MONACO EXPLORATIONS INDIAN OCEAN EXPEDITION PART 2

“SAYA DE MALHA ECOSYSTEM” Project

2– 17 November 2022

S.A. AGULHAS VOYAGE 055

IIOE-2 EP49

PROVISIONAL REPORT

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MARCH 2023

Foreword

This report is the provisional version of the Saya de Malha Ecosystem project (*Saya de Malha*: a *multidisciplinary study of the Joint Management Area*) conducted during the second part of the Indian Ocean Expedition of Monaco Explorations. This report is the first deliverable requested in Article 6 of the agreements signed between Monaco Explorations and the IRD on the one hand, and between Monaco Explorations and the Museum National d'Histoire Naturelle (MNHN) on the other hand:

« Le Partenaire remettra un rapport intermédiaire présentant les résultats intermédiaires du Projet à EDM au plus tard 6 (six) mois après la fin de la Mission ».

In accordance with the provisions of the application for Marine Scientific Research in the Mauritius-Seychelles Joint Management Area (JMA), the dissemination of this report has been subject to prior authorization from the Designated Authority of the Mauritius-Seychelles JMA.

Note: The painting presented in the front page is by Chloe Thibault, one of the artists invited by Monaco Explorations on board the S.A. Agulhas II

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1- Participants

The Saya de Malha Project gathered an international multidisciplinary team of 39 scientists: 14 from the Seychelles, 11 from Mauritius and 14 from France (or assimilated), all composed of 20 female and 19 male.

Table 1. List of participants by country

Surname	Name	Organisation	Department	Country of residence	Citizenship	Research area	Gender
Theresine	Patsy	Seychelles Parks and Gardens Authority (SPGA)		Seychelles	Seychelles	Marine biology	F
Bonne	Rodney	Seychelles Parks and Gardens Authority (SPGA)		Seychelles	Seychelles	Marine biology	M
Mangroo	Rosabella	Seychelles Fishing Authority (SFA)	Research Section	Seychelles	Seychelles	Environmental Sciences	F
Vidot	Annie	Seychelles Fishing Authority (SFA)	Research Section	Seychelles	Seychelles	Zooplankton	F
Barreau	Estelle	Seychelles Fishing Authority (SFA)	Research Section	Seychelles	Seychelles	Marine biology	F
Gordon	Nuette	University of Seychelles	Blue Economy Research Ins	Seychelles	South Africa	Phytoplancton	F
Sorry	Abel	Ministry of Fisheries and the Blue Economy	Dept of the Blue Economy	Seychelles	Seychelles	Environmental Sciences	M
Dine	Mariette	Ministry of Fisheries and the Blue Economy	Dept of the Blue Economy	Seychelles	Seychelles	Marine biology	F
Talma	Sheena	Talma Consultancy		Seychelles	Seychelles	Underwater Video surveys	F
Maria	Joshua	University of Seychelles	Student	Seychelles	Seychelles	Environmental Sciences	M
Marzocchi	Bianca	University of Seychelles	Student	Seychelles	Seychelles	Environmental Sciences	F
Labonte	Camilla	University of Seychelles	Student	Seychelles	Seychelles	Ocean Science and Marine conservation	F
Jeanne	Terry	Fisherman, Sea cucumber expert		Seychelles	Seychelles	Observer	M
Marsac	Francis	Institut de recherche pour le développement (IRD)	UMR Marbec	Seychelles	France	Chief scientist, PI	M
Bissessur	Dass	Department for Continental Shelf, Maritime Zones Admin & Exploration (CSMZAE)	Oceanography/Marine Geosciences	Mauritius	Mauritius	Geophysics	M
Rawat	Arshad	Department for Continental Shelf, Maritime Zones Admin & Exploration (CSMZAE)	Oceanography/Marine Geosciences	Mauritius	Mauritius	Physical oceanography	M
Coopen	Priscilla	Department for Continental Shelf, Maritime Zones Admin & Exploration (CSMZAE)	Oceanography/Marine Geosciences	Mauritius	Mauritius	Physical oceanography	F
Sauba	Keshav	Department for Continental Shelf, Maritime Zones Admin & Exploration (CSMZAE)	Oceanography/Marine Geosciences	Mauritius	Mauritius	Goosciences	M
Oozeeraully	Yuneeda	Department for Continental Shelf, Maritime Zones Admin & Exploration (CSMZAE)	Oceanography/Marine Geosciences	Mauritius	Mauritius	Physical oceanography	F
Roy	Prerna	Mauritius Oceanography Institute (MOI)	Biotechnology	Mauritius	Mauritius	Marine biotechnology and molecular medicine	F
Oogarah-Bissessur	Preeti Nitisha	Mauritius Oceanography Institute (MOI)	Biotechnology	Mauritius	Mauritius	Marine biotechnology and molecular medicine	F
Bhagooli	Ranjeet	University of Mauritius	Dept of Biosciences & Ocean Studies	Mauritius	Mauritius	Coral reefs	M
Kaullysing	Deepeeka	University of Mauritius	Dept of Biosciences & Ocean Studies	Mauritius	Mauritius	Malacology, coral reefs	F
Ramah	Sundy	Ministry of Blue Economy, Marine Res, Fisheries and Shipping	Fisheries Training & Extension Centre	Mauritius	Mauritius	Marine Ecophysiology	M
Munbodhe	Vikash	Ministry of Blue Economy, Marine Res, Fisheries and Shipping	Albion Fisheries Research Centre	Mauritius	Mauritius	Fisheries and coral reefs	M

Cont'd

Surname	Name	Organisation	Department	Country of residence	Citizenship	Research area	Gender
Ménard	Frédéric	Institut de recherche pour le développement (IRD)	IRD Marseille / UMR M IO	France	France	Zooplankton, video survey	M
Ternon	Jean-François	Institut de recherche pour le développement (IRD)	IRD Sète / UMR Marbec	France	France	Physical and chemical oceanography	M
Galletti	Florence	Institut de recherche pour le développement (IRD)	IRD Sète / UMR Marbec	France	France	Law of the Sea and marine environment	F
Taillandier *	VIncent	Laboratoire de Villefranche (LOV)	Equipe OMTAB	France	France	Oceanography engineer	M
Dimier *	Céline	Laboratoire de Villefranche (LOV)	Equipe OMTAB	France	France	Oceanography engineer	F
Noyon	Margaux	Nelson Mandela University	Ocean Science Campus	South Africa	France	Zooplankton	F
Corbari	Laure	Muséum National d'Histoire Naturelle	UMR ISYEB / Exploration, Espèces et Evolution	France	France	Benthic biodiversity: crustaceans	F
Bouchet	Philippe	Muséum National d'Histoire Naturelle	UMR ISYEB / Exploration, Espèces et Evolution	France	France	Benthic biodiversity: molluscs	M
Le Gall	Line	Muséum National d'Histoire Naturelle	UMR ISYEB / Exploration, Espèces et Evolution	France	France	Benthic biodiversity: algae. Divers leader	F
Vassard	Emmanuel	Muséum National d'Histoire Naturelle		France	France	Diver	M
Moutardier	Grégoire	Muséum National d'Histoire Naturelle		France	France	Diver	M
Frutos	Inmaculada	University of Lodz	Dept of Zoology & marine invertebrates	Poland	Spain	Benthic biodiversity: crustaceans	F
Gouillieux	Benoit	Bordeaux University	UMR EPOC / Ecologie Biochimie syst. côtiers	France	France	Diver	M
Hourdez	Stéphane	Centre National de la Recherche Scientifique (CNRS)	UMR LECOB / Observatoire Océanologique de Banyuls	France	France	Diver	M
Rota	Bernard	GLOBICE Réunion		France	France	Marine megafauna	M

** Staff of the B5 (BGC Argo project) bringing assistance and expertise in the Saya de Malha project*

The research programme included 10 work packages (WPs) to cover the diversity of objectives. Each WP gathered between 4 and 19 members (except WP9 with a single member). The same individual could be assigned to several WPs. There were one or two coordinators by WP.

WP1 - Seafloor mapping
WP2 - Physical and chemical oceanography
WP3 - Phytoplankton
WP4 – Marine particles and zooplankton
WP5 - Benthic invertebrates and sponges inventory
WP6 - Photo-physiological studies of photosynthetic organisms
WP7 - Scuba diving operations and specimen collection
WP8 - Video survey and ROV
WP9 - Megafauna
WP10 - International Law of the Sea and its relationships with marine science

Five WPs (2, 3, 4, 5 and 8) included operations during day and night, with specific teams for each shift, consequently there were two coordinators for each of these day/night WPs.

The present scientific report will detail activities and results for each of the ten WPs, as well as the training sessions.

2- Brief overview of the Saya de Malha Bank

The Saya de Malha Bank is one of the underwater features of the arc-shaped Mascarene Ridge, which stretches over 2000 km between the Seychelles in the North and Mauritius in the South (Fig. 1). It is also one of the largest submerged banks in the world (40,000 km²) with a surface area equivalent to Switzerland. The Ridge is comprised of elements of very different geological origin and age. The Seychelles Plateau comprises pre-cambrian granite about 650 MY old. At the other end, Mauritius is only a few million years old and was formed by a crustal hotspot now located under the volcanically active island of Réunion. As for Saya de Malha, the bank was formed 35 MY ago by the Reunion hotspot and is composed of basaltic basal rock overlaid with limestone, a 1500 m thick cover, the remnants of coral reefs. Millions of years ago, the bank was one or more mountainous volcanic islands, like present-day Mauritius and Réunion, which subsequently sank below the waves. Some of the banks may have been low islands as recently as 18,000-6,000 years ago, when sea levels were up to 130 m lower during the most recent ice age [*excerpt of the baseline study of the Indian Ocean Expedition, sept 2022*]. Saya de Malha includes a small underwater feature, the Ritchie Bank in its northern part. Some places of Saya de Malha outcrop less than 10 m from the surface and the depth is less than 50 m on the sectors located at the eastern periphery of the bank. Depths generally remain less than 200 m in the central part of the Bank; but can reach 350 m in the southwest region of the Bank. Current knowledge holds that Saya de Malha supports the largest contiguous phanerogam meadow in the world with 80 to 90% of shallow surfaces being covered by seagrasses dominated almost exclusively by *Thalassodendron ciliatum* (Burnett et al. 2001) from depths up to 30-40m.

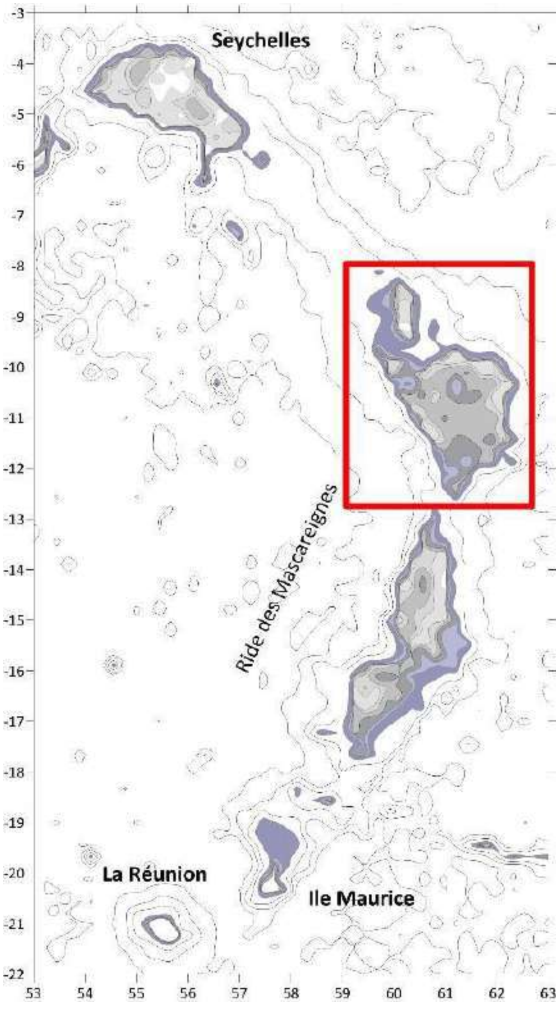


Figure 1. The regional setting of Saya de Malha Bank (red square) in the Mascarene Ridge

The Saya de Malha Bank is located at the northern limb of the South Subtropical Gyre of the Indian Ocean. The South Equatorial Current (SEC) driven by the Southeast Trades carries water of the Indonesian Throughflow in a westerly direction, all the way to Madagascar. It crosses the Mascarene Ridge and a part of the flow is deflected around the topographic rise. The current increases in velocity in the pass between Richie Bank and Saya de Malha in the North, and in the sill separating Saya de Malha to Nazareth Bank in the South. The current pattern is modified by the monsoon (North-east or South West) but these seasonal changes do not affect the circulation on the Mascarene Ridge south of 7°S (Fig. 2)

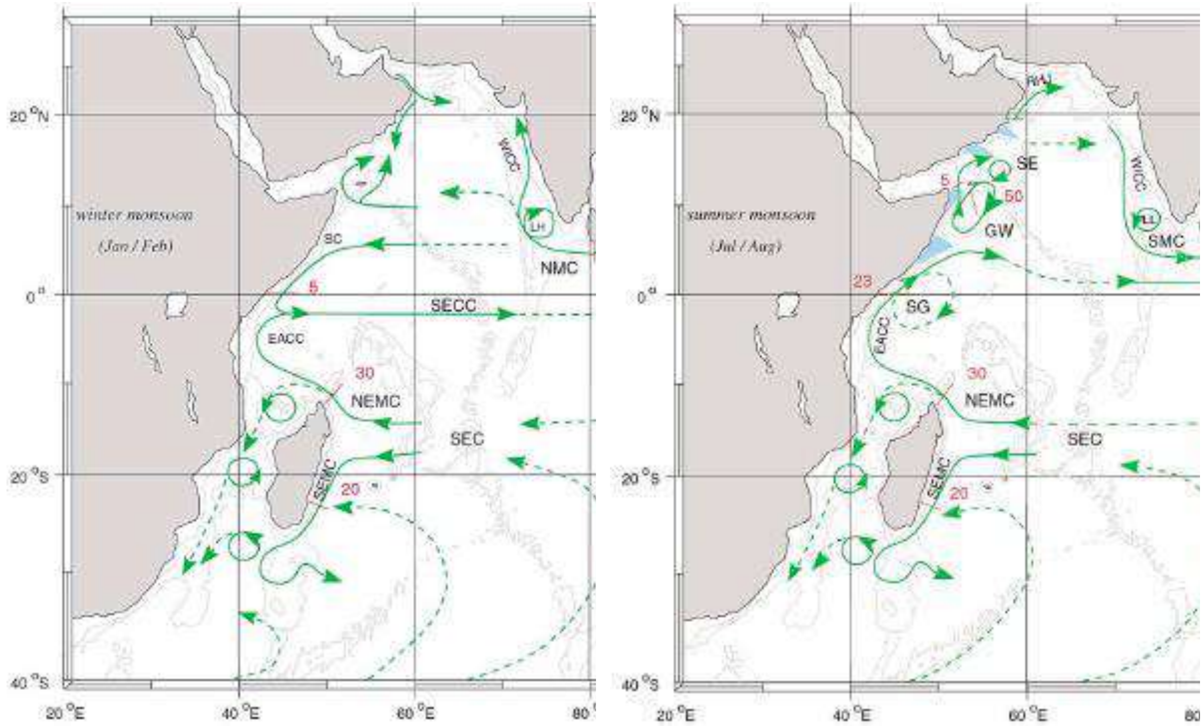


Figure 2. Circulation pattern in the West Indian Ocean during the winter (or North-East) monsoon (left) and during the summer (or south-east) monsoon (right)

Beyond its biogeographical and scientific interest, Saya de Malha has a special status in terms of governance. Following a joint request by Seychelles and Mauritius to the Commission on the Limits of the Continental Shelf for the extension of their continental shelf, these two countries obtained in 2011 the shared sovereignty of Saya de Malha granting them rights to exploit sedentary living resources (bottom dwelling) and mineral resources of the soil (metals) and subsoil (oil, gas). It is then the only Joint Management Area (JMA) in the Indian Ocean, with specific limits beyond the EEZ boundaries of the two island countries (Fig. 3).

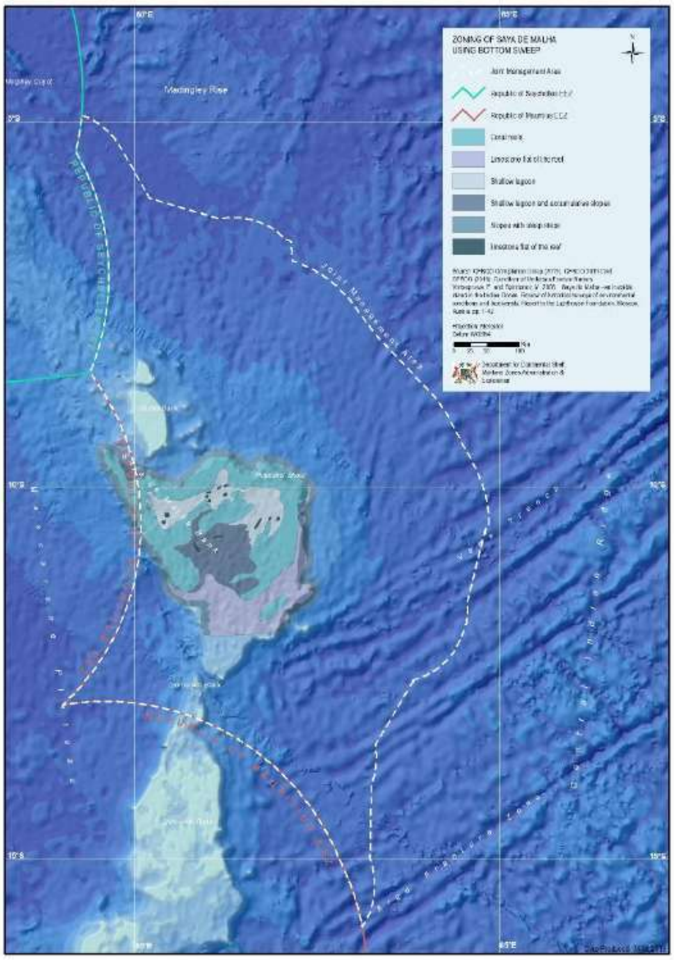


Figure 3. Delimitation of the Saya de Maha Joint Management Area. The jurisdiction only concerns the seabed and subsoils, whereas the water column remains in the High Seas domain.

3- Cruise narrative

S.A. Agulhas II was mobilized in Cape Town, South Africa. She left Cape Town on 3 October. *S.A. Agulhas II* called successively in Port Louis, Mauritius (10-12 October) and Le Port, Reunion (13-14 October) where additional scientific equipment shipped from France for the Saya de Malha project was loaded on board. This included Argo floats transported in a 20-ft container that was returned to the shipping company and diving equipment, towed gears, and tanks transported in a 40-ft container that was stowed on the helicopter deck.

After the sequence of operations undertaken on Aldabra, from 19 to 25 October, *S.A. Agulhas II* continued the scientific programme on the way to Port Victoria, Seychelles. The call at Port Victoria from 29 to 31 October marked the end of the first part of the Expedition with the changeover of many participants.

The second part of the Expedition starting in Seychelles and ending in Mauritius (Fig. 4) was dedicated mainly to the multidisciplinary investigation of the Saya de Malha Bank. The underway projects were also continued. In addition, a marine mammal observer joined the Expedition. *S.A. Agulhas II* left Port-Victoria on 31st October at 8:50 pm local time (GMT+4).

After leaving the Mahe Plateau, the ship joined the position 6°S/60°E that was reached on 2nd November at 00:40 local time (LT) where a deep (2000 m) CTD station was performed and three Argo floats were deployed (B5 project). From there, the ship headed south to Richie Bank. The first set of operations of the Saya de Malha project started on 2nd November at 22:45 LT by a series of three CTD stations in the strait between Richie Bank and Saya de Malha Bank. The last series of measurements associated to the Saya de Malha project took place during the night between 17th and 18th November where 6 XBT casts were done in the strait between Saya de Malha and Nazareth Banks. From there, *S.A. Agulhas II* headed south along the eastern edge of Nazareth Bank, to St Brandon, which was reached on 19th November, 05:10 LT. After 2 days of operation from north to south of the St Brandon archipelago, the ship took its course to Mauritius where it arrived on 22nd November at 08:15 am LT. Most participants disembarked in Mauritius.

An overview of the Expedition was presented in the evening to HE Mr Eddy Boissézon, Vice-President of the Republic of Mauritius and Mr Sudheer Maudhoo, Minister of Blue Economy, Marine Resources, Fisheries and Shipping and other officials from Mauritius

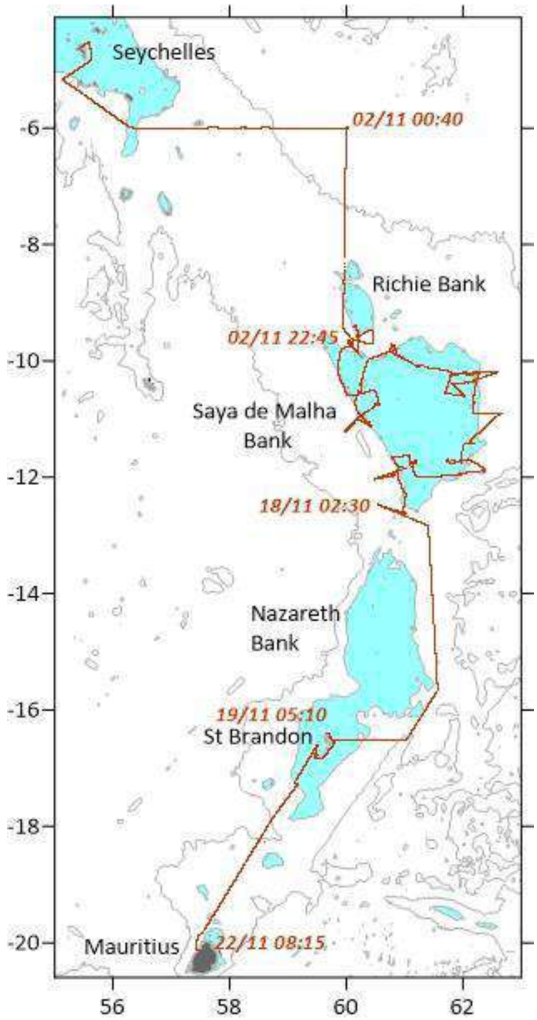
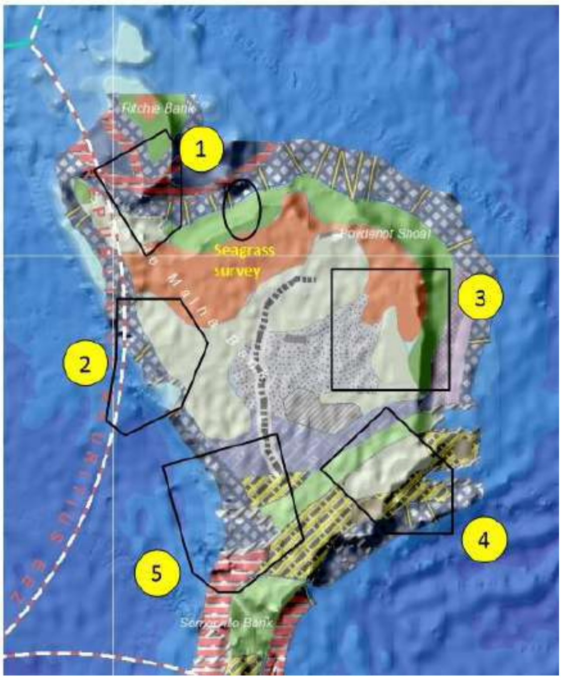


Figure 4. Track of the second part of the expedition, from Seychelles to Mauritius, through Saya de Malha Bank and St Brandon.



As for the operations conducted on the Saya de Malha Bank, the large size of the area (~40 000 km²) and limited time (2 weeks) did not allow a full coverage of the bank, then five areas had been selected during the preparatory phase, based on the diversity of the sediments that were described by previous cruises (Fig. 5). A small area in the north of the Bank was also selected to undertake a short survey of the seagrass meadow. The ship surveyed the areas 1 to 5 sequentially, and the seagrass area was surveyed on the route between areas 2 and 3.

Figure 5. The five sampling areas (black boxes) and the seagrass meadows area distributed over the sediment landscape of Saya de Malha.

4- Objectives of the project

Potential activities in the Mauritius-Seychelles JMA are closely linked to the Blue Economy initiatives of both countries, where the development of income-generating activities in the JMA is devised without causing significant impacts on the ecosystem. The characterisation of the most fragile and vulnerable areas of critical habitats is a prerequisite for any maritime planning of future activities and this is the purpose of this project.

The Saya de Malha project was designed with a goal of **"Science for Marine Governance and Planning Support"**, with the following objectives:

- To complement the existing scientific information on the marine environment of the shallow areas of the Saya de Malha Bank and its slopes;
- To undertake an inventory of the benthic biodiversity, to assess the species richness and possible endemism, in order to map the sensitive habitats that may require specific conservation measures;
- To publish the main results in international journals;
- To produce fact sheets on the habitats and communities of the Saya de Malha Bank;
- To contribute to policy briefs for institutional stakeholders and policy makers in Seychelles and Mauritius.

5- Work details

A variety of operations corresponding to each WP was conducted during the Saya de Malha project. The map in Figure 6 indicates the distribution of operations in the different box areas, on the shelf and in the deep ocean waters (three stations from the slope to a distance of 20 to 25 nm offshore). Towed gears refer to Warén dredge, beam trawl and epipelagic sledge (WP5). CTD stations (WP2) include the Bongo and Multinet (WP4). The SVP and SSD are the two types of drifters deployed during the cruise (WP2).

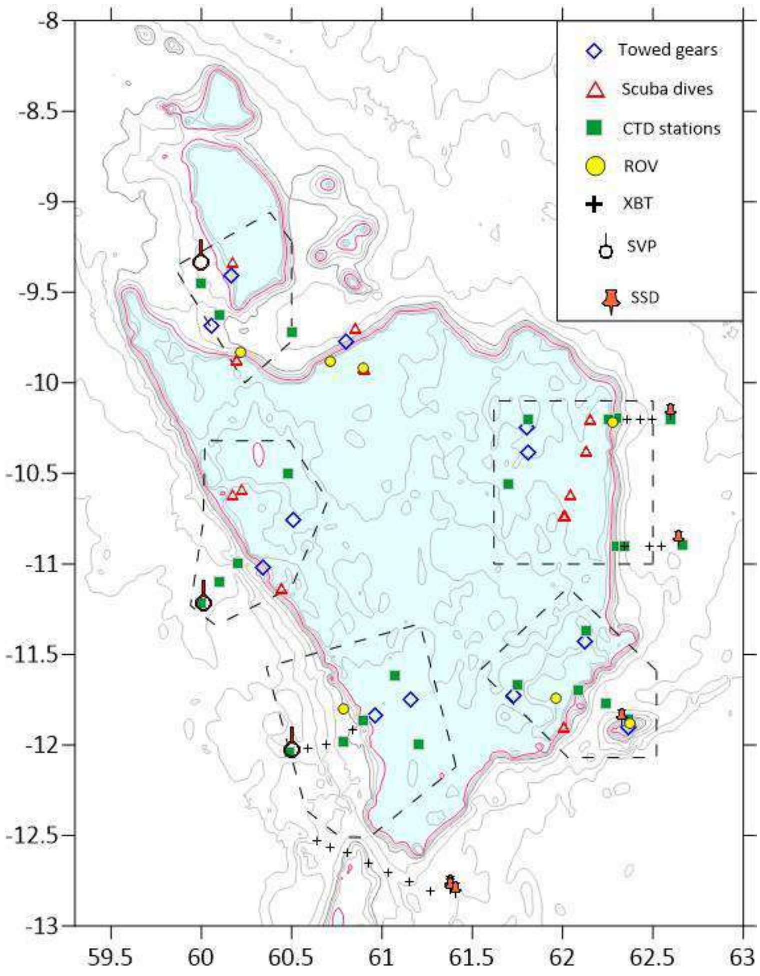


Figure 6. Location of the operations by category.

CTD stations : 25
XBT profiles : 19
Surface drifters : 10 deployments
Bongo nets : 20
Multinet : 5
Scuba dives : 11
ROV : 7 dives
Towed gears: 13 sites, 46 sets

5.1 Seafloor mapping (WP1)

Coordinator : Dass Bissessur
Team: Mariette Dine, Camilla Labonte, Arshad Rawat, Keshav Sauba, Abel Sorry

5.1.1 Methods

The *S.A. Agulhas II* is equipped with the Single Beam EchoSounder (SBES) Simrad EA600 and the Simrad EK60 from Kongsberg Maritime. Both are used to provide accurate depth data navigation and for carrying out bathymetry transects.

No Multi Beam Echo Sounder (MBES) is mounted on the vessel for undertaking swath bathymetry surveys.

The Sub Bottom Profiler, the Kongsberg TOPAS PS18, was also used for imaging of the sediment layers (sub seafloor imaging) along bathymetry transects.

The navigation and depths along the ship's route were visualised using Quinsy software package from QPS Maritime Software Solutions.

Quinsy has also been used to visualise the available multibeam bathymetry data of the area, collected by the Nansen cruise in 2018 and Mascara cruise in 2019, to finalise the stations location where the benthic samplings using towed gears (dredge, trawl and sledge) have been carried out and where the ROV surveys have been undertaken.

5.1.2 Preliminary results

Since no MBES was available, no wide-swath bathymetry maps could be produced along the tracks. The vessel used the available MBES data to navigate safely over and across the shallow areas of the Saya de Malha Bank.

The collected SBES data provided depth information below the vessel along its route (and transits) for the uncovered/unchartered areas. Despite these limitations, these data constitute new information to add to the current database for seafloor mapping of the bank and for navigation purposes. Figure 7 shows the depth along the lines sailed by the ship. We display two of the four frequencies used by the SBES, 38 kHz to cover the deeper areas and 200 kHz for a finer description of the shallow areas.

The information collected by the ship highlighted some discrepancy with the GEBCO bathymetric dataset (2022 version) in a few sectors of the bank. For instance, the deep basin (> 300 m) indicated on the GEBCO map in the northwest part of the bank (Fig. 8) does not exist. In this area, the *S.A. Agulhas II* measured depths comprised between 80 and 40 m. Similarly, in the northeast corner of the bank, GEBCO indicates larger depths (up to 250 m) than those measured during our survey (< 120 m). Eventually, the GEBCO data of the southern region of the bank indicates depth often deeper than 300 m, whereas the *S.A. Agulhas II* recorded flat bottom not exceeding 300 m

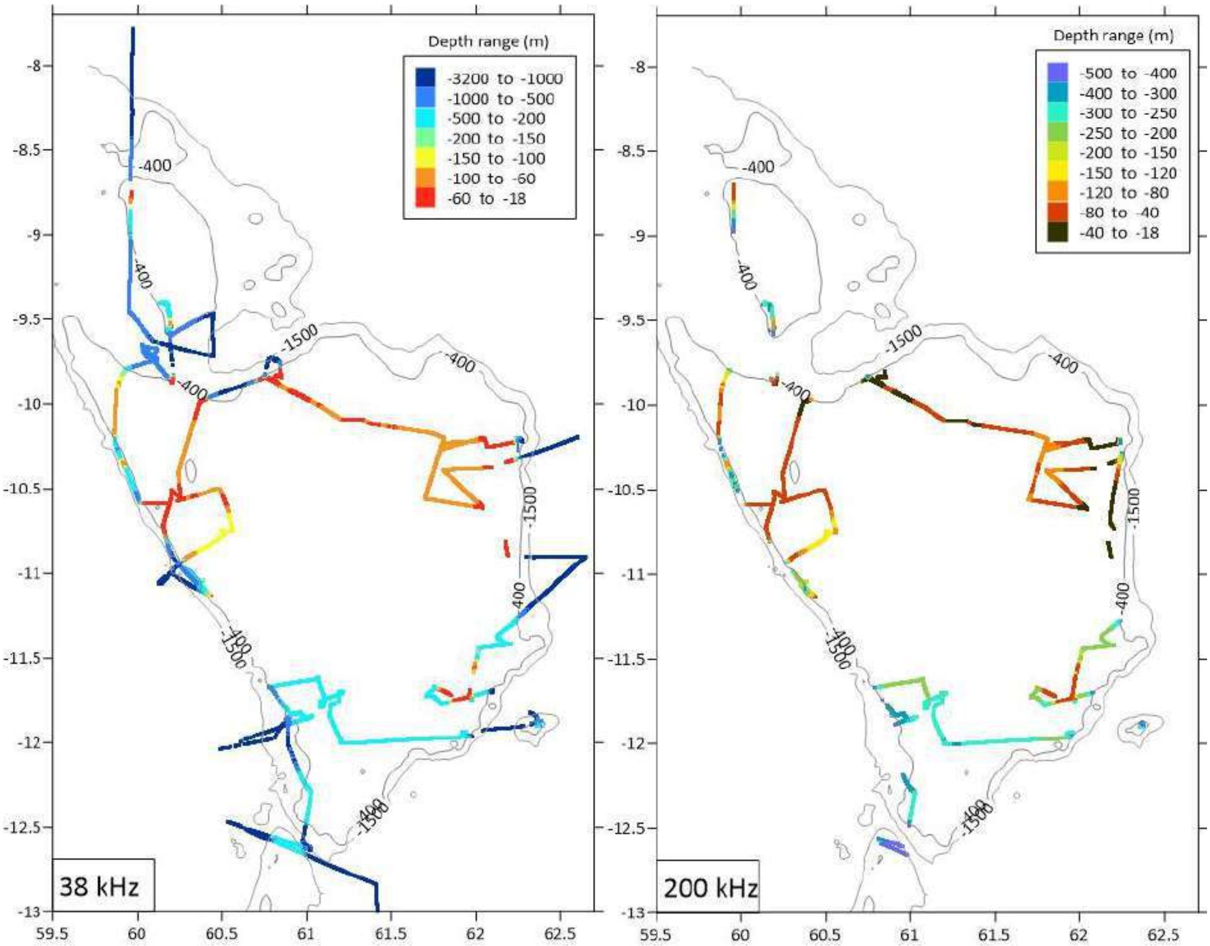


Figure 7. Depth measured by the SBES of the S.A. Agulhas II along sailing lines over the Saya de Maha Bank and outside its slopes. Two frequencies are shown to cover a large range of depths along the tracks.

