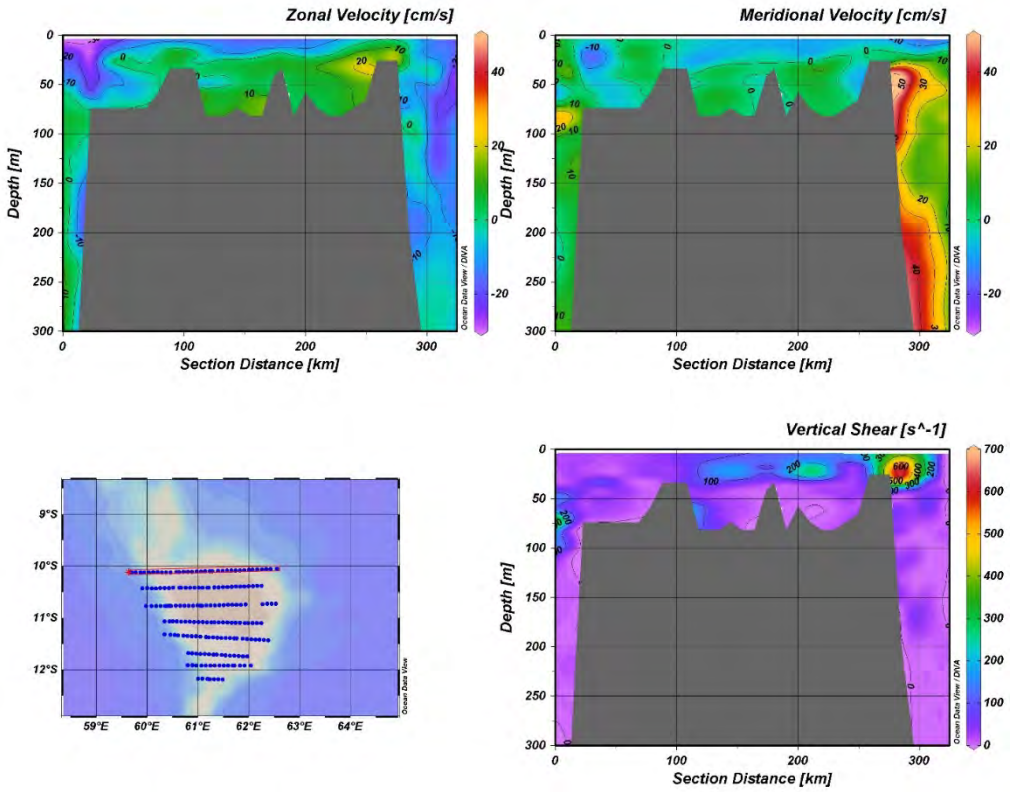

Figure 3.1.26. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 1.

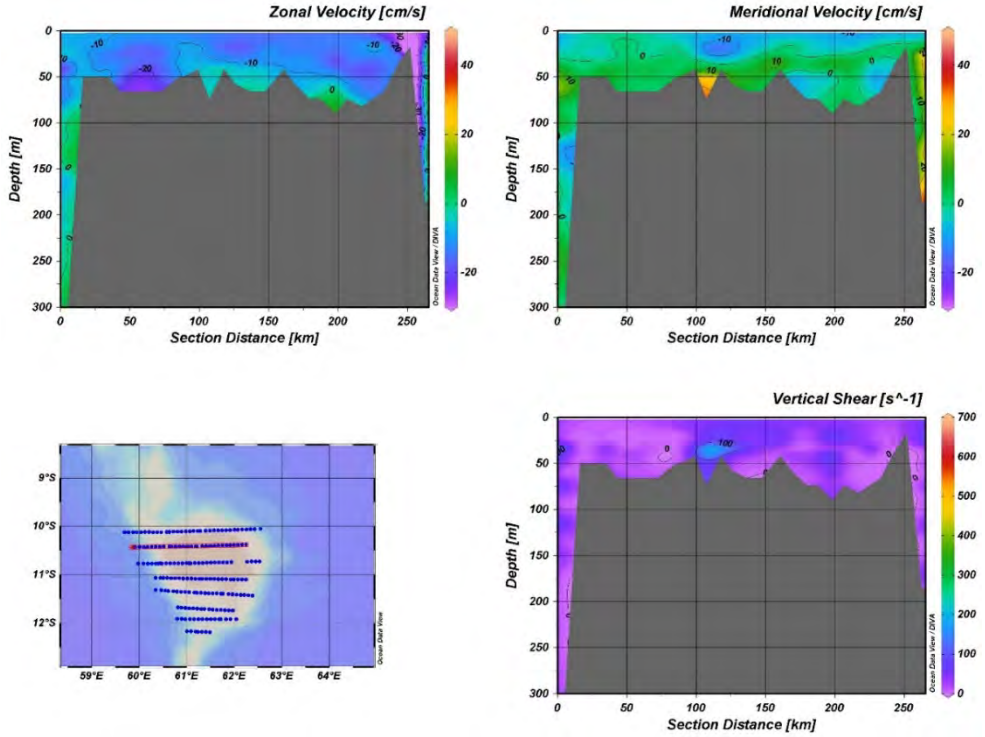

Figure 3.1.27. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 2.

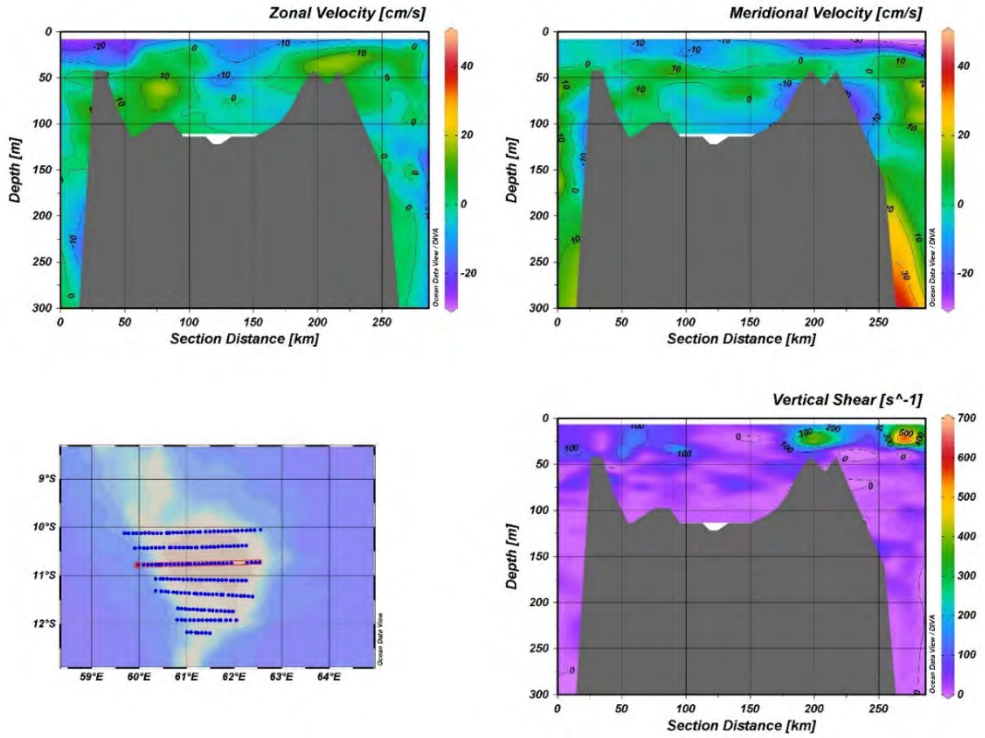

Figure 3.1.28. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 3.

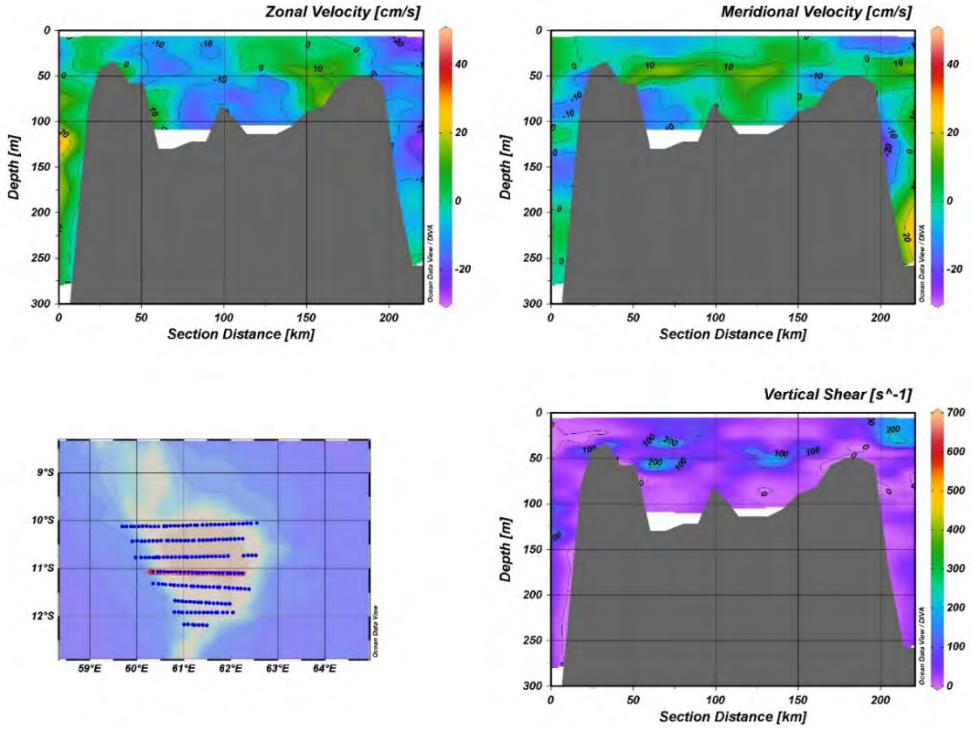

Figure 3.1.29. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 4.

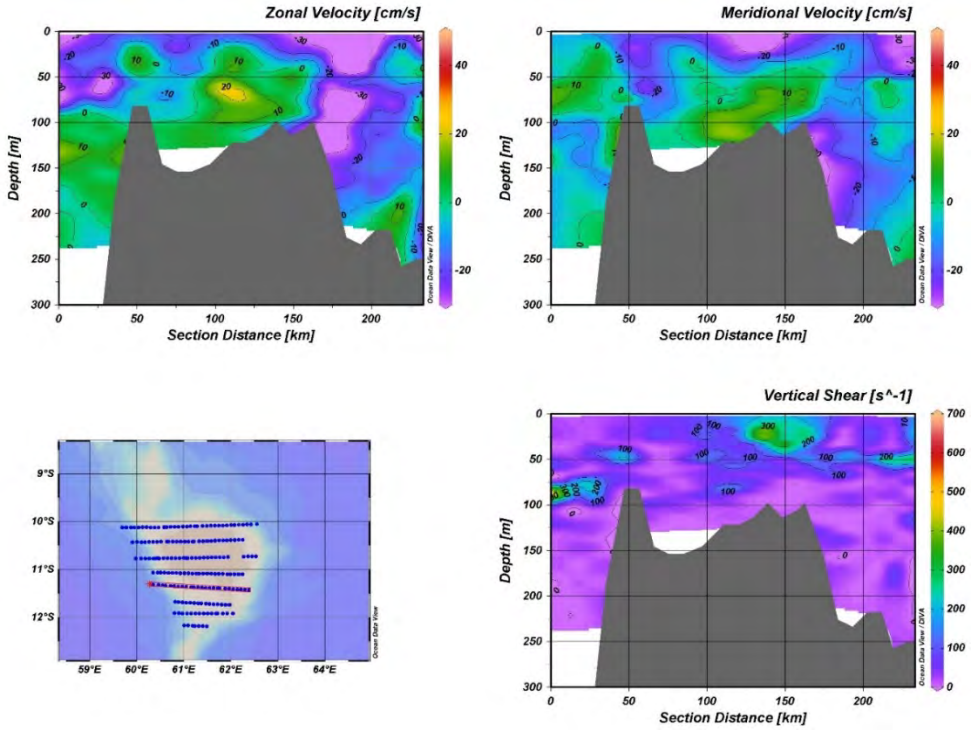

Figure 3.1.30. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 5.

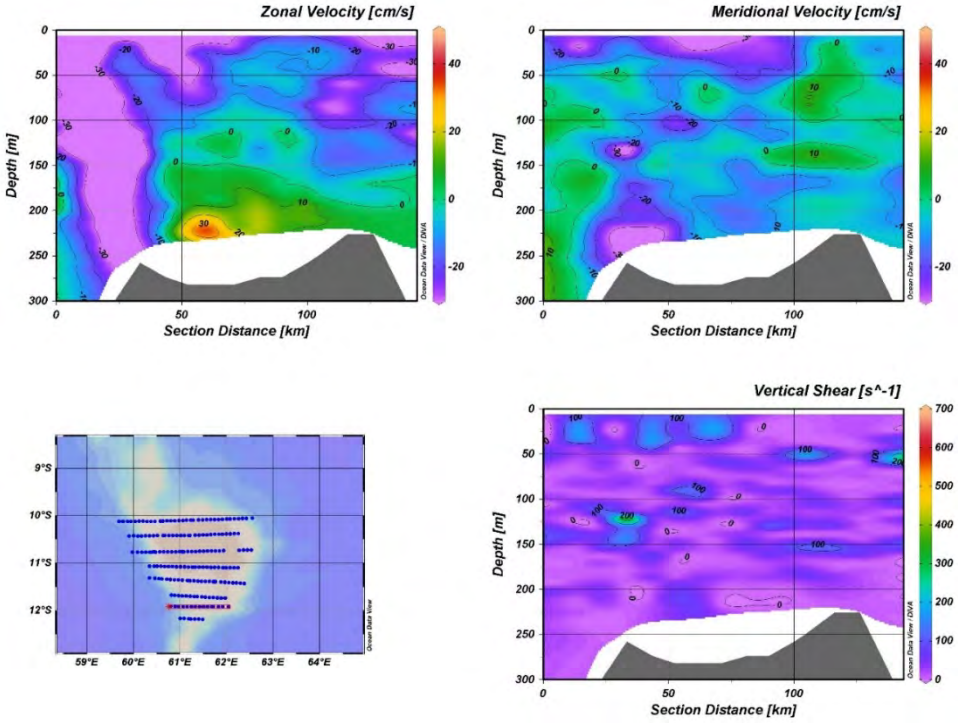

Figure 3.1.31. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 7.

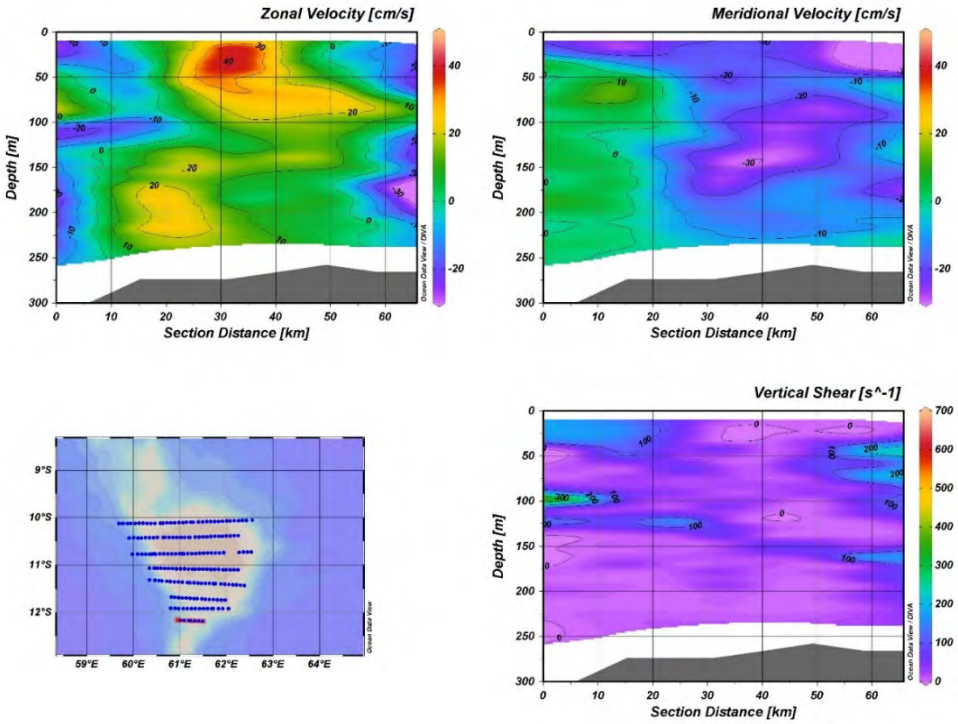

Figure 3.1.32. Zonal velocity (top left), meridional velocity (top right), vertical shear (bottom right) and map of Saya de Malha (bottom left) for Transect 8.

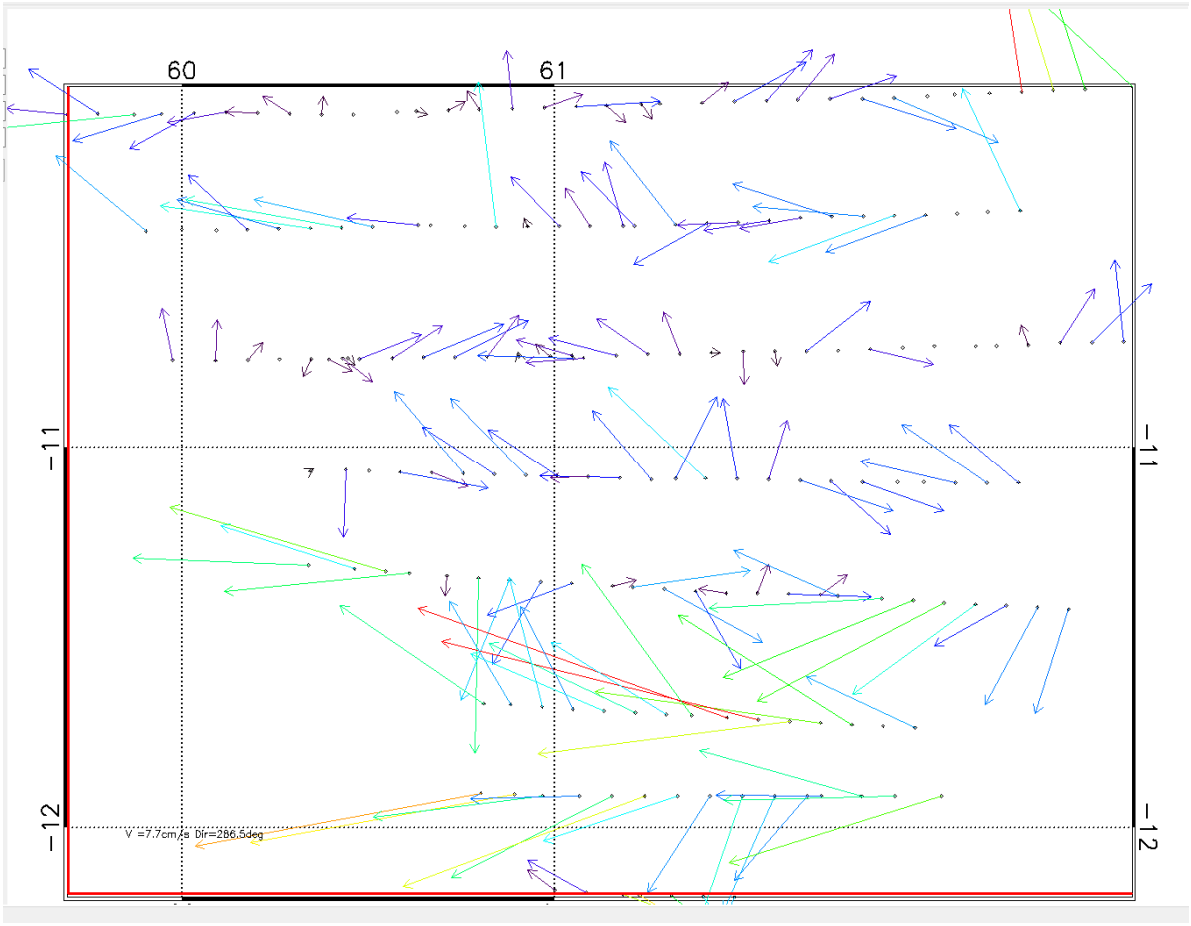

Figure 3.1.33. Current direction over Saya de Malha bank at 50m depth.

Surface properties

The temperature and salinity distributions across the Saya de Malha bank as recorded by the thermosalinograph with a water intake at 4 m are illustrated in Figures 3.1.34 and 3.1.35.

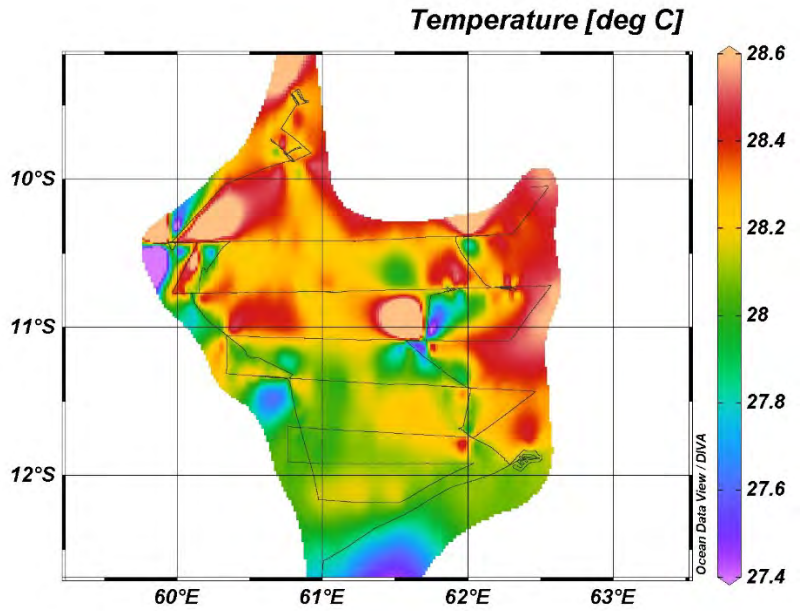

Figure 3.1.34. Surface temperature distribution over Saya de Malha from thermosalinograph data (Black lines represent the survey track).

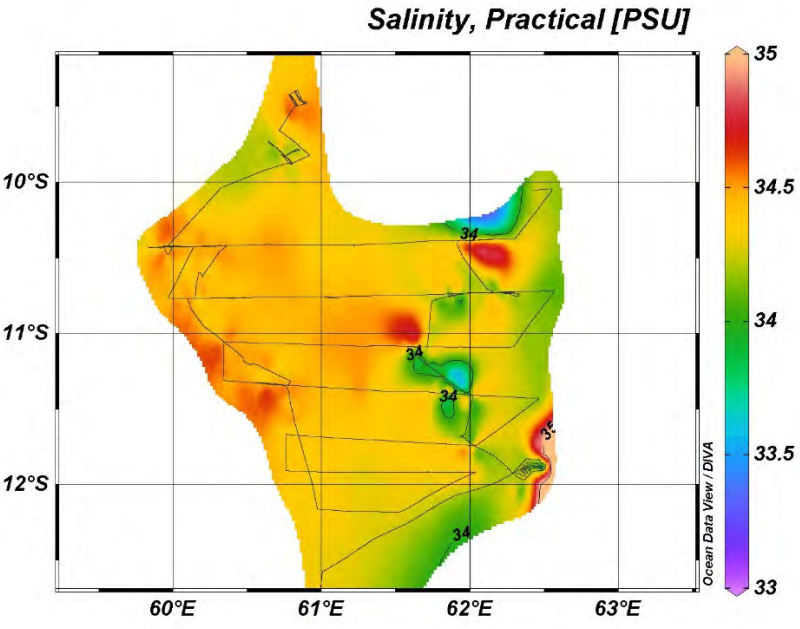

Figure 3.1.35. Surface salinity distribution over Saya de Malha from thermosalinograph data (Black lines represent the survey track).

Nazareth Bank

A total of 10 CTD stations were surveyed in the Nazareth Bank. The stations reached a maximum depth of 300m. All the parameters demonstrated a constant value for the surface mixed layer (up to 30-60m). Both temperature and salinity showed a typical profile with temperature decreasing and salinity increasing with depth (Figure 3.1.36). The dissolved oxygen decreased at 100m depth while fluorescence showed a sub-maxima at the same depth.

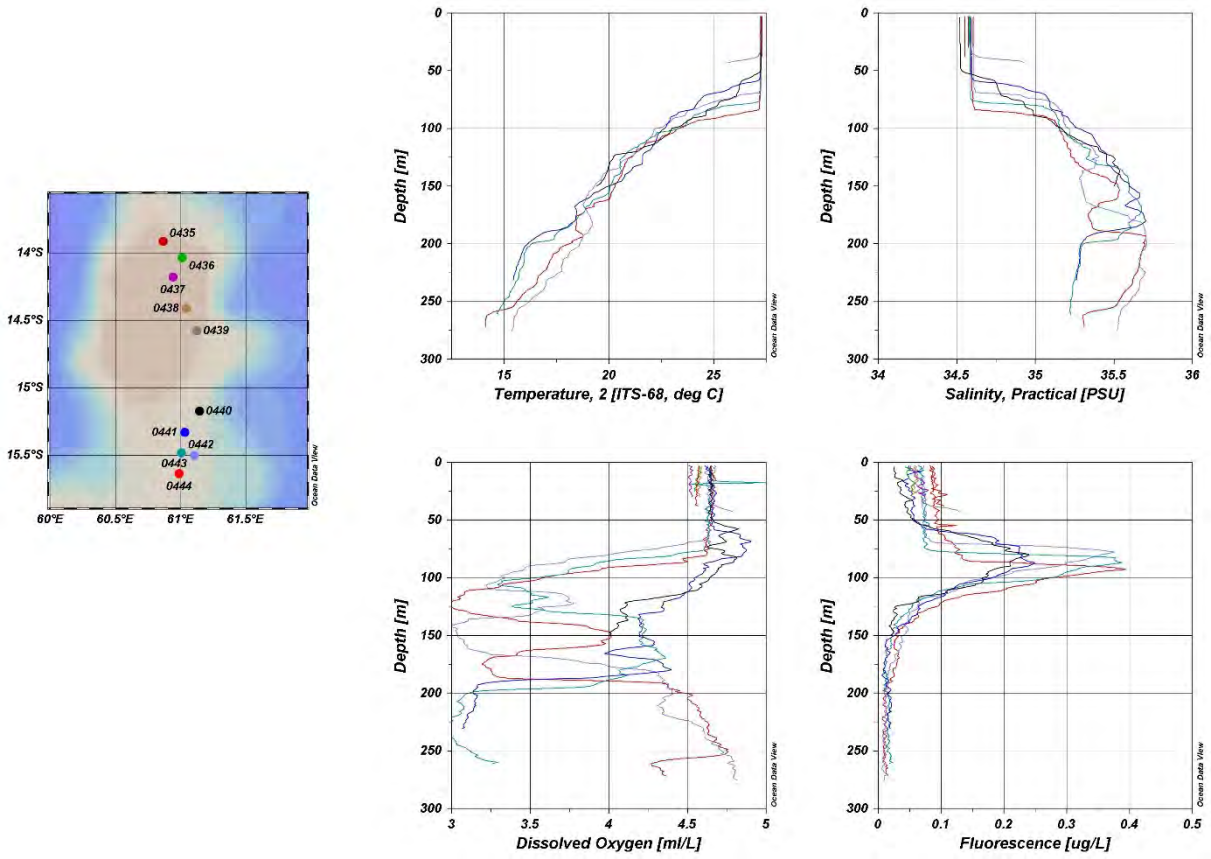

Figure 3.1.36. CTD stations for temperature (°C) (top centre), salinity (PSU) (top right), dissolved oxygen (ml/L) (bottom centre) and fluorescence (µg/L) (bottom right) over the Nazareth Bank.

3.2 Geomorphology and benthic substrates

Swath bathymetry survey

Swath bathymetry data was acquired along the ship's cruise track on pre-defined transects, transits and at specific study areas in Saya de Malha and Nazareth banks (Figs 1.2, 1.4, 1.6) Two seamounts located adjacent to the Saya de Malha bank were also mapped during the cruise, and the results are illustrated in Figure 3.2.2 and 3.2.3.

The two multibeam sounders (MBES) recorded the bathymetry that was viewed in real time on SIS and on Olex. Data in ascii xyz format was exported from Olex, gridded and then plotted without processing other than what pre-processing is done by Olex. These data are only suitable for a first glance at the output and further processing is a task for the future.

The resulting bathymetry maps (Fig. 3.2.3-3.2.7) depicts the topography and structure of the seabed with a very high resolution compared to the bathymetry derived from satellite altimetry (Sandwell and Smith or Gebco). The eastern and western slopes of the bank are also well defined. For this exercise the grids were produced using the EM 302 data with a resolution of 200m, enough to view the seafloor features of the deep ocean but not for the shallow plateau where the multibeam swath covered only an extent of approximately 60 to 100 m across for each transect. Only a few examples of bathymetry maps are shown here.

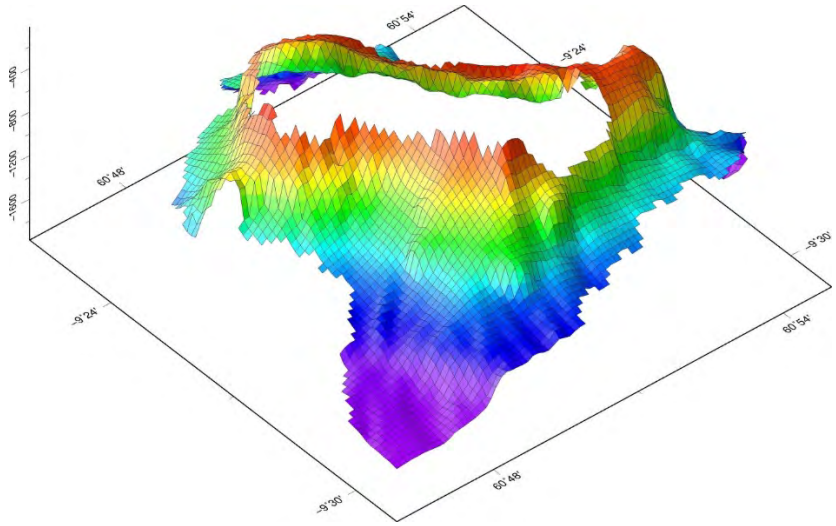

Figure 3.2.1. Bathymetric 3D view of the seamount located north of the Saya de Malha Bank (view from SW). The seamount has not been completely mapped due to time constraint. The measured water depth at the top of the seamount, although not represented here, is 19.1m.

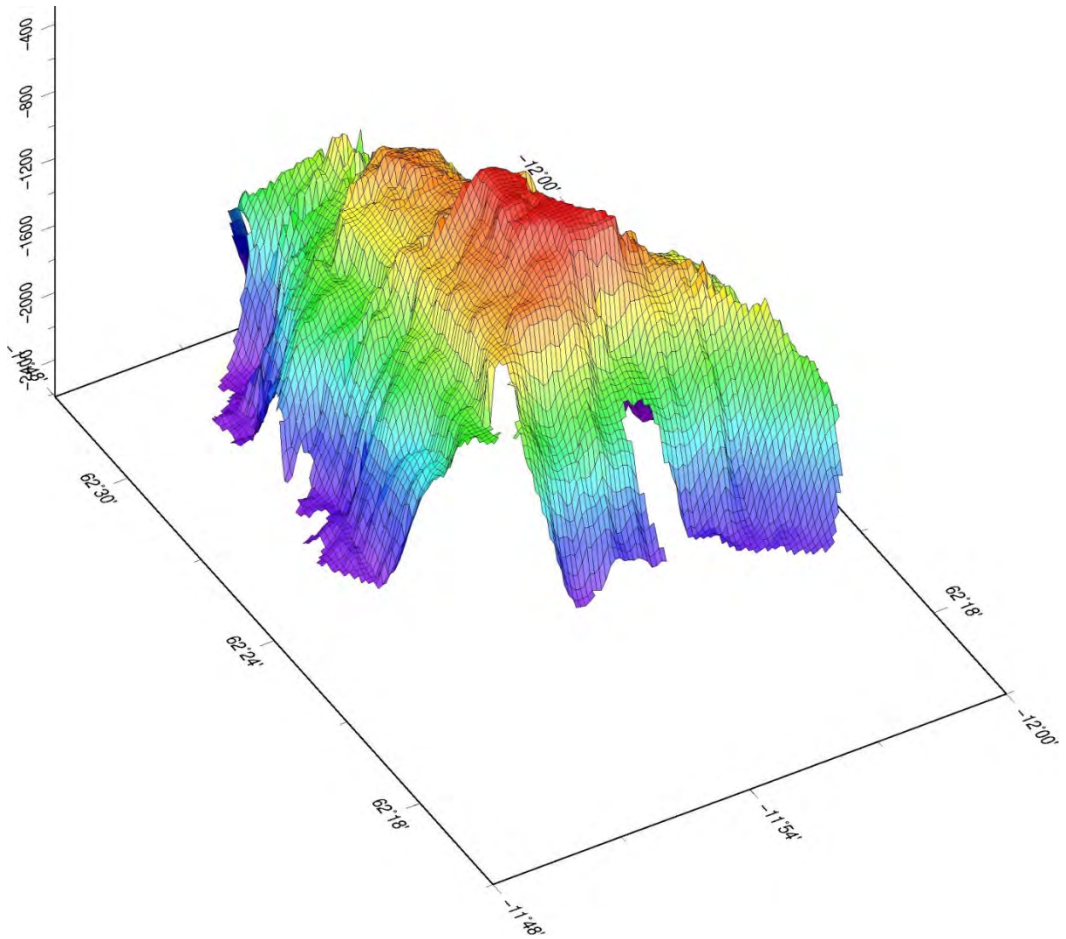

Figure 3.2.2. Bathymetric 3D view of the seamount located south-east of the Saya de Malha Bank (view from NW). Note the flat summit of the seamount.

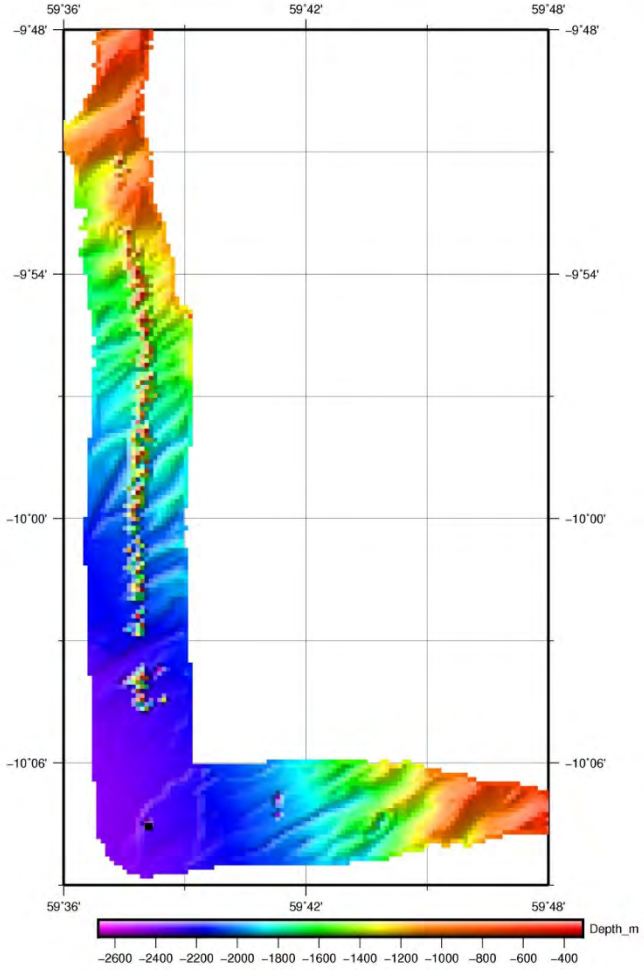

Figure 3.2.3. Bathymetry of the northern slope of Saya de Malha Bank on the transit to start Transect 1 (transects shown in inserted map in Fig. 3.2.8 below). The artefacts that appear on the image reflect the inadequate processing of the data.

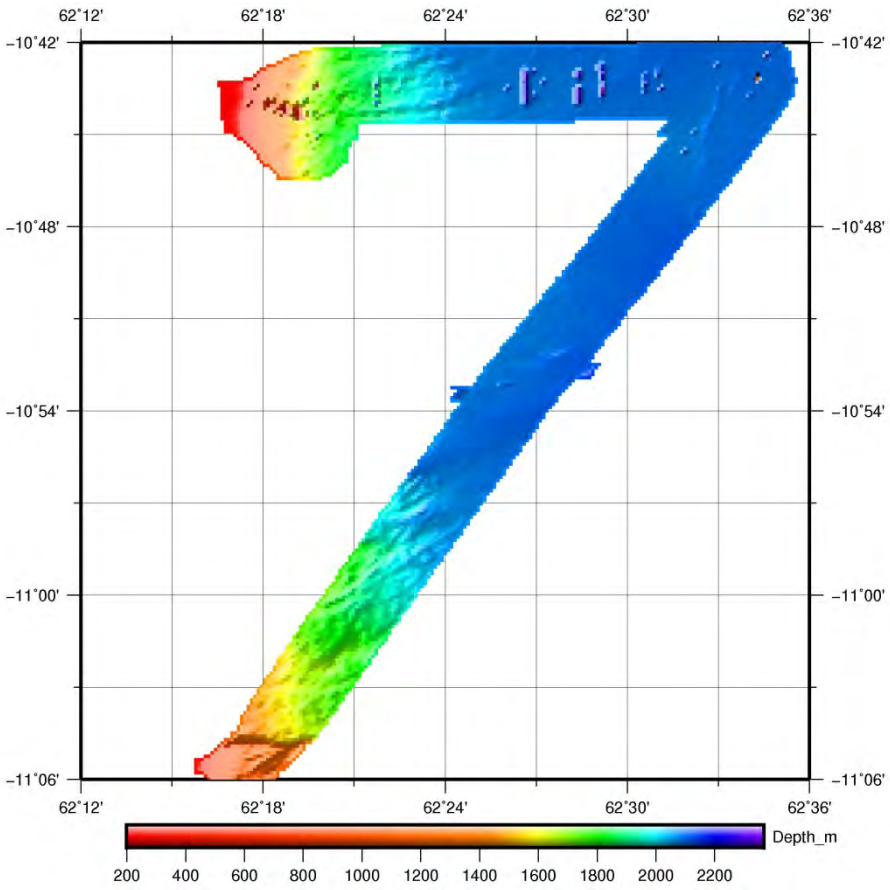

Figure 3.2.4. Bathymetry of the eastern slope of Saya de Malha Bank on the transit from Transect 3 to 4 (transects shown in inserted map in Fig. 3.2.8 below). The artefacts that appear on the image reflect the inadequate processing of the data.

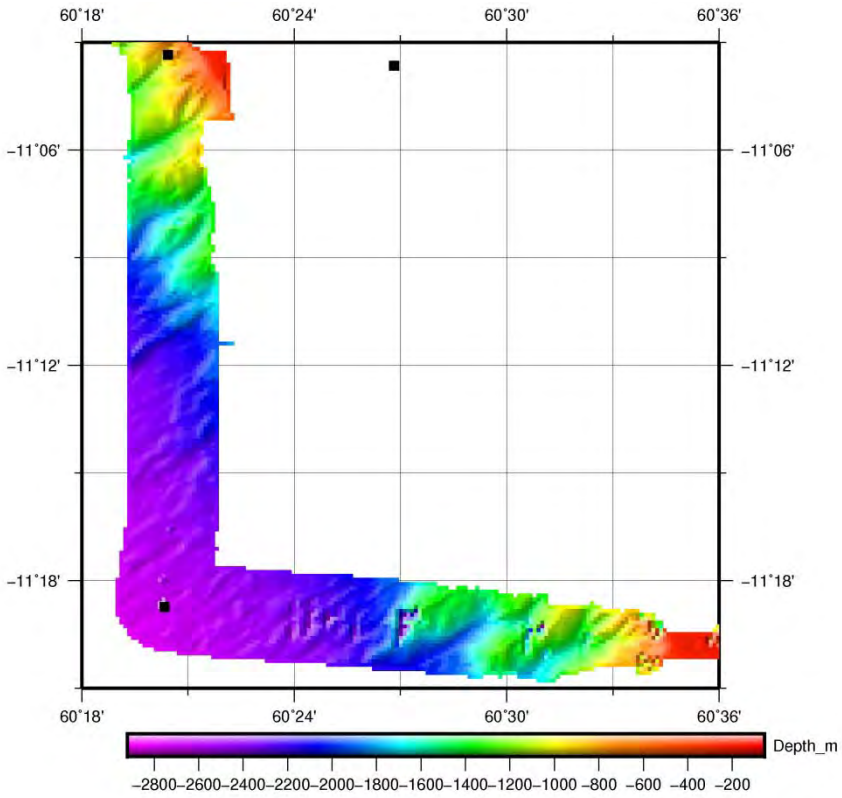

Figure 3.2.5. Bathymetry of the western slope of Saya de Malha Bank on the transit from Transect 4 to 5 (transects shown in inserted map in Fig. 3.2.8 below). The artefacts that appear on the image reflect the inadequate processing of the data.

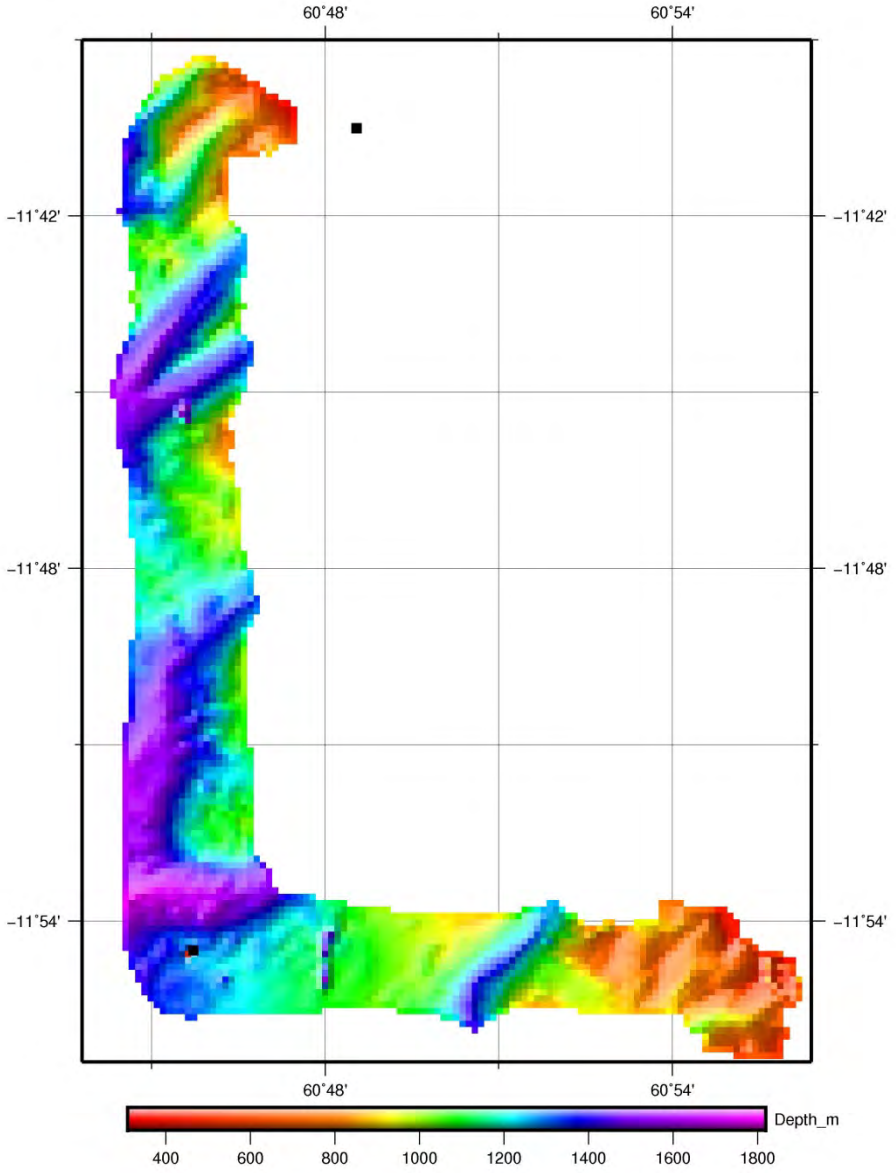

Figure 3.2.6. Bathymetry of the western slope of Saya de Malha Bank on the transit from Transect 6 to 7 (transects shown in inserted map in Fig. 3.2.8 below). Note the well-defined structures of the seabed.

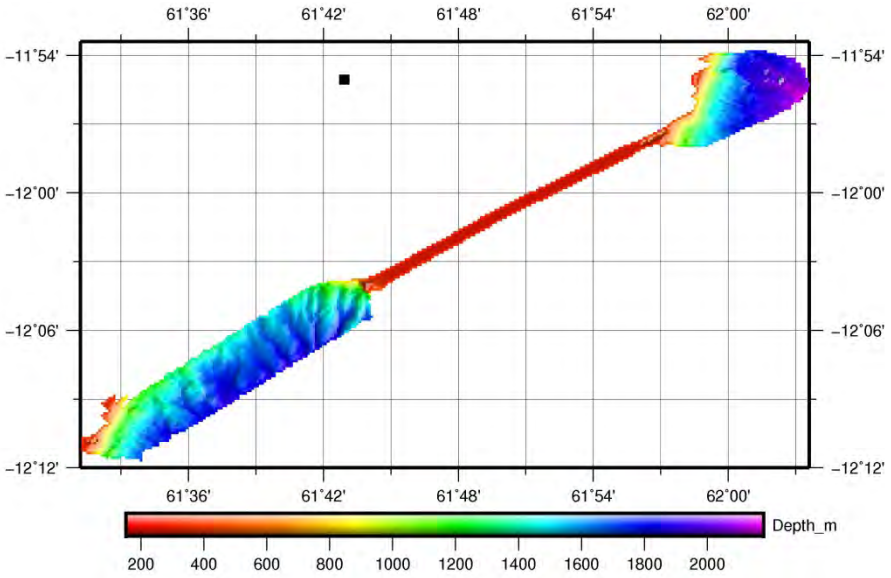

Figure 3.2.7. Bathymetry of the western slope of Saya de Malha Bank on the transit from Transect 7 to 8 (transects shown in inserted map in Fig. 3.2.8 below). Note the very narrow swath (in red), due to the very shallow plateau, between the deep areas.

Latitudinal depth profiles

Depth profiles of the Saya de Malha Bank along the 8 transects at different latitudes (Fig. 3.2.9) illustrate the shallow areas to the northeast, and the gradual deepening of the plateau towards the south. These data were generated from the EK80 single-beam sounder. Characteristic small and large very shallow rather flat-topped subareas occur on the northernmost sections. Slopes on the western and eastern sides are steep in most transects, and most profiles suggest that the margins of the bank are comparatively shallow. It was noteworthy that the 200-300m deep plateau troughs indicated in several global bathymetry sources (e.g. GEBCO) to occur in northern parts of the bank (transects 1-2) were non-existent.

The 'Nansen Sinkhole'

On Transect 5, at 62°00.488E, 11°24.540 S, a particular feature occurred, provisionally named the 'Nansen Sinkhole' (Fig 3.2.9, 3.2.10). Surrounded by the 260m deep seabed, the hole is circular at the rim and has nearly vertical walls and a wide conical shape. The bottom depth at the centre is approx. 385m, so the depth of the cone is about 125m. The ROV inspection of the hole revealed almost sediment-free steep rock from top to bottom, and some sediment at the bottom, including coral debris presumably fallen from the edges above.

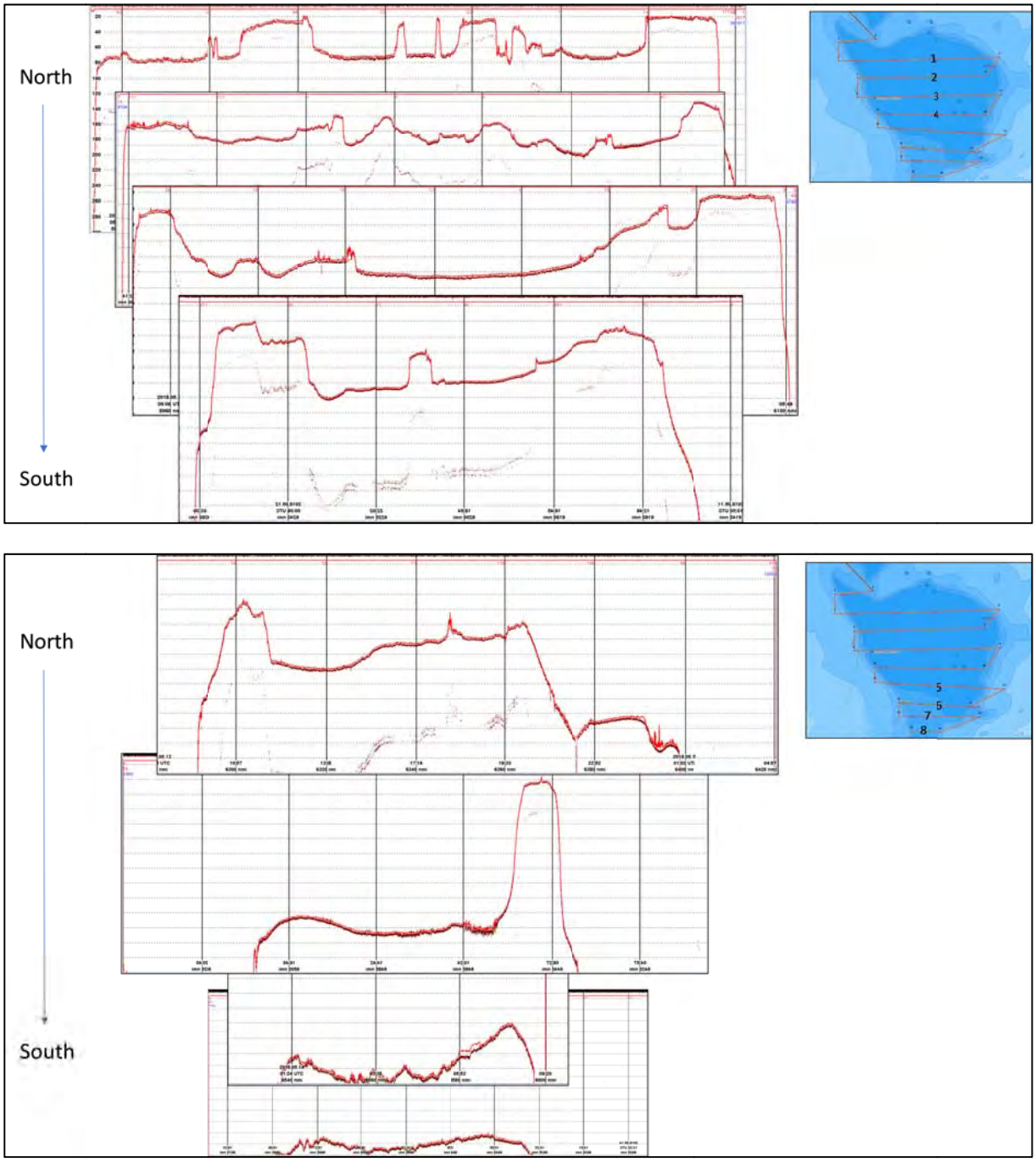

Figure 3.2.8. Depth profiles (0-300m) along Transects 1-4 (upper) and 5-8 (lower) of the Saya de Malha Bank. Data from the EK80 single-beam sounder, 38 KHz. The relative latitudinal positions of the transects are approximate.

