Work Package 4.2
Monitoring case studies in Croatia

Plić Lagnjići

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Deliverables: D4.2.1, D4.2.2, D4.2.3, D4.2.4

Titles:

D4.2.1 Explorative survey with multibeam echosounder (MBES) and/or ROV/scuba
D4.2.2 Set up of an integrated monitoring system in situ (including high tech foto/video and 3D filming for monitoring and communication purposes
D4.2.3 Extension of monitoring execution to other parameters (i.e. biological components)
D4.2.4 Collection and reporting of obtained data

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Case study responsible PP: University of Zadar (UNIZD)

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EXECUTIVE SUMMARY

This report describes the results of a survey carried out from September 2019 until June 2021 in the area of the Lagnjići reef, on the north-west part of Dugi Otok island, Croatia. Monitoring of reefs is essential for the continuous evaluation of their structural and ecological evolution, hence their capacity of sustaining different economic activities, in line with the principles of Blue Economy. This activity, funded by the EU through the Interreg Italy-Croatia CBC programme, was initiated in recognition of the underexploited potential for sustainable use of some natural and artificial reefs located in the Adriatic Sea and is part of ADRIREEF (Innovative exploitation of Adriatic Reefs in order to strengthen blue economy) project.

• Aim of the survey is a transborder investigation aimed at highlighting the unexploited potential of 7 selected reefs, natural or artificial, located offshore the Italian and Croatian coasts of the Adriatic Sea.

• During the survey, innovative technologies with low environmental impact were tested, based on the outcomes of ADRIREEF WP3.4 “Identification of technologies for underwater monitoring of reefs.”. However, a few modifications may have been introduced to reflect Case Studies specifics or to address unexpected situations occurred during practical activities at sea.

• Explorative survey was carried out using Side scan sonar Humminbird Helix 12 CHIRP MSI+ GPS G3 and software Autochart Pro, Underwater drone Chasing model Gladius Mini, Scuba diving equipment (diving bottles, fins, dive computers, manometers Apex, etc.), BRUV (Baited Remote Underwater Video, camera, two aerial drones all buyed wih ADRIRREF project funding.

• The scope of this work also includes an assessment of the potential reef vocation for the specific CS (e.g. tourism, farming, aquaculture, fishing, environmental safeguard, ...).

The main findings of this study were as follows:

Natural reef Lagnjići was chosen for research and monitoring activities. The location of the reef is in the mid part of the Adriatic Sea, on the north-west part of Dugi Otok island. *In order to examine exploitation potential, the following equipment was purchased and used: side scan sonar, three underwater drones and scuba diving equipment, 6 BRUV systems, camera and* two aerial drones *The monitoring activities were done during summer 2019, spring/summer 2020 and spring/summer 2021. During those activities detailed geomorphological characteristics and complete structure of the reef and seabed were done using the sonar. Reef Lagnjići is a shallow reef with a vertical wall on its south side. Most of the reef is covered with P. oceanica meadows except infralitoral and litoral part of the island and vertical wall which is a coralligenous habitat. It also contains a shipwreck of the Italian cargo ship Michele. Also, water parameters and the quality of water were measured during the monitoring phase. One part was dedicated to the analysis of benthic community*

found on the reef as well as for the analysis of observed fish population. In order to get a complete picture and to recognise economic and ecological aspects of the reef, human impact and tourist pressure were analysed. Therefore, it can be concluded that this reef offers potential development for various commercial activities such as diving activities, especially for the beginners. It could be also suitable for small scale fishing or a place for making underwater photography. Because of its big biodiversity it is a great polygon for student education. There is also a threat during summer for diving activities because of the big tourist pressure and quite big maritime traffic (jet ski, boats..). Also because the location was discovered by an Influencer 2 years ago it is now one of the most overcrowded sites in Zadar County. Therefore a plan for anchoring of the vessels must be provided because of the protection of P. oceanica meadows.

1. INTRODUCTION

The main objective of the monitoring was to examine exploitation potential of the natural reef but also to determine morphological, chemical, biological and other features. Environmental load and quantity of maritime traffic at the reef were also examined. Furthermore, the monitoring aimed to recognise ecological and economic aspects related to the reef, potential threats to the reef and opportunities for local communities and stakeholders of Zadar County. The monitoring has been carried out by using innovative and integrated monitoring systems that are non-harmful and have little or no impact to nature.

The natural reef Lagnjići was never a part of any research and was mainly used by local fishermen (professional, sport and recreational). That was one of the main reasons why this specific reef has been chosen for exploration and subject for research and monitoring activities. Given its good location, vicinity to tourist and diving centres, this reef offers potential development for various commercial activities which are in accordance with the project objectives and Blue Economy requirements.

After an introductory exploration of the site, geomorphological mapping was done. Water parameters were taken (biological, chemical, physical) by IRB. Benthic communities found on the reef were done by SUNCE and UNIZD. Fish assemblages were done by UNIZD. Furthermore, the human impact on the environment is shown in line with tourist potential of the surrounding area that could develop exploitation activities at the reef, including diving and fishing. Main results of the monitoring are presented in the conclusion chapter

2. GEOMORPHOLOGICAL MAPPING

2.1. Description of equipment and acquisition/processing techniques

Geomorphological mapping of the reef was conducted with high quality side scan sonar Humminbird Helix 12 CHIRP MSI+ GPS G3 (Figure 1.). This sonar combines tournament-ready technologies like MEGA Side Imaging+, MEGA Down Imaging+, Dual Spectrum CHIRP Sonar, AutoChart Live and intuitive Cross Touch control. Helix 12 has the ability of wi-fi, Bluetooth, Ethernet and NMEA 2000 connections. On the large 12 inch screen there can be up to four customizable viewing panes so it is possible to view multiple technologies at once. Below are explanations for some of the most important features. New Side Imaging brings crystal-clear viewing up to 200 feet on either side of a boat, while Down Imaging allows underwater clarity with coverage down to 200 feet below the boat. Dual spectrum offers two ways of search; wide mode for maximum coverage and narrow mode for maximum details.

Figure 1. Helix 12 CHIRP MSI+ GPS G3

With AutoChart Live it is possible to create real-time maps of certain spots as well as to map depth contours, bottom hardness and vegetation. Using sonar, it is possible to estimate the hardness of the reef seabed and the presence of vegetation. Bottom hardness and vegetation cannot be displayed at the same time in Chart View but can be shown in software and done as images. Bottom hardness shows strong sonar returns resulting from compact sediment, rocks, etc. The range of bottom hardness shown on the chart can be adjusted by changing the minimum and maximum range on the display. The selected range affects how the bottom hardness colours are displayed. Vegetation is shown by the density, Higher the density more green colour will be on the picture (*P. oceanica* meadows). All data collected with the sonar is analysed with Auto Chart Pro software (Figure 2.).

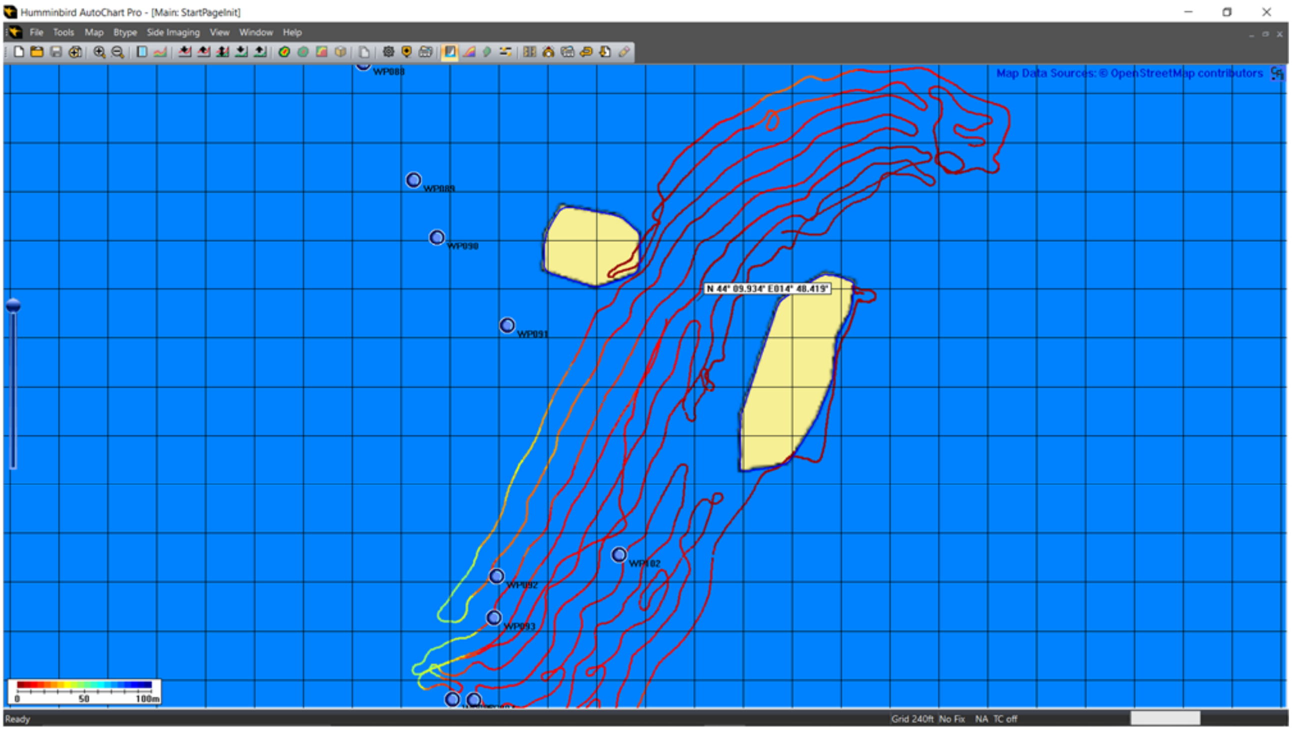

Figure 2. AutoChart Pro software

2.2. Survey results

The survey is based on the geographical position of the reef and main morphological characteristics, as well as the characteristics of the seabed. In order to get the best possible picture of the reef and characteristics of surrounding area, the listed features will be explained.

