MOL (Mitsui OSK Lines) Mauritius International Fund for Natural Environment Recovery and Sustainability

Brief Report of Activities during 2024 fiscal year

Joint project with:
The University of Mauritius and
The Biodiversity and Environment institute (NGO)

Title of the Project

A scientific approach for the conservation and restoration of Mauritius Coral Reefs under the combined effects of climate change and marine pollution

Principal Investigator: Beatriz Estela CASARETO, Appointed Professor

Graduate School of Science and Technology (GSST)

Shizuoka University

Content of this report

(1) Joint field surveys at Belle Maare , Ille d'Ambre and Grand Goube reefs

* physico-chemical parameters of the water including nutrients, organic matter, light intensity, temperature and salinity
* Biological parameters including photosynthetic pigments, pico-nanoplankton, phytoplankton and zooplankton
* Physiological parameters of selected corals: pigments and zooxanthellae concentration, HAS, LPO, Glucose and Glycerol

(2) Physiological parameters of selected corals from Belle Mare and Ile d'Ambre: pigment concentration, density of the endosymbiotic algae Symbiodiniaceae and their health state, immune response (antioxidant enzymes, glucose Glycerol)

(3) Coral Incubation Experiment to test physiological responses under heat and strong illumination stresses

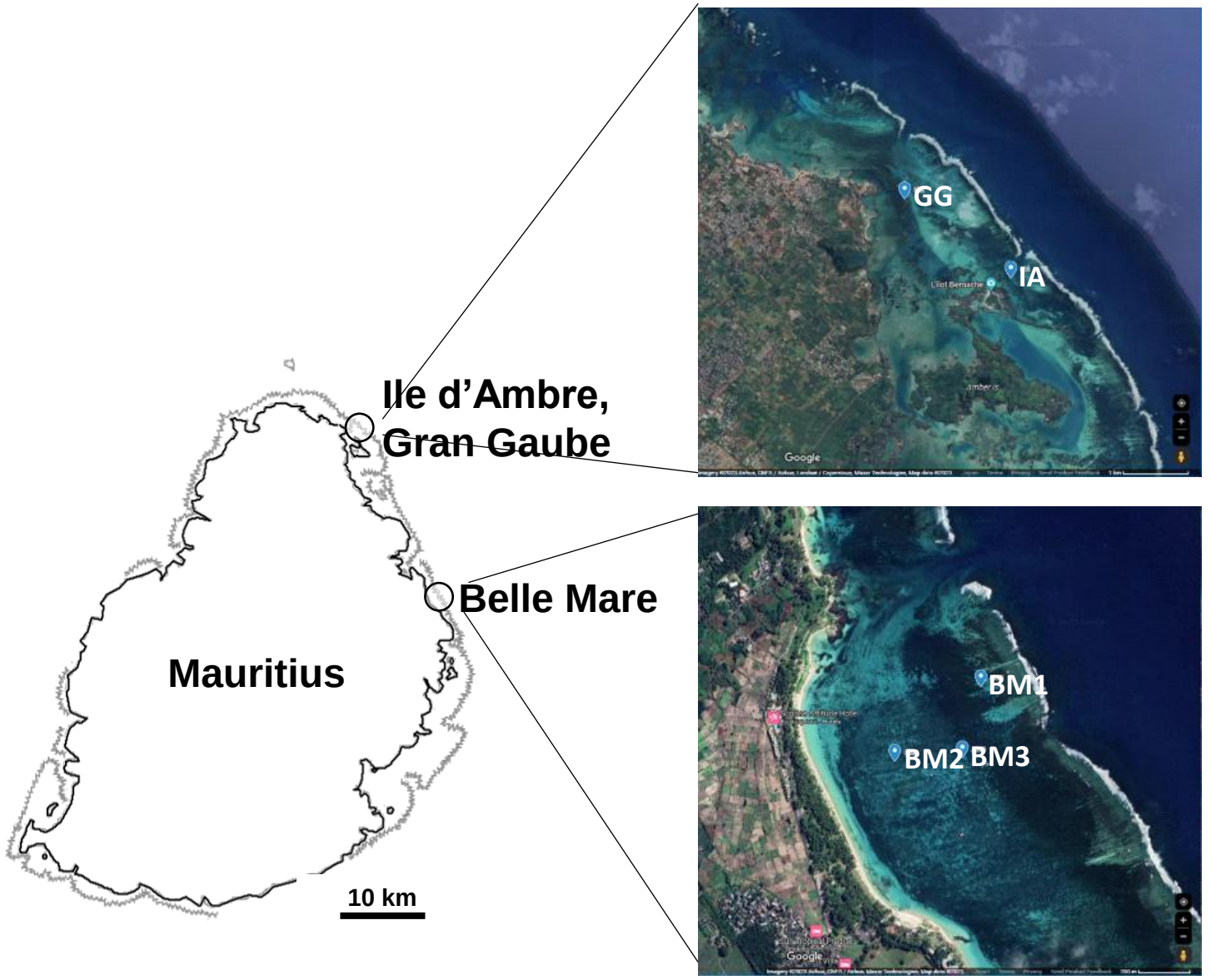
* Incubations objectives, targeted corals, set-up and methods
* Changes in ammonia concentration during incubations
* Changes in photosynthetic pigments and zooxanthellae concentrations
* Corals primary productivity
* Antioxidant capacity of corals: HAS and LPO concentrations
* glucose and glycerol concentrations

(4) Capacity Building: scientific and Social Impact

* Workshop on "Coral Reef and its associated Biodiversity under Climate Change" on 9 September 2024, Venue: Long Beach Hotel Resort, Belle Mare
* TV interviews, Scientific publications and presentations at International Symposia
* Educational Activities by BEI and UoM during fiscal year 2024

(5) 2025 fiscal year proposed schedule

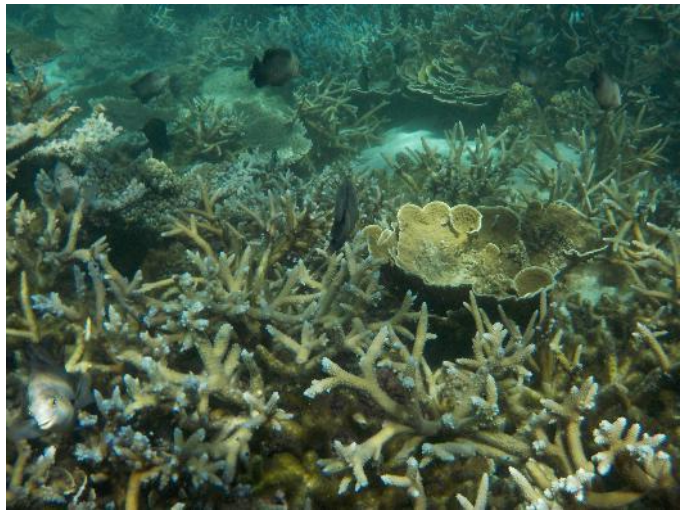
Location of the study sites (Belle Mare, Ile d'Ambre, and Gran Gaube) and surveyed stations.



Joint Survey (SU, UoM and BEI) at Belle Mare on September 3, 2024

Plankton sampling

Joint SU, UoM and BEI field trip



Corals' observation

Phosphate concentration was high in the three studies stations. This pattern is attributed to the effect of fertilizers added to the agriculture fields in this season of the year, therefore the N/P resulted to be lower than 10 which is the theoretical value. Station BM2 near the shore showed also lower salinity values indicating possible intrusion of spring water with high nutrient content.

Date Sampling point	2024/9/3 Belle-Mare Stn. BM1	2024/9/3 Belle-Mare Stn. BM2	2024/9/3 Belle-Mare Stn. BM3
NO3(µM-N)	0.332 ± 0.008	4.357 ± 0.137	0.264 ± 0.020
NO2(µM-N)	0.050 ± 0.004	0.095 ± 0.012	0.045 ± 0.005
NH4(µM-N)	0.437 ± 0.029	0.864 ± 0.043	0.549 ± 0.134
PO4(µM-P)	0.697 ± 0.257	0.669 ± 0.058	0.695 ± 0.345
SiO2(µM-Si)	2.575 ± 0.134	17.232 ± 0.598	3.283 ± 0.151
N/P(TIN/PO_4)	1.2	7.9	1.2
POC(µg/L)	47.4	57.0	40.0
PON(µg/L)	2.3	4.9	2.7