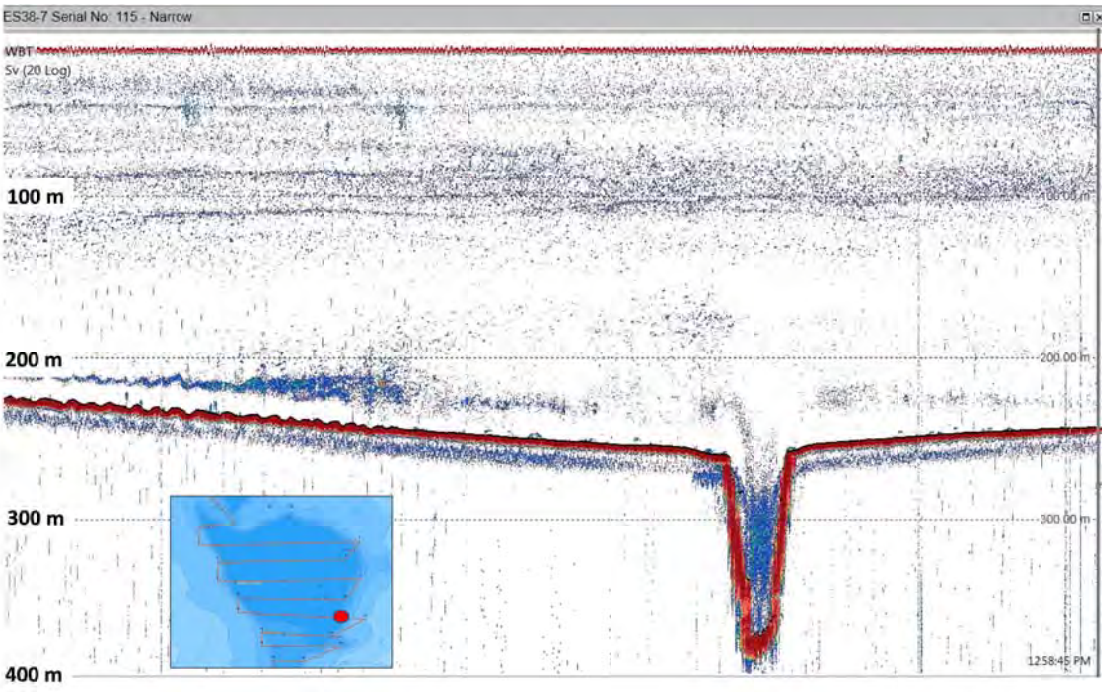

Figure 3.2.9. The prominent hole provisionally named the 'Nansen Sinkhole', and its approximate locations on Transect 5 of the Saya de Malha survey. Depth profile from EK 80, 38 KHz.

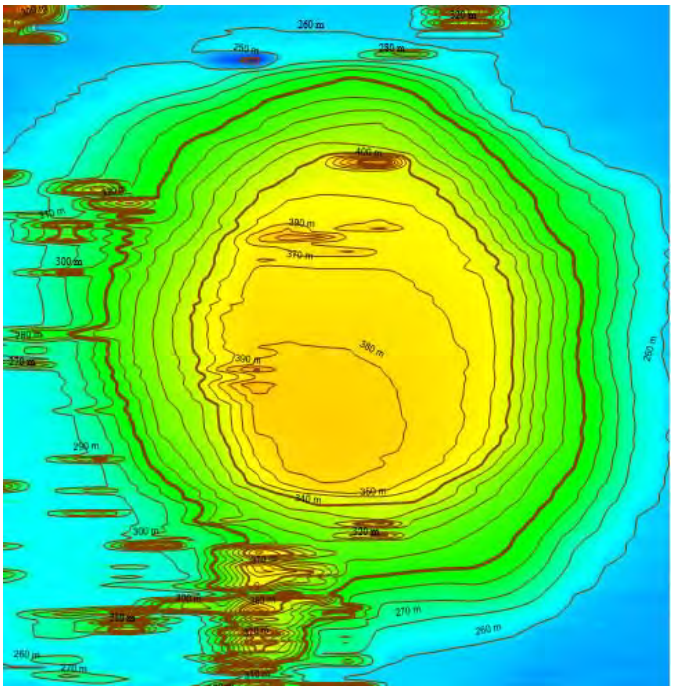

Figure 3.2.10. Bathymetry of the 'Nansen Sinkhole' derived from data from the multibeam echosounder. The data have not been post-processed to remove erroneous records, e.g. along the edges of the hole.

Benthic substrates

The Video Assisted Multi Sampler (VAMS) system was used to collect sediment samples at different depths. The VAMS consist of a sampling platform with hydraulic operated grabs, current meter, CTD and sonar. At each station, bottom sediment was collected using the 5 hydraulic grabs with 4 of them having double chambers.

The 1cm top layer of sediment is taken off for chemical analyses and subsamples were taken for the following:

- Total Hydrocarbon Count (THC)
- Total Organic Content (TOC)
- Heavy metals (HM)

The top 5cm layer was taken for meiofauna (Meio) and grain-size analyses (GSA).

Preliminary results for grain-size analysis (GSA) and total organic and carbonate content (TOC/TCC) are given in this report. Grain size is considered as one of the most significant physical properties of sediments. Granulometry can provide essential information related to the source of sediment, transportation patterns and depositional characteristics. Sediment is also the major site for organic matter which is decomposed mainly by bacteria and thus interchanging nutrients with overlying waters.

Grain-size analysis

A sieve-shaker with 6 different sieve mesh sizes was used to perform the granulometric analysis. The sieve mesh sizes utilised are: 2000 μm, 1000 μm, 500 μm, 250 μm, 125 μm and 63 μm. The fraction remaining in the pan is taken as 20 μm fraction. The weight retained in each sieve is noted and all data is integrated into Gradistat Package (Blott and Pye, 2001) to calculate the related statistics.

Total organic and carbonate content

Sediment subsamples are placed in crucibles and the weight is noted. The weight loss is measured after heating the samples overnight at 105 °C, at 550 °C for 4 hours to remove organic matter and at 1000 °C for 2 hours to remove the carbonates. The percentage of total organic matter (% TOC) and total carbonate content (TCC) are calculated as shown hereunder:

% TOC = [pre-ignition weight (105°C) (g) - post-ignition weight (550°C) (g)] / pre-ignition weight (105°C) (g) * 100)

% TCC = [post-ignition weight (g) (550°C) – weight after 1000°C burn out (g)]/ pre-ignition weight (105°C) (g) * 100

Table 3.2.1. Description of grain-size analysis results of sediment samples from Saya de Malha and Nazareth Banks.

		Saya de Malha Bank – Leg I										Saya de Malha Bank - Leg II			Nazareth Bank	
Station no.		**SS1**	**SS3**	**SS4**	**SS8**	**SS9**	**SS13**	**SS15**	**SS21**	**SS25**	**SS26**	**SS36**	**SS40**	**SS41**	**SS44**	**SS49**
DEPTH /m		132	74	30	62	55	28	55	160	288	251	44-37	73	381	38	133
SAMPLE TYPE:		Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Moderately Sorted	Unimodal, Poorly Sorted	Unimodal, Moderately Sorted	Unimodal, Moderately Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Poorly Sorted	Unimodal, Moderately Sorted	Unimodal, Poorly Sorted
SEDIMENT TYPE:		Poorly Sorted Coarse Sand	Poorly Sorted Fine Sand	Poorly Sorted Very Coarse Sand	Poorly Sorted Coarse Sand	Poorly Sorted Very Coarse Sand	Poorly Sorted Medium Sand	Moderately Sorted Coarse Sand	Poorly Sorted Very Coarse Sand	Moderately Sorted Medium Sand	Moderately Sorted Coarse Sand	Poorly Sorted Very Coarse Sand	Poorly Sorted Fine Sand	Poorly Sorted Fine Sand	Moderately Sorted Very Coarse Sand	Poorly Sorted Very Coarse Sand
FOLK ANDWARD METHOD (Description)	MEAN:	Coarse Sand	Medium Sand	Coarse Sand	Coarse Sand	Coarse Sand	Coarse Sand	Coarse Sand	Coarse Sand	Medium Sand	Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Coarse Sand	Coarse Sand
	SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Moderately Sorted	Poorly Sorted	Moderately Sorted	Moderately Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Moderately Sorted	Poorly Sorted
	SKEWNESS:	Fine Skewed	Symmetrical	Symmetrical	Symmetrical	Very Fine Skewed	Coarse Skewed	Fine Skewed	Very Fine Skewed	Symmetrical	Symmetrical	Very Fine Skewed	Symmetrical	Very Coarse Skewed	Very Fine Skewed	Very Fine Skewed
	KURTOSIS:	Mesokurtic	Mesokurtic	Very Platykurtic	Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic	Very Platykurtic	Leptokurtic	Mesokurtic	Leptokurtic	Platykurtic	Leptokurtic	Mesokurtic	Very Platykurtic
	MODE (Φ)	0.500	2.500	2.500	0.500	0.500	1.500	0.500	1.500	1.500	0.500	0.500	2.500	2.500	-0.500	0.500

A total of 40 samples of sediment (representing 15 stations) were analyzed for granulometry, which included either duplicates or triplicates for most stations. The resulting weights in each sieve fractions were averaged (for duplicates and triplicates) and processed in Gradistat Package (Blott and Pye, 2001). The description of results is given in Table 3.2.1.

Total organic and carbonate content

A total of 26 sediment samples (representing 15 stations) were processed for TOC/ TCC, which included duplicates and triplicates for some samples. The results for TOC/TCC are given in Table 3.2.2.

These preliminary results indicate that the most frequently occurring grain size (mode) is **0.5 Φ**, which is **coarse sand** based on the Wentworth class size. Most of the stations with coarse sand are poorly sorted (1.0 – 2.0 Φ) (Folk, 1966). Only four stations (SS3, SS4, SS40 and SS41) have a mode of 2.5 Φ which indicate that the sediment type is fine sand. Further statistical analysis will be carried out and the most frequently occurring grain size at each station will be represented on a GIS map.

The percentage total organic content (TOC) of sediment samples collected at all stations varies between 2.37% and 7.68% (average = 4.02%) while the percentage total carbonate content (TCC) varies between 39.59 % and 42.78 % (average 41.38). The TOC and TCC of samples from Saya de Malha is not much different from samples collected in the nearshore waters of Mauritius (e.g. Albion lagoon: average TOC = 3.37 %, average TCC = 40.55%). The TOC and TCC of all samples collected will be represented on a GIS map for a better visual interpretation.

Table 3.2.2. Description of results of TOC and TCC of sediment samples from Saya de Malha and Nazareth Banks.

Station number	Total organic content (%)	Total carbonate content (%)
SS1(1)	3.385383606	40.82349456
SS1(3)	4.565930884	40.56889118
SS1(4)	3.668240644	41.12889122
SS4(1)	3.690253373	41.60404503
SS4(2)	3.67822656	41.43391133
SS4(3)	3.73457709	41.62283748
SS8(1)	4.208974779	41.03504749
SS8(2)	3.993189909	41.05659599
SS8(3)	4.048070841	40.53295933
SS3(2)	3.42715003	41.71541757
SS3(3)	3.388185654	41.7257384
SS3(4)	3.401846717	41.84557331
SS9(2)	5.240912933	40.67674407
SS9(3)	4.769922731	39.59404913
SS9(4)	4.446205184	40.60095385
SS13(2)	3.844276538	41.96684824
SS13(3)	4.468109514	41.4652799
SS15 G3	7.464300527	40.11376429
SS36 G1	3.135019594	42.29361661
SS40 G1	3.798792987	41.51292306
SS47	7.681780481	40.1313243
SS41 G4	3.153957529	42.24903475
SS26 G1	2.693869929	42.77977497
SS21 G1	3.059057147	42.40200083
SS49 G1	3.243868458	42.24258037
SS25 G4	2.372399341	42.69944619

3.3 Chemical oceanography and phytoplankton

The environmental setting of the biota, including harvestable resources, was poorly known and the aim was to characterize the physical and chemical properties, as well as pelagic primary productivity, of the waters in the survey area. Data collected in the study area would feed into databases for the Indian Ocean as a whole.

Nutrients

Saya de Malha

Water samples were collected at 22 CTD stations along the hydrographical transects during Leg I with an additional 5 CTD stations during Leg II of the cruise at the Saya de Malha Bank (Figure 3.3.1). This report includes preliminary results for the nutrient analysis (phosphate and silicate) of water samples collected from stations 391-415 in the Saya de Malha bank only. These were analyzed at the Mauritius Oceanography Institute.

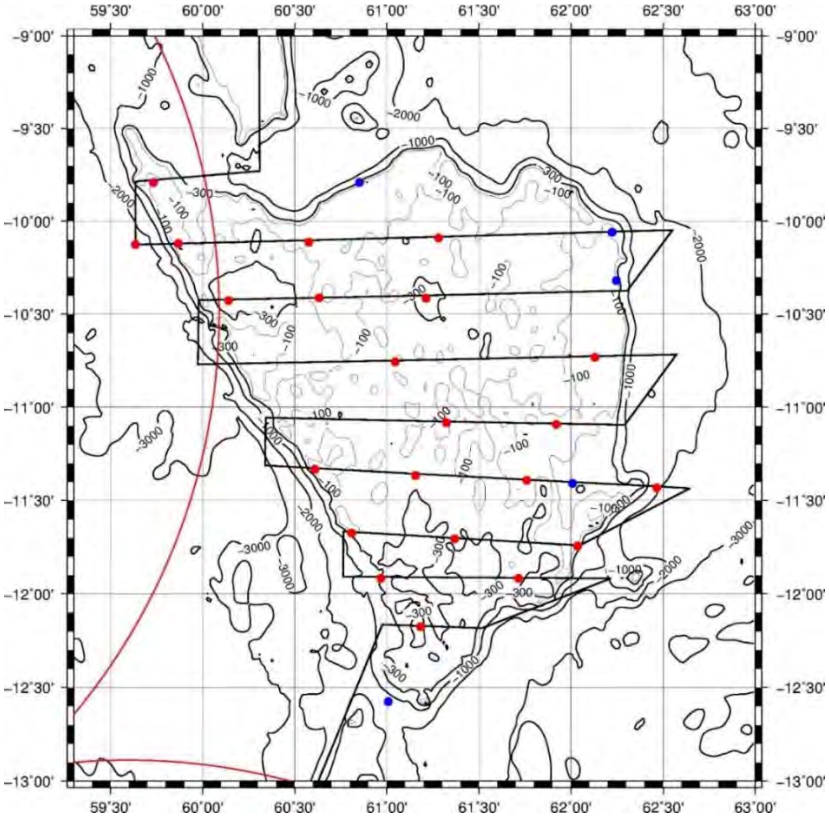

Figure 3.3.1. Sampling stations at Saya de Malha for nutrient to be analyzed at the Mauritius Oceanography Institute (MOI) *(red dots - leg I, blue – leg II).*

In addition, 216 samples were collected from the same and some additional stations to be analyzed by the Institute of Marine Research, Norway. Samples represent 32 CTD stations. *[Note: Chloroform was not added to the samples at station 391 to 402].*

Nazareth Bank

A total of 21 seawater samples to be later analyzed for nutrients were collected at 7 CTD stations on the Nazareth Bank (Figure 3.3.2).

A summary of the samples collected is at Annex II.

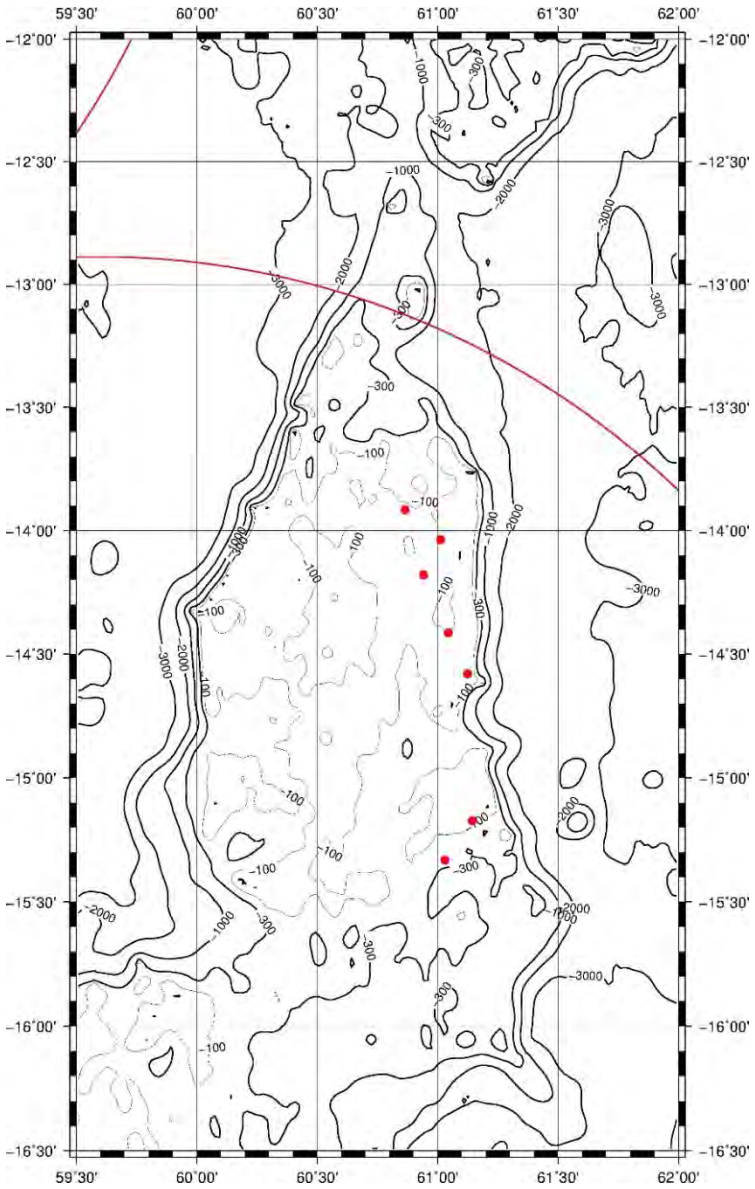

Figure 3.3.2. Sampling stations at Nazareth Bank for nutrients.

At the MOI, the concentrations of different nutrients were measured by automated colorimetric analysis using a nutrient analyser (EasyChem Plus, Systea). The methodology of nutrients is based on the Easychem plus Method EASY which describes the preparation and colorimetric analysis of the nutrients on the analyser.

The determination of phosphate content is based on the molybdenum blue method (Murphy & Riley, 1962; Grasshoff *et al*., 1999). The phosphate present in the samples reacts with

ammonium molybdate and potassium antimony tartrate in an acidic medium to form an antimony-phospho- molybdate complex which is further reduced to an intensely coloured molybdenum blue complex by ascorbic acid. Absorbance is measured at 880 nm. The preparation and colorimetric analysis of phosphate is based on the EasyChem Plus method EASY-PO4SW-01 rev.0 and EPA 365.1.

The determination of dissolved silicon compounds in natural waters is based on the formation of a yellow silico-molybdic acid when an acid sample is treated with a molybdate solution (Chow & Robinson, 1953; Grasshoff *et al*., 1999). The absorbance is measured at 880 nm. The preparation and the colorimetric analysis of silicate is based on the EasyChem Plus method EASY-Sio2SW - 01 rev.0 and EPA 370.1.

A total of 145 seawater samples for nutrients were collected during the cruise survey. A status of the samples analyzed thus far is shown below in Table 3.3.1. The distribution of phosphate (Figure 3.3.3) and silicate (Figure 3.3.4) which have been analyzed are shown in the series of graphs below. For ease of representation, 4 stations (sequential) have been grouped per graph.

Table 3.3.1: Geolocations and the depths of water samples collected in the Saya de Malha Bank during the survey, with the status of sample analysis (✓- analysis completed; blue boxes- samples collected at these stations at the specified depths)**.**

Leg	Station	GPS Position		Date and Time (UTC)	Depth (m)	Nutrient Samples	Samples analyzed
I	391	09 47.50	059 43.90	5/7/2018 13:47	131	✓	✓
	392	10 07.55	059 38.10	7/5/2018 20.35	2347	✓	✓
	393	10 07.18	059 52.08	8/5/2018 01.15	74	✓	✓
	394	10 06.79	060 34.51	8/5/2018 10.00	27	✓	✓
	395	10 05.43	061 16.83	8/5/2018 16.05	29	✓	✓
	396	10 02.80	062 32.99	9/5/2018 00.31	2172		
	397	10 24.88	061 12.75	9/5/2018 11.17	68	✓	✓
	398	10 24.73	060 37.93	9/5/2018 16.07	60	✓	✓
	399	10 25.70	059 54.08	9/5/2018 22.55	1204		
	400	10 25.62	060 08.38	10/5/2018 01.40	51	✓	✓
	401	10 46.18	059 58.42	10/5/2018 06.10	2129		
	402	10 45.39	061 02.70	10/5/2018 16.39	128	✓	✓
	403	10 43.91	062 07.79	11/5/2018 02.41	26	✓	✓
	404	10 43.11	062 34.27	11/5/2018 07.47	2125		
	405	11 05.54	061 55.17	11/5/2018 13.41	52	✓	✓
	406	11 04.98	061 19.39	11/5/2018 19.20	120	✓	✓
	407	11 03.68	060 26.79	12/5/2018 01.51	61		
	408	11 18.66	060 20.31	12/5/2018 04.32	2700		
	409	11 19.98	060 36.53	12/5/2018 08.19	195	✓	✓
	410	11 21.96	061 09.33	12/5/2018 13.50	156	✓	✓
	411	11 23.53	061 45.57	12/5/2018 19.50	109	✓	✓
	412	11 25.94	062 27.90	13/5/2018 01.42	2068	✓	
	413	11 44.65	062 02.11	13/5/2018 06.33	284	✓	✓
	414	11 42.35	061 22.04	13/5/2018 11.55	248	✓	✓
	415	11 40.49	060 48.52	13/5/2018 17.39	265	✓	✓
	416	11 54.52	060 45.63	13/5/2018 21.17	1309		
	417	11 55.02	060 58.00	13/5/2018 23.54	328	✓	
	418	11 55.02	061 42.86	14/5/2018 06.13	265	✓	
	419	09 39.52	060 42.87	14/5/2018 09.35	2078		
	420	12 10.55	061 10.93	14/5/2018 16.58	207	✓	

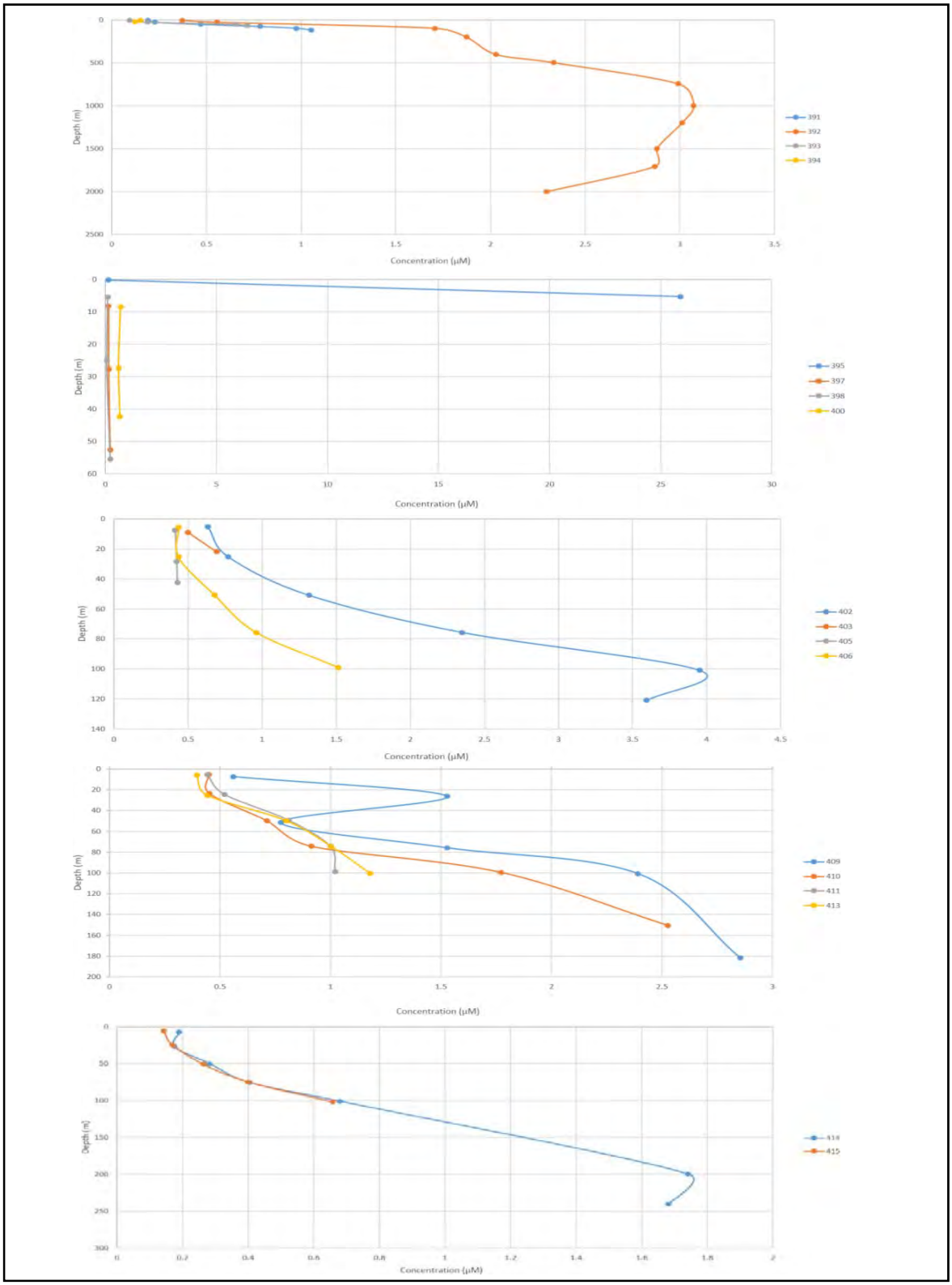

Figure 3.3.3. Phosphate measurement from water samples collected at the specified stations (numbered 391-415) and at different depths.

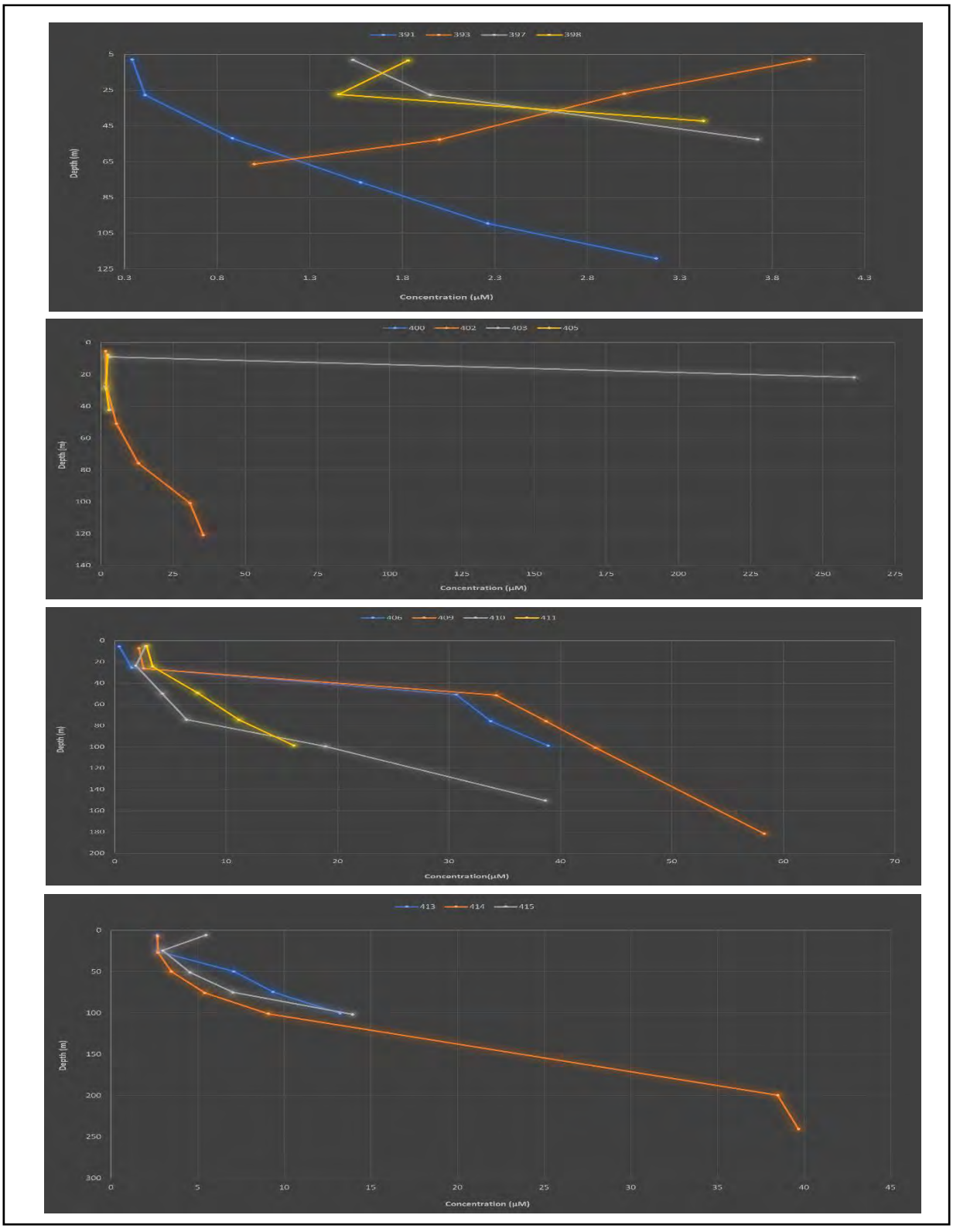

Figure 3.3.4. Silicate measurements from water samples collected at the specified stations (numbered 391-415) and at different depths.

The preliminary results indicate that the concentrations of phosphate and silicate increase with depth. The increase in phosphate levels might be due to the fact that the phosphate sinks into deeper water as a result of decay by bacteria and is returned to the depleted surface water through upwelling. On the other hand, high concentrations of silicate at an increasing range from 0.01 µM to 163 µM at a depth of 2000 m has been recorded at station 392 (Figure 3.3.5). Silicate is an essential nutrient for diatoms and radiolaria as they utilize silicate to form their skeletal parts. The concentrations increase with depth as the dead diatoms and radiolaria sink into the deep sea. In addition, the silicate content also increases with the age of water mass.

The samples were also analyzed for ammonia; however, the concentration of ammonia was below the detectable limit (<0.01µM) at stations 391 to 398.

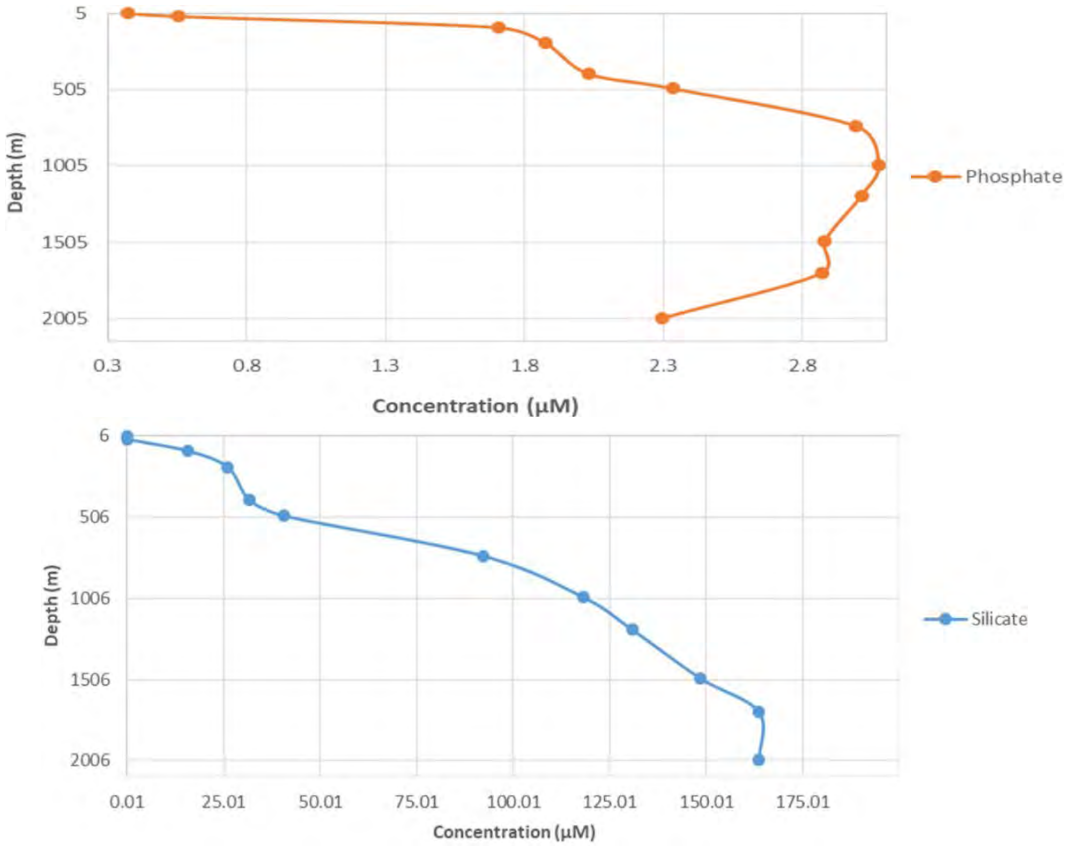

Figure 3.3.5. Silicate and phosphate measurements from water samples collected at station 392.

Total Alkalinity and pH

Primary data: Total Alkalinity (TA) and pH_{tot}

The average standard deviation of the triplicate TA measurements (n=247) is 1.9 µmol.kg^{-1}. The average difference between the measurements of CRM total alkalinity and their nominal value did not exceed ±2.6 µmol.kg^{-1}, when the batch was freshly opened. Hence, the total alkalinity data were not corrected for any potential drift in the normality of the titrant and the

standard deviation reflects the accuracy of the volume of seawater on which titration was performed.

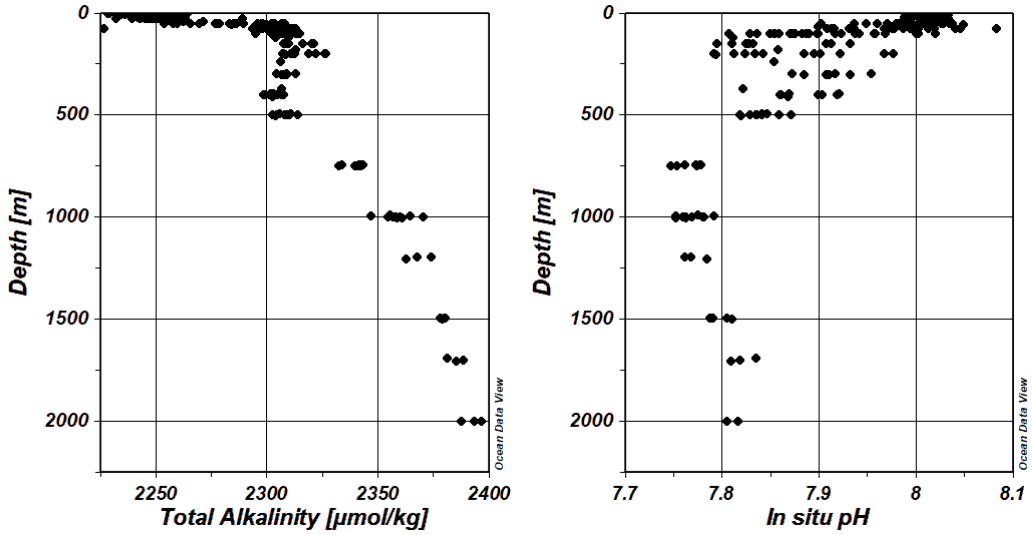

Figure 3.3.6. Vertical profiles of total alkalinity (left) and pH_{tot} (*in situ*, right). All bottle data merged (cruise DFN2018406).

TA (Fig. 3.3.6) ranges from 2224.9 µmol.kg^{-1} and 2396.4 µmol.kg^{-1} with higher values at depth than in surface. In the mixed layer zone, down to 150 m, TA is scattered and exhibits a strong dependency on salinity. A significant relationship (r^2=0.95, n=211) is found with salinity in this region (Fig. 3.3.7).

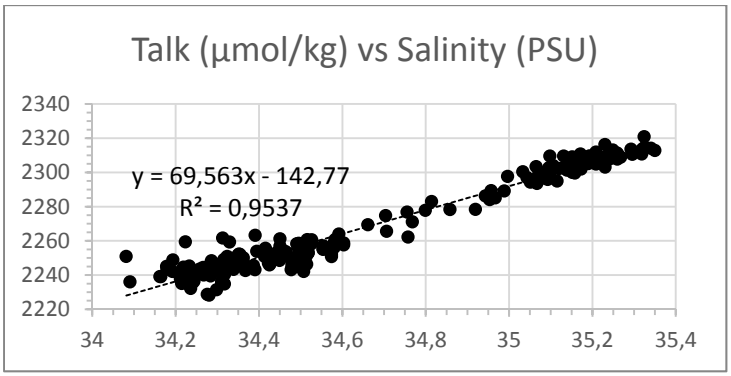

Figure 3.3.7. Total alkalinity versus salinity in the mixed layer zone (0-150 m - n=211).

pH_{25} was determined spectrophotometrically at each depth of the CTD profiles and, occasionally, discrete samples were collected at 4 m depth using the underway thermosalinograph water outlet. The average standard deviation of the duplicate measurements (n=247) is lower than 0.001. *In situ* pH_{tot} was calculated from pH_{25}, conductivity, temperature and pressure.

Vertical profiles of pH_{tot} show a minimum value of about 7.750 at 1000 m that stabilizes around 7.78 at greater depths (Fig. 3.3.6). Above 500 m, pH_{tot} exhibits a great variability with another minimum at depths of 150-200 m and values between 7.898 and 8.083 in surface.

Partial pressure of carbon dioxide (pCO_2), dissolved inorganic carbon concentration (DIC) and saturation state (Ω)

The speciation of the carbonate system is computed from primary data and ancillary parameters acquired during the CTD cast, using a well described set of constants.

The partial pressure of carbon dioxide (pCO_2) ranges between 402 µatm and 452 µatm at the surface and increases steadily with depth to reach a first maximum between 100 m and 200 m depth with values slightly below 800 µatm (Fig. 3.3.8). A second maximum of a similar amplitude is observed deeper in the water column, around 750 m.

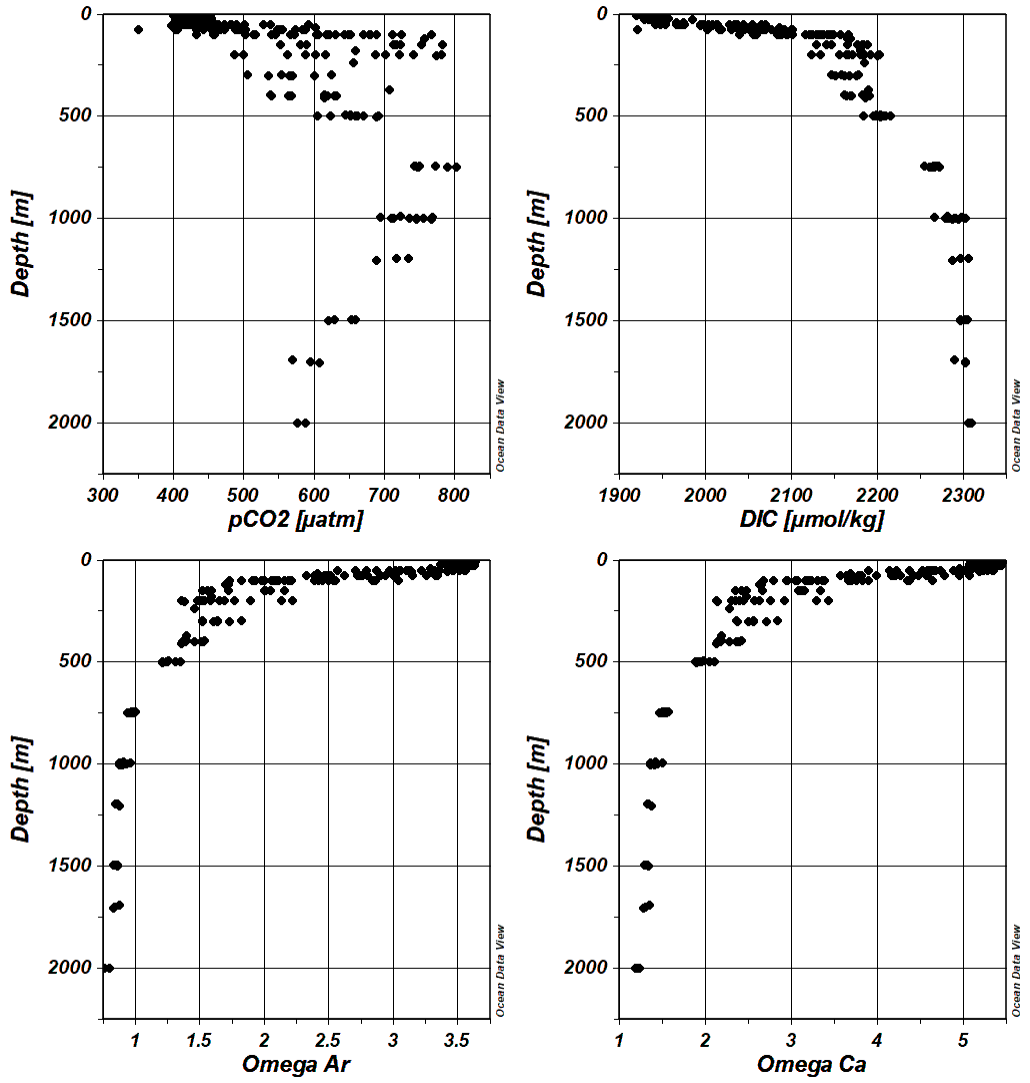

Figure 3.3.8. Vertical profiles of calculated parameters pCO_2 (upper left), DIC (upper right), Ω_{Ar} (lower left) and Ω_{Ca} (lower right). All bottle data merged - cruise DFN2018406.

Dissolved inorganic carbon (DIC) concentration increases with depth from a minimum value of 1920 µmol.kg^{-1} in surface to a maximum value of 2308 µmol.kg^{-1} at 200 m (Fig. 3.3.8). The lower water column is characterized by DIC concentrations around or higher than 2300 µmol.kg^{-1}.

Saturation depth profiles for aragonite and calcite are similar in shape (Fig. 3.3.8). While calcite remains oversaturated (Ω_{Ca} above 1.2) in the entire column, undersaturation is reached for aragonite at depths of 750 m and deeper. At the deepest sampling, Ω_{Ar} averages 0.78 (1.22 for Ω_{Ca}) while surface values are around 3.5 for aragonite and 5.2 for calcite.

Dissolved oxygen concentration is inversely correlated to CO_2 concentration (r^2=0.95, n=175) as a consequence of organic matter respiration and photosynthesis in the water column (Fig. 3.3.9).

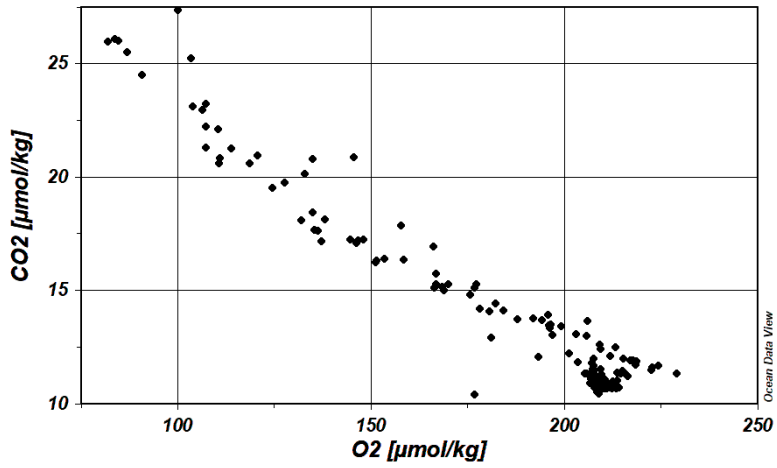

Figure 3.3.9. Carbon dioxide concentration as a function of oxygen concentration in the top 150 m of the water column.

Discussion

Total alkalinity values in surface (Fig. 3.3.6) are in agreement with historical data obtained by Fry *et al.* (2015) at a similar latitude in the Indian Ocean. Surface water pCO_2 (Fig. 3.3.8) is in overall equilibrium with atmospheric CO_2 concentration, on average 405 ppmV in May-June 2018 (Source NOAA's ESRL GMD database, station SEY on Mahe Island, Seychelles). On Figure 3.3.10, the area centered on 10°S-61°E of the northern Saya de Malha region exhibits a strong signature with a ΔTA up to -25 µmol.kg^{-1} and a ΔpCO_2 up to +45 µatm, compared to adjacent areas. Such a signal is characteristic of marine calcification ($2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + CO_2$) and has been captured in the northern part of the Saya de Malha bank, where corals and coralline algae (*Halimeda*) predominate in a very shallow habitat (sometimes shallower than 25 m).

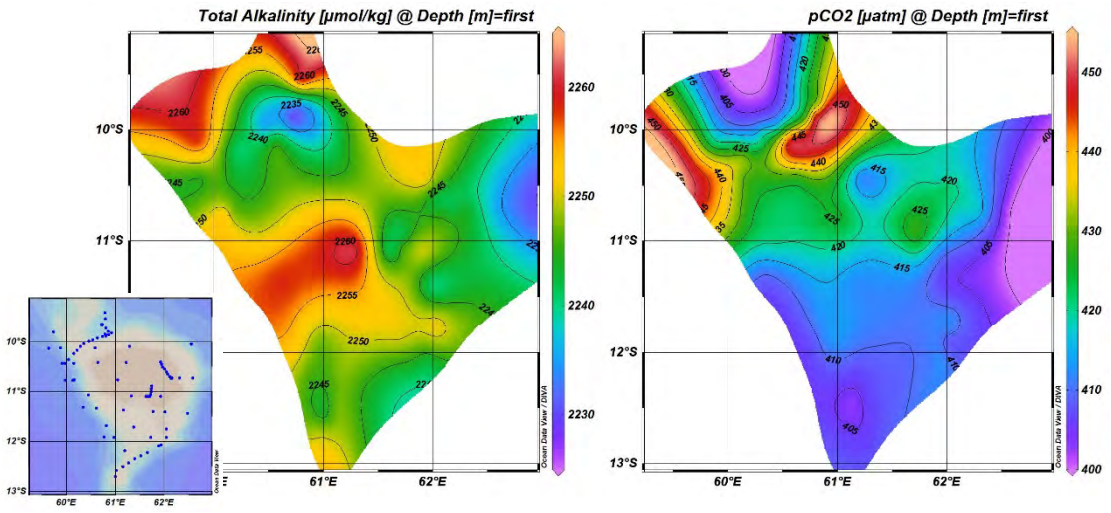

Figure 3.3.10. Mapping of surface total alkalinity and pCO_2 in the Saya de Malha region in May 2018.

The depth of the aragonite saturation horizon (Ω_{ar} =1) was found lower than 1000 m along 60-62°E, in 1994-1996 (Johnson *et al*., 2002) and rose to around 750 m, based on our estimate. A shoaling of the aragonite saturation by 44 m has been described by Sarma *et al.* (2002) in the Indian Ocean between 1974 and 1994 by considering an increase of anthropogenic CO_2 only. Adding an increase of apparent oxygen utilization (AOU) to the anthropogenic effect, as a result of the broad anthropogenic disturbance on the open ocean, the same authors found a shoaling by 124 m of the aragonite saturation state. The aragonite saturation in surface waters corresponds to the climatological value of 3.5 found by Jiang *et al.* (2015) between May and October at 20°S in the Western Indian Ocean.

Phytoplankton and their photophysiology

The main aim was to investigate the spatial distribution and photophysiological conditions of primary producers from the Saya de Malha Bank. The diversity and spatial distribution of micro-phytoplankton was documented. The photophysiology of microphytoplankton was also determined. This study presents the first reporting of photophysiological studies using chlorophyll a fluorescence technique in the waters of Saya de Malha.

Annex VII provides detailed descriptions of methods and additional density graphs for diatoms and dinoflagellates.

Samples derived

The sampling was done on Leg I and Leg II on the Saya de Malha region, as well as on the Nazareth Bank. The first leg involved some 32 stations divided into four main categories namely very shallow (<50m), shallow (~150m), medium (~400m) and deep (≥1000). The second leg of the sampling focused on more intense sampling at selected sites. On Nazareth only four locations were sampled. The respective station numbers with their appropriate depths are given in Table 3.3.2.

Collection and preservation of micro-phytoplankton

While deploying the CTDs, water samples for micro-phytoplankton analyses were collected using Niskin bottles from two different depths, namely near-surface (4-8m) and upper water layer (24-28m) at different stations. Surface samples (0m) were also collected through bucket sampling. Microphytoplankton samples were collected using a 5 μm mesh-sized phytoplankton net.

Additionally, at 8 stations microphytoplankton samples were collected using a 10 μm mesh-sized net, with a diameter of 35 cm, which was hauled upwards (at less than 0.1 m s^{-1}) from 30 m to the surface. Samples were preserved in 1% Lugol's solution and refrigerated for later identification of major groups of microphytoplankton and community structure analyses. A total of 186 samples have been collected for phytoplankton and chlorophyll analyses.

Identification of microphytoplankton and determination density and community structure

Quantification and identification of micro-phytoplankton was carried out using a Sedgewick Rafter Counting Chamber under a light microscope at magnification x100, x200 and x400. Although the preserved samples are stable for a long period of time, microphytoplankton will be analyzed within two months following collection. Micro-phytoplankton will be categorized into three groups: diatoms, dinoflagellates and cyanobacteria and micro-phytoplankton densities will be presented as cells L^{-1}. Following identification to genus level, Simpson's Diversity Index and Similarity Index analyses will be carried out at each site.

Samples collected from the CTDs and hauling methods will be used for quantitative and qualitative assessments, respectively.

Table 3.3.2. Sampling stations and zones at Saya de Malha & Nazareth Bank, Mascarene Plateau.