Lagnjići reef is situated in the mid part of the Adriatic Sea close to the north-western shore of the Dugi Otok island. The location of the reef is 0.6nm offshore from Dugi Otok island and 18nm from the city of Zadar. The nearest place to the location is Pantgera bay with three small fishing villages. The nearest tourist places are Božava and Molat villages.

Geographical position of the reef is:

φ = 44° 09.88'N

λ = 14° 48.37' E

First explorative survey with Helix 12 was held in June 2019. and was finished in August 2020. Mapping operation was only possible during nice weather with calm sea so that the quality of data is high. The use of sonar gave us 100% coverage of the seabed morphology and reef area, which was fundamental for proper monitoring process. This high-resolution sonar of 1.100 kHz is suitable for measurements carried out at relatively shallow depths (up to 60m).

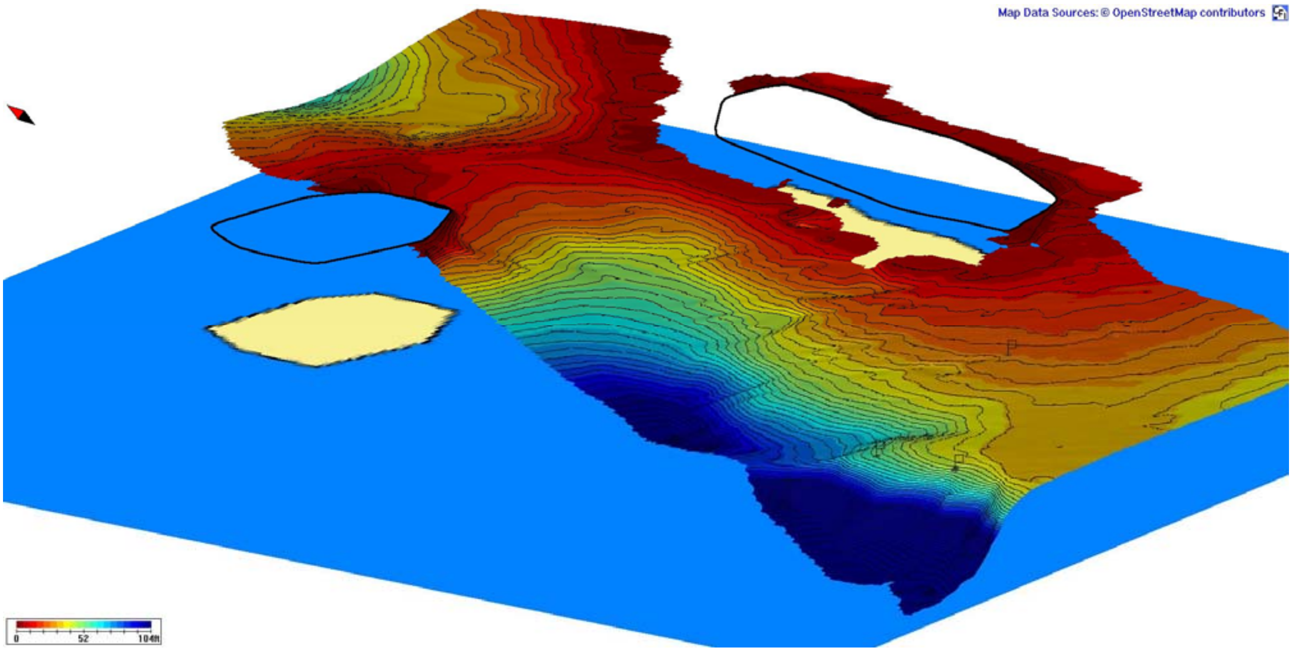

Figure 3. Bathymetric map

Figure 3. represents the 3D depth map. With this solution Humminbird Autochart allows to view a novel and different perspective of the depth map. There are several display options when the maps are in 3D like

Different Aspect Ratio (DAR) or True Aspect Ratio (TAR), mesh desplay, black or colour contours, etc. The figure herein presents the TAR and colour contours (colour and depth legend is dispayed next to the map).

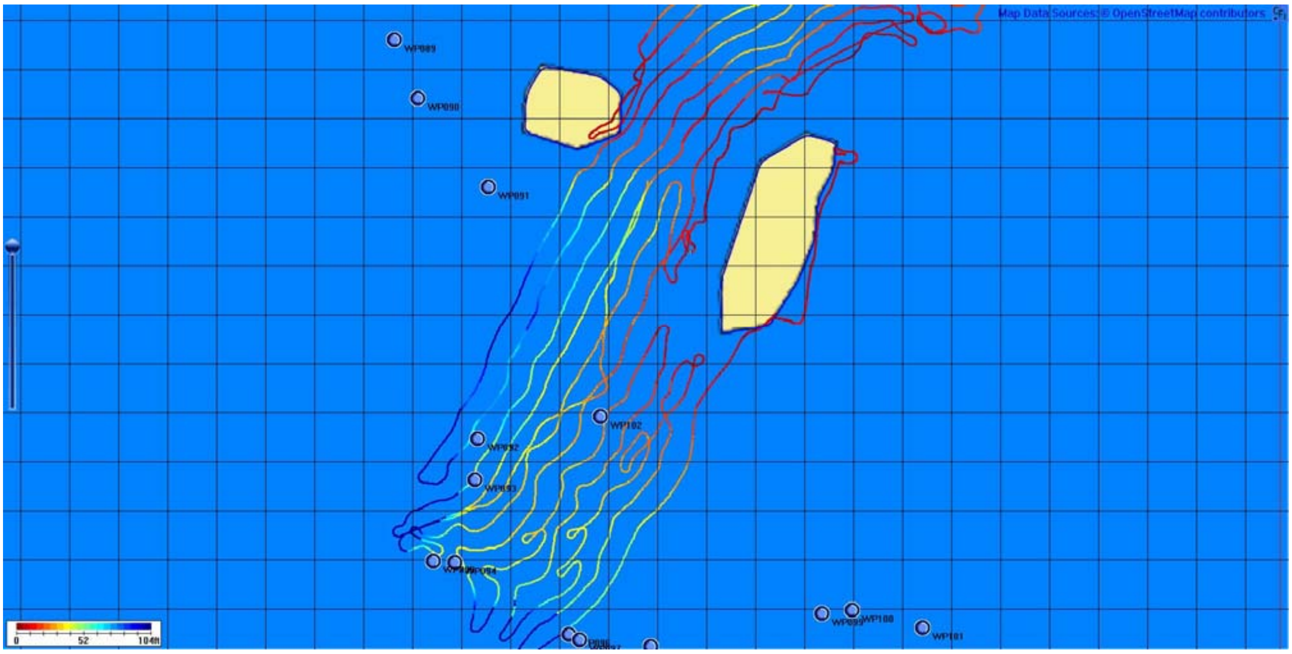

Figure 4. Bathymetric map

Figure 4. represents the 2D depth map with coloured depth contour lines (colour and depth legend is displayed next to the map), displayed depths (depth labels) and grid lines. Each of the mentioned data is actually a layer which can be displayed or hidden based on user preferences.

As for depth contours we also did the bottom hardness. Figure 5. represents bottom hardness and actually shows strong sonar returns resulting from compact sediment, rocks, etc. The range of bottom hardness shown on the chart can be adjusted by changing the scale. The selected range affects how the bottom hardness colours are displayed. On Figure 6 the smaller number (darker colours) represent the bottom with weaker signal return (soft sediment / presence of vegetation etc.) while the larger scale number (red colour) represent the stronger signal and therefore hard surface like rocks, vertical walls and coralligenous habitat which increases with depth.

