ABSTRACTS BOOK

2021

WACOMA

I INTERNATIONAL CONFERENCE ON WATER AND COASTAL MANAGEMENT

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UCA Universidad de Cádiz

UAlg UNIVERSIDADE DO ALGARVE

SEA EU

With the support of the Erasmus+ Programme of the European Union

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2021

WACOMA

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CONGRESS PROGRAM

ALMA MATER STUDIORUM
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MONDAY 19 JULY

Hour	Activity
09:30 – 10:00	**Opening Ceremony**
10:00 – 11:00	**Keynote talk** **Magdalena Santana Casiano** University of Las Palmas de Gran Canaria, Spain
11:00 – 11:30	**Q&A session – keynote talk**
11:30 – 12:00	**Coffee Break**
12:00 – 12:30	**Guest talk** **Alejo Martínez Sansigre** Quasar Science Resources, Spain
12:30 – 13:00	**Session** **Climate Change and Global Warming** **Kyle Sweeney:** Change Adaptation in Northern and Southern Europe: A Comparison of Adaptation Initiatives in Denmark and Spain **Yada Trapletti Lanti:** Estimating the Blue Carbon Storage in an artisanal Saltpan: CO2 sink or source? **Q&A session - keynote talk**
13:00 – 14:00	**Workshop** **COEDPA** (Cooperation, Education and Participation)
15:30 – 16:30	**Keynote talk** **Julián Blasco** Institute of Marine Sciences of Andalusia, CSIC, Spain
16:30 – 17:00	**Q&A session – keynote talk**
17:00 – 17:30	**Coffee Break**

17:30 – 18:00	**Guest talk** **Elisa Rojo Nieto** UFZ, Germany
18:00 – 19:30	**Session** **Water resources quality and pollution** **Ayesha Rafiq:** Effects of bioplastic and tire rubber leachates on the Mediterranean mussel, Mytilus galloprovincialis ontogeny and physiology **Ayesha Siddiqua Asha:** Early life development toxicity of cigarette butt leachates **David Salvatierra Guerrero:** Experimental evidence of how contamination might modify the shrimps' population dynamics and make them susceptible to spatial isolation **Kuddithamby Gunaalan:** Bio-based plastics are not always biodegradable, and biodegradable plastics are not always bio-based: which cause concerns for the marine environment? **Pavani Nadeesha Premarathne Mohotti Arachchige:** Ecological status of benthic communities after a long story of trade-off between conservation and exploitation in the Goro Lagoon, northern Adriatic Sea **Sakinat Mojisola Ahmad:** Amount, sources and composition of sedimentary organic matter, and associated influences on sedimentary mercury in an impacted estuarine system, mobile bay, Alabama **Q&A session - keynote talk**

TUESDAY 20 JULY

Hour	Activity
10:00 – 11:00	**Keynote talk** **Mike Elliott** University of Hull, UK (09:00 UK time)
11:00 – 11:30	**Q&A session – keynote talk**
11:30 – 12:00	**Coffee Break**
12:00 – 12:30	**Guest talk** **John Icely** Sagremarisco, Portugal
12:30 – 14:00	**Session** **Ecosystem based management: Ecosystem services and human wellbeing** **Ariel Rojas Garrote:** Proposal for the Restoration of tidal Marshes on the left bank of the Guadalquivir Estuary: Trebujena Marshes **Daina Mathai:** Mapping Ecosystem service flow in Ungwana bay, Kenya **Hop T.B. Hoang:** Whale watching as ecotourism in Sagres, Portugal - It is possible? **Juan Manuel Bustos García:** Impacts of coastal tourism in seagrass ecosystems and human wellbeing in the Bay of Cadiz (Spain, SW) **Laura Chavarria Zuñiga:** The Ostrom's Social-Ecological System Framework modified for Urban Ecosystem Assessment **María Aranda García:** Saltmarsh fragmentation in a mesotidal estuary: implications for medium to long-term management **Pablo Cárdenas Camacho:** Diet composition and seasonal variations of mysid Mesopodopsis slabberi in Guadalquivir river estuary and its potential use in aquaculture **Q&A session - keynote talk**