Sampling Leg	**Stations /Zones**	**CTD#**	**Echo-Depth (m)**	**GPS coordinates**	**Sampling Date**	**Sampling Time (MRU)**	**Sampling depths (m)**	**Chl a**	**PAM**	**Lugol**	**PhytoHaul**	**Remarks**
I (Saya de Malha)	1	391	131	09 47.50S; 059 43.90E	07/05/18	17:47	0, 5, 10, 25	√	√	√		
	2	392	2347	10 07.55S; 059 38.10E	07/05/18	00:30	0, 5, 28	√	×	√		
	3	393	74	10 07.18S; 059 52.08E	08/05/18	05:30	0, 7, 27	√	√	√		PAM done on benthic samples: Green algae (1&2), red algae (1&2), Brown epiphytes, Sand covered leafy stuff, brown/orange thin with white arms, red coralline algae, anemone; samples to be identified jointly with Mr Ramah (AFRC)
	4	394	27	10 06.79S; 060 34.51E	08/05/18	14:00	0,7,22	√	√	√		PAM done on benthic samples: Corals healthy & bleached (Heliopora & Porites species), Other corals (Cyphastrea,

Sampling Leg	Stations /Zones	CTD#	Echo-Depth (m)	GPS coordinates	Sampling Date	Sampling Time (MRU)	Sampling depths (m)	Chl a	PAM	Lugol	PhytoHaul	Remarks
												Favites (HL&BL), Halimeda (big & small leaves), Dictyosphearia, Tubastrea (aposymbiotic), Sponges (orange, red); samples to be identified jointly with Mr Ramah (AFRC)
	5	395	29	10 05.43S; 61 16.83E	08/05/18	20:05	0, 5, 25.7	√	√	√	√	
	6	396	2172	10 02.80S; 62 32.99E	09/05/18	06:00	0, 7, 27	√	√	√		
	7	397		10 24.88S; 61 12.75E	09/05/18	15:00	0, 8.139, 28.280	√	√	√	√	
	8	398		10 24.73S; 60 37.93E	09/05/18	20:30	0, 5.39, 24.88	√	√	√		
	9	399		10 25.70S; 59 54.08E	10/05/18	03:00	0, 7.82, 27.224	√	×	√		
	10	400	51	10 25.62S; 60 08.38E	10/05/18		0, 8.159, 27.224	√	√	√		
	11	401	2,100	10 46.18S; 59 58.42E	10/05/18	10:00	0, 4.112, 25.717	√	√	√		

Sampling Leg	Stations /Zones	CTD#	Echo-Depth (m)	GPS coordinates	Sampling Date	Sampling Time (MRU)	Sampling depths (m)	Chl a	PAM	Lugol	PhytoHaul	Remarks
	12	402		10 45.39S; 61 02.70E	10/05/18	20:30	0, 5.362, 25.368	√	×	√	√	
	13	403		10 43.91S; 62 07.79E	11/05/18	6:30	0, 8.978, 21.441	√	√	√		PAM done on benthic samples: Seagrass species (2), spongy algae, brown encrusting algae (lobophyta?), red encrusting algae, halimeda-like green algae, reddish brown bubble algae, big leaf brown algae (brownish and reddish parts), Reddish/Brown feuille fries (epiphyte of seagrass), Mushroomy sponge (brown button type), greenish/bluish sponge, purplish sponge, orange ball sponge, filamentous outgrowing red algae, money foram (roundish leaf with a small

Sampling Leg	Stations /Zones	CTD#	Echo-Depth (m)	GPS coordinates	Sampling Date	Sampling Time (MRU)	Sampling depths (m)	Chl a	PAM	Lugol	PhytoHaul	Remarks
												stalk? Algae?); samples to be identified jointly with Mr Ramah (AFRC)
	14	404		10 43.11S; 62 34.27E	11/05/18	12:30	O, 8.16, 28.003	√	√	√		
	15	405		11 05.54S; 61 55.17E	11/05/18	17:30	0, 7.617, 28.810	√	√	√		
	16	406		11 04.98S; 61 19.39E	11/05/18	23:20	0,5.458, 25.425	√	√	√	√	
	17	407	61	11 03.68S; 60 26.79E	12/05/18	05:51	0, 7, 26	√	√	√		
	18	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled		Cancelled
	19	408	2700	11 18.66S; 60 20.31E	12/05/18	08:32	0, 5.6, 24.8	√	√	√		
	20	409	195	11 19.98S; 60 36.53E	12/5/18		0, 7.299, 26.297	√	√	√		
	21	410	156	11 21.96S; 61 09.33E	12/05/18		0, 5.83, 24.14	√	√	√		
	22	411	109	11 23.53S; 61 45.57E	12/05/18	23:50	0, 5.317, 24.7	√	X	√	√	
	23	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled	Cancelled		Cancelled

Sampling Leg	Stations /Zones	CTD#	Echo-Depth (m)	GPS coordinates	Sampling Date	Sampling Time (MRU)	Sampling depths (m)	Chl a	PAM	Lugol	PhytoHaul	Remarks
	24	412		11 25.94S; 62 27.90E	13/5/18	6:00	0, 4, 25	√	√	√		
	25	413		11 44.65S; 62 02.11E	13/5/18	10:30	0, 5.735, 25.297	√	√	√		
	26	414			13/05/18	16:00	0, 7, 27	√	√	√		
	27	415	265	11 40.49S; 60 48.52E	13/05/18	21:52	0, 5.841, 24.881	√	√	√		
	28	416	1302	11 54.52S; 60 45.63E	14/05/18	01:15	0, 8.86, 27.65	√	√	√		
	29	417	222	11 55.02S; 60 58.00E	14/05/18	3:43	0, 7, 27	√	X	√	√	
	30	418	265	11 55.02S; 61 42.86E	14/05/18	10:13	0, 5.47, 25.05	√		√	√	
	31	419	2078	11 55.06S; 62 02.32E	14/05/18	13:35	0, 7, 27	√		√		
	32	420	207	12 10.55S; 61 10.93	14/05/18	20:55	0, 5, 24	√		√	√	
II (Saya de Malha)		421						√		√		
		422						√		√		
		423						√		√		
		432	380				0-371	√	√	√		

Sampling Leg	Stations /Zones	CTD#	Echo-Depth (m)	GPS coordinates	Sampling Date	Sampling Time (MRU)	Sampling depths (m)	Chl a	PAM	Lugol	PhytoHaul	Remarks
	Block 36	VAMS						√		√		
	Block 38	VAMS						√		√		
	Block 39	VAMS						√		√		
	Block 40	VAMS						√		√		
		433	1719	12 05.02S; 61 52.73E	26/05/18	18:06						
		434	1068	12 34.55S; 61 00.43E	26/05/18	22:06	0, 5, 25	√	X	√		
Nazareth Bank		435	43	13 54.97S; 60 51.90E	27/05/18	08:49	0, 4, 25	√	√	√		
		436	36	14 02.27S; 61 00.74E	27/05/18	10:23	0, 5, 24	√	√	√		
		437	31	14 10.85S; 60 56.47E	27/05/18	13:21	0, 10, 30	√	√	√		
		438	32	14 24.87S; 61 02.64E	27/05/18	16:31	0, 9, 28	√	X	√		
		439	56	14 34.82S; 61 07.43E	27/05/18	18:49	0, 6, 24	√	X	√		
		440	170	15 10.42S; 61 08.64E	29/05/18	11:59	0, 9, 29	√	X	√		
		441	242	15 19.96S; 61 01.83E	29/05/18	17:52	0, 4, 25	√	X	√		

Determination of Chlorophyll a levels

Chlorophyll *a* analysis will be carried out in the onshore laboratory. The samples were filtered using a Whatman glass fibre filters (0.45 µm pore size) with a Millipore pump. Chlorophyll *a* pigment will be extracted using 90% acetone for 24 hours at 4^{o}C and their concentration will be determined by spectrophotometric reading (Spectronic® GenesysTM 8 spectrophotometer) (at UoM) and fluorometric method (at IMR, Norway).

Chlorophyll a fluorescence and estimated primary productivity

The fluorometric method was used to assess the photo-physiology of microphytoplankton by measuring the fluorescence of chlorophyll *a*, thus determining the relative electron transport rate (*rETR*) and non-photochemical quenching (NPQ) when exposed to a series of rapidly (10s) changing light climates (RLC) (McMinn *et al*. 2012). Using the RLCs the *rETR* and NPQ were estimated at each irradiance.

At each irradiance the respective relative electron transport rate (*rETR*) was calculated by the formula below:

$$rETR = 0.5 \times \Phi PSII \times PAR,$$

where PAR is the photosynthetically active radiance.

Non-photochemical quenching is the process by which oxygenic photoautotrophs harmlessly dissipate excess light absorbed as heat and fluorescence. When light energy absorption exceeds the capacity for utilization, there is a need to dissipate the energy to protect the light harvesting structures from photo-oxidative damage. It is given by the formula:

$$\mathrm{NPQ} = \frac{F_m - F_m'}{F_m'}$$

Estimated relative productivity for each site will be calculated using the formula Estimated Primary productivity, P, defined as P = ($rETR_{max}$× Chl).

Established methods described for phytoplankton and corals, respectively, will be employed.

Spatial variation of Chlorophyll *a* at Saya de Malha and Nazareth Banks

The highest chlorophyll *a* concentration (Fig. 3.3.11) was around 0.200mgm^{-3} which were at CTD 399, 400 and 410 whereas the minimum was around 0.005mgm^{-3}. The highest mean chlorophyll *a* concentration was recorded in the region of Saya de Malha Bank.

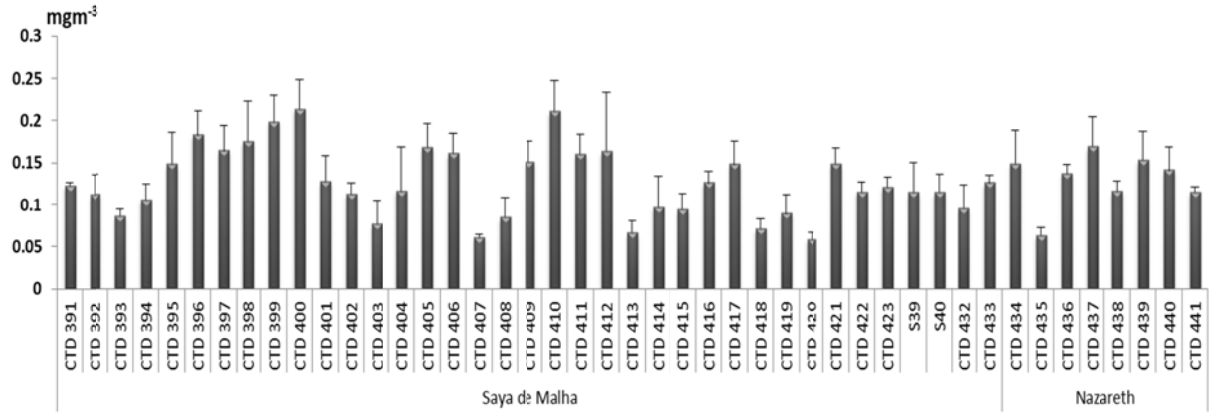

Figure 3.3.11. Surface (<0.5m) chlorophyll a variation at different CTD stations at Saya de Malha and Nazareth banks. 500ml of water sample was filtered for the chlorophyll a analysis. Bars represent mean±SD (n=3).

Density of Phytoplankton

The highest peaks of phytoplankton density which were recorded at Saya de Malha were at CTD numbers; 395, 397, 402, 406, 410, 421 and on average the density varied around 35000 cells/Liter (Fig. 3.3.12.).

At Nazareth Bank, the highest mean density of phytoplankton was recorded at CTD 437 and the lowest was at CTD 440. A decreasing trend was noted from CTD 434 up to CTD 440 (Fig. 3.3.13).

In addition to the composite graphs shown in the following, Annex VII contains additional density graphs for individual genera of diatoms and dinoflagellates.

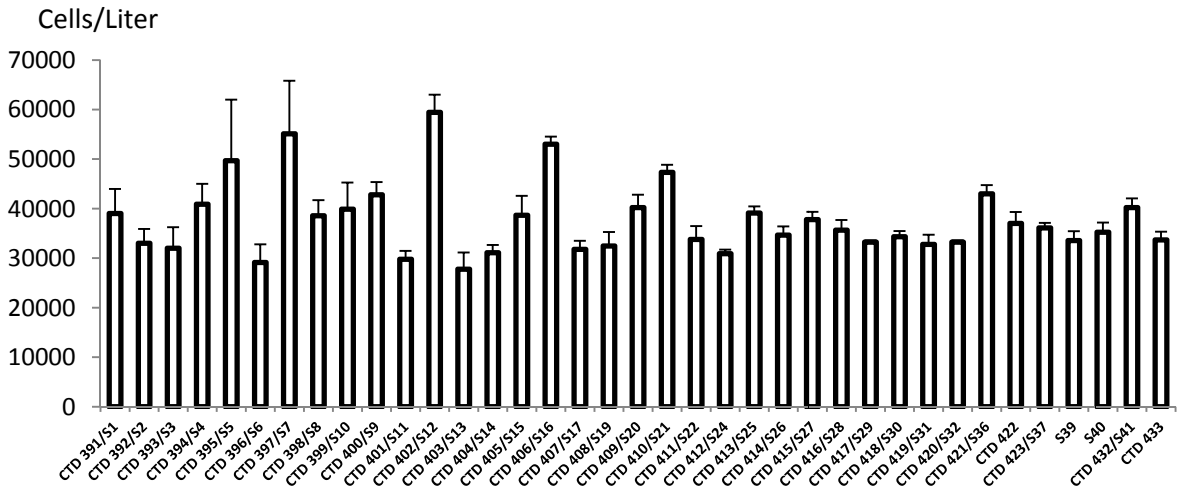

Figure 3.3.12. Spatial variation of phytoplankton at different CTD numbers around at Saya de Malha Bank.

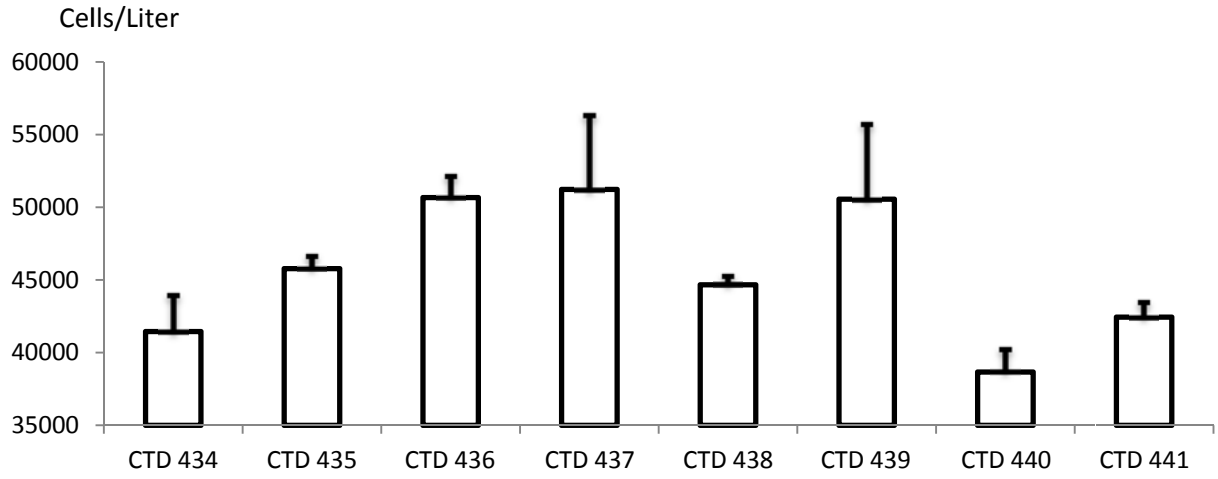

Figure 3.3.13. Spatial variation of phytoplankton at different CTD numbers around at Nazareth Bank.

Density of diatoms

The density of diatom at Saya de Malha varied mostly between 20000-25000 cells/liters and peaks were recorded at CTD 395, 397, 402 and 406 (Fig. 3.3.14).

The lowest average density of diatoms at Nazareth Bank was recorded at CTD 440 which was around 25,000 cells/liter and the highest was at CTD 436, 437 and 439 around 35,000 cells/liter (Fig. 3.3.15).

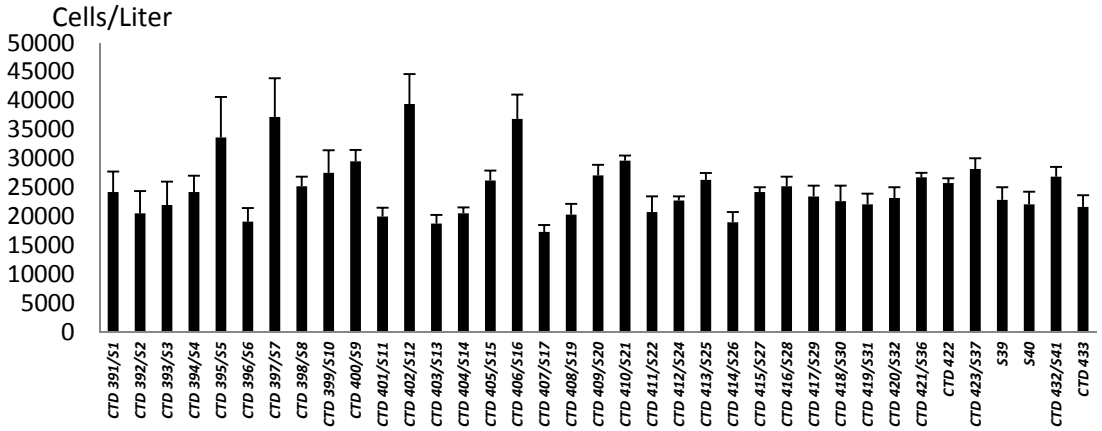

Figure 3.3.14. Spatial variation of diatom at different CTD number around at Saya de Malha Bank.

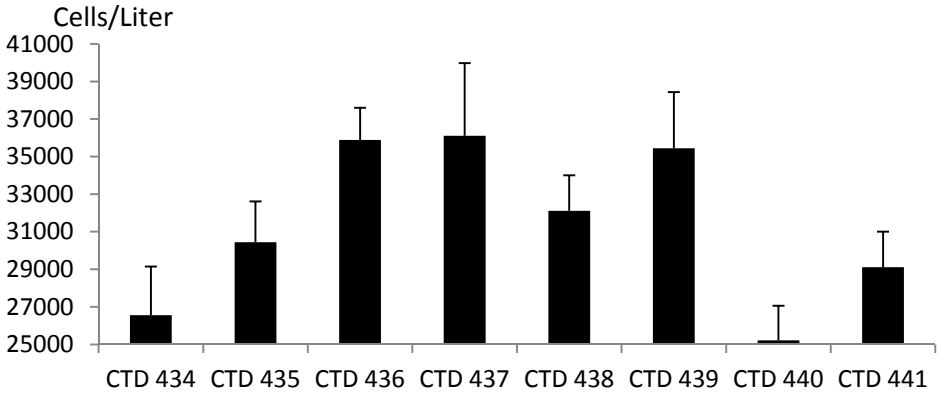

Figure 3.3.15. Spatial variation of diatoms at different CTD numbers around at Nazareth Bank.

Density of dinoflagellates

The highest peaks in the density of dinoflagellates were recorded at CTD 402 which was around 20,000 cells/liter and the average lowest density varied around 7000 cells/liter (Fig. 3.3.16).

The highest density of dinoflagellates at Nazareth Bank was around 14,000 cells/liter and the lowest varied around 13,000 cells/liter (Fig.3.3.17).

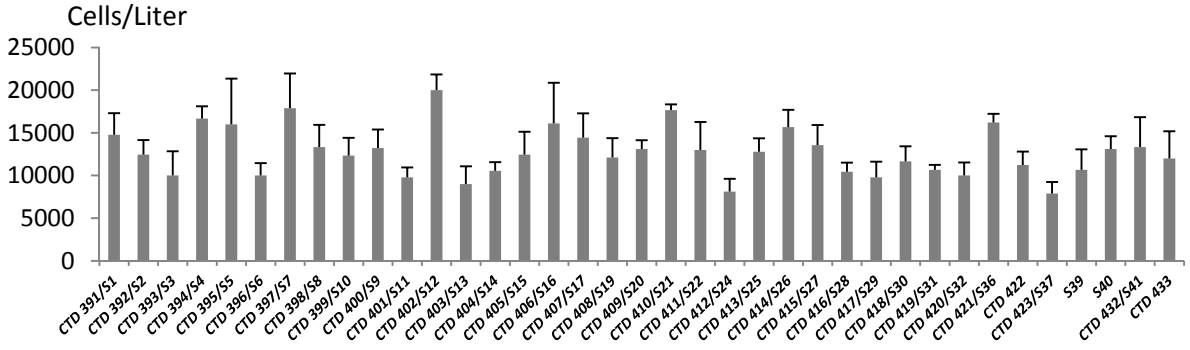

Figure 3.3.16. Spatial variation in the density of dinoflagellates at different CTDs at Saya de Malha Bank.

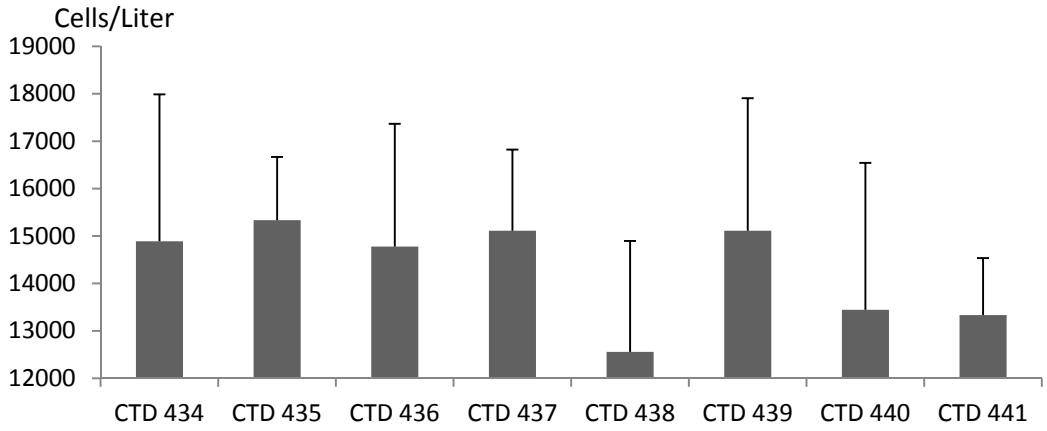

Figure 3.3.17. Spatial variation of dinoflagellates at different CTD numbers around at Nazareth Bank.

Common Species and composition of phytoplankton at Saya de Malha and Nazareth

Common diatom and dinoflagellate genera are illustrated in Figures 3.3.18 and 3.3.19. There was not a huge difference in the diversity distribution in seawater samples collected from CTDs at Saya de Malha and Nazareth banks.

Compositions of diatoms and dinoflagellates in Saya de Malha and Nazareth are illustrated by pie charts in Figures 3.3.20-3.3.23.

Amongst diatoms on Saya de Malha,, *Coscinodiscus* (16%) was more dominant followed by *Navicula* (15%), *Nitzchia* (13%) and *Chaetoceros* (10%) As for the other identified genera, the percentage varied between 1-5% (Fig 3.3.20)

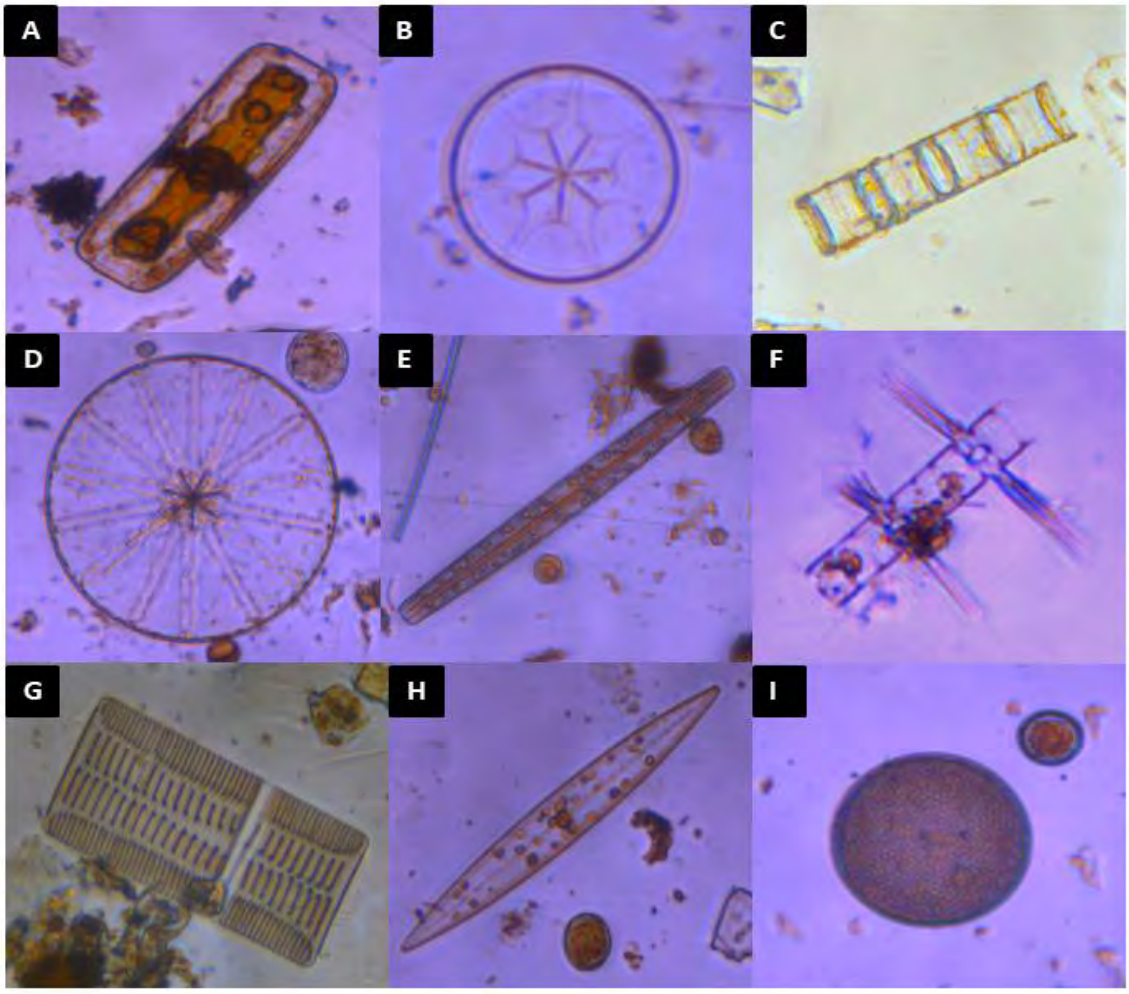

Figure 3.3.18. A: *Navicula* sp.; B: *Asteromphalus* sp; C: *Skeletonema* sp; D: *Actinoptychus* sp; E: *Thalassionema* sp; F: *Chaetoceros* sp; G: *Fragillaria* sp; H: *Nitzchia* sp; I: *Coscinodiscus* sp.

Figure 3.3.19. A: *Oxyphysis*; B: *Peridinium*; C: *Pyrocystis*; D: *Ceratium* sp1; E: *Ceratium* sp2; F: *Oxytoxum*; G: *Dinophysis* sp; H: *Ceratium* sp3; I: *Ceratium* sp4.

At the CTD station of Nazareth Bank, the diatom genera of *Coscinodiscus* (17%) was more dominate followed by *Navicula* (12%), *Chaetoceros* (10%) and *Rhizosolenia* (9%). The genera *Nitzchia* was less dominate at Nazareth Bank compared to Saya de Malha Bank (Fig. 3.3.21).

Among the dinoflagellate genera at Saya de Malha Bank, the *Ceratium* was more dominate followed by *Oxyphysis* (15%), *Oxytoxum* (14%) and *Peridinium* (12%) (Fig 3.3.22).

At Nazareth Bank the dominate dinoflagellates was the *Ceratium* (24%) same like Saya de Malha Bank followed by *Oxyphysis* (17%). The trend eventually followed a change in diversity percentage dominance for *Peridinium* (15%) and *Oxytoxum* (13%) where *Peridinium* was more dominate (Fig 3.3.23).

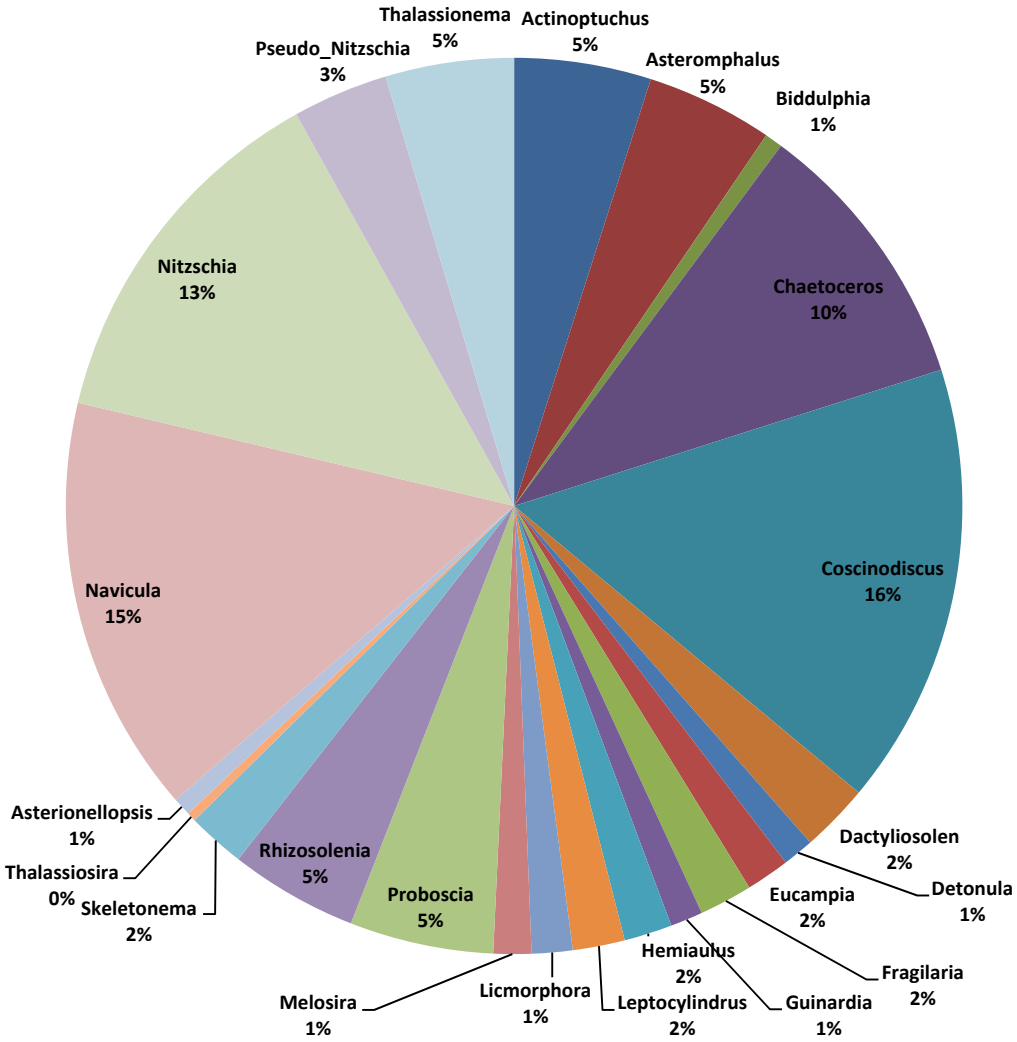

Figure 3.3.20. The percentage diatom genera distribution at Saya de Malha Bank.

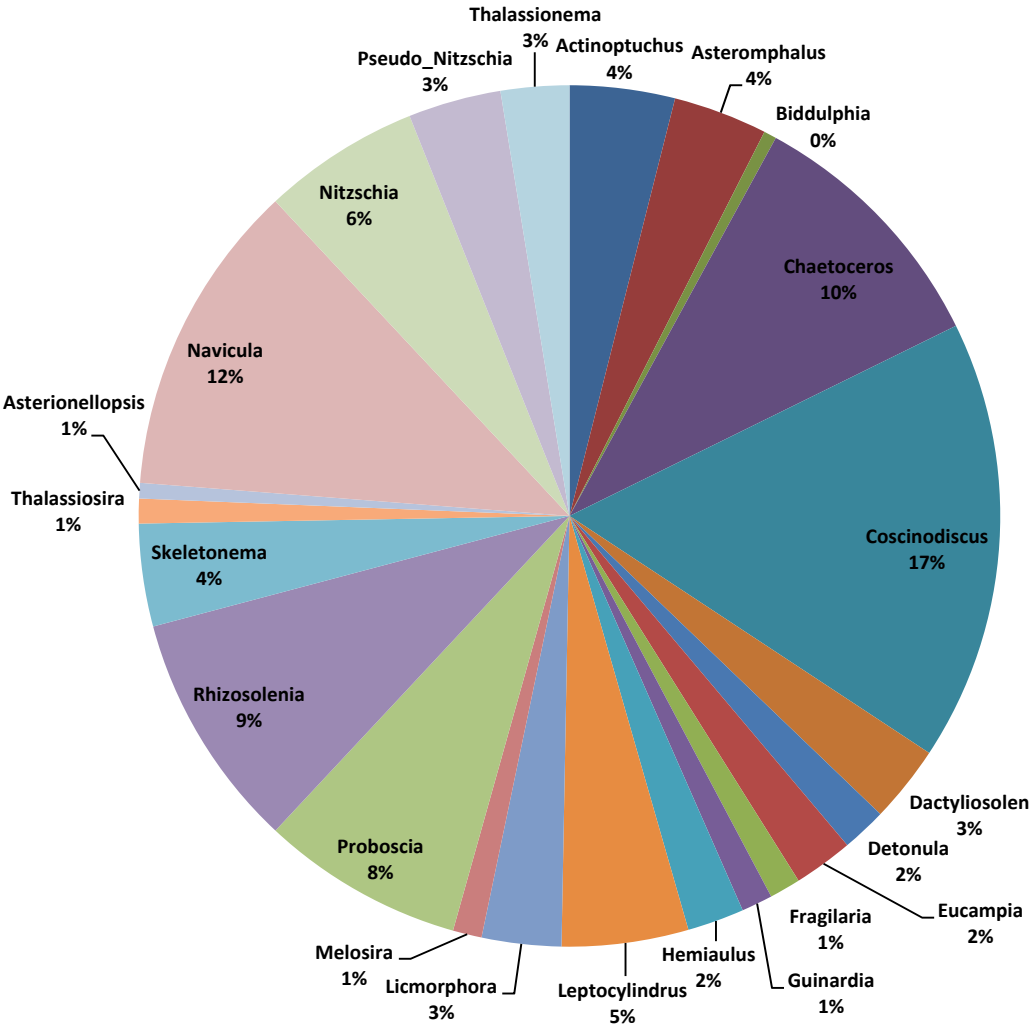

Figure 3.3.21. The percentage diatom genera distribution at Nazareth Bank.

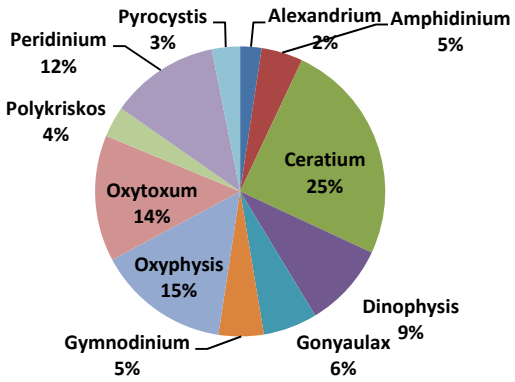

Figure 3.3.22. The percentage dinoflagellates genera distribution at Saya de Malha Bank.

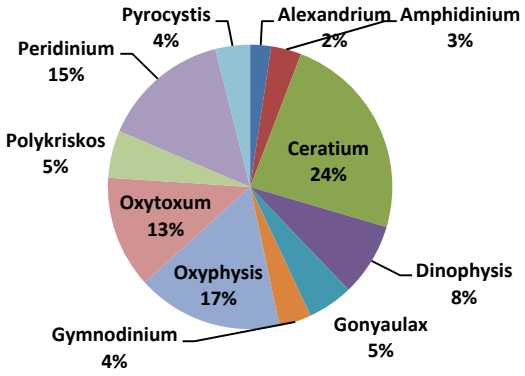

Figure 3.3.23. The percentage dinoflagellates genera distribution at Nazareth Bank.

Photophysiology of phytoplankton communities

The effective quantum yield (Fig 3.3.24 A) and non-photochemical quenching (NPQm) (Fig. 3.3.24 B) of microphytoplankton did not differ among the three tested depth ranges, namely 0-4m, 5-10m and 21-29m while the rETRm tended to increase with depth (Fig. 3.3.24 C). Chlorophyll a (Fig. 3.3.25 A) and estimated relative productivity (Fig. 3.3.25 B) decreased with increasing depth. The variations in productivity among the CTD stations are shown in Figure 3.3.26.

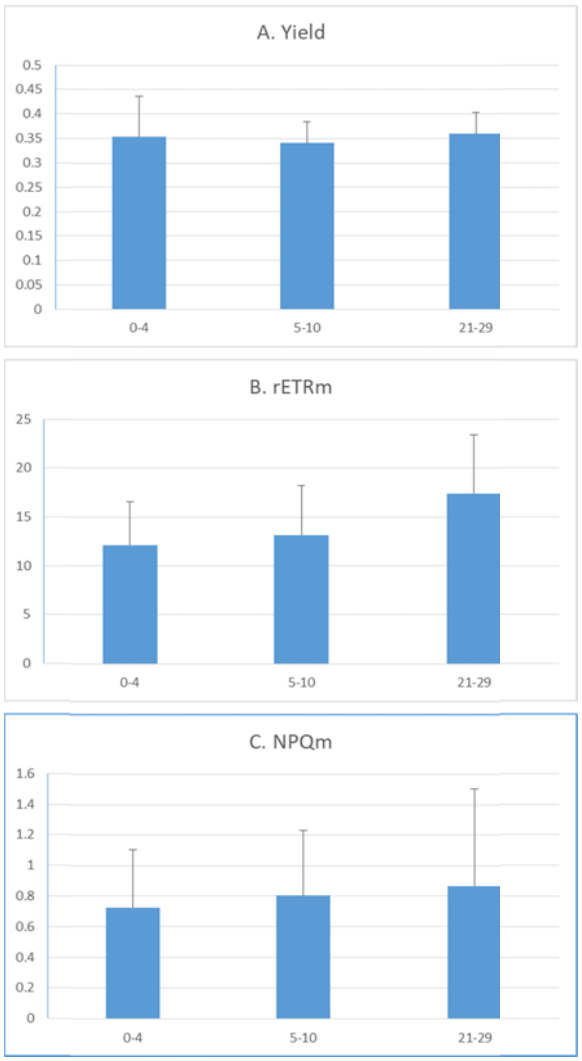

Figure 3.3.24. Photo-physiology of microphytoplankton at different depth ranges (m). A. Yield; B. rETRm and C. NPQm.

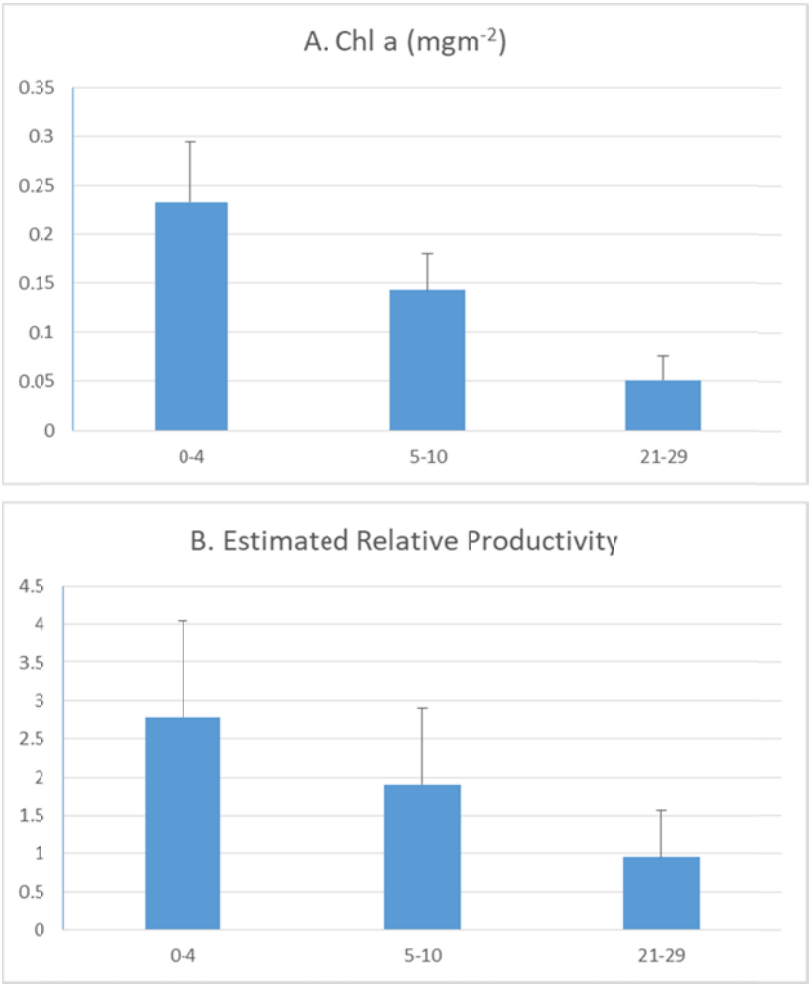

Figure 3.3.25. Chlorophyll a (mgm-2) (A) and Estimated relative productivity (B) of microphytoplankton at different depth ranges (m).

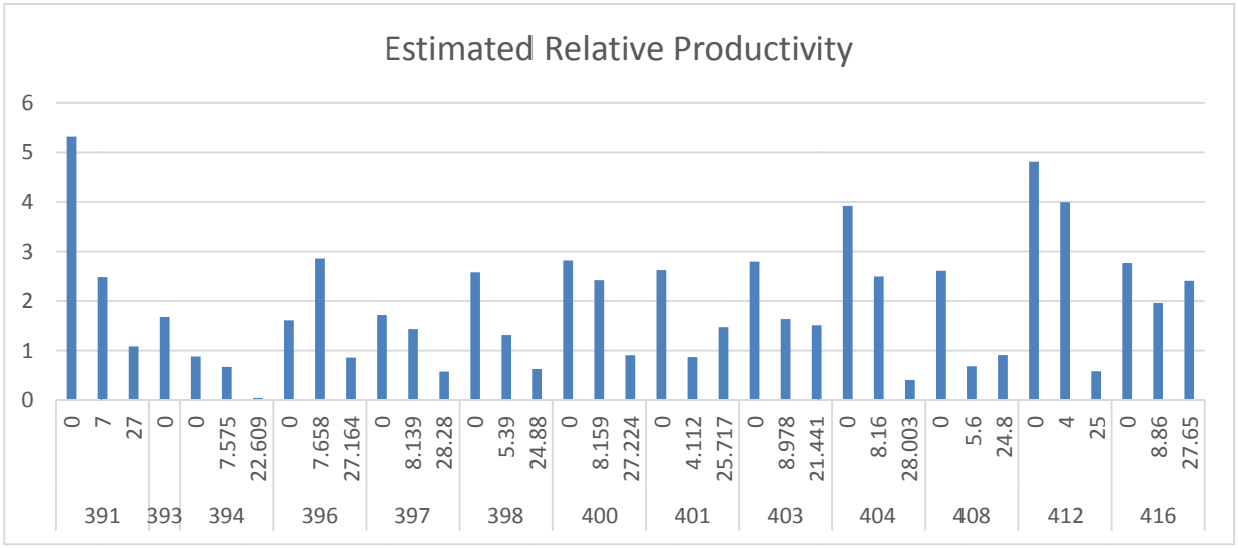

Figure 3.3.26. Variation in estimated relative productivity (expressed as the product of rETRmax and chl a mg m-2) in the water column at some CTD stations and respective collection depths (m).

Phytoplankton and primary productivity: Conclusions

A total of 23 and 11 genera of diatoms and dinoflagellates, respectively, were found at both Saya de Malha and Nazareth banks during the sampling conducted in May 2018 through the Nansen 2018 Research Cruise at the Mascarene plateau. The mean total density of micro-phytoplankton varied at both Saya de Malha (3.0 – 6.0 x 10^4 cellsL^{-1}) and Nazareth (3.6 – 5.0 x10^4 cellsL^{-1}) banks, thus indicating an absence of bloom densities. The mean chlorophyll a concentration varied between 0.05 to 0.2 mgm^{-3} at the studied CTD stations at Saya de Malha and Nazareth banks. At some of the studied CTD stations the effective quantum yield, non-photochemical quenching (NPQ) did not different among depth ranges 0-4, 5-10 and 21-29m, while the rETRm tended to increase and chlorophyll *a* considerably increased with depth. The relative estimated productivity at some studied CTD stations exhibited decrease with an increase depth range.

3.4 Zooplankton

A total number of 23 WP2 samples were collected on Leg I and II at the Saya de Malha bank (Fig. 1.2 & 1.5, Table 3.4.1). For each station biomass samples were taken and frozen for analysis by the IMR.

Table 3.4.1. Station number, bottom depth, sample depth and position of zooplankton samples collected with a WP2 at Saya De Malha.

Station # (same as CTD st.)	Bottom Depth, m	Sample Depth, m	Position (decimal deg., lon, lat))
HD 395	28	28-0	-10.0905, 61.2805
HD 397	68	60-0	-10.4146, 61.2125
HD 397	68	30-0	-10.4146, 61.2124
HD 402	127	30-0	-10.7565, 61.0450
HD 402	127	120-0	-10.7566, 61.0449
HD 406	120	30-0	-11.0829, 61.3233
HD 406	120	120-0	-11.0830, 61.3233
HD 411	106	90-0	-11.3922, 61.7596
HD 411	106	30-0	-11.3922, 61.7595
HD 417	326	200-0	-11.9169, 60.9667
HD 417	326	30-0	-11.9169, 60.9667
HD 418	264	30-0	-11.9170, 61.7143
HD 418	264	200-0	-11.9170, 61.7143
HD 420	285	30-0	-12.1758, 61.1821
HD 420	285	200-0	-12.1758, 61.1825
HD 428	504	30-0	-10.7312, 62.2950
HD 428	521	200-0	-10.7312, 62.2950

Station # (same as CTD st.)	Bottom Depth, m	Sample Depth, m	Position (decimal deg., lon, lat))
HD 429	1005	30-0	-10.7317, 62.3013
HD 429	1011	200-0	-10.7317, 62.3013
HD 430	88	80-0	-10.7230, 62.2586
HD 430	88	30-0	-10.7300, 62.2586
HD 431	548	30-0	-10.7306, 62.2959
HD 431	548	200-0	-10.7308, 62.2958

Results of the identification of the samples and biomass estimation is pending following onshore post-processing in IMR and the Univ. of the Seychelles and UWC, South Africa.

Jellyfish occurred in five out of 18 trawls (Table 3.4.2). Three different species were caught, of which the most abundant was an unidentified species. Due to the specimens being very small and almost completely transparent it was not possible to identify the species onboard. Specimens were collected for onshore morphometric and genetic analysis (South Africa). The other species collected in trawl were *Periphylla periphylla* and *Pelagia* sp. (Table 3.4.2).

Table 3.4.2. Jellyfish collected during trawl in Saya De Malha.

Trawl Station #	Species
1	Unidentified sp.
6	*Periphylla periphylla*
10	Unidentified sp.
15	*Pelagia* sp.
18	*Pelagia* sp.

Fish eggs and larvae

In total, 47 CUFES stations were sampled, where 33 stations contained fish eggs and 17 contained fish larvae. In total 562 fish eggs and 56 fish larvae were collected. All ichthyoplankton are unidentified pending onshore post-processing.

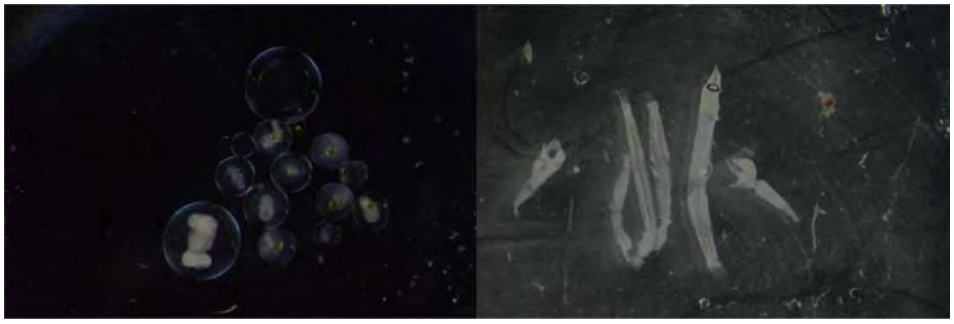

Figure 3.4.1. Unidentified fish eggs and larvae collected during CUFES stations in Saya De Malha.

3.5 Pelagic and demersal fish

Pelagic trawl sampling (Saya de Malha Bank)

A total of 10 pelagic trawls were carried out on Saya de Malha, of which one was a meso-pelagic trawl with the headline at 420 m (Table 3.5.1). All the trawls were carried out at night except for the first trawl which took place in the afternoon. The trawls were also done blindly as little information was gained from acoustics about the pelagic resources of the area.

Table 3.5.1. Fishing stations on Saya de Malha Bank.

Station	Gear type	Date	Duration (min)	Depth (m)	END GPS		Catch (kg)/hr
					LAT (S)	LONG (E)	
1	Pelagic trawl	10.05.2018	28.1	60	10°45.87	60°26.38	2.1
2	Pelagic trawl	10.05.2018	31.2	30	10°45.98	61°5.20	520.57
3	Pelagic trawl	15.05.2018	31.8	5	11°12.97	60°35.02	38.85
4	Pelagic trawl	15.05.2018	56.4	Surface	11°12.16	60°30.47	41.47
5	Pelagic trawl	16.05.2018	43.3	Surface	10°25.34	60°20.85	74.42
6	Pelagic trawl	18.05.2018	62	420	9°45.02	60°39.56	11.27
7	Pelagic trawl	18.05.2018	55.3	6	9°47.73	60°49.54	89.92
8	Trap	19.05.2018		21	9°52.63	60°47.84	
9	Trap	20.05.2018		21	9°49.47	60°55.09	
10	Pelagic trawl	21.05.2018	59.3	Surface	10°23.03	62°25.41	91.25
11	Pelagic trawl	22.05.2018	45.4	Surface	10°23.05	62°0.39	5.23
12	Pelagic trawl	24.05.2018	60.3	Surface	11°5.46	61°40.63	37.08

Trawl 2 had the largest catch with a catch rate of 520.57 kg/hr. Trawl 1 which was the one that was done during daytime yielded the lowest catch with 0.98 kg obtained in half hour, which is approximately 2 kg per hour.

Station 4 and Station 6 had the highest diversity in their catch with 18 families caught during the two trawls, while station 9 and 12 had the lowest diversity with only nine families caught from both stations.

The main family caught in the trawls was Diodontidae which consisted of 45% of the overall catch on Saya de Malha (Table 3.5.2). Majority species was *Diodon holocanthus* (Fig. 3.5.1.) with an estimated 401 kg per hour caught which consisted 98% of the overall Diodontidae catch. Carangidae was the second most abundant family consisting of 16% of the overall catch and *Decapterus russelli* was the species that was most abundant making up almost 96% of the carangids catch.

The meso-pelagic trawl resulted with Myctophidae and Cephalopoda as the most abundant making up 42% and 23% respectively of the total catch of Station 6.

Overall the pelagic trawl catch on Saya de Malha was quite poor, and therefore the data collected is inadequate for any further analysis such as distribution, size composition and biomass estimates.

Table 3.5.2. Main fish families caught in pelagic trawls on Saya de Malha by percentage of overall catch.

FAMILY	**Percentage**
Diodontidae	45.47%
Carangidae	16.42%
Myctophidae	9.38%
Scombridae	7.48%
Crustacea	7.00%
Cephalopoda	6.21%
Sphyraenidae	3.85%
Nomeidae	1.26%
Mobulidae	1.12%

Figure 3.5.1. Catch from Trawl Station 2 (Main species *Diodon holocanthus*).

Five pelagic trawls (Trawl No.: 4, 5, 10, 11 and 12) were carried out a with gear depth at sea surface (0 m deep). The average catch rate for these trawls amounted to 49.88 kg/hr. The highest catch rate was obtained with the gear deployed at 30 m deep (Trawl 2). Average catch rate at different depths are at Figure 3.5.2.

