

## Ecological Monitoring of a Modular Artificial Reef with Cameras inside the Project SLAGREEF

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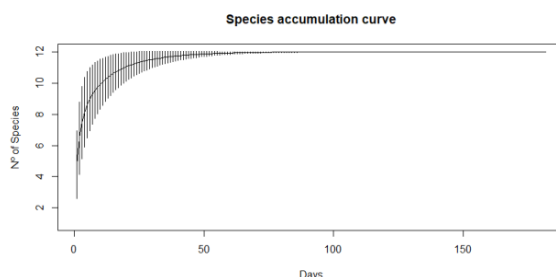
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**Keywords** – Artificial reef, restoration, artificial intelligence, cabled seafloor observatory, biodiversity indicators, fish community.

### I. ABSTRACT

Artificial Reefs (ARs) are human-made structures used also for marine ecosystem restoration, as they provide empty hard substrate to be colonized by benthic animals, such as mussels, and shelter for actively mobile animals, such as fishes [1]. “3D Slag Concrete Manufacturing Solutions for Marine Biotopes” (SLAGREEF) project going on at the OBSEA ([www.obsea.es](http://www.obsea.es)) [2] gives new solutions for building modular ARs biocompatible with the marine ecosystems (using no pollutants materials, such as bicarbonate) and promoting circular economy (using slags from the metallurgic industry that has a high disposal cost). In this framework, a biotope was deployed in the OBSEA environment located at 20 m depth and 4 km off the coast of Vilanova i la Geltrú (Barcelona, Spain) on the 3<sup>rd</sup> of July 2023. The deployed AR was monitored with a 4K PoE IP underwater camera from the deployment date until 31<sup>st</sup> December 2023. The camera was placed at about 3 m from the biotope shooting photos day and night each 30 min using artificial lights for night photos, turning them on and off 30 s before and after the capture. At the same time, water temperature data were gauged by a Seabird SBE37 CTD installed besides the camera every 10 sec. These data were averaged per 30 min, corresponding to the frequency of imaging, and undergone a Quality Control procedure issued by the United States Integrated Ocean Observing System (US-IOOS). The collected photos were automatically analysed with an Artificial Intelligence (AI) based software trained with YOLOv8 to obtain a 30 min interval continuous time-series of fish counts. Previously, the training set was achieved by manual classification of a subset of 1537 images following FishBase ([www.fishbase.org](http://www.fishbase.org)) and a Mediterranean fish taxonomical guide [3]. This time-series was analysed to obtain information on changes in species composition (richness) and relative abundance (evenness), and to study the environmental control on the fish community via Generalized Additive Models (GAMs) using REstricted Maximum Likelihood (REML) methods and adding Autoregressive Models (ARs). The analysis of 4270 photos resulted in a total of 24523 individuals belonging to 12 taxa (*Chromis chromis*, *Coris julis*, *Dentex dentex*, *Diplodus cervinus*, *Diplodus sargus*, *Diplodus vulgaris*, *Mullus surmuletus*, *Muraena Helena*, *Myliobatis* sp., *Seriola dumerili*, *Serranus cabrilla*, and *Sparus aurata*) (Table 1). Species accumulation curve was computed with the R software to detect the minimum days of video monitoring to achieve the richness plateau (in this case 150 days of monitoring) computing the mean and standard deviation of the number of species observed each day (Fig. 1). Furthermore, GAMs were performed to the maximum number of counts per day (hereafter “Max”) of each taxa detected and the biodiversity indexes computed from this data (response variables) using the water temperature (predictor variable) to detect a possible correlation (Table 2 and 3). These models showed significant relationship ( $p < 0.001$ ) between temperature and *Diplodus vulgaris* and *Serranus cabrilla* Max. These results prove that this environmental driver could affect the presence/absence of these species in the studied area in a context of ocean global warming. Concluding, despite remarking the importance of the ARs as Fish Aggregating Devices (FADs) this work outlines an automatic procedure to analyse photos from underwater seafloor observatories, such as the OBSEA, to obtain data on species composition changes and environmental control on the biological communities. This pipeline could be used in the future also to improve knowledge on the environmental effect on the marine species in real-time, setting alarms when environmental drivers exceed certain warning thresholds for the marine ecosystems. These actions are in accordance to the actual European and global politics to reach a good environmental status for the marine ecosystems in 2030, such as the Marine Strategy Framework Directive and the United States Decade of Ocean Science for Sustainable Development.