15:30 – 16:30	**Keynote talk** **Marcus Polette** Universidade do Val de Itajai, Brasil (11:00 Itajai – Brasil time)
16:30 – 17:00	**Q&A session – keynote talk**
17:00 – 17:30	**Coffee Break**
17:30 – 18:00	**Guest talk** **Mercedes García Barroso** Tecnoambiente, Spain
18:00 – 19:30	**Session** **Integrated coastal zone Management and Marine Spatial Planning** **Débora Gutierrez:** A proposal for MPAs participation in areas beyond national jurisdiction: the case of Macaronesia **Mohamed Mahmoud Elhadary:** Analysis for Integrated Management of Ria Formosa Coastal Lagoon using DAPSI(W)R(M) framework **Pedro Walter Flores Medina:** Strategic environmental sensitivity mapping for oil spill contingency planning in the Peruvian marine-coastal zone **Richard Takyi:** Adaptive Management of Environmental Challenges in West African Coastal Lagoons: Case of Ghana **Julia Terra Miranda Machado:** Implications of Offshore Wind Energy Developments in Coastal and Maritime Tourism and Recreation (Offline) **Q&A session - keynote talk**

WEDNESDAY 21 JULY

Hour	Activity
09:00 – 10:00	**Keynote talk** **Nadia Pinardi** University of Bologna, Italy
10:00 – 10:30	**Q&A session – keynote talk**
10:30 – 11:00	**Coffee Break**
11:00 – 11:30	**Guest talk** **Enrico Sassi** Lighthouse, Italy
11:30 – 14:00	**Session** **Observation and modelling systems for monitoring the marine environment** **Aminah Faizah Kaharuddin: The Use of Combined in situ and** Remote Sensing Datasets to Derive Phytoplankton Dynamics: Contributions to the Management of Blue Growth Sectors **Umesh Pranavam Ayyappan Pillai:** Assessing the sensitivity of seagrass landscaping as a nature-based solution in the coastal belt of Emilia Romagna **Ana Amaral Wasielesky:** Do current-driven dispersal and habitat patchiness explain local benthic diversity in the Mediterranean basin? **Diep Nguyen:** On the applicability of remote sensing techniques to detect soil salinization in the Mekong Delta, Vietnam **Helena Monteiro:** Harmful Algae Blooms on the Portuguese coast: cross-checking events with remote sensing ocean colour data for coastal management **Ibrahim Olayode Busari:** Impact of Land Use Land Cover (LULC) Variation on Hydrological Fluxes in Karasu Basin **M. Andrea Orihuela García:** Surface transport and distribution of trace metals through the Strait of Gibraltar

Masuma Chowdhury:
Environmental forcing on blue whiting year-class strength in the Porcupine bank (NE Atlantic)

Melisa Isgró:
Comparison of UAS and Sentinel 2 Multispectral Imagery for water quality monitoring in the Iberian Pyrite Belt (SW Spain)

Sayeda Umme Habiba:
Intertidal Topography Mapping Using the Waterline Method from Sentinel -2 Images of Inner Bay of Cadiz

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Sudheera Samarasinghe Gunasekara:
The influence of coastal currents on the movement patterns of Argyrosomus regius (Asso, 1801) along the northern shelf of the Gulf of Cadiz

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Tadesse Mucheye Azagaw:
Spatial and seasonal dynamic of intertidal microphytobenthos in a tropical estuary using Sentinel-2 multispectral satellite images.

Ibrahim Olayode Busari:
Impact of Land Use Land Cover (LULC) Variation on Hydrological Fluxes in Karasu Basin

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Andrea Casaucao Aguilar:
A holistic approach to assess the spatial distribution and dispersion of the European anchovy (Engraulis encrasicolus) early stages in the Gulf of Cadiz during the summer of 2016 (Offline)

Silvia Unguendoli:
Nature based solutions to contrast coastal erosion and flooding: numerical modeling application (Offline)

Silvia Unguendoli:
Uncertainty in coastal prediction:
application of the ensemble technique to coastal modelling (Offline)

Q&A session - keynote talk

15:30 – 16:30	**Keynote talk** **Javier López Lara** University of Cantabria, Spain
16:30 – 17:00	**Q&A session – keynote talk**
17:00 – 17:30	**Coffee Break**
17:30 – 18:00	**Guest talk** **Iñaki de Santiago** AZTI, Spain
18:00 – 19:30	**Session** **Coastal dynamics** **Dany Miguel Avalos Lliguin:** Coastal flooding of urban beaches: comparison of flooding estimation strategies **Jonas Stock:** Cliff Vulnerability Assessment of Rocky Coasts in southern Portugal **Maria F Macià:** Using Citizen Science to map shoreline change in a meso-tidal urban beach (#CoastSnapCadiz) **Tayna Nascimento Cruz:** Modelling upwelling index in the Southwest Coast of Portugal **Thet Oo Mon:** Coastal Hazard Evolution under Different Climate Change Scenarios in Ria Formosa, Portugal **Ana Aldarias:** Comparing water level values in the Guadalquivir River estuary and the Gulf of Cadiz continental shelf from a numerical model, satellite altimetry and in-situ data **Q&A session - keynote talk**