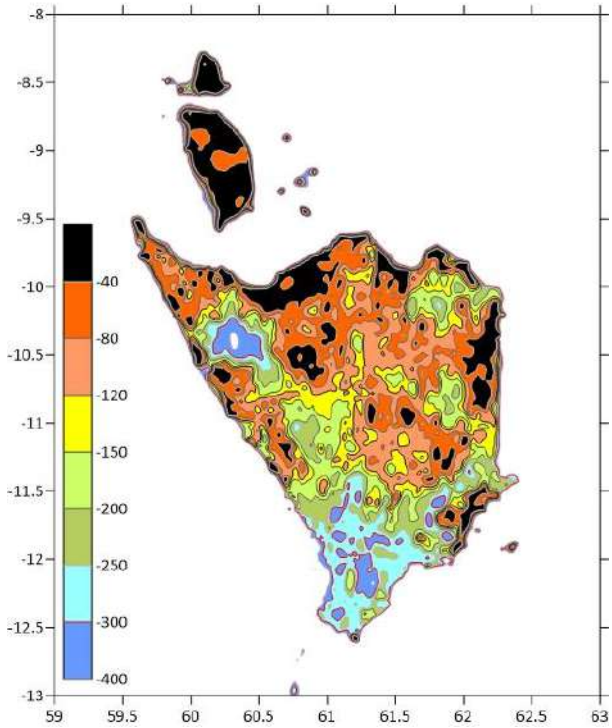


Figure 8. GEBCO 2022 bathymetric data of the Saya de Malha Bank. The color scale used here is the same as in the 200 kHz map of Figure 7

5.2 Physical and chemical oceanography (WP2)

Coordinators : Jean-François Ternon and Arshad Rawat
Team: Dass Bissessur, Priscilla Coopen, Céline Dimier, Camilla Labonte, Preeti Oogarah, Yuneeda Oozeeraully, Prerna Roy, Keshav Sauba, Abel Sorry, Vincent Tallandier

5.2.1 Methods

The operations in the WP2 included:

- CTD operations and calibration
- ADCP data continuous acquisition along ship track
- TSG data continuous acquisition along ship track
- XBT deployment at selected location
- Drifters deployment (SVP drogued floats and SSD surface drifters)

5.2.1.1 CTD operations and calibration

A Seabird 911+ V2 CTD system was used, coupled with a Seabird 32 Carousel/Rosette fitted with 24 Niskin bottles of 12L capacity each.

Of a total of 39 planned grid sampling stations, a total of 25 CTD profiles and rosette samplings were conducted (Table 2 and Fig. 9). The stations that were not sampled were largely excluded because more time was needed for dive (SD), towed gears (TG) and ROV operations. In total, all but one (Sta 28) deep stations were sampled, all at night shift (18 deep CTD stations). On the contrary, only seven (out of 20 planned) shallow stations were performed – all at day shift. It was decided in the early days of the cruise that repeated day/night shallow stations were not a priority – the zooplankton vertical migration could not be characterized (as initially thought) as the towed Bongo nets sampled the whole water column at these shallow stations. More time thus became available for other types of activities.

The CTD profiles reached depths as close to the bottom as possible (10 m above the seafloor thanks to the altimeter of the CTD/Rosette) where depth did not exceed 2000 m (the maximum reached depth for deeper stations). The station numbering followed the one of the CTD cast (including the 8 CTD profiles achieved during Part 1) to facilitate the correspondence in the numbering of all operations done at each station. For Saya de Malha, CTD/Rosette station number run from IO_009 to IO_033 (Fig. 9). Table 2 summarizes the stations metadata, with time, location, depth, number of sampled levels, plankton net type and station “grid-number” (ship-ID for the operation done at sea).

Several of the CTD stations were common with the project B5 (BGC BioArgo Floats), specifically stations IO_013, IO_018, IO_023 and IO_027. The CTD casts at the BGC stations were 2000 m deep and had a specific dense sampling in the upper 120 m (one bottle every 10m) for BioArgo calibration purpose. The station IO_034 has been a BGC station close to Saya de Malha but is not considered as a “Saya de Malha station”.

CTD sensors

The CTD was equipped with sensors for temperature, conductivity, pressure, oxygen, turbidity, fluorescence, transmission. It was associated with an UVP5 (Underwater Vision Profiler - voltage 4 on channel 8). The CTD was also equipped with an altimeter. Table 3 gives detailed information for each sensor.

Table 2. List of the CTD stations including date/time, lat/lon, bottom depth and maximum sampled depth, number of sampled depth, station IDs (see text) and the type of zooplankton net deployed. The stations highlighted in grey are the deep stations performed outside the Saya de Malha Bank.

		jour	heure TU	latitude	longitude	#CTD	fond	prof max profil CTD	Nb btles fermées	niveaux prélèvement	filets	ID-station
1	sta 1	02/11/2022	16:39	09°27.036 S	59°59.914' E	IO_009	722	700	16	12	Bongo	VOY-55-B1-1
2	sta 2	02/11/2022	20:03	09°37.803' S	60°05.948' E	IO_010	970	950	23	14	Bongo	VOY-55-B1-2
3	sta 3	03/11/2022	00:13	09°43.191' S	60°26.956' E	IO_011	1614	1000	23	15	Bongo	VOY-55-B1-3
4	sta 4	05/11/2022	09:56	10°30.00' S	60°28.786' E	IO_012	60	60	9	3	Bongo	VOY-55-B2-1
5	sta 5	05/11/2022	17:41	11°13.119' S	59°59.896' E	IO_013	2855	1500	24	16	Multinet	VOY-55-B2-2
6	sta 6	05/11/2022	21:45	11°06.007' S	60°05.962' E	IO_014	2740	1500	24	16	Bongo	VOY-55-B2-3
7	sta 7	06/11/2022	01:18	10°59.967' S	60°11.944' E	IO_015	1598	1000	23	13	Bongo	VOY-55-B2-4
8	sta 8	08/11/2022	15:30	10°11.979' S	61°48.576' E	IO_016	71	76	12	7	Bongo	VOY-55-B3-1
9	sta 9	08/11/2022	18:12	10°33.532' S	61°41.999' E	IO_017	70	76	17	8	Bongo	VOY-55-B3-2
10	sta 17	09/11/2022	16:13	10°12.061' S	62°36.025' E	IO_018	2196	2000	24	19	Multinet	VOY-55-B3-3
11	sta 18	09/11/2022	21:00	10°11.964' S	62°17.968' E	IO_019	1545	1500	24	17	Bongo	VOY-55-B3-4
12	sta 19	09/11/2022	23:56	10°12.243' S	62°15.278' E	IO_020	930	900	24	17	Bongo	VOY-55-B3-5
13	sta 22	11/11/2022	14:10	10°54.028' S	62°18.056' E	IO_021	897	850	23	17	Bongo	VOY-55-B3-6
14	sta 21	11/11/2022	17:20	10°54.290' S	62°20.527' E	IO_022	1830	1500	24	18	Bongo	VOY-55-B3-7
15	sta 20	11/11/2022	20:35	10°53.965' S	62°38.944' E	IO_023	2252	2000	24	19	Multinet	VOY-55-B3-8
16	sta 23	12/11/2022	03:25	11°22.248' S	62°07.707' E	IO_024	225	200	15	9	Bongo	VOY-55-B4-1
17	sta 24R	13/11/2022	06:40	11°40.241' S	61°44.957' E	IO_025	227	200	15	9	Bongo	VOY-55-B4-2
18	sta 31	13/11/2022	16:48	11°41.826' S	62°05.229' E	IO_026	870	880	22	15	Bongo	VOY-55-B4-3
19	sta 30	13/11/2022	19:20	11°46.213' S	62°14.387' E	IO_027	2274	2000	24	18	Multinet	VOY-55-B4-4
20	sta 29R	14/11/2022	00:12	11°51.700' S	62°21.988' E	IO_028	667	650	19	13	Bongo	VOY-55-B4-5
21	sta 32	14/11/2022	22:18	12°00.027' S	61°11.988' E	IO_029	284	287	18	12	Bongo	VOY-55-BOX5 -1
22	sta 33	15/11/2022	11:50	11°37.114' S	61°04.163' E	IO_030	209	200	16	10	Bongo	VOY-55-BOX5-2
23	sta 37R	16/11/2022	14:59	12°02.318' S	60°29.399' E	IO_031	2640	2000	24	18	Multinet	VOY-55-BOX5-3
24	sta 38R	16/11/2022	20:03	11°58.848' S	60°47.371' E	IO_032	1685	1500	22	16	Bongo	VOY-55-BOX5-4
25	sta 39R	16/11/2022	23:45	11°51.802'S	60°53.723	IO_033	765	755	23	14	Bongo	VOY-55-BOX5-5

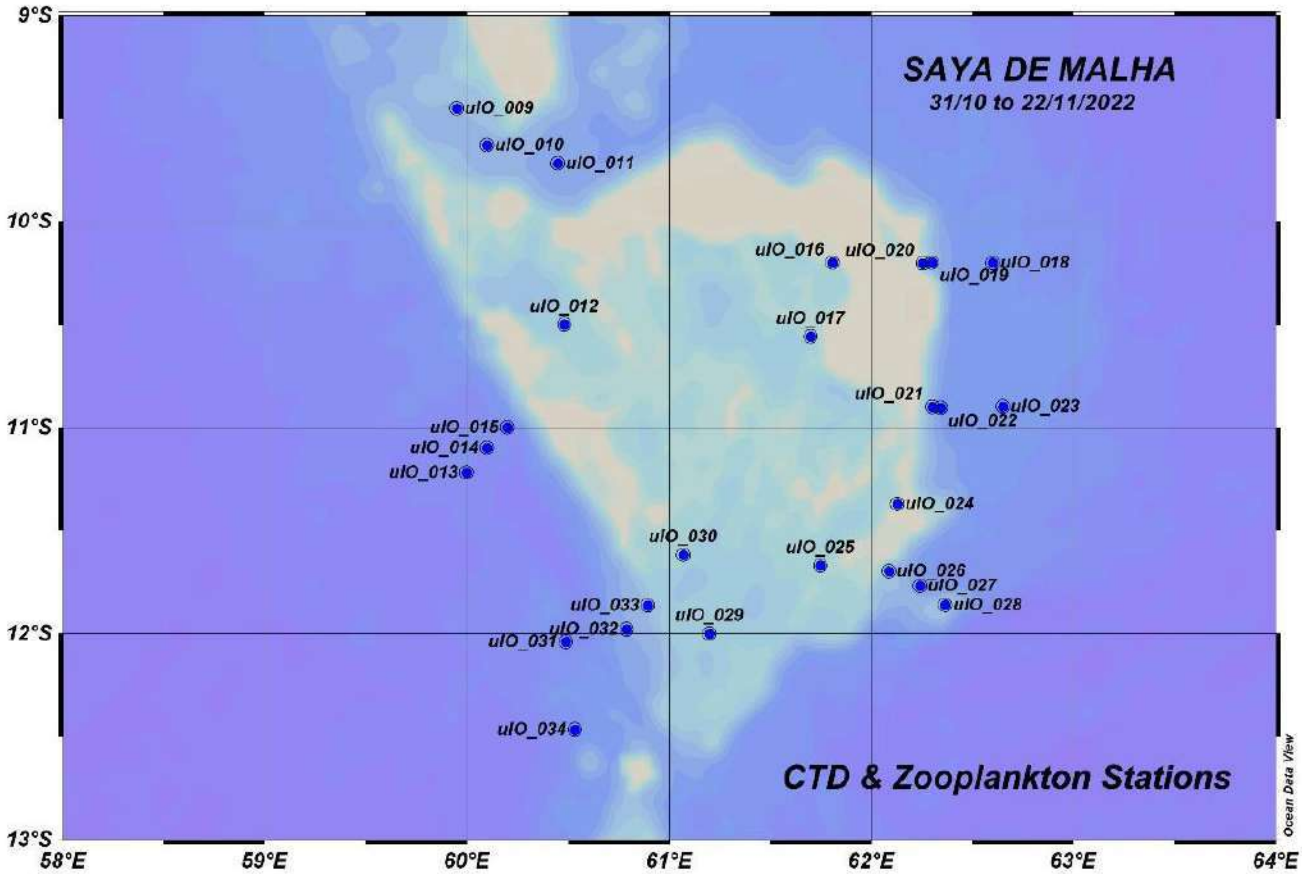


Figure 9. Map of the CTD stations done during the cruise labelled according to the CTD cast number

Table 3. Main characteristics of the CTD sensors operated during the cruise

Channel number	Sensor type	Sensor ID	Serial number	Calibration date
1	Temperature	TemperatureSensor SensorID="55"	5646	03/02/2021
2	Conductivity	ConductivitySensor SensorID="3"	4127	23/03/2021
3	Pressure	PressureSensor SensorID="45"	1096	05/03/2021
4	Oxygen	OxygenSensor SensorID="38"	1996	05/05/2016
5	OBS, WET Labs, ECO-BB	TurbidityMeter SensorID="70"	BBRTD-385	17/03/2021
6	Fluorometer, WET Labs ECO-AFL/FL	FluoroWetlabECO_AFL_FL_Sensor SensorID="20"	FLNTURTD-4362	11/11/2019
7	Transmissometer, WET Labs C-Star	WET_LabsCStar SensorID="71"	CST-1775DR	25/11/2019
8	Voltage 4	UVP5		
9	Voltage 5	free		
10	Altimeter	AltimeterSensor SensorID="0"	873	15/12/2018
11	Voltage 7	free		

CTD data analysis

The raw data provided by the CTD were analyzed using the Seasoft software SBEDataProcessing Win32 - Version 7.26.7.1. The process used is the standard one.

The oxygen sensor malfunctioned in the shallow part (~0-50 m) of almost each CTD profile (oxygen concentration much below the expected values). Therefore, the oxygen values are considered incorrect in this surface layer. The oxygen sensor also shifted between downward and upward profiles by almost 20 µmol kg^{-1} at station IO_019 (see Fig. 9). The sensor's malfunction is probably due to particles caught in the deepest part of the profile (close to the bottom). The oxygen profile looked correct at the following stations, despite smaller shifts observed at several stations. It was however decided not to replace the sensor to keep the benefice of the calibration by the Winkler titration on water samples done since the beginning of the cruise. Oxygen measurements have thus been more frequent to control *a posteriori* the validity of the O_2 CTD profiles (both upward and downward).

Rosette sampling

The CTD/Rosette system was deployed and operated by the crew and DFFE operators (South Africa).

Water samples were taken at depths depending on the shape of the fluorescence profile in the euphotic layer (surface; upper part of the DCM; DCM; lower part of the DCM, below the DCM). Some depth levels were systematically sampled (surface; 40m; 100m) for the plankton physiology study. In the deep layer, samples were taken at regular depths as far as possible (depending on the number of Niskin bottles available). Moreover, water samples were taken at different depths according to the shape of the profiles for oxygen and salinity measurements (for CTD calibration).

For CTD calibration purposes, salinity and DO samples were collected at depths chosen in order to cover the full range of values measured during the cruise and no gradient levels. Salinity measurements (101 samples) were done onboard using a Portasal salinometer, calibrated using OSIL

Normal Water standards. Oxygen titrations (using the Winkler method) were used to measure bottle oxygen values on board, within 24h of collection (147 samples). Discrete Fluorescence measurements were performed on board using a Turner Designs Trilogy Laboratory fluorometer (see phytoplankton section 5.3). Samples for nutrients analysis (324 samples) were collected at most of the sampled depths and pasteurized (2 hours minimum in an oven at 80°C) for storage and transport back to Brest. Measurements (nitrate, nitrite, phosphate and silicate) will be done by classical colorimetric method (IMAGO laboratory). Some depth levels have also been sampled, filtered and frozen to be analyzed in Mauritius (Prerna Roy & Preety Oogarah – MOI). Results obtained by the two methods will be compared.

5.2.1.2 ADCP current data

A hull mounted Acoustic Doppler Current Profiler (ADCP) from RD Instrument, measuring ocean current velocities and directions, was operated continuously along the transit of the survey. The frequency of the ADCP is 75 kHz with 8 m vertical resolution. This beam frequency only operates to a maximum depth of 800 m. However, for the purpose of this preliminary cruise report, only the surface currents at 30 m have been analysed.

The underway sampling of the ADCP was used to collect ocean current data in the region of the Mascarene Plateau. The ADCP data were pre-processed using the software, OSSI, developed at GEOMAR, Germany (Fisher et al., 2003) and adapted to the specifics of fishery surveys at IMR, Norway (Ostrowski, personal communication). The preliminary pre-processing involved removing erroneous data, bottom masking and correction of the misalignment between the ship and the ADCP beam axis. The misalignment and amplitude values were -0.5885 and 1.002813 respectively.

5.2.1.3 TSG data

Sea surface temperature and salinity were recorded all along the ship track using a SBE45 thermosalinograph (TSG). Sampling rate was set at 6 sec. The TSG data has not been processed so far. Salinity measured from a water samples collected at the upper Niskin bottle (surface samples at around 5 m depth) will be used to adjust the TSG salinity measurements.

5.2.1.4 XBT casts

Expandable BathyThermograph (XBT, T7 type) were launched to provide additional vertical temperature profiles in between some CTD stations: 16 around Saya de Malha, 3 on the way to St Brandon, 4 between St Brandon and Mauritius (Table 4). This was done during the “offshore” transects on both sides (East and West of the Saya de Malha bank) in order to highlight possible upwelling signatures. Along each of these transects, three XBTs were launched in order to have temperature profiles every ~5 NM. In addition, an XBT transect (7 XBT launched at ~6 NM intervals) has been achieved across the channel between Saya de Malha and Nazareth banks at the end of the Saya de Malha cruise when the ship left the study area toward Saint Brandon.

5.2.1.5 Drifters deployment

Two different types of surface drifters were deployed during the cruise:

- SVP (Surface Velocity Profiler): surface drifter drogued at 15m below sea surface. Four SVP provided by Météo France – La Réunion, as a contribution to the GDP (Global Drifter Programme of WMO (World Meteorological Organization), were deployed during Part 2: three on the western side of the Saya de Malha bank – to avoid interaction between the drifter’s drogue and the shallow bank topography, and one between Saint Brandon and Mauritius (Table 5). The last SVP drifter was deployed at the same time and location than one of the SSD drifter to test the behaviour of these two distinct lagrangian surface devices. The SVP drifters are equipped with air pressure (P) and sea surface temperature (SST) sensors as well. Data (lon, lat, P and SST) are transmitted by the drifter at 1h time rate. They can been accessed online in nearly real time (ERDDAP server at NOAA, USA).

Table 4. Time and position of XBT casts

Num XBT	Day	Time (UTC)	latitude	longitude	Max depth	FileName	Comment
1	09/11/2022	20:04	10°12.00' S	62°29.92' E	820 m	drop003.nc	radiale box 3 nord
2	09/11/2022	20:19	10°12.00' S	62°25.72' E	820 m	drop004.nc	radiale box 3 nord
3	09/11/2022	20:31	10°12.00' S	62°21.55' E	840 m	drop005.nc	radiale box 3 nord
4	11/11/2022	19:21	10°54.00' S	62°24' E	880 m	drop006.nc	radiale box 3 sud
5	11/11/2022	19:39	10°54.00' S	62°28.80' E	760 m	drop007.nc	radiale box 3 sud
6	11/11/2022	19:59	10°54.00' S	62°33.00' E	840 m	drop008.nc	radiale box 3 sud
7	16/11/2022	18:49	12°01.20' S	60°35.40' E	900 m	drop009.nc	radiale box 5
8	16/11/2022	19:16	12°00.00' S	60°41.40' E	805 m	drop010.nc	radiale box 5
9	16/11/2022	22:29	11°55.20' S	60°50.40' E	820 m	drop011.nc	radiale box 5
10	17/11/2022	22:32	12°31.85' S	60°38.35' E	880 m	drop012.nc	canal sud SDM
11	17/11/2022	22:49	12°33.84' S	60°42.87' E	920 m	drop013.nc	canal sud SDM
12	17/11/2022	23:08	12°35.78' S	60°48.35' E	380 m	drop014.nc	canal sud SDM
13	17/11/2022	23:40	12°39.02' S	60°55.50' E	420 m	drop015.nc	canal sud SDM
14	18/11/2022	00:06	12°42.15' S	61°02.17' E	920 m	drop016.nc	canal sud SDM
15	18/11/2022	00:35	12°45.31' S	61°09.01' E	880 m	drop017.nc	canal sud SDM
16	18/11/2022	01:06	12°48.52' S	61°16.25' E	780 m	drop018.nc	canal sud SDM
17	18/11/2022	20:35	16°29.83' S	60°43.46' E	900 m	drop019.nc	radiale Saint Brandon
18	18/11/2022	21:52	16°31.23' E	60°23.22' E	640 m	drop020.nc	radiale Saint Brandon
19	18/11/2022	21:52	16°31.24	60°12.15' E	220m	drop021.nc	radiale Saint Brandon
20	21/11/2022	11:08	17°08' S	59°11.42'E	260 m	drop022.nc	radiale St Brandon - Maurice
21	21/11/2022	12:34	17°14.86'S	59°08.98' E	290 m	drop023.nc	radiale St Brandon - Maurice
22	21/11/2022	15:17	17°35.31' S	58°56.08' E	900 m	drop024.nc	radiale St Brandon - Maurice
23	22/11/2022	00:10	19°01.00' S	58°02.50' E	850 m	drop025.nc	radiale St Brandon - Maurice

Table 5. Time and position of the deployments of SVP drifters

Num SVP	Day	Time (UTC)	latitude	longitude	serial num	location
1	02/11/2022	15:39	09°20.00' S	60°00.00' E	1601738	west channel north SDM
2	05/11/2022	20:54	11°13.19' S	60°00.87' E	1601739	st 9 - box 2
3	16/11/2022	14:29	12°01.78' S	60°30.13' E	1601741	st 37R - box 5
4	21/11/2022	18:00	18°15.00' S	58°15.00' E	1601740	St Brandon to Mauritius

- Sea Surface Drifters (SSD, see photo next page): SSDs were provided by the University of Western Australia (UWA) as part of the Sea Surface Drifters Drogue Project ME-IOE (N. D'Adamo and C. Pattiaratchi). SSDs are assembled at UWA. They are made of plastic pipes and contain a GPS device connected to a lithium battery pack to allow operation over up several months.

The deployment of ten SSD was planned during Part 2 (Table 6). Due to unexpected delay in GPS device (SPOT TRACE) availability, the SSDs used during Part 2 were not “ready to use”. Instead, new GPS units were provided during the call at Mahe. They have been set up once at sea. For the purpose of the experiment, the nominal frequency for data acquisition of the SPOT units was 1 hour. For four of the units, the frequency was set to 5 minutes (factory). It has not been possible to set up the frequency to 1 hour onboard, resulting in unexpectedly short lifetime of these four SSDs (see below).

The deployment of SSD during Part 2 was devised to complement 1) the set of drifters released during Part 1; and 2) the four SVP available for Part 2. In particular, SSDs were thought to highlight any shift of surface velocity induced by the shallow topography. Consequently, they were mostly deployed east of the bathymetric structures (the Saya de Malha bank and the Nazareth bank to the South). The last three of them were deployed between Saint Brandon and Mauritius, at the end of the cruise (one at the same location than the last SVP).

Table 6. Time and position of the deployments of SSD drifters

num SSD	day	time (UTC)	latitude	longitude	serial num	location
SSD 09	09/01/2022	15:50	10°12.00' S	62°36.00' E	ESN 0_4437211	st 17 - box 3
SSD 10	12/11/2022	00:20	10°54.21' E	62°38.66' E	ESN 0_4441194	st 20 - box 3
SSD 11	14/11/2022	14:45	11°53.43' S	62°19.62'E	ESN 0_4436324	st 29R - box 4
SSD 12	18/11/2022	01:22	12°48.4' S	61°22.5' E	ESN 0_4437210	East channel south SDM_1
SSD 13	18/11/2022	01:32	12°49.5' S	61°22.5' E	ESN 0_4440269	East channel south SDM_2
SSD 14	18/11/2022	01:42	12°50.5' S	61°24.6' E	ESN 0_4450210	East channel south SDM_3
SSD 15	18/11/2022	12:53	15°39.9' S	61°34.1' E	ESN 0_4447625	East Nazareth Bank
SSD 16	21/11/2022	18:00	18°15.00' S	58°30.00' E	ESN 0_4450211	St Brandon to Mauritius
SSD 17	21/11/2022	00:10	19°01.00' S	58°02.50' E	ESN 0_4450221	St Brandon to Mauritius
SSD 18	21/11/2022	04:21	19°47.48' S	57°33.76' E	ENS 0_4450215	St Brandon to Mauritius

5.2.2 Preliminary results

5.2.2.1 Characterization of water masses

Water masses were first characterised using the θ-S diagrams at each of the CTD stations (Fig. 10). These diagrams show a clear distinction between the stations depending on their location relative to the Saya de Malha bank, both for surface and sub-surface (left) and deep (right) water masses. Less salty waters are present east of the bank compared to the western side, which illustrates the westward transport of fresher Pacific Ocean waters by the South Equatorial Current. Water masses within channels north and south of Saya de Malha have still distinct characteristics (i.e. origin and mixing). The two easternmost stations (IO-023 and IO-025) also show distinct θ-S signature at sub-surface ($26.0 < \sigma < 26.5$). Nutrients concentration (not measured yet) will also be used to characterise the water masses distribution relative to the bank, especially on the slopes of the structure (expected upwelling signature).

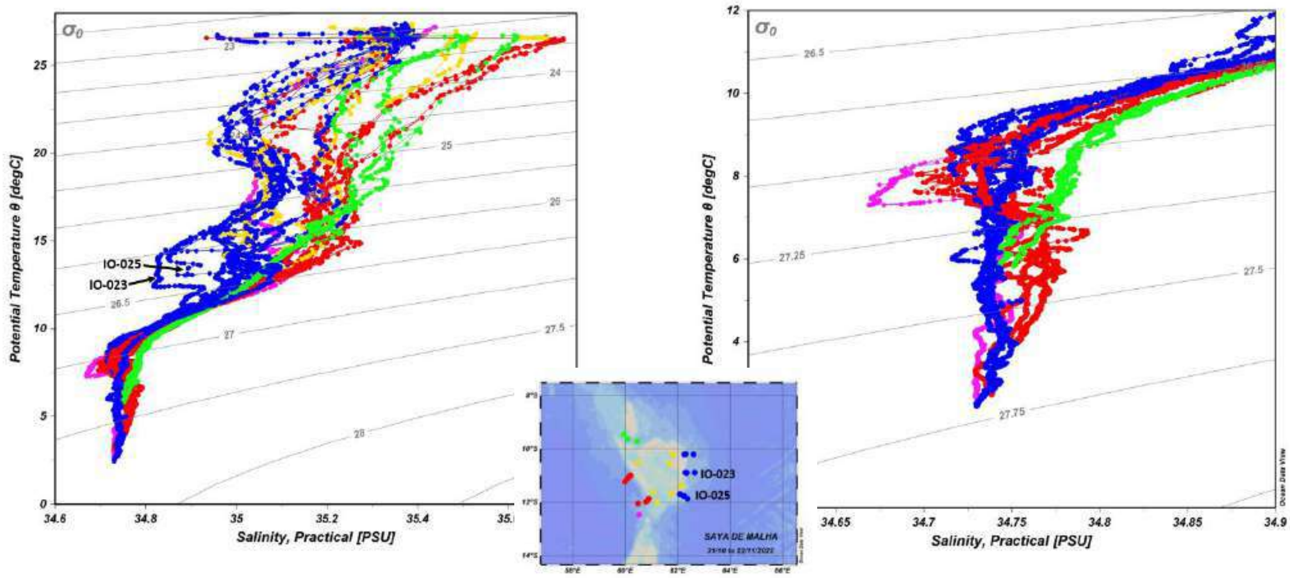


Figure 10. Left: θ-S diagram for all CTD stations during the Saya de Malha part. Colour code refers to the station location (blue: east of the bank; red: west of the bank; green: channel between Ritchie and Saya de Malha banks; yellow: on Saya de Malha bank; pink: east of the channel between Saya de Malha and Nazareth banks). Right: zoom on the deepest part of the CTD profiles.

5.2.2.2 ADCP current data

During the transit from Seychelles to Saya de Malha bank, the westward-flowing South Equatorial Counter Current could be observed at latitudes South of 7° S reaching velocities of about 40 cm s^{-1} at 30 m (Fig. 11). Along the 6°S transect, the current was northwards in the western part, turning to southwards in the eastern part, under the influence of a cyclonic eddy centered on 4°S. Further South, the SEC intensified on Ritchie Bank (8.6°S) reaching 60 cm s^{-1}.

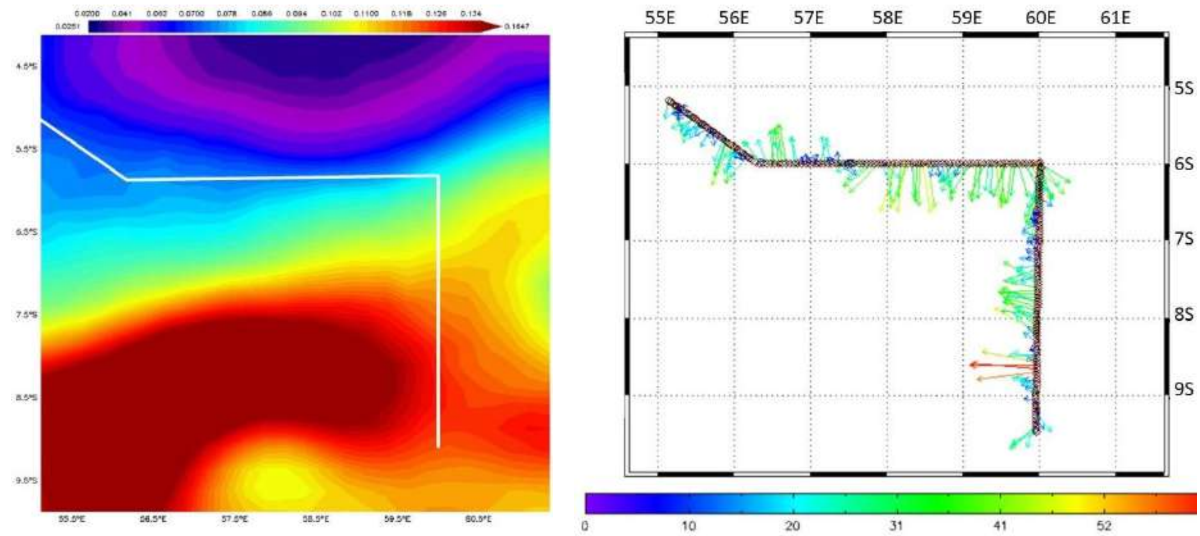


Figure 11. Left : Sea level anomalies (showing a cyclonic eddy in the north) with the ship track (white line) on the 1st November 2022. Right: Current velocity (in cm s^{-1}) and direction at 30 m measured by the ADCP during the transit from Seychelles to Saya de Malha bank (31 Oct to 2 Nov).