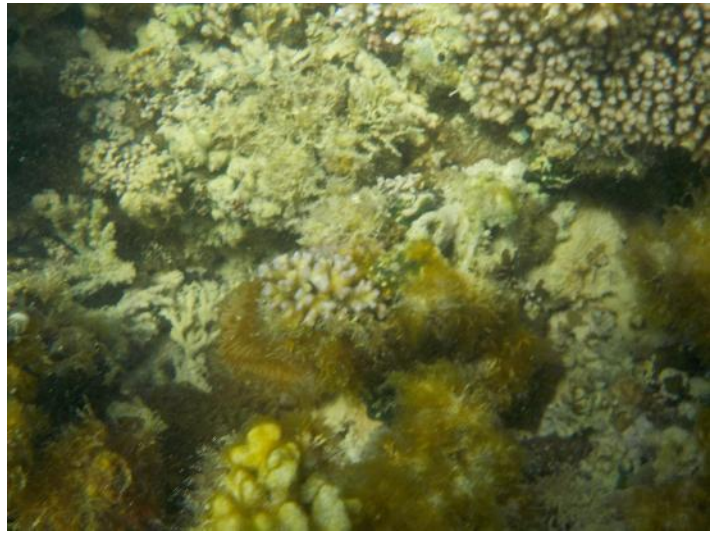
Date Sampling point	2024/9/3 Belle-Mare Stn. BM1	2024/9/3 Belle-Mare Stn. BM2	2024/9/3 Belle-Mare Stn. BM3
Depth (m)	2.7	1.8	2.1
Light (µmol/m^2 s)	606.7	466.6	618.8
Temperature(°C)	24.0	23.8	23.6
Salinity(psu)	35.2	34.1	35.3

Physico-chemical data taken during field trip

Joint Survey (SU, UoM and BEI) at Ille d'Ambre and Gran Gaube on September 7, 2024

Plankton sampling

Joint SU , UoM and BEI field trip



*Stylophora s*pp. corals at field

As same as in Belle Mare ,the effect of adding fertilizers is also evident in this field. Here the Nitrate concentration is also high at Grand Goube together with extraordinary Phosphate concentration, giving a very low N/P ratio.

Nutrients imputes in the reef waters as the consequence of adding fertilizers for agriculture, may affect the health condition of the corals and other reef organisms in Mauritius.

At Ille d'Ambre turbidity was observed as evidence from the low light intensity.

Date Sampling point	2024/9/7 Il d'Amble Stn. IA	2024/9/7 Gran Gaube Stn. GG
NO3(µM-N)	0.040 ± 0.037	0.748 ± 0.010
NO2(µM-N)	0.038 ± 0.006	0.127 ± 0.019
NH4(µM-N)	0.404 ± 0.081	0.742 ± 0.027
PO4(µM-P)	0.648 ± 0.144	0.866 ± 0.214
SiO2(µM-Si)	2.404 ± 0.133	6.453 ± 0.035
N/P(TIN/PO_4)	0.7	1.9
POC(µg/L)	66.5	54.4
PON(µg/L)	5.2	4.1

Date Sampling point	2024/9/7 Il d'Amble Stn. IA	2024/9/7 Gran Gaube Stn. GG
Depth (m)	1.7	3.1
Light (µmol/m^2 s)	395.2	574.4
Temperature(°C)	23.7	23.6
Salinity(psu)	35.1	35.2

Physico-chemical data taken during field trip

Some selected biochemical data collected at the two selected fields during September 2024

Pigments concentrations in the seawater

	Peridinin	Fucoxanthin	Diadinoxanthin	Zeaxanthin	DV-chl *a*	Chl *a* -allomer	Chl *a*	Total chl *a*
BM1	0.01	0.09	0.01	0.01	0.02	0.03	0.24	0.27
BM2	0.02	0.16	0.04	0.05	0.00	0.05	0.42	0.47
BM3	0.01	0.08	0.01	0.01	0.00	0.04	0.17	0.21
IA	0.01	0.09	0.01	0.01	0.01	0.02	0.23	0.25
GG	0.02	0.14	0.03	0.04	0.00	0.05	0.37	0.42

(µg pigments/L seawater)

Chl *a* was high at the near-shore station BM2 reflecting high phytoplankton abundance in this station. Chl-*a*-allomer (an oxidative form of chlorophyll *a*) was also high at Stn. BM2 suggesting the effect of multiple combined stressors on phytoplankton in the near-shore area.

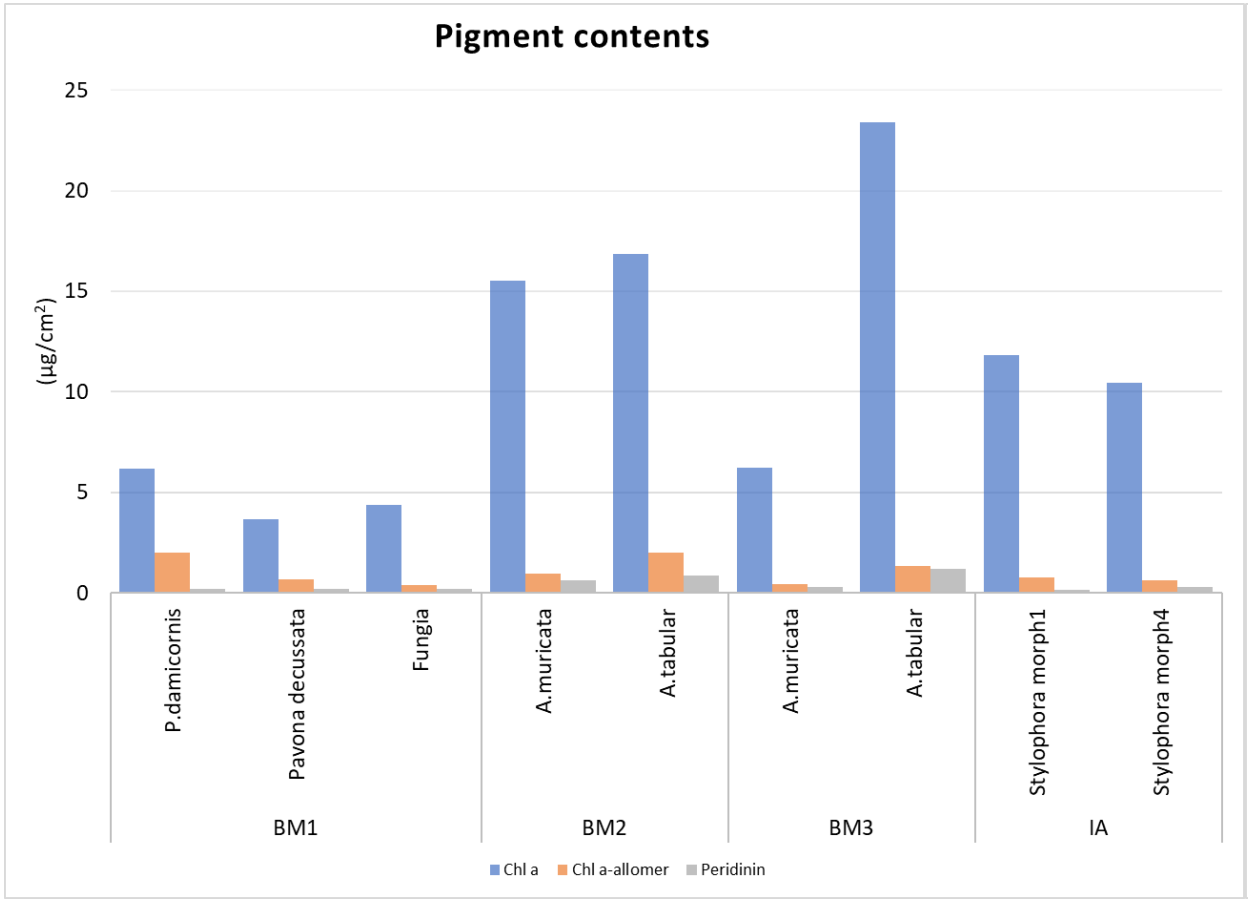
DV-chl-*a* *(*divinil Chl-a*)*(tracer pigment for the pico-cyanobacteria *Prochlorococcus* sp.) reflected the presence of *Prochlorococcus* sp. at Stn.BM1 and IA due to the inflow of open ocean water into those reefs. This is also in agreement with the high abundance of PCY at these stations. Bacteria abundance was high at Stn. BM2 and Ille d'Ambre indicating high microbial activity in those stations.