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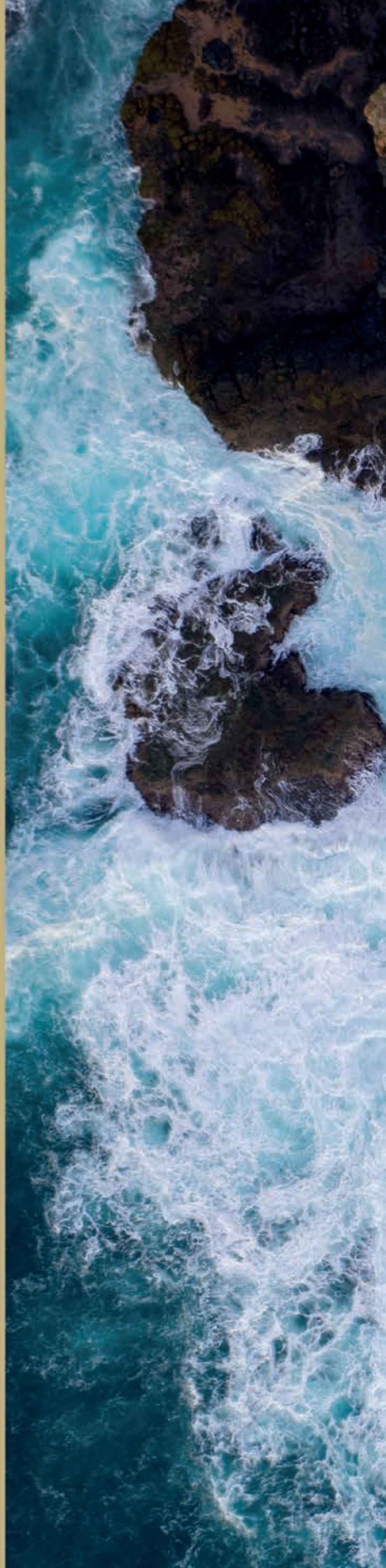

INVITED SPEAKERS

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Metals in the aquatic ecosystems: from legacy to emerging pollutants

Julián Blasco
Institute of Marine Sciences of Andalusia (CSIC). Campus Rio San Pedro. 11510 Puerto Real (Cádiz). Spain

In the frame of the 2030 Agenda for Sustainable Development of United Nations, the 14th goal is Life Below Water. This goal mentions the role of oceans and coastal areas as an essential component of the Earth system and critical for global food security and human health. One of the threats that can affect marine ecosystems is pollution. The nature and occurrence of pollutants in marine ecosystems is diverse and it is a consequence of the release from anthropogenic activities. Some of these pollutants are present in the aquatic ecosystems from ancient times (e.g., metals). The main sources of metals in coastal ecosystems are mining activities and some of them has been carried out from Roman's time. Although the extraction and treatment processes have been improved, even nowadays mining is a relevant source of pollution. From this point of view, metals can be considered as legacy pollutants. However, the development and applications of new technologies have generated the occurrence of new emerging pollutants in aquatic ecosystems. In this context, the nanoparticles and specifically metal nanoparticles are considered emerging pollutants and they are a new source of metals that can affect negatively the health of aquatic ecosystems. In this talk, we are going to show the relevance of metal pollution in aquatic ecosystems and how the occurrence of metal nanoparticles can represent a threat for these ecosystems, and that we know about their effect and that we need to know for assessing the risk.

Toward a cost-efficient adaptation planning strategy due to climate change-induced impacts applied to coastal structures and port systems

J.L. Lara*, D. Lucio, A.V. Fernández, I.J. Losada, A. Tomás, A. Toimil
IHCantabria - Instituto de Hidráulica Ambiental de la Universidad de Cantabria
Corresponding author email address*: jav.lopez@unican.es

In recent decades, climate change (CC) has already affected natural and human systems on all continents and in the oceans, with consequences for economic, productive, and social sectors (IPCC, AR5 (2014)), and is one of the great challenges facing society in the 21st century. Within the different elements that are located on the coast, port infrastructures are a key element as they deal with 80% of world trade by volume (UNCTAD, 2018). The design horizon of such infrastructures is less than 50 years, and many of them did not include changing climate conditions in their design. There are already studies (Izaguirre et al., 2020) that show that many ports around the world will become inoperative by the end of the century, because of climate change. However, the estimation of the loss of operability, together with expected failures in the structural integrity of many port works, is very complex due to the great uncertainty in future climate. The management of climate risks and the adaptation of these infrastructures, therefore, represent a major investment challenge that the present society is forced to face. In response, this work presents a new methodological framework to characterize climate change-induced risks in port infrastructures and establish adaptation measures. This planning will address the uncertainty associated with climate variability and change, and the structural, functional, and operational response of port infrastructure. The work will show applications in real port infrastructures. The framework is based on an accurate description of the risk terms, implementing the latest climate datasets and statistical techniques. It intends evaluating climate-change induced impacts for a better decision making and cost-effective adaptation planning.