The SEC is also well established over the surveyed region of Saya de Malha (10° S to 12.5° S, 59° E to 62.5° E) at 30 m (Fig. 12). The current velocities varied between 0 to 30 cm s^{-1} over the bank and up to 63 cm s^{-1} along the slopes.

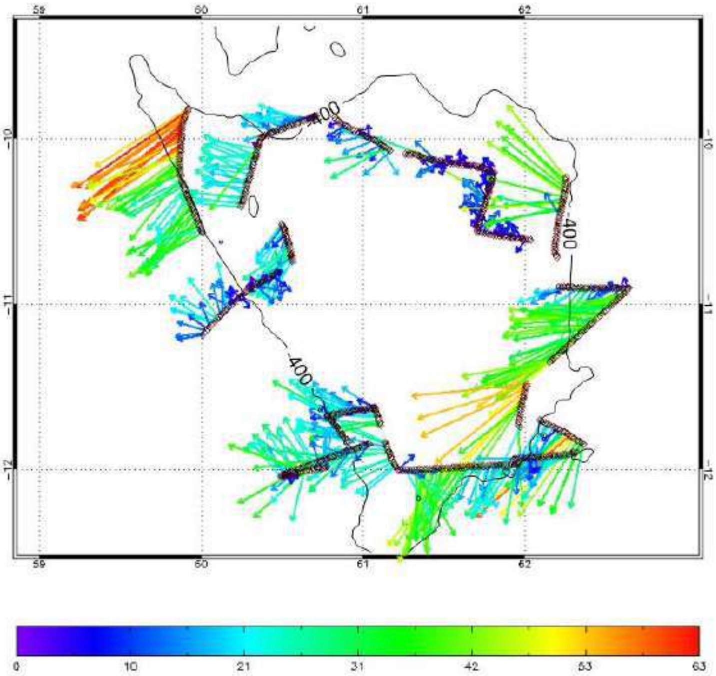


Figure 12. Current velocity (in cm s^{-1}) and direction at 30 m measured by ADCP over Saya de Malha (delimited by isobaths -400 m), from 2 to 17 November 2022

From Saya de Malha to the eastern slope of the Nazareth Bank (Fig. 13), the SEC was relatively strong with current velocities reaching 69 cm s^{-1} in the sill region separating Saya de Malha and Nazareth Bank, between latitudes 12° S – 13°S.

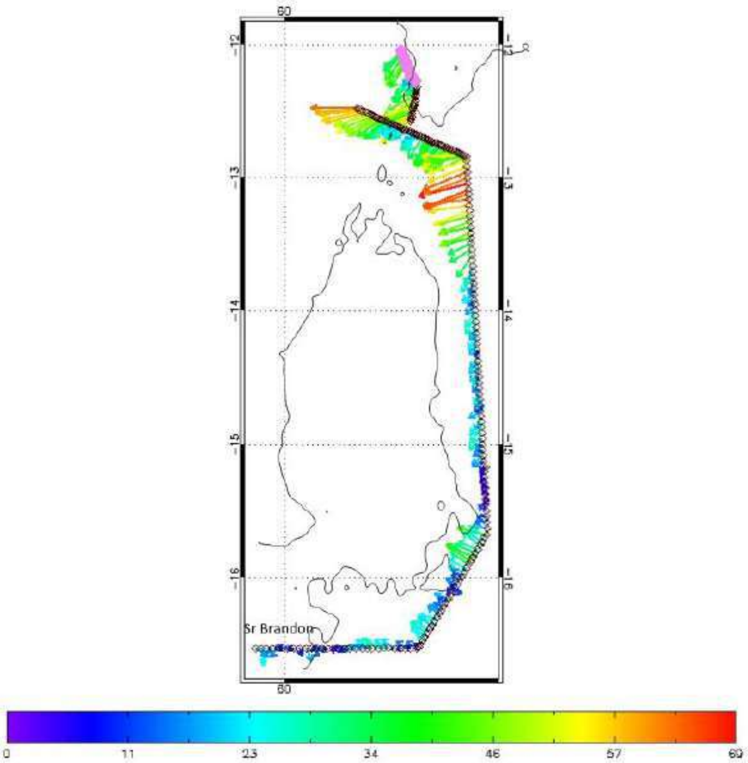


Figure 13. Current velocity (in cm s^{-1}) and direction at 30 m measured by ADCP along the eastern edge of the Nazareth plateau (delimited by isobaths -400 m), from Saya de Malha to St Brandon, on 18 and 19 November 2022.

Further processing needs to be carried out on the ADCP data including the removal of possible noise/interference caused by other acoustic equipment operating at the same time during the survey.

5.2.2.3 XBT casts

XBT were launched between CTD stations along the deep water transects perpendicular to the Saya de Malha bank in order to increase the spatial sampling resolution of the vertical temperature profiles. Only XBT temperature profiles are plotted in Figure 14. The same colour code is used for the two transects (blue for the XBT launched at the seaward position, red for the intermediate XBT and green for the XBT close to the bank slope). XBTs reached the depth of ~800m but only the first 400m of profiles are presented here for the sake of readability. The effect of the topography is not straightforward in both figures. The blue profiles (seaward) tend to show lowest temperature but more detailed analysis is needed to be able to conclude. Also, once available, the CTD temperature profiles along the same transects will add valuable information to determine the influence (or not) of the topography on the temperature vertical distribution. The figure highlights however significant differences in the temperature vertical distribution west and east of the bank, with a more pronounced stratification on the eastern flank of the bank. These differences need to be investigated in detail, in relation to the circulation along the slopes. Also, temperature is lower on the east than on the west (e.g. 20°C at 100m in box 3 (east) compared to 22°C to 26°C in box 5 (west) at the same depth).

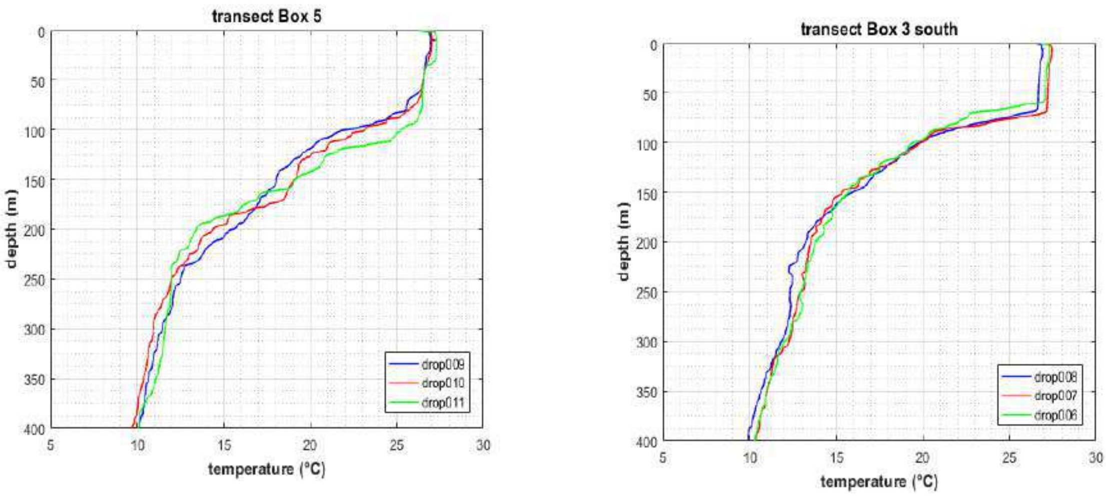
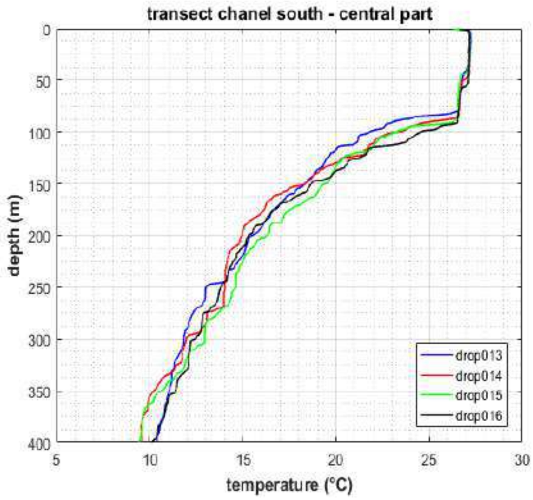


Figure 14. Left: Temperature profiles measured by 3 XTB launched on a transect perpendicular to the bank slope west of Saya de Malha (box 5): from the high sea (blue profile) to the bank slope (green profile). Right: same for 3 XBT on a transect east of Saya de Malha (box 3 south): from the high sea (blue profile) to the bank slope (green profile).

An XBT transect was performed along the channel between Saya de Malha and Nazareth banks. Seven XBTs, regularly spaced, were launched from the west (drop012) to the east (drop018) of the channel. Figure 15 presents XBTs launched in the central part of the channel, with a zoom on the 150m upper layer on the right panel. To be noted is the presence of a shallow seabed structure (~400m depth) in the centre of the channel (drop014 and drop015). This topographic structure seems to influence the temperature vertical distribution: the two corresponding profiles are very similar and they differ significantly for those west and east of the structure. In addition, the surface homogenous layer (from 0 to ~80m) splits at about 50m with probably the superposition of two different water masses. This vertical feature is observed all along the transect (7 XBTs) while it has not been identified on profiles both west and east of the Saya de Malha bank.



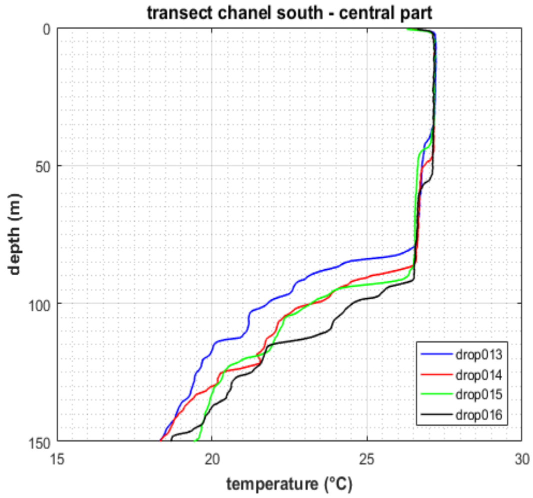


Figure 15. Left: Temperature profiles measured by 4 XBT launched on a transect crossing the channel between Saya de Malha and Nazareth banks, from west (drop013) to east. (drop016). Note that drop014 and drop 015 were above a relatively shallow topographic structure (about 400m depth). Right: same part of the transect with a zoom on the 0-150m upper layer.

5.2.2.4 Drifters deployment

Surface drifters (both SVP and SSD) trajectories are monitored thanks to the data transmitted hourly to satellites. An update (February 2023) of all drifter tracks is presented for both types of drifters (Fig.16). The last tracked SSD drifter stopped emitting on 9th February, while all 4 SVP drifters were still emitting on the 12th February. Both SVP and SSD trajectories agree with the large scale surface circulation of the south-west Indian Ocean:

1) westward transport within the South Equatorial Current, including retroflection to the east for a SVP and a SSD drifter in the northern part of the area, entering the South Equatorial Counter Current;
2) connection with the east African coast for the drifters flowing north of Madagascar;
3) transport by either the North and South East Madagascar Current for the drifters reaching the east coast of Madagascar;
4) eddy-driven circulation for one of the SSD having entered the northern Mozambique Channel; and
5) less straight circulation of the SVP deployed between Saint Brandon and Mauritius.

It is also interesting to point out that the 3 SSDs released almost simultaneously on the east on the channel between Saya de Malha and Nazareth banks followed almost exactly the same paths, showing no significant divergence in the current out of the channel. Smaller scale features related to meso- and submesoscale processes (see for instance the shape of the return trajectory of the northernmost SSD) are also revealed by the trajectories. All the trajectories will be compared to the surface circulation inferred from altimetry data. Comparison will also be done between SVP and SSD trajectories, wherever relevant.

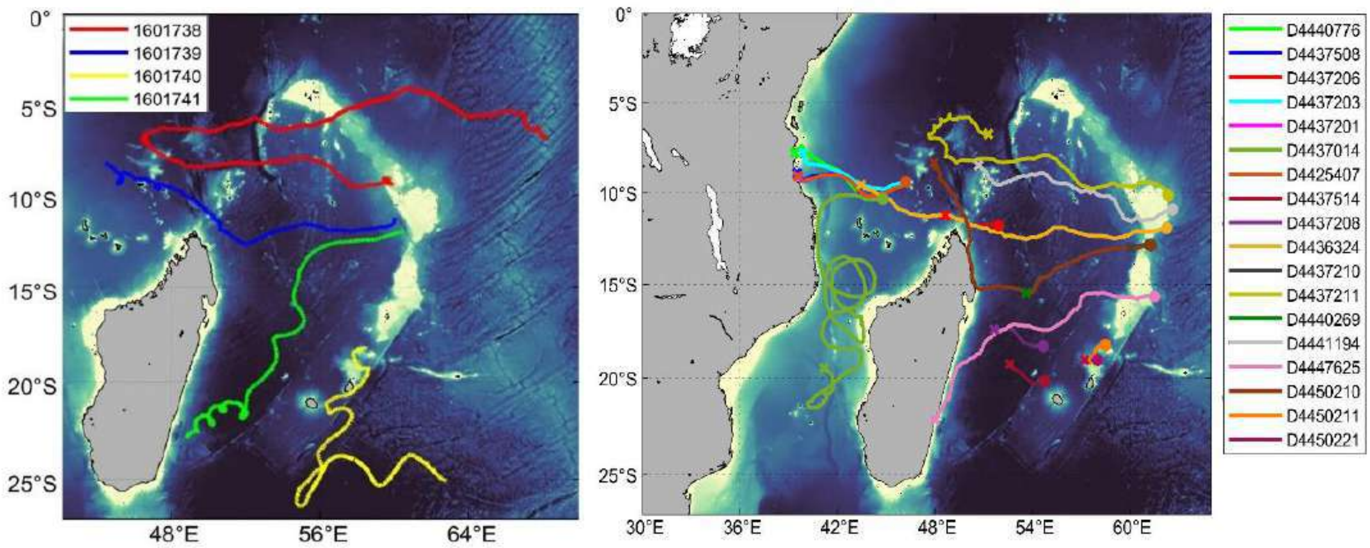


Figure 16. Left: Trajectories of the 4 SVP drifters deployed during the Saya de Malha part (as of 33 March 2023). Right: Trajectories of the 18 SSD drifters deployed during the whole Indian Ocean Expedition (final update: 09 February 2023). SSD drifters released east of the Mascarene Ridge were deployed during the Saya de Malha part.

5.3 Phytoplankton (WP3)

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Team: Estelle Barreau, Camilla Labonte, Rosabella Mangroo, Joshua Maria, Bianca Marzocchi

5.3.1 Methods

Phytoplankton biomass

Phytoplankton biomass was accessed based on the total chlorophyll-a content of water samples collected from the upper 200m of water column using 12L Niskin bottles attached to a 24-holder CTD rosette. Samples were taken based on the fluorescence maximum (Fmax) depth measured by the CTD fluorescence sensor, and generally included a surface (<5m), 40m, 60m, 80m, 100m, and 150m/200m depths. From all corresponding Niskin bottles 1L of water was collected and filtered through Fisherbrand MF300 (GF/C) glass fiber filters (25mm diameter, 0.7µm pore) under gentle vacuum. Filters were immediately placed in 6ml of 90% Acetone for chlorophyll-a extraction, and placed at +4°C for 24 hours, whereafter the fluorescence was read on a Turner-Designs Trilogy Laboratory fluorometer, calibrated prior for the non-acidification measurement of chlorophyll-a. For each batch, both the solid standard and a blank containing only 90% Acetone were measured prior to measuring of samples.

For size fractionated chlorophyll-a, 250 mL seawater was sequentially gravity filtered through a 20 µm, 2 µm and 0.2 µm 47 mm Nuclepore filters, and all filters placed in 6ml of 90% Acetone for extraction.

Total chlorophyll-a was calculated following the equation of Welschmeyer (1994);

Chl-a ($mg.m^{-3}$) = DF x R-reading x (FR_s – FR_b) x (Vol_a – Vol_s)

where:

DF = Dilution factor
R-reading = R-adjusted reading based on calibrated solid standard and batch solid standard reading
FR_s = Fluorometer reading of sample
FR_b = Fluorometer reading of blank
Vol_a = Volume of acetone used for extraction (ml)
Vol_s = Volume of sample filtered (ml)

The total Chl-a concentration will be used to assess the calibration of the fluorescence sensor of the CTD while the size fractionated Chl-a is an index of the proportion of micro-, nano- and picoplankton

Phytoplankton species composition

Based on *in situ* fluorescence data and depth of Fmax obtained by CTD, 5 samples of 1L of water were collected from corresponding Niskin bottle at surface, 40m, 60m, 80m and 100m depth. Samples were immediately concentrated by filtering each 1L through a 5µm screen and transferring the concentrated sample to 50ml sterile centrifuge vials. Samples were preserved with 1% glutaraldehyde and sealed for transportation back to Seychelles.

At the University of Seychelles laboratory, the samples will be stained with Rose Bengal, settled for 24 hours, and transferred to Sedgewick Rafter counting chambers and phytoplankton cells counted using a Zeiss Prima Star light microscope at 400x and 1000x magnification. A minimum of 200 cells will be counted per sample.

Taxa will be identified to species level when possible, using the nomenclature of Taylor et al. (2007), Metzeltin and Lange-Bertalot (2003), Lange-Bertalot (2001), Tomas et al. (1997), Krammer and Lange-

Berlato (1991), Archibald (1983) and Husted (1976); and potential risk assessed using literature and information from the Harmful Algal Event Database (HAEDAT), Ocean Biodiversity Observation System (OBIS), and the IOC-UNESCO Taxonomic Reference List of Harmful Microalgae (http://marinespecies.org/hab).

Statistical Analyses

Pairwise student t-tests and Pearson Product Moment Correlation analyses were performed on the chlorophyll-a data to determine; 1) significant differences with depth, 2) significant differences between day and night samples, 3) site positional differences in biomass and dominant size fractions, and 4) to determine whether any correlations are present between total chlorophyll-a and dominant size fractions. Furthermore, one-way ANOVAs will be performed on the CTD data together with phytoplankton biomass and species composition data to determine relationships between relative abundance and physico-chemical drivers (i.e., salinity, temperature, dissolved oxygen, pH, density, nutrients) for the phytoplankton community of the Saya de Malha Bank.

5.3.2 Preliminary results

Phytoplankton Biomass

Average total chlorophyll-a concentrations ranged from 0.02 ± 0.004 $mg.m^{-3}$ in deeper waters to 0.51 ± 0.04 $mg.m^{-3}$ at the maximum fluorescence level of 60–80m. Student t-tests further indicate a significant increase in total chlorophyll-a concentrations in the upper waters towards depths of 60 to 80m, where after a significant decrease was found towards 200m (Fig. 17). No significant differences were obtained for total chlorophyll-a samples collected at night or during day ($p>0.05$). However, significant differences were observed between the sampling sites (i.e., box positions) with Box 1 having significantly lower total chlorophyll-a biomass than Boxes 2, 3 and 5 (0.21 $mg.m^{-3}$ vs. 0.33, 0.36 and 0.34 $mg.m^{-3}$, respectively, $p<0.05$). Habitat area types within each of the boxes (i.e. Shallow, Ridge & Deep habitats showed only significantly higher total chlorophyll in the shallow areas of Boxes 2 and 3 (~0.55 mg $Chl\text{-}a.m^{-3}$, $p<0.01$), whereas for Boxes 4 and 5 remained low at 0.27 $mg.m^{-3}$ and 0.3 $mg.m^{-3}$, respectively. These figures were also comparable with the Ridge and Deep phytoplankton biomass within all the boxes (Table 7).

*Table 7. Average total chlorophyll-a ($mg.m^{-3}$) and phytoplankton size distribution (relative abundance, %) for the various sampling sites and habitat areas along the Saya de Malha Bank (mean ± Standard Deviation, **BOLD** = $p<0.05$).*

Area	Depth	Total Chl-a ($mg.m^{-3}$)	<0.2 µm %	2 µm %	>20 µm %	n
Box 1	Channel	0.21 ± 0.15	47 ± 18	36 ± 12	17 ± 11	18
Box 2	Deep	0.29 ± 0.14	64 ± 15	29 ± 13	7 ± 5	12
	Ridge	0.30 ± 0.13	65 ± 11	26 ± 13	9 ± 11	6
	Shallow	**0.55 ± 0.12**	61 ± 16	**35 ± 15**	**4 ± 2**	3
Box 3	Deep	0.30 ± 0.19	43 ± 17	38 ± 12	19 ± 11	24
	Ridge	0.34 ± 0.19	41 ± 24	30 ± 16	29 ± 14	12
	Shallow	**0.54 ± 0.16**	50 ± 16	**42 ± 18**	**9 ± 9**	10
Box 4	Deep	0.26 ± 0.15	59 ± 16	27 ± 17	14 ± 8	12
	Ridge	0.29 ± 0.17	52 ± 11	39 ± 7	9 ± 7	6
	Shallow	0.27 ± 0.16	54 ± 20	31 ± 17	15 ± 12	12
Box 5	Deep	0.37 ± 0.2	47 ± 16	29 ± 10	24 ± 17	5
	Ridge	0.41 ± 0.25	52 ± 20	24 ± 15	23 ± 18	5
	Shallow	0.30 ± 0.19	45 ± 20	**31 ± 16**	24 ± 23	15

Considering spatial distribution along a latitudinal and longitudinal axis across the Saya de Malha Bank, Box 1, 2 & 3 represented the Northern sites, Boxes 3 & 4 the Eastern sites, Boxes 4 & 5 the Southern sites and Boxes 2 and 5 the Western Sites. Student t-tests between North vs South, and East vs West indicate no significant differences in total chlorophyll-a between the areas (Table 8).

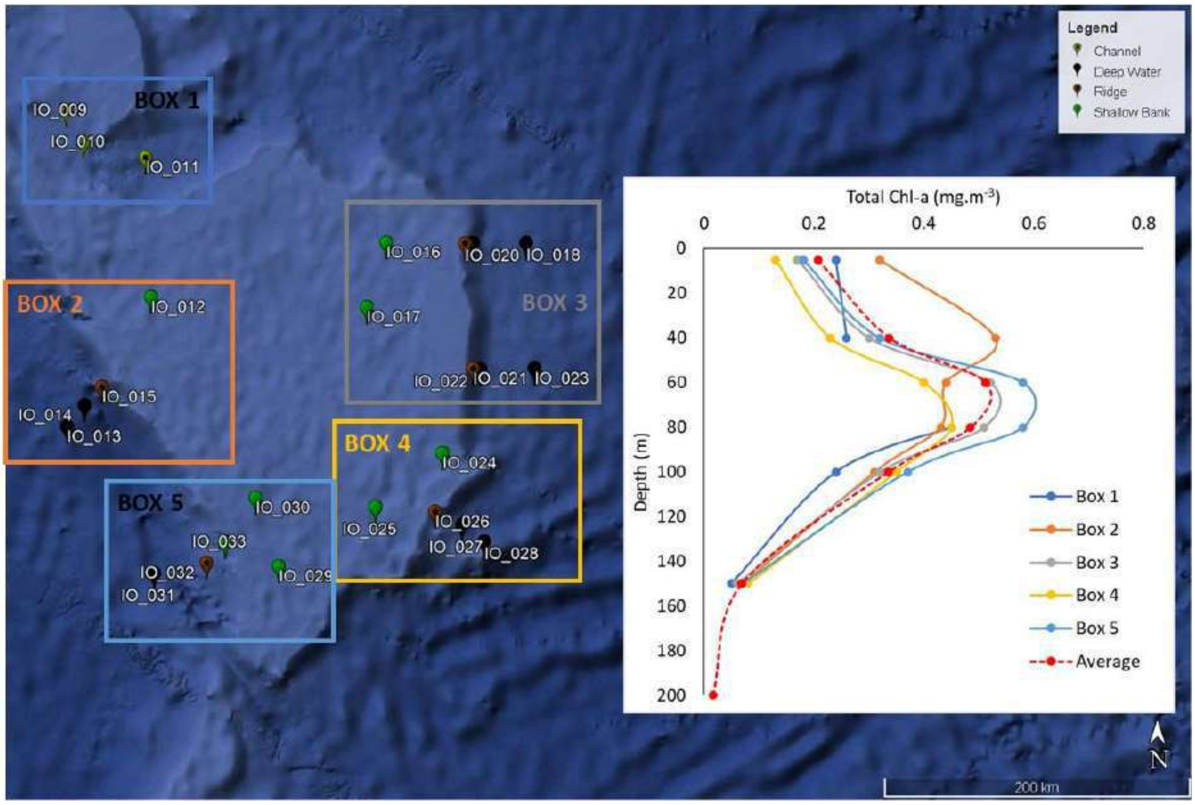


Figure 17. Box and habitat area map indicating positions of CTD sampling sites, and total chlorophyll-a (mg.m^{-3}) for the five sampling boxes along the Saya de Malha Bank as well as the overall average for the region.

Table 8. Average phytoplankton biomass (mg Chla.m^{-3}) and size distribution (% relative abundance) along a spatial scale of the Saya de Malha Bank (mean ± standard deviation).

Area	Box	Total Chla- (mg.m^{-3})	<0.2 µm %	2 µm %	>20 µm %	n
North	1,2 & 3	0.32 ± 0.2	49 ± 19	35 ± 14	16 ± 13	85
South	4 & 5	0.31 ± 0.2	52 ± 18	30 ± 15	18 ± 16	60
East	3 & 4	0.33 ± 0.19	49 ± 19	34 ± 15	17 ± 12	76
West	2 & 5	0.33 ± 0.19	54 ± 18	29 ± 13	16 ± 18	51

Size-fractionated chlorophyll-a biomass was dominated by picoplankton (0.2 to 2 µm), followed by nanoplankton (2 to 20 µm) and micro-plankton (<20µm) (Table 9). Picoplankton had highest relative abundance at the surface (~60%) and decreased towards deeper waters (~23%), whereas micro-plankton increased slightly in deeper waters (~36%) as compared to surface and mid-waters (~13 – 19%, respectively). Nanoplankton remained almost uniformed throughout the water column ranging from 27 – 41% (Table 9). Comparisons between the size distributions within the various sampling boxes further indicate significant changes in size fractions (Table 7). Although picoplankton dominated all communities, in Boxes 3 and 5, relative abundance was below 50%, compared to the other boxes which remained above 50%. Micro-plankton were also significantly lower in Box 2 (4-9 %), while significantly higher in Box 5 (~23%, $p<0.05$). Between East and West, however, there were significant differences observed across all the phytoplankton size ranges ($p < 0.05$), although both areas were dominated by pico- and nano-plankton. The Eastern Bank did show slightly more larger sized phytoplankton present, while the Western Bank mainly had pico-plankton present (~54% relative abundance, $p<0.001$). Between North and South, only the larger microplankton (>20 µm) showed significant differences in relative abundance, with higher abundance in the Southern than Northern regions (~ 18% vs ~16%, respectively, $p = 0.01$).

Table 9. Overall size distribution of phytoplankton (% relative abundance) along depth profile for the Saya de Malha Bank (n = 140).

	Relative Abundance			$mg.m^{-3}$
	0.2µm	**2µm**	**20µm**	**Total Chl-a**
Surface	60%	27%	13%	0.15
40m	57%	33%	10%	0.21
60m	41%	41%	18%	0.32
80m	52%	29%	19%	0.31
100m	53%	29%	18%	0.17
150m	38%	38%	24%	0.052
200m	23%	41%	36%	0.022
Average	**46%**	**34%**	**20%**	

Overall the phytoplankton communities along the Saya de Malha Bank appear well-mixed with no apparently significant correlation between sizes (i.e., functional groups) and total chlorophyll-a measured (Figure 18). Some spatial differences however, can be observed with higher total chlorophyll-a measured mainly in shallower/shelf areas (i.e. IO_016). Furthermore, some spatial differences in the relative abundance of pico-, nano- and micro-plankton could be observed, especially between shallow and deeper areas of the bank (Figure 19). These changes together with differences in chlorophyll-a biomass will be investigated in relation to nutrient data as well as physical ocean data via multivariate and ordination analyses to determine important drivers for primary productivity of the Bank, and especially the East vs West spatial patterns observed at the time of the cruise, and often via satellite remote sensing (i.e., Figure 20).

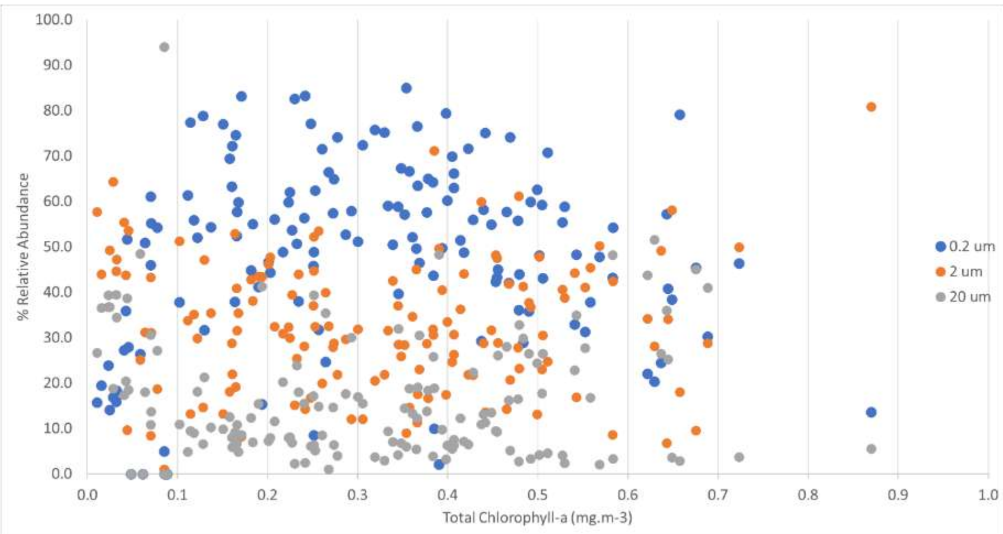


Figure 18. Overall comparison between total chlorophyll-a (mg.m-3) and phytoplankton size distribution (% relative abundance) for all sites and depths.

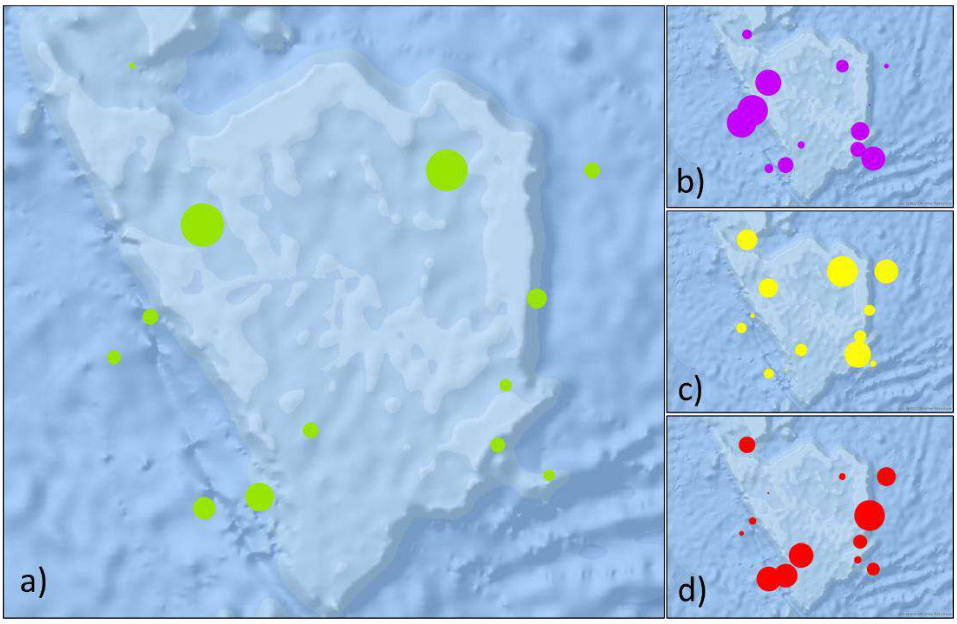


Figure 19. a) Overall mean total chlorophyll-a (mg.m-3) and relative abundance distribution of b) pico-, c) nano- and d) micro-plankton along the habitat areas of the Saya de Malha Bank.