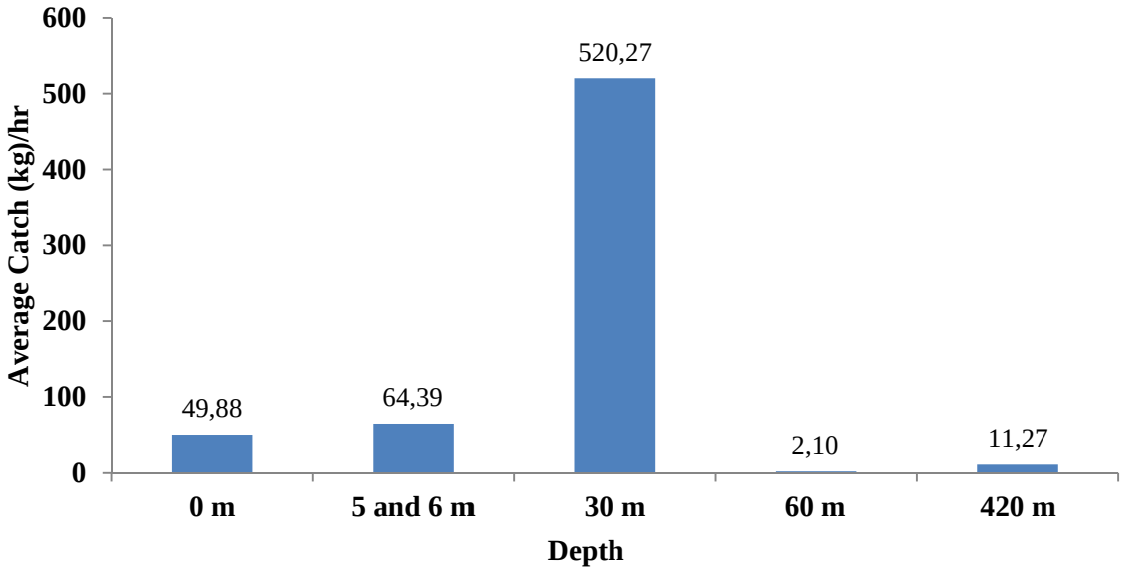

Figure 3.5.2. Average catch rate by depth.

Length frequency data was collected from two species, *Decapturus russelli* and *Selar crumenophthalmus*. A total of 200 specimens of *D. russelli* from pelagic trawls were sampled for length and ranged from 11 to 22 cm, while 100 specimens of *S. crumenophthalmus* ranged from 21 to 27 cm. The length frequency distributions for both species are at Figures 3.5.3 and 4.

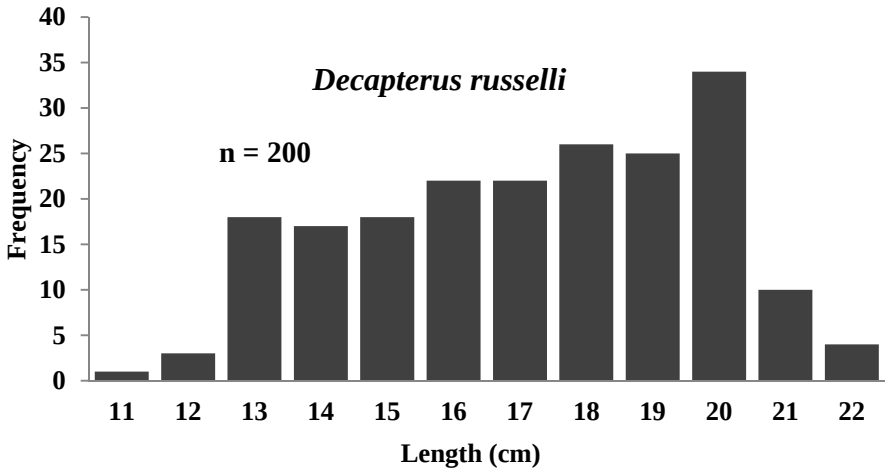

Figure 3.5.3. Length frequency distribution of *Decapterus russelli* from pelagic trawls from Saya de Malha Bank

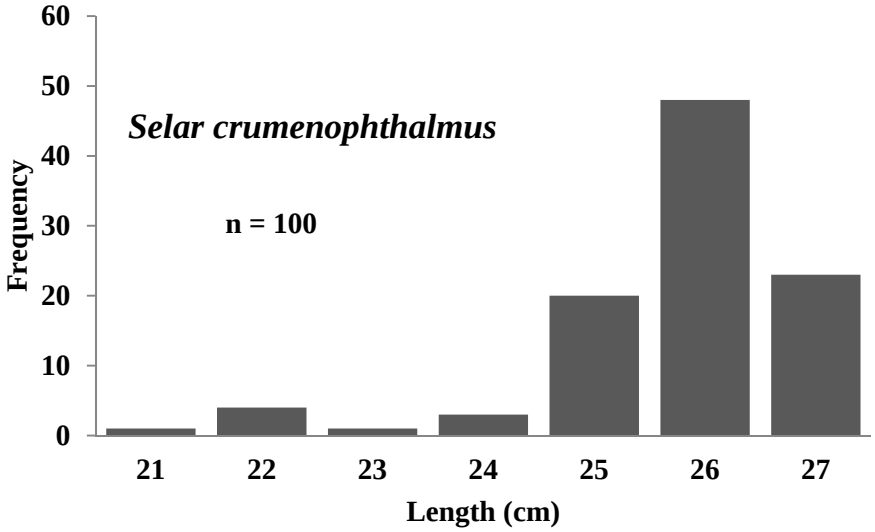

Figure 3.5.4. Length frequency distribution of *Selar crumenophthalmus* from pelagic trawls on Saya de Malha Bank.

Pelagic Trawl Sampling on Nazareth Bank

Two pelagic trawl tows were made on the Nazareth Bank but resulted in minimal catches. The first pelagic trawl on the Nazareth Bank was carried out at depth ranging from 10 m to 50 m, with a bottom depth of 132 - 197 m. The catch amounted to 0.428 kg, with a catch rate of 0.524 kg /hr. The second pelagic trawl resulted in a nil catch. Details of trawls are in Table 3.

Table 3.5.3. Fishing stations with pelagic trawls on the Nazareth Bank.

Station	Gear type	Date	Duration (min)	End Gear depth(m)	END GPS		Catch (kg)/hr
					LAT (S)	LONG (E)	
15	Pelagic Trawl	29.05.2018	49.00	10	15°17.4	61°59.85	0.524
17	Pelagic Trawl	30.05.2018	66.81	50	15°31.1	61°5.76	0

Demersal fish observations from VAMS - Leg I

The fish data from the video observations by the VAMS remain to be fully analyzed, and the following results are provisional.

A total of 17 families were observed from the ROV video footages at 30 - 80 m deep, and 8 families at 160 - 290 m. The main families frequently occurring in the shallow waters are: Lethrinidae, Labridae, Carangidae. The deeper areas (more than 150 m deep), the Sparidae family was recurrently encountered. Details are put in Table 3.5.4.

Trap sampling

Bottom trawlings were not permissible on Saya de Malha. To supplement fish observations by video, attempts were made to deploy baited traps (Figure 3.5.5) to obtain samples and abundance data for the shallowest areas. Only two sets of three traps were attempted.

Station 8 and 9 were the two trap stations and on each station three baited traps were left to soak overnight. Both traps were placed at a depth of 21 m in a seagrass and sand bottom (Table 1).

Table 3.5.4. Families observed from videos during Leg I.

Depth	Family
30-80m	Gobiidae
	Tetraodontidae
	Callionymidae
	Echeneidae
	Syngnathidae
	Lethrinidae
	Labridae
	Pomacentridae
	Carangidae
	Apogonidae
	Trichonotidae
	Synodontidae
	Lutjanidae
	Monacanthidae
	Pleuronectidae
	Mullidae
	Cirrhitidae
160-290m	Carangidae
	Sparidae
	Cirrhitidae
	Pomacentridae
	Scorpaenidae
	Chlorophthalmidae
	Gobiidae
	Caproidae

Figure 3.5.5. Traps before deployment.

The main species caught in the traps were *Lethrinus mahsena* (Fig 3.5.6) with 9 individuals caught at Station 8, and ten (10) individuals caught at station 9. Other species caught in the traps were one (1) *Siganus sutor* at Station 8 and two (2) specimens of *Carcharhinus amblyrhynchos* and one (1) *Lutjanus gibbus* at Station 9.

Figure 3.5.6. Catch from traps a) *Lethrinus mahsena* and b) *Carcharhinus amblyrhynchos.*

Demersal Trawl Fishing on Nazareth Bank

Four (4) bottom trawl tows were made in the designated rectangular area on the southeastern Nazareth Bank where bottom trawling was permitted, in the depth range 150-300m (Table 3.5.5). Catch information is provided in Annex III.

Table 3.5.5. Fishing stations with bottom trawls on the Nazareth Bank.

Station	Gear type	Date	Duration (min)	End depth (m)	END GPS		Catch (kg)/hr
					LAT (S)	LONG (E)	
13	Bottom Trawl	29.05.2018	28.77	213	15°9.89	61°9.75	26.64
14	Bottom Trawl	29.05.2018	28.89	240	15°19.4	61°1.79	9.17
16	Bottom Trawl	30.05.2018	30.05	279	15°29.3	61°0.91	50.36
18	Bottom Trawl	31.05.2018	31.05	288	15°38.8	61°0.08	45.76

The main species caught differed between trawls. The main species caught in Trawl 13 was *Squatina africana* (Fig. 3.5.7 and 8)) with a catch rate of 20.15 kg/hr, comprising of 75.15% of the catch. The most abundant species for the other trawls were a) Trawl 14: *Diodon holocanthus* 26.49 %, b) Trawl 16: *Trigla* sp. 38.79 %, and d) Trawl 18 *Champsodon* sp. 31.64 %. Figure 3.5.7 shows the species composition by weight of each 4 bottom trawls carried out.

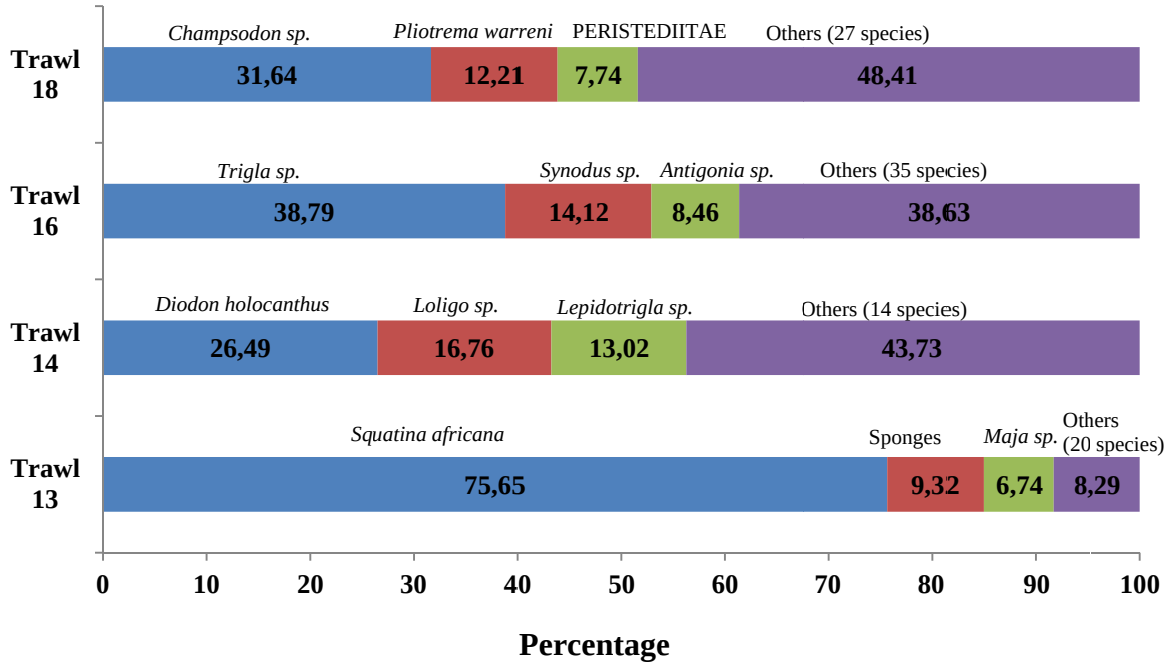

Figure 3.5.7: Percentage distribution of species caught from bottom trawls

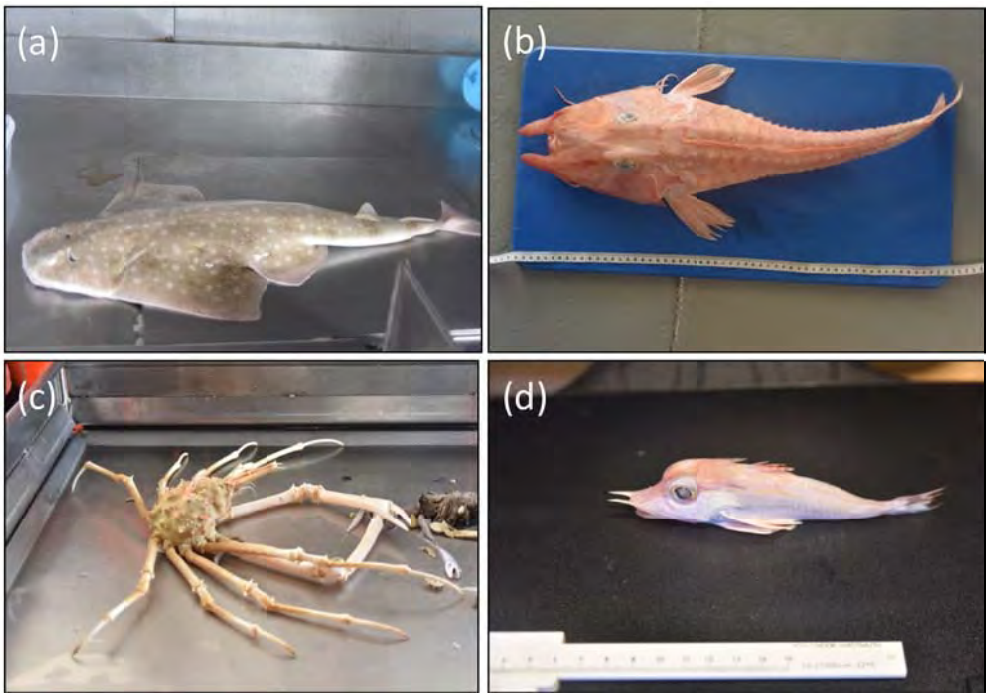

Figure 3.5.8: Catch from bottom trawls on Nazareth Bank a) *Squatina africana*, b) *Peristediidae*, c) *Maja* sp. and d) *Trigla* sp.

Identification of fishes using DNA barcoding

Fish, crustaceans, sponge and cephalopod specimens collected during this survey will be identified through DNA barcoding at the Mauritius Oceanography Institute. Around 438 samples (Table 3.5.4) have been collected for genetics analysis (from either tissue sample or fin clips) from the Saya de Malha and Nazareth Banks.

Tissue from the dorsal part (<500 mg), or the fin clip of each fish specimen collected was excised onboard the vessel following each trawl and frozen at -20°C pending further genetic analysis. All specimens collected for tissue sampling were photo-documented.

At the MOI, 50-100 mg (or less in cases of juvenile or small species) were excised from the tissue and transferred into 1.5 ml microcentrifuge tubes containing absolute ethanol. The ethanol was changed twice to sterilize the samples prior to DNA extraction.

Genomic DNA (gDNA) was extracted using the DNAEasy Blood & Tissue Kit (Qiagen), using the manufacturer's protocol. The presence of gDNA following the extraction procedure was verified on 1 % agarose gel (exampled in Figure 3.5.4), following which a polymerase chain reaction (PCR) was carried out to amplify the cytochrome oxidase C subunit 1 (CO1) mitochondrial gene. This gene is highly conserved and is routinely used to identify specimens from different kingdoms down to the species level. The PCR reaction was carried out in 50 µl reactions containing 4 µl of gDNA template, dNTP mix (0.05 mM), primers F2 (5′-TCGACTAATCATAAAGATATCGGCAC-3′) and R2 (5′-ACTTCAGGGTGACCGAAGAATCAGAA-3′) (0.01 mM each), 10 x PCR buffer with $MgCl_2$ (1x), Taq Polymerase (0.5 units) and water. Amplifications were performed using an Eppendorf thermal cycler. The thermal regime consisted of an initial step of 2 min at 95 °C, followed by 35 cycles of 0.5 min at 94 °C, 0.5 min at 54 °C, and 1 min at 72 °C, followed in turn by 10 min at 72 °C and then held at 4 °C (Ward *et al*., 2005).

A small amount of the PCR product (6 µl) was mixed with loading dye and SYBR green dye, loaded on a 1.6 % agarose gel and viewed under UV light (exampled in Figure 3.5.5). A DNA ladder was added to check for the correct length of amplification of the PCR products. The PCR step was considered positive when amplified bands were obtained at the desired length (645-655 base pairs). The products with positive results were then sent for sequencing at the BGI (Beijing, China) for analysis. The sequences were then compared to two databases: NCBI and BOLD System databases, to obtain the identification of the specimen.

Table 3.5.4. List of tissue samples and fin clips taken from collected specimens in the Saya de Malha and Nazareth Banks.

Samples for genetics (MOI)	**Number of tissue samples**	**Number of fin clips**	**Trawl station number**
ACANTHURIDAE	3		7, 10, 11
ALEPOCEPHALIDAE	1		6
Anthias sp.	2		18
Antigonia sp.	14		13, 16, 18
APOGONIDAE	9		4, 7, 11, 15
Ariomma sp.	5		18
Arnoglossus sp.	6		13, 16

Samples for genetics (MOI)	Number of tissue samples	Number of fin clips	Trawl station number
Astronesthes sp.	2		6, 7
Avocettina sp.	1		6
BALISTIDIDAE sp. (incl. juvenile)	2		4, 7
BARBOURISIIDAE	1		6
BELONIDAE	3		2, 4, 10
BOTHIDAE (incl. juvenile)	3		7, 18
Brama Orcini	1		10
BRAMIDAE	2		4, 6
Branchiostegus doliatus	2		14, 16
Bregmaceros sp.	4		4, 5, 6, 11
Callionymus gardineri	1		18
Canthigaster rivulata (incl. juvenile)	1		5
Carangoides equula	14		14, 16, 18
Caranx sp.	1		6
Carcharhinus amblyrhynchos	1		9
CARRANGIDAE	2		3, 7
Centroberyx druzhinini	1		16
Cephalopods	28		4, 6, 12, 13, 14, 16, 18
CEPOLIDAE	2		16
Chamsodon sp	15		2, 14, 16, 18
Charybdis sp.	7		13
Chaunax sp.	6		16, 18
Cheilopogon sp.	1		12
CHLOROPHTHALMIDAE	10		16, 18
Chlorophthalmus sp.	4		13
Crustaceans	2		16
Cubiceps pauciradiatus	3		4, 6, 10
Cubiceps sp. (incl. juvenile)	1		7
Cyclichthys orbicularis	1		2
Decapterus russelli	8		2, 4, 5, 12, 13, 16
Decapterus sp.	2		14
Diodon holocanthus	11		2, 10, 14, 16
Dipterygonotus balteatus	2		3, 5
Diretmus argenteus	1		6
Echeneis naucrates (incl. juvenile)	1		5
Echeneis sp.		1	11
Emmelychthys nitidus	2		16, 18
Engyprosopon granisquama	2		13
Euthynnus affinis	3		12
EVERMANNELLIDAE	1		6
GEMPYLIDAE	2		10, 16
Gempylus serpens	2		6
GOBIIDAE (incl. juvenile)	18		13, 14, 16, 18

Samples for genetics (MOI)	Number of tissue samples	Number of fin clips	Trawl station number
Gonostoma sp.	1		6
Halieutaea sp.	8		16, 18
HEMIRAMPHIDAE	2		10
Hermit crab	1		16
HOLOCENTRIDAE	1		7
Holocentrus sp. (incl. juvenile)	2		4
Holothuria (Sea cucumber)	1		14
Hoplichthys sp.	12		14, 16, 18
Howella sp.	1		6
Ibacus novemdentatus	5		13, 16
Katsuwonus pelamis	1		2
Lagocephalus guentheri	2		2, 5
Lepidopus sp.	1		16
Lepidotrigla sp.	10		14, 18
Leptocephalus (incl. juvenile)	3		4, 6
Lethrinus cf *mahsena*	20		8,9
Loxodon macrorhinus	1		12
Lutjanus gibbus	1		9
Maja sp.	2		13, 18
Malacosteus sp.	1		6
MELLAMPHIDAE	1		6
MONOCANTHIDAE (incl. juvenile)	1		6
MULLIDAE	2		14
MYCTOPHIDAE	7		3, 6, 10
NEMICHTHYDAE	1		6
OCTOPODIDAE	2		16
OGCOCEPHALIDAE	1		13
OPHICHTHIDAE	9		5
OSTRACIIDAE	3		7
PARALEPIDIDAE	2		4
Paratrachichthys sajademahalensis	1		16
PERISTEDIIDAE		2	16, 18
Plectranthias morgansi	2		18
Pliotrema warreni (Plistiophorus nancyae)		2	18
Porifera	2		13
Priacanthus prolixus	3		16, 18
Rastrelliger karagurta	1		5
Rhinobatos sp.	1		16
Saurida tumbil	3		2,5
SCOMBRIDAE (incl. juvenile)	3		1, 7, 10
Selar crumenophthalmus	3		2, 11,12
Shrimps (incl. larvae and juvenile)	22		2, 4, 6, 16
Siganus sutor	1		8

Samples for genetics (MOI)	Number of tissue samples	Number of fin clips	Trawl station number
Sphyraena acutipinnis	2		5, 11
Sphyraena barracuda	1		5
Sphyraena quenie	1		6
Sphyraena sp.	1		4
Squatina africana	1		13
Starfish	11		14, 16
STERNOPTYCHIDAE	1		6
Sternoptyx sp.	1		6
Stomidae sp.	1		6
SYNODONTIDAE	15		14, 16, 18
SYNOGLOSSIDAE	7		16, 18
TETRADONTIDAE	1		13
TRIACHANTIDAE	4		16
Trigla sp.	5		18
TRIGLIDAE	5		16
Tylerius spinosissimus	6		13, 16
Uranoscopus sp.	6		14, 18

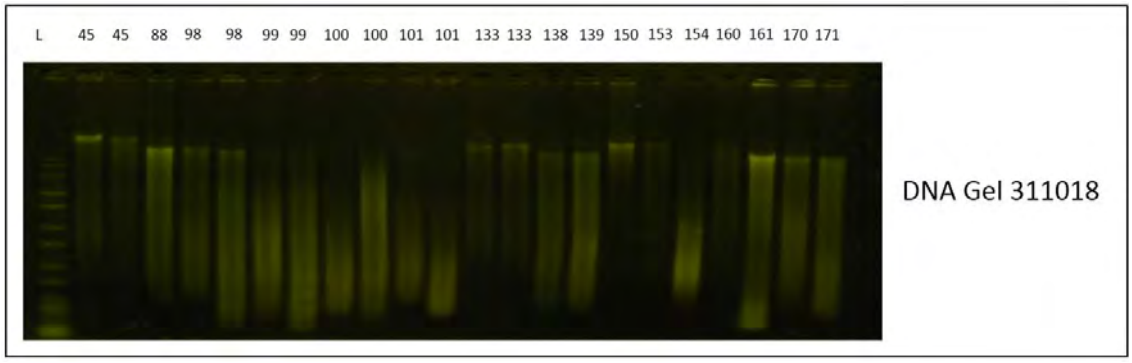

Figure 3.5.4. Verification of the extraction procedure to obtain gDNA from fish tissue samples, resolved on 1% agarose gel and viewed under UV light (L- DNA ladder, numbers indicate the specimen identification number).

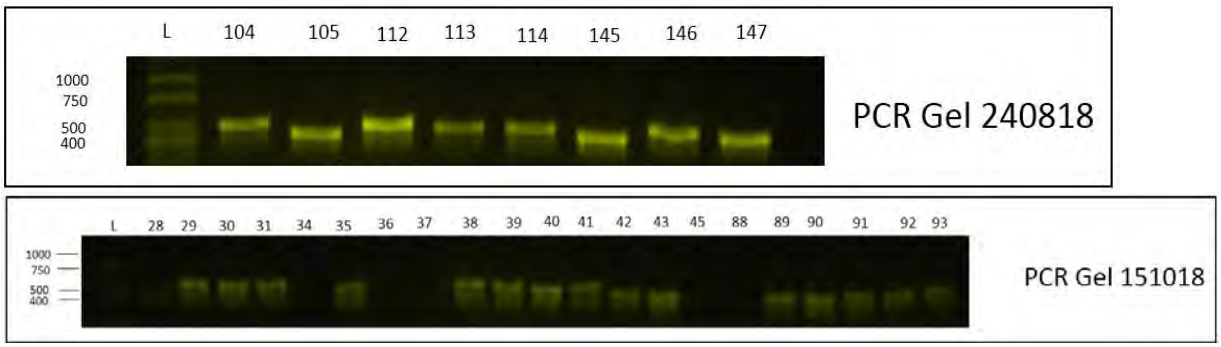

Figure 3.5.5. PCR products resolved on a 1.6% agarose gel to verify the amplification of COI gene using the F2R2 primer pair, viewed under UV light (L- DNA ladder, numbers indicate the specimen identification number).

The list of fish specimens identified by genetics at the Mauritius Oceanography Institute from the trawl catches in the Saya de Malha Bank is given Table 3.5.5 and in Annex IV.

Table 3.5.5. Tentative fish taxa identified using genetic barcoding.

Nansen sample ID #	***Tentative genetic identification***
2	Genus: *Champsodon*
5	*Decapterus macrosoma*
6	*Katsuwonus pelamis*
7	Genus: *Lagocephalus*
8	Genus: *Ablennes*
9	*Selar crumenophthalmus*
10	Genus: *Decapterus*
11	Genus: *Diodon*
13	*Dipterygonotus balteatus*
18	*Decapterus tabl*
23	Genus: *Lestrolepis*
24	Genus: *Ariosoma*
25	*Cubiceps pauciradiatus*
27	*Sufflamen chrysopterum*
28	Genus: *Myripristis*
29	Genus: *Centropyge*
30	*Bleekeria mitsukurii*
31	*Sphyraena sp. 1*
35	Genus: *Sphyraena*
38	*Decapterus macrosoma*
39	*Dipterygonotus balteatus*
40	Genus: *Rastrelliger*
41	Genus: *Echeneis*
42	Genus: *Canthigaster*
43	Genus: *Lagocephalus*
46	*Cubiceps pauciradiatus*
47	Genera: *Poromitra, Melamphaes*
48	Genus: *Gonostoma*
49	Genus: *Leptostomias*
50	*Lampadena luminosa*
51	Genera: *Notoscopelus* *Notoscopelus caudispinosus*
52	*Notoscopelus caudispinosus*
53	Genus: *Chauliodus*
58	Genus: *Serrivomer*
59	Genus: *Howella*
61	*Myctophum spinosum*

Nansen sample ID #	***Tentative genetic identification***
62	*Sternoptyx diaphana*
78	*Melanonus zugmayeri*
79	Genus: *Borostomias*
80	Genus: *Chiasmodon*
81	Genus: *Coccorella*
82	Genus: *Bregmaceros*
83	Genus: *Diplophos*
84	*Chaetodon kleinii*
85	*Centropyge acanthops*
86	*Zenion hololepis*
89	Genus: *Lethrinus*
90	Genus: *Euthynnus*
91	Genus: *Parupeneus*
92	*Acanthurus mata*
93	Genus: *Lethrinus*
97	Genus: *Parupeneus*
102	*Odonus niger?*
103	Genus: *Caranx*
104	*Lethrinus sp.*
105	*Siganus sutor*
107	Genus: *Sphyraena*
108	*Gempylus serpens*
112	*Lutjanus malabaricus /gibbus*
114	*Carcharhinus amblyrhynchos*
135	*Symbolophorus evermanni*
136	*Cubiceps pauciradiatus*
137	*Katsuwonus pelamis*
140	*Zanclus cornutus*
141	*Brama orcini*
143	*Acanthurus mata*
144	*Nealotus tripes*
145	*Echeneis naucrates*
147	*Sphyraena flavicauda*
149	*Acanthurus mata*
151	*Parapriacanthus ransonneti*
154	*Decapterus macrosoma*
157	*Euthynnis affinis*

DNA barcoding is an extremely valuable tool in identifying organisms to the species level. However, this method is still limited by the availability of trusted resources in the publicly accessible databanks.

During these analyses, most specimens could be identified to the genus level, others to species level. A few specimens could not be identified simply because there was no match in either one, or both, of the two databases NCBI and BOLD Systems. This suggests that they could either be species that have not been worked on previously, or whose sequences have not been uploaded into the public domain or they may represent new species altogether.

Although genomic DNA (gDNA) was successfully extracted from all specimens, around 35 samples from the trawls in the Saya de Malha bank failed to amplify using the primer pair F2R2. gDNA extraction was again performed on these samples, and those having the highest amount of gDNA have been used for amplification using the primer pair F1R1. These results are still being analyzed and have not been included in this report.

The results are preliminary and more in-depth analyses are required, especially in cases where the sequencing results are ambiguous and where specimens could only be specified to genus level. These specimens call for expert taxonomic identification. Although efforts have concentrated on the analysis of all fish specimens from this region, a few samples did not amplify using this specific primer pair and amplification using different primer pairs will have to be explored.

Hydroacoustic observations along survey tracks

Observations of total backscattering area (S_a) values along the survey tracks are shown on Figure 3.5.6. The values were overall low and showed no geographical pattern. Based on examination of frequency response patterns, the records were primarily attributed to plankton and micronekton.

Examples of echograms along transects across Saya de Malha from the 38 KHz transducer are shown in Figure 3.5.7. In all transects a scattering layer occurred, including at the break between the plateau and the upper slopes.

The low occurrence of pelagic fish on the echograms may reflect that fishes in the area have low target strengths, however, low abundance is compatible with the very poor catches of pelagic fish in the trawls.

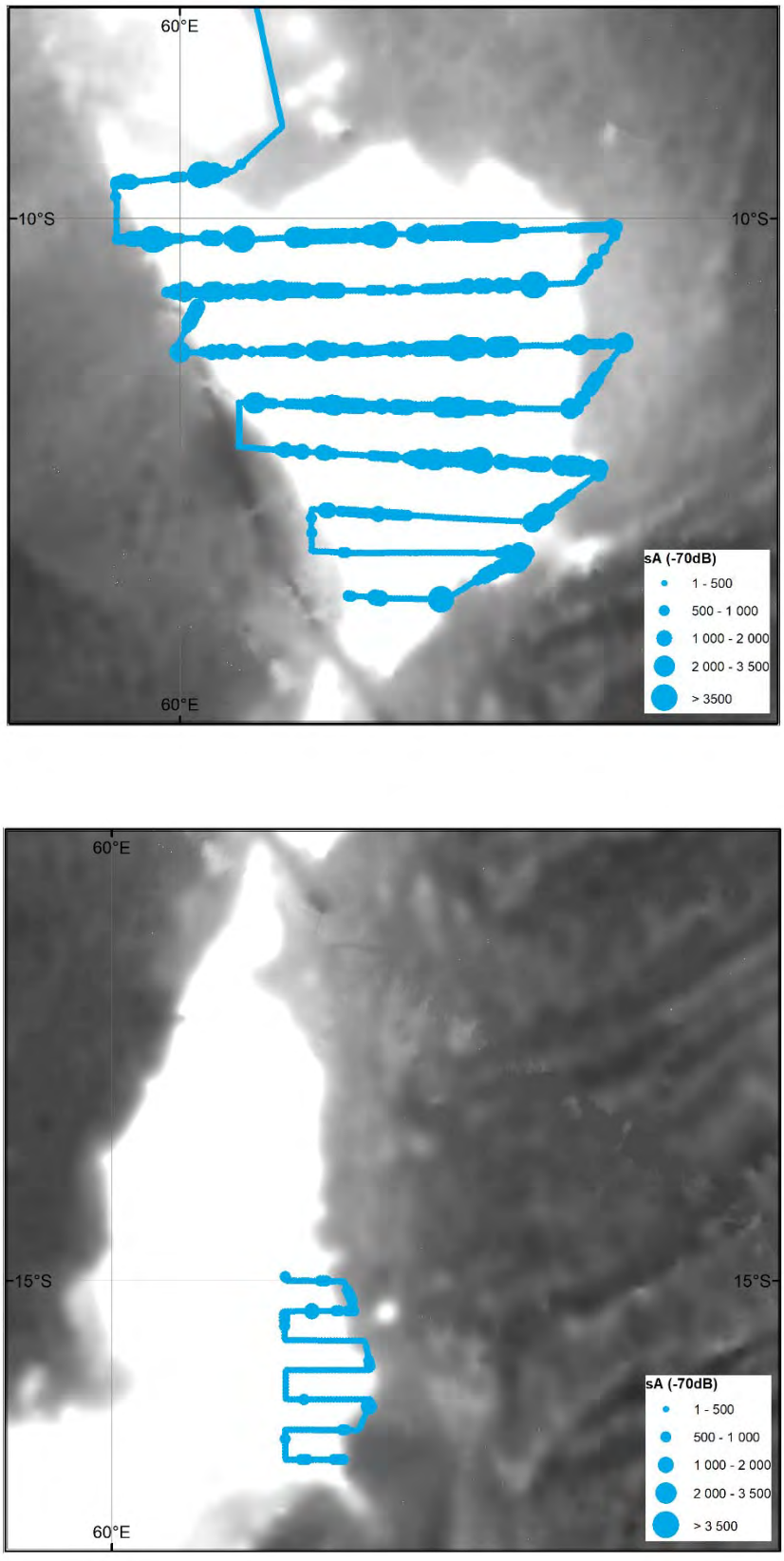

Figure 3.5.6. Area backscattering observed along the survey tracks on the Saya de Malha (upper) and Nazareth Banks (lower). Data from the EK80, 38 KHz transducer.

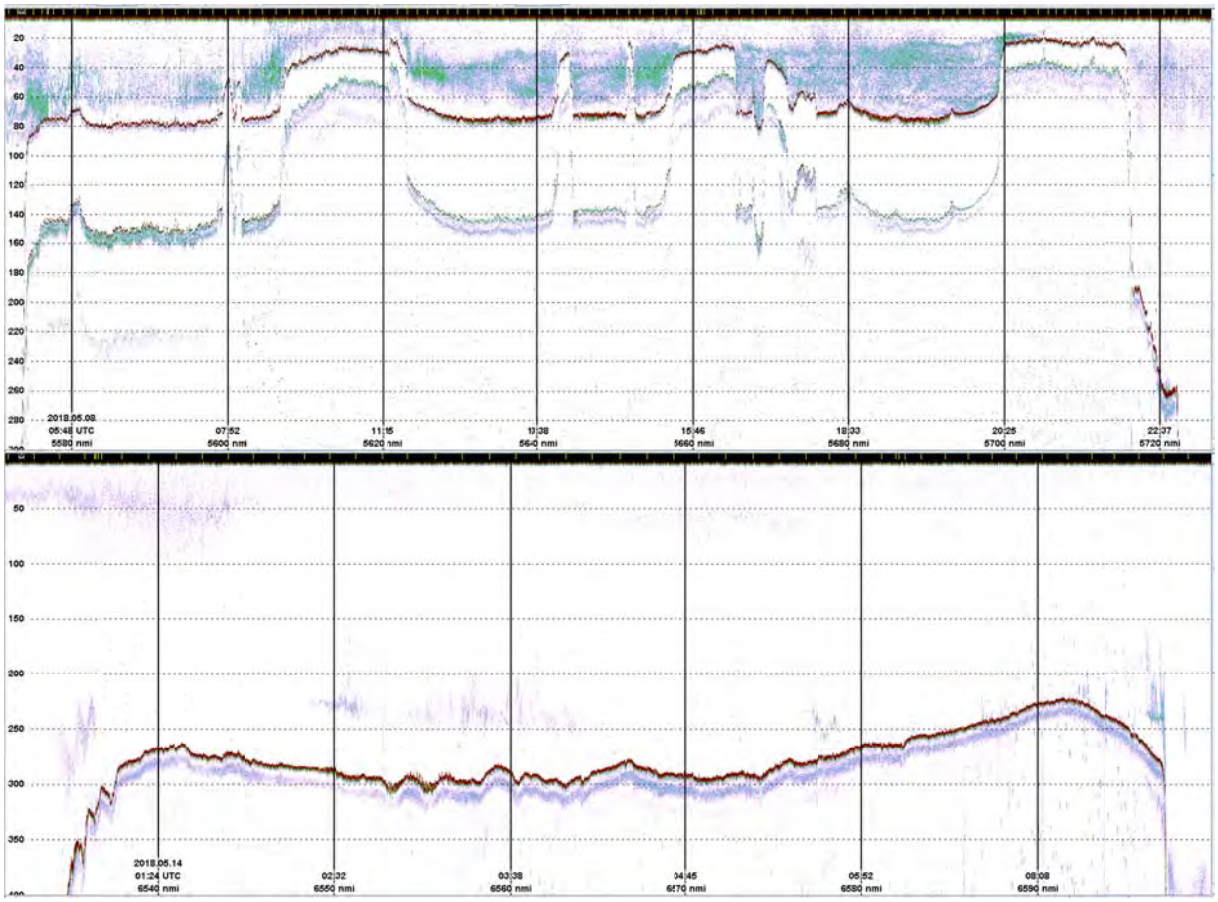

Figure 3.5.7. Two examples of echograms (38 KHz, -70dB) from transects crossing the Saya de Malha Bank. Distance between vertical lines are 20 n.m. (upper) and 10 n.m. (lower, 18520m).

3.6 Benthos

On Leg I and II, and also on the Nazareth Bank, multiple VAMS dives provided substantial video images to characterize habitats and megafauna on the banks and on the slopes of the bank to a depth of maximum 1000m (Fig. 1.3, 1.4, 1.7 and Tables 1.2, 1.3, 1.4). The recording of substrate and faunal information has not been completed and will be reported on extensively at a later stage. The same is the case for infauna sampled with the VAMS grabs (see later for sampling overviews)

Shallow bank areas have rich seagrass and coral areas, whereas deeper parts have wide sedimentary flats and rocky patches. The sediments seem overall very thin. In general, the seabed communities in deeper areas appeared impoverished, perhaps not unexpected in an area flushed by relatively oligotrophic watermasses.

Some provisional observations using VAMS and ROV

Table 3.6.1 lists taxa of animals and plants observed and sampled by the VAMS grabs and video cameras. Some provisional descriptions for epifauna, infauna, hexactinellid sponges, and seagrass are given below.

Table 3.6.1. List of Benthic Organism observed and collected during the survey.

Phylum	Class	Family	Species
Mollusca	Bivalvia	Arcidae	
		Cardiidae	
		Pectinidae	
		Veneridae	
		Donacidae	
		Mactridae	
		Lucinidae	
	Gastropoda	Cypraeidae	*Ipsa childreni*
		Conidae	
		Muricidae	
		Tubinidae	
		Ranellidae	
		Terebridae	*Triplostephanus triseriatus*
		Strombidae	*Canarium erythrinum* *Persististrombus granulatus*
		Bursidae	*Marsupina sp.*
		Calliostomatinae	*Calliostoma depictum*
		Cerithiidae	
		Margenellidae	*Volvarina philipinarum*
		Naticidae	*Polinices* sp.
		Bullidae	*Bulla vernicosa*
		Cassidae	*Casmaria ponderosa*

Phylum	Class	Family	Species
Tracheophyta (Seagrass)	Magnoliopsida	Cymodoceaceae	*Thalassodendrum ciliatum*
	Magnoliopsida	Hydrocharitaceae	*Halophila decipiens*
Chlorophyta (Green Seaweed)	Ulvophyceae	Halimedaceae	*Halimeda opuntia* *Halimeda incrassate* *Halimeda discoidea* *Halimeda sp.*
		Udoteaceae	*Udotea spp.*
		Caulerpaceae	*Caulerpa cupressoides* *Caulerpa racemosa*
		Ulvaceae	*Ulva lactuca*
		Siphonocladaceae	*Dictyosphaeria* sp.
Rhodophyta (Red Seaweed)	Florideophyceae	Lithothamniaceae	*Lithothamnion* sp.
		Fryeellaceae	*Fryeella* sp.
Corals	Anthozoa	Poritidae	*Porites lutea*
		Helioporidae	*Heliopora coerulea*
		Acroporidae	*Acropora* spp.
Sponge	Hexactinellida	Pheronematidae	*Semperella schultzei*
		Hyalonematidae	*Hyalonema (Cyliconema) apertum*
		Euplectellidae	*Euplectella* sp.

Epifauna

The epifaunal observations were performed by the visual observations of the bottom with the VAMS ROV, and from the grabs as well. The amount of epifaunal organisms seemed to be very unlikely for the oceanic bank except shallow-water stations and several others deeper stations where it was observed to be very difficult to distinguish between the dominating fauna.

The most important features which provide the distribution of epifaunal organisms were depth (includes such factors as light, influence of the wave activity on the bottom and temperature) and relief of the bottom: flat or slope (corresponds to type of bottom substratum: sand and gravel of Calcium aragonite origin, bedrock or mix). As the transects moved to shallow water, the topography of the sea floor changed considerably whereby *Halimeda* sp, *Lithothamnion* sp and Scleractinian corals were mostly dominant at the photic zones.

In shallow-water flats (depth 20-70 meters with the inhabitants responsible for the primary production) the dominating forms of organisms were: sea grass – *Thalassodendron ciliatum*; calcarous red algae *Lithothamnion* sp; green algae *Halimeda* sp. In various location, where *Halimeda* species were dominant over the area, the first 5cm layer of the sediment consisted mainly of its dead calcareous leaves. Shallow waters also provided a range of degraded coral

colonies such as: branching *Porites*, *Acropora* sp., *Heliopora* sp., *Tubastrea* sp, *Cyphastrea* sp., *Turbinaria* sp, *Fungia* sp, *Favites* sp, *Favia* sp, *Galaxea* sp being more dominant among others. These calcified algae and corals, together with foraminiferans is likely to believe to form the reefal construction as well as notable portion of the bottom sediments – sand and gravel in the investigated area. The additional source of bottom sediments and reefal boulders are remnants of the fossil gastropods and bivalves.

The areas predominately occupied by one of the listed above form are well recognized during the visual observations: *Thalassodendron ciliatum*, *Halimeda* sp and corals (with *Lithithamnion*) or only *Lithothamnion*. Sometimes, sands with no epibentic domination. These 5 communities likely represent different stages of the succession.

The deeper locations were divided into two zones: 40-100 m and 100-1000 m. The first zone was characterized by the presence of very poor fauna where flat, sandy rocky slopes area were observed. At the 100-1000m depth zone, more diverse fauna was observed on the different substrata, which were mainly dominant by sand or rocks.

Infauna

The primary observation showed presence of few infaunal organisms in the grab samples. Only occasional polychaets and living bivalves were representatives of macroinfaunal organisms. The preliminary observation of meiobenthic organisms showed presence of possible live foraminifera only. Some epifauna collected by grabs were: echinoderms, corals, sponges, turbellarians, bryozoans, gastropods among others. An overall good amount of dead shells of bivalves, gastropods and scaphopods were observed from the grab samples after sieving indicating the possibility of a good infaunal life residing in these areas before. The most common bivalves and family obtained from the grabs were from the families listed in the Table 3.6.2 and Figures 3.6.1 below:

Table 3.6.2. List of most common bivalves and gastropods found during grabs on Saya de Malha Bank.

Most common Bivalves and Gastropods families obtained from the grabs	
Bivalves	**Gastropods**
Arcidae	Cypraeidae
Cardiidae	Conidae
Pectinidae	Muricidae
Veneridae	Tubinidae
Donacidae	Ranellidae
Mactridae	Terebridae
Lucinidae	Strombidae
	Bursidae
	Calliostomatinae
	Cerithiidae
	Margenellidae
	Naticidae
	Bullidae
	Cassidae

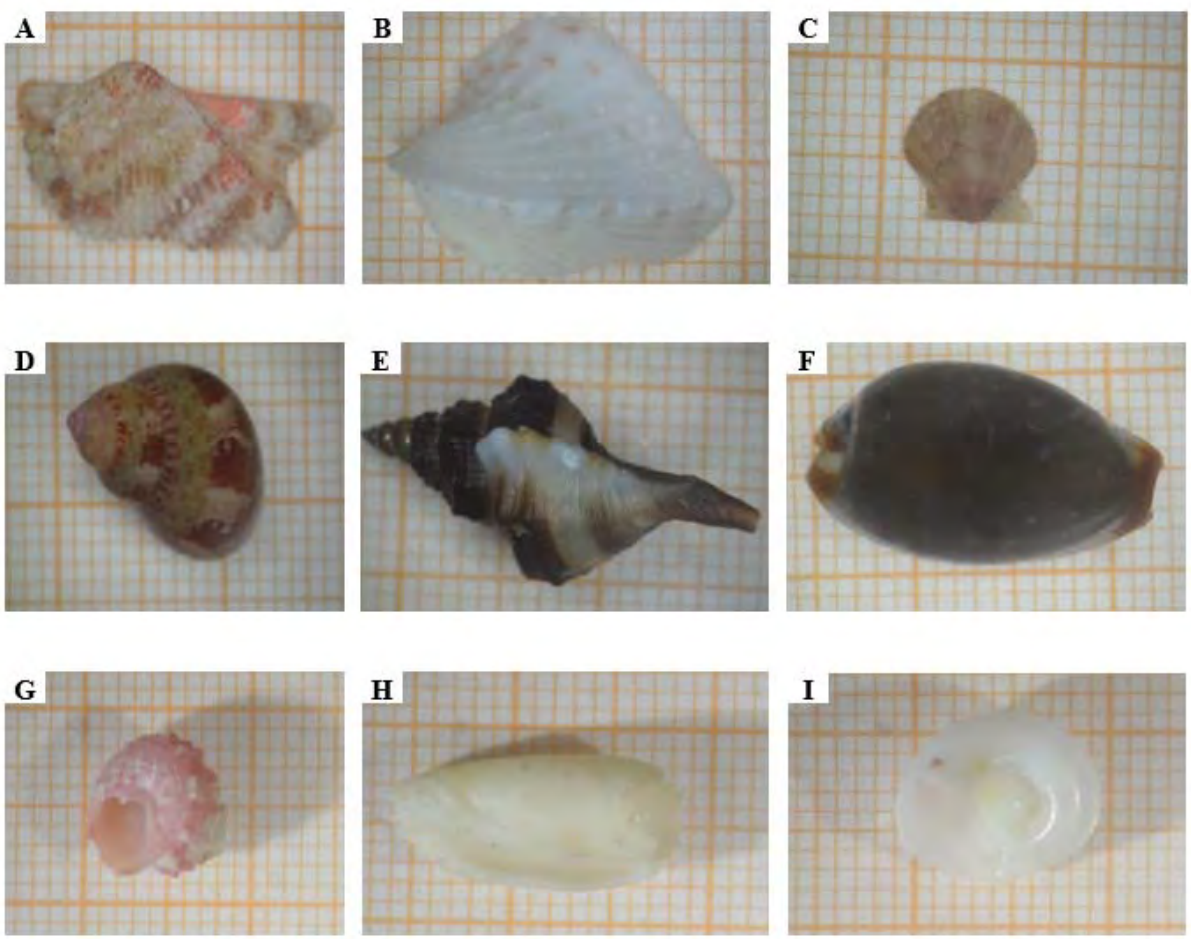

Figure 3.6.1. Some common bivalve and gastropod families obtained during the grabs. A: Arcidae, B: Cardiidae, C: Pectinidae, D: Turbinidae, E: Ranellidae, F: Cypraeidae, G: Calliostomatinae, H: Margenellidae and I: Naticidae.

Seagrass distribution

Three species of seagrass were observed during the different transects made in the shallow waters (70m – 27m) namely *Thalassodendron ciliatum* and *Halophila decipiens* whereby the seagrass bed *T. ciliatum* were usually observed in association with the seaweed *Caulerpa cupressoides,* Figures 3.6.2. Seagrass were found to occur starting as deep as depth of 70m, mainly consisting of *Thalassodendron ciliatum,* and forming meadows as the depth started to become shallower. The seaweed *C. cupressoides* , was observed mainly within the *T. ciliatum* meadows while they showed to occur on their own in Nazareth Banks as well. No large beds were noted for this seaweed species over both Saya de Malha and Nazareth Banks. *H. decipiens* were observed to occur as from depth of 50m deep. Previous reports have described this species within the Saya de Malha bank. However, this species was known to occur to depth of 30m.

Previous expedition reports mentioned about 3 main species occurring in the shallow water of Saya de Malha namely: *T. ciliatum, H. decipiens* and *Enhalus acroides*. This expedition confirmed the presence of two species of seagrass, where *T. ciliatum* being dominant and forming large meadow. However, no *E. acroides* were observed during this cruise mission.

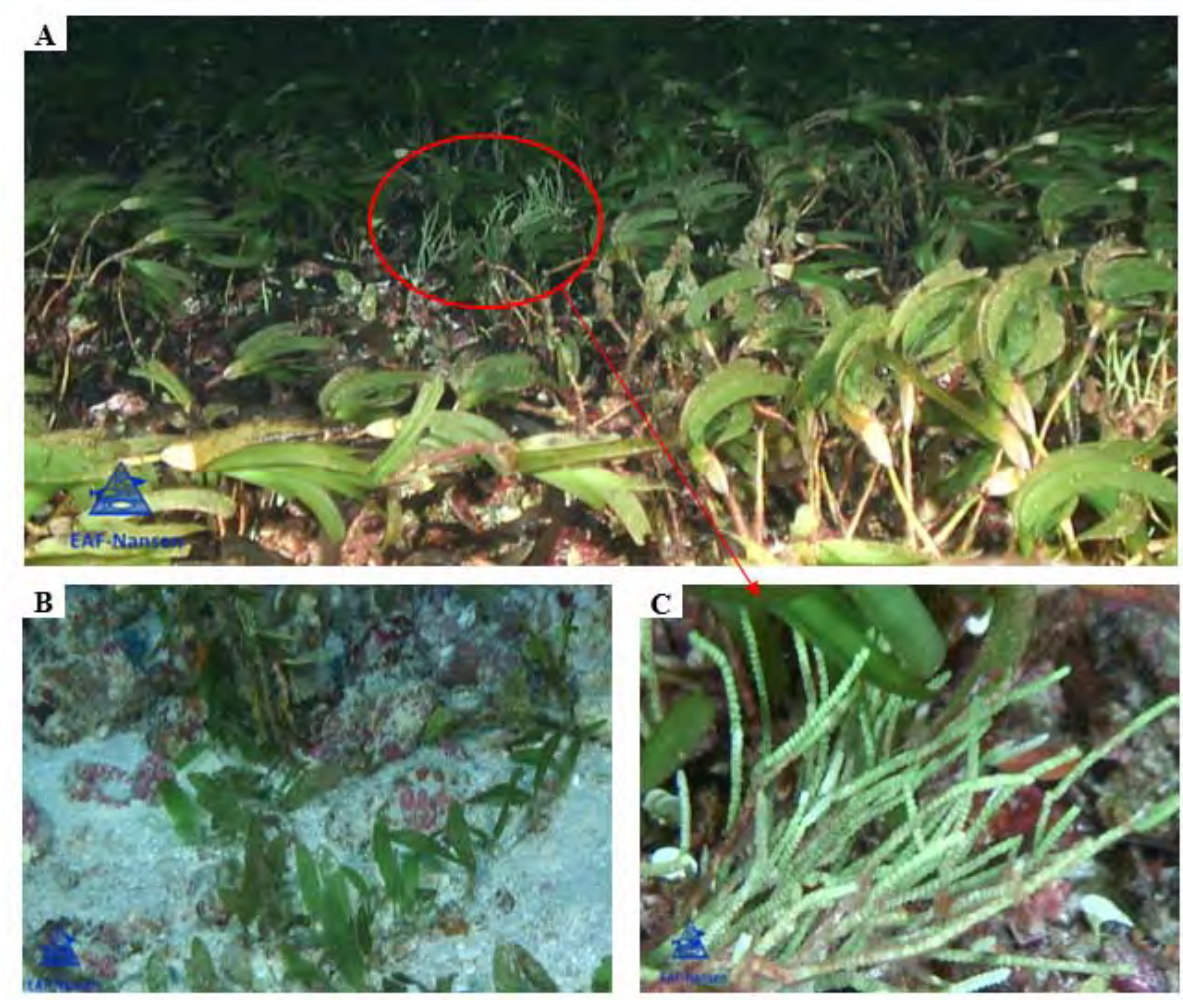

Figure 3.6.2. Seagrass species in the Saya de Malha Bank. A: *Thalassodendron ciliatum* meadow, B: *Halophila decipiens* and C: *Caulerpa cupressoides* (Seaweed).