A Coupled numerical modelling strategy for the assessment of seagrass nature-based solutions against storm surges

N. Pinardi(1), P. A. Umesh(1), J. Alessandri(1,2), S. Unguendoli(2), I. Federico (3), S. Causio (3), A. Valentini (2)
(1) Department of Physics and Astronomy, University of Bologna, Italy (2) Hydro-Meteo-Climate Service of the Regional Agency for Prevention, Environment and Energy of Emilia-Romagna, Arpae-SIMC, Italy (3) Euro-Mediterranean Center on Climate Change (CMCC), Lecce, Italy

Operational oceanography has transformed our capacity to understand, monitor and forecast the global open ocean and its coastal environment. The advent of real time observations, embedded in an international data sharing infrastructure, and short-term numerical ocean forecasting has allowed to reconstruct the past ocean state from several decades to a century, to forecast the ocean conditions up to ten days in the future. The European operational oceanography framework is driven by the Copernicus Marine Environment Monitoring and Forecasting Service that makes available satellite, in situ, and global as well as regional current, sea level, wave, and pelagic biogeochemistry reanalyses, and forecasts. These developments have created a fertile framework for an overall enlarged digital representation of the coastal environment, from events to climate time scales.

The Sustainable Development Goals targets focus on pollution reduction and monitoring of the environmental status of the global coastal ocean. In this paper we show a novel framework for the assessment of Nature Based Solutions (NBS) in the coastal zone using the operational oceanographic framework and a new suite of coupled numerical ocean models. This coupled modelling strategy allows us for the first time to answer “what if” scenario questions such as: are indigenous seagrass meadows capable to reduce storm surge energy, sea level, and waves, and reduce coastal erosion? Our answer is yes, and we will try to show that this is true for both the present and the future climate scenario. Furthermore, this framework allowed to discover the nexus between seagrass NBS and reduction of coastal erosion and open new avenues for future studies.

Wave farm impact assessment on coastal zones: the case of Bimep zone (northern Spain)

Iñaki de Santiago*, Roland Garnier, Pedro Liria, Ibon Galparsoro, Juan Bald
* AZTI Marine Research, Member of Basque Research and Technology Alliance (BRTA).
idsantiago@azti.es

In the present study the impact of wave farms on the coastal region of the Basque coast (northern Spain) is evaluated. The studied wave farm is composed by 80 wave energy captors deployed at 80 m water depth at 4 km from the coast in the Bimep area. The coastal zone under the study extends along 11 km and is composed by cliffs and one beach. The present methodology differs from the classical approach (where a few representative wave scenarios are used to analyse the coastal impact), since long-term wave data series (~60 years) are used to tackle the problem. A series of hydrodynamic and morphodynamic indicators are used to analyse the nearshore impact. We demonstrate that the wave farm impact on the Basque coast in terms of wave power (P) and significant wave heights (Hs) is limited. In average, the wave farm removes approximately 0%-8% of P and 0-5% of the Hs at the coast. The wave farm impact on the beach dynamics is relatively small and not uniform along the beach. While the western part of the beach undergoes a slight accretion, the central area is hardly modified, and it is only on the eastern contour of the beach where erosion occurs. Since, both accretion and erosion magnitudes are considerably low, it could be considered that the wave farm does not provide any protective effect for the beach. Future investigations on how these results could feed other impact studies (ecological effects) should be carried out to design robust integrated coastal management strategies.

A deep learning approach to identify Posidonia oceanica using Sentinel-2 satellite images: the case of the Balearic Islands

Alejo Martínez-Sansigre (1), Masuma Chowdhury (1), Maruška Mole (1), Isabel Caballero de Frutos (2), Ignacio de la Calle (1)
(1) Quasar Science Resources, Camino de las Ceudas 2, 28232 Las Rozas de Madrid, Madrid, Spain
(2) Instituto de Ciencias Marinas de Andalucía (ICMAN), Consejo Superior de Investigaciones Científicas (CSIC), Avenida República Saharaui, 11510 Cadiz, Spain