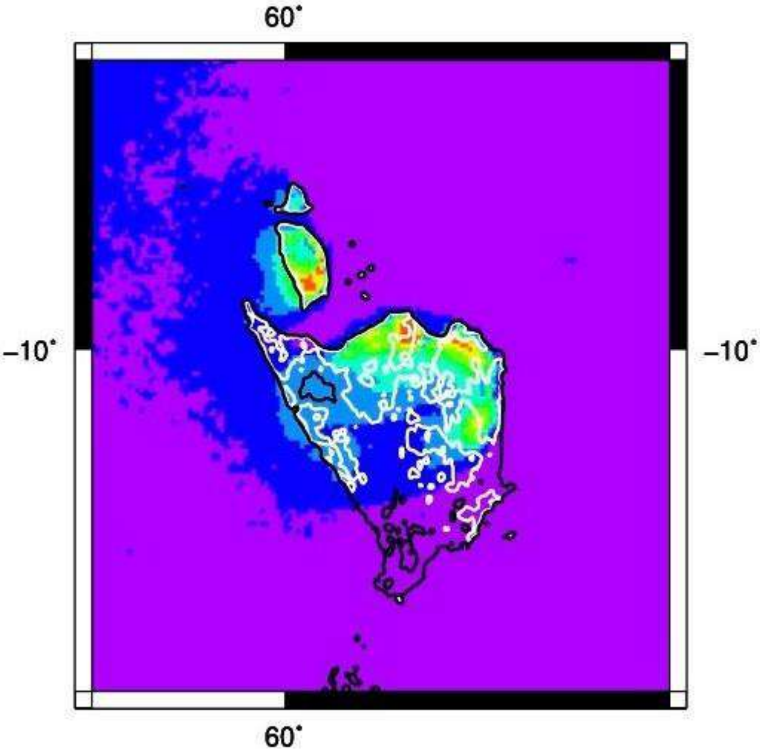
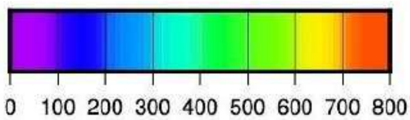


Figure 20. Frequency of pixels (color scale) with Chlorophyll-a concentration above 0.2 mg m^{-3} to highlight sectors of recurrent primary productivity (source: Dr Fabrizio d'Ortenzio, CNRS, LOV). Phytoplankton enrichment tends to occur more frequently along the western edge of the Richie and Saya de Malha Bank, compared to the eastern side that is oligotrophic



5.4 Marine particles and zooplankton (WP4)

Coordinators : Margaux Noyon & Frédéric Ménard
Team: Rodney Bonne, Patsy Theresine, Annie Vidot

This work is conducted in collaboration with the COMPLEX team from the Laboratory of Villefranche-sur-Mer and is in continuity to the first part of the EDM cruise (Reunion to Seychelles).

5.4.1 Methods

The investigation of marine particles and mesozooplankton was assessed using three different types of gear: 1) the Underwater Vision Profiler 5 (UVP5) and traditional plankton nets; 2) a Multinet and 3) a Bongo net.

- The CTD rosette was equipped with a UVP5 and data were collected over the whole water column at each CTD stations on the downcast (Table 12).
- The Multinet (9 nets of 300 µm mesh size, 0.5 m^2 opening area - model Maxi, Hydrobios) was deployed at the most 'offshore', or deepest, station of each transect around Saya de Malha, vertically from 900 m to the surface at approx. 0.5m s^{-1}. The Multinet was deployed 'offline' and the pre-programmed sampling depth were (in meters): 900 – 700 – 500 – 350 – 250 – 200 – 150 – 100 – 50 – surface.
- At all the other pelagic stations, a Bongo net (200 µm mesh size, 0.25 m^2 opening area) was towed obliquely from 200m, or to 10 m above the seabed at the stations shallower than 200m, to the surface. The net was equipped with a pressure sensor to accurately determine the sampling depth. It was lowered vertically in the water column to the required depth and towed obliquely up with the ship cruising at 1 to 1.5 knot.
- Note that the depth sensor had many 'bad data' or 'noisy' data coming through, especially when more tension was put on the cable. To avoid any issues (e.g. pressure sensor software shutting down entirely), we chose to lower the net vertically and only then move forward while hauling the net in.

Both nets were equipped with flowmeters to determine the volume of seawater filtered (quantitative samples) and the plankton net samples were preserved in borax buffered formaldehyde (4% final concentration). For the Bongo net samples, the net (without the flowmeter) was used for live observations on board. See Table 11 for the details of each nets and volume filtered.

5.4.2 Preliminary results

No results has been produced so far. The samples will be analysed at the LOV, France, using a Zooscan to identify the different taxa and to calculate the biovolume and the size spectrum of organisms. We plan to send a Seychellois scientist to be trained to the Zooscan methodology at LOV (contact Dr Fabien Lombard) and to perform the analyses.

Table 10. List of UVP casts

Profile_id	Bottom depth	CTD filename	Latitude	Longitude	Station (or Grid #)	Part
io_station_001	4873	io_001	-19.301	54.59949	io_station_001	1
io_station_002	4227	io_002	-12.4007	53.29867	io_station_002	1
io_station_003	3600	io_003	-10.45	50.00181	io_station_003	1
io_station_004	3633	io_004	-10.184	44.47782	io_station_004	1
io_station_005	4062	io_005	-9.25536	45.54962	io_station_005	1
io_station_006	4629	io_006	-7.59926	48.29898	io_station_006	1
io_station_007	4200	io_007	-5.3014	52.0005	io_station_007	1
io_station_008	3360	io_008	-5.59439	60.0115	io_station_008	1
io_station_009	726	io_009	-9.27063	59.56914	voy_055_B1_1	2
io_station_010	970	io_010	-9.37803	60.05948	voy_055_B1_2	2
io_station_011	1614	io_011	-9.43191	60.26956	voy_055_B1_3	2
io_station_012	62	io_012	-10.3	60.28786	voy_055_B2_1	2
io_station_013	2855	io_013	-11.1312	59.59896	voy_055_B2_2	2
io_station_014	2740	io_014	-11.0601	60.05962	voy_055_B2_3	2
io_station_015	1598	io_015	-10.5997	60.11944	voy_055_B2_4	2
io_station_016	71	io_016	-10.1198	61.48576	voy_055_B3_1	2
io_station_017	70	io_017	-10.3353	61.41999	voy_055_B3_2	2
io_station_018	2196	io_018	-10.1206	62.36025	voy_055_B3_3	2
io_station_019	1545	io_019	-10.1196	62.17968	voy_055_B3_4	2
io_station_020	930	io_020	-10.1224	62.15278	voy_055_B3_5	2
io_station_021	897	io_021	-10.5403	62.18056	voy_055_B3_6	2
io_station_022	1830	io_022	-10.5429	62.20527	voy_055_B3_7	2
io_station_023	2252	io_023	-10.5397	62.38944	voy_055_B3_8	2
io_station_024	225	io_024	-11.2225	62.07709	voy_055_B4_1	2
io_station_025	227	io_025	-11.402	61.45	voy_055_B4_2	2
io_station_026	870	io_026	-11.4183	62.05229	voy_055_B4_3	2
io_station_027	2274	io_027	-11.4621	62.14387	voy_055_B4_4	2
io_station_028	667	io_028	-11.517	62.21988	voy_055_B4_5	2
io_station_029	289	io_029	-12.0003	61.11988	voy_055_Box5_1	2
io_station_030	209	io_030	-11.3711	61.04163	voy_055_Box5_2	2
io_station_031	2497	io_031	-12.024	60.29399	voy_055_Box5_3	2
io_station_032	1740	io_032	-11.5885	60.47371	voy_055_Box5_4	2
io_station_033	760	io_033	-11.5161	60.53318	voy_055_Box5_5	2

Table 11: List of mesozooplankton nets

Sample_name	latitude (Deg Min)	longitude (Deg Min)	Date	Time (UTC)	Local time	Day/ Night	bottom depth (m)	Station_ID	CTD filename	Grid #	Net type & number	Depth max	Depth min	Volume Filtered (m3)	barcode
EDM_station_009	09°27.036 S	59°59.914' E	02/11/2022	18:06	22:06	N	726	EDM_station_009	io_009	voy_055_B1_1	Bongo	180	0	96	EDM000000218
EDM_station_010	09°37.803' S	60°05.948' E	02/11/2022	21:23	01:23	N	970	EDM_station_010	io_010	voy_055_B1_2	Bongo	200	0	177	EDM000000222
EDM_station_011	09°43.191' S	60°26.956' E	03/11/2022	0:20	04:20	N	1614	EDM_station_011	io_011	voy_055_B1_3	Bongo	200	0	139	EDM000000213
EDM_station_012	10°30.00' S	60°28.786' E	05/11/2022	0:20	04:20	D	62	EDM_station_012	io_012	voy_055_B2_1	Bongo	50	0	61	EDM000000214
EDM_station_013_9	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_9	899.4	699.3	137	EDM000000205
EDM_station_013_8	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_8	699.2	497.2	148	EDM000000207
EDM_station_013_7	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_7	497.2	349.1	87	EDM000000208
EDM_station_013_6	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_6	348.9	247.7	60	EDM000000209
EDM_station_013_5	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_5	247.3	200	29	EDM000000210
EDM_station_013_4	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_4	199.4	149.4	33	EDM000000211
EDM_station_013_3	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_3	149	97.3	33	EDM000000217
EDM_station_013_2	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_2	97.2	49.9	27	EDM000000215
EDM_station_013_1	11°13.119' S	59°59.896' E	05/11/2022	21:30	01:30	N	2855	EDM_station_013	io_013	voy_055_B2_2	Multinet_1	50.1	0.4	47	EDM000000221
EDM_station_014	11°06.007' S	60°05.962' E	05/11/2022	23:30	03:30	N	2740	EDM_station_014	io_014	voy_055_B2_3	Bongo	200	0	111	EDM000000206
EDM_station_015	10°59.967' S	60°11.944' E	06/11/2022	0:52	04:52	dawn	1598	EDM_station_015	io_015	voy_055_B2_4	Bongo	200	0	135	EDM000000204
EDM_station_016	10°11.979' S	61°48.576' E	08/11/2022	17:58	22:58	N	71	EDM_station_016	io_016	voy_055_B3_1	Bongo	200	0	18	EDM000000203
EDM_station_017	10°33.532' S	61°41.999' E	08/11/2022	20:36	01:36	N	70	EDM_station_017	io_017	voy_055_B3_2	Bongo	200	0	2	EDM000000201
EDM_station_018_9	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_9	898.7	697.7	139	EDM000000190
EDM_station_018_8	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_8	697.4	495.9	136	EDM000000191
EDM_station_018_7	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_7	496.3	348.4	111	EDM000000195
EDM_station_018_6	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_6	347.9	248.2	66	EDM000000196
EDM_station_018_5	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_5	248.2	97.7	29	EDM000000198
EDM_station_018_4	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_4	197.8	147	31	EDM000000179
EDM_station_018_3	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_3	146.8	97	28	EDM000000199
EDM_station_018_2	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_2	96.2	48.4	38	EDM000000197
EDM_station_018_1	10°12.061' S	62°36.025' E	09/11/2022	18:10	23:10	N	2196	EDM_station_018	io_018	voy_055_B3_3	Multinet_1	48	0.6	36	EDM000000200
EDM_station_019	10°11.964' S	62°17.968' E	09/11/2022	22:33	03:33	N	1545	EDM_station_019	io_019	voy_055_B3_4	Bongo	200	0	171	EDM000000189
EDM_station_020	10°12.243' S	62°15.278' E	09/11/2022	23:20	04:20	N	930	EDM_station_020	io_020	voy_055_B3_5	Bongo	200	0	267	EDM000000188
EDM_station_021	10°54.028' S	62°18.056' E	11/11/2022	3:58	08:58	N	897	EDM_station_021	io_021	voy_055_B3_6	Bongo	200	0	123	EDM000000187

Sample_name	latitude (Deg Min)	longitude (Deg Min)	Date	Time (UTC)	Local time	Day/ Night	bottom depth (m)	Station_ID	CTD filename	Grid #	Net type & number	Depth max	Depth min	Volume Filtered (m3)	barcode
EDM_station_022	10°54.290' S	62°20.527' E	11/11/2022	16:52	21:52	N	1830	EDM_station_022	io_022	voy_055_B3_7	Bongo	200	0	136	EDM000000192
EDM_station_023_9	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_9	898.7	697.7	139	EDM000000160
EDM_station_023_8	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_8	697.4	495.9	136	EDM000000163
EDM_station_023_7	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_7	496.3	348.4	111	EDM000000164
EDM_station_023_6	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_6	347.9	248.2	66	EDM000000168
EDM_station_023_5	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_5	248.5	197.7	29	EDM000000171
EDM_station_023_4	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_4	197.8	147	31	EDM000000172
EDM_station_023_3	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_3	146.8	97	28	EDM000000175
EDM_station_023_2	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_2	96.2	48.4	38	EDM000000182
EDM_station_023_1	10°53.965' S	62°38.944' E	11/11/2022	22:52	03:52	N	2252	EDM_station_023	io_023	voy_055_B3_8	Multinet_1	48	0.6	36	EDM000000193
EDM_station_024	11°22.248' S	62°07.707' E	12/11/2022	4:19	09:19	D	225	EDM_station_024	io_024	voy_055_B4_1	Bongo	200	0	148	EDM000000156
EDM_station_025	11°40.241' S	61°44.957' E	13/11/2022	7:25	12:25	D	227	EDM_station_025	io_025	voy_055_B4_2	Bongo	200	0	205	EDM000000153
EDM_station_026	11°41.826' S	62°05.229' E	13/11/2022	16:49	21:49	N	870	EDM_station_026	io_026	voy_055_B4_3	Bongo	200	0	118	EDM000000155
EDM_station_027_9	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_9	898.3	697.3	119	EDM000000159
EDM_station_027_8	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_8	697	498.1	124	EDM000000165
EDM_station_027_7	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_7	497.2	348.4	91	EDM000000166
EDM_station_027_6	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_6	347.8	248.8	60	EDM000000167
EDM_station_027_5	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_5	248.6	198.2	30	EDM000000161
EDM_station_027_4	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_4	198.2	148.4	29	EDM000000162
EDM_station_027_3	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_3	147.8	98.5	29	EDM000000144
EDM_station_027_2	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_2	97.9	48.7	35	EDM000000158
EDM_station_027_1	11°46.213' S	62°14.387' E	13/11/2022	21:20	02:20	N	2274	EDM_station_027	io_027	voy_055_B4_4	Multinet_1	48.4	0	37	EDM000000152
EDM_station_028	11°51.700' S	62°21.988' E	14/11/2022	23:30	04:30	N	667	EDM_station_028	io_028	voy_055_B4_5	Bongo	200	0	108	EDM000000157
EDM_station_029	12°00.027' S	61°11.988' E	14/11/2022	23:00	04:00	N	289	EDM_station_029	io_029	voy_055_Box5_1	Bongo	200	0	137	EDM000000154
EDM_station_030	11°37.114' S	61°04.163' E	15/11/2022	12:53	17:53	D	209	EDM_station_030	io_030	voy_055_Box5_2	Bongo	200	0	126	EDM000000139
EDM_station_031_9	12°02.318' S	60°29.399' E	16/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_9	898.8	696.9	134	EDM000000127
EDM_station_031_8	12°02.318' S	60°29.399' E	17/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_8	696.9	499.5	127	EDM000000180
EDM_station_031_7	12°02.318' S	60°29.399' E	18/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_7	499	350.5	100	EDM000000151
EDM_station_031_6	12°02.318' S	60°29.399' E	19/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_6	350.2	247.7	63	EDM000000150
EDM_station_031_5	12°02.318' S	60°29.399' E	20/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_5	247.4	198.3	28	EDM000000129

Sample_name	latitude (Deg Min)	longitude (Deg Min)	Date	Time (UTC)	Local time	Day/ Night	bottom depth (m)	Station_ID	CTD filename	Grid #	Net type & number	Depth max	Depth min	Volume Filtered (m3)	barcode
EDM_station_031_4	12°02.318' S	60°29.399' E	21/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_4	197.8	145.9	33	EDM000000130
EDM_station_031_3	12°02.318' S	60°29.399' E	22/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_3	146.2	98.4	32	EDM000000132
EDM_station_031_2	12°02.318' S	60°29.399' E	23/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_2	98.1	48.3	32	EDM000000137
EDM_station_031_1	12°02.318' S	60°29.399' E	24/11/2022	17:00	22:00	N	2497	EDM_station_031	io_031	voy_055_Box5_3	Multinet_1	48.3	0.4	35	EDM000000138
EDM_station_032	11°58.848' S	60°47.371' E	16/11/2022	20:35	01:35	N	1740	EDM_station_032	io_032	voy_055_Box5_4	Bongo	200	0	164	EDM000000126
EDM_station_033	11°51.802'S	60°53.723	16/11/2022	23:00	04:00	N	760	EDM_station_033	io_033	voy_055_Box5_5	Bongo	200	0	159	EDM000000125

(1) Net was tangled, sample was rich. If analysed, volume filtered will have to be estimated from other nets. Same length of wire out and similar angle.

5.5 Benthic invertebrates and sponges inventory (WP5)

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5.5.1 Methods

5.5.1.1 Diving methods

The habitats sampled encompass all bottom types, from mud, seagrass to coral rubble, and drop-offs, living reefs being just one of the habitat types to be studied. The depth range sampled was from 20 to 50 m. Large-/medium-sized specimens of selected species were visually documented by divers in representative habitats while trying to sample as many habitats as possible. A variety of techniques are used to specifically sample micro-invertebrates.

- Sight harvesting: this technique requires expert divers as most organisms blend into their environment to often achieve perfect mimicry with their hosts. Sight harvesting requires know-how, experience and intuition: the choice of blocks to be turned, attention to differences in sediment granulometry, camouflaged species or individuals (homochromy or mimicry), etc. Only experienced divers and collectors will be able to spot commensals, parasites and animals living in symbiosis.

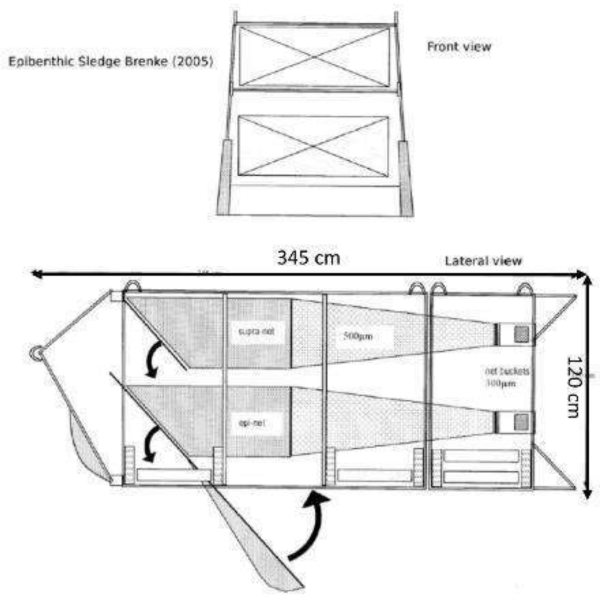
- Suction sampling: A suction sampler consists of a 2-meter-long tube connected to a source of compressed air that empties into a 1 mm-mesh net. The suction sampler is operated on soft seafloor sediments, to collect the upper 1-2 cm of material and the thin layer of ooze and microalgae found in rock crevices. A suction sample typically covers 1 to 2 square meters of seafloor and generates 2-15 liters of bottom material.

- Brushing baskets: A brushing basket consists of a 1 mm-mesh net protected inside and outside by sturdy laundry baskets. Loose rocks and coral rubble are placed in the basket and vigorously brushed by hand. The cleaned rock is returned to its place and the residue accumulates in the net. Alternatively, and especially in deeper water (30-50 meters) with limited SCUBA autonomy, the basket can be filled with loose rocks and lifted to the surface where the rocks will be brushed. A brushing sample typically covers 1 to 2 square meters of seafloor and generates 1-5 liters of bottom material.

5.5.1.2 Towed gears

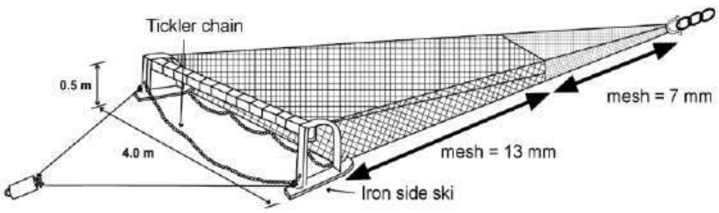
Suprabenthic sledge (EBS)

The EBS is a gear sliding at the surface of the sediment, sampling vagile small fauna above the bottom called "Suprabenthos". The suprabenthic communities are mainly composed by Peracarid crustaceans (Amphipoda, Isopoda, Cumacea, Tanaidacea). The sledge was towed on distances not exceeding 170 m. The EBS is equipped with two nets, i.e. an upper supranet and a lower epinet. The mesh size of the nets is 500 µm. The cod ends are equipped with net-buckets containing a 300 µm mesh window (Brenke 2005). To avoid contamination by planktonic organisms a lever mechanism is attached to the front doors, which are closed while the gear has no contact to the bottom. Metallic grids (about 3 cm mesh size) were attached to the entrance of the nets to avoid collection of big nodules, which may clog or damage the nets (Corbari L., UMR7205; M. Blacewicz & I. Frutos, Univ. Lodz)



Beam trawl

The standard French beam trawl is composed of a 4 meter (m) wide wooden beam that is fixed onto heavy iron runners situated at both ends of the bar. These runners serve as skis so that the trawl can glide along the seafloor. The height of the iron side-skis (0.5 m, length 0.45 m, giving an effective height of 0.35 m) defines the vertical opening of the net, the beam determines the horizontal opening of the net. The heavy weight of the runners at the base of the opening of the net settles the trawl and keeps it well on the ground. A fine-mesh net (15 and 12 mm) is attached to this system; the ground rope of the net is strengthened with chain to allow it to dig into the sediment and stir up organisms or substrate on and in the sediment. A tickler chain (4.5 m long, 10 kg) is placed before the net. A conical net proper is situated behind the ground rope. This conical shape allows for good filtration of the water and guides the organisms caught in the net towards the cod-end of the trawl. The cod-end is double-layered, with an inner finer meshed bag. The trawl is connected to the warp of the ship by two 4 m long wires, forming a triangle with the beam (crowfoot). The trawl is generally deployed at a speed of 2.5-4.5 knots (with pay-out speed about 1 m/sec) and towed at 1-2.5, mostly 1.5 knots ground speed. During the Saya de Malha project, the beam trawl was deployed on distances of 800 m.



	French beam trawl
Type of frame	Iron side skis (100 kg)
	Wooden beam (70 kg)
Span	4.0 m
Mouth height	0.5 m
Mouth width	3.8 m
Mouth area	1.9 m^2
Net length	8.8 m
Stretched mesh width	13 mm
	7 mm
Total weight	230 kg
Tickler chain	4.5 m long, 10 kg

__Warén Dredge__

The Warén Dredge consists of a strong metallic frame behind which is placed a net to retain sediment and fauna. The frame is connected to a wire and hauled by a boat at slow speeds (1-2 knots), sometimes slower depending on seafloor roughness. The bag of the dredge is composed of several layers; an inner bag made of thinner mesh (3-5 mm) is protected by 1-2 outer layers with a larger mesh size (20-50 mm) and a stronger weave. In the Warén Dredge used during the Tropical deep-sea Benthos programme and related expeditions, the external layer is made of a strong metallic ring net.

Table 12. Position and characteristics of the towed operations (DW: dredge / CP:beam trawl /EB: suprabenthic sledge)

Date	Box	Op Ref	Number MNHN	Gear type	START POSITION							END POSITION							Duration (mn)	Distance (m)	Depth (m)	AMSOL Stat Ref
					Local time	Latitude S		Longitude E		Dec_lon	Dec_lat	Local time	Latitude S		Longitude E		Dec_lon	Dec_lat				
						Deg	Min	Deg	Min				Deg	Min	Deg	Min						
3/11/22	1	TG1	5400	DW		9	24.538	60	10.13	60.17	-9.41		9	24.829	60	10.533	60.18	-9.41	0:00	924	286	
3/11/22	1	TG1	5401	DW	12:57	9	24.166	60	9.03	60.15	-9.40	13:09	9	24.344	60	9.341	60.16	-9.41	0:12	664	244	
3/11/22	1	TG1	5402	DW		9	25.076	60	10.49	60.17	-9.42		9	25.224	60	10.62	60.18	-9.42	0:00	367	317	
4/11/22	1	TG2	5403	CP	15:36	9	40.208	60	2.766	60.05	-9.67	15:46	9	40.395	60	2.939	60.05	-9.67	0:10	472	873	
4/11/22	1	TG2	5404	CP	17:54	9	41.466	60	3.829	60.06	-9.69	18:12	9	41.698	60	4.033	60.07	-9.69	0:18	572	862	
5/11/22	2	TG3	5405	DW	17:00	10	45.504	60	30.33	60.51	-10.76	17:13	10	45.602	60	30.516	60.51	-10.76	0:13	394	112	
5/11/22	2	TG3	5406	DW	17:41	10	45.688	60	30.87	60.51	-10.76	17:58	10	45.760	60	31.138	60.52	-10.76	0:17	512	110	
6/11/22	2	TG4	5407	DW	14:27	10	59.357	60	18.91	60.32	-10.99	14:47	10	59.649	60	19.103	60.32	-10.99	0:20	644	196	AM01353
6/11/22	2	TG4	5408	DW	15:34	10	59.947	60	19.32	60.32	-11.00	15:50	11	0.192	60	19.51	60.33	-11.00	0:16	572	205	AM01353
6/11/22	2	TG4	5409	DW	17:32	11	2.054	60	20.99	60.35	-11.03	17:52	11	2.290	60	21.242	60.35	-11.04	0:20	646	214	AM01354
6/11/22	2	TG4	5410	CP	18:50	11	2.633	60	21.61	60.36	-11.04	19:06	11	2.830	60	21.825	60.36	-11.05	0:16	540	201	AM01355
7/11/22	North SMB	TG5a	5411	DW	7:53	9	49.812	60	45.46	60.76	-9.83	8:03	9	49.759	60	45.569	60.76	-9.83	0:10	233	204	AM01357
7/11/22	North SMB	TG5b	5412	CP	12:16	9	44.192	60	48.05	60.80	-9.74	12:46	9	44.561	60	48.435	60.81	-9.74	0:30	988	1419	AM01358
7/11/22	North SMB	TG5b	5413	DW	9:32	9	44.811	60	50.22	60.84	-9.75	9:42	9	44.915	60	50.125	60.84	-9.75	0:10	261	1158	AM01359
9/11/22	3	TG6	5414	CP	12:08	10	23.284	61	48.5	61.81	-10.39	12:19	10	23.295	61	48.717	61.81	-10.39	0:11	408	76	AM01363
9/11/22	3	TG6	5415	EB	13:23	10	23.298	61	48.89	61.81	-10.39	13:28	10	23.301	61	48.961	61.82	-10.39	0:05	130	73	AM01364
10/11/22	3	TG7	5416	CP	12:27	10	14.019	61	48.6	61.81	-10.23	12:47	10	14.366	61	48.608	61.81	-10.24	0:20	643	76	AM01368
10/11/22	3	TG7	5417	EB	13:38	10	14.52	61	48.61	61.81	-10.24	13:43	10	14.604	61	48.612	61.81	-10.24	0:05	156	73	AM01369
10/11/22	3	TG7	5418	EB	14:12	10	14.675	61	48.61	61.81	-10.24	14:18	10	14.761	61	48.616	61.81	-10.25	0:06	159	73	AM01370
10/11/22	3	TG7	5419	CP	15:59	10	15.423	61	47.51	61.79	-10.26	16:29	10	15.955	61	47.367	61.79	-10.27	0:30	1021	80	AM01371
12/11/22	4	TG8	5420	DW	10:56	11	24.996	62	10.33	62.17	-11.42	11:16	11	25.037	62	10.698	62.18	-11.42	0:20	684	215	AM01378
12/11/22	4	TG8	5421	CP	12:24	11	25.115	62	11.44	62.19	-11.42	12:54	11	25.167	62	11.93	62.20	-11.42	0:30	907	215	AM01379
12/11/22	4	TG8	5422	EB	13:52	11	25.145	62	12.33	62.21	-11.42	13:57	11	25.154	62	12.418	62.21	-11.42	0:05	156	214	AM01380
12/11/22	4	TG8	5423	DW	16:12	11	26.777	62	0.864	62.01	-11.45	16:32	11	27.116	62	0.771	62.01	-11.45	0:20	651	204	AM01381
12/11/22	4	TG8	5424	DW	17:23	11	27.684	62	0.602	62.01	-11.46	17:33	11	28.020	62	0.546	62.01	-11.47	0:10	631	161	AM01382
13/11/22	4	TG9	5425	DW	14:09	11	43.532	61	42.71	61.71	-11.73	14:29	11	43.629	61	43.039	61.72	-11.73	0:20	630	230	AM01384
13/11/22	4	TG9	5426	CP	15:39	11	43.626	61	43.64	61.73	-11.73	16:09	11	43.626	61	44.16	61.74	-11.73	0:30	956	219	AM01385
13/11/22	4	TG9	5427	EB	17:02	11	43.625	61	44.54	61.74	-11.73	17:07	11	43.625	61	44.62	61.74	-11.73	0:05	146	321	AM01386
14/11/22	4	TG10	5428	DW	15:54	11	53.934	62	21.62	62.36	-11.90	16:17	11	54.096	62	21.74	62.36	-11.90	0:23	372	307	AM01391
14/11/22	4	TG10	5429	DW	18:06	11	52.331	62	22.83	62.38	-11.87	entangled in rock								300	554	AM01392
15/11/22	5	TG11	5430	DW	7:06	11	46.521	61	9.254	61.15	-11.78	7:26	11	46.359	61	9.558	61.16	-11.77	0:20	638	266	AM01395
15/11/22	5	TG11	5431	CP	8:28	11	46.093	61	10.19	61.17	-11.77	9:08	11	45.813	61	10.899	61.18	-11.76	0:40	1405	261.5	AM01396
15/11/22	5	TG11	5432	EB	10:07	11	45.636	61	11.3	61.19	-11.76	10:12	11	45.590	61	11.374	61.19	-11.76	0:05	168	263	AM01397
15/11/22	5	TG11	5433	CP	12:01	11	41.947	61	11.85	61.20	-11.70	12:21	11	42.000	61	12.327	61.21	-11.70	0:20	883	235	AM01398
15/11/22	5	TG11	5434	DW	14:45	11	47.436	61	5.361	61.09	-11.79	14:56	11	47.436	61	5.435	61.09	-11.79	0:11	137	269	AM01399
16/11/22	5	TG12	5435	DW	6:58	11	49.872	60	55.07	60.92	-11.83	7:15	11	49.823	60	55.303	60.92	-11.83	0:17	450	318	AM01401
16/11/22	5	TG12	5436	CP	8:54	11	49.972	60	55.63	60.93	-11.83	9:24	11	49.802	60	56.275	60.94	-11.83	0:30	1232	306	AM01402
16/11/22	5	TG12	5437	DW	10:48	11	49.574	60	56.91	60.95	-11.83	11:13	11	49.437	60	57.368	60.96	-11.82	0:25	880	292	AM01403
16/11/22	5	TG12	5438	DW	13:08	11	51.752	61	0.034	61.00	-11.86	13:28	11	51.562	61	0.365	61.01	-11.86	0:20	707	266.5	AM01404
16/11/22	5	TG12	5439	CP	14:50	11	51.177	61	1.049	61.02	-11.85	15:10	11	50.964	61	1.416	61.02	-11.85	0:20	786	260	AM01405
16/11/22	5	TG12	5440	DW	16:15	11	50.732	61	1.815	61.03	-11.85	16:30	11	50.592	61	2.063	61.03	-11.84	0:15	527	302.5	AM01406
17/11/22	5	TG13	5441	DW	8:38	12	16.272	61	0.597	61.01	-12.27	8:58	12	16.583	61	0.859	61.01	-12.28	0:20	753	302.5	AM01409
17/11/22	5	TG13	5442	CP	10:24	12	17.206	61	1.391	61.02	-12.29	10:39	12	17.335	61	1.499	61.02	-12.29	0:15	312	285.5	AM01410
17/11/22	5	TG13	5443	CP	14:44	12	36.815	61	0.291	61.00	-12.61	15:24	12	37.082	61	0.72	61.01	-12.62	0:40	936	1067	AM01411
17/11/22	5	TG13	5444	EB	5:00	12	37.95	61	1.564	61.03	-12.63	5:00	12	38.061	61	1.673	61.03	-12.63	0:00	288	1086	AM01412
17/11/22	5	TG13	5445	DW	8:09	12	36.053	60	55.85	60.93	-12.60	8:28	12	35.909	60	55.549	60.93	-12.60	0:19	615	431	AM01413

First steps of zoological collection on board

For each collection operation (diving or towed), the contents of the sample are photographed to document the nature of the substrate.