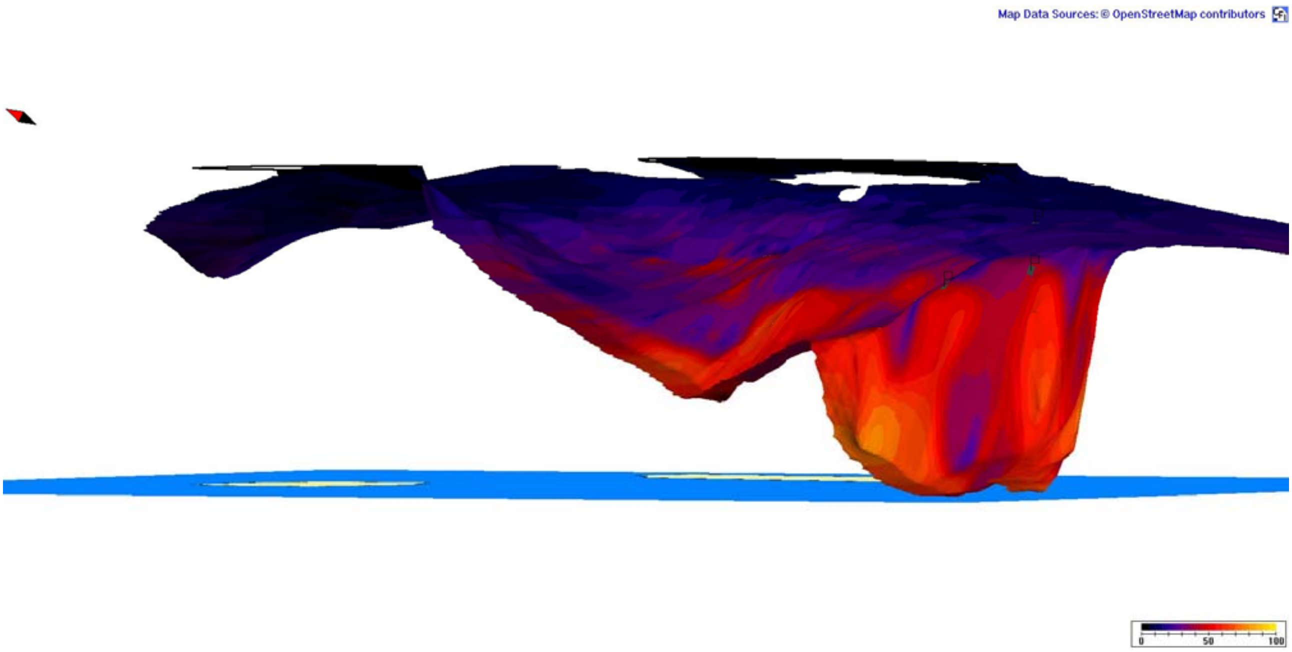

Figure 5. Bottom hardness of Lagnići reef. On the scale it can be seen that darker colours represent *P. oceanica* meadows with sandy patches. Red and orange colours represent vertical coralligenous wall and

rocky habitat. There can also be seen patches of rocks in *P. oceanica* meadows and parts of sunken Michelle ship.

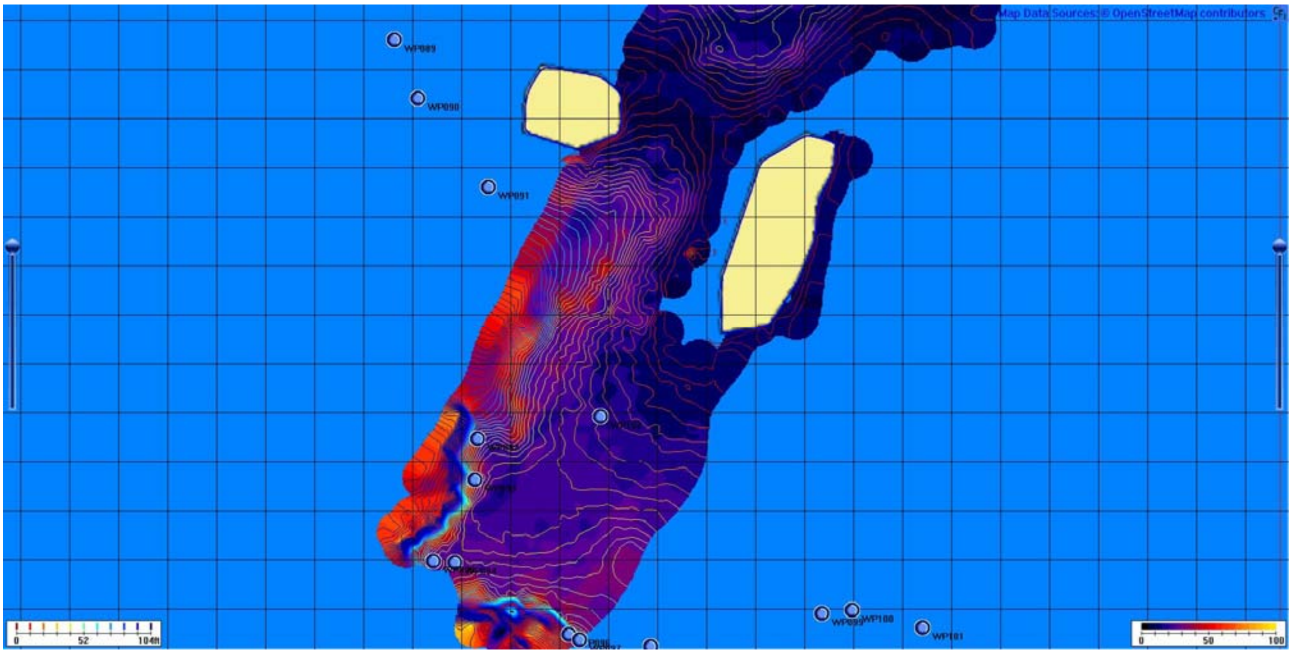

Figure 6. Bottom hardens in correlation with depth. Small pieces of sunken boat Michelle can be seen between Vele and Male Lagne islands

Also there was a vegetation map made with one of the applications that our sonar has (Figure 7.). It shows correlation between vegetation and depth as *P. oceanica* meadows slowly decrees in density towards shallow infralitoral and litoral habitat near islands and also towards deeper parts of the reef where coralligenous habitat begins.

Figure 7. Vegetation – depth correlation on the reef. Deeper and shallow water has less vegetation than range between 6m and 22m

3. SAMPLING TECHNIQUES AND METHODS OF ANALYSIS

3.1. Speed and direction of water currents

Because the location of Lagnjići reef is near Dugi otok island it is well protected from strong currents and we didn't make that research.

3.2. Water column parameters

For collecting physical - chemical measurements EXO Multiparameter Probe was used (Figure 8). EXO Multiparameter Probe has integrated f-DOM Smart Sensor, Conductivity / Temperature Sensor, Optical Dissolved Oxygen Sensor and pH Sensor for measuring physical - chemical parameters in the field. The probe collects the data with up to four user- replaceable sensors and an integral pressure transducer. Each sensor measures its parameters via a variety of electrochemical, optical, or physical detection methods. Each port accepts any EXO sensor and automatically recognizes its type. Depending upon user-defined settings, the EXO1 will collect data and store it in probe or transfer the data to a collection platform (DCP), or relay data directly to a user's PC or the EXO Handheld. TOC measuring principle is based on the high temperature combustion of the sample in an air or O2 stream above 680 °C. Totally bound or dissolved carbon is converted into CO2 which is quantitatively determined by means of a NDIR detector.

During monitoring phase of our reef, water quality as well as physical and chemical parameters were analysed. Water samples were taken during four explorative surveys in 2020. They were conducted during all seasons so that we have a full year scale of parameters. For each season an in situ survey was conducted but also water samples were taken a frozen to -22^{o}C.

Figure 8 EXO Multiparameter Probe used for collecting water column parameters

Nutrient parameters that were part of interest are nitrate (NO_3), nitrite (NO_2), phosphate (PO_4) and silicate (SiO_4). They were analysed using Shimadzu TOC Analyzer (Figure 9.). Subsamples for ammonia were fixed immediately after collection onboard with 1 mol L^{-1} phenol/EtOH and determined in the laboratory.

Figure 9. Shimadzu TOC used for nutrient analysis

3.3. Benthic community settled on the reef

For sampling of benthic communities on the reef we used all techniques that were used for fish assemblage, plus camera photo. We didn't used any of standardised protocols or techniques because SUNCE carried out a detail research of benthic community and provided results in their report of Lagnjići reef.

3.4. Fish assemblage

The methods used for sampling of fish communities on the reef are all non-harmful. The methods are:

- BRUV (Baited Remote Underwater Video)
- UVC (Underwater Visual Census)
- ROV (Remote Operated Vehicle

3.4.1. Baited Remote Underwater Video (BRUV)

A fast development in technology over the last 20 years has made the use of cameras in underwater research a common thing. Whether for abundance or length of the fish, deep or shallow water, cameras are now days used for sampling of fish assemblages more than ever (Watson et al., 2005.). There are two basic ways of using cameras, mono or stereo system. Both ways cameras are pointed down or parallel with sea bottom. If the system has a bag with bait then we are talking about BRUV. Those systems can be armed with infrared lights, moving sensors,… The biggest pros of this method are that it can be used on big depths, several times during the day, it is non-expensive and easy to use and it is non-harmful (Langlois et al., 2010., Cappo et al., 2007.).

A comparison was made weather the use of bait increases abundance or not. It is found that the use of bait increases abundance of carnivore and omnivore species but does not decrease the abundance of herbivore species (Harvey et al., 2007). Stereo system is used when we want to have a precise length of the fish using a calibration and a software program for measuring. The program is not precise in MM but a class range of 10cm can be provided.

In our research we used a stereo and a mono system. Stereo system has two cameras put in a waterproof housing. The housings are attached to the metal frame and are pointed parallel to the sea bottom. Housings are made out of technical plastic and are waterproof up to 100 meters. The cameras used in our case are GoPro Hero 3 Silver, GoPro Hero 4 Silver Plus and a GoPro Hero Black 5. All cameras are high 4K resolution (1920 x 1080) and have a battery life up to 3 hours. In our case we also used BackPack batteries to extend that life span up to six/six and a half hours. The frame of the system is made out of stainless steel. The bar where the cameras are attached is one meter long and the distance between the cameras is 70 centimeters. The housings are moved for 8º to the center of the system so that the max range of the system in clear water would be around 7 meters. The system has 4 detachable legs that can be armed with leads if the current is too strong so that it can't be moved. On the left and right side the system is connected to the floating rope and on the other end with a buoy (Figure 11.). For the bait we used fresh sardines. The whole system is 1m tall which is the standard height for BRUV.

Each system had 3 or 6 replicates, depending on the battery lifetime, in duration of 45 minutes. We used maximum of 6 systems per day.