Hexactinellid sponges

The west slope showed presence of *Semperella schulzei* (800-600 m) and *Hyalonema (Cyliconema) apertum* (1000-400 m) *Euplectella* sp. (400-500 m), possessing anchorate spicules on the sands. Several representatives of Hexactinosida: *Aphrocallistes* (dead skeletons) and, likely *Farrea*, and several genera of Euretidae) were observed on bedrocks. They all attach to the bottom directly by their base. Several specimens of *Pheronema* were also observed on both types of substrata. These sponges have a wide tuft of anchorate spicules.

On the east slope, no reliable representatives adopted for the life on sands were observed (they were probably situated deeper than the observed zone). The specimens living on hard substrata are more diverse: numerous specimens of alive *Aphrocallistes* together with *Farrea* and several genera of Euretidae at depth 1000 – 200 m, Corbitellinae (likely *Corbitella*) at depth about 200 m, represantatives of the family Rossellidae 400-20 m. The only hexactinellids with anchorate type of fixation observed hire was *Pheronema* at depth about 200 m which was observed in the east slope on the rocky substratum.

Photophysiology of symbiotic benthic organisms and seaplants

Fluorometric method using the Pulse Amplitude Modulator (PAM) device was used to assess the photophysiology of seaplants and symbiotic marine invertebrates by measuring the fluorescence of chlorophyll *a* thus determining the relative electron transport rate (*rETR*) and non-photochemical quenching (NPQ) when exposed to a series of rapidly (10s) changing light climates (RLC) (McMinn *et al.* 2012). Using the RLCs the *rETR* and NPQ were estimated at each irradiances.

At each irradiance the respective relative electron transport rate (*rETR*) was calculated by the formula below:

$$rETR = 0.5 \times \Phi PSII \times PAR$$

where PAR is the photosynthetically active radiance.

Non-photochemical quenching is the process by which oxygenic photoautotrophs harmlessly dissipate excess light absorbed as heat and fluorescence. When light energy absorption exceeds the capacity for utilization, there is a need to dissipate the energy to protect the light harvesting structures from photo-oxidative damage. It is given by the formula:

$$NPQ = \frac{F_m - F_m'}{F_m'}$$

Estimated relative productivity for each site will be calculated using the formula Estimated Primary productivity, P, defined as $P = (rETR_{max} \times Chl)$.

Spearman's correlation (using SPSS software) will be used to analyse the relationship between physico-chemical parameters (as and when available) with the total density of micro-phytoplankton. Statistica 10.0 software will be used for computing data and statistical analysis. ANOVA may be carried out to test the differences within measured parameters and different zones at the two studied areas, followed by Tukey's Post hoc analysis for comparison of means. Density data will be log transformed while chlorophyll *a* will be arcsin (square root) transformed prior to ANOVA analyses.

First graphical overviews of the analysis results are included here.

PSII activity of healthy vs bleached parts of corals

Objectives:

- Assess photophysiology of healthy-looking and bleached corals
- Determine zooxanthellae genetic types

Preliminary results:

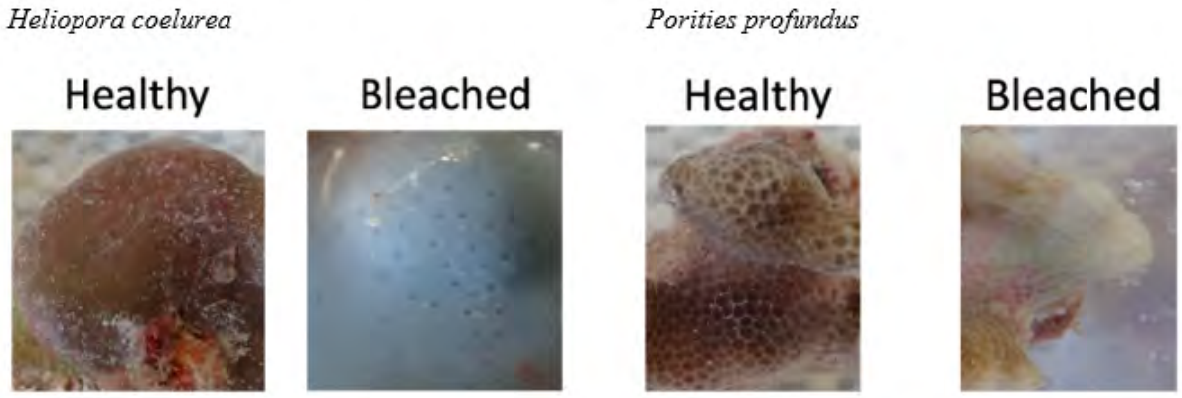

Figure 3.6.3. Appearance of healthy and bleached corals.

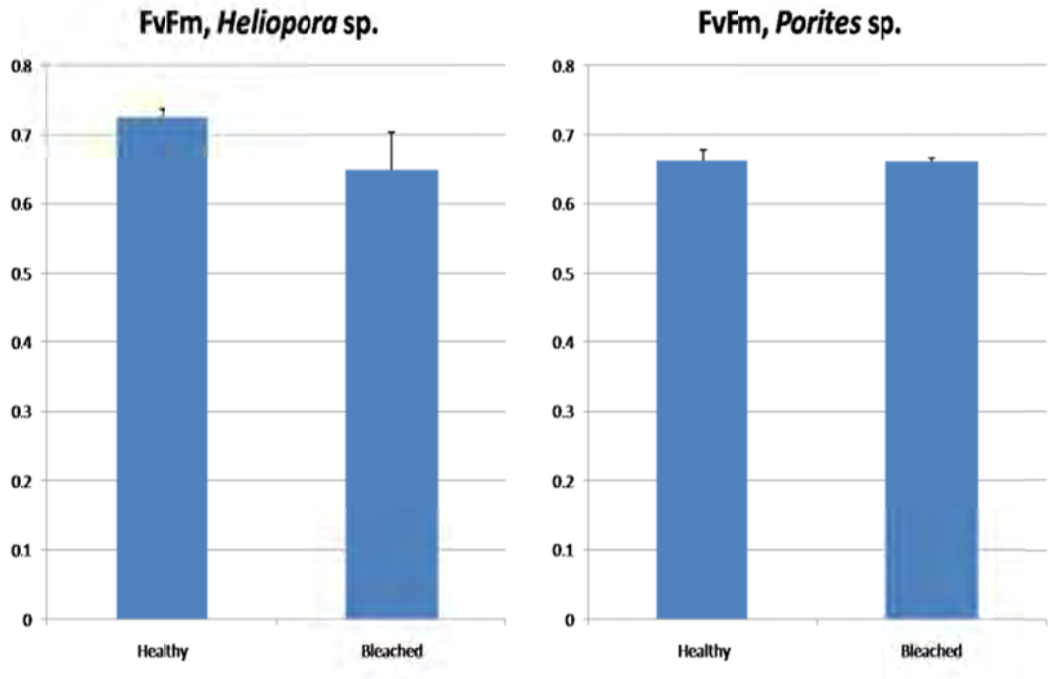

Figure 3.6.4. PSII activity of healthy vs bleached parts of corals.

rETR of healthy vs bleached parts of corals

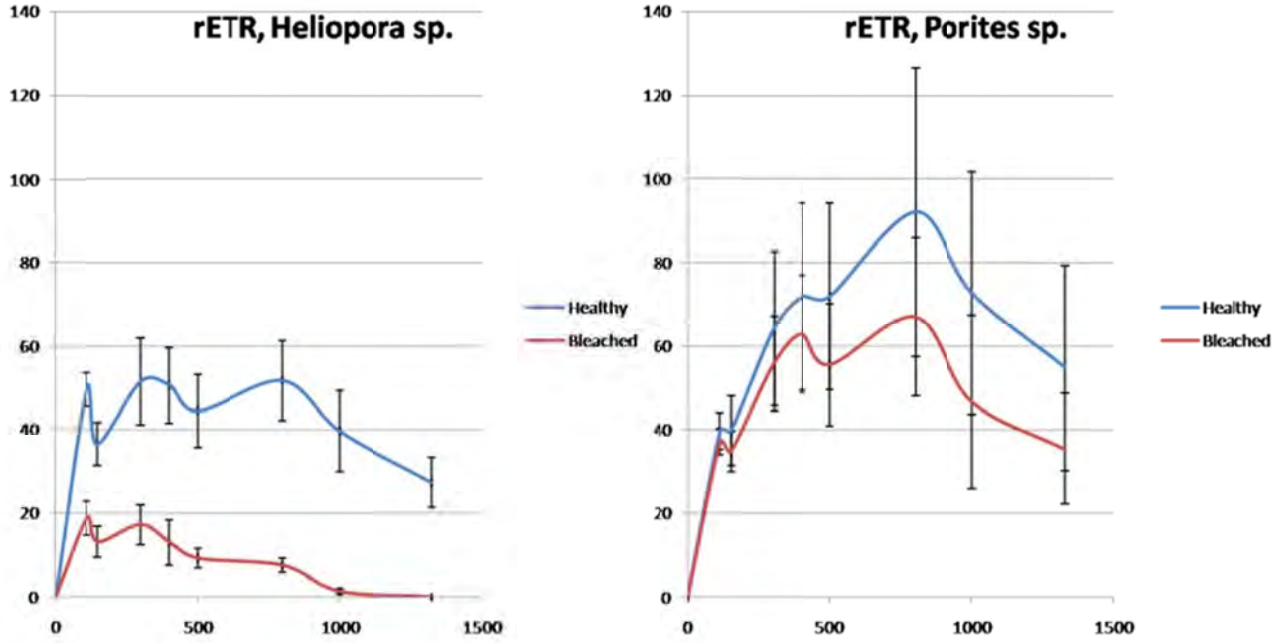

Figure 3.6.5. rETR of healthy vs bleached parts of corals.

NPQ of healthy vs bleached parts of corals

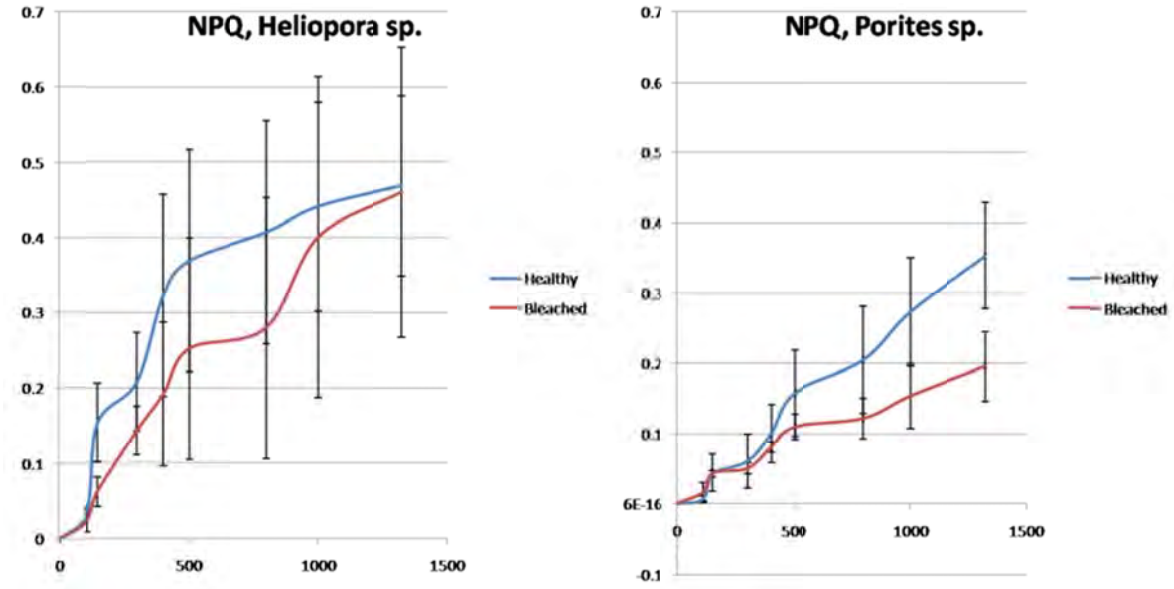

Figure 3.6.6. NPQ of healthy vs bleached parts of corals.

Photophysiology of seaplants from Saya de Malha

Objectives:

Assessment of the photophysiology of seaplants from JMA, Saya de Malha

Preliminary results for green and red algae, and seagrasses:

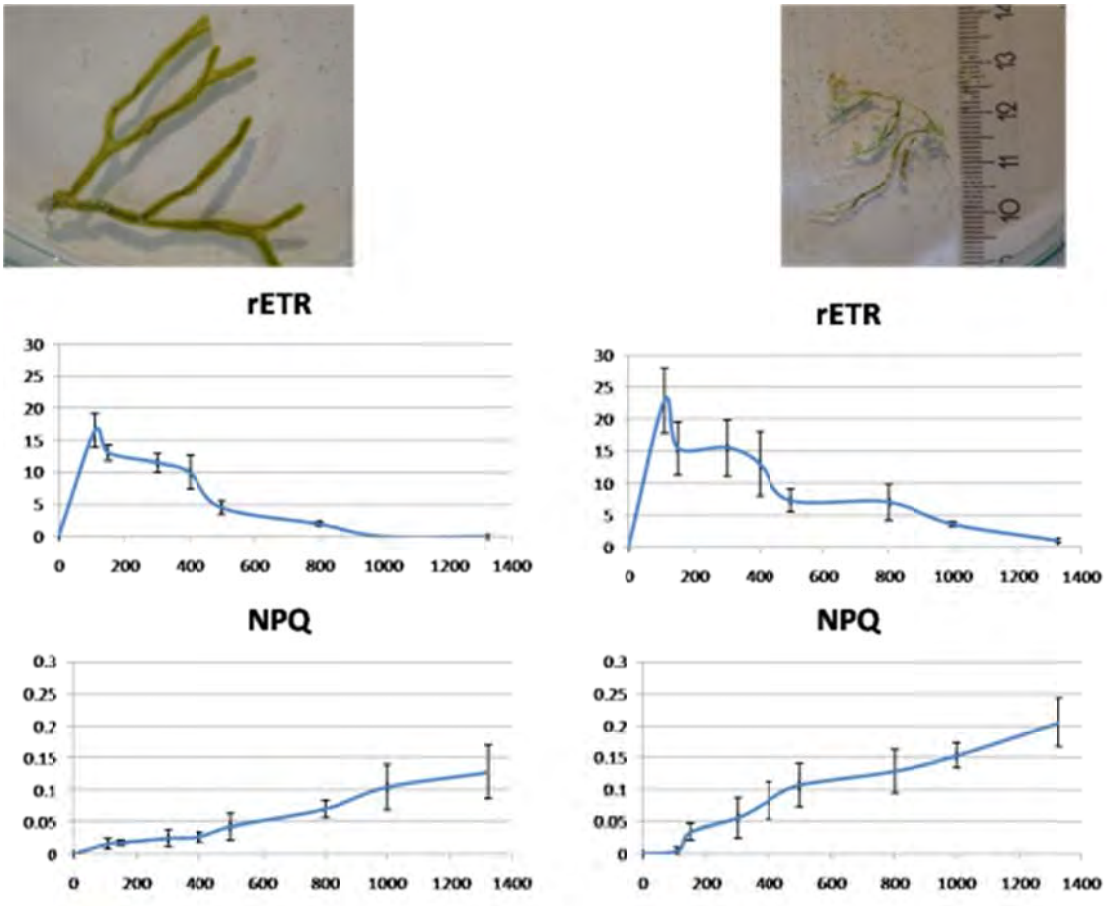

Figure 3.6.7. Green Algae Photophysiology, 75 m.

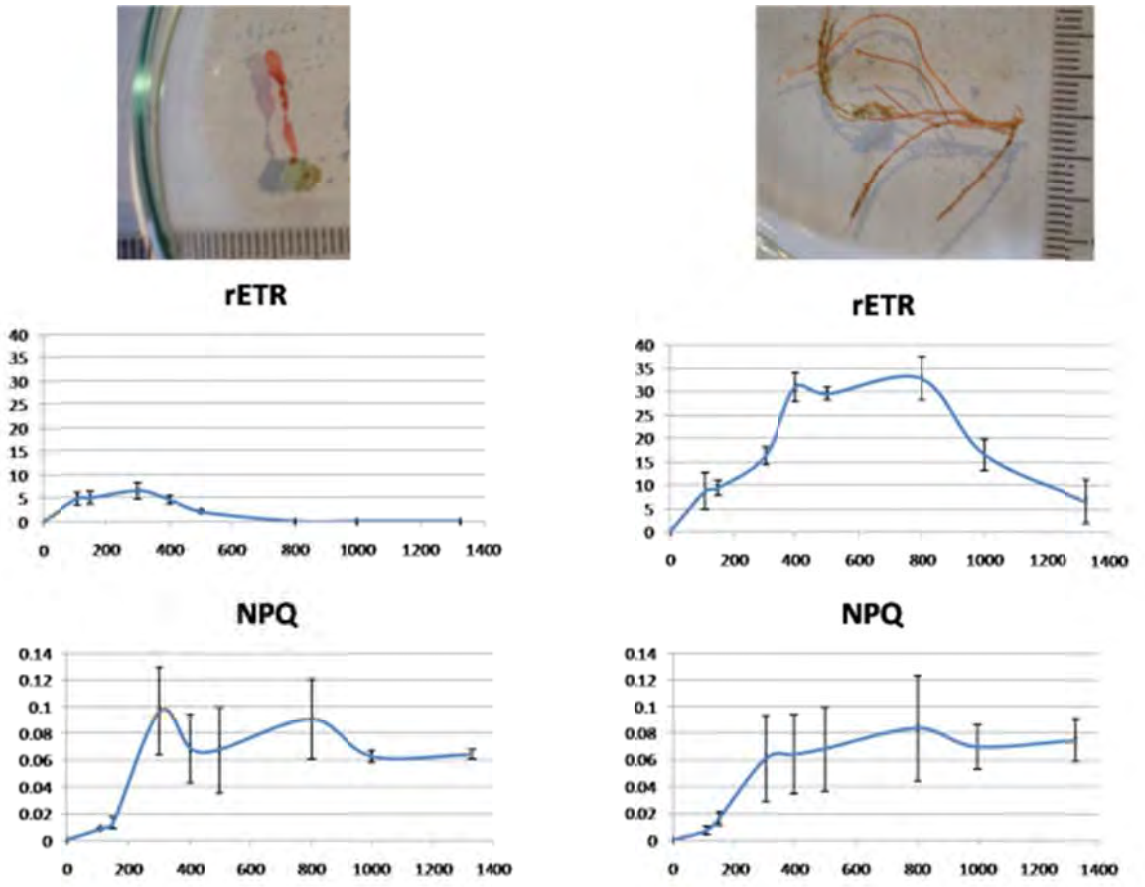

Figure 3.6.8. Red Algae Photophysiology.

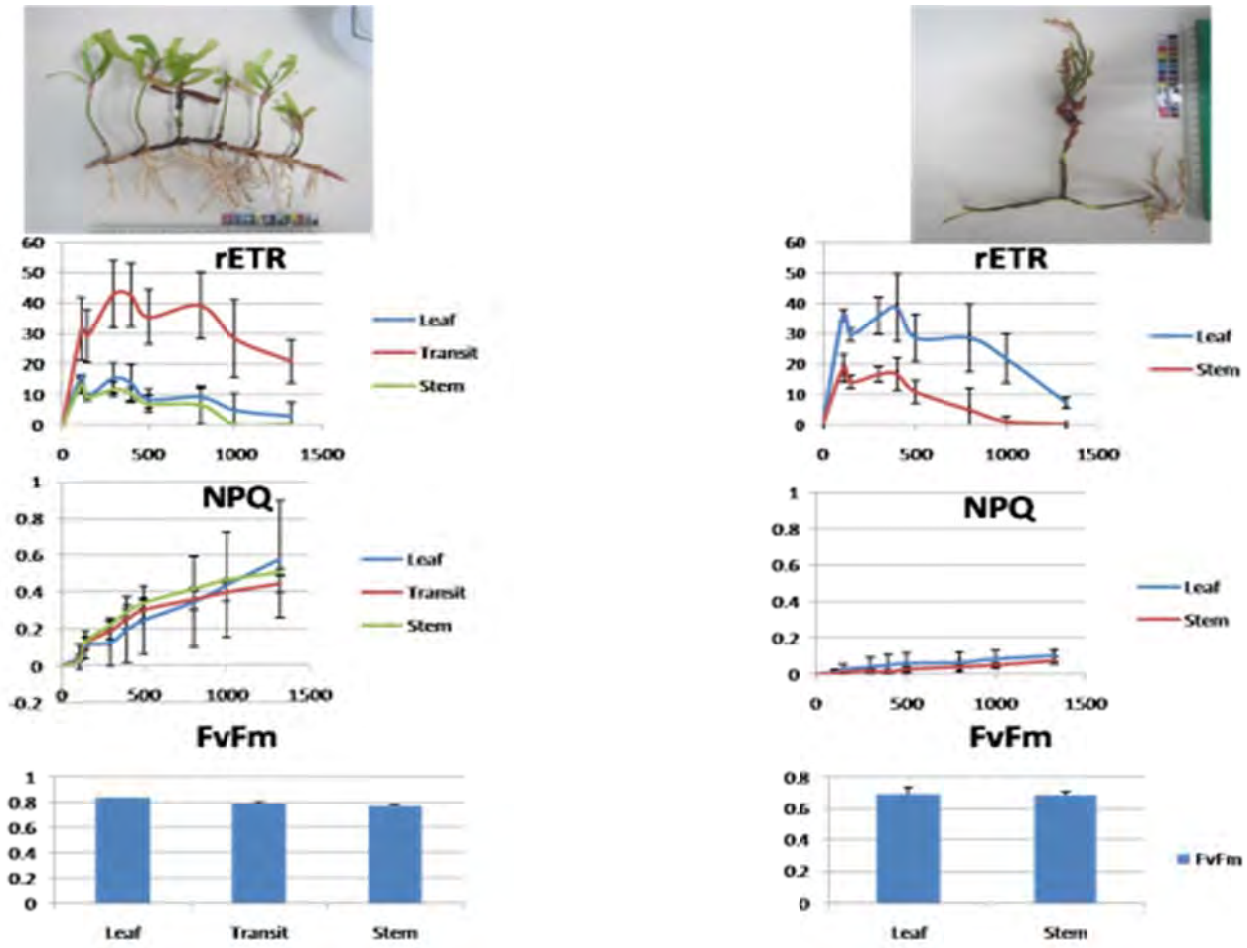

Figure 3.6.9. Seagrass photophysiology.

Sediment and benthic infauna sampling overviews

Sampling of benthic meio- and macrofauna in sediments was conducted during the VAMS operations, but the faunistic analyses have yet to be completed. The following describes the sampling effort.

Saya de Malha Bank – Leg I

During the Leg I on Saya de Malha Bank, 12 dives with the VAMS were done and at least 2 full sediment grabs for chemical analysis were collected for only 10 dives. Sand was the dominant substrate in most locations (see also Ch. 2), with the exception of superstation 27 which had hard substrate as shown in Table 3.6.3.

Table 3.6.3. Station number, Depth and Bottom type for Leg I on Saya de Malha Bank.

Superstation number				
SS1-Gr1	7/5/2018	132	Sandy with rubbles	√
SS3-Gr2	8/5/2018	74	Sandy	√
SS4-Gr3	8/5/2018	30	Sandy/Gravel	√
SS8-Gr4	9/5/2018	62	Sandy	√
SS9-Gr5	10/5/2018	55	Sand	√
SS13-Gr6	11/5/2018	28	Gravel sand	√
SS15-Gr7	11/5/2018	55	Sand	√
SS20-Gr8	12/5/2018	199	Sandy mud	x
SS21-Gr9	12/5/2018	160	Ancient reef/Hard substrate	√
SS25-Gr10	13/5/2018	288	Sand	√
SS26-Gr11	13/5/2018	251	Sandy mud	√
SS27-Gr12	13/5/2018	267	Hard substrate	x

Annex V gives information about the chemical parameters subsampled from the grabs for the superstations on Leg I. Results for Total Hydrocarbon Content (THC), Total Organic Content (TOC), Grain-Size Analysis (GSA) were described in Ch. 2, but the same samples were also explored for Heavy Metals (HM), Microplastics (MP) and Meiofauna (Meio). Biological samples from 1mm sieve (Bio 1mm) and Biological samples from 5mm sieve (Bio 5mm) during Leg I on the Saya de Malha Bank are shown in Figure 3.6.10.

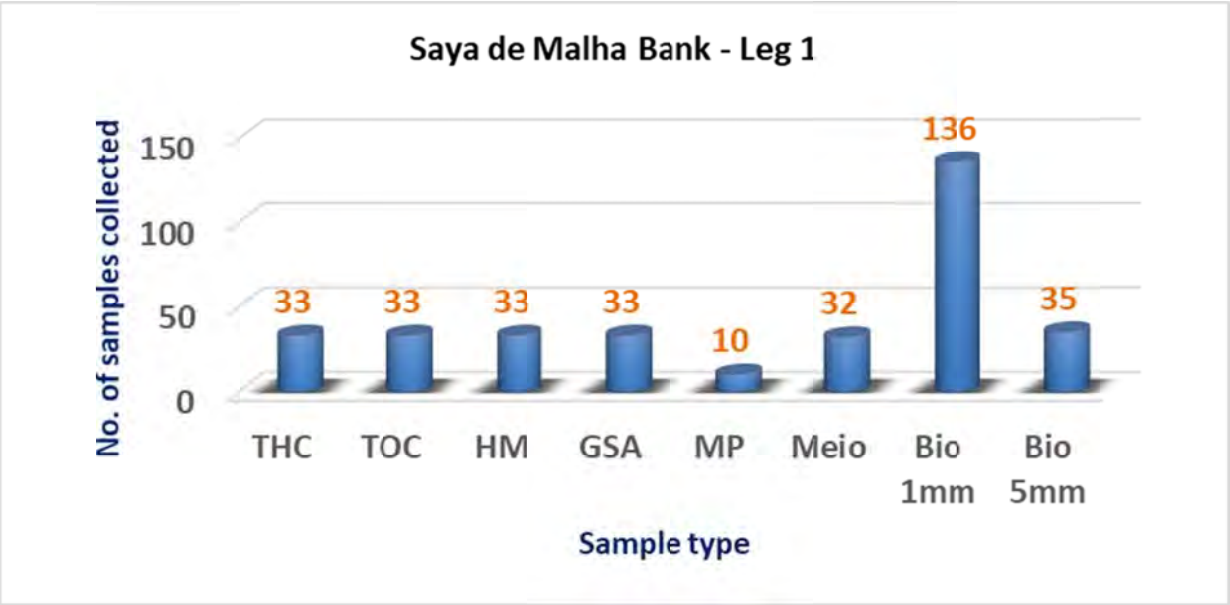

Figure 3.6.10. Chemical and Biological samples collected during Leg 1 on Saya de Malha Bank.

Saya de Malha Bank – Leg II

The Leg II on the Saya de Malha Bank comprises of 9 superstations (32 dives) and one additional station on a seamount. Table 3.6.2 gives a summary of superstations number and depth where sediment was collected. Stations where sediment grabs were not collected are not shown. Only 2 superstations namely SS40 and SS41 had3 and 4 full sediment grabs collected respectively and subsampled for chemical analysis. The total number of samples collected for Total Hydrocarbon Count (THC), Total Organic Content (TOC), Heavy Metals (HM), Grain-Size Analysis (GSA), Microplastics (MP), Meiofauna (Meio), Biological samples from 1mm sieve (Bio 1mm) and Biological samples from 5mm sieve (Bio 5mm) during Leg 2 on the Saya de Malha Bank are shown in Figure 3.6.11. The sediment samples for chemical analysis are kept frozen and the biological samples are preserved in formaldehyde for future laboratory investigation. Annex V provides information about the chemical parameters subsampled from the grabs for the superstations during leg 2 on Saya de Malha Bank.

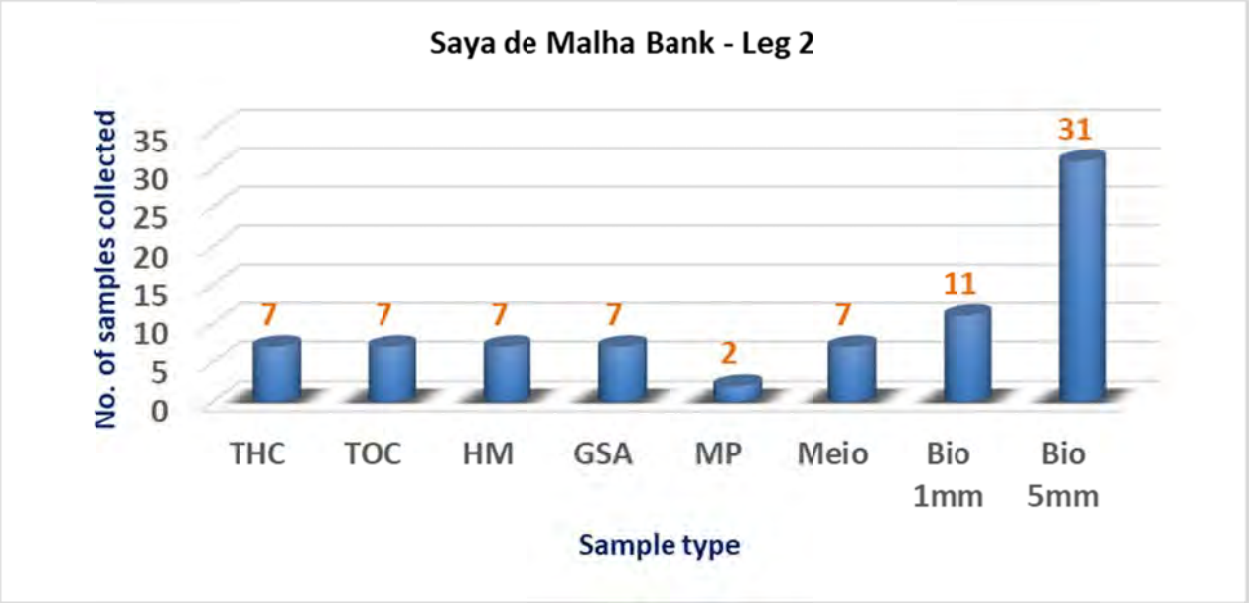

Figure 3.6.11. Chemical and Biological samples collected during Leg 2 of Saya de Malha.

Table 3.6.4. Station number and Depth of sediment collection for Leg 2 on Saya de Malha Bank.

Station number	Date	Depth (m)	Sediment collected for chemical analysis
SS34	16-05-2018	287	X
SS36	19-05-2018	37,44	X
SS37	20-05-2018	32,34	X
Station Seamount	20-05-2018	26	X
SS38	21-05-2018	34	X
SS39	22-05-2018	23,30	X
SS40	22-05-2018	73	√
SS41	25-05-2018	381	√

Nazareth Bank

On Nazareth Bank, sediment samples were collected at 6 superstations (SS43, SS44, SS45, SS46, SS47 and SS49) and adequate amount of sediment for chemical analysis was collected at 3 superstations (SS45, SS47 and SS49). The total number of samples collected for chemical analysis and further biological investigations are shown in Figure 3.6.12 below.

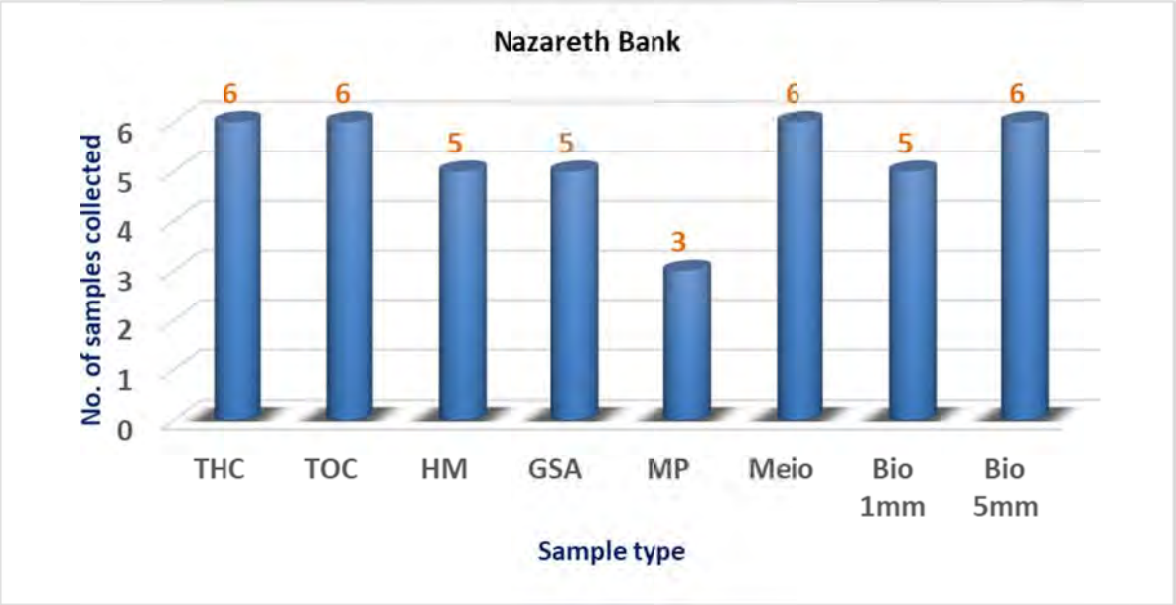

Figure 1.6.12. Chemical and Biological samples collected during Leg 2 on Nazareth Bank.

Annex V gives information about the chemical parameters subsampled from the grabs for the superstations at Nazareth Bank.

Table 3.6.5. Station number and Depth of sediment collection for Nazareth.

Station number	Date	Depth (m)	Bottom type	Sediment collected for chemical analysis
SS43	27/5/2018	43	Sandy, seagrass patches	X
SS44	27/5/2018	38	Live massive corals	X
SS45	27/5/2018	35	Seagrass beds, gravel	√
SS46	27/5/2018	62	Seagrass beds	X
SS47	27/5/2018	58	sandy, seaweeds	√
SS49	29/5/2018	133	sandy	√

3.7 Mammals, birds and turtles

In Saya de Malha no marine mammal encounter was recorded. One sighting of marine turtle was logged on the 9th May 2018 during dedicated observation period. The individual was seen briefly while diving in front of the boat and only yellowish-brown carapace was observed. A total of 11 bird sightings were logged during dedicated observation periods for the length of the cruise with a total of 52 individuals recorded. In most cases the species were unidentified as the birds were too far from the boat. Three opportunistic observations of birds comprising of over 100 Lesser noddies *Anous tenuirostris* flying over boat on 17th May 2018 in late evening (Fig. 3.7.1), one Red-footed booby Sula sula (Fig. 3.7.2) on the 21st May 2018 resting on the ship's mast, and lastly one Fregate bird Fregata sp. feeding aft of the boat on the 25th May 2018 was recorded. An opportunistic sighting of a Whale-shark *Rhicodon typus* was also logged on the 16th May 2018.

In Nazareth one marine mammal encounter was recorded on the 28th May 2018, during dedicated visual observations. The two individuals were identified as dolphins (Fig 3.7.3) but species undetermined as there was no clear visual on the dorsal fin. An approximation of 92 Sooty tern, *Sterna fuscata* (Fig. 3.7.4) was sighted from 13 sighting records logged during dedicated observation on the 28th May and one individual was opportunistically seen on the deck the same morning.

Figure 3.7.1. Lesser noddy landed on the ship.

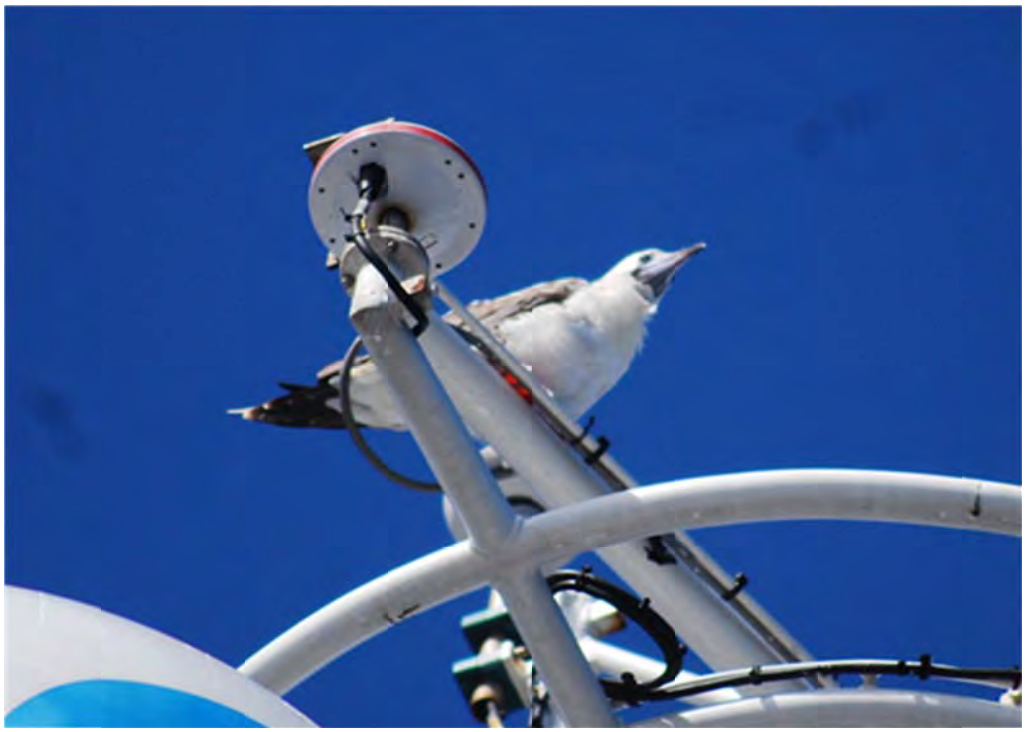

Figure 3.7.2. Red-footed booby resting on ship's mast.

Figure 3.7.3. Marine mammal observed in Nazareth.

Figure 3.7.4. Sooty terns observed in Nazareth.

3.8 Other observations, incl. microplastics and litter

Microplastics

Out of eight manta trawl and 47 CUFES stations only three manta trawl and three CUFES stations contained microplastics (Table 3.8.1). Two larger pieces of plastic were collected during the 3rd CUFES station which was included in the table below.

Table 3.8.1. Number of microplastics collected in Saya De Malha, cruise number 2018406.

Station #	Depth (m)	# of objects in sample	Tray #	Start Position	Stop Position
5	28	4	HD 320	-10.09055 61.2808	-10.0922 61.2877
7	68	2	HF 578	-10.4148 61.2127	-10.4188 61.2199
30	264	1	HF 577	-11.917 61.7144	-11.9194 61.7228
CUFES 2	26-74	1	HD 321	-10,1158 60,5287	-10,107 60,7714
CUFES 3	74-42	2	HD 319	-10,1069 60,7717	-10,0866 61,4556
CUFES 23	123-127	2	HF 579	-10,7586 60,9157	-10,7632 61,0385

Litter (plastic foil) was observed in only a single VAMS dive. Apparently Asian candy wrap.

CHAPTER 4. SUMMARY AND PROVISIONAL CONCLUSIONS

Considerable onshore post-processing and further analyses of data and samples are required to draw firmer conclusions and paint a broader picture relating to the main aims of the mission. This report primarily describes the sampling effort and some provisional outcomes.

The cruise was carried out as planned, with only relatively minor adjustments to the approach described in the Sailing Order. By taking advantage of underway learning and new observations, these adjustments ensured that the outcome was enhanced. Fortunately, the sampling conditions were favorable for most of the time available, facilitating good sampling and function of most technologies.

The underway sampling of bathymetry data, physical and chemical properties and ocean current data documented patterns across the Saya de Malha and Nazareth, two major bank areas facing the influence of the oceanic westward-flowing oceanic currents. The watermasses above the bank is well mixed, but the banks appeared flushed by relatively swift currents. Stations immediately off of the bank showed the expected regional oceanic patterns.

The visual observations of biological communities (plant and animals) from the shallow seagrass meadows above approximately 30m depth to the deepest slope communities along the margins of the banks were documented. Shallow bank areas have rich seagrass and coral areas, whereas deeper parts have wide sedimentary flats and rocky patches. The sediments seem overall very thin. In general, the seabed communities in deeper areas appeared impoverished, perhaps not unexpected in an area flushed by relatively oligotrophic watermasses.

The fish communities in midwater and on the seabed were studied by plankton nets, midwater trawls and the ROV with a HD video camera. In addition, attempts were made to record midwater biota by multifrequency echosounder. The latter was not very successful because the abundance and character of scatterers indicated very low densities of fish. Trawl catches were small, yet sometimes relatively diverse. This was also the case in the Nazareth Bank, where (as opposed to on the Saya de Malha) permission was granted to sample by bottom trawl within a small rectangle in the southeast. Also in this area, the catches indicated low abundance of fish.

Work for future months and years comprise full analyses of samples and data. This will add value to the results outlined in this report, and will demonstrate that the cruise provided data and collections enhancing the baseline information on the two study areas. Thereby the effort will fulfill the overriding objectives of the EAF-Nansen Science plan and the expectations expressed in the plans agreed with the Joint Management Area Commission and Mauritius.

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ANNEX I. DECK FORMS FOR RECORDING MAMMALS AND OTHER WILDLIFE

MARINE MAMMAL AND OTHER WILDLIFE RECORDING FORM - EFFORT

Ship/ platform name .....

Record the following for all watches, even if no marine mammals are seen.

Date	**Observer's/ operator's name(s)**	**Time of start of section of watch** (UTC, 24hr clock)	**Time of end of section of watch** (UTC, 24hr clock)	**Start position** (latitude and longitude)	**Depth at start** (m)	**End position** (latitude and longitude)	**Depth at end** (m)	**Speed of vessel** (knots)	**Wind dir'n**	**Wind force** (B'fort scale)	**Sea state** (g/ s/ c/ r)	**Swell** (o/ m/ l)	**Vis.** (visual watch only) (p/ m/ g)	**Sun glare** (visual watch only) (n/ wf/ sf/ vf/ wb/ sb/ vb)	**Precip.** (n/ l/ m/ h/ s)

Sea state: g = glassy (like mirror); s = slight (no/ few white caps); c = choppy (many white caps); r = rough (big waves, foam, spray)
Swell: o = low (< 2 m); m = medium (2-4 m); l = large (> 4 m)
Visibility: p = poor (< 1 km); m = moderate (1-5 km); g = good (> 5 km)
Sun glare: n = none; wf = weak forward; sf = strong forward; vf = variable forward; wb = weak behind; sb = strong behind; vb = variable behind
Precipitation: n = none; l = light rain; m = moderate rain; h = heavy rain; s = snow

MARINE MAMMAL AND OTHER WILDLIFE RECORDING FORM – SIGHTINGS

<table>
<tr><td colspan="3">Ship/ platform name</td><td colspan="2">Sighting number (start at 1 for first sighting of survey)</td></tr>
<tr><td colspan="3">Date</td><td>Time at start of encounter (UTC, 24hr clock)</td><td>Time at end of encounter (UTC, 24hr clock)</td></tr>
<tr><td colspan="5">How were the animals first detected?
□ visually detected by observer keeping a continuous watch
□
□ visually spotted incidentally by observer or someone else</td></tr>
<tr><td>Observer's/ operator's name</td><td colspan="2">Position (latitude and longitude)</td><td colspan="2">Water depth (metres)</td></tr>
<tr><td colspan="2">Species/ species group</td><td colspan="3" rowspan="2">Description (include features such as overall size; shape of head; colour and pattern; size, shape and position of dorsal fin; height, direction and shape of blow; characteristics of whistles/ clicks)</td></tr>
<tr><td colspan="2">Range to animal (when first seen or heard) (metres)</td></tr>
<tr><td>Total number</td><td>Number of adults (visual sightings only)</td><td>Number of juveniles (visual sightings only)</td><td>Number of calves (visual sightings only)</td><td>Photograph taken
□ yes □ no</td></tr>
<tr><td colspan="5">Behaviour (visual sightings only)</td></tr>
</table>

ANNEX II. DETAILS OF SAMPLING STATIONS FOR NUTRIENTS

Site	Leg	Station	GPS Position		Date and Time (UTC)	Depth (m)	Nutrient Samples	
			Latitude (S)	Longitude (E)			MOI	IMR
Saya de Malha	1	391	09 47.50	059 43.90	7/5/2018 13:47	131	■	■
		392	10 07.55	059 38.10	7/5/2018 20.35	2347	■	■
		393	10 07.18	059 52.08	8/5/2018 01.15	74	■	■
		394	10 06.79	060 34.51	8/5/2018 10.00	27	■	■
		395	10 05.43	061 16.83	8/5/2018 16.05	29	■	■
		396	10 02.80	062 32.99	9/5/2018 00.31	2172		■
		397	10 24.88	061 12.75	9/5/2018 11.17	68	■	■
		398	10 24.73	060 37.93	9/5/2018 16.07	60	■	■
		399	10 25.70	059 54.08	9/5/2018 22.55	1204		■
		400	10 25.62	060 08.38	10/5/2018 01.40	51	■	■
		401	10 46.18	059 58.42	10/5/2018 06.10	2129		■
		402	10 45.39	061 02.70	10/5/2018 16.39	128	■	■
		403	10 43.91	062 07.79	11/5/2018 02.41	26	■	■
		404	10 43.11	062 34.27	11/5/2018 07.47	2125		■
		405	11 05.54	061 55.17	11/5/2018 13.41	52	■	■
		406	11 04.98	061 19.39	11/5/2018 19.20	120	■	■
		407	11 03.68	060 26.79	12/5/2018 01.51	61		■
		408	11 18.66	060 20.31	12/5/2018 04.32	2700		■
		409	11 19.98	060 36.53	12/5/2018 08.19	195	■	■
		410	11 21.96	061 09.33	12/5/2018 13.50	156	■	■
		411	11 23.53	061 45.57	12/5/2018 19.50	109	■	■
		412	11 25.94	062 27.90	13/5/2018 01.42	2068	■	■
		413	11 44.65	062 02.11	13/5/2018 06.33	284	■	■
		414	11 42.35	061 22.04	13/5/2018 11.55	248	■	■
		415	11 40.49	060 48.52	13/5/2018 17.39	265	■	■
		416	11 54.52	060 45.63	13/5/2018 21.17	1309		■
		417	11 55.02	060 58.00	13/5/2018 23.54	328	■	■
		418	11 55.02	061 42.86	14/5/2018 06.13	265	■	■
		419	09 39.52	060 42.87	14/5/2018 09.35	2078		■
		420	12 10.55	061 10.93	14/5/2018 16.58	207	■	■
	2	421	11 20.51	060 46.27	15/5/2018 14.06	72		
		422	10 25.93	059 50.33	16/5/2018 23.07	2020		
		423	09 47.46	060 51.07	18/5/2018 21.21	110	■	
		424	09 39.52	060 42.87	19/5/2018 16.06	1711		
		425	10 03.56	062 13.40	20/5/2018 22.46	192	■	
		426	10 03.39	062 20.28	21/5/2018 00.13	1418		
		427	10 19.17	062 14.73	21/5/2018 18.05	215	■	
		428	14 34.82	061 07.43	22/5/2018 23.25	506		
		429	10 43.90	062 18.08	23/5/2018 00.48	1008		
		430	10 43.80	062 15.52	23/5/2018 16.13	92		
		431	10 43.81	062 17.76	23/5/2018 17.17	570		
		432 (hole)	11 24.53	062 00.49	25/5/2018 06.42	380	■	■
		433	12 05.02	061 52.73	26/5/2018 10.25	1719		
		434 (channel)	12 34.55	061 00.43	26/5/2018 18.06	1068	■	■
Nazareth		435	13 54.97	060 51.90	27/5/2018 04.49	43	■	■
		436	14 02.27	061 00.74	27/5/2018 06.23	36	■	■
		437	14 10.85	060 56.47	27/5/2018 09.21	31	■	■
		438	14 24.87	061 02.64	27/5/2018 12.31	32	■	■
		439	14 34.82	061 07.43	27/5/2018 14.49	56	■	■
		440	15 10.42	061 08.64	27/5/2018 07.59	170	■	■
		441	15 19.96	061 01.83	29/5/2018 13.52	242	■	■

ANNEX III. RECORDS OF FISHING STATIONS

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 1
DATE :10/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 10°45.87
start stop duration Lon E 60°26.38
TIME :11:08:28 11:36:31 28.1 (min) Purpose : 1
LOG : 5973.92 5975.98 2.0 Region : 9800
FDEPTH: 10 60 Gear cond.: 0
BDEPTH: 120 105 Validity : 0
Towing dir: 0° Wire out : 400 m Speed : 4.4 kn
Sorted : 0 Total catch: 0.98 Catch/hour: 2.10

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
FISH LARVAE	0.53	2890	25.51
SALPS	0.53	464	25.51
C E P H A L O P O D A	0.39	627	18.37
CARANGIDAE, juvenile	0.33	1414	15.51
JELLYFISH	0.10	118	4.90
Diodon holocanthus	0.08	2	3.78
SYNODONTIDAE, juvenile	0.06	246	2.94
APOGONIDAE, juvenile	0.02	51	0.97
OGCOCEPHALIDAE	0.02	4	0.92
NOMEIDAE, juvenile	0.01	30	0.32
C R U S T A C E A N S	0.01	2	0.31
DACTYLOPTERIDAE, juvenile	0.01	6	0.31
SCOMBRIDAE, juvenile	0.00	11	0.20
CYNOGLOSSIDAE	0.00	17	0.16
C R A B S	0.00	2	0.12
CARANGIDAE	0.00	2	0.10
Leptocephalus, juvenile	0.00	9	0.05
TETRAODONTIDAE, juvenile	0.00	2	0.03
Total	2.10		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 2
DATE :10/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 10°45.98
start stop duration Lon E 61°5.20
TIME :18:25:08 18:56:22 31.2 (min) Purpose : 1
LOG : 6022.05 6024.56 2.5 Region : 9800
FDEPTH: 0 30 Gear cond.: 0
BDEPTH: 126 127 Validity : 0
Towing dir: 0° Wire out : 450 m Speed : 4.8 kn
Sorted : 0 Total catch: 270.96 Catch/hour: 520.57

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Diodon holocanthus	369.03	10884	70.89
Decapterus russelli	135.87	2060	26.10
1			
Cyclichthys orbicularis	7.68	77	1.48
Katsuwonus pelamis	5.38	2	1.03
Saurida tumbil	1.08	77	0.21
Selar crumenophthalmus	0.58	2	0.11
S H R I M P S	0.53	10	0.10
Lagocephalus guentheri	0.23	2	0.04
C E P H A L O P O D A	0.09	169	0.02
Champsodon sp.	0.08	15	0.01
SYNODONTIDAE, juvenile	0.02	108	0.00
BELONIDAE	0.01	2	0.00
Total	520.57		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 3
DATE :15/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 11°12.97
start stop duration Lon E 60°35.02
TIME :16:23:47 16:55:36 31.8 (min) Purpose : 1
LOG : 6760.24 6762.71 2.5 Region : 9800
FDEPTH: 0 5 Gear cond.: 0
BDEPTH: 98 155 Validity : 0
Towing dir: 0° Wire out : 220 m Speed : 4.7 kn
Sorted : 0 Total catch: 20.61 Catch/hour: 38.85