Posidonia oceanica is a seagrass species which provides a habitat for aquatic life to live, feed and breed in. It is considered to be highly valuable ecologically and is now included amongst priority habitats. Monitoring of Posidonia oceanica seagrass meadows is mostly done by submarine remotely operated vehicles and boats equipped with side-scan sonar but recently satellite imaging data has also been used to identify the seagrass meadows. Here we present a novel method of identifying Posidonia oceanica from optical satellite data, based on automatic classification with a neural network, commonly known as deep learning. The technique requires atmospherically-corrected RGB images and in situ data to train the network. We apply the technique to Sentinel-2 images of the Balearic Islands in Spain, where we find a mean accuracy of 98,5%, with 94% of pixels correctly classified as non-Posidonia and 4.5% correctly classified as Posidonia. Our classification is able to reproduce in detail the shape of the seagrass meadows around most of the archipelago, with a correct recovery rate of 85% for the Posidonia pixels. With refinement, our classification method can provide an extremely cost-effective way to monitor variations of Posidonia oceanica using the Sentinel-2 archive (2015-present).

Techniques and Tools to Monitor and Manage Coastal Areas

E. Sassi, S. Sandroni; Lighthouse S.pA.

The need of knowing what's on the seafloor is an historical fact that justifies human curiosity of exploring and need to exploiting what's underneath the sea. Whether this is driven by surviving needs, by scientific interests or by economical interest, science developed many tools to approach the depths.

Mainly they can be divided in tools that allows direct assessment or indirect assessment. The first includes tools from the simplest divers' goggles to the most sophisticated manned or unmanned vehicles such as bathyscaphes or ROV's and AUV's mounted cameras that allowed to directly see and explore the deepest seafloors in the world and direct sampling of the sediments using grabs or coring tools. On the other side the indirect tools include a multitude of sensors that can be either mounted on vessels or on ROV's and AUV's, or towed during the navigation, that allow to gather acoustic signals that are converted in data to be interpreted by scientists. These are bathymetric tools like Multi-Beam Echo Sounders (MBES), or imaging sensors like Side Scan Sonars (SSS), Sub Bottom Profilers (SBP).

MBES provide information related to the depths of the seafloor and to the morphology in the same way a topographical survey is intended for land areas. While on land the nature of the terrain is evident at a first glance, offshore this is possible only interpreting data derived from SSS survey. Acoustic data from SSS surveys provide information on the nature of the seabed if it is rocky or covered by sediments, if vegetation is present and what kind for some extent and proved information on presence of objects of different nature whether they are natural or manmade. SBP data complete the evaluation with information about the subsurface in the few meters below the seafloor.

While acoustic methods are used for covering wider area and then narrow down the scale of investigation to detail the main interests' targets, the direct visualisation of the seafloor investigates smaller extent areas and objects. The two approaches do not exclude themselves but most of the time they are complementary. Direct methodologies can integrate the geophysical tools by check whatever has been interpreted on maps and charts and providing what is known as ground-truthing and classify the seabed nature.

Seabed classification can be done for different purposes such as ecological evaluation and monitoring, bathymetric mapping or engineering purposes.

The topic of this presentation is to panoramic review of the different tools used to image and monitor the seafloor mainly in the coastal areas and on how the geophysical industry is using them to support the different purposes.

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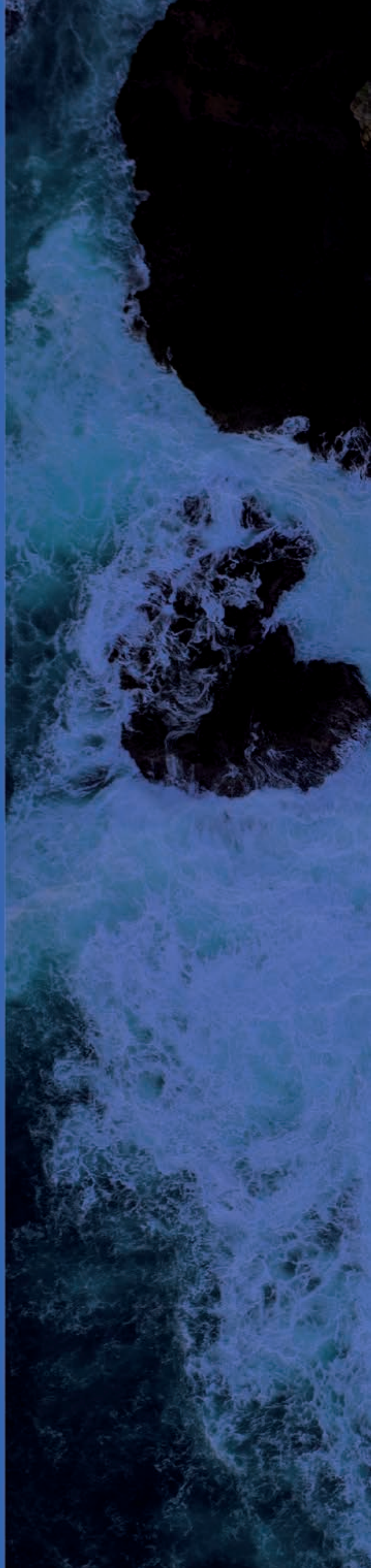
1. Coastal dynamics