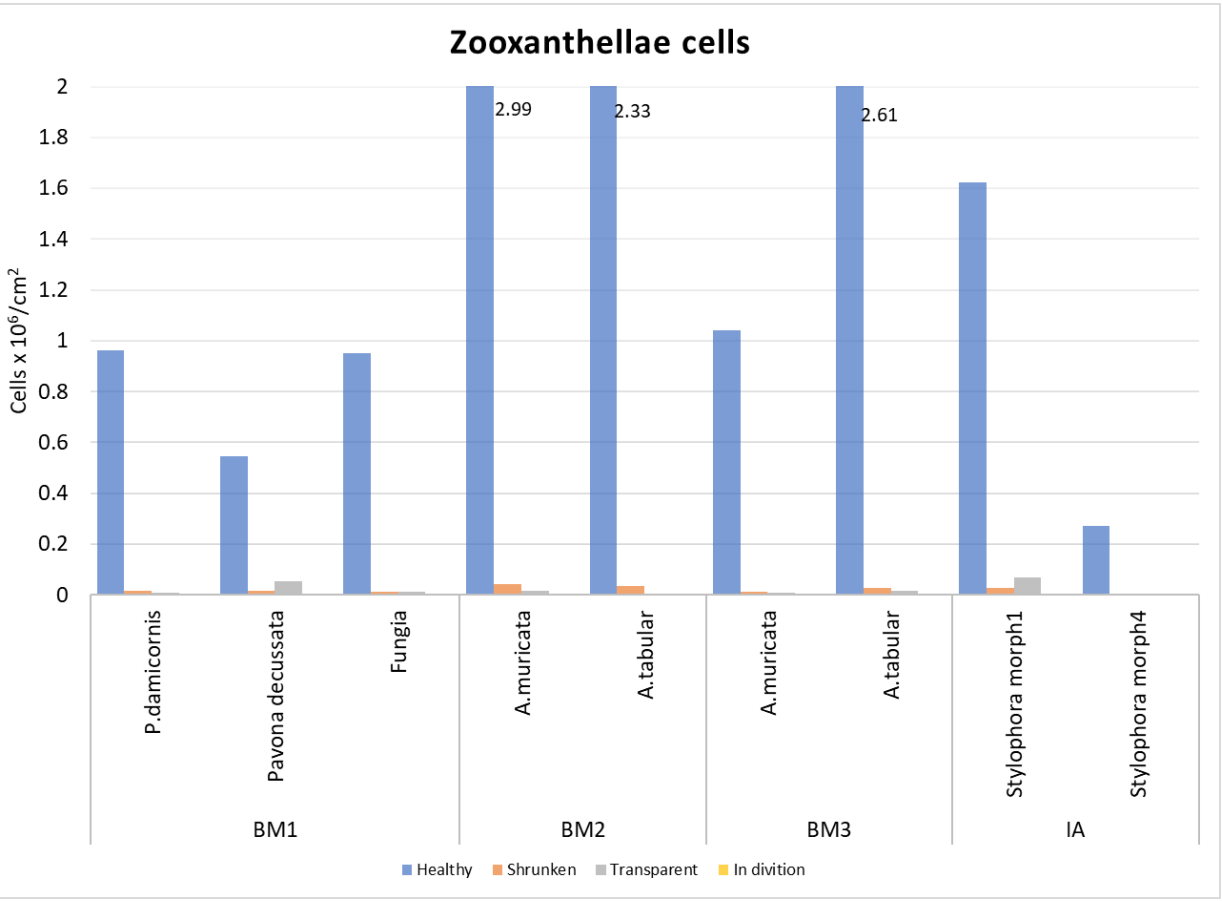
Pico-nanoplankton concentration

Station		Cells ml^{-1}
Belle Mare (Stn.BM1)	**BA**	150,908
	PCY	4,635
	HPNF	10
Belle Mare (Stn.BM2)	**BA**	541,462
	PCY	678
	HPNF	10
Belle Mare (Stn.BM3)	**BA**	209,350
	PCY	452
	HPNF	10
Ile d'Ambre (Stn.IA)	**BA**	634,531
	PCY	2,600
	HPNF	10
Gran Gaube (Stn.GG)	**BA**	284,635
	PCY	791
	HPNF	10

BA: bacteria; PCY: pico-cyanobacteria; HPNF: heterotrophic pico-nano flagellates

Physiological parameters of selected corals from Belle Mare and Ile d'Ambre: pigment concentration, density of the endosymbiotic algae *Symbiodiniaceae* and their health state



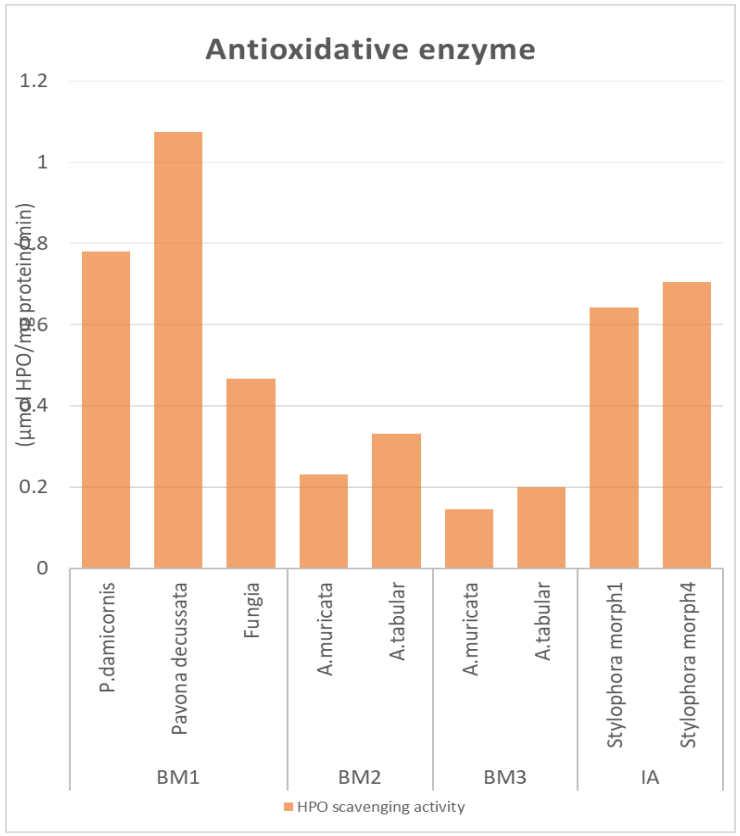


Chl-*a*, indicator of the abundance of the endosymbiont Symbiodiniaceae, varied among species. Particularly *Acropora tabular* kept high concentrations of Chl-*a* in both sites. Concentration of Chl-allomer, an indicator of oxidative stress, was high in *Pocillopora damicornis*, indicating some oxidative stress in this coral

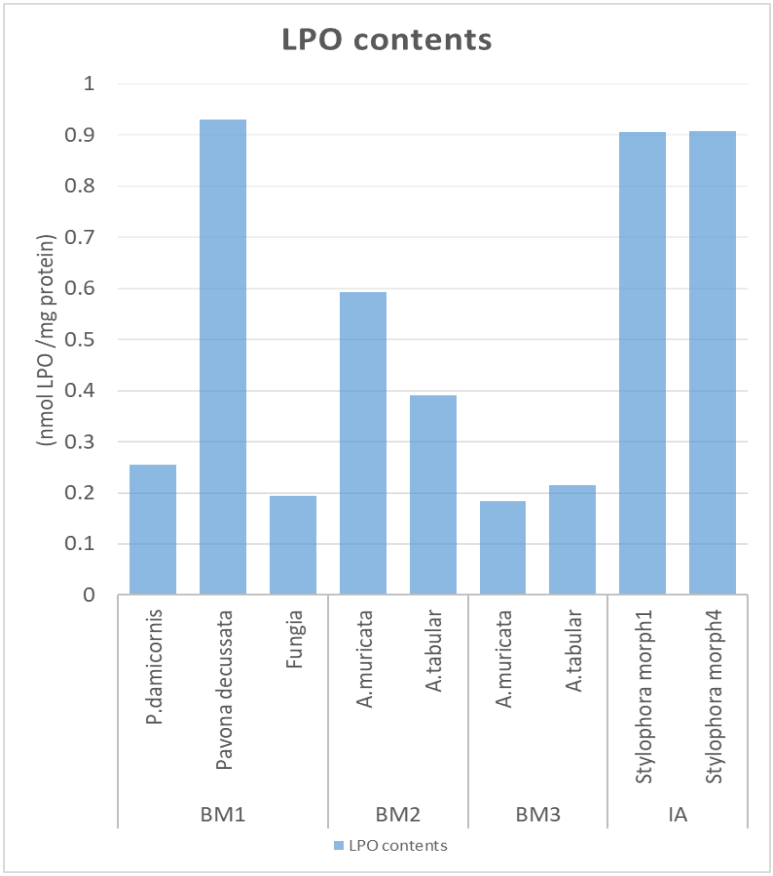
Abundance of zooxanthellae widely varied among coral species. Particularly *Acropora tabular* keeps high zooxanthellae density in agreement with the high Chl a concentration.