These contents are rinsed with seawater and sieved through a stack of sieves with decreasing mesh size. The organisms are then sorted by main zoological groups (Crustaceans, Molluscs, Echinoderms, Cnidarians, Polychaetes, Fish, others...) on a large table located on the deck. The tiny organisms are examined in the lab under stereo microscopes. A series of specimen representative of the diversity of the station is selected and photographed. The organisms are then packaged with a rot-proof label mentioning the station number, depth, date and mission. The whole set is stored in 80° ethanol or formaldehyde (fish, ascidians).

For molecular studies, procedures have been set up in particular for organisms for which tissue samples must be taken before fixation as in the case of fish that are fixed with formaldehyde. Similarly, during fixation, shell molluscs have a tendency to shrink; the tissues are therefore poorly fixed if they are not collected in the field. A procedure has therefore been put in place to ensure traceability between the sample, the specimen and possibly the photo taken in the field. This procedure notably involves the use of Matrix tubes identified with a unique 2D bar code.

5.5.2 Preliminary results

At the date of release of this report, the specimen had not yet reached their destination, the MNHN, which is planned by early April 2023. The first in-depth analysis of the collection will start in September at a taxonomy workshop organised by the MNHN with several world taxonomist experts of the different taxa collected. The descriptions presented here are those resulting from the first sorting and rough classification done on board by the WP5 team. Tables 13 and 14 display a preliminary inventory of specimen by taxa collected during the cruise.

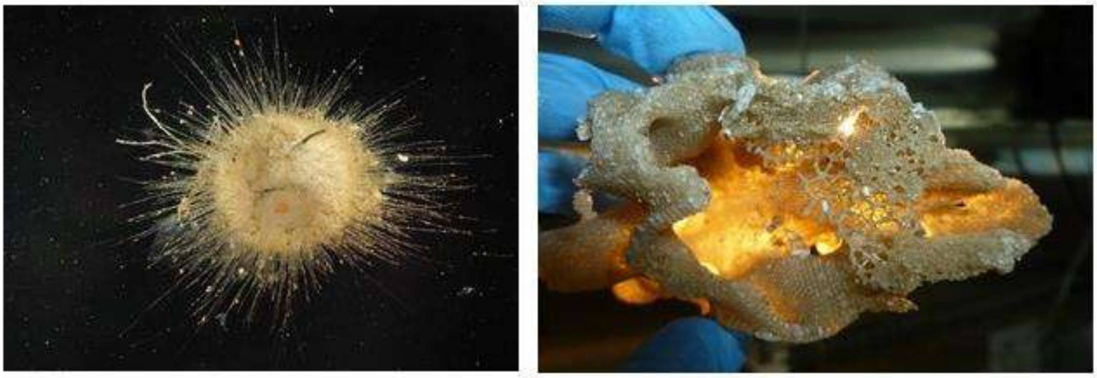
Sponges

Marine sponges are sessile organisms that produce an array of chemicals, called secondary metabolites, which they use as a defence mechanism, in response to their environment. These chemicals have been shown to have numerous pharmacological properties, which the Mauritius Oceanography Institute (MOI) is currently investigating for their potential against cancer, Alzheimer and diabetes, in order to find drug leads. Additionally, the same species of sponges can produce different secondary metabolites, depending on the environment they live in, which adds to the diversity of chemicals being produced in various locations and environments.

The research conducted during the Monaco Explorations' Indian Ocean Expedition, has enabled the collection of sponge specimen, which will further contribute to the research at MOI. Sponges were collected by dives and by towed gears (Table 13):

- 86 sponge specimen were collected by scuba diving, at depths approximately ranging from 24 to 58m. Some specimen that have not been investigated for their pharmacological properties at the MOI research unit, are shown in the pictures below. DNA and Taxonomy identification need to be carried out to confirm identity of specimen.
- 33 sponge specimen were collected by towed gears, at depths approximately ranging from 80 to 1000m. The majority of sponge specimen were silicious sponges (see photos below).

Sponge specimens collected by dive (depth 24 to 58 m)



Sponge specimens collected by towed gears (depth 80 to 1000 m)

Table 13. List of sponges specimen collected by dives and towed gears in the different box areas

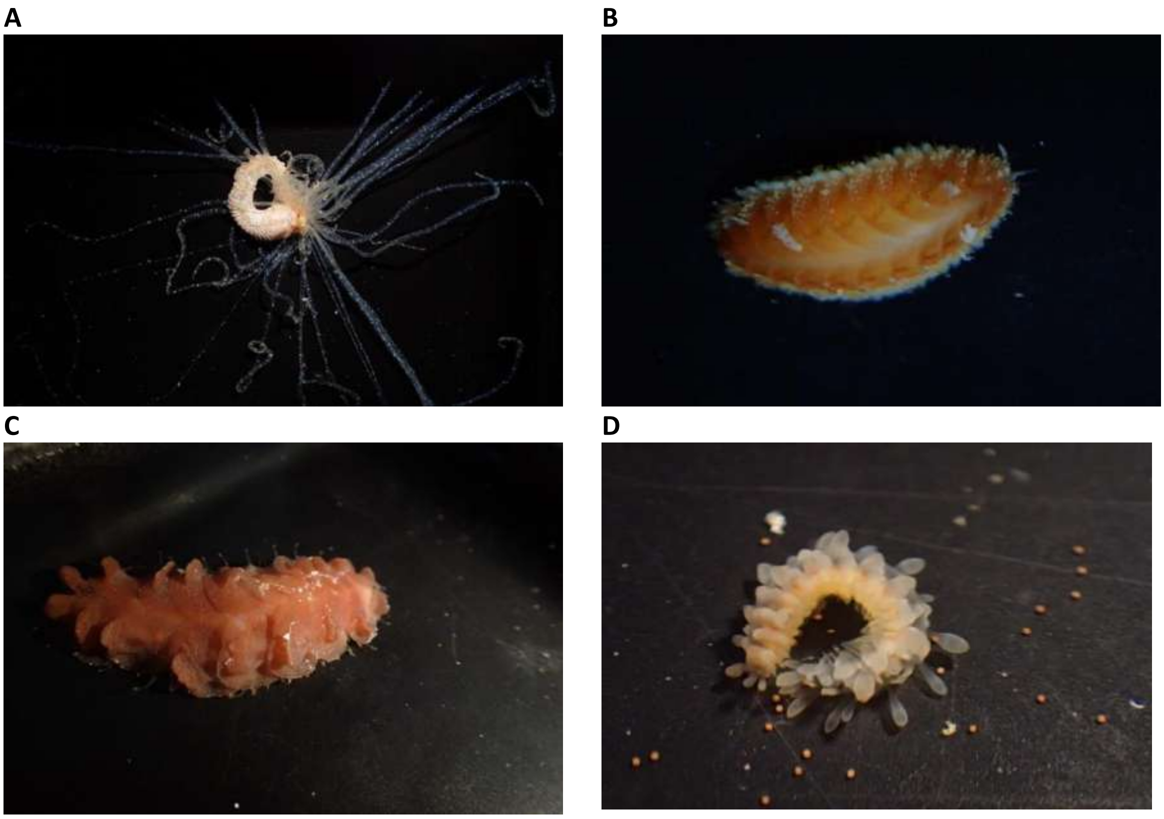
Specimen collected by dives	No of Specimen	Depth (m)
Box 1	6	42
Box 2	5	37- 50
North SMB	16	24- 58
Box 3	39	24- 29
Box 4	14	47
Box 5	6	

Specimen collected by towed gears	No of Specimen	Depth (m)
Box 1	2	286- 370
Box 2	6	112- 214
North SMB	1	205
Box 3	3	80
Box 4	11	204- 321
Box 5	10	

Annelids

In total, 331 lots of annelids were collected during the Saya de Malha part. These lots can contain from 1 to about 30 specimens (this latter mostly for small annelids). About a third of these lots remain unsorted and will be part of a dedicated workshop, the remaining ones have been sorted at least to the family level (20 families represented). Some specimens of the family Polynoidae (124 lots total) were identified to the genus level but many specimens in the family remain to be identified more precisely (74 lots).

A special attention was also given to associations of polychaetes with other invertebrates: holothurians, starfish, other annelids, stylasterid corals and black corals.

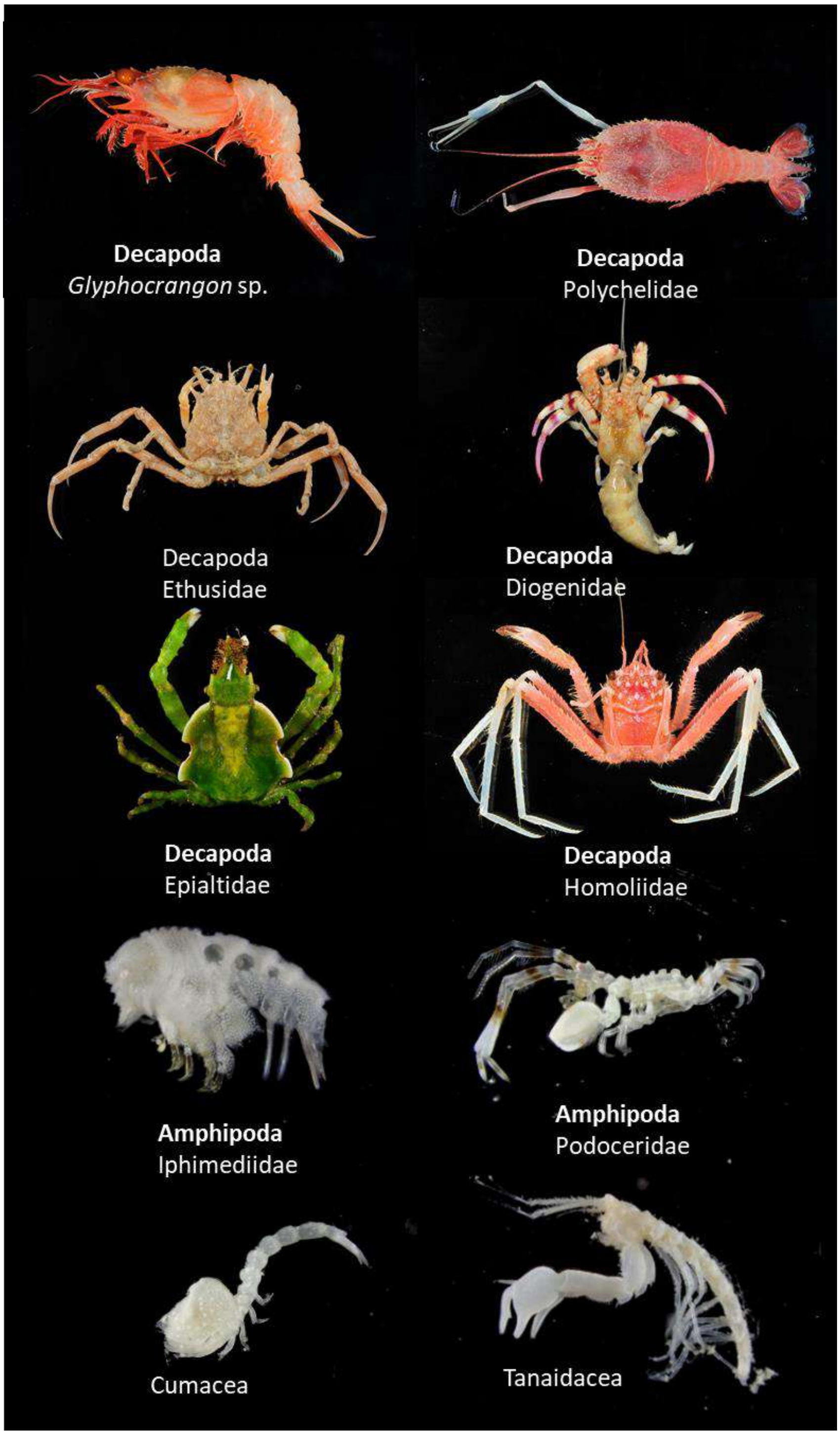


A. *Terebellidae, Eupolymnia sp./* ***B.*** *Iphione sp./****C.*** *Possibly new species of Polynoidae./* ***D.*** *Asterophilia sp., associated with a starfish.*

Crustaceans

In total, 650 lots of crustaceans were collected during the Saya de Malha part, originating from sampling by scuba diving or towed gears. In terms of relative abundance and relying on the inventory of samples, 56 % of the total sampled crustaceans are represented by decapods (shrimp Caridea, Crab Brachyurans and shrimp Dendrobranchiatia. The other main part of sampled crustaceans is represented by Peracarids. Peracarida is a superorder of malacostracan crustaceans divided into 12 orders, mainly represented in the marine realm by orders such as Amphipoda, Isopoda, Mysida, Lophogastrida, Cumacea, Tanaidacea. With more than 25000 known species, Peracarida is considered as a hyper-diversified group with many more species yet to be discovered and described. This gap of knowledge relies on their small sizes, difficult to sample and their fragile body. In total, 231 lots of peracarids have been sampled and sorted under stereomicroscopes, corresponding at last to more than 1000 specimens. In terms of diversity, it is quite difficult to provide a species list: first because the time on the field is dedicated to the sampling effort and not to taxonomy and secondly, because this material will be dispatched to a large community of taxonomists, experts of taxonomic groups. Anyway, based on our experience on the field and our taxonomic knowledge of the crustaceans, it is possible to provide an estimation of the diversity captured during the Saya de Malha part.

According to the photos of fresh crustaceans and sorting of macro- and micro-crustaceans performed with stereo microscopes, we expect to have sampled from 200 to 250 species of crustaceans.



The figure here illustrates the diversity of shape and colours among the crustaceans collected during the cruise. Regarding the decapods, on-board photos (about 150 photos) have already been exchanged with the specialists of the different taxonomic groups. It is noticeable that the crab of the family Ethusidae (Station CP5419, 80 m depth) has never been seen before (pers. comm. P. Castro, specialist of this group) and is probably a new species for science. Most of the shallow water decapods from diving operations seem related to the South Madagascar fauna, but specialists provide only general impression and specimens will be carefully studied in order to determine the possible connection with South Madagascar.

Little is known about peracarids from this area, or even in Indian Ocean. The families Urothoidae, Oedicerotidae, Eusiridae, Leucothoidae, Phliantidae, Caprellidae, Iphimediidae, Dexaminiidae, Podoceridae, Stillipediidae, Synopiidae, Atylidae. The bulk samples from the Epibenthic sledge, dedicated to the sampling of the suprabenthic fauna will increase the list of Amphipod families and species as well as Tanaïds, Mysids, Cumaceans and Isopods.

Molluscs

47 species of molluscs had been collected on Saya de Malha by Gardiner's Sealark expedition in 1905, and 130 by the Soviet R/V Odyssey in 1984. A rough estimate is that 300 to 400 species were sampled during the *S.A. Agulhas II* expedition in 2022.

There is practically no overlap between the fauna from diving depths (20-50 meters) and the fauna from deeper water (70 meters and deeper) sampled by dredges and trawls. Roughly half of the species were sampled during the dives, and the other half by dredging and trawling. Two species-rich families straddle both depths zones, albeit with different species: the Marginellidae and the Columbellidae, represented by respectively ca 20 and 10-15 species. Most are small to minute, with adult sizes in the range of 2-15 mm, and it is remarkable that the Sealark expedition of 1905 had collected respectively none and one species, demonstrating the efficiency of the collecting and sorting methods used during the *S.A. Agulhas II* expedition. Likewise, the Muricidae and Fasciolariidae, with respectively ca 15 and 10 species, also occur at all depths and are represented by quite few specimens. By contrast, the families Triphoridae and Cerithiopsidae, represented respectively by ca. 15 and ca. 10 species, are almost entirely confined to the shallow areas. The turrid families, generally extremely diverse in both shallow and deep water, are altogether represented by 20-30 species. Special attention has been given during the dives to nudibranchs and other seaslugs, represented by ca. 40 species, plus another 10 in the dredges and the trawls.

In the summit area, the bivalves are mostly cemented: *Tridacna* (2 species, see below), *Malleus*, 2 species of large oysters; or are byssally attached: *Pteria* (2 or 3 species, bysally attached to hydroids or gorgonians), *Pinctada* (pearl oyster, a single specimen). However, single loose valves of cockles (Cardiidae) and Glycymeridae indicate that further infaunal bivalves are present in the area. In deeper water, bivalve assemblages with *Bentharca*, *Microcardium*, Verticordiidae, Poromyidae, and *Cuspidaria* are encountered on soft bottoms.

Just as important, some families are noticeably absent. Among the families of « seashells », the herbivorous family Strombidae, characterized by long-distance dispersing larvae, is unexpectedly remarkably scarce, with only 2 juveniles *Strombus* (s.l.) and 3 adult *Lambis* (2 species) found ; the predatory miters (family Mitridae) are altogether missing ; only three species of Terebridae were documented, and the necrophagous Nassariidae are also almost completely absent, either in shallow or in deep-water : no *Nassaria*, a couple of species of *Nassarius*, one species of *Phos*. The larger species of the family Cerithiidae are almost completely absent, but one *Bittium*-like species is very common in the summit area. The vetigastropods (Trochidae, Fissurellidae) are remarkably poorly diverse in the summit area. The absence of Pyramidellidae is noticeable but may in part be explained by the absence of mud/silt bottoms in shallow water.

Overall, the summit area gives an impression of a depauperate fauna, with low biomass and small specimens in species that normally reach a larger size. It is tempting to ask whether this is a result of overfishing and environmental degradation. In this respect, the complete absence of species of the genus *Caecum* is noticeable. These microgastropods, with adult sizes of 2-4 mm, are often abundant in coarse sand and persist in the most overfished situations, as long as the sediment remains unpolluted. We thus believe that the absence of *Caecum* on Saya de Malha is not attributable to pollution or overfishing and is an interesting evidence that many absences are very probably natural and reflect dispersal restrictions. Likewise, the paucity of infaunal bivalves is noticeable and, correlatively, of their predator gastropod family Naticidae.

Biologically remarkable catches

The lepetelloids are small limpets specialized in feeding on / degrading organic substrates. Species of *Lepetella* feed on empty tubes of the polychaete Hyalinoecia, and what may represent a new species was found at CP5412 in 1420 meters. Species of *Bathysciadium* live exclusively on cephalopod beaks decaying on the bottom in deep water. No species was previously known from the tropical Indian Ocean, but one species probably new to science was sampled at DW5445 in 430 meters. Species of *Addisonia* live exclusively in spent elasmobranch (rays and sharks) egg-cases. What may be a new species of this genus, or even a new genus, was found in a spent chimaera egg-case at CP5403 in 875 meters.

By contrast, the complete absence of sunken wood and its associated fauna is worth noticing. Wood material (whole trees, branches, leaves) is normally carried out at sea by rivers and then dispersed by currents to hundreds if not thousands of kilometers away. Saya de Malha has of course no direct source of trees and the South Equatorial Current is unlikely to bring trees/wood from further East, as there are no island/emerged land to act as source of wood.

Emblematic species

The giant clam *Tridacna rosewateri* was discovered by diving during the Soviet expedition of 1988, and it was again found by us in the shallowest parts of the Saya de Malha Bank. Its distinctiveness has been genetically confirmed. Elsewhere, it is a species known only from Nazareth Bank (Cargados Carajos) and Tromelin, and can thus be considered to be iconic of the coral reefs depths on Saya de Malha. A second species of giant clam, *T. squamosa*, is also present on Saya.

Conus primus was described based on specimens allegedly collected in 80-98 m, and it is known from a handful (7 or 8) specimens collected during Soviet times, and never seen subsequently. Our expedition collected one freshly dead empty shell by diving in 42 meters.

Two emblematic species found on Saya de Malha: conus primus (left) and Tridacna rosewaterii (right)

Have we saturated the sampling of benthic organisms on Saya de Malha ?

After an intensive sampling of the nature that was undertaken on Saya de Malha, the questions that naturally arise are: how complete is our inventory of the benthic invertebrates / algae? What have we missed?

Sirenko (1993) recorded many species of « seashells » in the shallowest part of the bank (« 12 meters ») that we did not find. This may reflect the fact that none of our dives were shallower than 20 meters, and we would then have missed a segment of the reef fauna. For instance, the Sealark expedition of 1905 had recorded the small abalones *Haliotis pustulata* and *H. ovina*, and the Soviet expedition had recorded *Haliotis* cf. *varia*, whereas we did not get abalones at all. Conversely, we noted the almost absence of strombs, and this is confirmed by earlier expeditions: a single species of stromb and no *Lambis* had been found by the Sealark expedition of 1905 ; one stromb and two *Lambis* were found by the Odyssey expedition of 1984.

Of special concern are various species of « seashells » that were described in the 1990s based on material collected by Russian or Ukrainian vessels, either as a result of the Soviet research expeditions, or as a by-catch of commercial trawlers. We did find *Conus primus*. We possibly found (pending confirmation of the identification of our catches in the lab) *Closia limpida*, *Fusinus malhaensis*, and *Murex surinamensis*. But we did not find *Amalda danilai*, *A. trippneri*, *Conus gordyi*, *Haustellum bondarevi*, *H. danilai*, *Lyria bondarevi*, *L. doutei*, *L. surinamensis, Morum vicdani*, *Perotrochus metivieri*, *Phalium vector*, and *Semicassis bondarevi*. [In addition, Khromov and co-authors described 4 species of cuttlefish (*Sepia bathyalis*, *S. mascarensis*, *S. saya* and *S. tala*); we probably did not use the right gear to sample *Sepia*, but got *Sepia* (a single specimen) on one occasion, and this may represent one of Khromov's species. In other words, and although our sampling was far more detailed than what had been achieved in the 1980s-1990s, we did not find the majority of the species of seashells known before the Monaco expedition. This may be because we did not hit the right depth range (80-200 m ?) in the right sector of the bank; and/or it may be because the Russian/Ukrainian catches were the result of hundreds of commercial otter-trawl hauls that covered a much larger surface of the bottom of the area, unmatched by our beam trawl.

Finally, one cannot avoid noting the occurrence of some remarkable taxa that were found only once and never again, for example we found in abundance of a species of *Turritella* on a bottom of fine calcareous mud in 80 m, which was not found anywhere else. In the same vein, the ROV collected in 300 meters a single specimen of a fasciolariid gastropod, which was not collected at all by the towed gears.

To summarize, all this points out to a probably much more diverse fauna of perhaps 1,000 species of molluscs, of which we found between ¼ and 1/3. The explorations carried by our expedition, combining bulk sampling, sieving on a fine mesh, and sorting with stereomicroscopes, has undoubtedly documented hundreds of species for the first time on Saya de Malha. But clearly more dives in the shallowest part of the bank, and more hauls by dredging/trawling would be needed for a full inventory.

<u>Endemism</u>

How much of the mollusc fauna of Saya de Malha can be considered endemic to Saya de Malha? This is a difficult question because declaring a species to be endemic supposes that (i) the species-level taxonomy of the fauna has been worked up and (ii) other locations in this sector of the Indian Ocean have been adequately investigated. This is of course still far from being the case as long as the catches of the *S.A. Agulhas II* expedition have not been worked up. We have over 500 specimens/samples of molluscs specifically prepared for DNA sequencing, and the results of this sequencing will also shed light on the possible isolation of Saya de Malha populations of already known species.

Because of the accretionary growth of their shell, the gastropods are uniquely suited to discuss issues of larval dispersal and potential endemism. Several families (Tonnoidea, Architectonicidae) are well-known for their long-distance teleplanic larvae and vast geographical ranges: their occurrence on Saya de Malha would represent an extreme of "non-endemism". Endemism would be expected to occur in species with paucispiral protoconch indicative of non-planktotrophic larval development, an extreme of which is represented by the three narrow-range volutes (which we did not find) with crawl-away juveniles; non-planktotrophy is the rule also in the family Marginellidae, which is well represented on Saya de Malha. In between these two extremes, a number of families may exhibit one or the other of the two developmental modes, and a number of species of, e.g., Columbellidae, Fasciolariidae, Turridae, were noticed with paucispiral protoconchs, and represent putative new species endemic to Saya de Malha.

All in all, we can speculate that perhaps up to 20% of the molluscs living on Saya de Malha are endemic species new to science. The challenge will be to properly describe them in the context of the "taxonomic impediment".

Three species, confirmed new to science, discovered on Saya de Malha Bank by the Monaco Expedition in November 2022: a crab Ethusidae *(upper left), a shrimp Stenopus sp (upper right) and a gastropod* Lamellarinae *(lower centre)*

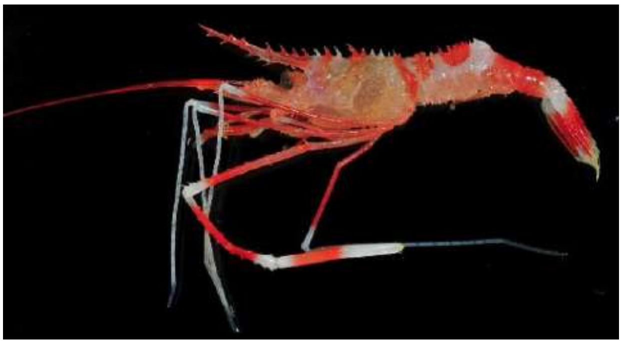


Table 14. List of samples by taxa. A batch comprises from 1 to 10 specimen

Taxa			Number of batches	Destination
1/ Mollusca			**524**	**MNHN (Paris)**
	Polyplacophora		5	
	Bivalvia		102	
	Gastropoda		396	
	Scaphopoda		8	
	Solenogastra		4	
	Cephalopoda		9	
2/ Crustacea			**650**	**MNHN (Paris)**
	Decapoda		370	
	Peracarida			
		Amphipoda	100	
		Isopoda	62	
		Mysida	9	
		Lophogastrida	6	
		Tanaidacea	37	
		Cumacea	10	
		unsorted peracarida	7	
	Other Crust.		45	
	Decapoda		4	JMA
3/ Algae			**358**	**MNHN (Paris)**
	brown		3	
	green		68	
	Rhodophyta		283	
	seagrass		4	
4/Annelida			**341**	**MNHN (Paris)**
	Polynoidae		124	
	Fam. Annelida		108	
	Unsorted annelida		109	
5/ Bulk samples			**52**	**MNHN (Paris)**
	Sediment		6	
	Sledge samples/ Gandalf		48	
6/ Fish			**149**	
	tissues + vouchers		139	MNHN (Paris)
	mix		10	JMA
7/ Ascidians			**20**	**MNHN (Paris)**
8/ Echinodermata Ophiurids			**90**	**MNHN (Paris)**
9/ Echinodermata (except Ophiurids)			**168**	**JMA**
	Asteroidea		62	
	Echinoidea		84	
	Holothuroidea		12	
	Crinoidea		10	
10/ Cnidaria			**94**	**JMA**
	Hexacorallia		30	
	Octocorallia		64	
11/Porifera			**119**	**JMA**
	Shallow water		86	
	Deep sea		33	

5.6 Photo-physiological studies of photosynthetic organisms (WP6)

Coordinator: Ranjeet Bhagooli
Team: Deepeeka Kaullysing, Vikash Munbodhe, Sundy Ramah, Mariette Dine

Photo-physiological studies of seaplants and symbiotic invertebrates give insights into the functioning and health status of these important marine organisms, which contribute to the food chain and food web. The recent innovative advancement in chlorophyll fluorescence technique has provided rapid study tools to assess photosynthetic functioning from single cell to small organism / colony level imaging scale. In this study, the imaging Pulse-Amplitude-Modulated (PAM) fluorometer was employed to assess the photo-physiology of seaplants and symbiotic marine invertebrates of Saya de Malha under the Monaco Explorations Indian Ocean Expedition in November 2022. Seaplants included seaweeds and seagrass while marine symbiotic invertebrates included giant clams, hard and soft corals. Phytoplankton diversity, density and estimated productivity were investigated. Additionally, the thermal tolerance of some selected rhodophytes and corals were determined.

The main objectives were to:

1. Assess the photo-physiology of seaplants and symbiotic invertebrates collected from Saya de Malha;
2. Assess the density, distribution and estimated productivity of phytoplankton; and
3. Determine the thermal tolerance of selected rhodophytes and scleractinian corals.

5.6.1 Methods

<u>*Sites for sample collection*</u>

Seawater samples from CTDs and surface samples at respective stations (Table 15) were collected for later micro-phytoplankton and pico-nanoplankton analyses. Micro-phytoplankton samples were collected by filtering 5 L of seawater from several depths using a 5 µm plankton net while two 50 ml samples from each depth were collected for pico-nanoplankton analyses. Samples for micro-phytoplankton and pico-nanoplankton were preserved in lugol and formaldehyde, respectively. Seawater samples have been collected for later chlorophyll and nutrient analyses.

<u>*Thermal Experiments – Experimental Design*</u>

Samples such as rhodophytes (red coralline algae and other red algae) and corals were exposed to 26, 29 and 32°C for a duration of 22hrs to test the thermal tolerance of these photosynthetic organisms. Rapid light curves (RLCs) were run using the Imaging-PAM and effective quantum yield at photosystem II (ΦPSII) were noted. Other relevant parameters like maximum electron transport rate (ETRmax) and non-photochemical quenching (NPQ) will be calculated later. For reliable comparison among species, yield values relative to initial were used.

<u>*Chlorophyll fluorescence measurements*</u>

The effective quantum yield at PSII (ΦPSII) was determined as ratio of the difference between the maximum fluorescence (F_m') and base fluorescence (F_o') to F_m'. F_o' and Fm′ were measured using a weak light (1 µmol quanta m^{-2} s^{-1}) and a saturating pulse of 4000 µmol quanta m^{-2} s^{-1}. Rapid light curves (RLCs) were generated using a light range of 0 to 700 µmol quanta m^{-2} s^{-1} increasing at an interval of 20s. The maximum electron transport rate (ETR_{max}) will be calculated as ΦPSII*PAR, where PAR is photosynthetic active radiation.

Table 15: Sites and samples collected.