Also we used a mono BRUV system that is consisting of an open box where the camera is placed. Camera used on this system was GoPro Hero 5 and is placed in its own housing. The maximum depth range for this system is 45 meters. It has 4 detachable legs that can, as in the case of stereo system, be placed with weights so that the current can't move it. It is also made out of stainless steel (Figure 10.). The lifetime of a camera on this system is around 3 hours and it depends on water temperature.

Data analysis was carried out in laboratory by the same fish expert so that if there is any mistake it would be the same for every survey. For each species we took N-max (maximum number of individuals for one species per frame). For the fish length measurement in all our research we use SeaGIS event measure. Fish were measured in 10cm range and divided in classes.

Figure 10. Mono BRUV system used in research

Figure 11. Stereo BRUV system used in research

Figure12. BRUV deployment

3.4.2. Underwater Visual Census (UVC)

Limitations for using destructive sampling methods, especially in protected areas, have led up to different type of visual census methods. Most of them are conducted in shallow water and with snorkelling with or without the use of cameras. The method of UVC is fast, easy to replicate and can collect data for various parameters as species, abundance, habitat, density,… Cons for this method are conditions in the water such as turbidity which can make harder for a diver to recognise the species, especially fish (Lowry et al., 2012.). Biggest difficulties come from mistakes made by the diver. Most of them are related with fish behaviour which is provided by diver himself, ability of the diver to recognise certain fish species, abundance and length of the fish. Different studies indicate that a diver can attract the fish, mostly carnivore species, but also it can scare them away (Langlois el al., 2010.). One of the biggest problems is the observation of small cryptic species in well structured habitat (Lipej and Bonaca, 2006.).

In our case we used two methods. One was a classic UVC with the use of a lure and the other one was a DOV (Diver Operated Video). UVC with the lure was conducted in shallow water on transects of deferent length and width of 2 meters. Each length was replicated each time the survey was conducted. Beginning and the end of the transect was a well marked object. The fish count was written on the white plastic ring with a waterproof pen.

DOV used in our research was equipped with two GoPro Hero 4 cameras that were placed in waterproof housings that were attached to the metal frame (Figure 13.). It was used only once because the program for stereo system analysis was not working.

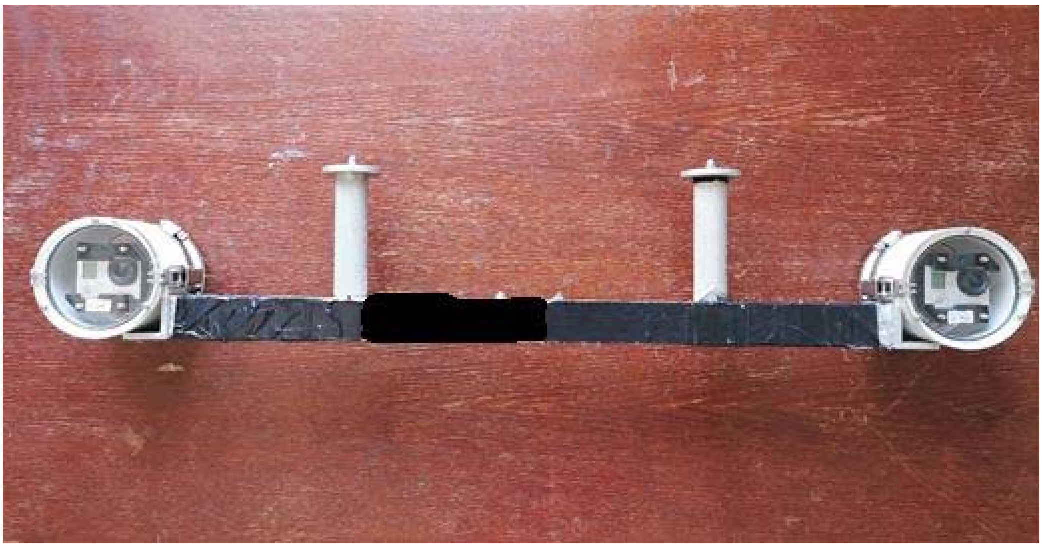

Figure 13. DOV used in research

3.4.3. Remote Operated Vehicle (ROV)

ROV (Remote Operated Vehicle) is every underwater vessel that is operated on distance with crew member. With fast technological development human crews are replaced and ROV can be operated from land or boat by remote control. Biggest advantage of these small ROV's is that they easy to navigate through small spaces such as interior of sunk ships or small underwater caves. Also if the ROV is lost there is only material loss. In past this kind of vehicles were expensive if you wanted high resolution cameras and all advantages listed above, but nowadays that is not the case. One of such vehicles is Gladius Mini ROV by French company Chsing (Figure 14.).

Figure 14. Gladius Mini ROV

ROV’s dimensions are 15.1 x 8.8 x 5.4 inches and weighs 2,5 kilos. The colour is yellow so it can be easily found if lost or stuck. It has 5 propulsors that provide stability, direction and speed of the ROV which can be max 4 knots or 2m/s. There are two rear motors that are responsible for horizontal movement. The rest are for moving up and down and stabilization. Namely, when all the motors are turned on the system can be adjusted so that ROV moves 45 degrees regarding to the sea bottom which is the best angle for filming. It has a 4K camera (12 million pixels) that cam film videos or take pictures in high resolution. For working in deeper water it has two LED lights, each 1200lm of power. The autonomy of the ROV is around 2 hours depending on water temperature and is 100 meters waterproof. The ROV is attached to the base station with 150 meters of optical cable covered in yellow kevlar suit. The base station has integrated memory of 64GB but additional micro SD card can be added (Figure 15.).

Figure 15. Base station and micro SD card

Inside the base station there is a WiFi antenna that serves for connecting to the drive pad. Tablet or the mobile phone must be put on the drive pad so that the ROV can be operated (Figure 16.).

Figure 16. Drive pad (console) of the ROV

On the screen you can see battery life time, water temperature for the depth on which the ROV is found at that time, picture of the situation in front of the camera and current depth (Figure 17.). The ROV was used for vertical transects on the coralligenous wall and for the Michele shipwreck.

Figure 17. Explorative survey carried out by using Chasing Gladius Mini ROV

4. RESULTS AND DISCUSSION

4.1. Speed and direction of water currents

Because the location of Lagnjići reef is near Dugi otok island it is well protected from strong currents and we didn't make that research.

4.2. Water column parameters

As the location of the reef is on open sea, all physical and chemical parameters were typical for this kind of area. The temperature was mesured up to depth reachable to open water divers (20 meters) as they are the targeted group for tourist activities. The pH factor and the dissolved organic matter is also in balance for this kind os environment. Typically the nitrates were low during winter and high during late spring, mid summer and early autumn. The salinity is slightly increased which can be explained by high temperatures the whole 2020. year. Nutrient load in general is very low becuse the location is far from big cities and industries and represents a typicall open sea environment. PAHs and PCBs in the water column were not detected and the sanitary quality was excellent.

Bellow in the text can be found figures and tables with physical and chemical parameters.