## II. FIGURES



**Fig. 1.** Richness accumulation curve obtained from the video monitoring of an artificial reef at the OBSEA seafloor cabled observatory from the 3<sup>rd</sup> of July 2023 until 31<sup>st</sup> of December 2023 with number of monitoring days as sampling effort.

## III. TABLES

**Table 1.** Sum of fish count (Sum) and relative percentages (%) of the 12 fish taxa detected during the video monitoring of an artificial reef at the OBSEA seafloor cabled observatory from the 3<sup>rd</sup> of July 2023 until 31<sup>st</sup> of December 2023.

Species	Sum	%
<i>Diplodus sargus</i>	292	1.19
<i>Coris julis</i>	2484	10.13
<i>Chromis chromis</i>	20247	82.56
<i>Serranus cabrilla</i>	445	1.81
<i>Myliobatis</i> sp.	17	0.07
<i>Dentex dentex</i>	451	1.84
<i>Diplodus cervinus</i>	161	0.66
<i>Seriola dumerili</i>	11	0.04
<i>Mullus surmuletus</i>	40	0.16
<i>Sparus aurata</i>	35	0.14
<i>Diplodus vulgaris</i>	329	1.34
<i>Muraena helena</i>	11	0.04
Total	24523	/

**Table 2.** General Additive Model results using daily maximum counts time series of each taxa detected against the water temperature data as predicting variable. DF is the degree of freedom value. “\*”, “\*\*”, and “\*\*\*” indicate significance at level  $\alpha = 0.05, 0.01, \text{ and } 0.001$ , respectively.  $R^2$  measures the proportion of the response variable variance that can be explained by the predicting variable.

Species	DF	p value	$R^2$	Deviance Explained (%)
<i>Diplodus sargus</i>	2.21	0.16	0.0300	4.18
<i>Coris julis</i>	1.52	0.7	-0.0006	0.98
<i>Chromis chromis</i>	1.00	0.317	0.0001	0.69
<i>Serranus cabrilla</i>	1.00	$<2 \cdot 10^{-16}$ ***	0.2970	30.20
<i>Myliobatis</i> sp.	1.00	0.00112 **	0.0641	7.04
<i>Dentex dentex</i>	1.00	0.00128 **	0.0625	6.89
<i>Diplodus cervinus</i>	1.59	0.173	0.0175	2.81
<i>Seriola dumerili</i>	1.00	0.603	-0.0050	0.19
<i>Mullus surmuletus</i>	2.27	0.00592 **	0.0757	9.00

Martech 2024.  
 Marine Technology Workshop  
 06, 07th June. Palma, Balearic Islands, Spain

<i>Sparus aurata</i>	1.00	0.807	-0.0064	0.04
<i>Diplodus vulgaris</i>	6.91	1.22*10 <sup>-6</sup> ***	0.2560	29.10
<i>Muraena helena</i>	1.00	0.00339 **	0.0508	5.73
Total	1.00	0.577	-0.0047	0.22

**Table 3.** General Additive Model results using biodiversity indexes' time series computed from daily maximum counted fish individuals detected during the video monitoring against the water temperature data as predicting variable. DF is the degree of freedom value. “\*”, “\*\*”, and “\*\*\*” indicate significance at level  $\alpha = 0.05, 0.01,$  and  $0.001,$  respectively.  $R^2$  measures the proportion of the response variable variance that can be explained by the predicting variable.

Biodiversity Index	DF	p value	R <sup>2</sup>	Deviance Explained (%)
Richness	1.00	0.379	-0.002	0.53%
Shannon	1.00	0.0421*	0.021	2.80%
Simpson	1.00	0.0593 .	0.018	2.41%
Evenness	1.10	0.422	-0.001	0.75%

### III. ACKNOWLEDGEMENTS

Authors want to acknowledge European Project Semester Students 2023 at EPSEVG-UPC who contributes for the preliminary reef design: Emma CANAVATE, Kim DEHAAN, Lucie DZUIRKA, Yassine EL HAJJI. Authors want to acknowledge economical support from Plan Estatal de Investigación Científica y Técnica y de Innovación, convocatoria 2021 de Proyectos estratégicos orientados transición ecológica y transición digital 2021 for for SLAGREEF funding, 3D slag concrete manufacturing solutions for marine biotopes, TED2021-129760B-I00. Damianos Chatzievangelou was funded by a Juan de la Cierva Formación Postdoctoral Fellowship (Ref: FJC2021-047734-I; financed by MCIN/AEI/10.13039/501100011033 and European Union NextGenerationEU/PRTR funds).

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