Date	Station No	Samples	Depth (m)
Microplankton and Pico-nanoplankton			
2 Nov 22	IO-009	Water from surface + CTD	0, 3, 40, 80, 100
2 Nov 22	IO-010	Water from surface + CTD	0, 3, 40, 75, 100
3 Nov 22	IO-011	Water from surface + CTD	0, 3, 40, 80, 100
5 Nov 22	IO-012	Water from surface + CTD	0, 5, 80, 100
5 Nov 22	IO-013	Water from surface + CTD	0, 5, 65, 80, 100
6 Nov 22	IO-014	Water from surface + CTD	0, 5, 40, 60, 80, 100
6 Nov 22	IO-015	Water from surface + CTD	
8 Nov 22	IO-017	Water from surface + CTD	0, 5, 30, 50, 70
8 Nov 22	IO-016	Water from surface + CTD	0, 5, 50
9 Nov 22	IO-018	Water from surface + CTD	0, 5, 40, 100
9 Nov 22	IO-020	Water from surface + CTD	5, 40, 60, 100
11 Nov 22	IO-022	Water from surface + CTD	0, 5, 40
11 Nov 22	IO-021	Water from surface + CTD	0, 5, 40, 80, 100
12 Nov 22	IO-024	Water from surface + CTD	
13 Nov 22	IO-025	Water from surface + CTD	0, 5, 40, 100
13 Nov 22	IO-026	Water from surface + CTD	0, 5, 40, 90, 100
14 Nov 22	IO-028	Water from surface + CTD	0, 5, 40, 100
14 Nov 22	IO-029	Water from surface + CTD	0, 5, 25, 40, 100
16 Nov 22	IO-031	Water from surface + CTD	0, 5, 40, 90, 100
16 Nov 22	IO-033	Water from surface + CTD	5, 40, 100
Trawl / Towed gears			
4 Nov 22	TG2 / CP	Surface water	0
Diving sites / Collections			
4 Nov 22	SD 2 / YR02	Surface water	0
5 Nov 22	SD 3 / YR03	Surface water	0
6 Nov 22	SD 4 / YS04	Red Coralline Alga 1 (RCA 1) maerl	38.7
6 Nov 22	SD 4/ YR05	Fleshy Red Algae (Ceramiales)	37
7 Nov 22	SD 5/ YS06	Red Coralline Alga (RCA 2) (ball type)	58
8 Nov 22	SD 6 / YR09	*Acropora* Branching Colony	19.2
8 Nov 22	SD 6 / YR09	*Danafungia* sp. 1	19.2
8 Nov 22	SD 6 / YR09	*Danafungia* sp. 2	19.2
8 Nov 22	SD 6 / YR09	*Herpolitha* sp.	19.2
9 Nov 22	SD 8 / YR13	*Tridacna rosewateri* (Adult)	23.5
9 Nov 22	SD 8 / YR14	*Tridacna rosewateri* (Adult)	26
10 Nov 22	SD 9 / YR16	*Acropora robusta*	24
10 Nov 22	SD 9 / YR16	*Tridacna rosewateri* (Juvenile)	24
10 Nov 22	SD 9 / YR15	*Tridacna squamosa*	24
10 Nov 22	SD 9 / YR15	*Galaxaura rugosa*	24
11 Nov 22	SD 10 / 16	*Heliopora coerulea*	27
11 Nov 22	SD 10 / 17	*Acropora* tabular	29
11 Nov 22	SD 10 / YR17	*Sinuopta* sp.	26.5

11 Nov 22	SD 10 / YR18	*Pocillopora sp.*	27
13 Nov 22	SD 11 / YR18	*Gardineroseris* sp.	27
13 Nov 22	SD 11 / YR18	*Cyphastrea* sp.	27
13 Nov 22	SD 11 / YR22	Soft Coral	47
13 Nov 22	SD 11 / YR22	Gorgonian	47
13 Nov 22	SD 11 / YR22	*Favia* sp.	47

5.6.2 Preliminary results

Objective 1: Photo-physiology of collected specimens

Lithophylon sp.

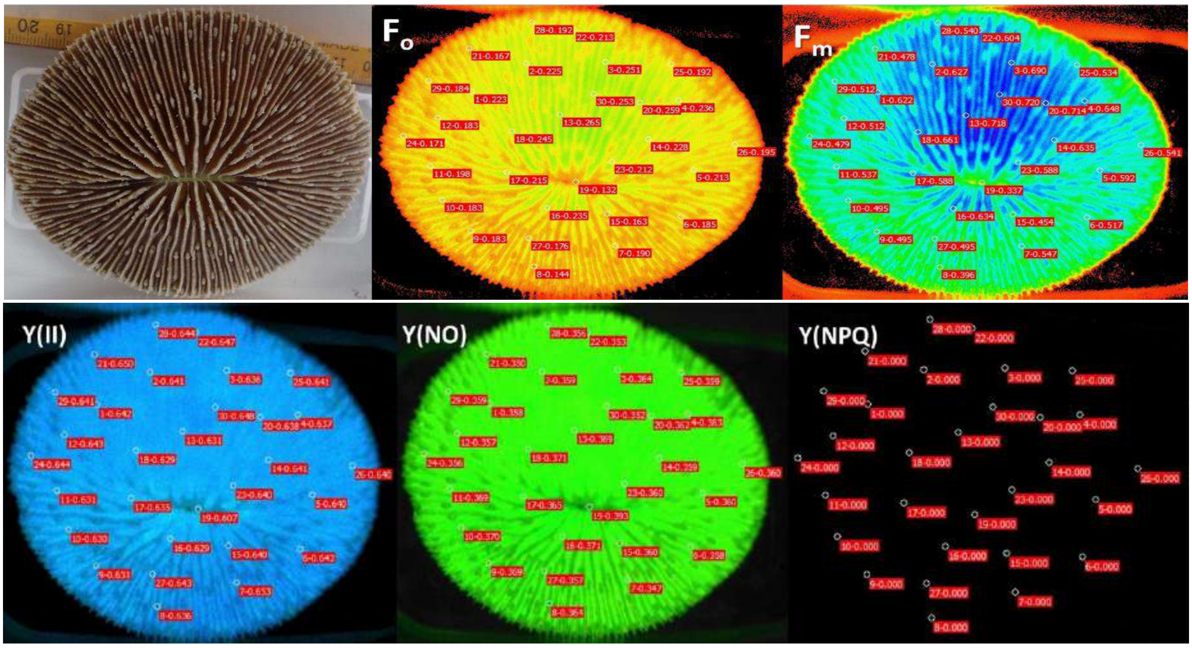


Figure 21. Yield at photosystem II of coral Lithophylon sp.

Giant clams – *Tridacna rosewater*

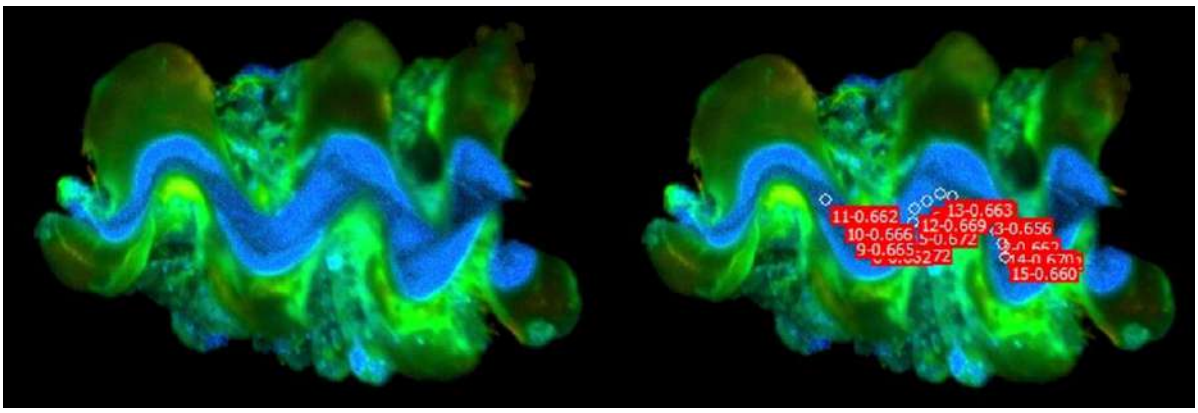


Figure 22. Yield at photosystem II of giant clam Tridacna rosewateri

The effective quantum yield values of about 0.600 in both *Lithophylon* and *Tridacna* indicated that these organisms were photosynthetically healthy (Fig 21 & 22).

Objective 2: Phytoplankton

Collected samples will be analysed later.

Objective 3: Thermal experimental trials

The thermal trials for 26, 29 and 32°C treatments were more or less maintained at respective temperatures during the experimentation period of 22hrs (Table 16). Temperature was measured using data loggers at intervals of 15 min.

Table 16. Temperature variations during 22hr of exposure

	Temperature (°C)		
	Red Coralline Alga1	**Gorgonian**	**Branching *Acropora* sp.**
Tank - 26°C	25.85±1.07	26.42±0.39	26.51±0.27
Tank - 29°C	29.04±0.90	28.88±0.47	29.14±0.40
Tank - 32°C	31.62±0.85	32.34±0.77	32.37±1.04

The Red Coralline Alga 1 had its Φ_{PSII} reduced at both 29 and 32°C after 22hrs of treatment (Fig. 23 & 24). The gorgonian was mostly affected at 32°C after 22 hrs of treatment. The Φ_{PSII} of the gorgonian after 22hrs at 32°C did show spatial variations within the fragments exposed (Fig. 24B). The branching *Acropora* sp. had its Φ_{PSII} reduced after 22hr of treatment at 32°C and was visually bleached (Figs 23C & 23C).

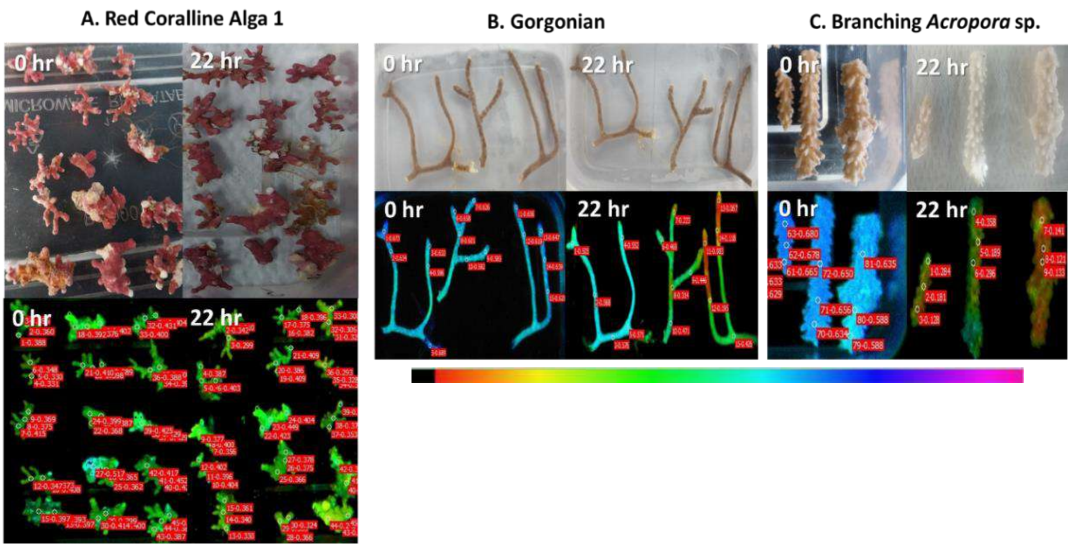


Figure 23. Natural and IPAM images for yield initially and after 22hr treatment at 32°C for Red Coralline Alga 1 (A), gorgonian (B) and branching Acropora sp. (C).

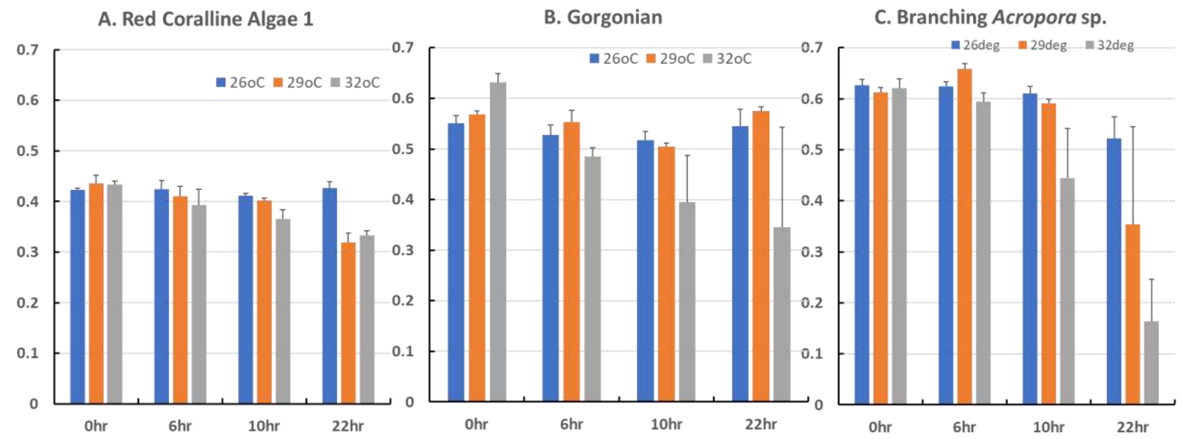


Figure 24. Effective quantum yield (Φ_{PSII}) of red coralline alga 1, gorgonian, branching Acropora sp. Exposed to 26, 29 and 32°C for a duration of 22hrs.

In order to compare the Φ_{PSII} responses among the red coralline alga 1, gorgonian and branching *Acropora* sp., relative Φ_{PSII} to initial, i.e., values prior to the start of the thermal stress, for respective treatments were calculated (Fig. 25). At 29°C after 22hr, the red coralline alga 1 and branching *Acropora* sp. seemed to be more vulnerable than the gorgonian. However, at 32°C after 22hr treatment, the red coralline alga 1 was more tolerant than the gorgonian and branching *Acropora*.

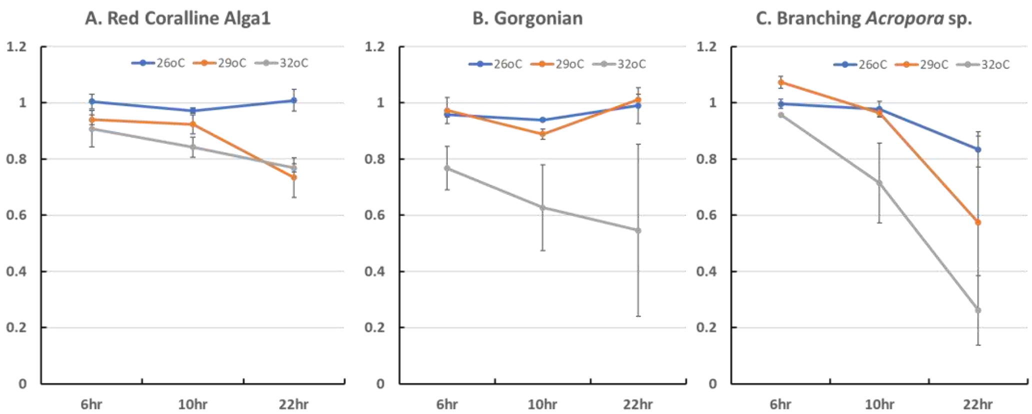


Figure 25. Relative (to initial) effective quantum yield (Φ_{PSII}) of red coralline alga 1, gorgonian, branching Acropora sp. exposed to 26, 29 and 32°C for a duration of 22hrs.

<u>*Main Preliminary findings*</u>

1. Imaging-PAM is a good rapid method for assessing the physiological health of photosynthetic marine organisms tested; and,
2. Red coralline alga 1 appears to be most tolerant among the tested species to the exposed thermal conditions. Gorgonian and branching *Acropora* may not survive climate change-driven warming oceans as they are thermally vulnerable.

5.7 Scuba diving operations and specimen collection (WP7)

Coordinator: Line Le Gall
Team: Benoit Gouilleux, Stéphane Hourdez, Grégoire Moutardier, Emmanuel Vassard

5.7.1 Methods

Two C-Worker 880 SRP dive support boats, chartered for the expedition, were used for the two teams of divers. One team (3 divers) operated on shallow depths (20-30 m) with open circuit systems, while the second team (2 divers) did deeper dives (to 60 m) using rebreather/recycler system. The two boats remained under close surveillance, at a sight distance from the *S.A. Agulhas II*, throughout the dives

The divers used the different sampling techniques described in 6.5.1, i.e. sight harvesting ("cherry-picking"), suction sampling and brushing baskets.

The specimen were stored in containers or small bags by the divers during the dive. The bags were then hauled on board the support boat. The collection were displayed and sorted in the lab of the *S.A. Agulhas II* after each dive, for everyone to see and to start sorting by large taxonomic group.

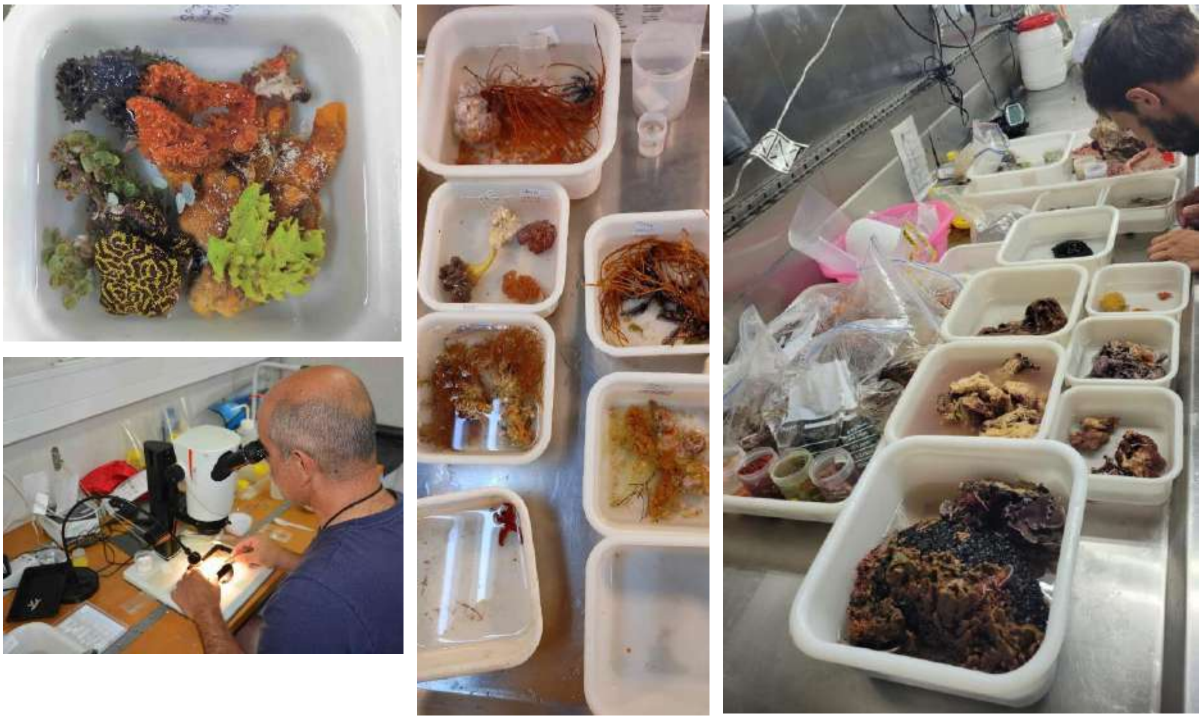
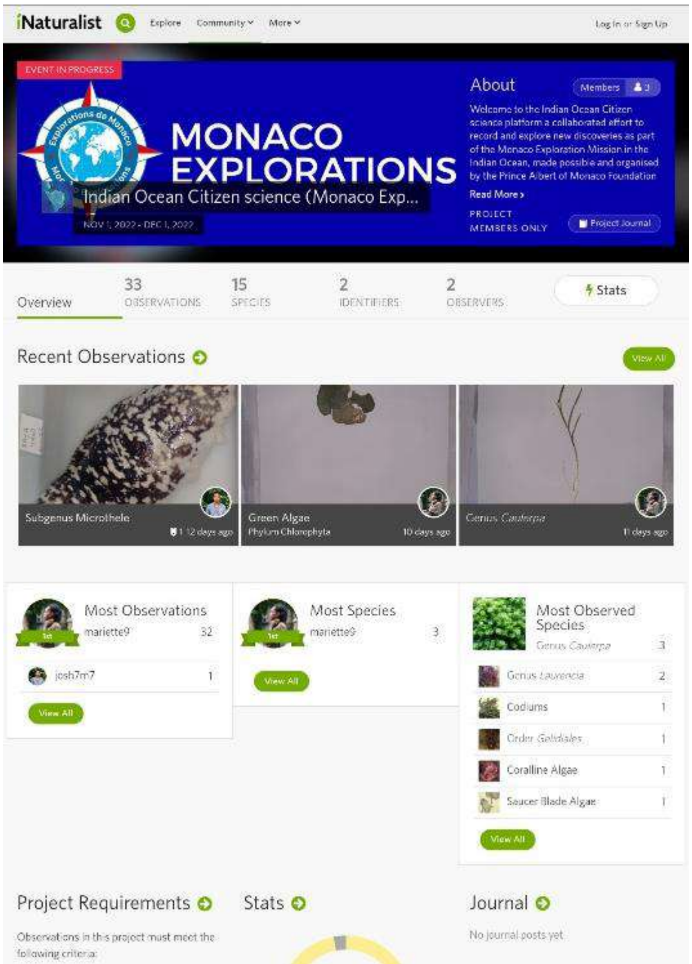


Figure 26. Display of specimen collected after each dive. The collection is roughly sorted by large taxonomic group for first examination. A more detailed sorting and identifcation whenever possible, is performed by taxonomist experts under binocular magnifying glasses. Specimen are then preserved in formaldehyde or 80° alcohol, the latter allowing genetic analyses if needed.

Algae collection for a regional herbarium project

The collection of algae has been one project developed by a young Seychellois scientist. SeyCCAT BGF-5 grantee Ms Mariette Dine got the opportunity to work along with Prof. Line le Gall from the MNHN on board the Monaco Expedition on the Saya de Malha cruise. The trip contributes to the following activities as part of her 2 year project: Activity 1.3.3 *Capacity building in herbariology*, i.e. pressing techniques for macroalgal species; Activity 1.3.4 *Verification and confirmation of species*; and Activity 2.1.5 *Establish communication with international network for knowledge transfer and sharing.* Her first herbarium press of 35 duplicate specimens comprising of 34 algal specimen and 1 seagrass was produced.



Arrangements were made for grantee to bring the samples back to Seychelles where it will be stored and curated at the Seychelles National Herbarium, one of the grantees close collaborators. Aside from the specimen collection, the grantee is also making use of iNaturalist to digitalise the pressed specimens, while they are still fresh to assist in identification of specimens, with the help of professor Line le Gall.

Materials used included Herbarium press set, which is composed of wooden pressers, rubber bands, newspapers, water absorbent card paper, absorbent wipe sheet and baking paper. Specimens where simply placed on a water absorbent card paper with a layer of absorbent wipe sheet, then layered by newspaper. This was then changed on several occasions, to ensure that the specimens would dry properly

In the herbarium press, details of location and species is to be identified by the main collector at the MNHN of Paris and the information made available on the Monaco share folder.

For digitalization, grantee made use of iNaturalist, a community science platform used in Seychelles by the Plant Conservation Action group (PCA), under the Seychelles bio-gallery a National project that engages with NGO's and all nature lovers allowing them to have access to a platform of taxonomist and other nature lovers who can help in species identification, either at the genus level or the down to the species level. The app is user friendly, and can be used on any hand held device. Grantee also had the opportunity to introduce the initiative to the research members on board which included 13 representatives from Seychelles, 11 from Mauritius and 15 researchers from Europe/Monaco representatives.

5.7.2 Preliminary results

The collection made by the divers are included in the inventory listed in Table 13.

With regards to the algae collection project, at the end of the project, the grantee acquired basic skills in preparing herbarium press and access to literature and guidance from the head coordinator for specimen collection, which will be very helpful in implementing the main research activities under the seyCCAT BGF-5 project early 2023. T

The grantee produced guidelines on how to sign up on the iNaturalist platform under a created community project name Indian Ocean citizen science – Monaco expedition Seychelles and Mauritius which can be viewed through this link https://www.inaturalist.org/projects/indian-ocean-citizen-science-monaco-exploration-seychelles-mauritius , for participants to upload pictures of specimens they found interesting on the trip and what they would like to know more about.

5.8 Video survey and ROV (WP8)

Coordinators: Sheena Talma & Frédéric Ménard
Team: Florence Galletti, Francis Marsac, Rosabella Mangroo, Nuette Gordon, Annie Vidot, Bianca Marzocchi

5.8.1 Methods

We used two types of low-cost cameras in different configurations to record marine life above the sea floor and in the water column. Macrofauna, especially fishes, sharks and turtles, were the main targets of our simple-to-deploy visual observation systems in shallow water ecosystems. Our cameras could not be deployed deeper than 100m.

Moorings

For seven of the dives, we deployed a mooring that is displayed in Fig. 27.

The mooring was equipped with four cameras. Two waterproof boxes deployed at two depth levels (2 meters above the seabed, and another 2 meters above the lower box) contained 2 cameras each. One camera was set to take photos and the other videos. In addition, we equipped the near-bottom box with a hydrophone in order to record noise as indicator of marine life activity. Batteries enclosed in the boxes powered the instruments. The mooring specification and the containers were designed by Herve Demarcq (IRD Marbec Sète), who also provided the cameras.

The mooring was recovered at the end of each dive and data were downloaded on board.

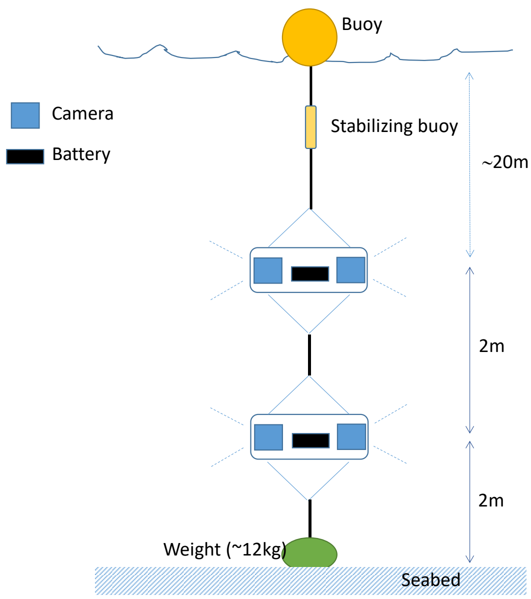


Figure 27. Design of the moored cameras

Cameras attached to the ROV

For the two ROV operations carried out during the seagrass survey, we attached two cameras on the front arms of the ROV, and one camera at the rear of the ROV cage.

During each operation, the ROV was brought back on board twice, in order to carry out three successive transects at different locations.

Remotely Operated Vehicle (ROV)

The core team that operated the Saab Seaeye Cougar XT ROV consisted of one supervisor, two pilots and one surveyor (Fig. 28). Sheena Talma and Francis Marsac planned the dives and the whole team contributed to record the events on a log book during the dives (duration ranging from 1 to 8 hours). The ROV was fitted with 4K cameras, an articulated arm to collect samples and four sampling boxes to store the specimen collected. In addition, a low-cost deep-sea prototype camera was attached to the ROV during dives. The Ocean Discovery League designed the camera which was tested to better understand its capabilities in the field with the aim of making the deep sea more accessible to interested parties. A total of 7 surveys were undertaken with the ROV to allow for benthic communities to be documented and strategically collected at depths below SCUBA limits. All surveys were modelled after surveys used by the Nekton project and other collaborators from the region. The reasoning was to conduct surveys that could then be compared with other surveys conducted in the region. This protocol has previously been implemented in Seychelles, Comoros, Maldives, seamounts in the Southern Ocean and South Africa. Surveys were conducted at four priority depths of 30, 60,120 and 250 meters. These surveys were not always possible due to time constraints and topography of the area surveyed. The surveys were conducted over a transect distance of 250m at a speed of 0.2 knots, each transect was then replicated twice to ensure replications for further statistical analysis. A more detailed protocol is detailed below.

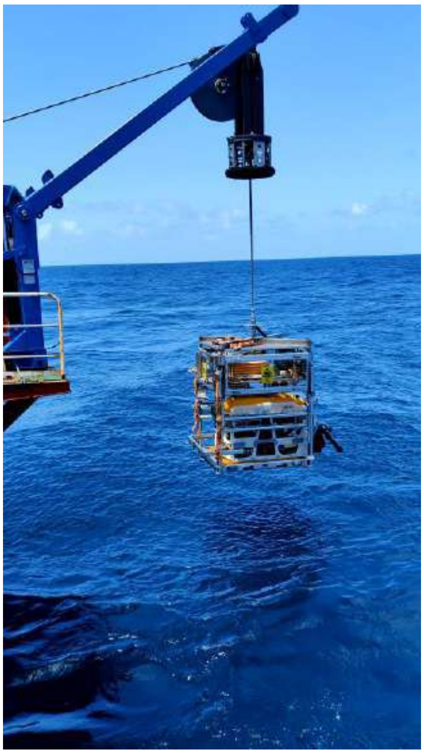


Figure 28. ROV in its cage during deployment (left) and ROV pilots in the operation room.

Pre-deployment checks and activities

1. Assessment of available bathymetry to create dive plan based on available depths and distance of transit between dive depths.
2. Formulate dive plan.
3. Ensure that 4K camera is recording appropriately and that lights and laser works
4. Ensure that the synchronised cameras are working
5. Ensure that recording sheets dive info logs and dive event sheets are printed

On descent

4K Recording was started at time arriving at the bottom whereby transects will begin. The synchronised cameras are turned on at the beginning of deployment. Time of launch, time of bottom in site and depth of bottom in site are all recorded.

On bottom

Three transects at 250 m in length were conducted at depths indicated in the dive plan. Start and finish time and start and finish depth were recorded on the Dive Info Sheet. The start and finish of transects was indicated by turning on and turning off the lasers. A constant altitude from the seafloor between

1-2 m was sought on all dives. Depth and location was obtained from the *ROV and S.A. Agulhas II* electronic equipment.

<u>On ascent</u>

The time off bottom, depth leaving bottom and time on surface were recorded on Dive Info Sheet.

<u>Post-dive -Data Export</u>

Download data from 4K cameras, synchronised cameras and back of ROV. Save data on multiple hard drives to ensure at least one back up

Table 17. Position, time and main information on the 7 ROV dives at Saya de Malha

ROV Dive #	Date	Time (UTC+5)	Location	Transect depths (m)	Comments
SDM_001	03 to 04 November 2022	23h25 – 03h07	Saya de Malha North	30, 60, 120, 250 m and exploratory at 700 m	Only one 250m transect was conducted at each of these depths as time was limited
SDM_002	07 November 2022	10h28 – 15h02	Saya de Malha North	30 m – Grass surveys only	Sea grass survey conducted for Blue Economy Department
SDM_003	08 November 2022	12h17 - 13h30	Saya de Malha North	30 m Sea grass survey	Sea grass survey conducted for Blue Economy Department
SDM_004	10 to 11 November 2022	23h10 – 05h21	Saya de Malha East	30, 60m, 120m, 250 m	Three 250m transects collected at each depth
SDM_005	12 November 2022	20h36 – 04h26	Saya De Malha South East	60m, 120m, 250 m	3 transects at each depth. No 30m bathymetry line – 30m line too far for transit
SDM_006	14 November 2022	06h39 – 14h43	Seamount	Exploratory 200-500 m	No transects conducted here. Seamount was purely exploratory. There was a 2 hour pause between transects.
SDM_007	15 to 16 November	21h33 – 04h45	Saya De Malha South west	270 m, 500 m, 700 m	Transects were conducted at 270m and 500m

5.8.2 Preliminary results

5.8.2.1 Cameras

<u>Moored cameras</u>

Cameras did not work properly at each deployment. The table below summarizes the recorded footages.

STATION	Date	Depth (m)	Lat	Long	Upper camera		Lower camera	
					Video	Photo	Video	Photo
Mooring#1	07/11/2022	25m	09° 55' 28'' S	60° 54' 13'' E	NO	YES	YES	YES
Mooring#2	08/11/2022	18m	09° 49' 51'' S	60° 51' 00'' E	Partially	NO	YES	YES
Mooring#3	09/11/2022	28m	10° 36' 51'' S	62° 02' 36'' E	YES	YES	YES	YES
Mooring#4	10/11/2022	22m	10° 22' 45'' S	62° 07' 43'' E	YES	YES	YES	YES
Mooring#5	10/11/2022	22m	10° 12' 36'' S	62° 09' 36'' E	YES	YES	YES	YES
Mooring#6	11/11/2022	23m	10° 43' 46'' S	62° 12' 15'' E	YES	YES	YES	YES
Mooring#7	11/11/2022	28m	10° 54' 00'' S	62° 11' 24'' E	YES	YES	YES	NO

We carried out on board a preliminary examination of the images recorded during the moorings (Fig. 29). We observed one turtle once, very few sharks, few large fish. Overall, the macrofauna is not abundant in the water column of the observed sites. Large predators were not detected by our cameras.

We observed carangids and probably one skipjack tuna (*Katsuwonus pelamis*, to be confirmed) but most of the observed fishes were benthopelagic and coral species (e.g. black triggerfish *Melichthys niger*, short-nosed unicornfish *Naso brevirostris*). Videos allowed us to record several fish schools evolving in the water column.