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Coastal flooding of urban beaches: comparison of flooding estimation strategies

Dany Avalos1, Theocharis A. Plomaritis1, Iñaki de Santiago2
1 Universidad de Cádiz, Departamento de Ciencias del Mar, Facultad de Ciencias del Mar y Ambiental
2 AZTI Marine Research, Member of Basque Research and Technology Alliance (BRTA).
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ABSTRACT
World coastlines experience ongoing growth of urban areas. Under present day climate conditions, approximately 10 million people live in coastal communities exposed to coastal flooding. Wave run-up during storms can increment by many meters water elevation, increasing the likelihood of flooding from overtopping/overwash events. However, there have been few attempts to forecast overtopping, due to the large number of input data requirements, such as, high resolution regarding wave conditions, beach morphology and sea coastal defence structures data; as well as, the lack of reliable methods for validation of overtopping events. The present research used video derived intertidal and synthetic subtidal bathymetry with topographic information for development of digital elevation models (DEM) used to extract cross-shore beach profiles to forecast overtopping during 7 storms recorded between 2015-2020. An empirical model (Eurotop) and a numerical model (XBeach) were applied to simulate overtopping conditions and the results were validated by means of videoimaging. The empirical model after calibration correctly predicted the occurrence of overtopping with 82.5% accuracy at low computational cost. The numerical model presented higher capacity at predicting, by forecasting correctly 86.47% overtopping events, as well as predicting the absence of overtopping suggesting a good prediction of ´hazard´/´no hazard´ limit. Reliable forecast of overtopping aids decision-makers to prevent-mitigate risks, and increase the preparedness of coastal communities to extreme water events.

KEYWORDS
Coastal flooding, videoimaging, empirical model, numerical model.

INTRODUCTION
Coastal areas account for 20% of earth's surface; they host 10% of the world's population and deliver a high value for costal ecosystems services (Wahl et al., 2016). Large socioeconomic benefits generated from coastal ecosystem services is linked to the improvement of the wellbeing of societies which has lead world coastlines to an ongoing growth of urban areas (McGranahan et al., 2007). Wave run-up during storms can increment by many meters the still and instantaneous water elevation in coastal zones, particularly in step beaches where the likelihood of overtopping/overwash (key contributors of coastal flooding) highly increases (Stokes et al., 2021).

Forecasting wave overtopping during storm events is critical in the application of coastal flooding strategies. Currently, most coastal flooding models do not take into account wave overtopping at coastal defences; some of the main constrains for this approach is the lack high resolution of wave conditions, up-to-date morphology data, and methods to validate wave overtopping predictions at seawalls. The present research compares coastal flooding estimations by means of a set of empirical formulas (Eurotop II) and a processed based numerical model (XBeach) to forecast wave overtopping in coastal environments that include natural barriers and engineering structures. Validation of overtopping took place by means of videoimaging. This method could allow to simulate overtopping/overwash occurrence to provide forecasting of overtopping and to categorize flooding hazards across individual locations in coastal urban areas with natural beaches (Stokes et al., 2021). The selected flooding strategy proposed in this work could become a suitable method to apply in beaches with similar characteristics to the study site in the Basque Coast region.

MATERIALS AND METHODS

The study site is located in the Basque Coast (Northern Spain). The site selected is the beach of Zarautz (Fig. 1), located within the Bay of Biscay. The site is a long embayed beach that extends for 2.3 km of coastline and comprises two well defined sectors; i) A natural area that accounts for 30% of the beach composed by sand dunes reaching up to 10 m, and ii) an urban area that accounts for the 70% of the remaining beach. Zarautz is an embayed beach type that is considered a pilot beach to forecast and set up flooding alarm levels by the Basque regional authorities. Wave data for 7 storm events from 1 of January 2015 – 31 od October 2020 was obtained from the Bilbao-Vizcaya buoy. Water level data was obtained with datasets from the Bilbao 3 tidal gauge from Spanish Port Authorities Measuring Networks and Forecasting Systems. Storm characteristics were measured hourly when overtopping was observed by video images.