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Diodon holocanthus	28.30	943	72.85
MYCTOPHIDAE	7.88	4927	20.29
Champsodon sp.	2.24	701	5.78
C E P H A L O P O D A	0.23	45	0.58
Dipterygonotus sp.	0.09	11	0.22
Decapterus russelli	0.08	2	0.22
SYNODONTIDAE, juvenile	0.01	45	0.02
S H R I M P S	0.01	98	0.02
FISH LARVAE	0.00	4	0.01
FISH LARVAE	0.00	9	0.01
0			
Bregmaceros sp.	0.00	8	0.01
Holocentrus sp., juvenile	0.00	2	0.00
Leptocephalus, juvenile	0.00	4	0.00
HEMIRAMPHIDAE	0.00	6	0.00
CARANGIDAE, juvenile	0.00	2	0.00
Total	38.85		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 4
DATE :15/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 11°12.16
start stop duration Lon E 60°30.47
TIME :17:44:34 18:40:55 56.4 (min) Purpose : 1
LOG : 6765.18 6769.25 4.1 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 196 70 Validity : 0
Towing dir: 0° Wire out : 220 m Speed : 4.3 kn
Sorted : 0 Total catch: 38.95 Catch/hour: 41.47

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
MYCTOPHIDAE	18.92	24377	45.62
C E P H A L O P O D A	9.83	100	23.70
Euthynnus affinis	5.41	2	13.04
Diodon holocanthus	3.71	232	8.93
Cubiceps pauciradiatus	2.46	149	5.93
Sphyraena acutipinnis	0.79	2	1.90
PARALEPIDIDAE	0.14	31	0.33
Decapterus russelli	0.08	2	0.19
Champsodon sp.	0.06	17	0.15
Holocentrus sp., juvenile	0.02	14	0.05
Decapterus russelli, juvenile	0.01	4	0.04
S H R I M P S	0.01	281	0.03
0			
Leptocephalus, juvenile	0.01	6	0.02
S H R I M P S	0.01	15	0.02
APOGONIDAE	0.01	10	0.02
BALISTIDAE, juvenile	0.00	1	0.01
HEMIRAMPHIDAE, juvenile	0.00	5	0.00
SYNODONTIDAE, juvenile	0.00	10	0.00
PARALEPIDIDAE, juvenile	0.00	1	0.00
BRAMIDAE, juvenile	0.00	1	0.00
Total	41.47		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 5
DATE :16/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 10°25.34
start stop duration Lon E 60°20.85
TIME :18:42:38 19:25:58 43.3 (min) Purpose : 1
LOG : 6832.59 6835.86 3.3 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 77 73 Validity : 0
Towing dir: 0° Wire out : 190 m Speed : 4.5 kn
Sorted : 0 Total catch: 53.73 Catch/hour: 74.42

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Rastrelliger kanagurta	36.34	187	48.84
4			
Sphyraena barracuda	28.12	1	37.78
3			
Decapterus russelli	5.08	144	6.83
2			
Sphyraena acutipinnis	2.66	32	3.57
Dipterygonotus sp.	1.02	60	1.38
Saurida tumbil	0.51	14	0.69
FISH LARVAE	0.37	983	0.50
Todarodes sp.	0.14	44	0.19
Diodon holocanthus	0.12	8	0.17
Stoloteuthis sp	0.01	12	0.02
0			
S H R I M P S	0.01	1	0.01
Canthigaster rivulata, juvenile	0.01	1	0.01
Lagocephalus guentheri, juvenile	0.01	1	0.01
Decapterus russelli, juvenile	0.01	3	0.01
Echeneis naucrates, juvenile	0.00	1	0.00
Total	74.42		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 6
DATE :18/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 9°45.02
start stop duration Lon E 60°39.56
TIME :17:59:16 19:01:17 62.0 (min) Purpose : 1
LOG : 6956.95 6959.97 3.0 Region : 9800
FDEPTH: 150 420 Gear cond.: 0
BDEPTH: 0 13 Validity : 0
Towing dir: 0° Wire out : 1000 m Speed : 2.9 kn
Sorted : 0 Total catch: 11.65 Catch/hour: 11.27

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
MYCTOPHIDAE	4.76	0	42.24
C E P H A L O P O D A	2.59	79	23.01
Chauliodus sloani	1.03	35	9.10
MELAMPHAIDAE	0.55	15	4.89
Gonostoma sp.	0.46	28	4.12
SALPS	0.41	47	3.61
Avocettina sp.	0.39	80	3.43
ALEPOCEPHALIDAE	0.22	6	1.97
S H R I M P S	0.15	190	1.29
Gonostoma elongatum	0.14	4	1.20

SERGESTIDAE	0.13	84	1.12
Diretmus argenteus	0.09	11	0.77
Malacosteus sp.	0.06	6	0.52
BARBOURISIIDAE	0.06	1	0.52
JELLYFISH	0.06	31	0.52
Sternoptyx sp.	0.06	6	0.52
Malacosteus sp.	0.06	4	0.52
Astronesthes sp	0.04	2	0.34
HISTIOTEUTHIDAE	0.02	1	0.17
Cubiceps sp.	0.02	9	0.16
Total	11.27		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 7
DATE :18/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 9°47.73
start stop duration Lon E 60°49.54
TIME :21:57:49 22:53:07 55.3 (min) Purpose : 1
LOG : 6973.03 6977.45 4.4 Region : 9800
FDEPTH: 0 6 Gear cond.: 0
BDEPTH: 534 326 Validity : 0
Towing dir: 0° Wire out : 180 m Speed : 4.8 kn
Sorted : 0 Total catch: 82.89 Catch/hour: 89.92

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
S H R I M P S	62.27	50142	69.25
MYCTOPHIDAE	13.02	2441	14.48
C E P H A L O P O D A	5.75	4711	6.39
Caranx sp.	3.99	1	4.44
Sphyraena qenie	2.67	1	2.97
Gempylus serpens	1.00	2	1.11
Leptocephalus, juvenile	0.43	146	0.48
PARALEPIDIDAE	0.43	81	0.48
CARANGIDAE, juvenile	0.33	16	0.36
BALISTIDAE, juvenile	0.11	16	0.12
APOGONIDAE, juvenile	0.01	9	0.01
SYNODONTIDAE, juvenile	0.00	244	0.01
Total	90.01		100.10

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 8
DATE :19/05/18 GEAR TYPE: TR NO: 1 POSITION:Lat S 9°52.63
start stop duration Lon E 60°47.84
TIME :06:00:00 18:00:00 720.0(min) Purpose : 1
LOG : 6994.62 6994.62 0.0 Region : 9800
FDEPTH: 21 21 Gear cond.: 0
BDEPTH: 21 21 Validity : 0
Towing dir: 0° Wire out : 0 m Speed : 0.0 kn
Sorted : 0 Total catch: 1.32 Catch/hour: 0.11

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Lethrinus cf mahsena	0.10	1	87.88
Siganus sutor	0.01	0	12.12
Total	0.11		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 9
DATE :19/05/18 GEAR TYPE: TR NO: 1 POSITION:Lat S 9°49.47
start stop duration Lon E 60°55.09
TIME :18:30:00 08:30:00 840.0(min) Purpose : 1
LOG : 7111.84 7111.84 0.0 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 20 21 Validity : 0
Towing dir: 0° Wire out : 0 m Speed : 0.0 kn
Sorted : 0 Total catch: 9.72 Catch/hour: 0.69

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Carcharhinus amblyrhynchos	0.36	0	51.26
Lethrinus cf mahsena	0.32	1	45.95
Lutjanus gibbus	0.02	0	2.79
Total	0.69		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 10
DATE :21/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 10°23.03
start stop duration Lon E 62°25.41
TIME :20:29:22 21:28:41 59.3 (min) Purpose : 1
LOG : 7253.62 7258.29 4.7 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 2099 1969 Validity : 0
Towing dir: 0° Wire out : 200 m Speed : 4.7 kn
Sorted : 0 Total catch: 90.22 Catch/hour: 91.25

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
MYCTOPHIDAE	39.08	7102	42.82
C E P H A L O P O D A	36.98	1156	40.52
Cubiceps pauciradiatus	8.88	356	9.73
Leptocephalus, juvenile	3.50	701	3.84
MYCTOPHIDAE	0.76	146	0.83
Brama orcini	0.59	12	0.65
GEMPYLIDAE, juvenile	0.58	23	0.63
SCOMBRIDAE, juvenile	0.45	17	0.49
Zanclus cornutus, juvenile	0.34	35	0.37
SYNODONTIDAE, juvenile	0.03	70	0.04
JELLYFISH	0.02	29	0.02
HEMIRAMPHIDAE, juvenile	0.02	23	0.02
Bothidae - juvenile	0.02	40	0.02
ACANTHURIDAE, juvenile	0.02	23	0.02
OSTRACIIDAE, juvenile	0.00	6	0.00
Total	91.25		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 11
DATE :22/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 10°23.05
start stop duration Lon E 62°0.39
TIME :17:14:33 17:59:58 45.4 (min) Purpose : 1
LOG : 7308.08 7311.94 3.9 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 71 77 Validity : 0
Towing dir: 0° Wire out : 200 m Speed : 5.1 kn
Sorted : 0 Total catch: 3.96 Catch/hour: 5.23

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Echeneis sp.	3.14	3	60.10
Selar crumenophthalmus	1.57	5	30.05
Sphyraena acutipinnis	0.40	4	7.58
ACANTHURIDAE, juvenile	0.11	86	2.02
APOGONIDAE	0.01	1	0.12
SYNODONTIDAE, juvenile	0.00	17	0.06
FISH LARVAE	0.00	13	0.05
Bregmaceros sp.	0.00	1	0.03
OSTRACIIDAE, juvenile	0.00	1	0.01
HEMIRAMPHIDAE, juvenile	0.00	1	0.01
Total	5.23		100.01

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 12
DATE :24/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S 11°5.46
start stop duration Lon E 61°40.63
TIME :22:14:32 23:14:50 60.3 (min) Purpose : 1
LOG : 7458.05 7462.89 4.8 Region : 9800
FDEPTH: 0 0 Gear cond.: 0
BDEPTH: 93 110 Validity : 0
Towing dir: 0° Wire out : 200 m Speed : 4.8 kn
Sorted : 0 Total catch: 37.27 Catch/hour: 37.08

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Euthynnus affinis	19.76	5	53.29
Mobula sp.	10.05	1	27.10
Echeneis naucrates	5.01	4	13.52
Loxodon macrorhinus	1.59	1	4.29
Selar crumenophthalmus	0.33	1	0.89
Decapterus russelli	0.13	4	0.35
Cheilopogon sp.	0.10	1	0.27
Diodon holocanthus	0.09	2	0.24
C E P H A L O P O D A	0.01	1	0.03
ACANTHURIDAE, juvenile	0.00	2	0.01
Total	37.08		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 13
DATE :29/05/18 GEAR TYPE: BT NO: 1 POSITION:Lat S 15°11.01
start stop duration Lon E 61°8.76
TIME :05:21:28 05:50:14 28.8 (min) Purpose : 1
LOG : 8196.20 8197.69 1.5 Region : 9800
FDEPTH: 214 213 Gear cond.: 0
BDEPTH: 214 213 Validity : 0
Towing dir: 0° Wire out : 480 m Speed : 3.1 kn
Sorted : 0 Total catch: 12.77 Catch/hour: 26.64

SPECIES	CATCH/HOUR		% OF TOT.
	weight	numbers	
Squatina africana	20.15	6	75.62
Sponges - round	2.48	8	9.32
Maja sp.	1.79	2	6.73
CHarybdis sp.	1.00	4	3.76
Ibacus novemdentatus	0.44	8	1.64
Loligo sp.	0.26	6	0.99
CORAL	0.18	96	0.67
Tylerius spinosissimus	0.07	13	0.26
Sepia sp	0.06	6	0.23
Synodus sp.	0.05	6	0.19
GOBIIDAE, juvenile	0.04	46	0.15
Engyprosopon grandisquama	0.03	4	0.12

TETRAODONTIDAE	0.03	2	0.10
0			
Champsodon sp.	0.01	2	0.04
Antigonia sp.	0.01	2	0.04
Decapterus russelli	0.01	2	0.03
PAGUROIDEA	0.01	2	0.03
OGCOCEPHALIDAE	0.01	2	0.03
Arnoglossus sp.	0.00	2	0.01
Leech	0.00	2	0.01
Unidentified	0.00	2	0.01
C R U S T A C E A N S	0.00	2	0.00
0			
C R U S T A C E A N S	0.00	2	0.00
Total	26.64		99.99

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 14
DATE :29/05/18 GEAR TYPE: BT NO: 1 POSITION:Lat S
15°20.88
start stop duration Lon E
61°1.43
TIME :12:39:28 13:08:22 28.9 (min) Purpose : 1
LOG : 8222.88 8224.43 1.6 Region : 9800
FDEPTH: 242 240 Gear cond.: 0
BDEPTH: 242 240 Validity : 0
Towing dir: 0° Wire out : 600 m Speed : 3.2 kn
Sorted : 0 Total catch: 0.00 Catch/hour: 0.00

SPECIES	weight	numbers	% OF TOT.
Carangoides equula	0.39	15	0.00
Decapterus sp.	0.07	4	0.00
Champsodon sp.	0.13	17	0.00
Diodon holocanthus	2.43	39	0.00
Sea cucumber	0.03	2	0.00
GOBIIDAE	0.26	274	0.00
Hoplichthys sp.	0.55	4	0.00
Branchiostegus doliatus	0.24	2	0.00
MULLIDAE	0.21	4	0.00
OPHICHTHIDAE	0.03	4	0.00
Polysteganus coeruleopunctatus	0.83	19	0.00
Sepia sp	0.77	25	0.00
Loligo sp.	1.54	44	0.00
Starfish	0.12	8	0.00
Starfish	0.02	2	0.00
0			
Synodus sp.	0.35	10	0.00
Lepidotrigla sp.	1.19	58	0.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 15
DATE :29/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S
15°14.63
start stop duration Lon E
61°2.79
TIME :16:02:54 16:51:54 49.0 (min) Purpose : 1
LOG : 8234.38 8238.51 4.1 Region : 9800
FDEPTH: 0 10 Gear cond.: 0
BDEPTH: 132 197 Validity : 0
Towing dir: 0° Wire out : 235 m Speed : 5.1 kn
Sorted : 0 Total catch: 0.43 Catch/hour: 0.52

SPECIES	weight	numbers	% OF TOT.
APOGONIDAE	0.29	69	56.10
Loligo sp.	0.21	12	39.74
JELLYFISH	0.02	10	3.46
Leptocephalus	0.00	4	0.58
TETRAODONTIDAE, juvenile	0.00	1	0.12
Total	0.52		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 16
DATE :30/05/18 GEAR TYPE: BT NO: 1 POSITION:Lat S
15°30.49
start stop duration Lon E
61°1.84
TIME :18:37:47 19:08:05 30.3 (min) Purpose : 1
LOG : 8336.41 8337.89 1.5 Region : 9800
FDEPTH: 288 276 Gear cond.: 0
BDEPTH: 288 276 Validity : 0
Towing dir: 0° Wire out : 680 m Speed : 2.9 kn
Sorted : 0 Total catch: 25.43 Catch/hour: 50.36

SPECIES	weight	numbers	% OF TOT.
Trigla sp.	19.53	652	38.78
Synodus sp.	7.11	85	14.12
Antigonia sp. 'yellow dorsal/a	4.26	265	8.46
PERISTEDIIDAE	3.47	2	6.88
Carangoides equula	2.87	127	5.70
Halieutaea sp.	2.22	22	4.41
GOBIIDAE, juvenile	1.58	864	3.15
Hoplichthys sp.	1.27	93	2.52
Sepia sp	1.01	24	2.01
Starfish	0.87	52	1.73
Chaunax sp.	0.83	14	1.65
Branchiostegus doliatus	0.73	2	1.46
CYNOGLOSSIDAE	0.73	16	1.46
Uranoscopus sp.	0.69	20	1.38
Tylerius spinosissimus	0.36	8	0.71
Ibacus novemdentatus	0.34	6	0.67
Decapterus russelli	0.30	4	0.59
Diodon holocanthus	0.29	10	0.58
CEPOLIDAE	0.28	4	0.55
Priacanthus prolixus	0.23	4	0.45
OCTOPODIDAE	0.23	8	0.45
BOTHIDAE	0.22	12	0.43
OPHICHTHIDAE	0.16	20	0.31
Triacanthodes ethiops	0.14	10	0.28
Chlorophthalmus sp.	0.13	42	0.26
HETERENCHELYIDAE	0.09	4	0.18
Rhinobatos sp.	0.08	2	0.16
Lepidopus sp.	0.06	2	0.13
Polysteganus coeruleopunctatus	0.06	2	0.11
Champsodon sp.	0.05	8	0.11
Emmelichthys nitidus	0.04	2	0.09
Rexea sp.	0.04	2	0.09
Coral - small	0.04	10	0.08
Centroberyx druzhinini	0.03	2	0.06
G A S T R O P O D S	0.01	12	0.03
Paratrachichthys sajademahalensis	0.01	2	0.01
Plastic	0.00	2	0.00
Total	50.36		100.00

R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 17
DATE :30/05/18 GEAR TYPE: PT NO: 8 POSITION:Lat S
15°29.51
start stop duration Lon E
61°1.29
TIME :20:03:32 21:10:21 66.8 (min) Purpose : 1
LOG : 8339.73 8344.35 4.6 Region : 9800
FDEPTH: 20 50 Gear cond.: 0
BDEPTH: 281 299 Validity : 0
Towing dir: 0° Wire out : 260 m Speed : 4.1 kn
Sorted : 0 Total catch: 0.00 Catch/hour: 0.00

SPECIES	weight	numbers	% OF TOT.
N O C A T C H	0.00	0	0.00

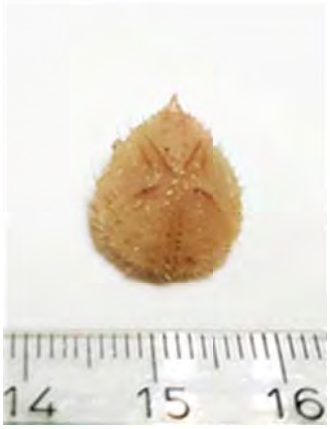
R/V Dr. Fridtjof Nansen SURVEY:2018406 STATION: 18
DATE :31/05/18 GEAR TYPE: BT NO: 1 POSITION:Lat S
15°39.92
start stop duration Lon E
61°1.08
TIME :13:16:54 13:42:28 25.6 (min) Purpose : 1
LOG : 8414.14 8415.65 1.5 Region : 9800
FDEPTH: 290 288 Gear cond.: 0
BDEPTH: 290 288 Validity : 0
Towing dir: 0° Wire out : 740 m Speed : 3.5 kn
Sorted : 0 Total catch: 19.49 Catch/hour: 45.76

SPECIES	weight	numbers	% OF TOT.
Champsodon sp.	14.48	1655	31.65
Pliotrema warreni	5.59	5	12.21
Synodus sp.	4.58	54	10.00
PERISTEDIIDAE	3.54	2	7.75
GOBIIDAE, juvenile	2.72	2723	5.95
Antigonia sp. 'yellow dorsal/a	2.16	70	4.72
Trigla sp.	1.62	66	3.54
Maja sp.	1.57	2	3.44
Halieutaea sp.	1.38	7	3.03
Lepidotrigla sp.	1.17	38	2.56
Ariomma sp.	1.17	14	2.56
Chaunax sp.	1.06	2	2.31
Loligo sp.	0.92	28	2.00
Uranoscopus sp.	0.70	5	1.54
Hoplichthys sp.	0.47	38	1.03
Sepia sp	0.45	14	0.97
Carangoides equula	0.40	9	0.87
CYNOGLOSSIDAE	0.38	5	0.82
BOTHIDAE	0.28	16	0.62
EXOCOETIDAE	0.28	2	0.62
C E P H A L O P O D A	0.28	2	0.62
Plectranthias morgansi**	0.12	5	0.25
Priacanthus prolixus	0.11	2	0.24
Anthias sp.	0.10	5	0.21
Emmelichthys nitidus	0.09	2	0.20
Synodus sp.	0.06	5	0.13
0			
Chlorophthalmus sp.	0.05	16	0.11
Coral - small	0.02	7	0.04
JELLYFISH	0.00	2	0.01
G A S T R O P O D S	0.00	16	0.01
Total	45.76		100.01

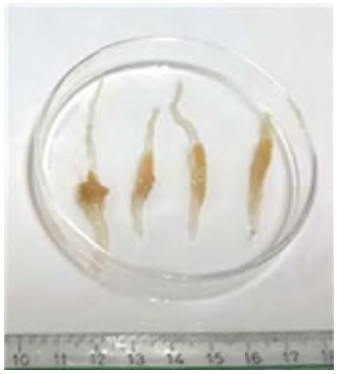
ANNEX IV. EPIFAUNAL AND INFAUNAL ORGANISMS COLLECTED FROM SEDIMENT GRABS

SS8

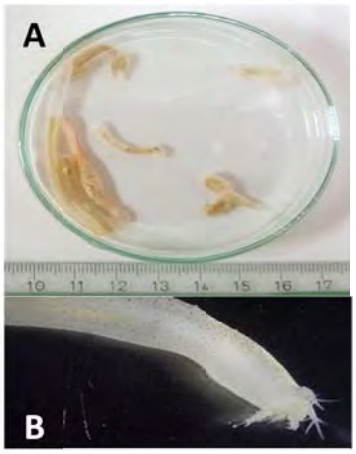
Juvenile fishes. Possibly from Family Mullidae



Echinoidea. Irregular urchins. Probably from Family Brissidae



Sponges. Unidentified.



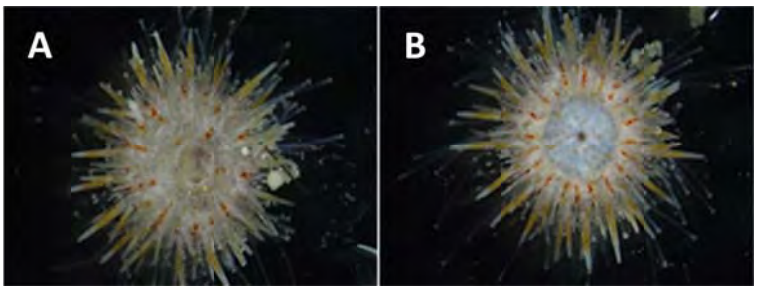
(A) Small sea cucumbers. Unidentified.

(B) Observation under microscope. Tentacles are conspicuous

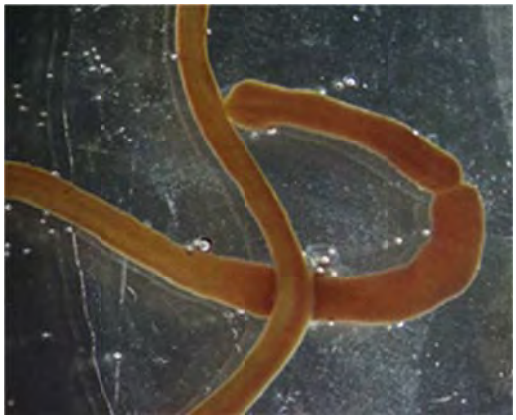
Polychaete worm. Unidentified. (Observation under microscope)

SS9

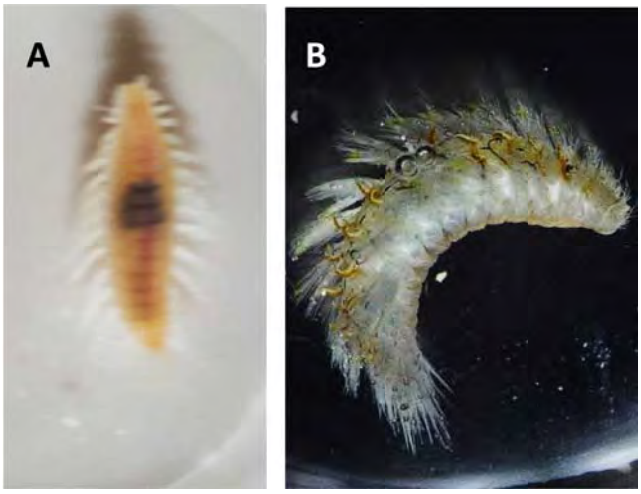
Irregular urchins. Echinoidea. Probably from Family Brissidae



Echinoidea. Small regular urchins. (A) Aboral side, (B) Oral side observed under microscope



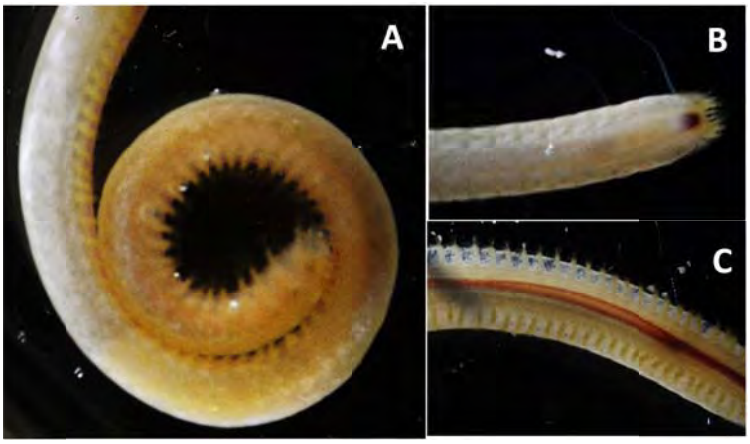
Nematoda (Roundworms). Unidentified.



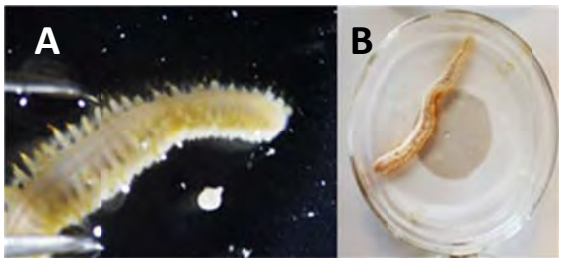
Polychaete worm. Unidentified. (Probably from family Amphinomidae). (A) Dorsal view, (B) Lateral view under microscope

SS13

Mantis shrimp larvae. Order Stomatopoda.



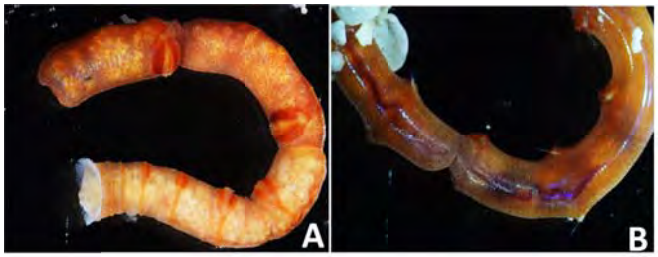
Polychaete worm. Unidentified. (A) posterior region, (B) anterior region, (C) trunk region observed under microscope



Polychaete worm. Unidentified. (A) Anterior region observed under microscope, (B) whole specimen.

Sponges. Class Demospongiae

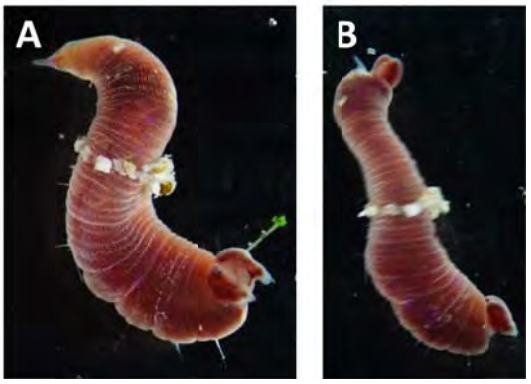
SS15



Polychaete worm. Probably from Maldanidae family. (A) anterior region with head, (B) trunk region observed under microscope

Polychaete worm. Unidentified. Specimen observed under microscope

Polychaete worm. Unidentified. (Probably from family Amphinomidae). (Specimen observed under microscope



Unidentified worm. (Probably from phylum Sipuncula, trumpet worm). (A and (B) are same specimen observed under microscope.

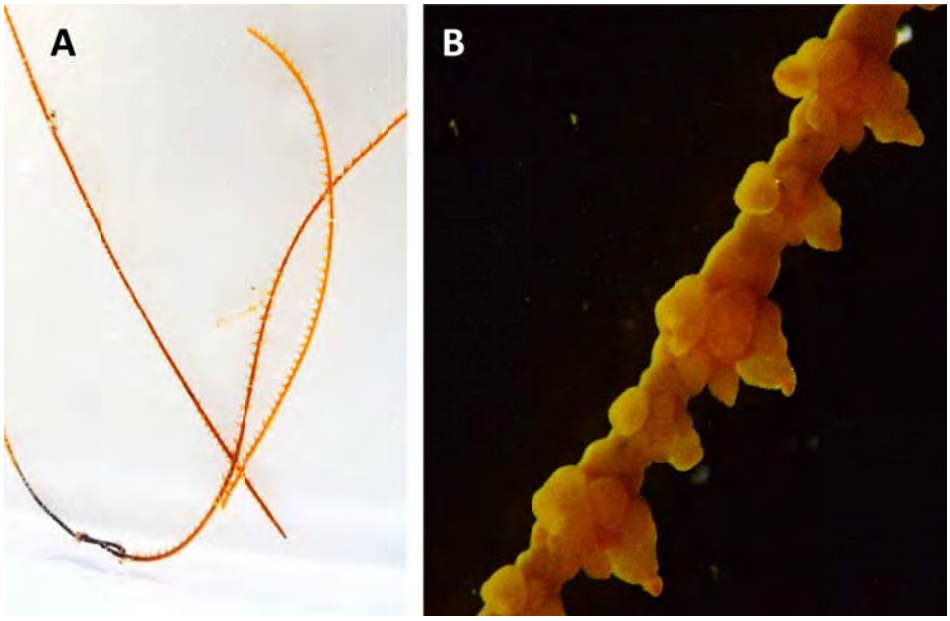
Polychaete worm. Unidentified.
(Specimen observed under microscope)

SS21

Crinoid, Featherstar. Class Crinoidea. (A) Top view, (B) Side view

Brittlestar. Class Ophiuroidea

SS25



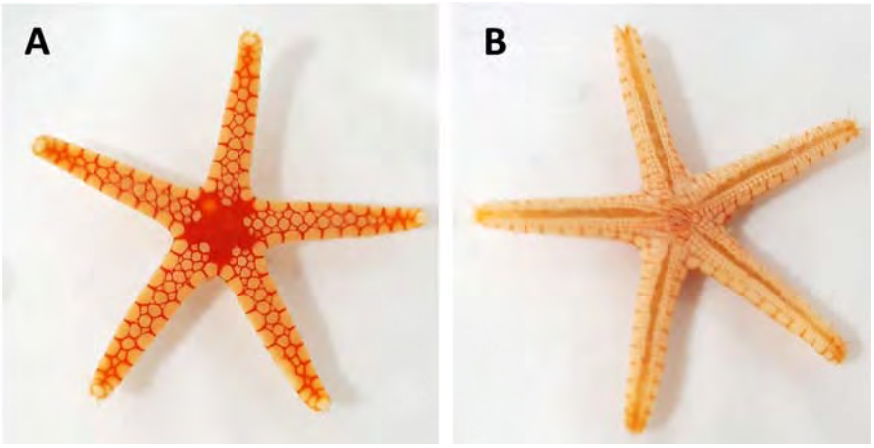
Sea pen. Order Pennatulacea. (A) Picture of 3 specimens, (B) Microscopic view

SS26 – Uncommon finding: Probably bones of a whale

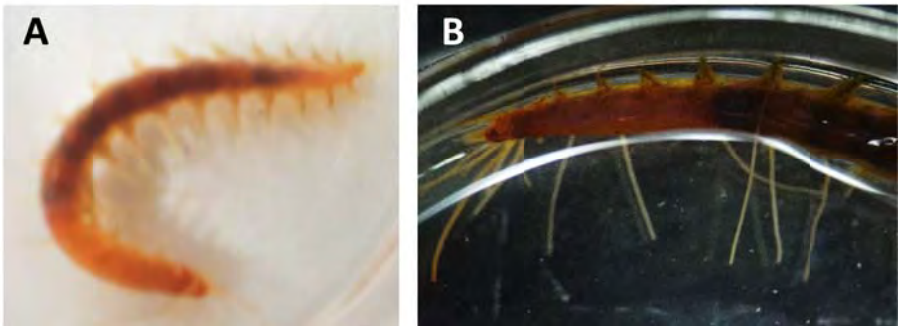
SS27

Crustacea. Unidentified shrimp

SS36



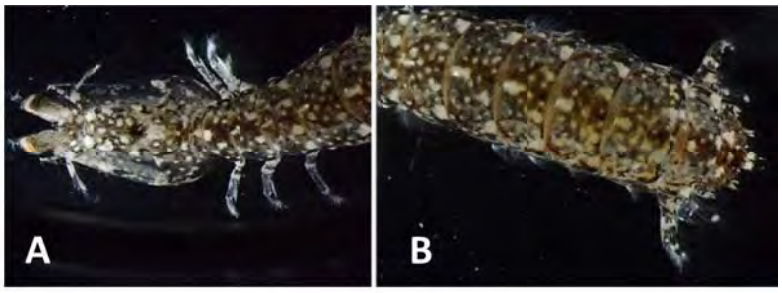
Sea star. Echinodermata. Class Asteroidea. (A) Aboral side, (B) Oral side



Polychaete worm. Unidentified. (Specimen observed under microscope). (A) Whole specimen, (B) Anterior part of specimen viewed under microscope

Polychaete worm. Unidentified.
(Specimen observed under microscope).

Polychaete worm. Unidentified.
(Specimen observed under microscope).



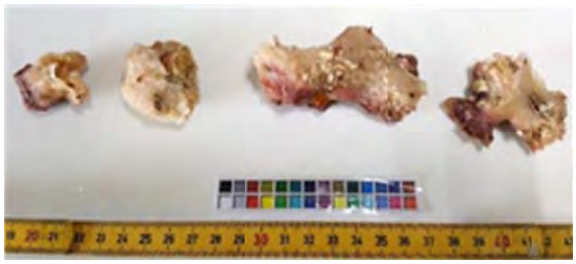
Mantis shrimp larvae. Order Stomatopoda. (A) Anterior and (B) Posterior parts of same specimen

Sea cucumber. Echinodermata. Unidentified

Small crab.

Brittlestars. Class Ophiuroidea

Station Seamount



Sponges. Class Demospongiae

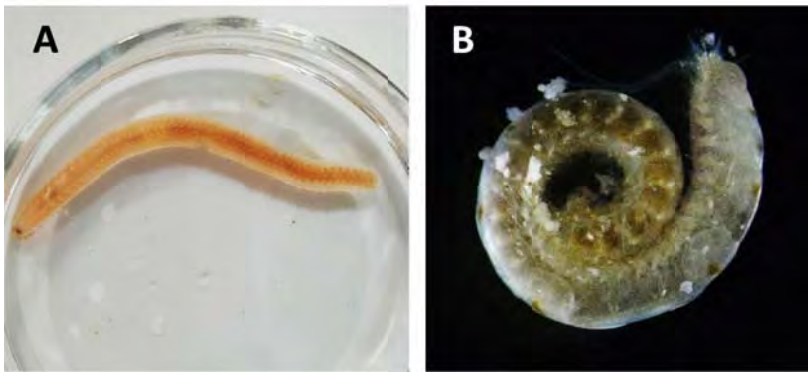
Small crabs. Crustacea

SS38

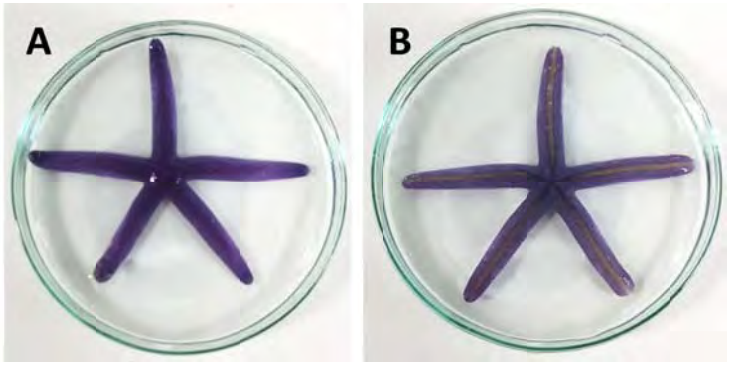
Mantis shrimp larvae. Order Stomatopoda

Brittlestar. Class Ophiuroidea

SS39



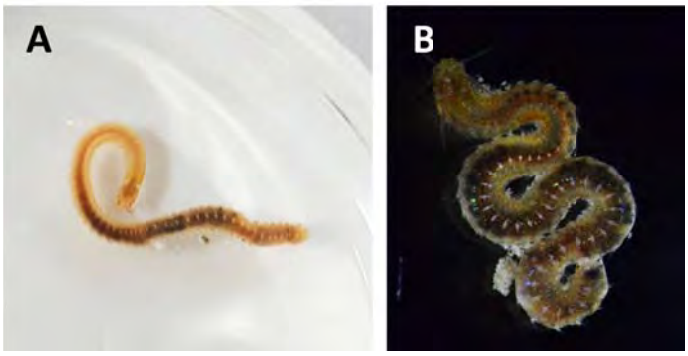
Polychaete worm. Unidentified. (A) Anterior region observed under microscope, (B) whole specimen.



Sea star. Echinodermata. Class Asteroidea.
(A) Aboral side, (B) Oral side

Brittlestar. Class Ophiuroidea

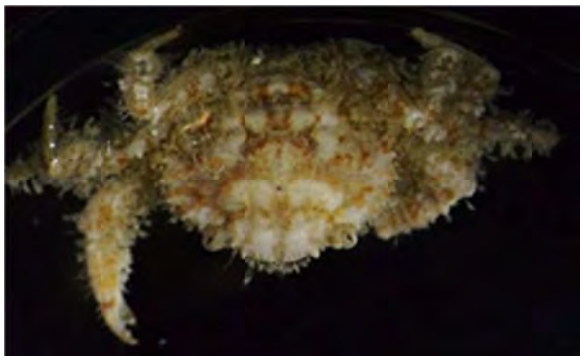
Brittlestar. Class Ophiuroidea



Polychaete worm. Unidentified. (A) whole specimen, (B) same specimen observed under microscope.

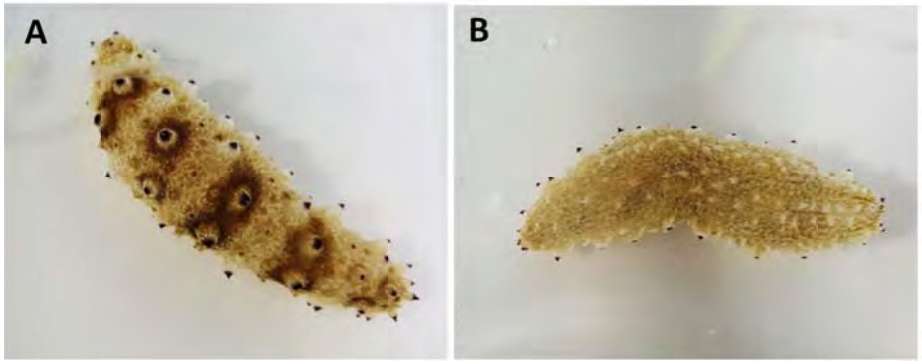
Shrimp. Subphylum Crustacea

Polychaete worm (fluorescent). Unidentified. Whole specimen observed under microscope.



Small crab. Crustacea Unidentified.
Whole specimen observed under microscope.

Small crab. Crustacea Unidentified.
Whole specimen observed under microscope.



Sea cucumber. *Holuthuria pervicax*. (A) Dorsal side, (B) Ventral side

SS40

Polychaete worm. Unidentified.
Whole specimen observed under microscope

Polychaete worm. Unidentified.
Whole specimen observed under microscope

SS41

Brittlestar. Class Ophiuroidea

Polychaete worm. Unidentified.

Brittlestar. Class Ophiuroidea. Unidentified

Small crabs. Crustacea. Unidentified.

Small crab. Crustacea. Unidentified.

Shells of wing-footed opisthobranchs. Probably *Covolinia spp*.

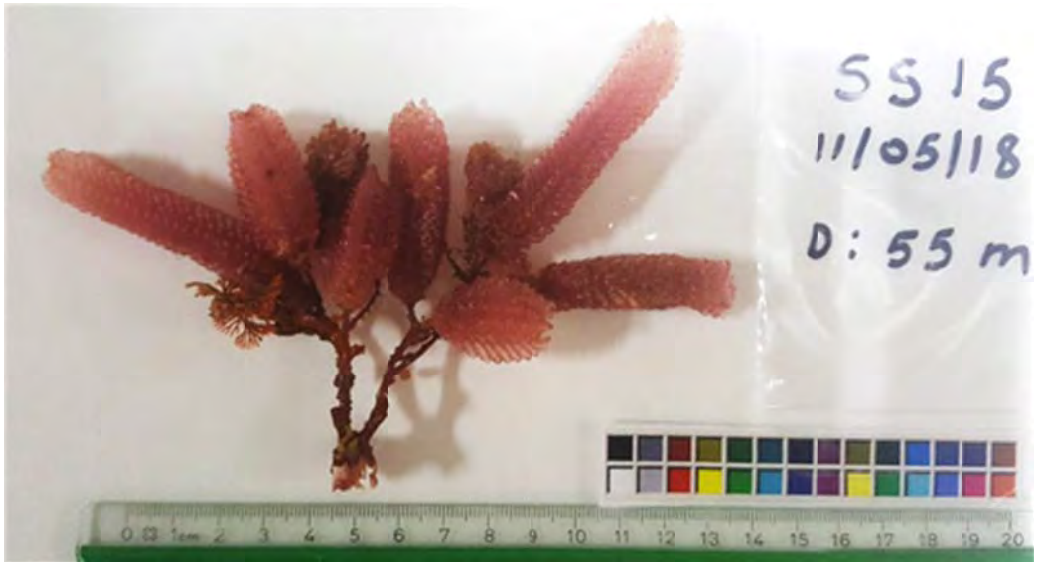
Seagrasses and seaweeds

SS13

Seagrass *Thalassodendron ciliatum*

Red algae. Unidentified.

SS15



Unidentified seaweed

SS36

Halimeda spp.

Station Seamount North

Seagrass *Thalassodendron ciliatum*

ANNEX V. LIST OF GRABS AND SAMPLES OF SEDIMENT

Table V.1. Chemical parameters subsampled from grabs for the superstations in Leg I on Saya de Malha Bank.

Station number	Date	Depth (m)	Bottom type	Grab1								Grab2								Grab3								Grab4							
				THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio	
										1 mm	5 mm								1 mm	5 mm							1 mm	5 mm							1 mm	5 mm
SS1-Gr1	7/5/2018	132	Sandy with rubbles	■	■	■	■	■	■	15	1	■	■	■	■		■	9	1	■	■	■	■		■	8	1	■	■	■	■		■	0	0
SS3-Gr2	8/5/2018	74	Sandy	■	■	■	■		■	3	1	■	■	■	■		■	3	1	■	■	■	■		■	7	1	■	■	■	■	■	■	0	0
SS4-Gr3	8/5/2018	30	Sandy/Gravel	■	■	■	■		■	2	1	■	■	■	■		■	2	1	■	■	■	■	■	■	2	1							0	1
SS8-Gr4	9/5/2018	62	Sandy	■	■	■	■		■	9	1	■	■	■	■		■	4	1	■	■	■	■	■	■	8	1	*						0	0
SS9-Gr5	10/5/2018	55	Sand	■	■	■	■		■	12	1	■	■	■	■		■	6	1	■	■	■	■		■	13	2	■	■	■	■	■	■	0	0
SS13-Gr6	11/5/2018	28	Gravel sand							0	0	■	■	■	■	■	■	1	2	■	■	■	■			1	2							0	0
SS15-Gr7	11/5/2018	55	Sand	■	■	■	■		■	0	0	■	■	■	■		■	6	3	■	■	■	■		■	7	3	■	■	■	■	■	■	4	1
SS20-Gr8	12/5/2018	199	Sandy mud	*						0	0	*						0	0	*						0	0	*						0	0
SS21-Gr9	12/5/2018	160	Ancient reef/Hard substrate	■	■	■	■		■	3	2							0	0	*						0	0	■	■	■	■	■	■	3	1
SS25-Gr10	13/5/2018	288	Sand							0	0	■	■	■	■		■	0	0	■	■	■	■	■	■	0	0	■	■	■	■		■	0	0
SS26-Gr11	13/5/2018	251	Sandy mud	■	■	■	■		■	4	1	■	■	■	■		■	2	1	■	■	■	■		■	2	1	■	■	■	■	■	■	0	1
SS27-Gr12	13/5/2018	267	Hard substrate	*						0	0	*						0	0	*						0	0	*						0	0

Note:

■ Sample collected

□ No sample collected

* No sediment in grabs

Table V.2. Chemical parameters subsampled from grabs for superstations in Leg 2 on Saya de Malha Bank

Station number	Date	Grab1								Grab2								Grab3								Grab4							
		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio	
								1mm	5mm							1mm	5mm							1mm	5mm							1mm	5mm
SS33	15-05-2018																																
SS34	16-05-2018							0	1																								
SS35	17-05-2018																																
SS36	19-05-2018							1	3							0	3							0	3							0	3
SS37	20-05-2018							0	2																								
Station Seamount	20-05-2018							1	1																								
SS38	21-05-2018							0	2																								
SS39	22-05-2018							1	1							1	3							1	2								
SS40	22-05-2018							1	1							1	1	*						0	0							1	1
SS41	25-05-2018							1	1							1	1							1	1							0	1

Table V.3. Chemical parameters subsampled from grabs for superstations on Nazareth Bank

Station number	Date	Depth (m)	Bottom type	Sediment collected for chemical analysis	Grab1								Grab2								Grab3								Grab4							
					THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio		THC	TOC	HM	GSA	MP	Meio	Bio	
											1mm	5mm							1mm	5mm							1mm	5mm							1mm	5mm
SS43	27/5/2018	43	Sandy, seagrass patches	X							1	1																							
SS44	27/5/2018	38	Live massive corals	X							1	2																							
SS45	27/5/2018	35	Seagrass beds, gravel	√							0	0							0	0							0	0							0	0
SS46	27/5/2018	62	Seagrass beds	X							0	0																							
SS47	27/5/2018	58	sandy, seaweeds	√							1	1																							
SS49	29/5/2018	133	sandy	√							1	1							1	1	*								*							

ANNEX VI. PROVISIONAL RESULT OF GENETIC IDENTIFICATION OF FISH SPECIMENS

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
2	No match	*Champsodon sp. 89 %* *Champsodon capensis, 89 %* *Champsodon vorax , 89 %*	**Genus: *Champsodon***	**CHAMPSODONTIDAE**	**Champsodon sp.**	
5	*Decapterus macrosoma, 100 %*	*Decapterus macrosoma, 100 %*	***Decapterus macrosoma***	**CARANGIDAE**	***Decapterus russelli***	
6	*Katsuwonus pelamis, 100 %*	*Katsuwonus pelamis, 100 %*	***Katsuwonus pelamis***	**SCOMBRIDAE**	***Katsuwonus pelamis***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
7	*Lagocephalus guentheri, 100 % Lagocephalus gloveri, 100 % Lagocephalus cheesemanii, 99.84 %*	*Lagocephalus guentheri, 99 % Lagocephalus gloveri, 99 % Lagocephalus cheesemanii, 99 % Lagocephalus spadiceus, 99 %*	***Genus: Lagocephalus***	**TETRAODONTIDAE**	***Lagocephalus guentheri***	
8	*Ablennes hians, 98.04 %, Tylosurus crocodilus, 94.41 %*	*Ablennes hians, 96 %, Tylosurus crocodilus, 94 %*	***Genus: Ablennes***	**BELONIDAE**	***BELONIDAE***	
9	*Selar crumenophthalmus, 100 % Megalaspis cordyla, 99.66 % Decapterus tabl, 99.66 %*	*Selar crumenophthalmus, 100 % Decapterus macarellus, 99 % Selar boops, 98 %*	***Selar crumenophthalmus***	**CARANGIDAE**	***Selar crumenophtalmus***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
10	*Decapterus russelli, 99.48 %* *Decapterus maruadsi, 99.48 %*	*Decapterus russelli, 99 %* *Decapterus maruadsi, 99 %* *Trachurus delagoa, 99 %*	***Genus: Decapterus***	**CARANGIDAE**	***Decapterus russelli***	blurry photograph, need to be retaken
11	*Diodon holocanthus, 100 %* *Diodon sp., 100 %* *Diodon hystrix, 100 %*	*Diodon holocanthus, 100 %* *Diodon sp., 100 %* *Diodon liturosus, 100 %*	***Genus: Diodon***	**DIODONTIDAE**	***Diodon holocanthus***	
13	*Dipterygonotus balteatus, 100 %*	*Dipterygonotus balteatus, 99 %* *Pterocaesio marri, 93 %* *Pterocaesio digramma, 93 %*	***Dipterygonotus balteatus***	**CAESIONIDAE**	***Dipterygonotus balteatus***	
14	*No match*	*No match*	***UI***	**UI**	***MYCTOPHIDAE***	blurry photograph, need to be retaken

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
18	*Decapterus tabl, 100 % Decapterus sp. 2, 99.62 % Decapterus kurroides, 99.24 %*	*Decapterus tabl, 100 % Decapterus kurroides, 99 %*	***Genus: Decapterus***	**CARANGIDAE**	***Decapterus russelli, juvenile***	blurry photograph, need to be retaken
20	*Lethrinus rubrioperculatus, 100 % Lethrinus amboinensis, 99.66 % Lethrinus conchyliatus, 99.49 %*	*Lethrinus rubrioperculatus, 99 % Lethrinus conchyliatus, 99 %*	***Lethrinus rubrioperculatus***	**LETHRINIDAE**	***APOGONIDAE***	
23	*No match*	*Lestrolepis japonica, 94 % Lestrolepis intermedia, 88 %, Lestrolepis cf. japonica, 88 % Lestrolepis sp. JP-2017, 88 %*	***Genus: Lestrolepis***	**PARALEPIDIDAE**	***PARALEPIDIDAE***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
24	*No match*	*Ariosoma shiroanago, 91 %, Ariosoma cf. major, 91 % Ariosoma meeki, 91 % Gorgasia sp., 91 % Ariosoma major, 91 %*	***Genus: Ariosoma****	**CONGRIDAE**	***Leptocephalus, juvenile***	
25	*Cubiceps pauciradiatus, 100 %*	*Cubiceps pauciradiatus, 100 % Cubiceps squamiceps, 99 %*	***Cubiceps pauciradiatus***	**NOMEIDAE**	***Cubiceps pauciradiatus***	
27	*Sufflamen chrysopterum , 100 % Sufflamen sp., 99.81 %*	*Sufflamen chrysopterum, 100 %, Sufflamen albicaudatum, 98 %*	***Sufflamen chrysopterum***	**BALISTIDAE**	***BALISTIDIDAE, juvenile***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
28	*Myripristis berndti, 100 %* *Myripristis earlei , 100 %* *Myripristis botche, 100 %*	*Myripristis berndti, 100 %* *Myripristis sp., 100 %* *Naso unicornis, 100 %*	***Genus: Myripristis***	**HOLOCENTRIDAE**	***Holocentrus sp., juvenile***	
29	*Centropyge argi, 100 %* *Centropyge acanthops, 100 %* *Centropyge resplendens, 100 %* *Centropyge sp., 100 %* *Centropyge aurantonotus, 100 %*	*Centropyge argi, 100 %* *Centropyge acanthops, 100 %*	***Genus: Centropyge***	**POMACANTHIDAE**	***BRAMIIDAE***	
30	*Bleekeria mitsukurii, 99.66 %*	*Bleekeria mitsukurii, 99 %*	***Bleekeria mitsukurii***	**AMMODYTIDAE**	***PARALEPIDIDAE, juvenile***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
31	*Sphyraena sp. 1, 100 % Sphyraena japonica, 87.32 %, Sphyraena acutipinnis, 86.93 %*	*Sphyraena sp., 82 % Sphyraena putnamae, 81 %,*	***Genus: Sphyraena***	**SPHYRAENIDAE**	***Sphyraena flavicauda***	
35	*Sphyraena chrysotaeni, 98.74 % Sphyraena pinguis, 98.74 %, Sphyraena obtusata, 98.74 %,*	*Sphyraena chrysotaeni, 99 % Sphyraena sp., 99 % Sphyraena obtusata, 99 %*	***Genus: Sphyraena***	**SPHYRAENIDAE**	***Sphyraena acutipinnis***	
38	*Decapterus macrosoma, 100 %*	*Decapterus macrosoma, 100 %*	***Decapterus macrosoma***	**CARANGIDAE**	***Decapterus russelli***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
39	*Dipterygonotus balteatus, 98.97 %*	*Dipterygonotus balteatuss, 99 %*	***Dipterygonotus balteatus***	**CAESIONIDAE**	***Dipterygonotus balteatus***	
40	*Rastrelliger kanagurta, 99.66 %, Rastrelliger brachysoma, 99.33 % Rastrelliger faughni, 98.99 %*	*Rastrelliger kanagurta, 99 % Rastrelliger brachysoma, 99 % Rastrelliger faughni, 99 %*	***Genus: Rastrelliger***	**SCOMBRIDAE**	***Rastrelliger kanagurta***	
41	*Echeneis naucrates, 100 % Remora remora, 99.81 % Echeneis neucratoides, 99.48 %*	*Echeneis naucrates, 100 % Remora remora, 99 %*	***Genus: Echeneis***	**ECHENEIDAE**	***Echeneis naucrates, juvenile***	