Hawksbill sea turtle *Eretmochelys imbricata* during Mooring#2 the 08/11/2022

Gray reef shark *Carcharhinus amblyrhynchos* during Mooring#7 the 11/11/2022

Yellowspotted trevally *Carangoides fulvoguttatus* during Mooring#5 the 10/11/2022

An undetermined Lutjanidae during Mooring#7 the 11/11/2022

Figure 29. Photos taken by the moored cameras

Cameras attached to the ROV

The depth of the two seagrass surveys carried out during the day on November 7 and November 8 did not exceed 20m. The ROV moved close to the bottom.

Because the ROV cage remains hanging in the water column above the ROV, the camera attached to the back of the ROV cage was too high in the water column and did not capture any interesting images. By contrast, the two cameras attached to the front of the ROV and turned to the sides recorded excellent images.

The seagrass beds (composed in majority of *Thalassodendron ciliatum*) are in good health. We observed a succession of parcels of seagrass with rhodolith beds and coral areas. This mosaic of habitats structures the seagrass bed ecosystem and shelters a diversity of organisms. However, we never observed abundant colonies of organisms, neither fishes of large size, nor large predators.

The information we collected shows that the plateau of Saya de Malha shelters key habitats representing probably a peculiar ecosystem vulnerable to non-regulated exploitation.

Further analyses of our images should be combined with ROV footages and with high-resolution bathymetric mapping performed with autonomous sensor-equipped board, in order to characterize and roughly estimate the distribution of the habitat and associated fauna.

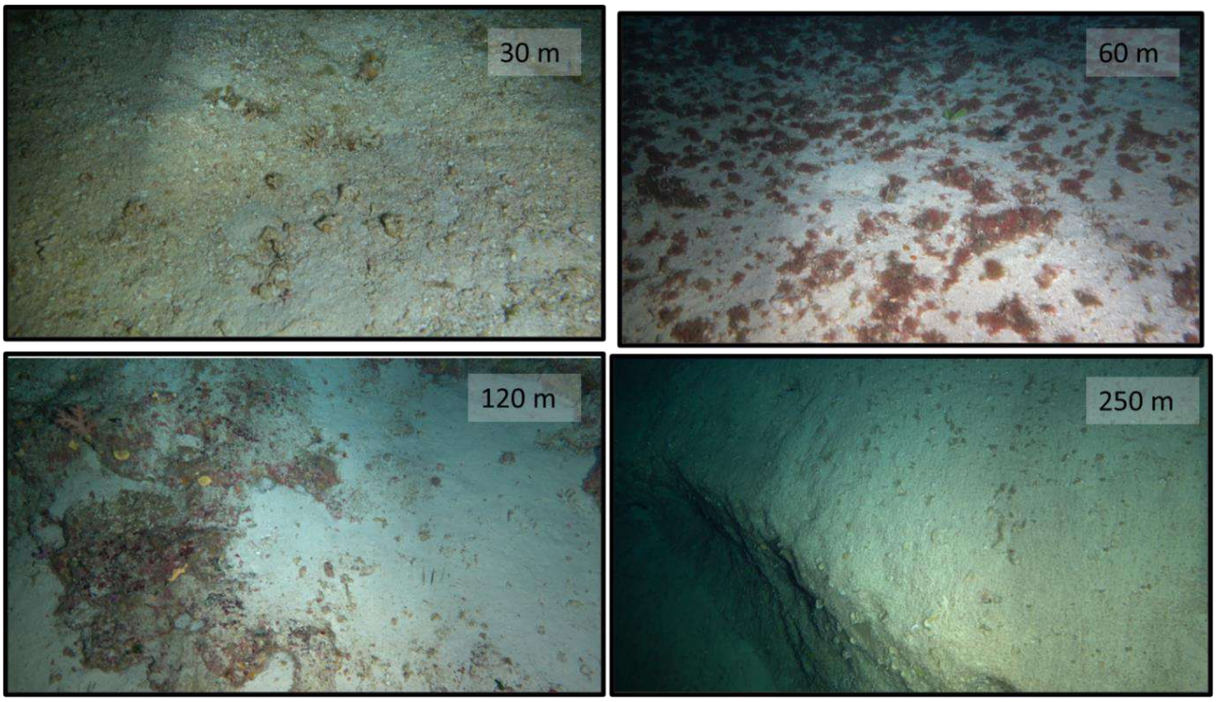
5.8.2.2 ROV surveys

ROV001: SDM_001 Site 1: North East Saya De Malha – Ritchie Bank

30 m: Sandy bottom with coral rubble. Very little structure, presence of some red and green algae. Lacked 3D complex environments or ledges or caves. Lacked large benthic communities or presence of hard or soft coral. Some occasional sections of rhodoliths.

60 m: Substrate dominated by gravel and rubble, prevalence of red algae and leafy green algae, lacked in complex structures or ledges and caves. Gentle slopped bottom.

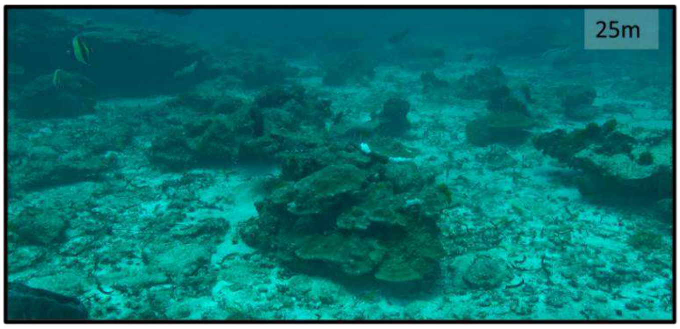
120 m: Rocky habitat with some sandy patches. Dominance of white whip corals, fleshy corals and encrusting varieties. Some structure such as caves and ledges seen during this transect



250 m: Flat seabed with gentle slope, intermittent boulders with Stylastrids and sponges. Very little variety of fish and corals seen at this depth.

ROV002 and ROV003: SDM_002 Site 1: North East Saya De Malha – Sea Grass Survey

20-30 m: Seagrass meadows covered a large expanse of the transects, the dominant species of seagrass noticed was *Thalassodendron* with some green algae. Sparse distribution of sea cucumbers, a school of rabbitfish was spotted. Patches of coral was seen between the seagrass, these were lively habitats with a mix of triggerfish, rabbitfish and surgeonfish. The transects at two different sites were conducted over two days at a speed of 0.4-0.6 knots. On the last day only one transect of 750-1000m was conducted due to a mechanical issue with the ROV winch.



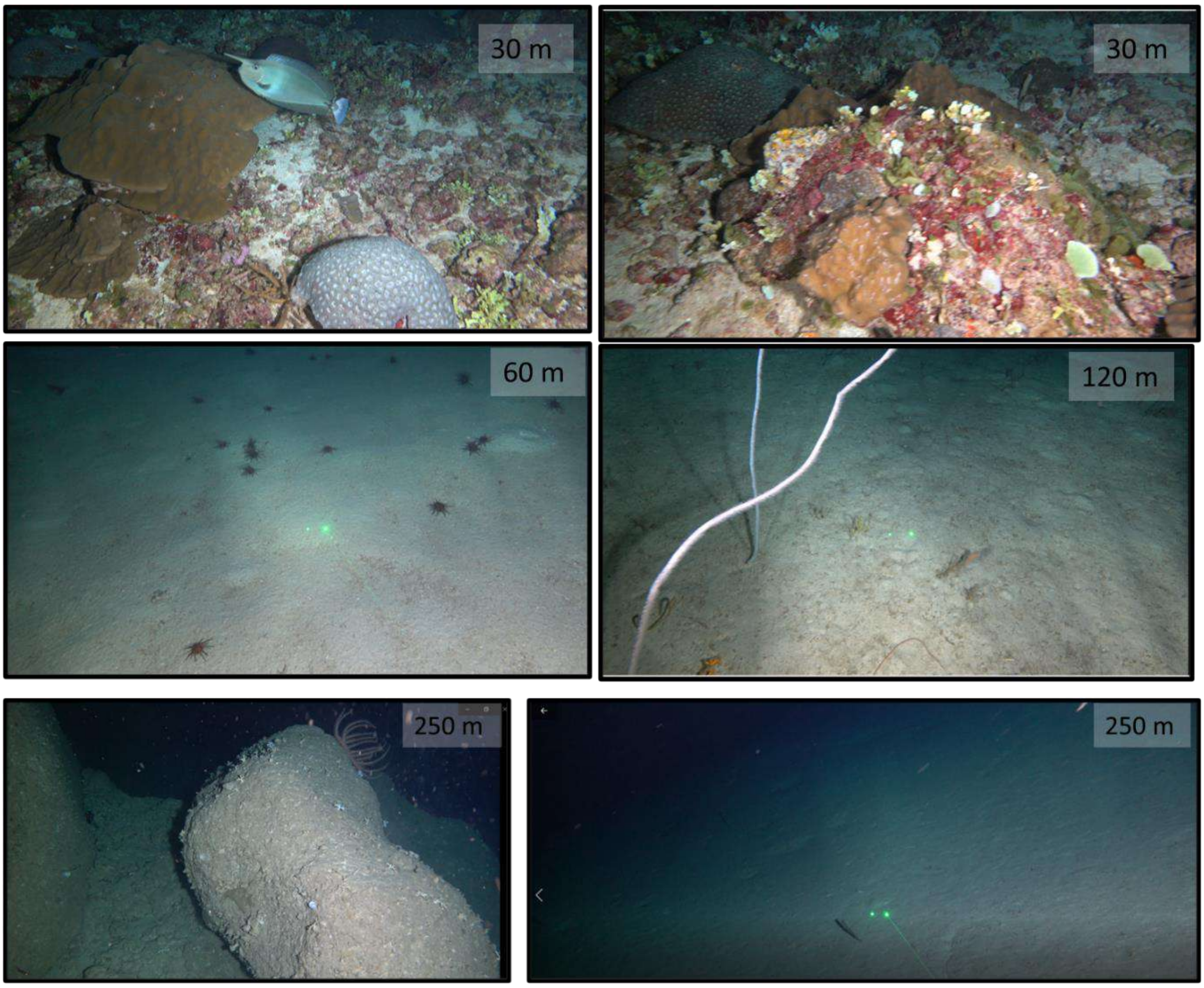
ROV004: SDM_004 West Saya De Malha

30 m: mixture of algae (*Halimeda* and encrusting algae) and coral as well as thodoliths. These corals included species like *Porites*, *Acropora* and *Turbinaria*. A mixture of different fish species were seen such as; white tip reef shark, moorish idol, snappers, groupers, surgeonfish, squirrelfish, rabbitfish, parrotfish and unicorn fish.

60 m: sandy bottom with no boulders or complex 3D structures, presence of red algae in high abundance and large aggregations of sea urchins. Limited diversity in seen with regards to corals. Large aggregations of sea urchins were present.

*120 m: r*ocky habitat with some sandy patches. Presence of some 3D structures in comparison to 60 m. Large quantities of coil corals (possibly Junceella / Viminella) and black corals.

250 m: sandy habitat with what appears to be large boulders at the end of the transects. Sandy bottom mostly consisted of brush black coral and echinoderms (sea urchins and sea stars). Boulders with complex structures had a bit more life, with a sighting of a Darwin slimehead as well as a large aggregation of shrimp, a variety of sponges and bryozansa. As well as stylastrids and a sighting of a Brinsingidae as previously seen in the Nansen cruise in 2018.

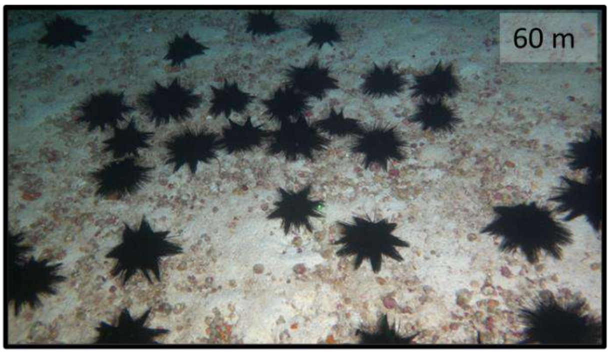


<u>ROV005: SDM_005 South West Saya De Malha</u>

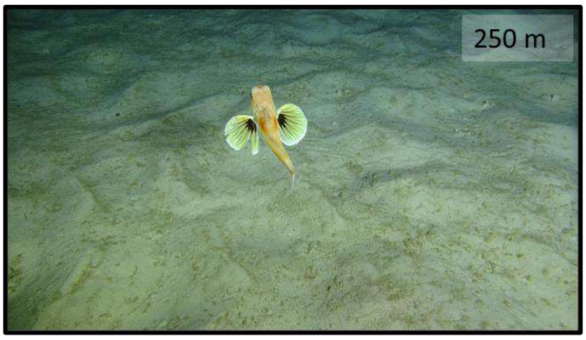
30 m: Transects conducted at 60 m because the 30m and shallower depths were too far away for transit.

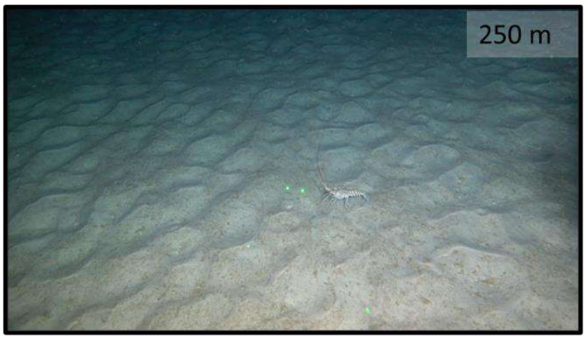
60 m: Sandy habitat with scattered rubble and large fields of rhodoliths, intermittent presence of black brush coral. Porcupine fish as well as echinoderms were sighted.

120 m: Sandy habitat with outcrops rocks creating complex structures. Some areas covered in rohdoliths. There was a prevalence of whip corals with some fan corals sponges, crinoids and red algae. Fish present include a single sighting of a file fish, nurse shark, several butterfly fish, Moorish idols.



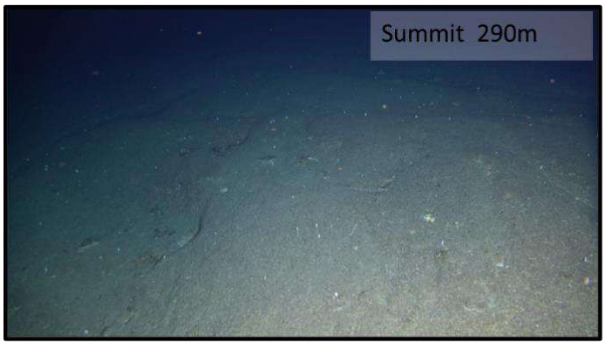
250 m: Dominantly sandy habitat with some algae and very little sponges or corals. Limited diversity in benthic and pelagic species. Several sightings of sea robbins (gurnards), lizard fish and a single sighting of a cray fish.

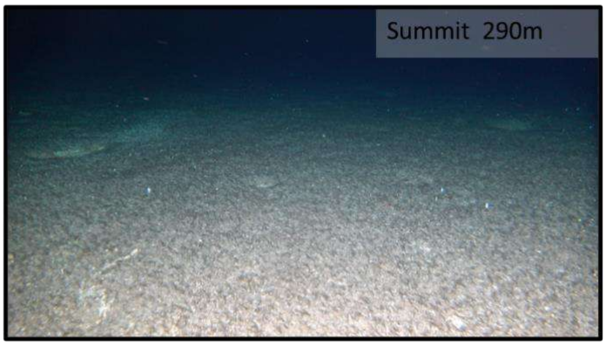


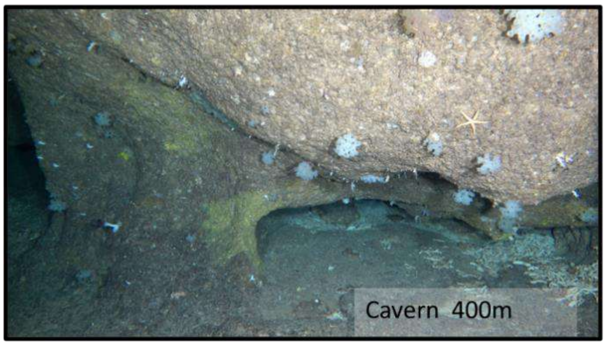


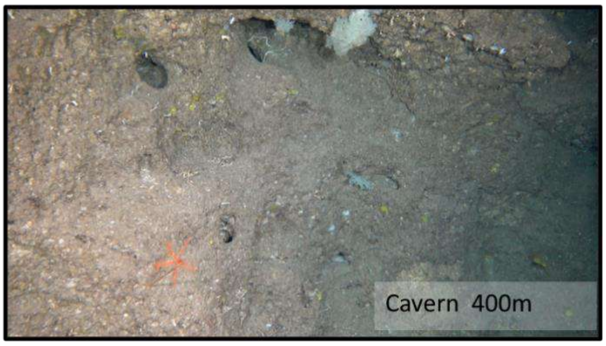
ROV6: SDM_006 Site Seamount South West Saya De Malha

The summit of seamount at 295m was made up of hard calcareous rock with pots and crevices of sand. Crevices and holes were occupied by bentho-pelagic fishes like sea robins (flying gurnards). Presence of some scattered sponges and solitary corals the dominant species seen were Stylastrids.

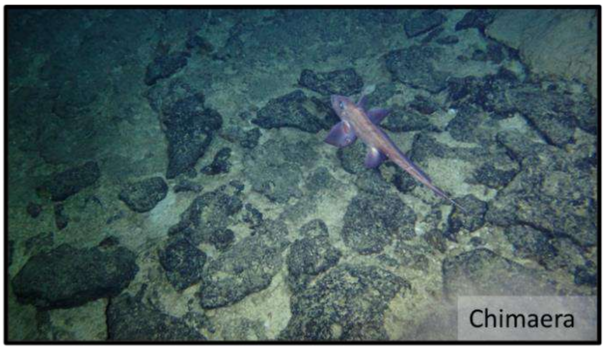








The flanks of the seamount was a complex system of caves and caverns on an almost vertical ledge dominated by sponges, crinoids, bryozoa and stylastrids. A variety of fish species were seen including single sightings of Darwin slimehead, chimaera and a hammerhead shark.



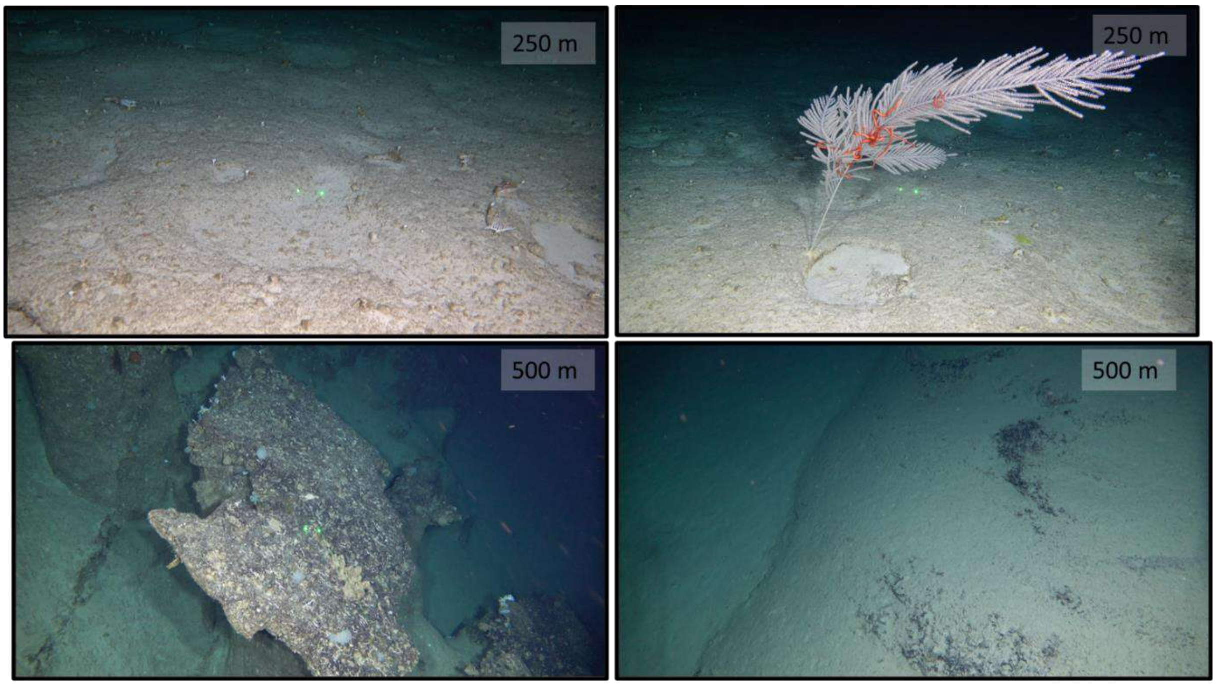
<u>ROV7: SDM 007 South East Saya De Malha</u>

No transects were conducted at 30,60 or 120m as the transit times to these depths were too far away for the allocated time. Transects were conducted at 250 and 500m only.

250 m: This area was similar to the seamount in structure, hard calcareous rock with caverns of sand. These caverns and cave often had the presence of a varity of fish. The dominant benthic species seen was stylastrids with interdispersed yellow fans. There were a few white fans sighted during the transect covered in sea stars, crinoids and on two occasions large white crabs.


Large white crab on fan coral, 250 m

500 m: Transects were conducted along the steep wall of the 500m line. This area was a mix of hard basalt rock outcrops and sandy slopes. Sandy slopes were quite bare, with some outcrop of whip corals. The Basalt rock in most cases were covered in bryozoans, sponges, yellow fan corals and polychaete casings.



5.9 Megafauna (WP9)

Coordinator: Bernard Rota

GLOBICE-Reunion is a scientific association whose objective is to study cetaceans in Reunion Island for the purpose of conservation. The Prefecture of Reunion Island approved GLOBICE in 2006 as an "Environmental Protection" association. GLOBICE is working in partnership with several organisations, research institutions and stakeholders, both at the local, national and international level, including the University of Reunion (Entropie lab), IRD, Ifremer, the International Whaling Commission, the International Union for Conservation of Nature (IUCN), etc... GLOBICE leads the IndoCet Consortium, a network of researchers actively involved in cetacean research and conservation in the South West Indian Ocean (www.indocet.org). GLOBICE promotes the results of its research programmes to the scientific community through peer-reviewed publications and conferences, to the local authorities and stakeholders (DEAL, Région Réunion, DMSOI, RNMR, etc.) and to the general public (conferences, school interventions, etc.).

The participation of a Marine Mammal Observer (MMO) in the Monaco Explorations Indian Ocean Expedition conducted from 31st October to 22 November from Seychelles to Mauritius, aims at carrying out a visual and acoustic survey on cetaceans, and marine megafauna in general, in this remote area. This campaign represents a unique opportunity to assess the presence of cetaceans along the Mascarene Plateau, and in particular Saya de Malha Bank and St Brandon shoal, which were poorly surveyed for cetacean to date. Within the framework of the present campaign, visual and acoustic monitoring was carried out by an experienced observer on board the *S.A. Agulhas II* (B. Rota).

5.9.1 Methods

The detection of marine mammals is based on both visual an acoustic monitoring. The visual survey consists in a continuous surveillance of the water surface by an experienced observer to detect the presence of cetaceans. Observations of other marine megafauna, marine birds, sea turtles and elasmobranchs, is also recorded, as well as marine debris.

The acoustic monitoring consists in collecting acoustic samples using an autonomous hydrophone, for later analysis.

The equipment used on board to capture megafauna data is made of:

- A Canon 70D camera with a 150-600 mm zoom lens
- A Garmin 73 GPS
- A pair of Swaroski 10x30 binoculars
- Standardised data sheets for reporting survey effort and sighting data
- A laptop computer for downloading and saving data
- An autonomous acoustic recorder (SoundTrap 300STD (Ocean Instrument).

5.9.1.1 Visual monitoring

A standard visual survey method was applied along the vessel track. It consisted in continuous monitoring at the front and on each side of the boat to detect the presence of cetaceans (or other marine megafauna) at the surface.

The upper deck of the boat, above the bridge, located 23m above the water, provided a 320° field of view on the horizon, allowing a visual detection up to several hundred meters (for dolphins) to few kilometres (large whales), depending on the species. A glass shelter was also provided. During transits, the vessel speed was around 14 knots and the visual survey effort was mainly focused to the front, within an angle of about 120°. This visual field was extended to 320° (160° on each part of the boat) when the vessel was stationary or steering at low speed (1.3 knots) to drag gear. Visual monitoring was carried out every day, over a period of time ranging from 8.15 a.m. to 6.15 p.m., with some breaks for lunch and resting (no possibility for switching observers since there was only one observer on board).

The vessel track was recorded using a handheld GPS. Visibility conditions were rated on a scale of 1 to 5, based on an assessment of environmental factors that may hinder animal detection, mainly wind speed, swell height and light conditions:

1: Null (wind > 4 Beaufort, waves or night),
2: Poor (wind >3 Beaufort, many « white horses » or low light),
3: Average (wind at 2-3 Beaufort, with some « white horses » or moderate swell),
4: Good (wind ≤2 Beaufort, calm sea, no swell),
5: Excellent (flat sea).

In case of visibility conditions lower than 3, the visual survey is normally interrupted. During this cruise, however, it was continued in order to detect any opportunistic sighting of marine mammals.

The detection of cetaceans and seabirds was carried out with naked-eyes, binoculars being used only to confirm the detection and the species identification and to collect sighting data. Whenever possible, photographs were systematically taken to confirm the species identification.

When observing cetaceans, or other megafauna, the following sighting data was recorded using a standardised datasheet:

- GPS position (latitude/longitude)
- Species
- Estimated group size
- Group activity (surface resting, foraging, breeding, travelling, undetermined)
- Radial distance between the animals and the vessel
- Bearing angle of the animals in relation to the ship's course.

These last two parameters allow to compute the perpendicular distance (x) of the animals to the vessel's track and therefore to estimate the width of the band being surveyed on either side of the vessel).

Monitoring of avifauna (and other megafauna) was carried out in conjunction with cetacean monitoring. Because sightings of seabirds are generally more numerous, only the number of individuals and their activity (flight, landing, chasing) were noted. Most identifications were made with binoculars based on morphological (size, colour, wing shape, etc.) and behavioural characteristics (frequency of wing beats, flight altitude, hunting technique, etc.). Photographs were in cases where there was a doubt on the species identification.

Observations of marine debris were also recorded. A photograph was systematically taken for further description.

5.9.1.2 Acoustic monitoring

The SoundTrap 300STD was deployed from the dinghy, during the dive trips, to get away from the noise generated by the *S.A. Agulhas II*. The acoustic recorder was either attached to a video mooring (IRD team) deployed at the bottom by the divers in depths of 25-30m, or towed behind the boat in deeper waters. The ST300STD was set to record continuously, using a sampling rate of 92kHz. The recording were analysed at the end of the survey to detect the presence of cetacean's vocalisations, within a radius of a few hundred metres (dolphins) to a few kilometres (large whales and sperm whales).

5.9.2 Preliminary results

5.9.2.1 Visual survey effort

A total of 119h of survey effort was carried out by the observer for 16 days, representing an average daily survey effort of 7.5h. The general visibility conditions encountered during the visual survey were mostly average to poor in the Saya de Malha area, severely restricting the detection of cetaceans. Good observation conditions (visibility of 4 and 5) were recorded only during half of the survey effort.

5.9.2.2 Marine megafauna sightings

During Part 2 of the cruise, 26 sightings of marine megafauna were made, including 9 species clearly identified. These species were grouped into three taxa: seabirds, cetaceans and marine turtles. Up to 40 observations of marine debris were also made.

Cetaceans sightings: Only two cetacean sightings were made during the survey, which were common bottlenose dolphins (*Tursiops truncatus*), representing a cumulative number of around 65 individuals. These sightings occurred on the eastern part of the Saya de Malha Bank.

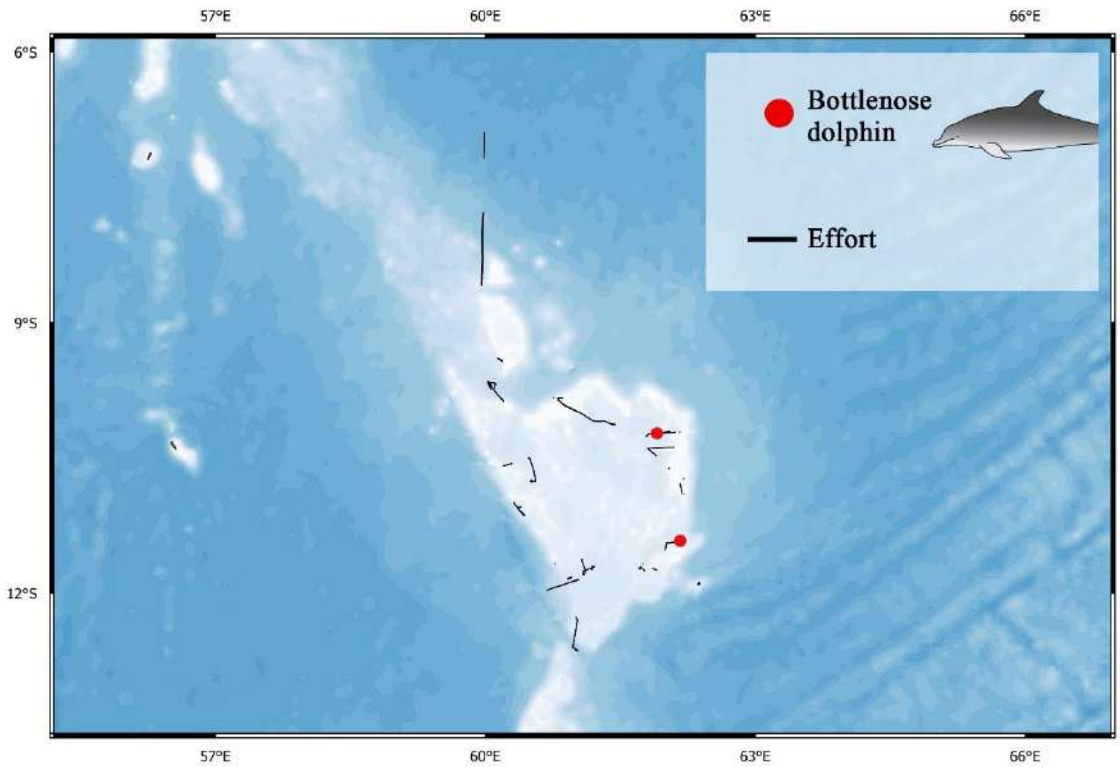


Figure 30. Map of cetacean sightings recorded during visual watch (effort) along the track.


Bottlenose dolphins (Tursiops truncatus) observed on the Saya de Malha Bank

<u>*Seabird sightings*</u>: Seabirds were the most common taxa observed (22 sightings). 5 species were clearly identified, most common species were sooty terns (n=6) and white tern (n=5).