Physiological parameters of selected corals from Belle Mare and Ile d'Ambre: immune response to environmental stressors

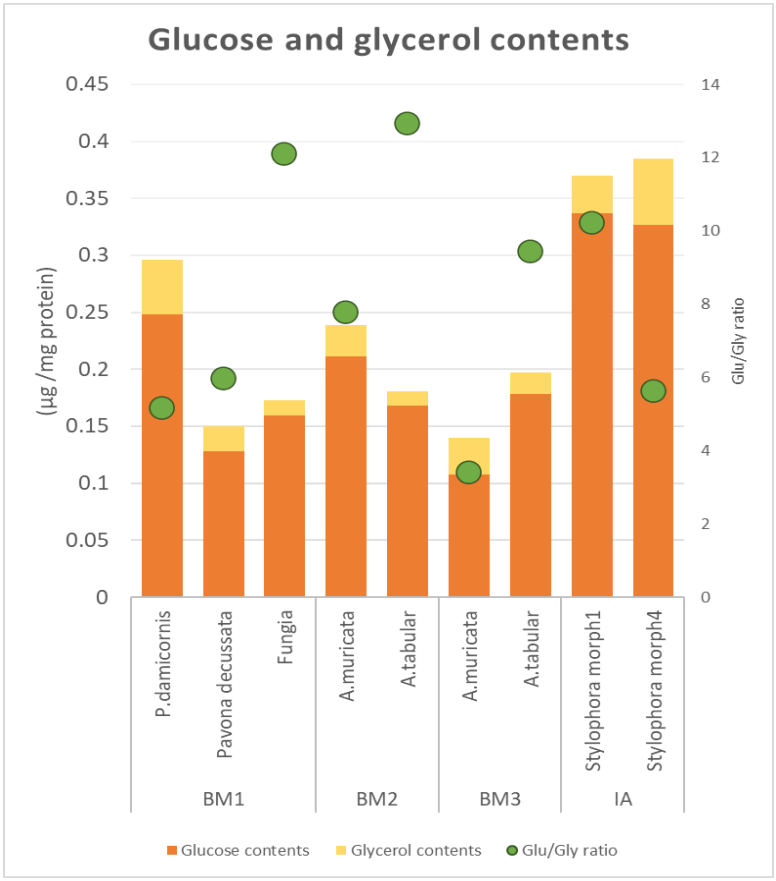
Antioxidative enzyme (hydrogen peroxide scavenging activity; HSA)



Lipid peroxide (LPO) concentration



Glycerol and glucose contents



High concentrations of the antioxidant enzyme HSA in *Pocillopora*, *Pavona*, and *Stylophora* indicate an active response to oxidative stress, and, especially *Pocillopora,* kept low level of LPO. *Pavona* spp. and *Stylophora* spp. showed relatively high levels of HAS but high concentration of LPO, indicating some oxidative damage in their tissues. Glucose/Glycerol ratio can be used as an indicator of stress of the zooxanthellae: as the translocation of glycerol increases when the symbionts are under stress, lower Glu/Gly ratio, as in the case of *P. damicornis*, *A. muricata* and *Stylophora* M4, may indicate a coral under stressful condition.

Coral incubation experiment

Objectives:

1) to assess physiological responses of selected corals under normal and stressful conditions (high seawater temperature and strong illumination)
2) To evaluate corals primary productivity under normal vs. stressful conditions

Target corals:

3 species from Belle Mare reef: *Galaxea fascilularis*, *Pocillopora eydouxi* and *Acropora tabular*

2 species from Ille D'ambre: *Stylophora* sp. morpho-2, *Stylophora* sp .morpho-3

1 species from Grand Goube: *Stylophora* sp. morpho-5

Experiment set-up:

Corals were incubated under ambient (24ºC) temperature or stress temperature (30ºC) and during 4 hours under strong illumination (~1800 to 1900 µm/cm/sec) or ambient illumination (~400µm/cm2/sec) vs dark conditions.

Measurements:

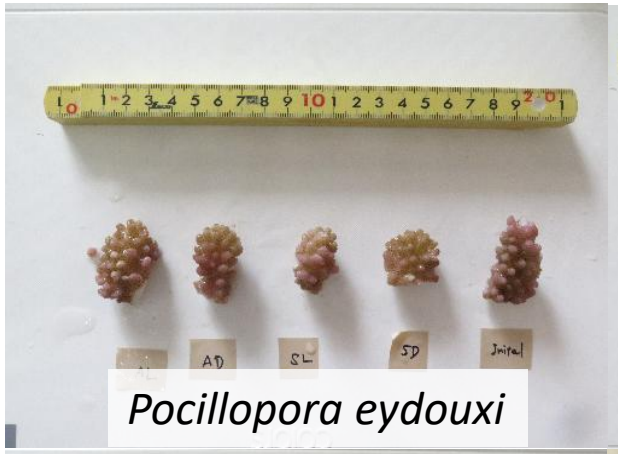
*** Coral incubated waters:** Dissolved oxygen, pH and nutrients

*** Coral tissues:** zooxanthellae density, photosynthetic pigments, hydrogen peroxide scavenging activity, lipid peroxide concentration, glucose and glycerol concentrations**.**

*** Continuous monitoring of light and temperature in the incubation chamber.**

Incubation set-up

Combine stress experiment of corals from Belle Mare



Pocillopora eydouxi

Tabular *Actopora*

Galaxea fascicularis

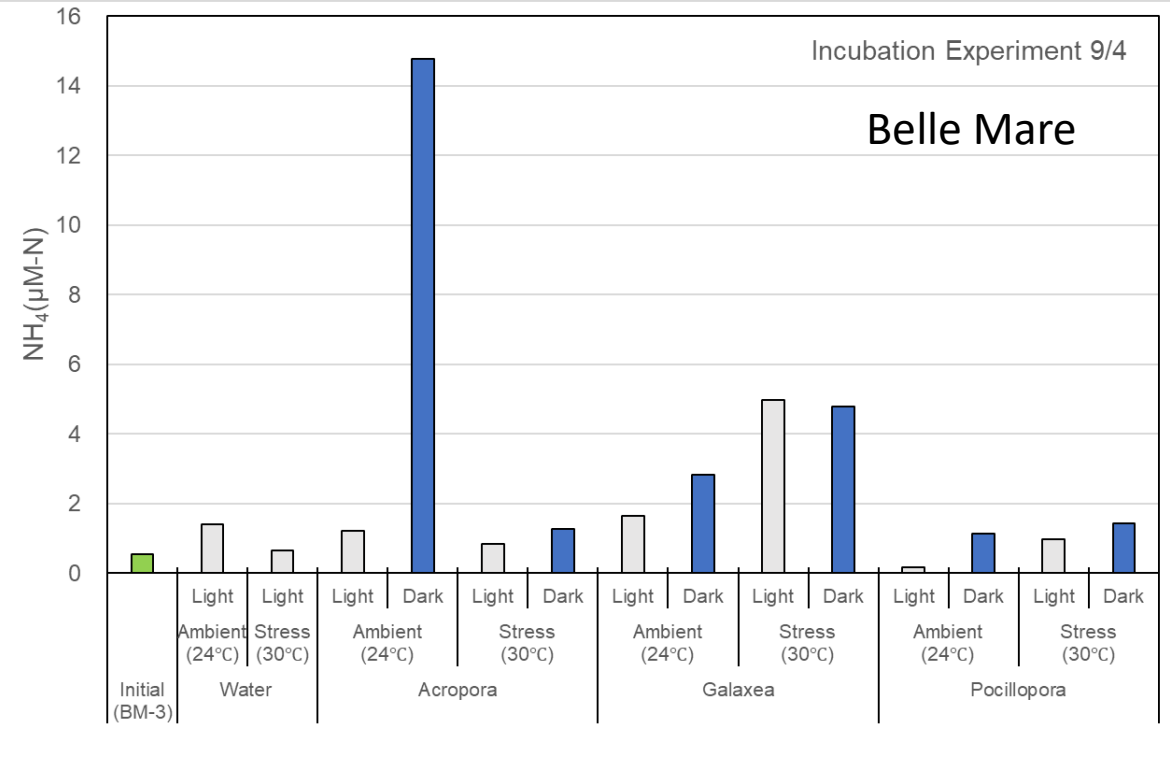
Combine stress experiment of corals from Ile d'Ambre and Gran Gaube