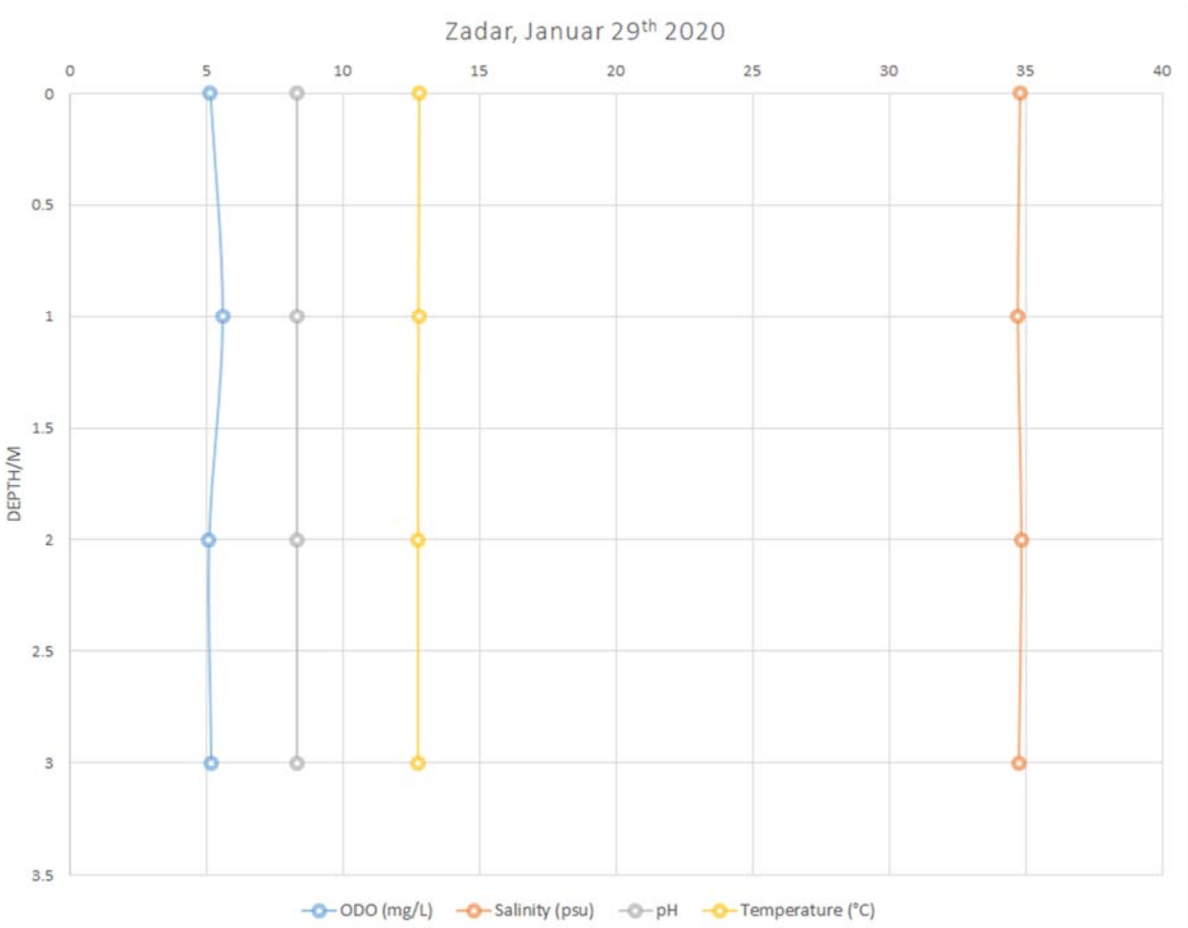

Figure 18. physical and chemical parameters during winter

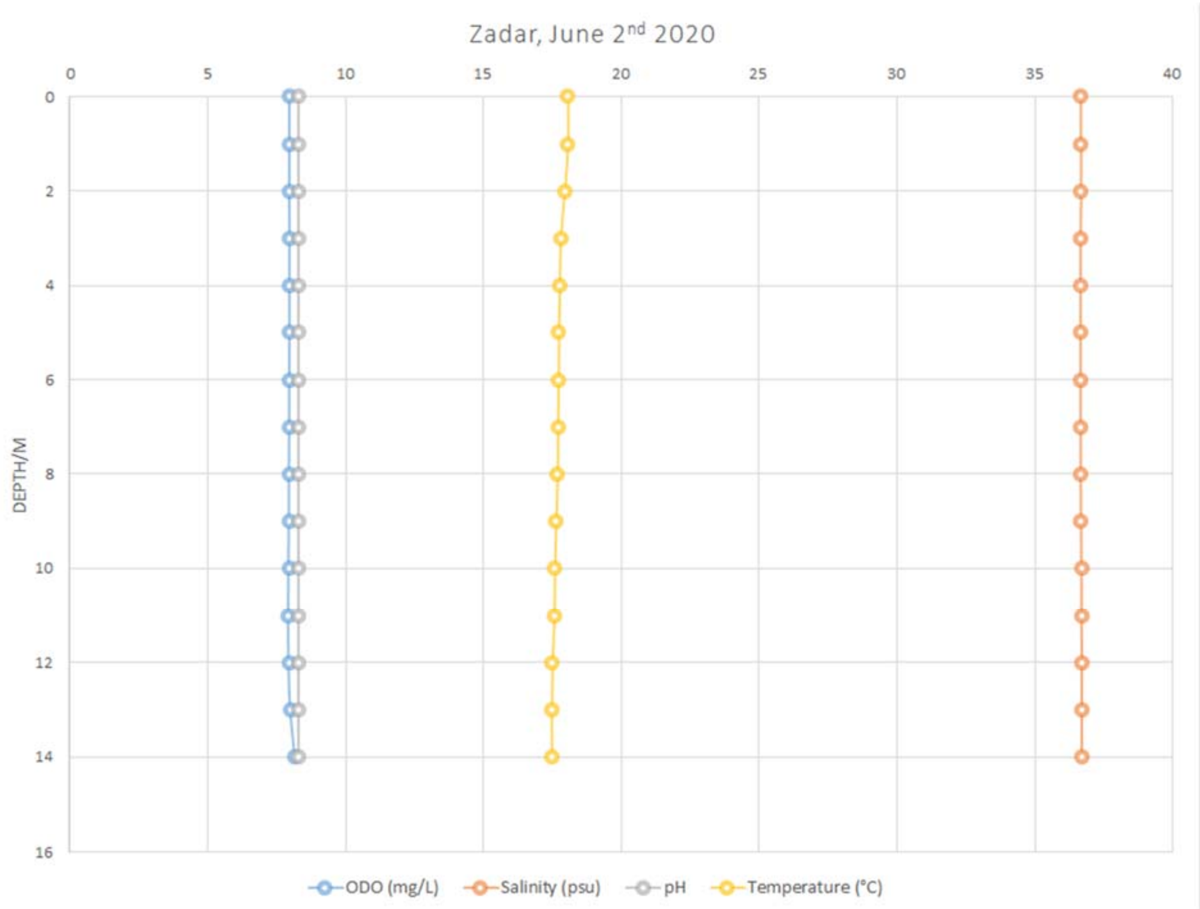

Figure 19. physical and chemical parameters during spring

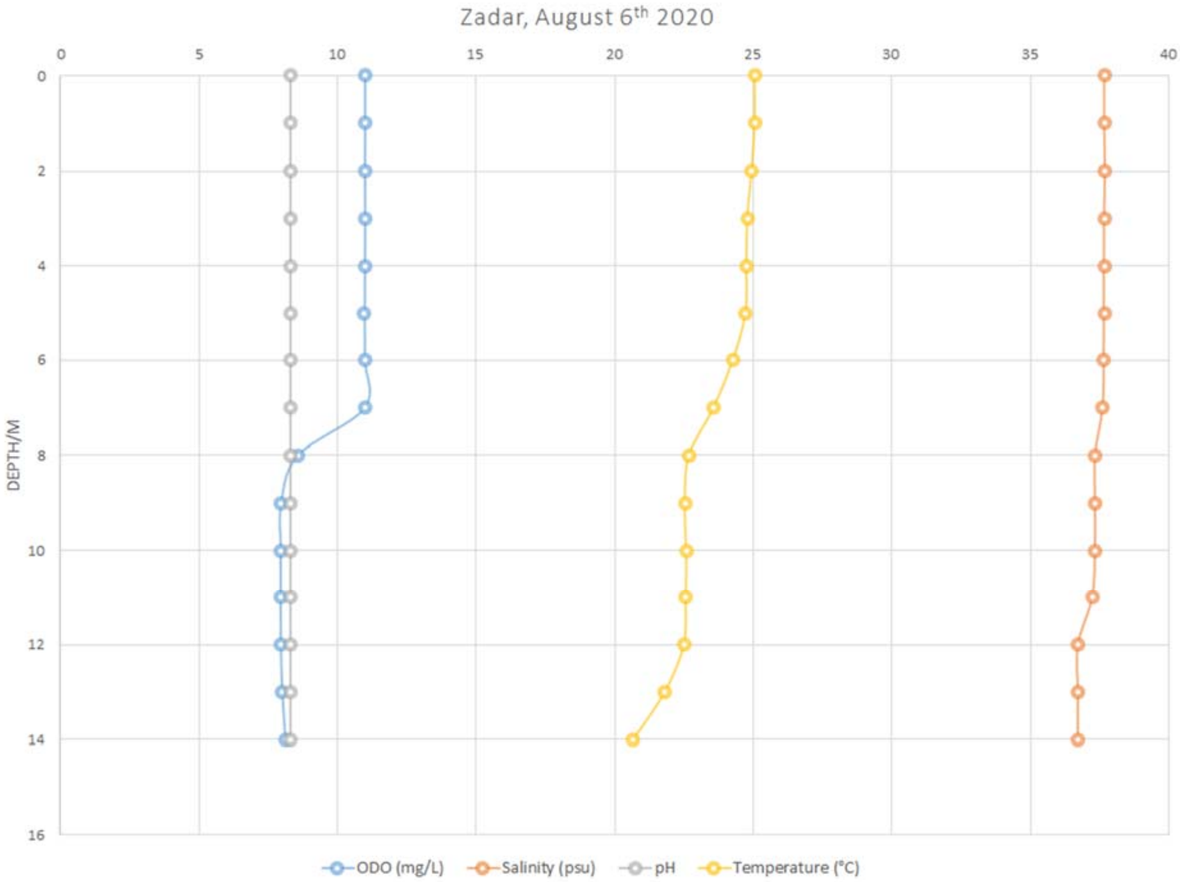

Figure 20. physical and chemical parameters during summer

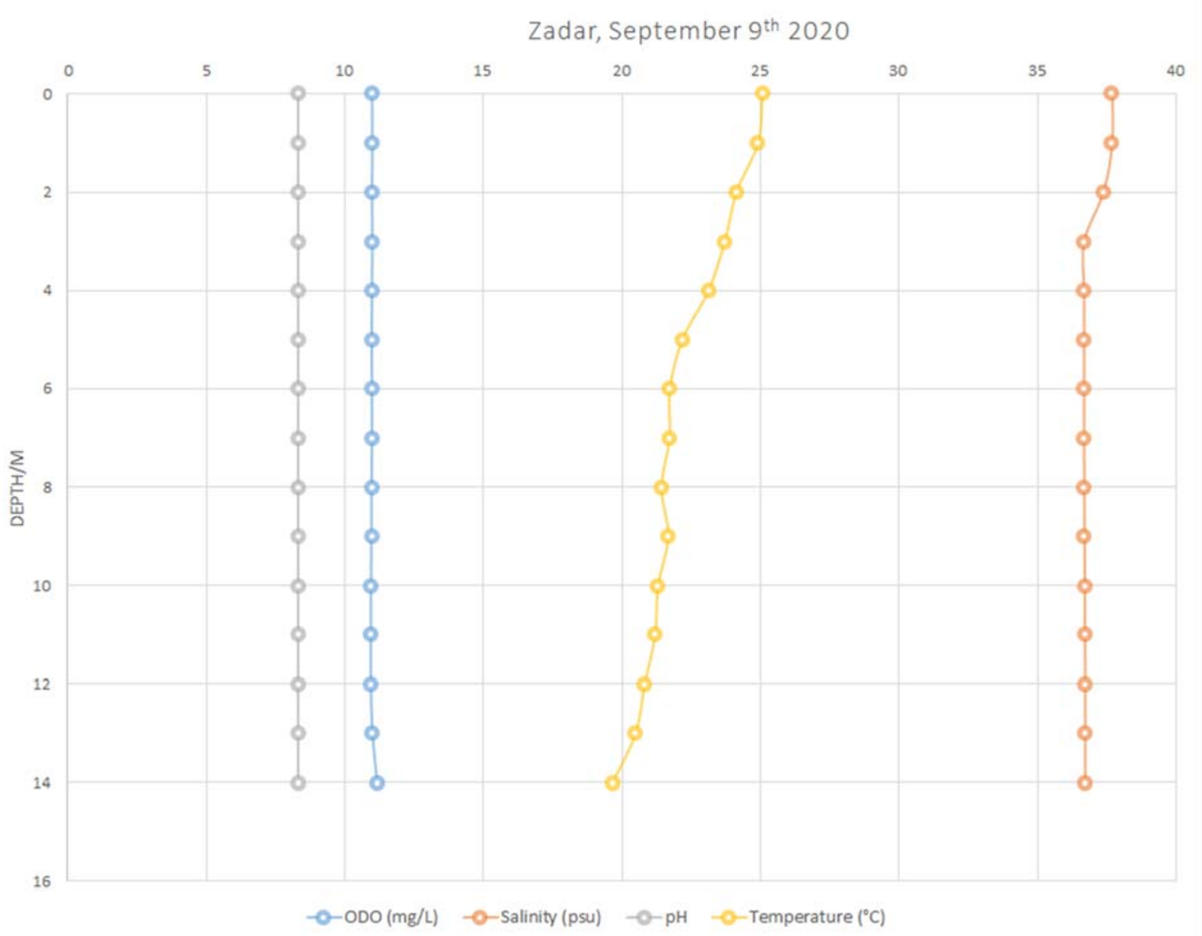

Figure 21. physical and chemical parameters during autumn

NUTRIENT	29.1.2020	2.6.2020	6.8.2020	9.9.2020
NO_3 (μmol l^{-1})	0,57596	1,57058	2,0812	2,54342
NO_2 (μmol l^{-1})	0,086673	0,061761	0,079234	0,08823
NH_4 (μmol l^{-1})	0,695416	1,163984	0,079234	1,105103
PO_4 (μmol l^{-1})	0,044826	0,063142	0,068444	0,076638
SiO_4 (μmol l^{-1})	4,129384	11,59334	12,92228	13,20743
TOC (mg l^{-1})	0,9359	1,145	1,335	1,383

Table 1. Nutrient values for each sampling season

For sediment analysis we did Polycyclic aromatic hydrocarbons (PAH) and Polychlorinated Biphenyls (PCB). Filtrated water samples (dissolved organic matter) were extracted 3 times using the mixture of 20 mL of hexane and dichloromethane (1:2). Collected extracts were transferred through analytically pure anhydrous sodium sulphate (Sigma Aldrich, anhydrous, ACS reagent, ≥ 99%). The extract was concentrated to nearly dry by rotary evaporation, then solvent exchanged into hexane around 1mL. The extracts were cleaned up using a five mL 2:3 (v/v) alumina: silica gel chromatography column. PAHs were eluted with 10 mL of n-hexane/dichloromethane (1:1 v/v). The fractions were concentrated to one mL under a stream of pure nitrogen and stored at 4 ◦C prior to instrumental analysis. A concentration of PAHs was determined using the gas chromatograph Shimadzu GC-2010 Plus with the Flame-Ionization Detector (GC-FID) and the Shimadzu 7683 Auto-sampler. All the values were low and the sanitary quality of the sediment was excellent. (Table 2.).

	29.1.2020.	2.6.2020	6.8.2020	6.8.2020
Σ PAH (mg/kg)	0.001	0.001	0.001	0.001
Σ PCBs (mg/kg)	0.001	0.001	0.001	0.001

Table 2. Polycyclic aromatic hydrocarbons (PAH) and Polychlorinated Biphenyls analysis shows low values and great sediment quality

For the presence of coliform bacteria we performed analysis according to ISO 16649-1:2013 (recently replaced by ISO 16649-1:2018). The targeted bacteria was Escherichia coli. Water samples of 100 mL were taken and transferred trough the membrane filter to a petri dish with Trypton-Galle-X-glucuronid (TBX) Agar (Merck, Darmstadt, Germany) and incubated at 44.5^{o}C for 24h. E. coli was not detected by laboratory analysis, as well as the other faecal coliforms (Table 3). The results were as expected because the location is on open sea and it is relatively far from villages and big cities.

Date	CE/ 100ml	E.coli/ 100ml
29.1.2020.	<60	<100
2.6.2020	<60	<100
6.8.2020	<60	<100
6.8.2020	<60	<100

Table 3. Presence of E. coli and other coliforms in water samples

4.3. Benthic community settled on the reef

Benthic communities settled on the reef can be divided into three groups based on the depth and community dominant representatives. Infra-littoral and littoral communities are mostly constructed of brown, green and red algae. Partially there are seagrass meadows present in these areas as they can mostly be found in sublittoral areas of the reef. From 22m of depth seagrass meadows slowly cross to coralligenous habitat. In our report we only covered seagrass meadows and partially some algae on the Michelle shipwreck. The rest of benthic communities were described in detail by SUNCE.