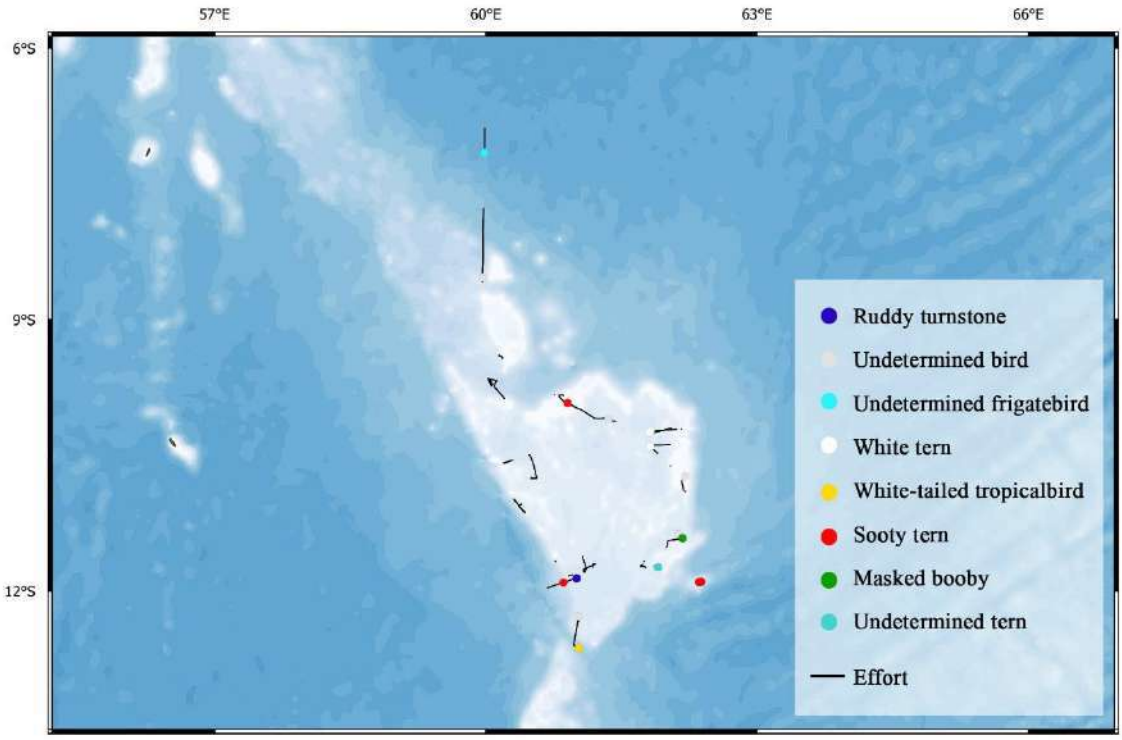


Figure 31. Map of seabird sightings recorded during visual watch (effort) along the track



Photos of white tern (left), masked booby (middle) and ruddy turnstone (right) observed during the survey

Sea turtle sightings: One green turtle (*Chelonia mydas*) and one hawksbill turtle (*Eretmochelys imbricata*) were sighted close to the boat, on the Saya de Malha Bank.

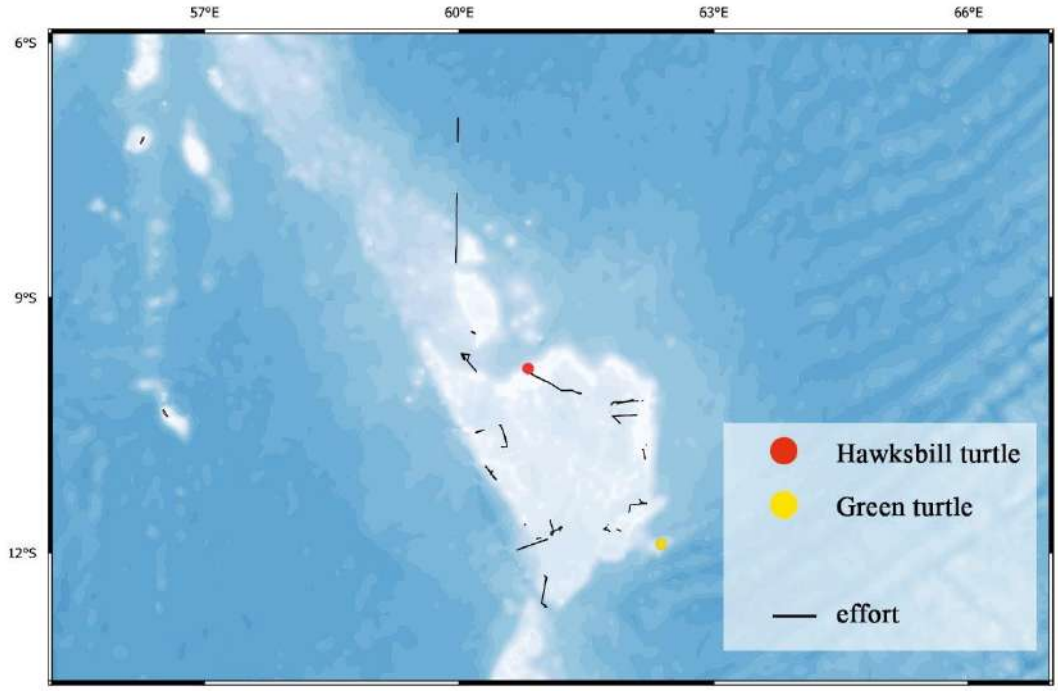


Figure 32. Map of marine turtle sightings along the track

Marine debris: During the survey, a total of 40 observations of floating marine debris were made. The majority of these were spotted on 2 days: 15 pieces of marine debris were seen on 09/11/2022 and 19 on 10/11/2022 in Box 3, east of the Saya de Malha bank. On 09/11/2022, the debris were concentrated between 10.3876 S/61.8549 E and 10.38 S/62.0903 E; and on 10/11/2022 between 10.210 S/62.160 E and 10.20 S/62.0055 E. This concentration of litter could be the result of converging marine currents. Some life was observed on the debris (shell, crabs) or underneath (fish).

5.9.2.3 Acoustic monitoring

5 recordings of approximately one-hour duration were made on the Saya de Malha Bank. Acoustic analysis of the recording indicated that no cetacean sound was recorded, while other types of biological sounds were recorded (Table 18).

Table 18. Acoustic recording during the S.A. Agulhas II survey

Date	Latitude	Longitude	Recording duration	Biological sounds
2022/11/09	-10,61	62,04	01:34:12	Fish sounds
2022/11/10	-10,38	62,13	01:40:55	Fish sounds
2022/11/11	-10,73	62,20	01:10:11	No biological sound
2022/11/11	-10,90	62,19	01:25:03	Fish sounds
2022/11/13	-10,90	62,01	01:24:04	Fish sounds

5.9.2.4 Preliminary conclusion

This opportunistic marine megafauna survey along the Saya de Malha Bank in the south-western Indian Ocean allowed the collection of few visual sighting data on cetacean and megafauna species in general. The low number of sighting is probably due to the poor sea-sate and visibility conditions encountered during the survey but also to the fact that this was not a megafauna-dedicated survey. A lot of time was spent in shallow waters, on the shelf of the Saya de Malha Bank, as opposed to the edge and the slope of the bank usually richer in cetacean diversity. The speed of the boat during transits was also quite fast which also made cetacean detection difficult. The presence of only one observer also limits the number of detections. These observations however complement the data available for this remote area, which was only poorly surveyed for cetaceans.

The data will contribute to the Indocet regional database, which aims at collating cetacean distribution data collected by MMO in offshore waters of the south-west Indian Ocean. The results will be disseminated regionally, via the Indocet Consortium, and will contribute to increase knowledge within existing Important Marine Mammal Areas (IMMAs) or might contribute to the identification of new ones. The results of the survey will also be disseminated locally by the partner organisations, via their various networks and outreach

5.10 The International Law of the Sea and its relationships with marine science

Coordinator: Florence Galletti & Dass Bissessur

The Ocean Science for governance theme aims at strengthening the understanding of the links between the International Law of the Sea and marine sciences, to inform the process of public decision-making in the ocean space.

5.10.1 Methods

International Law of the Sea Perspective and analysis

The status of the environment, close to the coastline, or in remote or deep areas, is not one of the unmentionables of the UNCLOS text. It has recognised marine scientific research (Part XIII, UNCLOS), in its capacity to inform and analyse ocean resources. Distinct from environmental Law, which addresses the marine domain in the perspective of protecting the natural environment, international Law of the Sea is now in need of instruments to keep the biological diversity in a status that is good enough to allow some level of exploitation. The division of maritime spaces remains the framework within which these concerns are addressed.

Fixed spaces or evolving ones in the Law of the sea applied to the Western Indian Ocean

This oceanographic campaign takes into account the diversity of these zones and their regimes, taking due account of the Republic of Mauritius and the Republic of Seychelles rights, jurisdictions and duties in the framework of a) the *Treaty concerning the joint exercise of sovereign rights over the continental shelf in the Mascarene plateau region, 13 March 2012*, as a bilateral agreement which created the Mauritius-Seychelles JMA, and b) of the *Agreement between the Government of the Republic of Mauritius and the Government of the Republic of Seychelles on the Delimitation of the Exclusive Economic Zone between the Two States, 29 July 2008*.

Law of the Sea applied to marine sciences and their practical concerns

Exchanges in the discussion group/self-education are built around law basic concepts, their historical use by States Parties to the Nairobi Convention (UNEP Regional Sea, 10 State Parties), and modern topics closely involving ecological sciences, geosciences and Law at sea and on oceanographic vessels. The spontaneous exchanges and training sessions are to illustrate 1) the relationship between Law and marine sciences which might be thought to have nothing to do with each other, and 2) the cases where the Law of the Sea is dependent on the data provided by marine research science to support public decision-making.

Overview of demands for the use of ocean areas and the legal issues this will raise

The presence of a range of profiles among the marine scientists on board is an opportunity to exchange free information on scenarios and demands for ocean uses that scientists and high-level policy makers are witnessing, that UNCLOS and partial cases have not foreseen. Researchers will have to be better prepared to new legal provisions announced in the BBNJ Treaty ("*International Legally Binding Instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biodiversity of areas beyond national jurisdiction*", IG5-1 August 2022 & IG5-2 February 2023), to industrial innovations requiring new uses as carbon dioxide removal technologies etc. and discuss how the current law can accommodate or reject this.

5.10.2 Preliminary results

Mobilizing marine and human sciences together for WIO State public decision support effort is quite new (for National Strategies or for WIO Regional Ocean Governance Strategy, ROGS 2023). The WP10 “Governance, Law of the sea, marine sciences, to public policies” try establishing several links between various disciplines for better describing cases matters of concern. It implies increasing the level of knowledge on common subjects, non-usually analysed with the same reasoning. Several trainings were useful between researchers working on closed thematic (environmental data, deep ecosystem, deep structures…) but without materials inferred from Law of the Sea, International fishing Law and environmental Law at Sea.

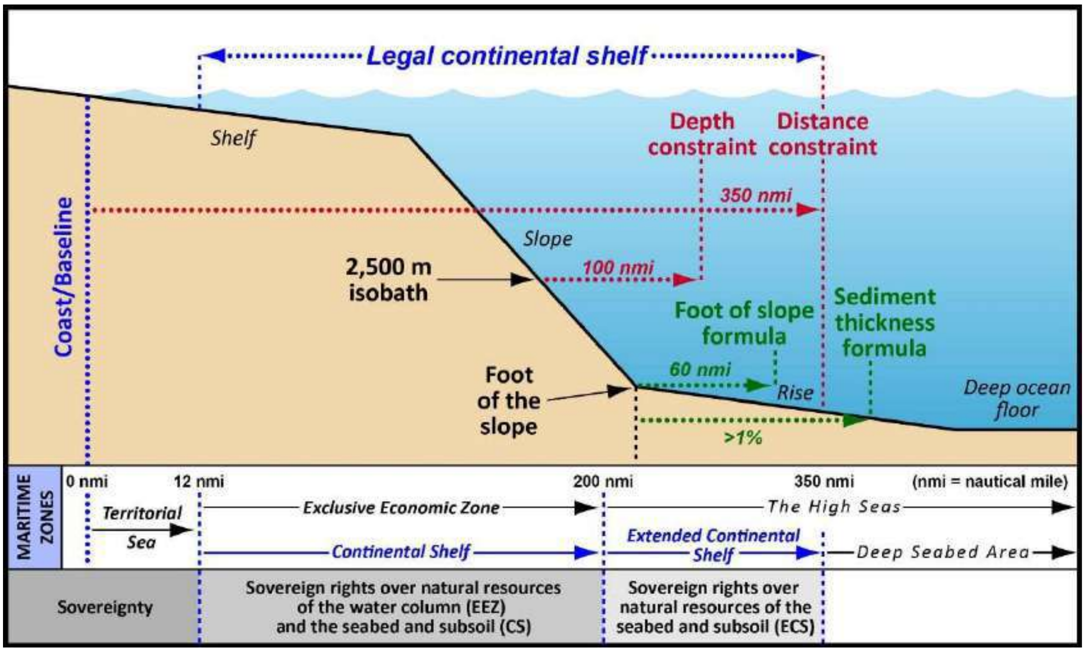


Figure 33. Maritimes zones and the procedures to establish the outer limits of the continental shelf on the Law of the Sea and LOSC (source: CLCS 2021)

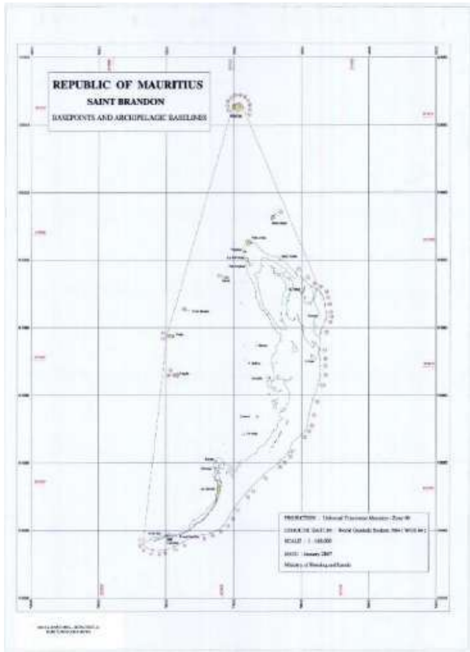
5.10.2.1 Training sessions

A choice of three training workshop was proposed for scientists members of public bodies, lecturers at Mauritius and Seychelles universities, high-level students, and civil society or stakeholders presents on board, and also for the crew of the *S.A. Agulhas II.*, on the 18th , 19th and 20th November 2022 . Up to 31 participants attended the three training sessions.

<u>Training 1 - Basic concepts and divisions of ocean areas, general aspects and Indian Ocean aspects“ (2h30)</u>

The "new Law of the Sea" originates from the United Nations Convention on the Law of the Sea (UNCLOS) of 10 December 1982, which came into force as from 16 November 1994. Its application in the Western Indian Ocean resulted in mapping maritime zones in accordance with UNCLOS, customary law, or international court judgments. On the one hand, spaces are mostly delimited by scientific approaches, such as internal waters, territorial seas, contiguous zones, exclusive economic zones (EEZ), single or extended continental shelves, the high seas, and the international Seabed area. On the other hand, sub-divisions are formed by fisheries zones, or specific marine spaces like archipelagic waters and baselines claims (the Republic of Seychelles as an example of a user of both normal and archipelagic baselines for four separate groups of islands) and their legal regimes.

This training addresses this fragmented governance, boundaries, delineation, and evolving maritime areas and claims, the 21th century legacy, to facilitate the step towards the second training more focused on ecological descriptions and the legal means to exploit or conserve several habitats and resources (Fig. 34).



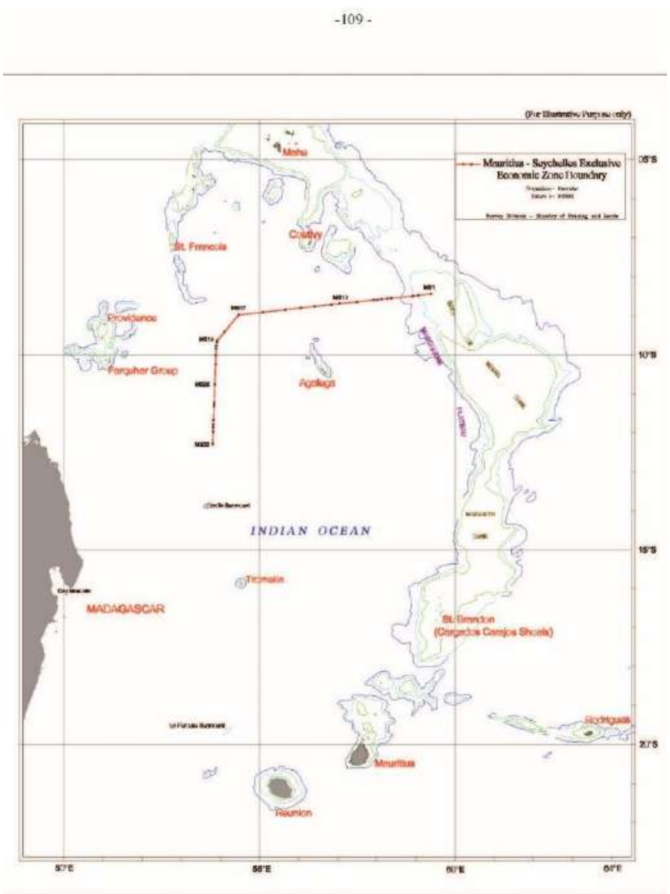
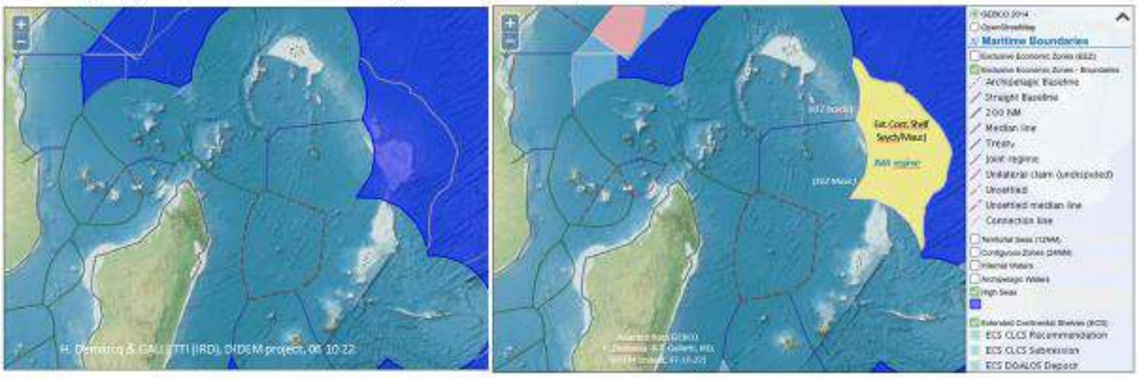


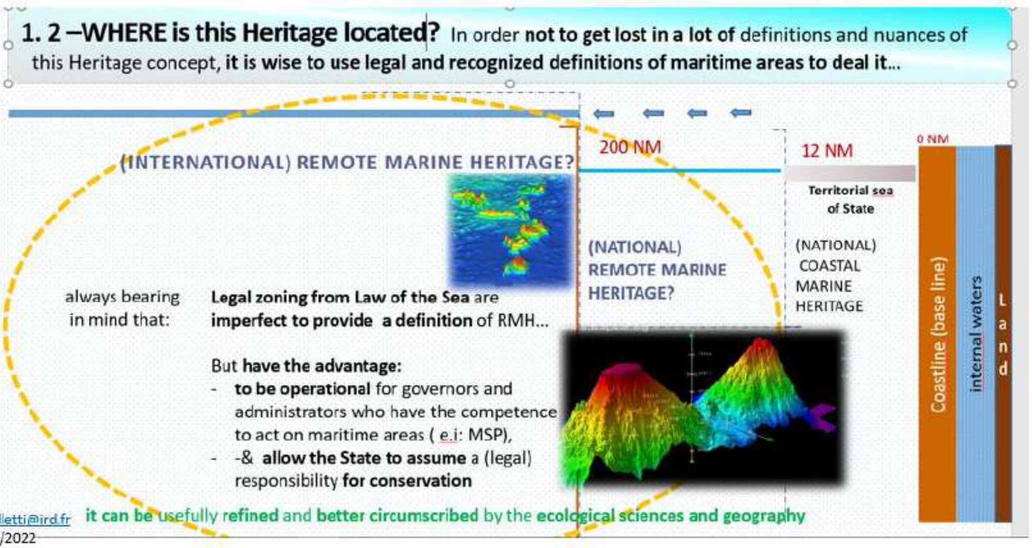
Figure 34. Delimitation line in the Agreement between the Government of the Republic of Mauritius and the Government of the Republic of Seychelles on the Delimitation of the Exclusive Economic Zone between the Two States, 29 July 2008 (Source: Law of The Sea Bulletin, 2009, n°69, p.109).

Limits of the Joint Zone between Mauritius and Seychelles as contained in the *Treaty concerning the joint exercise of sovereign rights over the continental shelf in the Mascarene plateau region* of 13 March 2012



__Training 2 -"Remote Marine Environmental Heritage". How to address this crosscutting and emerging issue of biodiversity governance (2h30)__

After a short introduction to the Marine Heritage definition, this training focuses on where Remote Marine Environmental Heritage is located and what is being made in a context of large progress in marine sciences. It also explains why we deal with such distant areas in WIO and the need that justify it (precautionary approach, economics of nations, well-being, others etc.). A second part is showing how to act on the Remote Marine Environmental Heritage, both with support given by bio-geographical and ecological divisions and support given by legal regimes available. Two hypotheses are presented: 1) act on the Remote Marine Environmental Heritage inside a 200 NM marker; and 2) act on the Remote Marine Environmental Heritage beyond a 200 NM marker (Areas Beyond National Jurisdiction, under acronym ABNJ -). An overview of two sectors of governance in ABNJ (fishery Law & governance/ Mining regime & governance) is given, with examples relating to non-living remote marine heritage (minerals) and to living marine heritage.

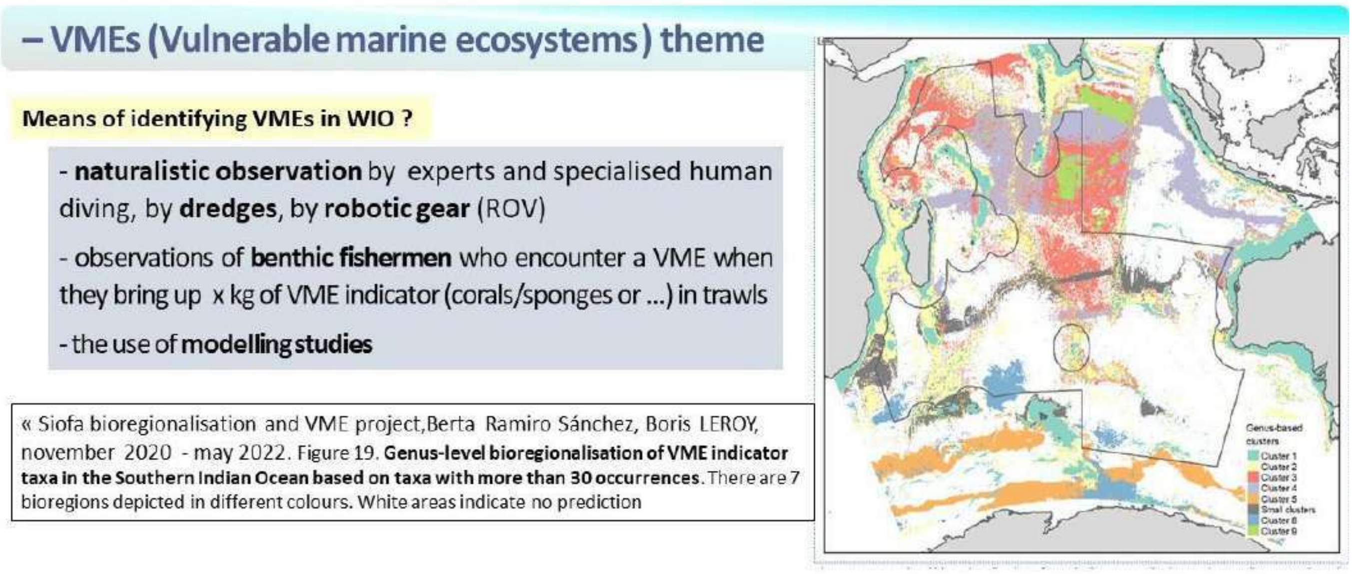


__Training 3 - Marine scientific research and Law of the Sea. Overview of some modern interactions and difficulties (2h30)__

This session aims at defining what marine scientific research (MSR) is done according to UNCLOS, what is part of MSR and what is not, and several related issues. It recalls the current situation where more steps are required (from marine sciences) to strengthen decision-making capacity for the conservation of marine heritage, and position of scientists in the face to this evolving situation.

Two specific cases were presented:

- identification of Vulnerable Marine Ecosystems (VMEs) and change in the legal regime if encountered (hard task, complementary or concurrency of real sampling data and modelling, deep-fishing sector supremacy on scientific advice)
- new issues and claims inferred from objects drifting at the ocean surface (floats from international Argo program, Fishing Aggregating Device FADS operated by the tuna industry, IUU fishing…)



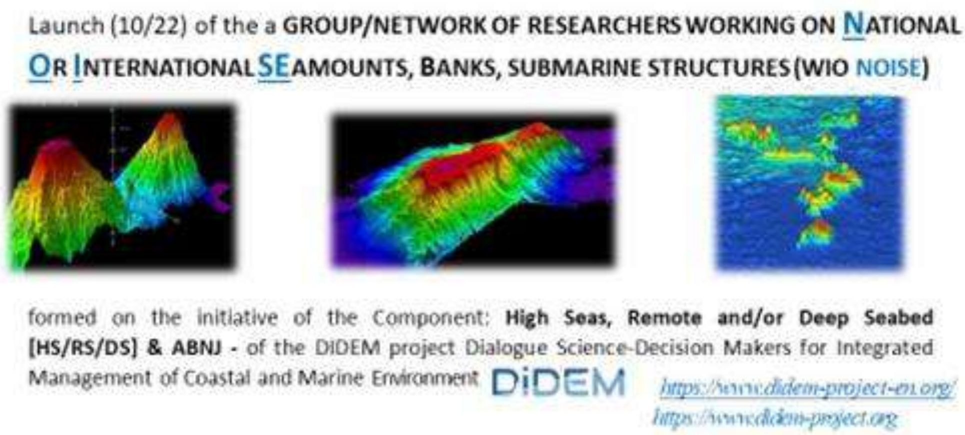
5.10.2.2 Role of the marine research for the remote and deep areas (JMA and other cases)

The discussion revolved around the following points:

- Do the Marine Spatial Planning exercises undertaken deal with Remote Marine Heritage, in whole, in part, not at all, etc…
- How to concretely initiate or increase scientific knowledge for the protection of the national Remote Marine Ecological Heritage?
- How does the discipline you represent and the work you do benefit both public policy and legislation in your country?
- What kind of data is urgently needed to protect the remote marine heritage?
- What about the research codes of conduct, the National researchers legal status and other kind of free research or research framework? Is there anything missing?

The first answers were a bit contrasted about the lack of data (which one, and which are the most urgent to collect), and to do what, notably the gap of economics data about environments, and how to speak about WIO environments in front of decision-makers? Answers converge to the fact that funds dedicated to marine sciences at low and high level are insufficient in face of the challenge to tackle, and the human capacity needs. The need of adapted technologies transfers, well-trained national experts, and the challenge into environmental education of the younger generations was unanimously recalled.

5.10.2.3 Launch of a group/network of researchers working on WIO national or international seamounts, banks and submarine structures



Opportunity

The DIDEM project (Dialogue Science-Decision Makers for Integrated Management of Coastal and Marine Environment, 2021-2023, ***https://www.didem-project-en.org***) has defended the merits of a cooperative campaign physically bringing on board researchers from both countries and other nationalities (France). It is an opportunity to confirm the launch of a GROUP/NETWORK of researchers working on WIO NATIONAL OR INTERNATIONAL SEAMOUNTS, BANKS and SUB MARINE STRUCTURES, which was announced at the 12th WIOMSA Symposium (10-15 October 2022) , during the Mini-Symposium "The contribution of marine science in areas beyond national jurisdiction in the western Indian ocean to the development of a regional ocean governance strategy", where a first meeting with the Mauritian delegation had taken place.

Theme: WIO seamounts as ecosystem and habitats monitoring and governance

A large number of WIO seamounts are concentrated along the South West Indian Ridge, on the Mozambique Plateau and on the plateau that extends over 1100 km south of Madagascar (Madagascar Ridge, Walters Shoal…), on the north of the Madagascar and to the north of Mauritius, and as far as the Seychelles, the Mascarene Ridge (from south to north, St. Brandon, Nazareth and Saya de Malha Plateaus…). Lot of them are probably remarkable in several aspects: abundant biodiversity, concentration of prey for predators, waypoints in the displacement of migratory species, VMEs. Because of their supposed biological abundance and richness (fishing operations are common), sometimes because of their mineral resources, these structures are of interest for many operators and this can threaten their particular ecosystems. The legal protection in the form of a governance framework to regulate exploitation of these features is almost absent, at least insufficient in the WIO, except for recent regulations on some benthic fisheries (SIOFA conservation and management measures - CMM) and perhaps for the JMA's case and Marine spatial planning exercises. More generally, closer to the coasts, the MSP varies (between 2014 and 2023…) depending on whether the pre-planning exercise was done in Seychelles or in Mauritius. During the first quarter 2023, the drafting of the MSP is underway for the JMA. Describing this feature, after others WIO cases, by means of advanced ecological knowledge and data collected informs on science-based conservation and may support the States (action within EEZ and continental shelf, possibly bilateral agreements, and multilateral strategies/actions) to engage any form of network protections on sites only partially documented by the LMEs, the EBSA process, or the previous WIO oceanographic cruises. The oceanic and legal sciences brought together will characterize the ecological features and legal status of these areas and will inform the process of a responsible public decision-making.

6 Technical training sessions

Apart from the training sessions dedicated to the Law of the Sea, described in detail in section 5.10, two technical trainings were delivered on the ship, during the transit from Saya de Malha to St Brandon.

6.1 Training 1 – Decoding and analysis of CTD casts using the Seasoft package – 16 Nov 2022 (Jean-François Ternon, IRD)

After a review of the main physical properties of the water masses in the ocean, and their description in the West Indian Ocean, a detailed description of the Seasoft software SBEDataProcessing_Win32_V7.26.7-b40, and the way to use it on CTD casts was delivered by the trainer.

The software has been installed beforehand on the trainees' laptops. The exercises used the CTD casts files collected during the cruise. The training session was attended by 18 participants.

6.2 Training 2 – Mapping NetCDF data with R - 17 and 18 Nov 2022 (Francis Marsac, IRD)

This technical training was to familiarize scientists with the use of the R package to create a map, taking three case study: mapping the GEBCO 2020 bathymetry of the Saya de Malha Bank, mapping temperature and dissolved oxygen at a given depth (4-dimension files), and mapping currents (requiring two 4-dimension files, i.e. zonal and meridional components) . The session was run under RStudio. On 17 November, R with all its necessary packages and scripts were installed on the laptops, as well as the datasets used in the exercises. This pre-session was to ensure that the system was operating correctly before starting the exercises the next day.

The exercise session started by briefly describing the properties of a NetCDF (nc) file, and by making a very basic description of R. Then, we went through a series of simple R scripts, from the very basic ones to open and read a 'nc' file and gradually adding instructions to display the map, then customizing the isobaths to be represented on the map and the associated color scale (in the case of the bathymetric map). For the temperature/oxygen and current maps, the participants learned how to perform a selection of data in a 4-dimension grid (longitude, latitude, time, depth) and to display the map.

This training session was attended by 19 participants.

7 Acknowledgements

The Saya de Malha project was part of the Indian Ocean Expedition coordinated by Monaco Explorations. We are grateful to the Government of Monaco, which supported through Monaco Explorations most of the cost of the expedition, including the chartering of *S.A. Agulhas II*. This vessel provided an exceptional working environment for the scientific teams, contributing to strengthening capacities among the scientists of the region. Gilles Bessero (ME) has been instrumental in managing the long and complex preparatory phase of the expedition which spanned over two and a half years, and we all warmly thank him for his full dedication to the projects of the expedition.

8 Participating institutions

Seychelles

Seychelles Fishing Authority

Ministry of Fisheries and Blue Economy
Republic of Seychelles

Seychelles National Parks Authority

University of Seychelles

Mauritius

Department for Continental Shelf, Maritime Zones Administration & Exploration

MOI
Mauritius Oceanography Institute

Ministry of Blue Economy, Marine Resources, Fisheries & Shipping

University of Mauritius

France

IRD
Institut de Recherche pour le Développement
FRANCE

Muséum Nal Hist Naturelle

Other

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University of Lodz

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Rodney BONNE
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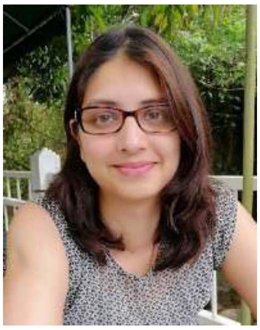

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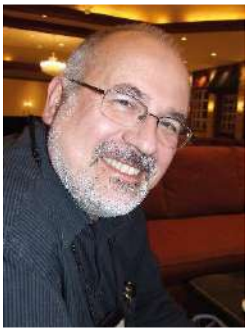

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Fabrizio d'ORTENZIO
Physical oceanography
Satellite data, Bio-Argo
CNRS, LOV, France