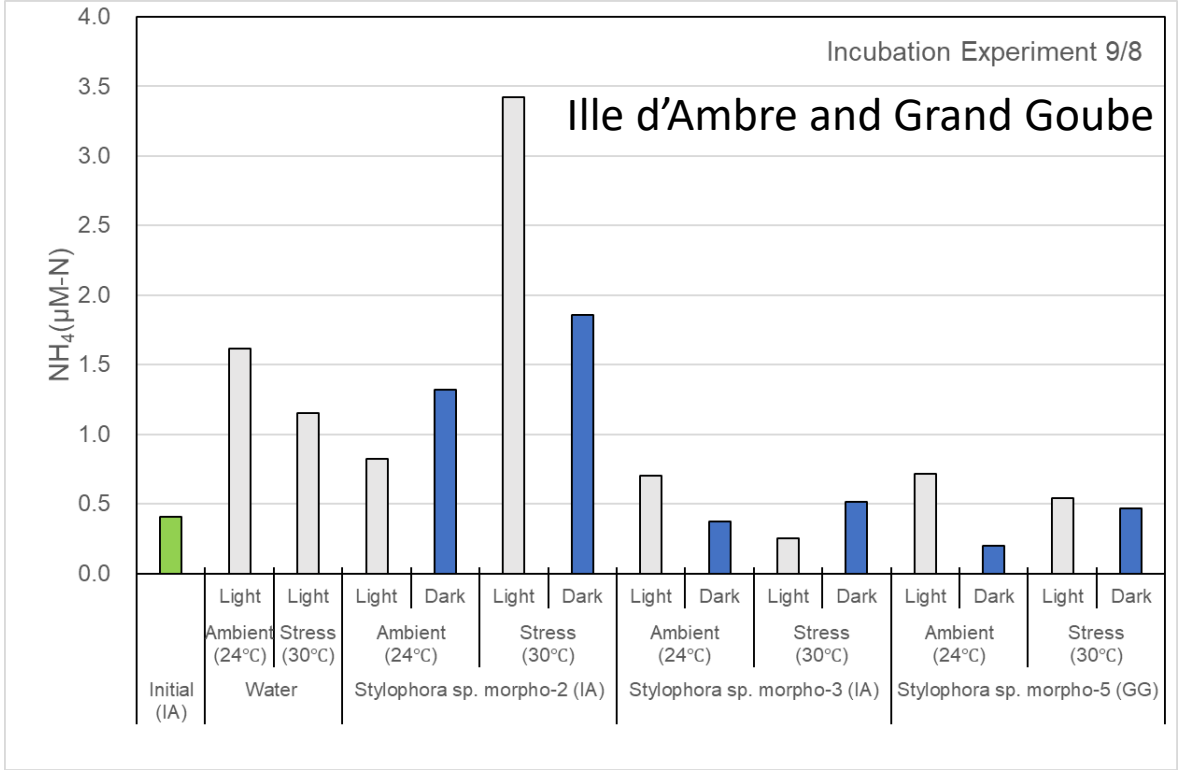
Stylophora morph2

Stylophora morph3

Stylophora morph5

Results: 1) Changes in ammonia concentration during incubations

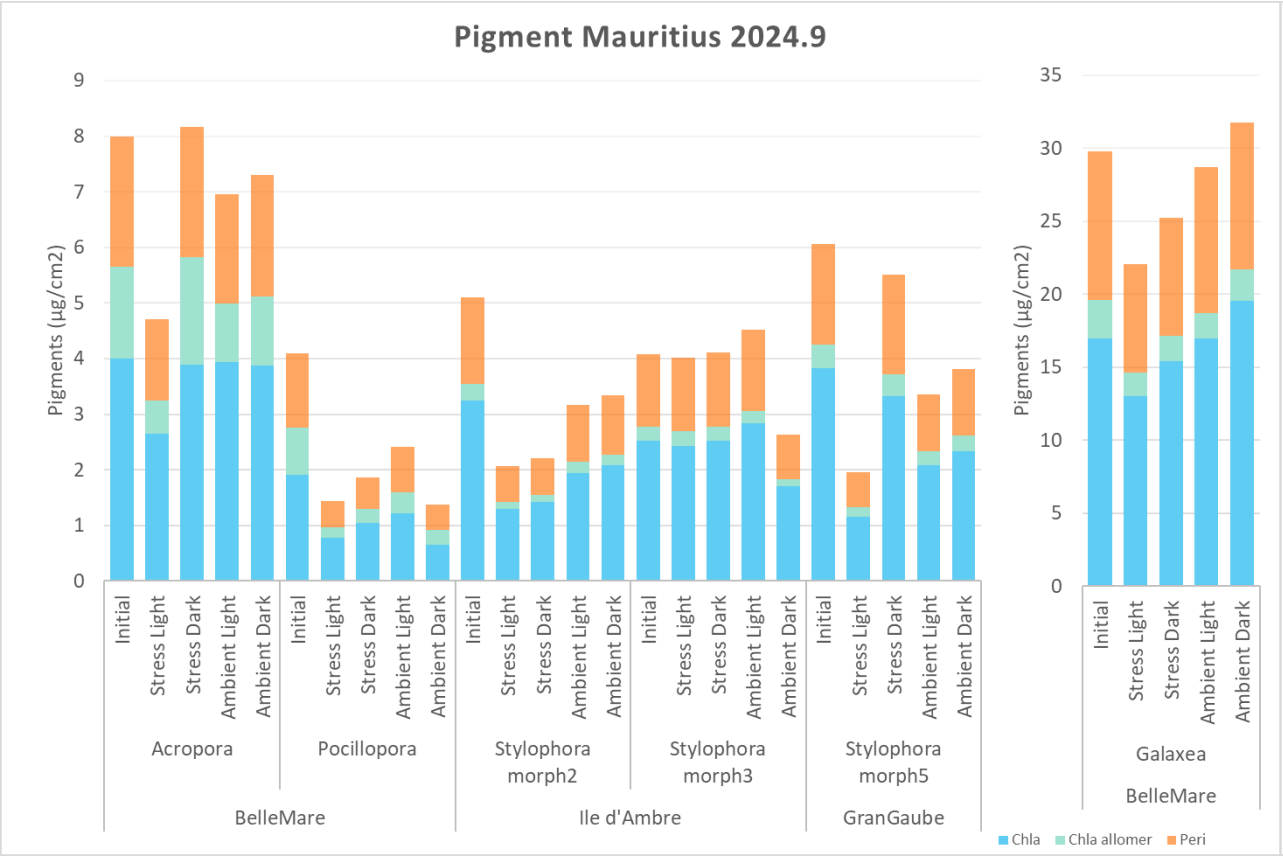




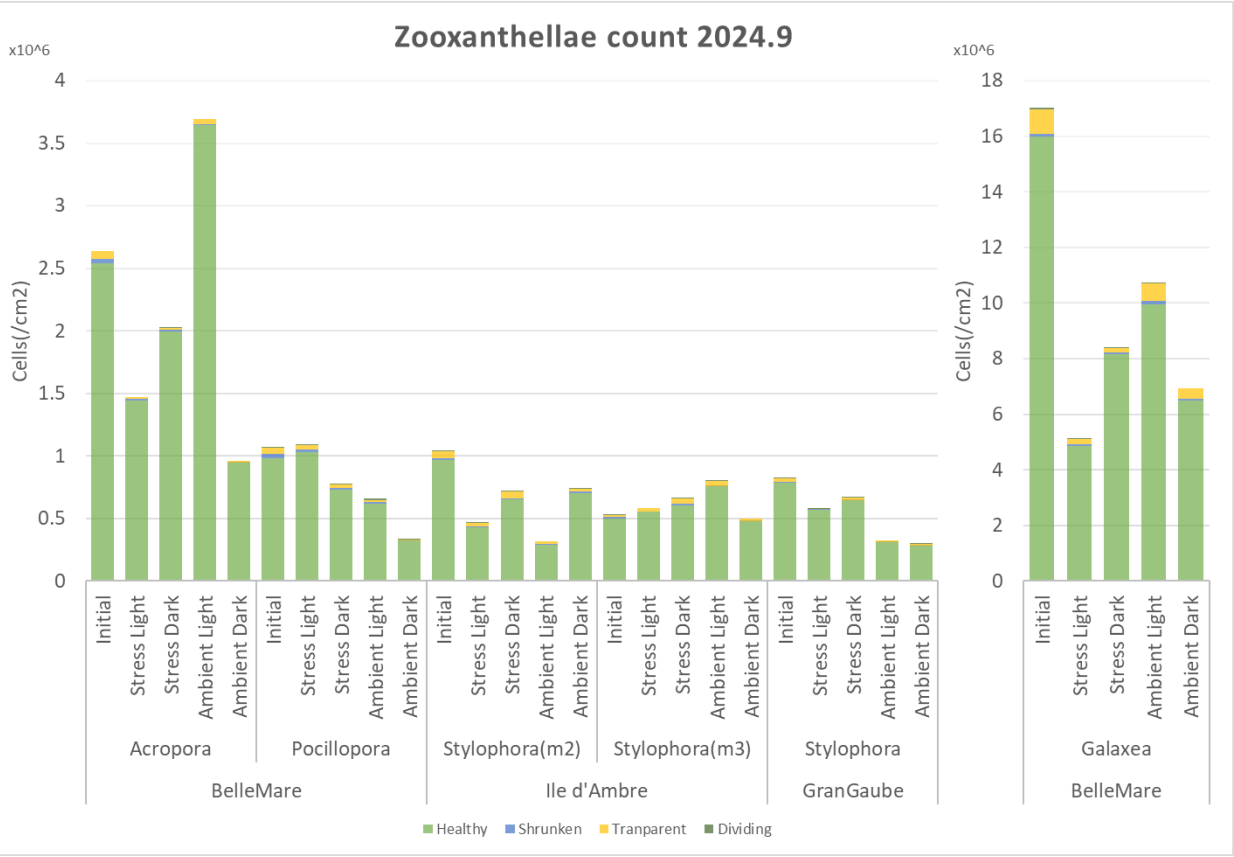
Ammonia could be used as an indicator of the metabolic activity; however, the responses of different corals were different under the combined stressors. In *Acropora* corals, the effect of high temperature stress was evident by decreasing release of ammonia (decreasing metabolic capacity) , however in *Stylophora* M2 the combined stresses activated the ammonia metabolism.

Results: 2) Changes in zooxanthellae abundance and pigment concentrations

Photosynthetic pigment concentrations



Number of zooxanthellae cells



Combined stresses affected the pigment concentration and zooxanthellae cell density in *Galaxea* and *Acropora* corals. *Stylophora* M5 corals also were affected by the combined stresses. *Pocillopora* corals were not strongly affected by the combined stressors.