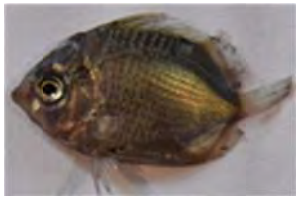
Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
42	*Canthigaster rivulata, 100 % Canthigaster smithae, 99.47 % Canthigaster supramacula, 98.4% Canthigaster rostrata, 98.22 %*	*Canthigaster rivulata, 100 % Canthigaster smithae, 99.47 % Canthigaster rostrata, 98 %*	***Genus: Canthigaster***	**TETRAODONTIDAE**	***Canthigaster rivulata, juvenile***	
43	*Lagocephalus guentheri, 100 % Lagocephalus gloveri, 100 % Lagocephalus cheesemanii,99.82 % Lagocephalus spadiceus, 99.65 %*	*Lagocephalus guentheri, 100 % Lagocephalus gloveri, 99 % Lagocephalus cheesemanii, 99% Lagocephalus spadiceus, 99 %*	***Genus: Lagocephalus***	**TETRAODONTIDAE**	***Lagocephalus guentheri, juvenile***	
46	*Cubiceps pauciradiatus, 99.39 %*	*Cubiceps pauciradiatus, 99 %*	***Cubiceps pauciradiatus***	**NOMEIDAE**	***Cubiceps pauciradiatus***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
47	*Poromitra crassiceps, 94 % Melamphaes lugubris, 94 %*	*Poromitra crassiceps, 94 % Melamphaes lugubris, 94 %*	***Genera: Poromitra Melamphaes***	**MELLAMPHAIDAE**	***MELLAMPHIDAE***	
48	*Gonostoma elongatum, 99.69 % , (Australia) Not right Gonostoma elongatum, 92 %*	*Gonostoma elongatum, 92 %*	***Genus: Gonostoma***	**GONOSTOMATIDAE**	***Gonostoma sp.***	
49	*No match*	*Leptostomias gladiator, 93 %*	***Genus: Leptostomias***	**STOMIIDAE**	***Stomiidae sp.***	
50	*Lampadena luminosa, 98.77 %*	*Lampadena luminosa, 98 %*	***Lampadena luminosa***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	
51	*Notoscopelus caudispinosus, 99.08 %*	*Notoscopelus caudispinosus, 99 %*	***Genera: Notoscopelus Notoscopelus caudispinosus***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
52	*Notoscopelus caudispinosus, 99.67 %*	*Notoscopelus caudispinosus, 98 %*	***Notoscopelus caudispinosus***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	
53	*No match*	*Chauliodus danae, 89 %*	***Genus: Chauliodus***	**STOMIIDAE**	***Malacosteus sp.***	
56	*Serrivomer sector, 98.77 %*	*Serrivomer sector, 98.77 %*	***Genus: Serrivomer***	**SERRIVOMERIDAE**	***Avocettina sp.***	
58	*Serrivomer sector, 98.77 %*	*Serrivomer sector, 98.77 %*	***Genus: Serrivomer***	**SERRIVOMERIDAE**	***NEMICHTHYDAE***	
59	*Howella zina, 99 %* *Howella atlantica, 98 %* *Howella sherborni, 98 %* *Howella brodiei, 94 %*	*Howella brodiei, 95 %*	***Genus: Howella***	**HOWELLIDAE**	***Howella***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
60	*Myctophum spinosum, 99 %*	*Myctophum spinosum, 99 %*	***Myctophum spinosum***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	
61	*Myctophum spinosum, 99 %*	*Myctophum spinosum, 99 %*	***Myctophum spinosum***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	
62	*Sternoptyx diaphana, 99 %*	*Sternoptyx diaphana, 99 %*	***Sternoptyx diaphana***	**STERNOPTYCHIDAE**	***Sternoptyx sp.***	
63	*Sternoptyx diaphana, 99 %*	*Sternoptyx diaphana, 99 %*	***Sternoptyx diaphana***	**STERNOPTYCHIDAE**	***Diretmus argenteus***	
64	*Could not be analysed due to poor sequence quality*				***STERNOPTYCHIDAE***	

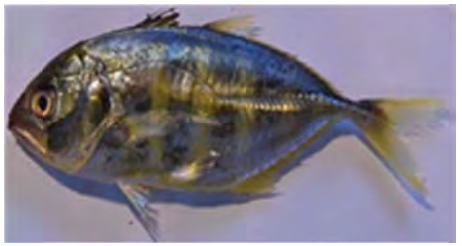
Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
78	*Melanonus zugmayeri, 99 %*	*Melanonus zugmayeri, 99 %*	***Melanonus zugmayeri***	**MELANONIDAE**	***UI***	
79	*No match*	*Borostomias panamensis, 90 % (unpublished)*	***Genus: Borostomias***	**STOMIIDAE**	***Astronesthes sp.***	
80	*Chiasmodon niger, 91 %*	*Chiasmodon niger, 91 %*	***Genus: Chiasmodon***	**CHIASMODONTIDAE**	***BARBOURISIIDAE***	
81	*Coccorella atlantica, 94 %*	*Coccorella atlantica, 94 %*	***Genus: Coccorella***	**EVERMANNELLIDAE**	***Evermannellidae***	
82	*No match*	*Bregmaceros atlanticus, 95 % (unpublished) Bregmaceros nectabanus, 87 % (published)*	***Genus: Bregmaceros***	**BREGMACEROTIDAE**	***Bregmaceros sp.***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
83	*Diplophos taenia, 99 %*	*Diplophos sp., 97 %*	***Genus: Diplophos***	**GONOSTOMATIDAE**	***Gonostoma sp.***	
84	*Chaetodon kleinii, 99 %*	*Chaetodon kleinii, 99 %*	***Chaetodon kleinii***	**CHAETODONTIDAE**	***UI***	
85	*Centropyge acanthops, 99 %*	*Centropyge acanthops, 99 %*	***Centropyge acanthops***	**POMACANTHIDAE**	***BRAMIDAE***	
86	*Zenion hololepis, 98.6 %*	*Zenion hololepis, 98 %*	***Zenion hololepis***	**ZENIONTIDAE**	***MONOCANTHIDAE, juvenile***	
87	*No match*	*Argentina silus, 85 %*	***???***	**ARGENTINIDAE**	***UI***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
88	*Lethrinus rubrioperculatus, 100 % Lethrinus amboinensis, 99.65 % Lethrinus conchyliatus, 99.48 % Lethrinus semicinctus, 99.48 % Lethrinus sp. 2, 99.48 % Lethrinus sp. PB5, 99.48 % Lethrinus ravus, 99.48 %*	*Lethrinus rubrioperculatus, 100 % Lethrinus conchyliatus, 99 %*	***Genus: Lethrinus***	**LETHRINIDAE**	***APOGONIDAE***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
90	*Euthynnus lineatus, 100 %, Euthynnus affinis, 100 %*	*Euthynnus affinis, 100 % Euthynnus lineatus, 99 %*	***Genus: Euthynnus***	**SCOMBRIDAE**	***SCOMBRIDAE, juvenile***	
91	*Parupeneus jansenii,100 % Parupeneus heptacanthus,100 % Parupeneus forsskali, 99.83 %*	*Mulloidichthys auriflamma, 100 % Parupeneus heptacanthus, 99 % Parupeneus forsskali, 99 %*	***Genus: Parupeneus***	**MULLIDAE**	***UI***	
92	*Acanthurus mata, 99.83 % Acanthurus xanthopterus, 99.65 %*	*Acanthurus mata, 99 %*	***Acanthurus mata***	**ACANTHURIDAE**	***ACANTHURIDAE***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
93	*Lethrinus rubrioperculatus, 99.84 % Lethrinus amboinensis, 99.84 % Lethrinus conchyliatus, 99.67 %* *Lethrinus sp. 2, 99.67 %* *Lethrinus sp. PB5, 99.67 %* *Lethrinus semicinctus, 99.67 %* *Lethrinus ravus, 99.51 %*	*Lethrinus rubrioperculatus, 99%* *Lethrinus conchyliatus, 99 %*	***Genus: Lethrinus***	**LETHRINIDAE**	***APOGONIDAE***	
97	*Parupeneus macronemus, 100 % Parupeneus barberinus, 100 %* *Parupeneus multifasciatus, 99.58 %*	*Parupeneus macronemus, 100 % Parupeneus barbarinus, 100 %* *Parupeneus multifasciatus, 99 %*	***Genus: Parupeneus***	**MULLIDAE**	***Cubiceps sp., juvenile***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
102	*Odonus niger, 100 %* *Melichthys niger, 99.63 %*	*Odonus niger, 100 %* *Melichthys niger, 99 %*	***Odonus niger?***	**BALISTIDAE**	***BALISTIDAE***	
103	*Caranx sexfasciatus, 100 %* *Carangoides chrysophrys, 100 %* *Caranx melampygus, 100 %*	*Caranx sexfasciatus, 100 %* *Caranx melampygus, 100 %*	***Genus: Caranx***	**CARANGIDAE**	***CARANGIDAE***	
104	*Lethrinus sp.*	*Lethrinus nebulosus 90%*	***Lethrinus sp.***	**LETHRINIDAE**	***Lethrinus cf. mahsena***	
105	*Siganus sutor 99.8%*	*Siganus sutor 99.8%*	***Siganus sutor***	**SIGANIDAE**	***Siganus sutor***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
106	*Caranx sexfasciatus, 100 % Carangoides chrysophrys, 100 % Caranx melampygus, 100 %*	*Caranx sexfasciatus, 100 % Caranx melampygus, 100 %*	***Genus: Caranx***	**CARANGIDAE**	***Caranx sp.***	
107	*Sphyraena putnamae, 100 % Sphyraena jello, 100 %*	*Sphyraena putnamae, 100 % Sphyraena jello, 100 %*	***Genus: Sphyraena***	**SPHYRAENIDAE**	***Sphyraena quenie***	
108	*Gempylus serpens, 100 %*	*Gempylus serpens, 100 %*	***Gempylus serpens***	**GEMPYLIDAE**	***Gempylus serpens***	
109	*Gempylus serpens, 100 %*	*Gempylus serpens, 100 %*	***Gempylus serpens***	**GEMPYLIDAE**	***Gempylus serpens***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
112	*Lutjanus malabaricus, 99 %* *Lutjanus gibbus, 99 %*	*Lutjanus malabaricus, 99 %* *Lutjanus gibbus, 99 %*	***Lutjanus malabaricus /gibbus***	**LUTJANIDAE**	***Lutjanus gibbus***	
114	*Carcharhinus amblyrhynchos, 99.5 %*	*Carcharhinus amblyrhynchos, 99 %*	***Carcharhinus amblyrhynchos***	**CARCHARHINIDAE**	***Carcharhinus amblyrhynchos***	
116	*Lethrinus sp.*	*Lethrinus nebulosus, 90 %*	***Lethrinus sp.***	**LETHRINUS**	***Lethrinus cf. mahsena***	
135	*Symbolophorus evermanni, 100 %*	*Symbolophorus reversus, 91 %* *Symbolophorus evermanni, 91 %* *Symbolophorus rufinus, 91 %*	***Symbolophorus evermanni***	**MYCTOPHIDAE**	***MYCTOPHIDAE***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
136	*Cubiceps pauciradiatus, 99.44%*	*Cubiceps pauciradiatus, 99 %*	***Cubiceps pauciradiatus***	**NOMEIDAE**	***Cubiceps pauciradiatus***	
137	*Katsuwonus pelamis, 100 %*	*Katsuwonus pelamis, 100 %*	***Katsuwonus pelamis***	**SCOMBRIDAE**	***SCOMBRIDAE, juvenile***	
140	*Zanclus cornutus, 100 %*	*Zanclus cornutus, 100 %*	***Zanclus cornutus***	**ZANCLIDAE**	***Zanclus cornutus, juvenile***	
141	*Brama orcini, 99.6 %* *Brama cf dussiumeri, 99 %*	*Brama orcini, 99 %* *Brama japonica, 99 %* *Brama sp., 99 %*	***Brama orcini***	**BRAMIDAE**	***Brama orcini***	
143	*Acanthurus mata, 100 %*	*Acanthurus mata, 100 %*	***Acanthurus mata***	**ACANTHURIDAE**	***ACANTHURIDAE, juvenile***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
144	*Nealotus tripes, 99.81 %*	*Nealotus tripes, 99 %*	***Nealotus tripes***	**GEMPYLIDAE**	***GEMPYLIDAE***	
145	*Echeneis naucrates, 99.85 %*	*Echeneis naucrates, 99.85%*	***Echeneis naucrates***	**ECHENEIDAE**	***Echeneis sp.***	
146	*Selar crumenophthalmus, 99.85%*	*Selar crumenophthalmus, 99%*	***Selar crumenophthalmus***	**CARANGIDAE**	***Selar crumenophthalmus***	
147	*Sphyraena flavicauda, 99.54%*	*Sphyraena flavicauda, 99.54%*	***Sphyraena flavicauda***	**SPHYRAENIDAE**	***Sphyraena acutipinnis***	
148	*No match*	*Caesio caerulaurea, 93 %*	***?***	**CAESIONIDAE**	***UI***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
149	*Acanthurus mata, 99.82 %*	*Acanthurus mata, 99 %*	***Acanthurus mata***	**ACANTHURIDAE**	***ACANTHURIDAE***	
151	*Parapriacanthus ransonneti, 99.64 %*	*Parapriacanthus ransonneti, 95 %*	***Parapriacanthus ransonneti***	**PEMPHERIDAE**	***APOGONIDAE***	
154	*Decapterus macrosoma, 100 %*	*Decapterus macrosoma, 100 %*	***Decapterus macrosoma***	**CARANGIDAE**	***Decapterus russelli***	
155	*Selar crumenophthalmus, 99.63 %*	*Selar crumenophthalmus, 99 %*	***Selar crumenophtalmus***	**CARANGIDAE**	***Selar crumenophtalmus***	
157	*Euthynnis affinis, 100 %*	*Euthynnis affinis, 100 %*	***Euthynnis affinis***	**SCOMBRIDAE**	***Euthynnis affinis***	

Nansen sample ID #	BOLD system	NCBI	Tentative genetic identification	Family as identified by DNA	Provisional Nansen Identification	Photographs of specimens
158	*Euthynnis affinis, 100 %*	*Euthynnis affinis, 100 %*	***Euthynnis affinis***	**SCOMBRIDAE**	***Euthynnis affinis***	
159	*Euthynnis affinis, 100 %*	*Euthynnis affinis, 100 %*	***Euthynnis affinis***	**SCOMBRIDAE**	***Euthynnis affinis***	

ANNEX VII. FURTHER DETAILS ON METHODS FOR STUDYING PHYTOPLANKTON PRODUCTIVITY AND PHYSIOLOGY, AND SPATIAL VARIATION IN THE DENSITY OF DIFFERENT PHYTOPLANKTON TAXA

1.0 Methodology

1.1 Phytoplankton diversity and density

1.1.1 Sample collection

10L of seawater was filtered through plankton net of mesh size 5 µm. After complete filtration, the tap of the plankton net was opened to collect the residue (30ml) into the sampling tubes. Immediately, the sample is fixed using 1% Lugols' solution and stored at 4°C (Zarauz and Irigoien, 2008). The maximum time lapse between sampling and fixation with Lugols' solution was kept as low as possible and it was always less than 15 minutes.

1.1.2 Sample preservation and storage

The samples preserved in lugol's solution were kept at 4°C until further processing in Mauritius (Mukherjee *et al.*, 2014). Centrifugation was done in the laboratory at the University of Mauritius so as to concentrate the sample into 1ml. Each sample was centrifuged to concentrate the phytoplankton into pellet. Filtered seawater is added to adjust the volume. Then the samples were loaded in the centrifuge set at 3500 rpm for 10min (Sadally *et al.*, 2014). The sea water is discarded through decantation from the tube and the pellet is collected a 1ml Eppendorf tube as shown in the Figure A1.1.

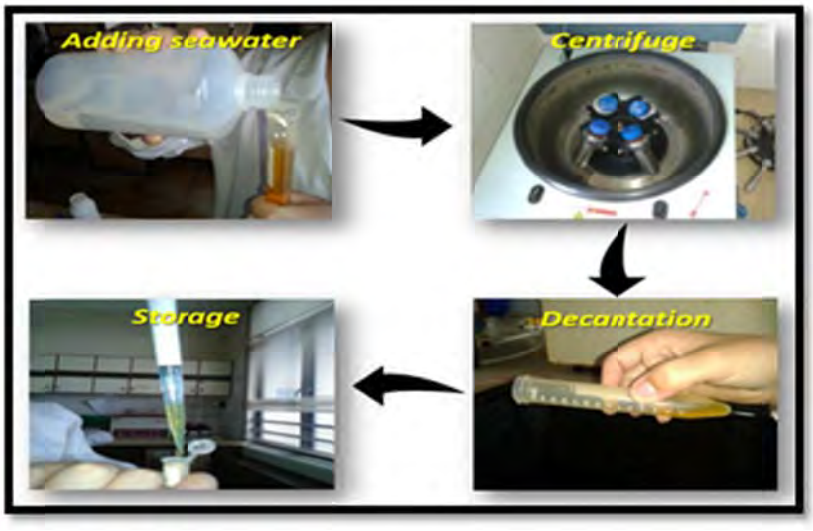


Figure A1.1: Steps to concentrate the phytoplankton from 30ml to 1ml.

1.1.3 Micro-phytoplankton identification and quantification

Micro-phytoplankton was identified according to Tomas (1997), Smith and Johnson (1996), and Verlencar and Desai (2004) and quantification was done using a Sedgewick Rafter Counting Chamber (Devassy and Goes, 1991) under a light microscope (Figures A1.2A, A1.2B).

The 1ml sample was loaded on a Sedgwick rafter counter chamber using a calibrated micropipette (Woelkerling *et al*., 1976). The sample was left to settle for 15 minutes before observation and counting under an inverted light microscope.

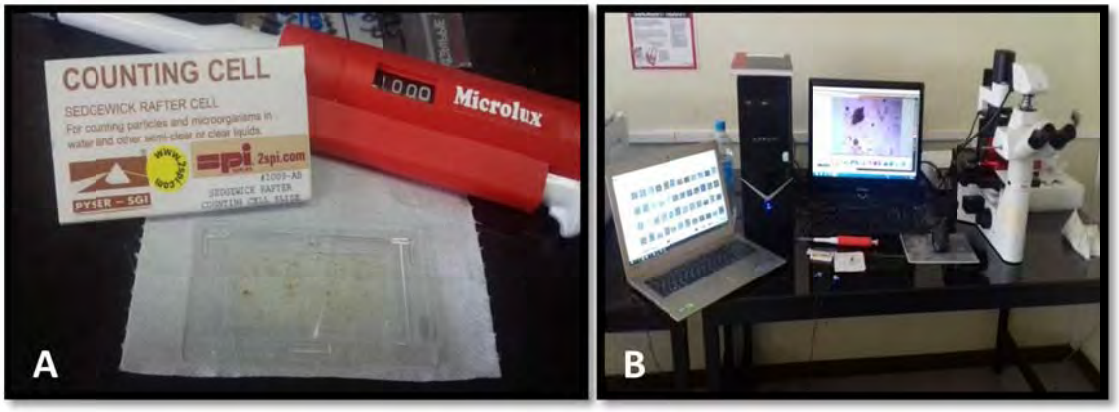


Figure A1.2: A. Loaded 1ml sample on Sedgwick rafter counting chamber; B. Analysis under a light microscope

1.2 Chlorophyll *a* determination

500ml of sea water was collected from the opaque Niskin bottle that brought up the water from different depths (Figure A1.3A). On board of the vessel, the sample of water was then filtered through Whatman glass fiber filter paper of 0.45 µm pore size using an automatic filtration apparatus (Figure A3B). The filter paper was collected and stored in 15ml tubes at -20°C until further processing.

In the laboratory, 10ml of 90% acetone was added to each tube containing the filter paper. They were left for 24 hours at 4°C to allow the extracted chlorophyll *a* pigment to move from the filter paper to the liquid 90% acetone (Jeffrey and Humphrey, 1975). Chlorophyll *a* was determined using a spectrophotometer (Spectronic® GenesysTM 8 spectrophotometer) (Figure A1.4A, A1.4B).

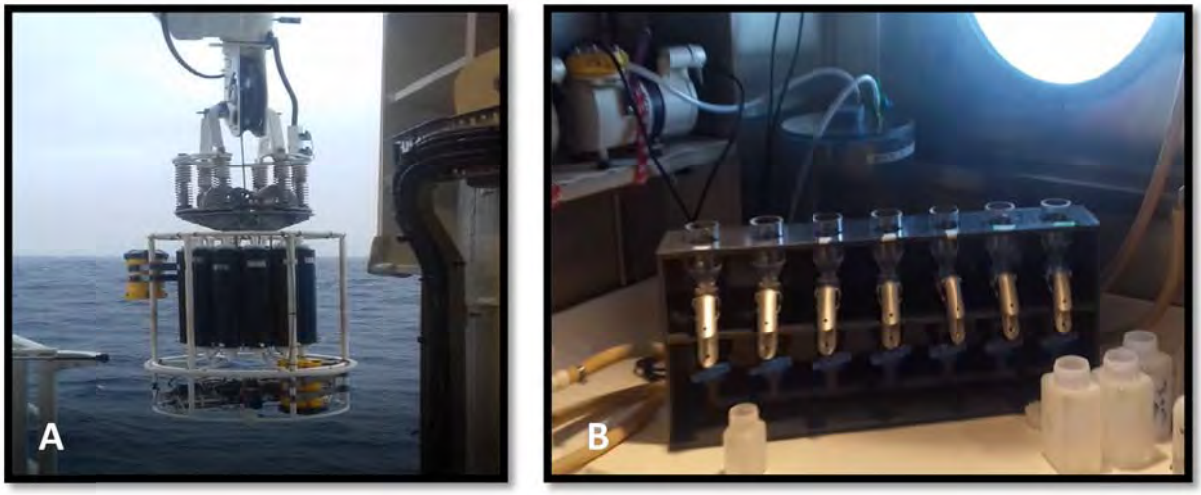


Figure A1.3: A. CTD with Niskin bottles for sample collection at various depths; B. Filtration apparatus for Chlorophyll *a* determination

Figure A1.4: A. The addition of 10ml of 90% acetone, B. Analysis of sample using a spectrophotometer

The concentration of Chlorophyll *a* was determined using the following formula (Jeffrey and Humphrey, 1975):

Chlorophyll *a* = $(11.85*(E_{664} - E_{750}) - 1.54*(E_{647} - E_{750}) - 0.08(E_{630} - E_{750}))*V_e/L*V_f$

Where;

L = Cuvette light-path in centimeter,

$\mathbf{V_e}$ = Extraction volume in milliliter

$\mathbf{V_f}$ = Filtered volume in litre and

Concentrations are in unit mg m^{-3}.

1.3 Chlorophyll *a* fluorescence and estimated productivity

10 ml of filtered samples using the 5 µm plankton net was adsorbed on filter papers using a syringe filtration apparatus. The filters with adsorbed micro-phytoplankton were submerged in filtered seawater in petri dishes (Figure A1.5B) and a Diving Pulse-Amplitude-Modulator (D-PAM) fluorometer was used to determine the electron transport rate of the microalgae (Figure A1.5A).

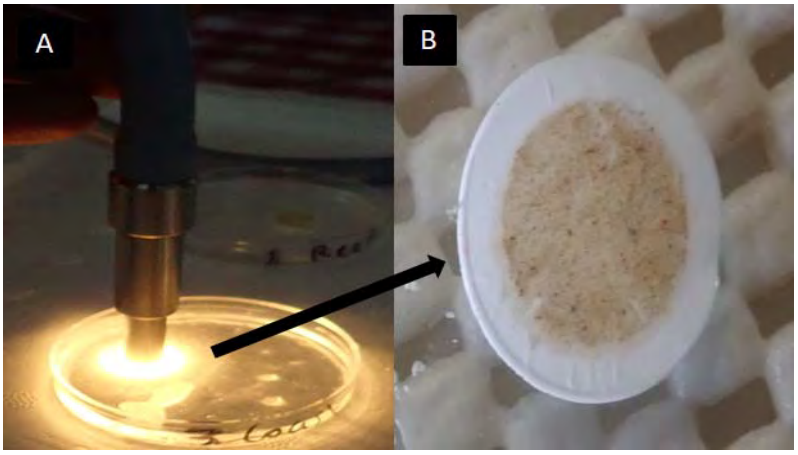


Figure A1.5: A. The probe of the D-PAM on the filter paper during a measurement, B. Adsorbed phytoplankton on filter paper for D-PAM measurement.

The D-PAM fluorometer (Submersible Photosynthesis Yield Analyzer, Walz, Germany) was used to assess the photo-physiology of micro-phytoplankton. by measuring the fluorescence of chlorophyll a thus determining the relative electron transport rate (rETR) and non-photochemical quenching (NPQ) when exposed to a series of rapidly (10s) changing light climates (RLC) (McMinn *et al.* 2005, 2012). Using the RLCs the rETR and NPQ were estimated at each irradiances.

At each irradiance the respective relative electron transport rate (rETR) was calculated by the formula below:

$$rETR = 0.5 \times \Phi PSII \times PAR$$

where PAR is the photosynthetically active radiance.

Non-photochemical quenching (NPQ) is the process by which oxygenic photoautotrophs harmlessly dissipate excess light absorbed as heat and fluorescence. When light energy absorption exceeds the capacity for utilization, there is a need to dissipate the energy to protect the light harvesting structures from photo-oxidative damage. It is given by the formula:

$$NPQ = \frac{(Fm - Fm')}{Fm'}$$

Estimated relative productivity for each sample at respective sites were calculated using the formula Estimated productivity, P, defined as P = (rETRmax× Chl *a*) (McMinn and Hegseth, 2004).

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2.0 Density of diatoms and dinoflagellates

Diatom genera

1. *Actinoptuchus*

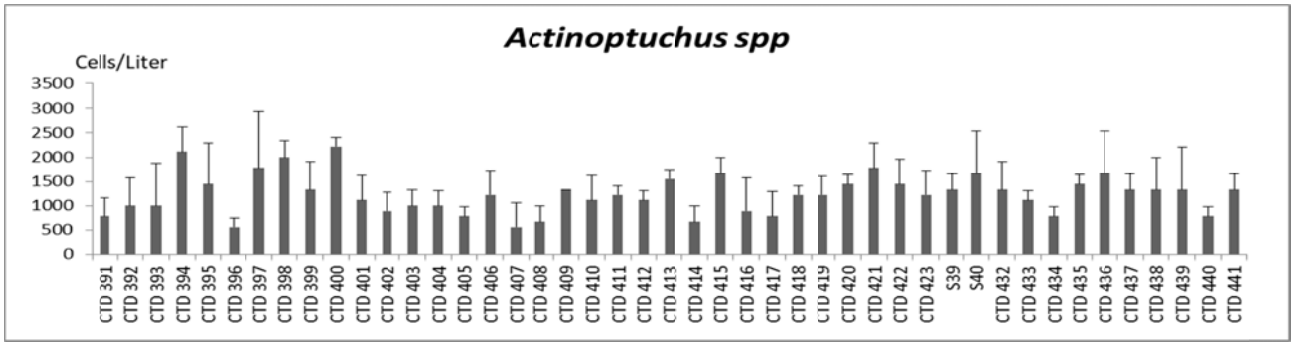

Figure A2.1. Spatial density variation of *Actinoptuchus* from CTD (391-441).

Low densities of *Actinoptuchus* were recorded at CTD number 396, 407, 408, 414, 417, 434, 440 and the highest density was at CTD 394 (2000 cells/liter) (Figure A2.1).

2. *Asteromphalus*

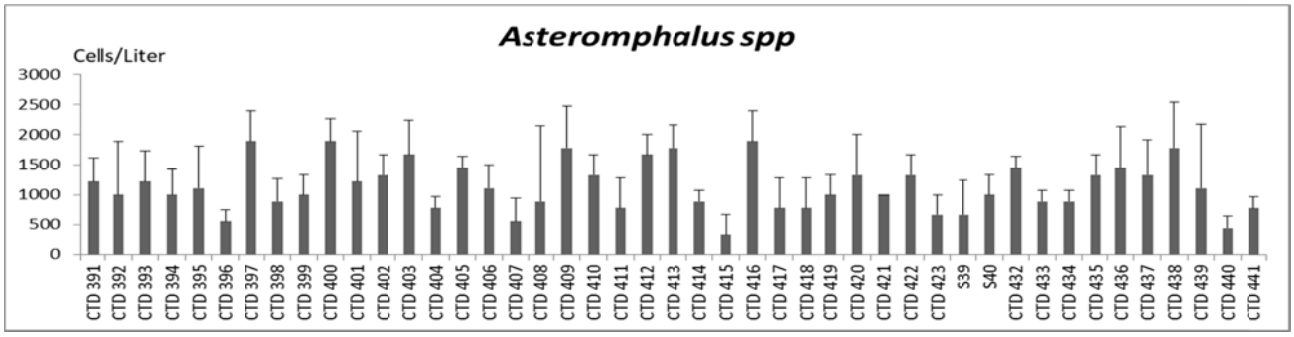

Figure A2.2. Spatial density variation of *Asteromphalus* from CTD (391-441).

The highest densities was recorded at CTD numbers 397, 400, 403, 409, 412, 413, 416. CTD 415 had the lowest density of *Asteromphalus* which was around 300 cells/liter (Figure A2.2).

3. *Biddulphia*

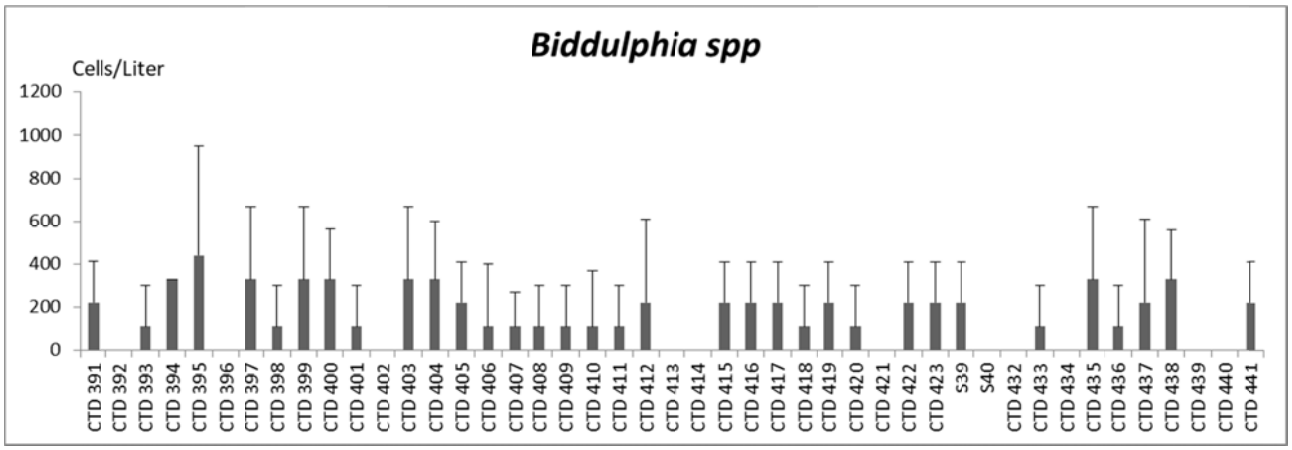

Figure A2.3. Spatial density variation of *Biddulphia* from CTD (391-441).

Biddulphia was absent in some CTD stations and most of the stations where it was present, the density varied below 350 cells/liter (Figure A2.3).

4. *Chaetoceros*

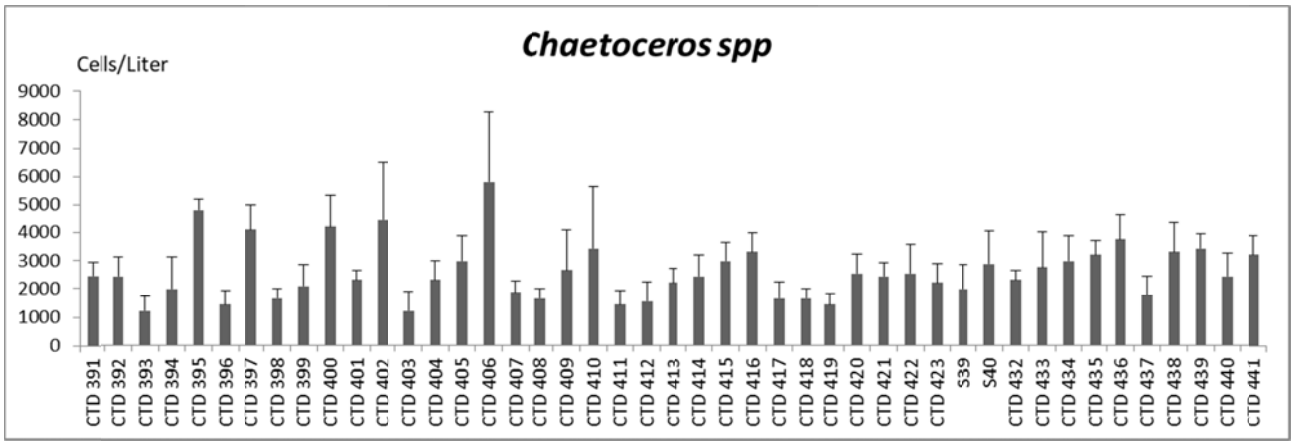

Figure A2.4. Spatial density variation of *Chaetoceros* from CTD (391-441).

The genera of *Chaetoceros* showed some highest peaks at some CTDs at Saya de Malha. At Nazareth Bank the cell number varied mostly below 2500 cells/liter (Figure A2.4).

5. *Coscinodiscus*

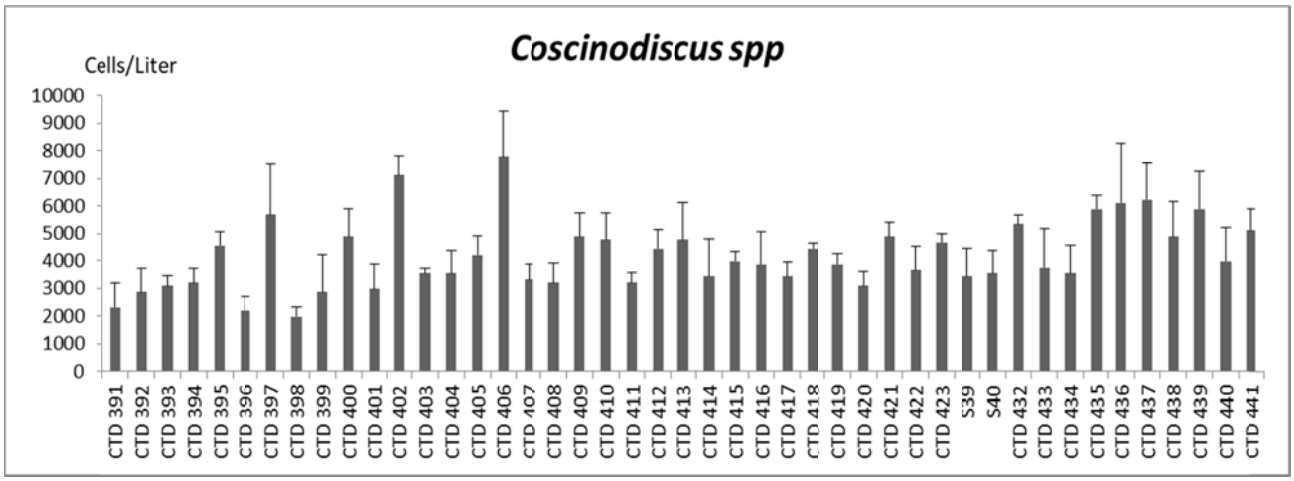

Figure A2.5. Spatial density variation of *Coscinodiscus* from CTD (391-441).

At Saya de Malha, *Coscinodiscus* peaked at 3 CTD stations (397, 402, and 406). At Nazareth, the density was fairly same for all sampling expect for CTD numbers 433, 434 and 440 (Figure A2.5).

6. *Dactyliosolen*

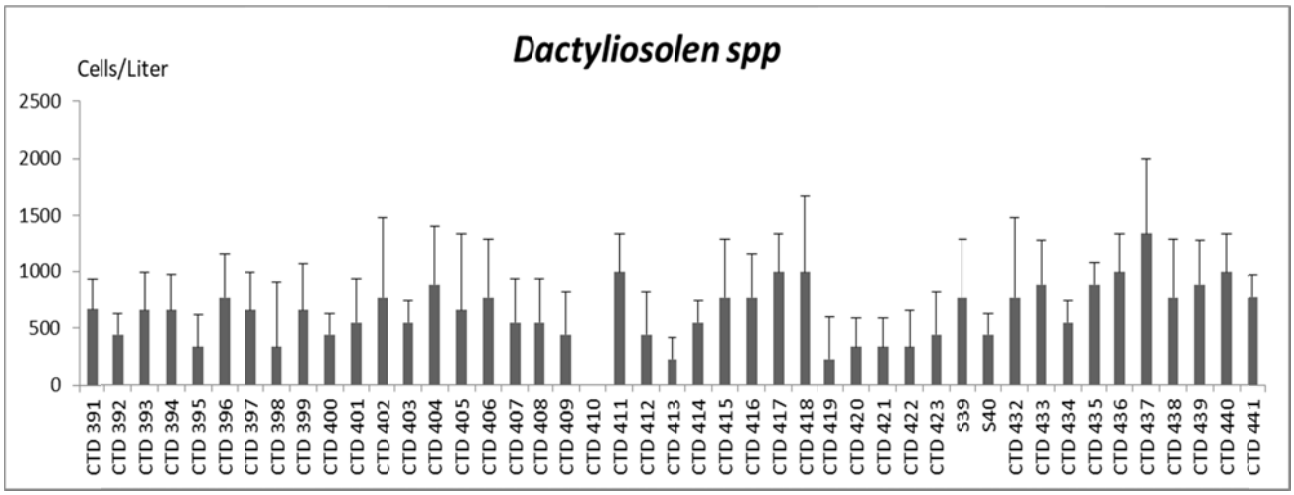

Figure A2.6. Spatial density variation of *Dactyliosolen* from CTD (391-441).

For the genus *Dactyliosolen*, Nazareth showed to have fairly higher density compared to Saya de Malha. This genera was not present at CTD 410 (Figure A2.6).

7. *Detonula*

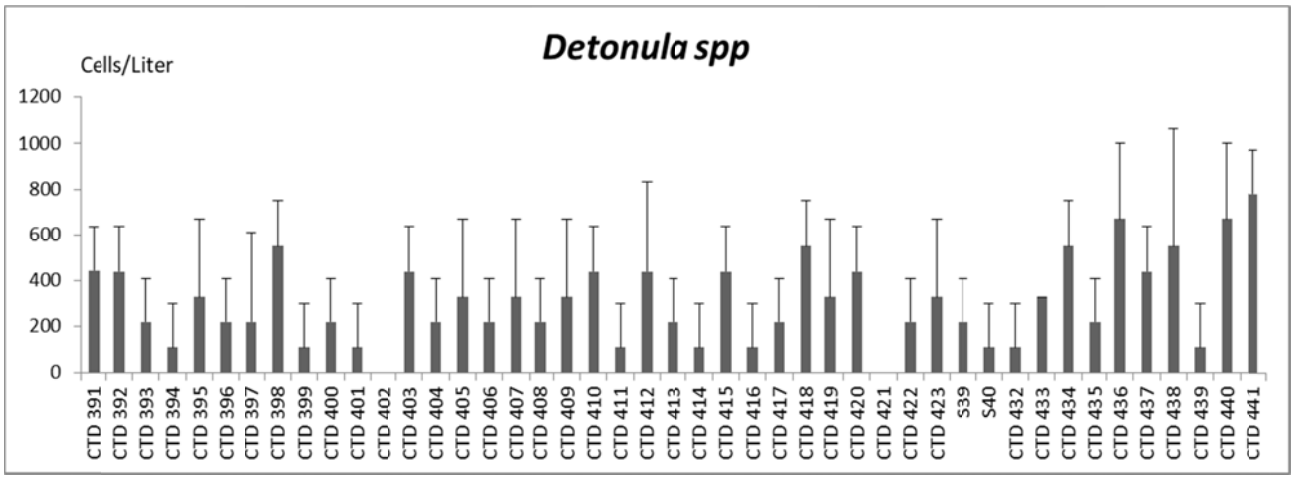

Figure A2.7. Spatial density variation of *Detonula* from CTD (391-441).

The genera *Detonula* was absent at CTD 402 and 421. The density was highest at the CTDs done at Nazareth Bank (Figure A2.7).

8. *Eucampia*

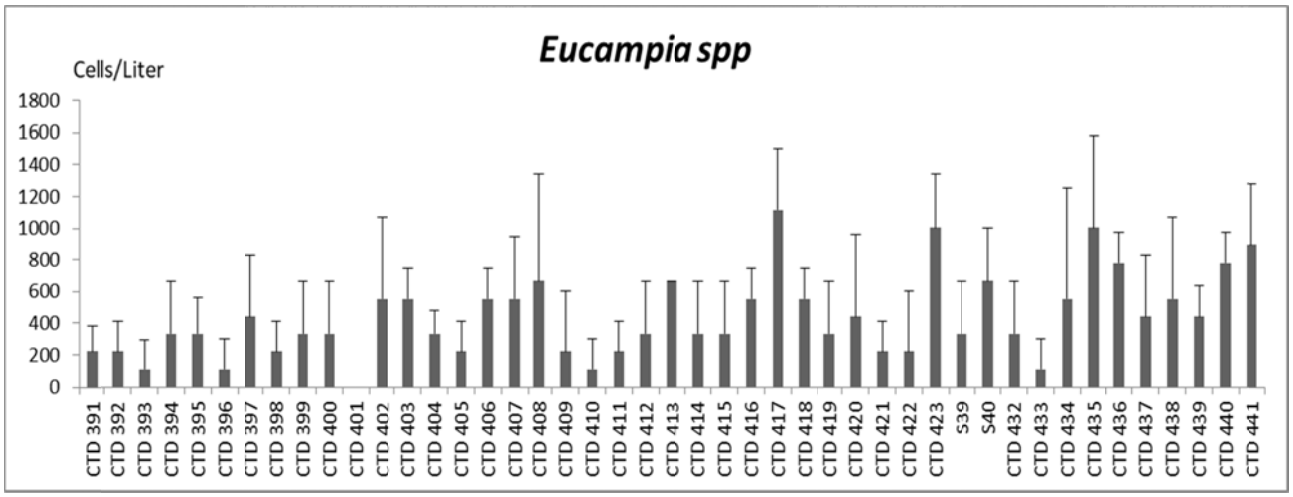

Figure A2.8. Spatial density variation of *Eucampia* from CTD (391-441).

The genus *Eucampia* was absent at CTD 401 and on average, it was highest in the Nazareth Banks (Figure A2.8).

9. Fragilaria

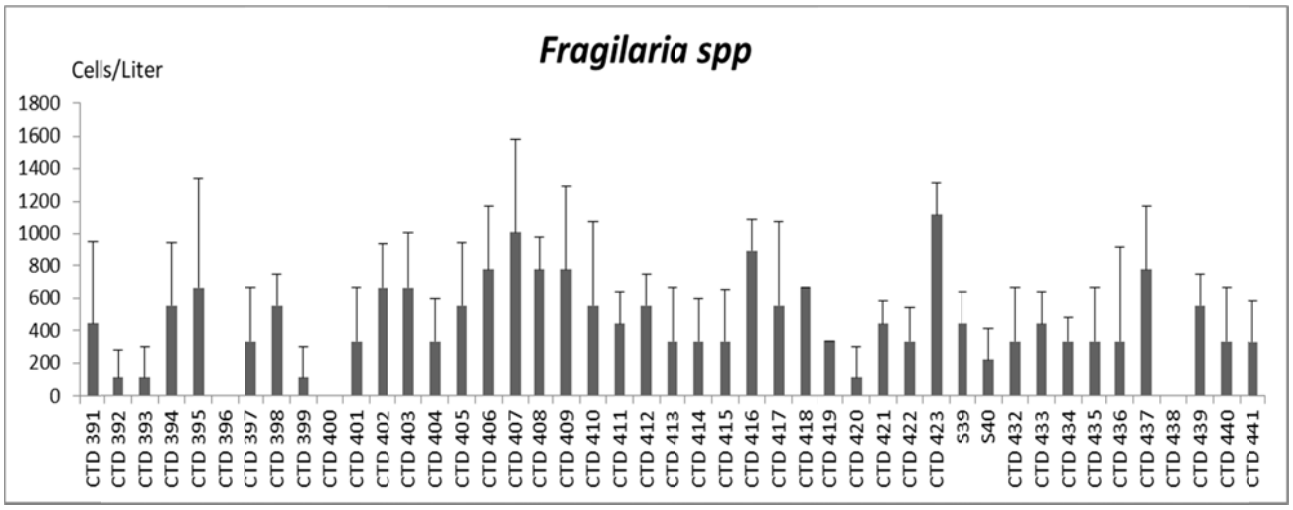

Figure A2.9. Spatial density variation of *Fragilaria* from CTD (391-441).

The genus *Fragilaria* had the highest peaks at CTD 407 and 423. At CTDs 396, 400, and 438, *Fragilaria* was not present (Figure A2.9).

10. Guinardia

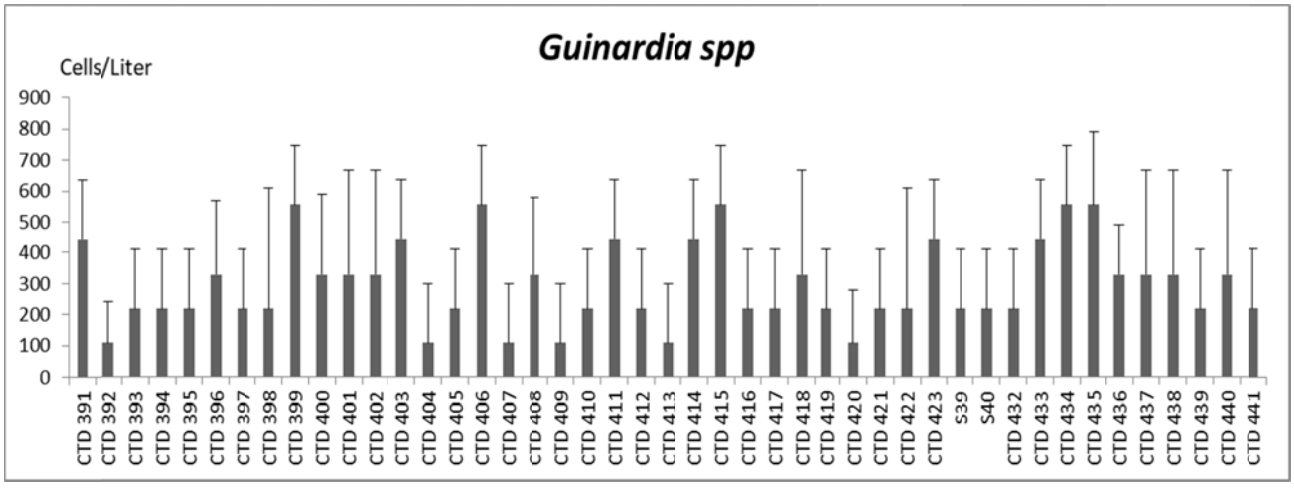

Figure A2.10. Spatial density variation of *Guinardia* from CTD (391-441).

The lowest densities of *Guinardia* genus was at Saya de Malha bank for the CTD samples 404, 407, 409, 413 and 420. At the CTDs of Nazareth, the density was fairly high (Figure A2.10).

11. Hemiaulus

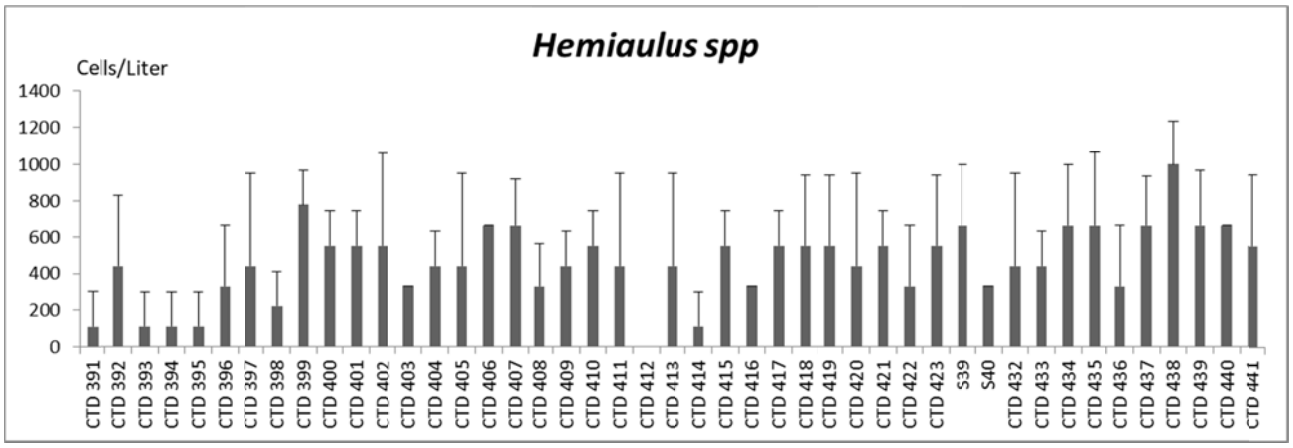

Figure A2.11. Spatial density variation of *Hemiaulus* from CTD (391-441).

The *Hemiaulus* genus was present everywhere except at the CTD 412. The density was fairly high in Nazareth Bank compared Saya de Malha. Low densities were recorded at the CTD number 391, 393, 394, 395, 398 and 414 (Figure A2.11).