Seawall crown, dune top and dune foot elevations

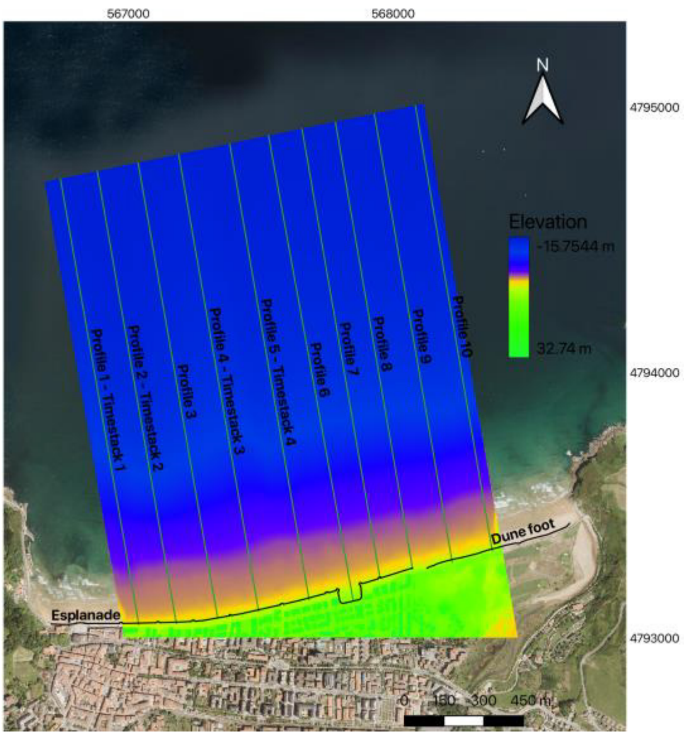

Fig. 1 Study site and DEM with location of beach profiles.

were measured using real-time kinematic position GPS (RTK-GPS). Zarautz's promenade width was obtained from aerial LIDAR measurements that covers the urban area of Zarautz. Timex images at 20-30-60 minute intervals were collected by averaging frames at 0.5 Hz over the interval periods and were used for digitalization of shorelines that covered the surf-wash zone to obtain intertidal data for each storm. Offshore synthetic bathymetry data from each storm were obtained by using the equilibrium beach profile formulae of Dean et al., (1991), and the bar-type beach profile with a concave-convex curve from Hsu et al., (2006). DEMs per each storm and beach profile type were assembled. Ten cross-shore beach profiles were extracted from the DEMs, eight in the engineered section and two in the natural sector. Four profiles were set along the seawall crown to coincide with the position of timestacks images that were used to observe overtopping/overwash events. Only those profiles with available timestack information were used for the validation of the models. Overwash at the natural section was obtained using the Stockdon et al., (2006) empirical formulae plus the water level from each storm. To forecast overtopping, the empirical equation 5.44 from Eurotop II (2018) 'Manual on wave overtopping for sea defences and related structures' was used on the engineered section. The XBeach numerical model was set up using a single direction propagation of infragravity waves and wave forcing to forecast run-up; the output was mainly a water level numerical sensor at the top of the seawall. Validation of overtopping was computed by the F score that uses a Hit rate from 0 for a model with no overlap between the observed overtopping from video images and predicted model discharge, to 1 for a model with a perfect overlap between the variables.

RESULTS AND DISCUSSION

Storms were analysed based on wave climate conditions and water level to link these parameters with overtopping occurrence. Storms presented high variability of overtopping occurrence that ranged from 3 to 71 events. Nearshore wave data was obtained by means of the SWAN (Booji et al., 1997) model. The nearshore wave parameters were then converted into deep water one using a reverse shoaling approach similar to Stokes et al., (2021). Storms recorded a mean significant wave height (Hs) of 3.82 m, mean peak wave period

(Tp) of 14.23 s, a mean pick direction (p) of 347o, and mean water level of 1.97 m. The comparison of wave and water level characteristics against overtopping events suggest that there is no dominant overtopping driver, and it is the balance between hydrodynamic characteristics which dictates the relevance of the overtopping. This have been seen in studies of overtopping estimations on coastal structures where wave conditions and water level that are in good agreement are described as a reliable parameter for estimations of wave overtopping (Suzuki et al., 2017).

Patterns of the foreshore morphology and the engineered seawall are associated to overtopping occurrence. For most storms, the intertidal slope decreases from the western to the eastern side of the foreshore; in contrast, the seawall crown heightens on the same direction which gives profile 1 (Fig. 1) the optimal steepness conditions to produce overtopping on a lower elevation zone of the seawall. Video imaging recorded 188 overtopping events in profile 1, 12 events in profile 2, 2 events in profile 3, and 1 event in profile 5.