Results: 3) primary productivity

		Net Primary P production (NPP) µg C/mg protein/1h	Respiration (R) µg C/mg protein/1h	Groth Primary Production (Gpp) µg C/mg protein/1h	P/R
Galaxea fasciculris	stress	0.07	0.35	0.42	1.21
	ambient	0.02	0.25	0.27	1.07
Pocillopora eydouxi	stress	12.45	45.80	58.25	1.27
	ambient	47.77	93.59	141.36	1.51
Acropora cytherea	stress	0.01	0.01	0.02	1.65
	ambient	0.004	0.008	0.014	1.47

		Net Primary P production (NPP) µg C/mg protein/1h	Respiration (R) µg C/mg protein/1h	Groth Primary Production (Gpp) µg C/mg protein/1h	P/R
Styllophora sp. morpho-2 (Ambre Island)	stress	0.02	0.018	0.04	2.20
	ambient	0.01	0.020	0.03	1.44
Styllophora sp. morpho-3 (Ambre Island)	stress	0.02	0.06	0.08	1.28
	ambient	0.04	0.05	0.09	1.75
Styllophora sp. morpho-5 (Brand Goube)	stress	0.06	0.06	0.12	1.98
	ambient	0.02	0.01	0.03	2.58

Net Primary Production (NPP) was calculated on the bases of increases in DO during the light incubations, and converted to organic carbon units

Respiration (R) was calculated on the bases of decreases in DO during the dark incubations, and converted to organic carbon units

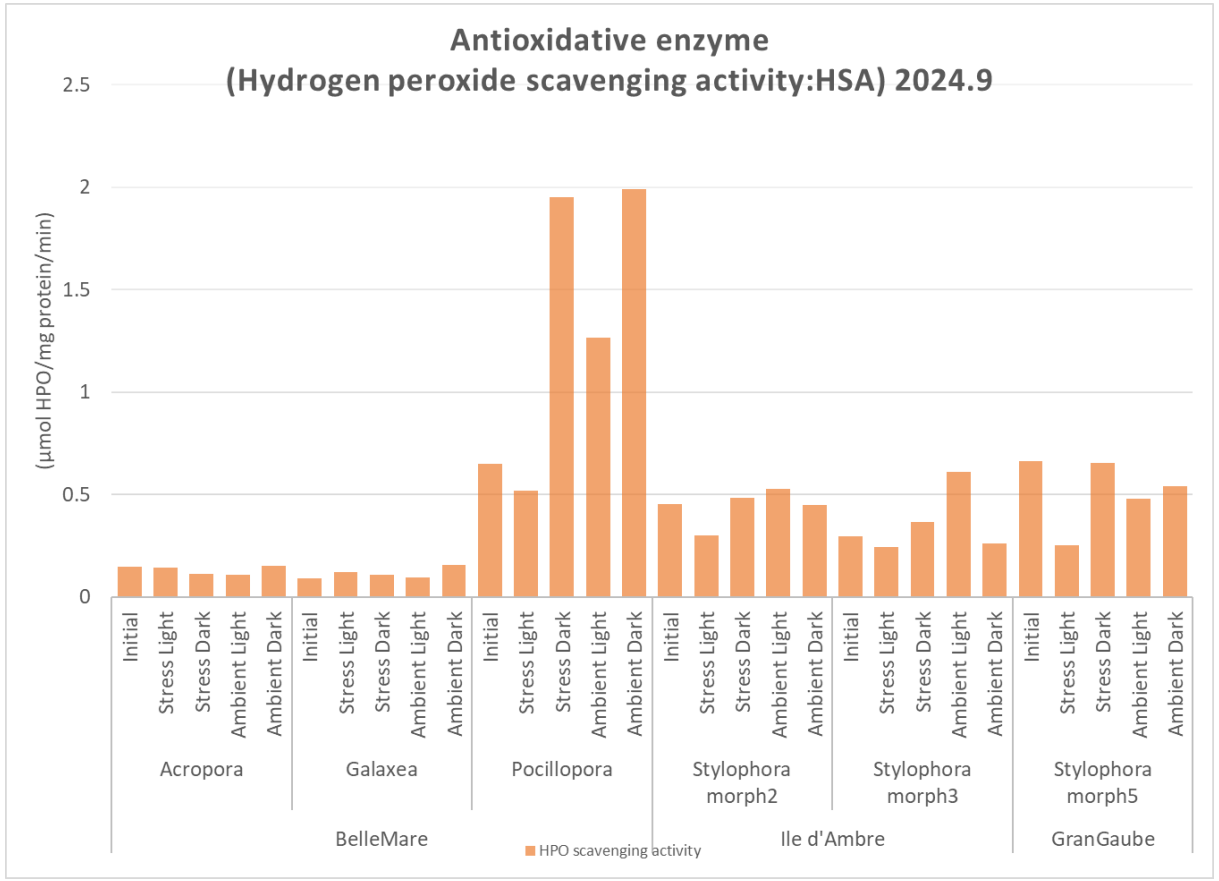
Growth Primary Production (GPP) was calculated as the sum of NPP and R (GPP=NPP+R)

P/R ratio was calculated as GPP/R

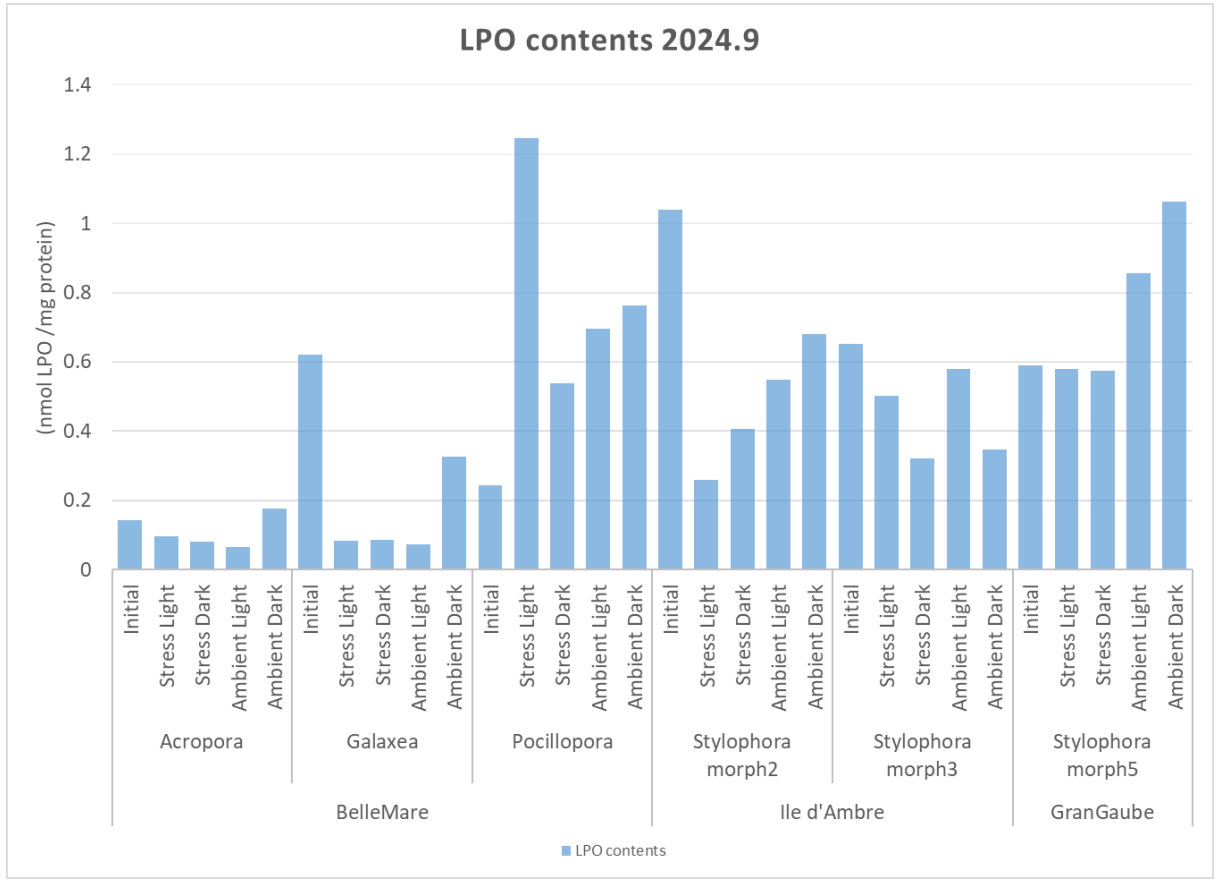
All corals showed P/R ratio higher than 1, indicating that net primary production was higher than respiration. In *Pocillopora* corals, the NPP was very high but also R was high, therefore the P/R ratio resulted similar to other corals.
In Ille d'Ambre and Grand Goube, *Stylophora* corals showed higher P/R ratio than the Belle Mare corals.