12. Leptocylindrus

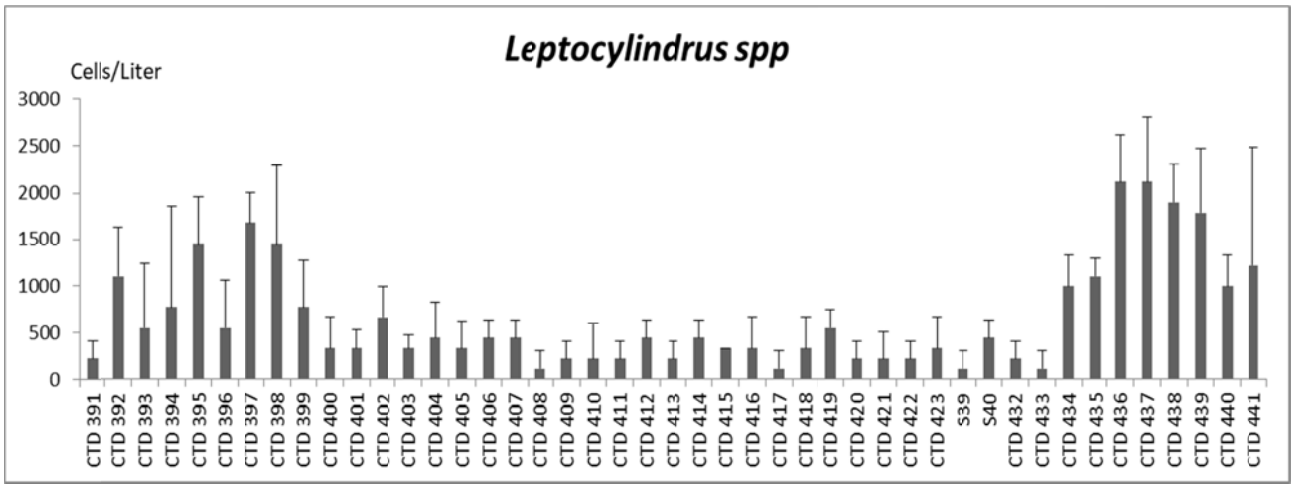

Figure A2.12. Spatial density variation of *Leptocylindrus* from CTD (391-441).

The genera *Leptocylindrus* was most dominate at the start of the sampling at Saya de Malha and at all the CTDs done at Nazareth Bank. From CTD 400 up to CTD 433 low density was recorded and was below 500cells/liter (Figure A2.12).

13. Licmorphora

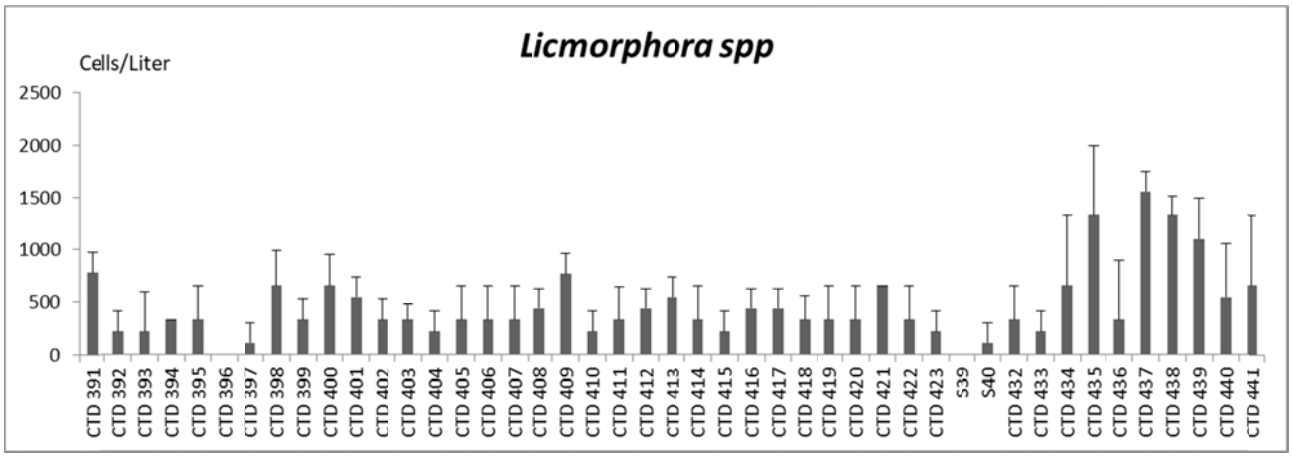

Figure A2.13. Spatial density variation of *Licmorphora* from CTD (391-441).

The *Licmorphora* genus was most abundant in during the CTDs done at Nazareth bank where the densities varied between 500-1500 cells/liter. It was absent during the sampling at the CTD 396 and station S39 (Figure A2.13).

14. Melosira

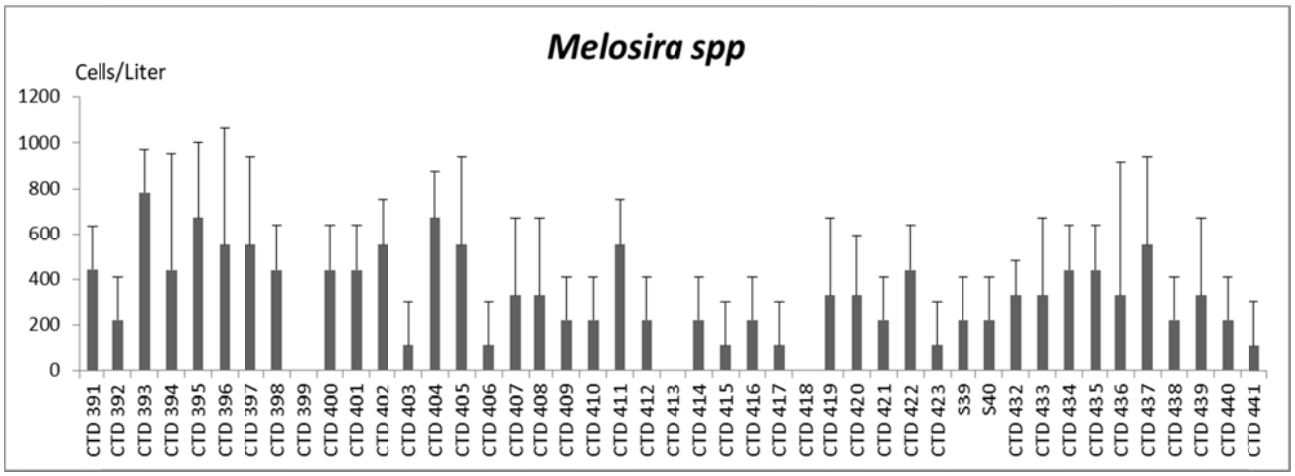

Figure A2.14. Spatial density variation of *Melosira* from CTD (391-441).

The *Melosira* genus was absent in the sampling of CTDs 399, 413 and 418. The highest peaks were recorded at the start of sampling in the Saya de Malha Bank (Figure A2.14).

15. Proboscia

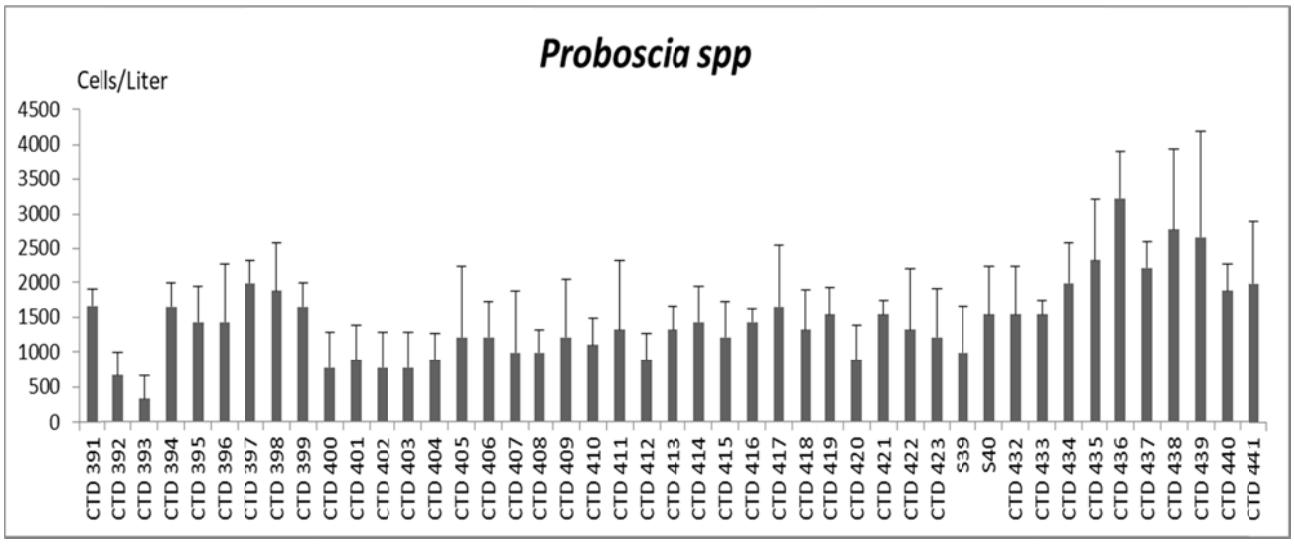

Figure A2.15. Spatial density variation of *Proboscia* from CTD (391-441).

Higher average of the density of *Proboscia* was recorded at the Nazareth Banks compared to Saya de Malha Bank (Figure A2.15).

16. Rhizosolenia

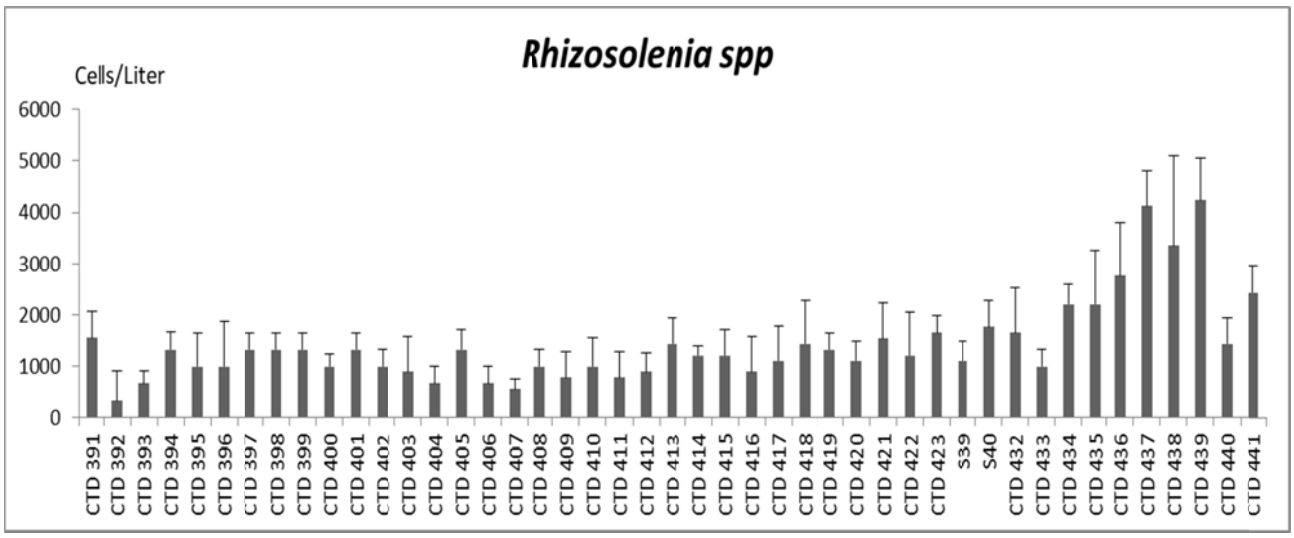

Figure A2.16. Spatial density variation of *Rhizosolenia* from CTD (391-441).

The *Rhizosolenia* genus was most abundant at the Nazareth Banks for the CTD numbers 434-441. For the rest of the CTD's stations, the density varied below 1200cells/liter (Figure A2.16).

17. Skeletonema

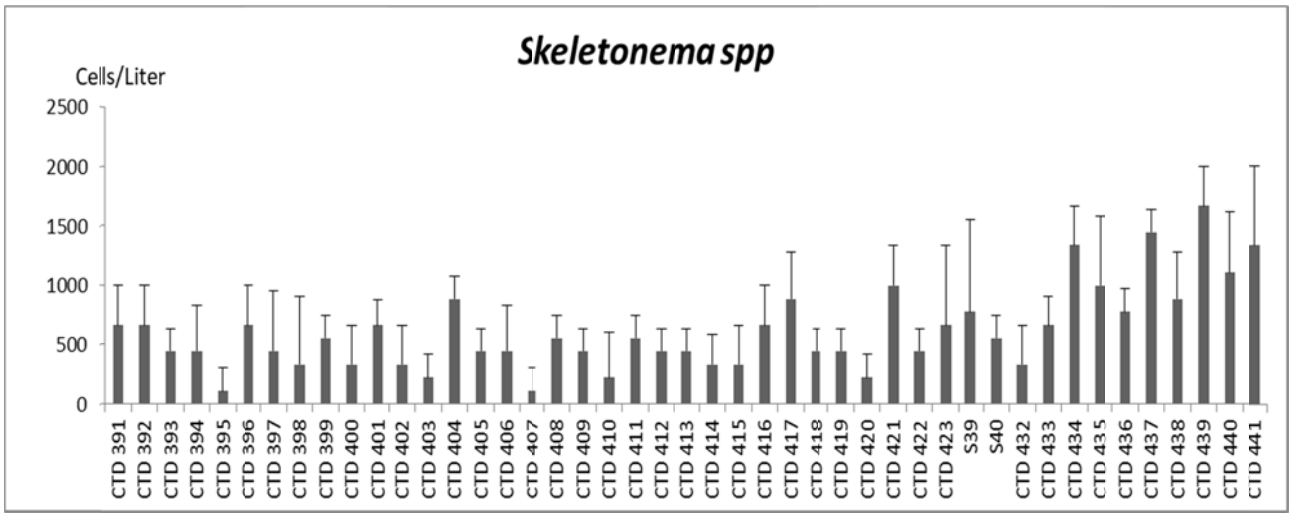

Figure A2.17. Spatial density variation of *Skeletonema* from CTD (391-441).

The genus *Skeletonema* showed higher density at Nazareth Bank compared to Saya de Malha Bank (Figure A2.17).

18. Thalassiosira

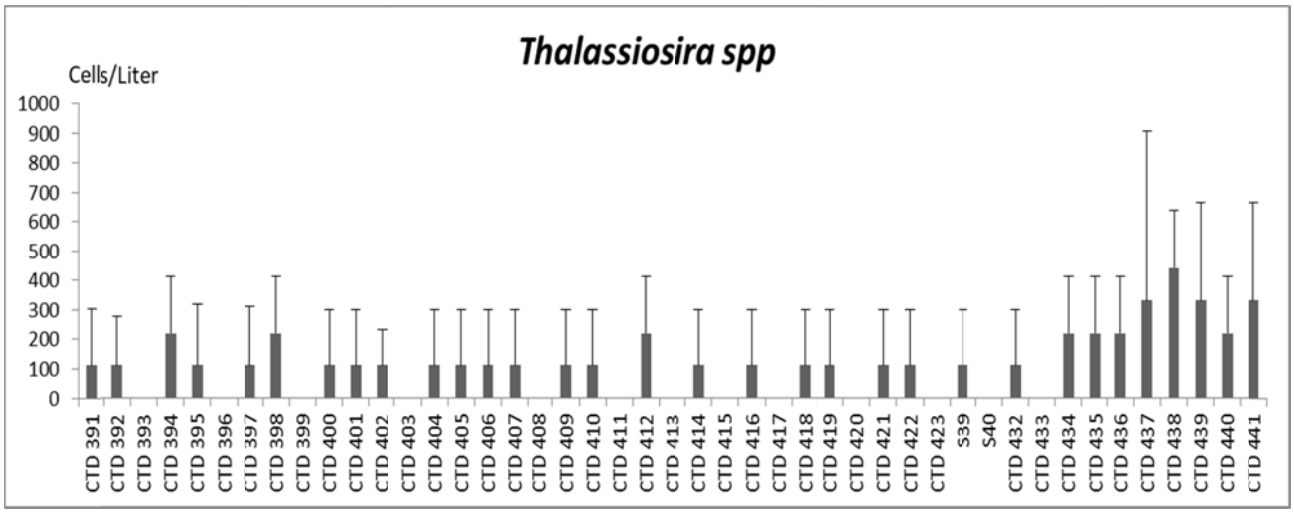

Figure A2.18. Spatial density variation of *Thalassiosira* from CTD (391-441).

The genus *Thalassiosira* was not present at 13 CTDs (393, 396, 399, 403, 408, 411, 413, 415, 417, 420, 423, S40, 433) and it density was highest at the CTDs of Nazareth Bank (Figure A2.18).

19. Asterionellopsis

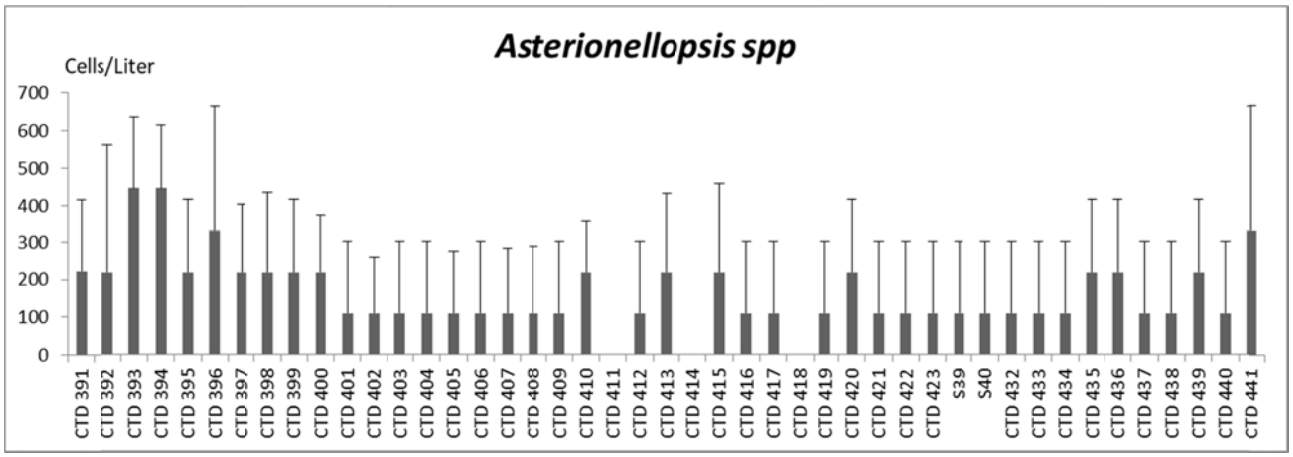

Figure A2.19. Spatial density variation of *Asterionellopsis* from CTD (391-441).

There were 4 peaks in the density of *Asterionellopsis* genus namely at CTD numbers 393, 394, 396 and 441. For the rest of the CTDs, the density was fairly constant ranging from 100-200 cells/liter (Figure A2.19).

20. Navicula

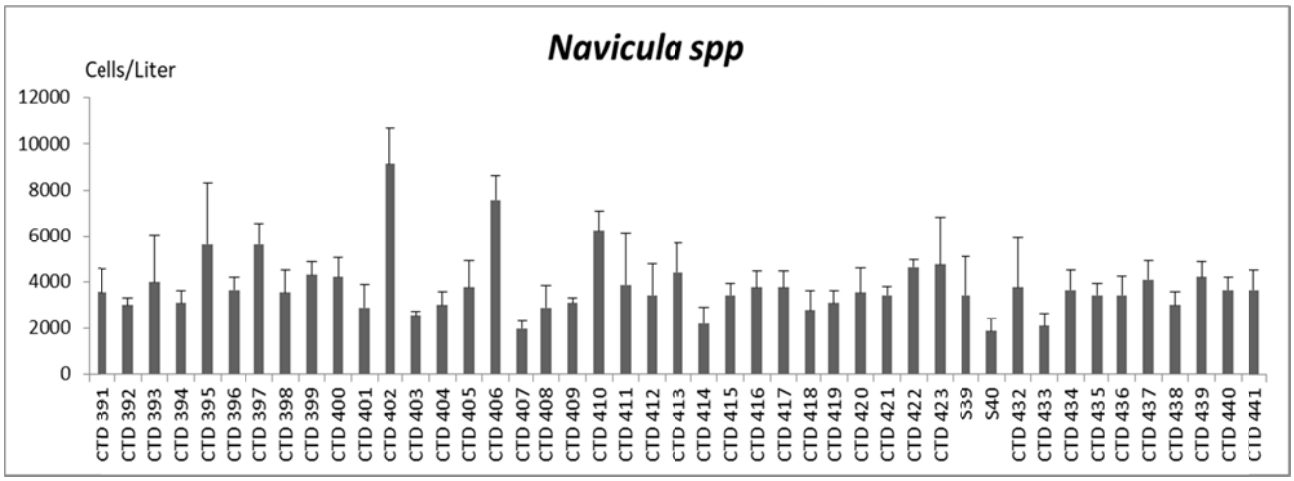

Figure A2.20. Spatial density variation of *Navicula* from CTD (391-441).

The highest density of *Navicula* genus was recorded at CTD402 followed by CTD406 and CTD410. For the rest of the CTDs sampling, the density varied between 1,500-5,000 cell/liter (Figure A2.20).

21. Nitzschia

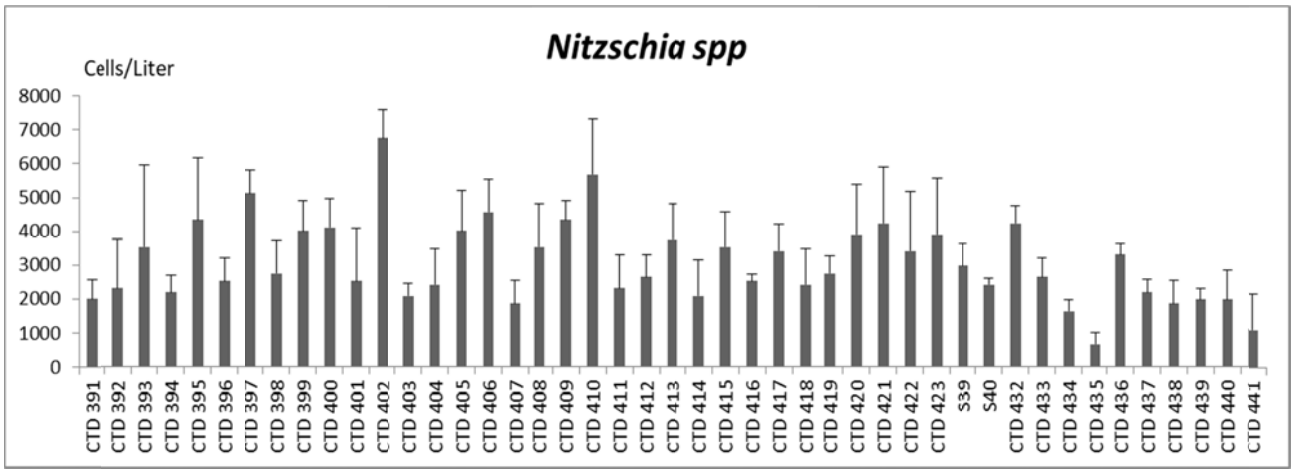

Figure A2.21. Spatial density variation of *Nitzschia* from CTD (391-441).

The genus *Nitzschia* showed a high variation in the density and the lowest density was at CTD 435 at Nazareth Bank (Figure A2.21).

22. Pseudo-Nitzschia

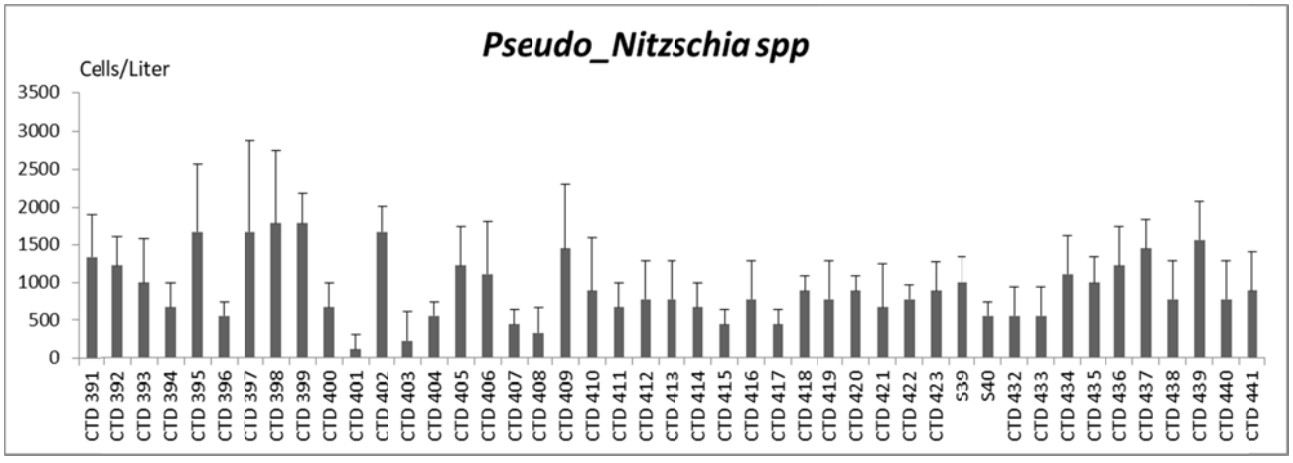

Figure A2.22. Spatial density variation of *Pseudo-Nitzschia* from CTD (391-441).

The lowest density of *Pseudo-Nitzschia* was recorded at CTD401 and the highest peaks were at CTD 395, 397, 398, 399 and 402 (Figure A2.22).

23. Thalassionema

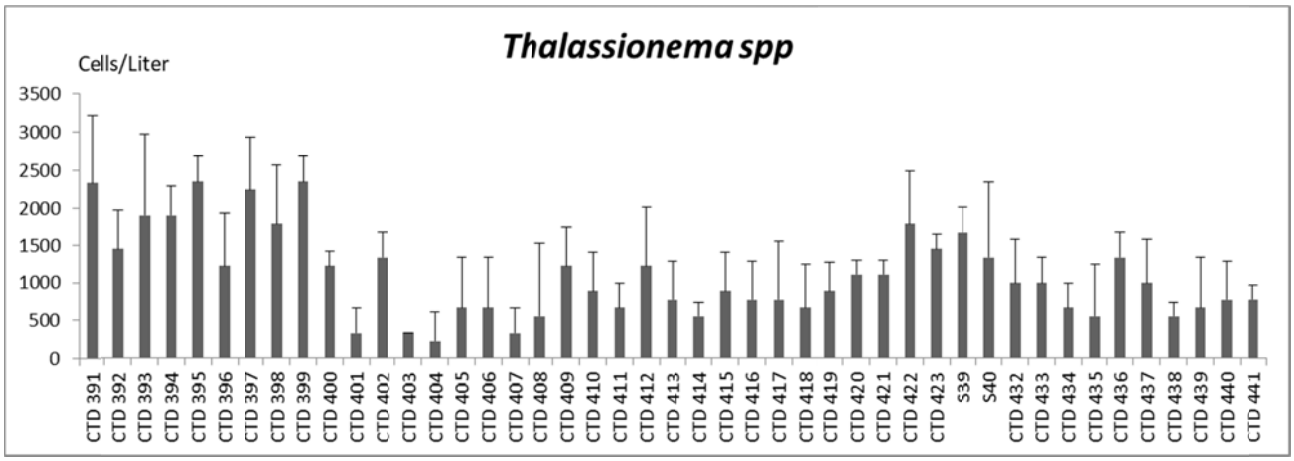

Figure A2.23. Spatial density variation of *Thalassionema* from CTD (391-441).

High density of *Thalassionema* was recorded at the start of the sampling from CTD 391 up to CTD 399 and the lowest density was during the CTD 401 up to CTD 408 (Figure A2.23).

Dinoflagellates

24. Alexandrium

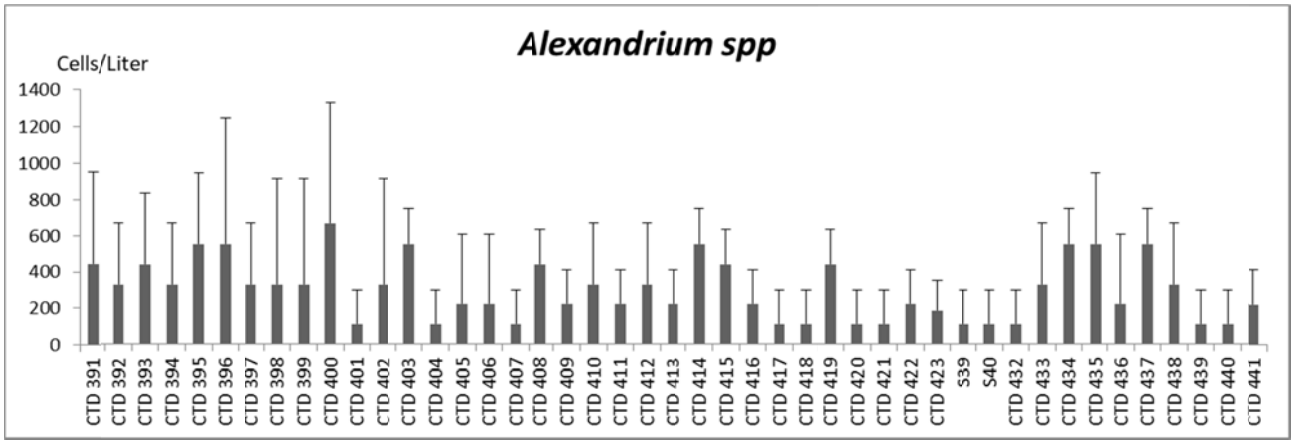

Figure A2.24. Spatial density variation of *Alexandrium* from CTD (391-441).

The genus *Alexandrium* was high during 3 sampling phases (CTD 391-400, 408-415 and 433-438). The lowest CTD was at CTD numbers: 401, 404, 407, 417, 418, 420, 421, S39, S40, 432, 439 and 440) (Figure A2.24).

25. Amphidinium

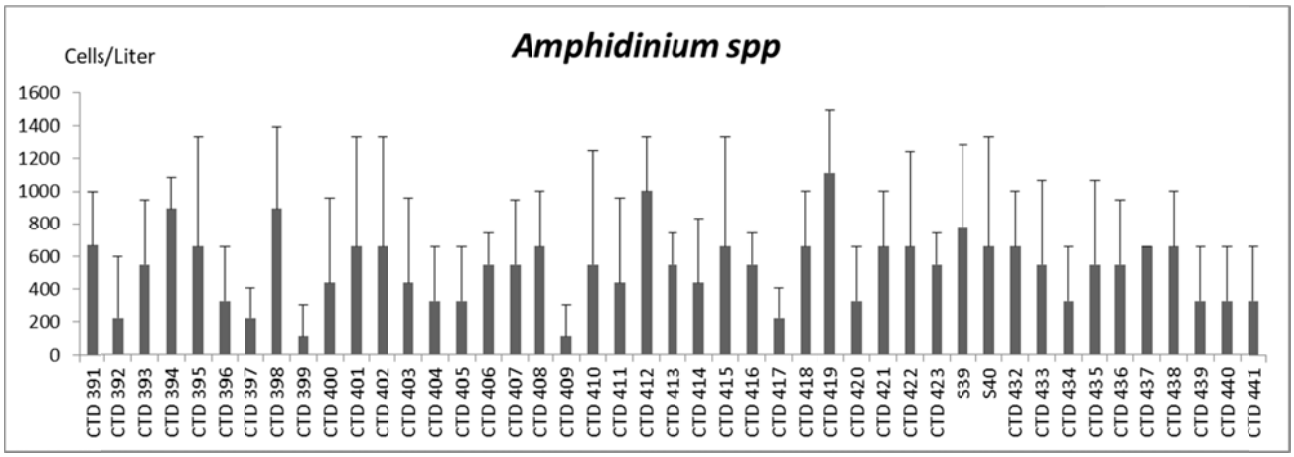

Figure A2.25. Spatial density variation of *Amphidinium* from CTD (391-441).

The genus *Amphidinium* showed highest density peaks at CTD 394, 398, 412 and 419 and the lowest was recorded at CTD 399 and 409 (Figure A2.25).

26. Ceratium

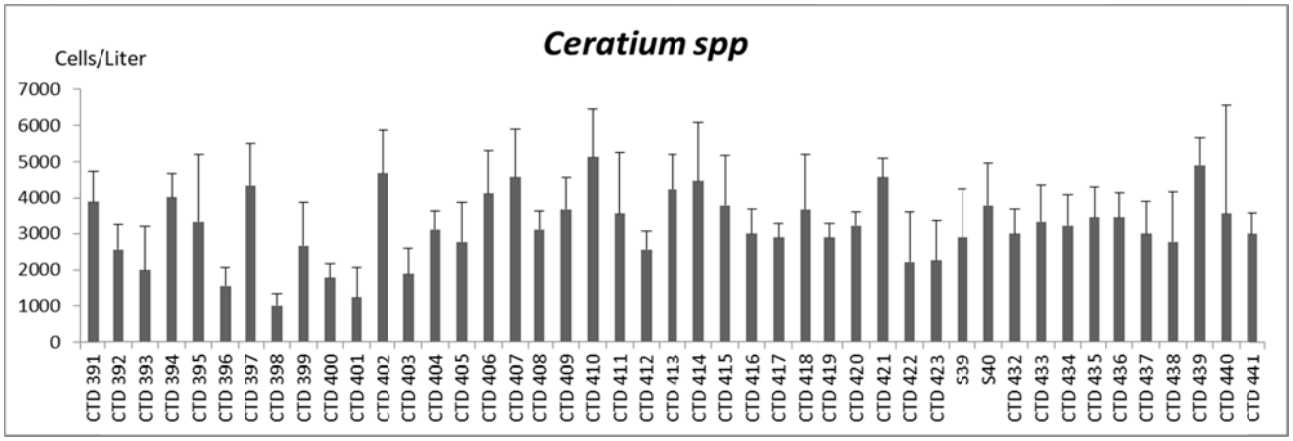

Figure A2.26. Spatial density variation of *Ceratium* from CTD (391-441).

The dinoflagellates *Ceratium* was among the genera with the highest density with over 3000 cells/liter. For this genus, the lowest density was recorded at CTD 398 and 401 which was around 1000 cells/liter (Figure A2.26).

27. Dinophysis

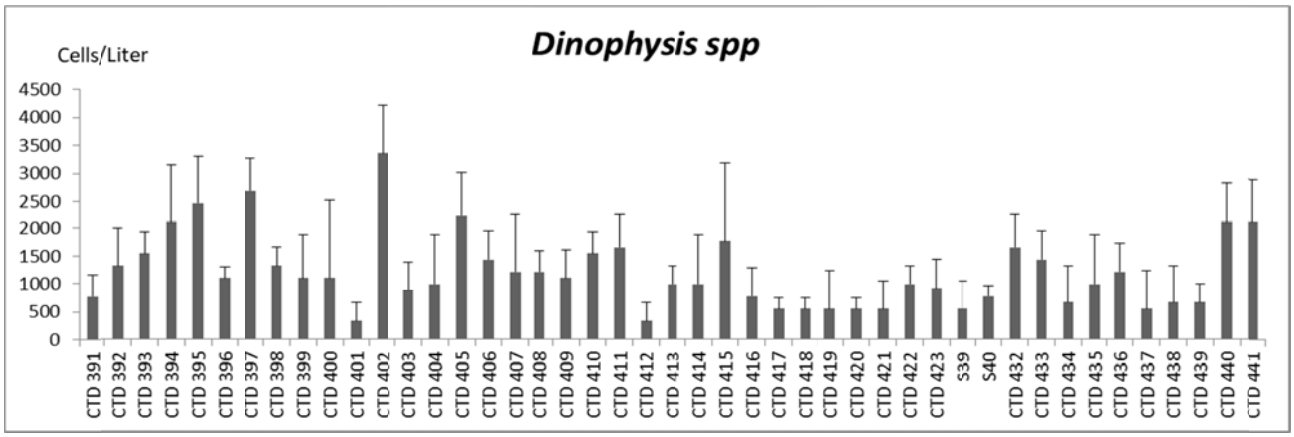

Figure A2.27. Spatial density variation of *Dinophysis* from CTD (391-441).

At more than half of the CTD stations, the variation of *Dinophysis* genus was between 500-1000 cells/liter except for some peaks at CTD395, 397, 402 which varied above 2000 cells/liter (Figure A2.27).

28. Gonyaulax

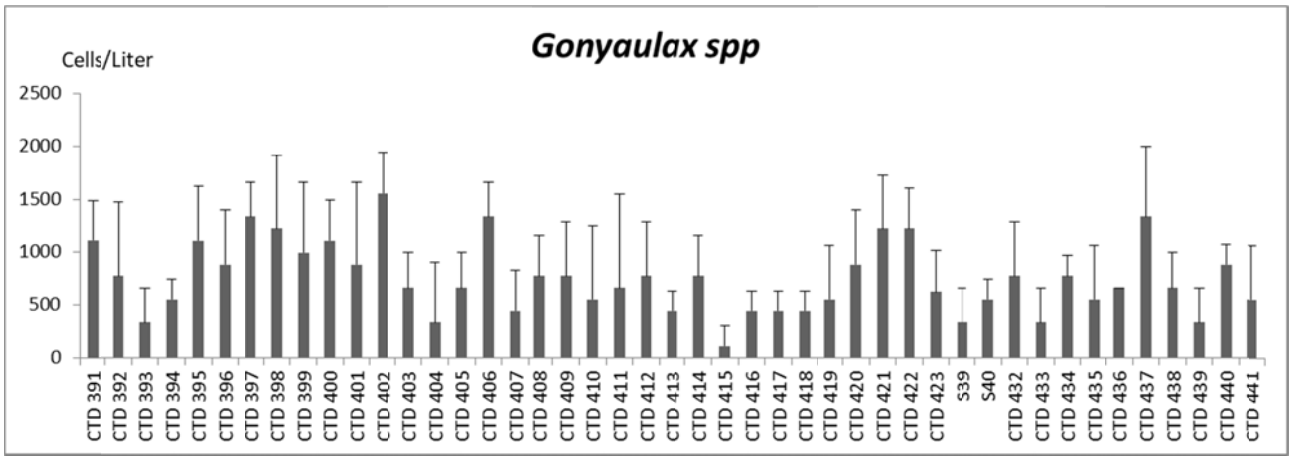

Figure A2.28. Spatial density variation of *Gonyaulax* from CTD (391-441).

The range for the diversity of *Gonyaulax* genus was between 100-1500 cells/liter. The highest was recorded at CTD 402 (approximately 1500 cells/liter) and lowest at CTD 415 (approximately 100 cells/liter) (Figure A2.28).

29. Gymnodinium

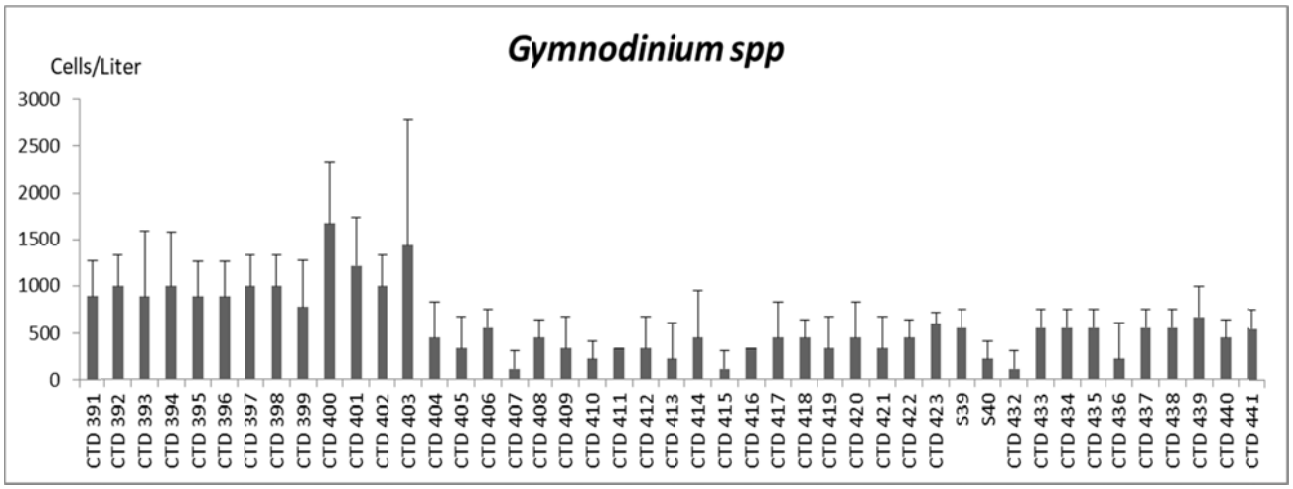

Figure A2.29. Spatial density variation of *Gymnodinium* from CTD (391-441).

Gymnodinium genus showed high density from CTD 391-403 and low density from CTD 404-441 (Figure A2.29).

30. Oxyphysis

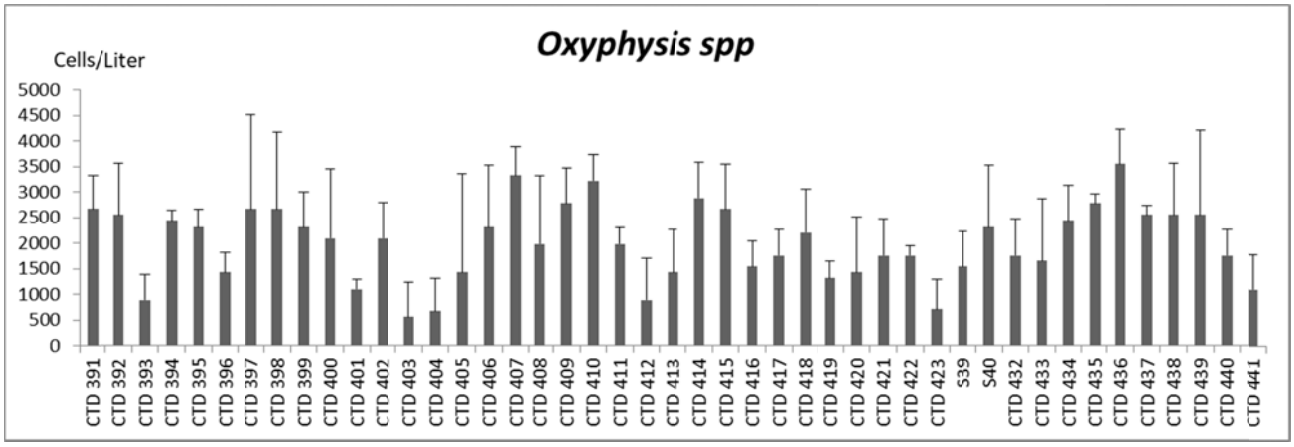

Figure A2.30. Spatial density variation of *Oxyphysis* from CTD (391-441).

The range for the density of *Oxyphysis* genus varied from minimum of 400 up to a maximum of 3400 cells/liter (Figure A2.30).

31. Oxytoxum

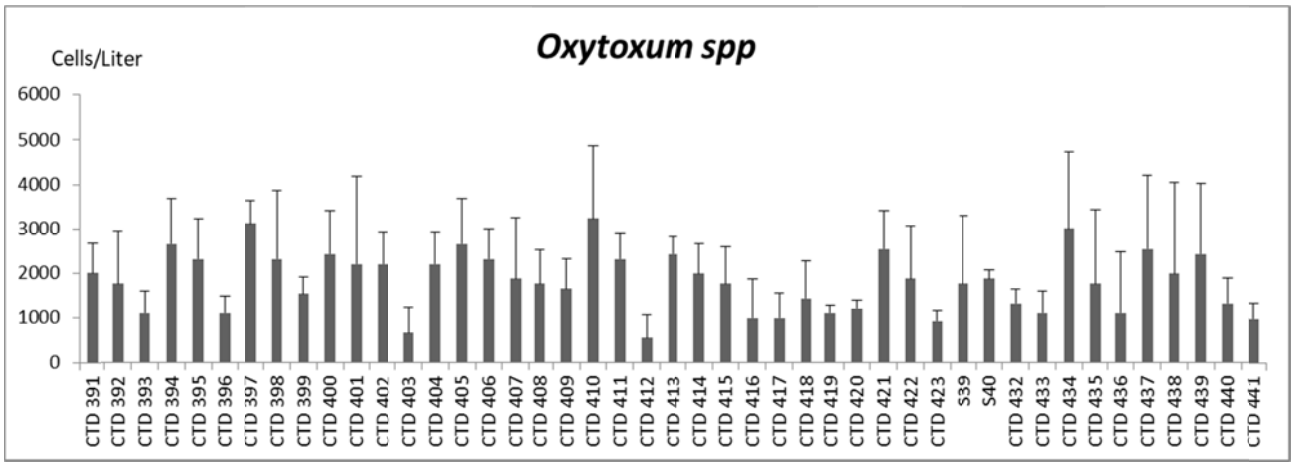

Figure A2.31. Spatial density variation of *Oxytoxum* from CTD (391-441).

The lowest densities of *Oxytoxum* were recorded at CTD stations 403 and 412 and the highest peaks were at CTD 397, 410 and 434 (Figure A2.31).

32. Polykriskos

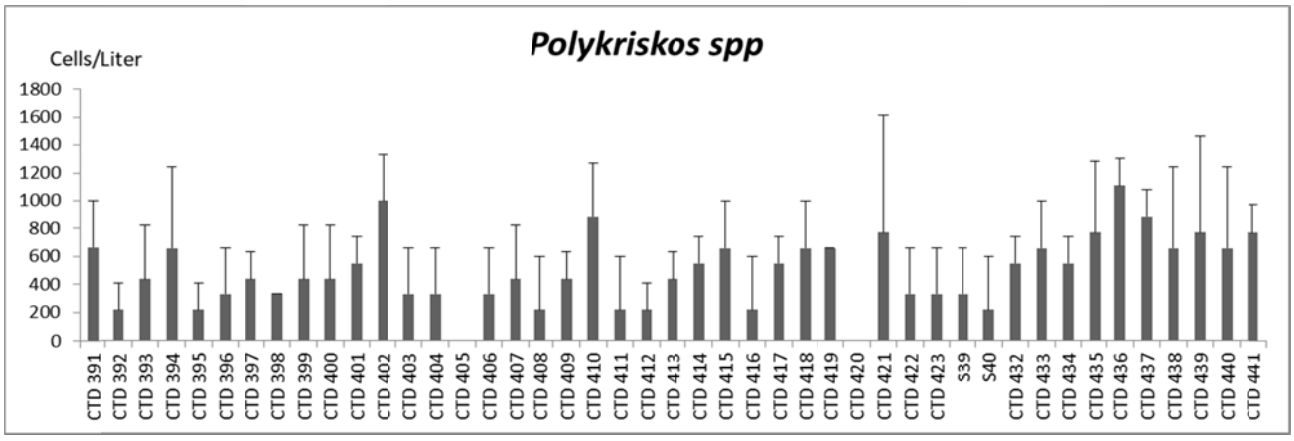

Figure A2.32. Spatial density variation of *Polykriskos* from CTD (391-441).

The *Polykriskos* genus was absent at the CTD stations 405 and 420. The lowest density was recorded at CTD 392, 395, 408, 411, 412 and 416 and the highest peaks were at CTD stations 402, 410 and 436 (Figure A2.32).

33. Peridinium

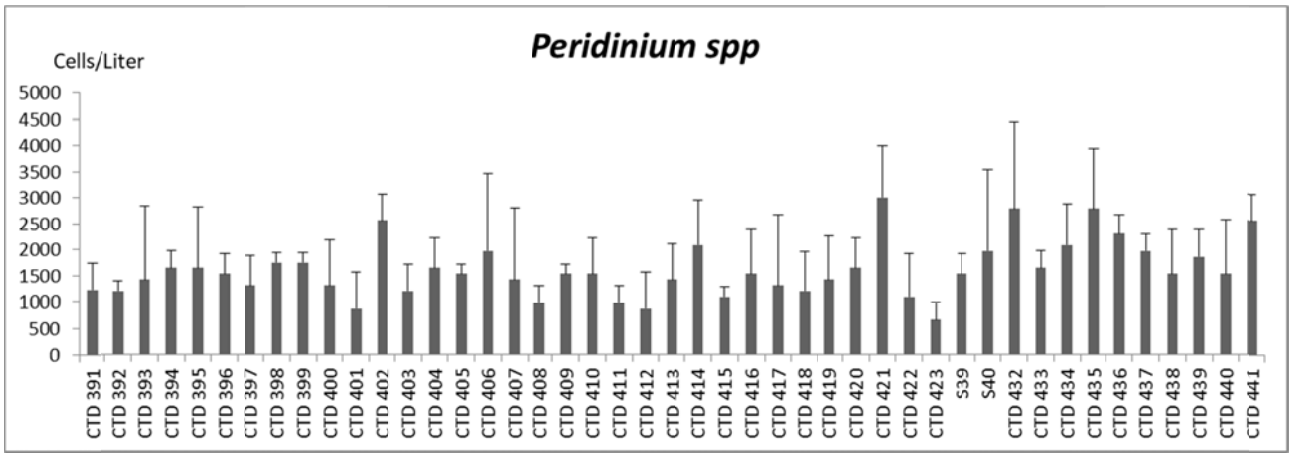

Figure A2.33. Spatial density variation of *Peridinium* from CTD (391-441).

The highest densities of *Peridinium* genus was recorded at the CTD stations 402, 414, 421 and at mainly all the stations at Nazareth Bank (Figure A2.33).

34. Pyrocystis

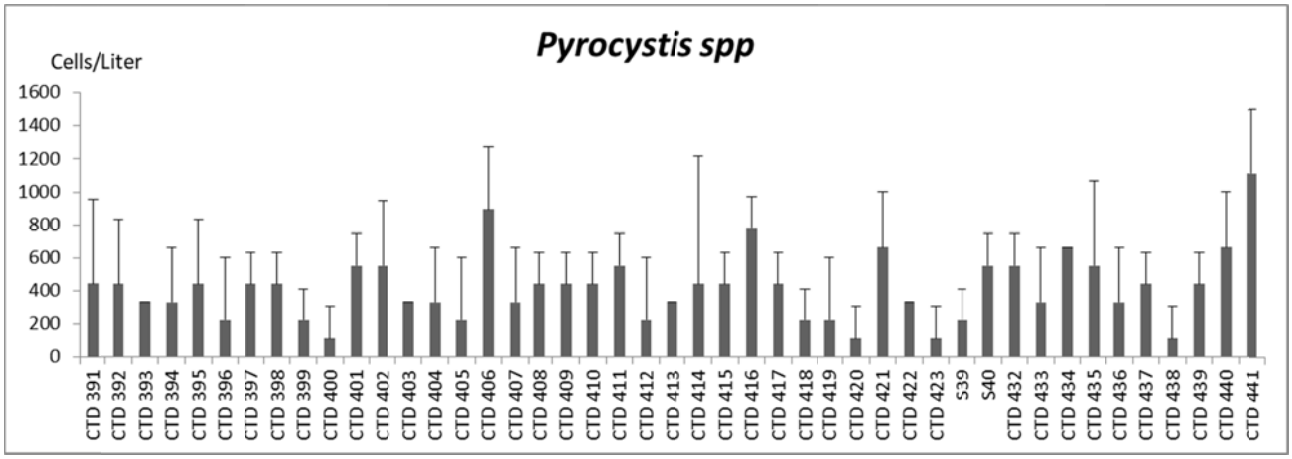

Figure A2.34. Spatial density variation of *Pyrocystis* from CTD (391-441).

Low densities of approximately 100 cells/liter of the genus *Pyrocystis* were recorded at several CTD stations namely CTD 400,420, 423 and 438 (Figure A2.34).