4.3.1. Seagrass

Seagrass communities cover most of the reef (>80%) and can be found from 6m up to 28 meters. The only representative is *Posidonia oceanica*. Seagrass are very important habitat but also as primary producers. They absorb carbon and thus remove CO2 from the atmosphere and reduce climate changes (Fourquearan et al. 2012). Also they provide ideal habitat for juveniles of vertebrates and invertebrates and protect against erosion (Orth et al. 2006.). On the east and north side of the reef seagrass meadows are dens and they do gently up to 28m of depth (Fifure 22.). On the south and west side of the reef seagrass meadows can be found going gently to around 17-22m and are replaced by vertical walls. Most of the meadows are well preserved but since the beginning of the project deterioration can be found in the density of the seagrass near the Michelle shipwreck. It is due to the anchoring of tourist boats since a world known influencer went for snorkelling back in 2019. (Figure 23.).

Figure 22. Dens *P. oceanica* meadow on the north side of the reef (23m)

Figure 23. Patches of dead *P. oceanica* leaves due to anchoring near the Michelle shipwreck

4.3.2. Algae

Most of the shallow rocky habitat on the reef is covered with brown infralitoral and fotofil algae. The most abundant representatives are *Padina pavonica* and *Sargasum vulgare* (Figure 24.). They can be also found on the Michelle shipwreck all along the body of the ship (Figure 25.). Most colonies can be found on the parts that are on the direct sunlight during most of the day like deck or bow (Figure 26.).

Figure 24. Small colony of *P. pavonica* and *S. vulgare* found on the reef

Figure 25. Body of the Michelle shipwreck covered with *P. pavonica*

Figure 26. Bow of the Michelle shipwreck covered in *P. pavonica*

Along the reef we found a decent amount of green algae which indicates a good proportion of nutrients and sunlight. Most representative green algae are from Codium genus. They are most present on the Michelle shipwreck and on the parts with stronger currents (Figure 27.).

Figure 27. Small colony of *Codium bursa* on the Michelle shipwreck

On the south east and south west part of the reef *Codium effesum* is present in depths up to 6 meter s.The colonies aren't too large and can be found in rocky pockets where the nutrients are most present (Figure 28.). Between islands Male and Vele Lagne in the shallowest part of the reef a small colony of *Acetabularia acetabulum* can be found (Figure 29.). On the parts where the reef goes vertical and also on some parts of Michelle shipwreck, *Codium vermilara* can be found (Figure 30.).

Figure 28. Small colony of *Codium effesum*

Figure 29. *Acetabularia acetabulum*

Figure 30. *Codium vermilara* on Michelle shipwreck

4.3.3. Other benthic representatives

Of other benthic species there is fair amount of sponges. Most present are *Chondrosia reniformis* (Figure 31.) and *Verongia aerophoba* (Figure 32.). First can be found on Michelle shipwreck as well on the rocky parts of the reef, the later can be found spread around the reef on all parts that are not covered with seagrass. Also there is a large colony of *Arbacia lixula* along the reef (Figure 31.). Of other Echinodermata representatives *Holothuria tubulosa* is present and sandy patches of the reef. From Arthropoda phylum *Chthamalus stellatus* can be found along the Michelle shipwreck (Figure 33.).