Results: 4) Hydrogen Peroxide scavenging activity and Lipid peroxidation (LPO) concentration

Antioxidative enzyme (hydrogen peroxide scavenging activity; HSA)



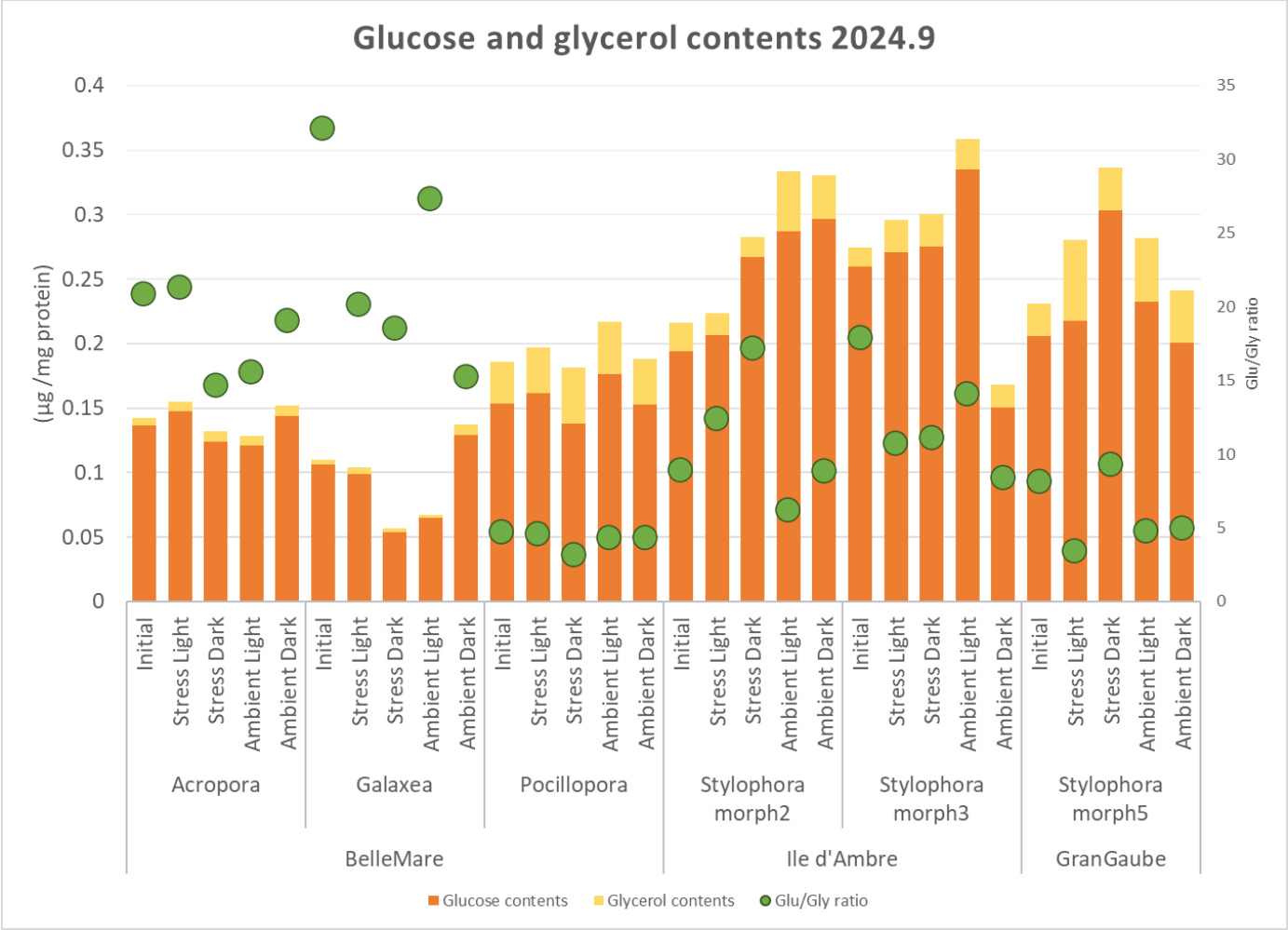
Lipid peroxide (LPO) concentration



High content of HAS in *Pocillopora,* showed a good performance when fighting oxidative stress. The decrease in HAS under light conditions indicates the utilization of this antioxidant enzyme and recovery (synthesis) during the night. In *Stylophora* corals differences in oxidative stress tolerance were observed among morphs, however in all morphs antioxidant capacity increased in stress (heat) conditions. Overall, the results show that *Pocillopora* can be considered a strong coral species under heat stress.

Results: 5) Glucose and Glycerol concentrations

Glycerol and glucose contents



Low Glu/Gly ratio in *Pocillopora* and *Stylophora* M5 indicate that these corals may be under stressful conditions, however they showed a good response in producing antioxidant enzymes

Capacity Building: scientific and Social Impact

Workshop organized in collaboration among UoM, SU, MOL and Sunlife hotel

Sunlife Ltd

University of Mauritius

(Pole of Research Excellence-Sustainable Marine Biodiversity and Dept. of Biosciences & Ocean Studies, Faculty of Science)

&

Shizuoka University, Japan

In collaboration with The Biodiversity and Environment Institute and with support of Mitsui O.S.K. Lines Ltd

Workshop on

"Coral Reef and its associated Biodiversity under Climate Change" (CRBCC2024)

Monday, 09 September 2024 at 09:00

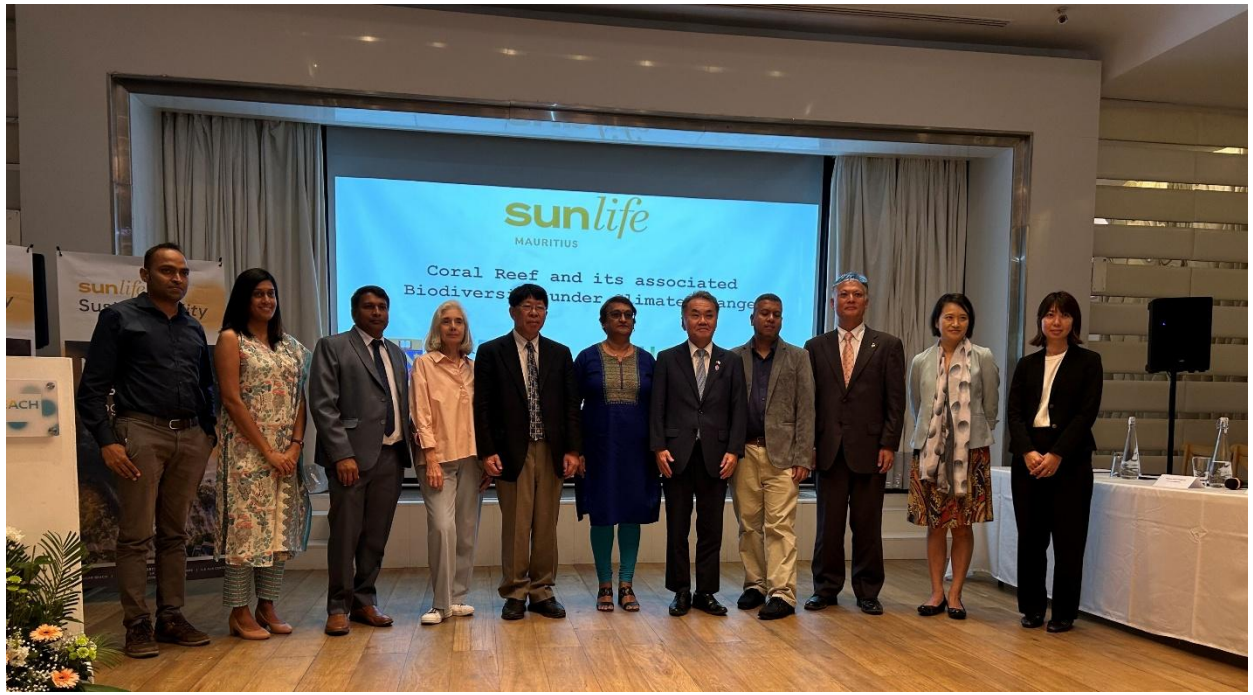
Venue: Long Beach Hotel Resort, Belle Mare

Proposed programme:

Time	Speaker	Title
09:00:09:05	Mr Christian JAQUIER General Manager of Long Beach Hotel, Belle Mare	Welcome Address from Sunlife
09:05-09:10	Assoc. Prof. (Dr) Preethee **GONPOT**, Dean of Faculty of Science, UoM	Address from UoM
09:10-09:15	Mr Kazuhiko **SUGANO**, Managing Director, MOL (Mauritius) Ltd	Address from MOL Ltd
09:15-09:30	His Excellency, Ambassador Mr Masahiro **KAN**	Opening Address
09:30-09:45	Mr Ali **ABDOOL** (Sunlife) / Prof Ranjeet **BHAGOOLI** (UoM)	Brief / Introducing Speakers
09:45-10:05	Prof. BE **CASARETO**, Shizuoka University, Japan	Eco-physiological response of corals under the climate change scenario
10:05-10:25	Prof. Y **SUZUKI**, Shizuoka University, Japan	Chemical-biological response of coral reef under the climate change and high CO_2 world
10:25-10:35	Dr Deepeeka **KAULLYSING** (UoM)	**Questions & Answers / Introducing Speakers**
10:35-10:55	Prof. Ranjeet BHAGOOLI (UoM)	Coral Reefs of the Republic of Mauritius
10:55-11:05	Dr Arvind **GOPEECHUND** (BEI) / Prof. Ranjeet **BHAGOOLI** (UoM)	Marine Life Biodiversity at Belle Mare
11:05-11:15	Dr Deepeeka **KAULLYSING** (UoM)	**Questions & Answers / Introducing Speakers**
11:15-11:20	Mr Ali **ABDOOL** (Sunlife)	Closing remarks
11:20 -11:45		**Light Refreshment**