Figure 31. *C. reniformis* and *A. lixula*

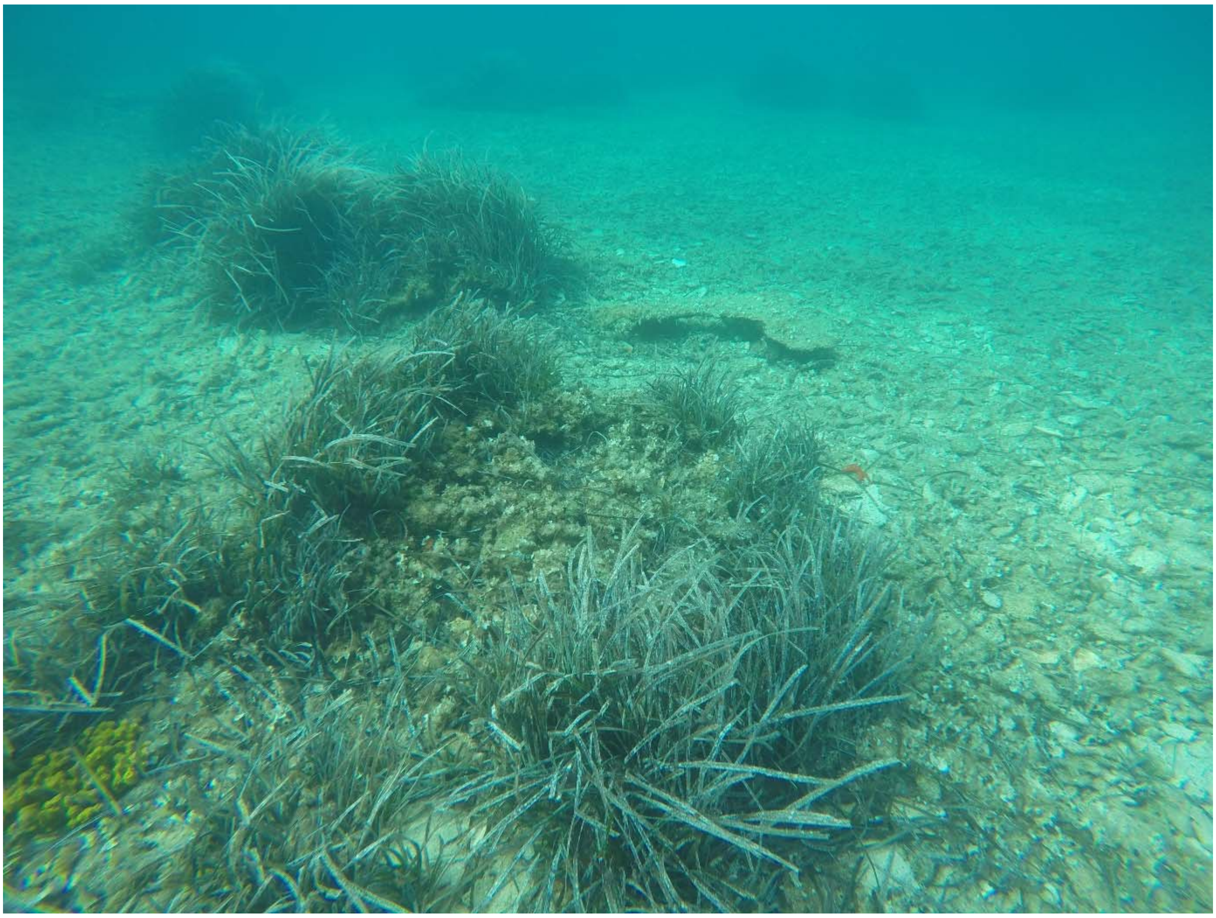

Figure 32. *Verongia aerophoba*

Figure 33. *C. stellatus* colony on Michelle shipwreck

4.4. Fish assemblage

The total 44 species were found on Lagnjići site during ten explorative surveys. For the easier work each species was given the abbreviation name (Table 4.). It is the combination of the first two letters of genus name and species name. First surveys were conducted during summer 2019. and the other ones during spring and summer 2020. and 2021. The most abundant species by the number of individuals are mesopelagic and batipelagic species that live in schools like *Chromis chromis*, *Oblada melanura* and *Spicara maena*. In species richness most abundant are mesopelagic and bati-pelagic species (Figure34.).

Species name	Abbreviation name
Atherina spec.	Ath
Boops boops	Bobo
Chromis chromis	Chch
Coris julis	Coju
Dentex dentex	Dede
Diplodus annulais	Dian
Diplodus puntazzo	Dipu
Diplodus sargus	Disa
Diplodus vulgaris	Divu
Epinephelus marginatus	Epma
Labrus bimaculatus	Labi
Labrus merula	Lame
Mugil cephalus	Muce
Mugilidae	Mug
Mullus surmuletus	Musu
Muraena helena	Muhe
Oblada melanura	Obme
Pagellus acarne	Paac
Pagellus erythrinus	Paer
Parablennius gatorugine	Paga
Parablennius sanguinolentus	Pasa
Sarda sarda	Sasa
Sarpa salpa	Sarsa
Scorpaena porcus	Scopo
Seriola dumerili	Sedu
Serranus cabrilla	Seca
Serranus hepatus	Sehe
	Sesc
	Spcr

Serranus scriba	Spau
Sparisoma cretense	Spsp
Sparus aurata	Spfl
Sphyraena sphyraena	Spma
Spicara flexuosa	Spsm
Spicara maena	Spca
Spicara smaris	Syci
Spondyliosoma cantharus	Sydo
Symphodus cinereus	Symed
Symphodus doderleini	Symel
Symphodus mediterraneus	Syoc
Symphodus melanocercus	Syroi
Symphodus ocellatus	Syros
Symphodus roissali	Syrti
Symphodus rostratus	Trip
Symphodus tinca	
Tripterygion spec.	

Table 4. Total number of species and their abbreviations

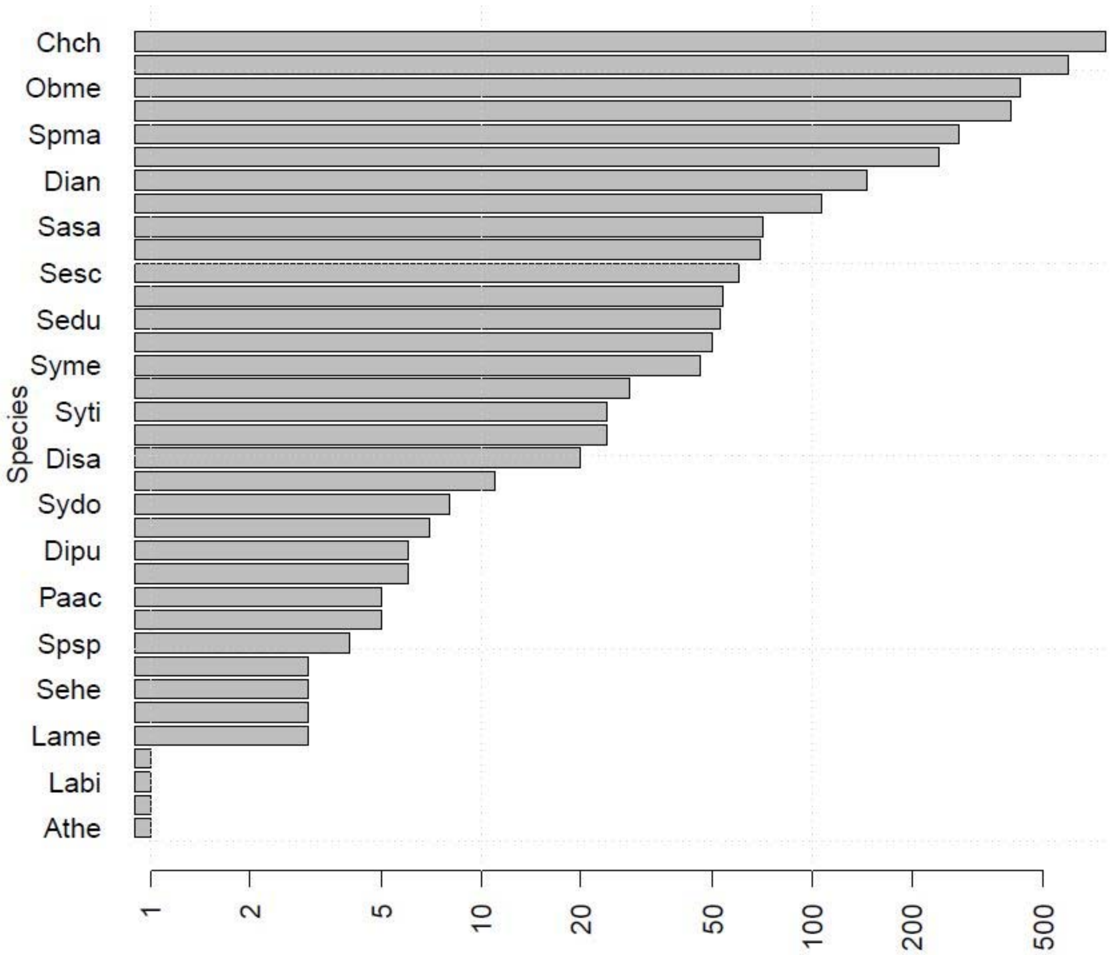

Figure 34. Total fish abundance for Lagnici site BRUV

As for the diference between sampling techniques it can be seen that BRUV recorded 39 species out of total 44 species. *Scorpaena scrofa*, two *blenidae* and two labridae*,* are the only found species with UVC that were not recorded with BRUV. As for the presence of the large predators, with the exception of *E. marginatus,* none were seen using UVC. Our conclusion is that they are scared of divers because this site is, as we found out talking to the local fishermen, a place where a lot of spearfishing and illegal night fishing with scuba is conducted.

No aberrations were found in species length structure. All species were in their normal distribution range for this kind of habitat. Most species are between 10-20 centimetres range and mesopelagic (Figure 35.). The structure and distribution of species along the site make this location excellent for scuba diving or photo-safari. This location potentially can be used for fishing tourism and sport fishing tourism.

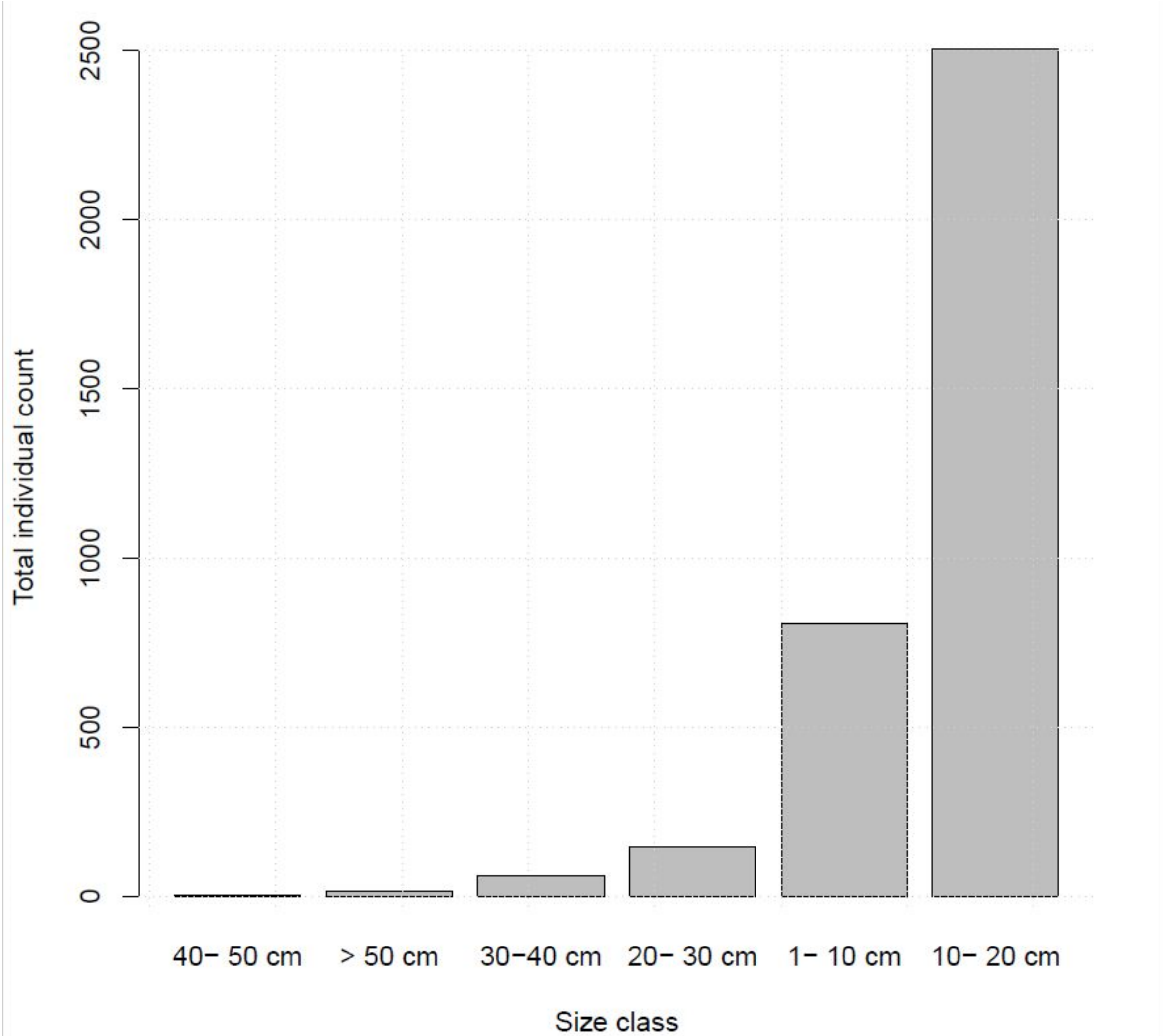

Figure 35. Fish size class for Lagnici site

4.4. Environmental load

Tourism

The location of the natural reef Plić Lagnjići is in the central Adriatic close to the north-eastern shore of the island Dugi otok. It is located between Rt Veli rat and Rt Bonaster. The nearest place to the location is Božava and Molat.

Dugi otok is the largest island among the north Dalmatian islands with a length of about 45 km and it is between 1 and 4 km wide, with the highest peak Vela Straža (338m). The coast of the island is facing the open sea but it is an island of great diversity. The part of the island is located in the Nature Park and it is mostly steep and dominated by beautiful cliffs and on the other part, on the southeast side of the island
There is a sandy beach Sakarun and coves. The island is very beautiful and it is a place where people can enjoy in the beauty of nature and the purity of the sea. As mentioned before, south-eastern part of the island is protected and declared as Nature Park. Also, the other part – north-western part of the island is declared as significant Croatian landscape and recognized as one of the most interesting areas of the Zadar County. On the island, inhabitants live in 12 places and the road connects all villages. It is well connected to the mainland by ferries and fast boats. Dugi otok is primarily place of relaxation but during the summer there are a lot of tourists and visitors.
Božava is a small town located on the north-eastern part of the island Dugi otok. It is a tourist and fishing center of this part of the island. Božava is attractive to visitors, especially during the summer because tourists can be transported with a tourist train to the famous beach Sakarun (Figure36.). Sakarun is probably one of the most famous beaches in Zadar County. The beach gained its reputation with the whiteness of the sand and clean sea, surrounded by pine trees. It is about 800 meters long and has an extremely large and shallow bathing area (at some 250 meters from the shore it is 3,5 meters deep). Near the beach are places Veli Rat, Veruni, Soline and Božava, but transport is organized only from Božava.

Figure 36. Sakarun beach

Also, the possibility of accommodation in a hotel complex in Božava attracts a lot of tourists. On the other hand, accommodation is provided for sailors, as there are berths in the port where ships can take supply of water and electricity.
On the other side of the location there is a small fishing village Molat on the south-western part of the Molat island. During the summer it becomes tourist and diving center for the whole area.

Diving centres

The island of Dugi otok has a rich underwater world but it is not so explored. On the one hand it could be said that the diving sites around Dugi otok are not well known to the general public, but on the other hand, diving tourism on the island exists almost from the time of Yugoslavia when one of the first centres in Božava was opened by a German diving enthusiast. The centre still exists today with minor changes. Five diving centres are located on the island of Dugi otok, some of them work permanently and some occasionally. Except the diving centre in Božava, there are two centres in Sali and two in Zaglav. Diving sites are located mostly on the outer, open side of Dugi otok so exploring them, depends on weather. The most attractive locations on the island are Lagnjići, shipwreck Michele, cliff Mežanj, Mišnjak shoal, Brbišćica caves Lagnjići are ideal for easy acquaintance with Dugi otok locations. The location of the shipwreck Michele is located near Lagnjići, a little bit to the northeast. Due to a navigation error, the ship stranded in 1983 on the shallow sandy bottom. Because of the very small depth, the deck and the superstructure of the ship were almost completely above the sea level, but today only certain parts can be seen above the surface. This location is very popular among underwater photographers due to the different effects and multitude of motives. Longer from Lagnjići to the south of the outside of Dugi otok you can find cliff Mežanj. Caution is needed in the approach due to the many sikes and smaller cliffs and also you must pay attention to possible currents and weather. Slightly south of Mežanj, there is a Mišnjak shoal which is an extraordinary location. It is not difficult to find it but diving spot requires experience. There is an underwater tower whose top is at a depth of fifteen meters. The bell tower itself is beautiful, with a multitude of gorgonians at 25 meters depth and fish that live here. It is one of the best locations only for the experienced divers. Going further to the south there is a smaller bay with caves called Brbišćica located directly opposite of the village Brbinj. The location is very special and probably most famous in this area. The inner – mainland side of Dugi otok does not abound in spectacular locations.

Maritime traffic

The island of Dugi otok is quite well connected to the mainland. There are daily ferry and HSC lines from Zadar.

Dugi otok has always been an attractive destination for all sailors who visited Croatia due to its indented coastline. In Sali, Brbinj and Božava moorings are arranged for the reception of ships with the possibility of supplying with water and electricity. Marina Baotić is located in Veli Rat. Anchoring is possible in other bays of Dugi otok which have set up a mooring buoy. Most famous bays on Dugi otok are Telašćica and Čuna (Figure 37.), which is connected with the Pantera bay by a narrow channel. Those locations are well known to yachtsman as they are a safe anchorage due to their position which gives protection from strong winds. One of the safest anchorages of Dugi otok towards the open sea is the deep Solišćica bay where Soline is located and Brbinjšćica bay.

Figure 37. Telašćica

5. CONCLUSION

Lagnjici reef has a large potential as a tourist destination because of all points of interest that can be found in this study. Large biodiversity, species richness and abundance make a great location for diving tourism. Scuba diving can be conducted on the south side of the reef and snorkelling or photo safari can be provided around Michelle shipwreck. Being it a shallow, low currents and almost pristine location it is ideal for this kind of activities. Also fishing tourism is ideal for the location but in coordination with local stakeholders. A large amount of fishing vessels would do the opposite thing and could potentialy collide with diving tourism. However there is problem that we found during our study. A large amount of boats attracted by the Michelle shipwreck has become a problem for the ecosystem. Since the world famous influencer discovered this location and put it on Instagram the number of boats anchoring per day has increased 6 times. That has made a big problem for the *P. oceanica* meadows and their condition. There is no organized anchoring so everyone is anchoring where ever they want. A lot of seagrass meadows are scared and therefore *P. oceanica* is in danger of being cut to patches and later with wind and currents it will completely disappear. Therefore an organized anchoring system must be provided by local stakeholders so that seagrass meadows and with them all ecosystem preserved and protected.

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ANNEX I - High tech foto/video and 3D filming for monitoring and communication purposes

Explain here how images and data were taken (e.g. equipment, acquisition and processing techniques) and how they were distributed to the wide public (e.g. include **link** to web pages, list dissemination events, citizen science activities if applicable to your CS,...)

Add more annexes if necessary.