Workshop on “Coral Reef and its associated Biodiversity under Climate Change” (CRBCC2024) Monday, 09 September 2024, at 09:00
Venue: Long Beach Hotel Resort, Belle Mare

Target audience: Proposed programme: UoM Marine Science and Coastal & Ocean Management Students, Sunlife Staff, and Relevant authorities and stakeholders.
Main aim: To disseminate research findings from University of Mauritius (UoM) and Shizuoka University (SU), Japan researchers, along with raising awareness among stakeholders including Sunlife staff, BEI and UoM students, on coral reefs of Mauritius, thermally resilient corals to global warming and how best they can be conserved, protected and managed in an era of global warming. Such targeted seminars are becoming more important than ever, given the increased frequency and intensity of mass coral bleaching and mortality due to global ocean warming ultimately leading to biodiversity and habitat losses



From left: Dr Arvind GOPEECHUND (BEI); Dr Deepeeka KAULLYSING (UoM); Prof. Ranjeet BHAGOOLI (UoM); Prof. Beatriz CASARETO (SU); Prof. Y. SUZUKI (SU); Assoc. Prof. (Dr) Preethee GONPOT, Dean of Faculty of Science (UoM); His Excellency, Ambassador Mr Masahiro KAN; Mr Ali ABDOOL (Sunlife); Mr Kazuhiko SUGANO, Managing Director, MOL (Mauritius); Ms. Wakana NAKAMURA 1rst secretariat of Japanese Embassy in Mauritius; Ms. Kanako OHTA (MOL)

Capacity Building and Social Impact

mbc 1 TV news interviewed Prof. R. Bhagooli and Prof. B E. Casareto regarding the status of coral reefs in Mauritius and the existence and role of heat-resistant corals (super corals).
The discussion focused on the conservation of super corals as well as those corals with low adaptation capacity to heat stress, particularly the endemic corals in Mauritius reefs.

Educational Activities by BEI and UoM during fiscal year 2024

18th September 2024 – Introducing younsters to snorkelling at Belle Mare


Training young marine scientists for field work at Belle Mare


Mangrove Sensitization & Awareness - 10 April 2024 at Le Morne


Collection of more pictures for the Marine Life Booklet – Beautifully recovered reef of Belle Mare


Publications and presentations at International Symposia

Published papers

Ricot M, Jeetun S, Jogee SY, Kaullysing D, Taleb-Hossenkhan N, Mbui MJ, Casareto BE, Suzuki Y, Wijayanti DP, Bhagooli R (2024): The coral reefs and fishes of St. Brandon, Indian Ocean Archipelago: Implications for sustainable fisheries. **Diversity**, 16, 710. https://doi.org/10.3390/d16120710

Jeetun S, Ricot M, Jogee SY, Kaullysing D, Taleb-Hossenkhan N, LaJeunesse TC, Philippart G, Collard O, Flot J-F, Wijayanti DP, Yucharoen M, Nascimento B, Suzuki Y, Casareto BE, Bhagooli R (2024): Morphological and genetic characterization of *Stylophora madagascarensis*, *Pocillopora acuta*, and *Pocillopora verrucosa* in Mauritius and their thermal photo-physiological stress responses. **Bulletin of Marine Science**, https://doi.org/10.5343/bms.2023.0124

Jogee SY, Gopalsing S, Jeetun S, Ricot M, Taleb-Hossenkhan N, Mattan-Moorgawa S, Kaullysing D, Wijayanti DP, Suzuki Y, Casareto BE, Bhagooli R (2024): Variable prevalence of diseases and compromised health conditions on hard corals around Mauritius Island, Western Indian Ocean. **Bulletin of Marine Science.** https://doi.org/10.5343/bms.2023.0123

Suzuki T, Casareto BE, Yucharoen, Dhora H, Suzuki Y (2024): Coexistence of nonfluorescent chromoproteins and fluorescent proteins in massive Porites spp. corals manifesting a pink pigmentation response. **Front. Physiol.** 15:1339907. https://10.3389/fphys.2024.1339907

Submitted manuscripts:

Shakeel Yavan Jogee, Enrico Montalbetti, Yohan Dider Louis, Simone Montano, Nawsheen Taleb-Hossenkhan, Deepeeka Kaullysing, Beatriz Estela Casareto, Yoshimi Suzuki, Davide Seveso, Ranjeet Bhagooli: Variable morphotypes, physiological traits and thermal stress responses of skeletal growth anomalies in the branching coral Acropora muricata. Submitted to **Coral Reefs** on 31st December 2024 through the ERCS2024

Participation in Symposia:

*** WIO (Western Indian Ocean) Futures meeting organized by Curtin University (Mauritius) under the theme - Marine Science - 15-17 September 2024**

1. Sruti Jeetun, Melanie Ricot, Shakeel Yavan Jogee, Deepeeka Kaullysing, Nawsheen Taleb-Hossenkhan, Todd Christopher LaJeunesse, Grégory Philipart, Olivier Collard, Jean-François Flot, Diah Permata Wijayanti, Mathinee Yucharoen, Bernado Nascimento, Yoshimi Suzuki, Beatriz Estela Casareto, **Ranjeet Bhagooli*: Previously misidentified *Pocillopora damicronis* from Mauritius turns out to be *P. acuta* and *P. verrucosa* with variable thermal bleaching responses.**

2. **Shakeel Yavan Jogee***, Marwyn Anasamy, Deepeeka Kaullysing, Nawsheen Taleb-Hossenkhan, Beatriz Estela Casareto, Yoshimi Suzuki, Ranjeet Bhagooli: **Morphological and eco-physiological characterisation of Skeletal Growth Anomalies on reef-building tabular *Acropora* spp. corals around Mauritius Island, Western Indian Ocean**

3. **Ashfaaq Korimbocus***, Maukshada Ramkalam, Shakeel Jogee, Sruti Jeetun, Deepeeka Kaullysing José Tena Medialdea, Yoshimi Suzuki, Beatriz Estela Casareto, Ranjeet Bhagooli: **Distribution of the edible bivalve mollusc, *Pinna muricata*, around Mauritius and Rodrigues Islands, Indian Ocean**

4. **Maukshada Kamakshi Ramkalam***, Muhammad Ashfaaq Korimbocus, Shakeel Yavan Jogee, Sruti Jeetun, Marwyn Anasamy, Deepeeka Kaullysing, Yoshimi Suzuki, Beatriz Estela Casareto, Ranjeet Bhagooli: **Satellite imagery reveals spatio-temporal changes in coral reef habitat in the south-east of Mauritius Island**

5. **Melanie V Ricot***, Sruti Jeetun, Shakeel Y Jogee, Deepeeka Kaullysing, Nawsheen Taleb-Hossenkhan, Beatriz E Casareto, Yoshimi Suzuki, Diah Permata Wijayanti, Ranjeet Bhagooli: **Reef fish diversity, density and biomass around St Brandon, Indian Ocean**

6**. Sruti Jeetun***, Melanie Ricot, Shakeel Yavan Jogee, Deepeeka Kaullysing, Nawsheen Taleb-Hossenkhan, Todd Christopher LaJeunesse, Grégory Philipart, Olivier Collard, Jean-François Flot, Diah Permata Wijayanti, Mathinee Yucharoen, Bernado Nascimento, Yoshimi Suzuki, Beatriz Estella Casareto, Ranjeet Bhagooli: **A first report of *Stylophora madagascarensis* around Mauritius and its thermal chlorophyll stress response**

*** ECRS (European Coral Reef Symposium, Naples, Italy, from 2 to 5 July 2024)**

1. **Ranjeet Bhagooli*,** Sruti Jeetun, Nawsheen Taleb-Hossenkhan, Todd Christopher LaJeunesse, Olivier Collard, Grégory Philipart, Jean-François Flot, Deepeeka Kaullysing, Yoshimi Suzuki, Beatriz Estela Casareto: **Differential thermal photo-physiological responses between *Stylophora* sp. morphs harbouring *Durusdinium* symbiont**

2. **Shakeel Yavan Jogee***, Nawsheen Taleb-Hossenkhan, Davide Seveso, Yohan Didier Louis, Enrico Montalbetti, Beatriz Estela Casareto, Yoshimi Suzuki, Deepeeka Kaullysing, Ranjeet Bhagooli: **Physiological and cellular responses of three morphotypes of skeletal growth anomalies on *Acropora muricata* under short-term thermal stress**