Results from discharge simulations of the empirical model observed that the model overestimates the overtopping; the model systematically predicts overtopping each time the total water level reaches the seawall toe. At the same time, from timestacks image data, it is noted that many times run-up reaches the seawall without the occurrence of an overtopping event. Based on this observation and to counteract the overestimation , a calibration factor ( ) was introduced. The parameter activates or deactivates the overtopping depending on the height at which the run-up reach in relation with the seawall height. was tested at values from 0 to 100% at intervals of 10% to find the ratio that produced the most accurate F values. At 0.2 (20% of the seawall height covered with water), the factor forecasted the most accurate overtopping occurrence for all profiles with timestacks information. Yet, the model continued overestimating overtopping.

For the validation of overtopping forecast, the Hit rate (F) is used as a proxy of the models success. Both methods the empirical model at lower com-

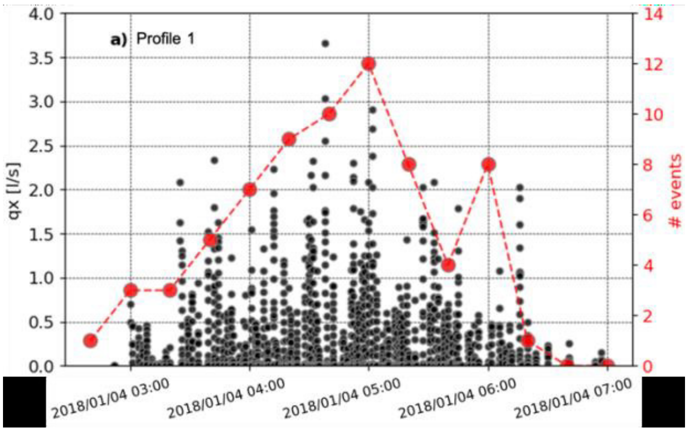

Fig. 2 XBeach Dean profiles discharge simulation and overtopping occurrence from video images for profile 1 during storm 4.

putational cost and the XBeach numerical model at a higher computational cost (Dean – Hsu profiles) presented good capacity to predict a significant number of overtopping events. 90.82% of these events were observed by timestack images in profile 1. The empirical model obtained the highest mean Hit rate (0.77). The addition of the factor increased the mean Hit rate to 0.87 in profile 1. This high Hit rate is caused by the nature of the empirical model to overestimate overtopping that coincides with the high overtopping occurrence recorded by video images in profile 1; the empirical model validated overtopping occurrence for all 7 storms at profile 1. However, the most accurate model to validate overtopping is XBeach. The results obtained by the XBeach-Dean profiles model show a mean Hit rate of 0.66 for profile 1 and the model validated 86.47% (Fig. 2) of all overtopping events recorded by images compared to 82.5% obtained in the empirical model after addition of the factor. The high variability between the number of overtopping events recorded by the images at each storm impacts the success of the mean Hit rate for the XBeach-Dean profiles, as each storm accounts for 0.14 of the total mean Hit rate independently of number of overtopping events recorded by image. Dean – Hsu profiles forecasted no overtopping in profile 1 for storms 2 – 3 in which timestack images recorded 8 overtopping events; this outcome lowered substantially the mean Hit rate. The empirical' model overtopping overestimation does not ensure higher accuracy by the model. For instance, during storm 4

– profile 1 (Fig. 2) the empirical model obtained a Hit rate of 0.8, whereas the XBeach obtained a Hit rate of 1. Similar outcomes were obtained in storms 1 and 5; while the mean Hit rate is lower for the XBeach Dean profiles, the model was the most accurate by validating more overtopping events than the empirical model. The XBeach-Hsu profiles model validated 80.2% of overtopping events, the lower validation percentage compared to the XBeach-Dean profiles model might be caused by the bar-type used for the XBeach-Hsu profiles that place a bar from the short that generates concave-covex curve on the cross-shore beach profiles.

Overestimation of overtopping by the empirical model forecasted various overtopping events at profiles 2-3-4 at times that timestacks images recorded no overtopping, this is consider by the F score as a proxy of false overtopping alarms forecasted by the model. In contrast, XBeach Dean – Hsu profiles models show good capabilities to not forecast overtopping at the same spatial and temporal variations at which video images recorded no overtopping which is described as a 'dry' condition by the F score. Once more, XBeach Dean profiles model was the most effective.

CONCLUSIONS

Wave climate conditions and water level data were used to study how hydrodynamic conditions could influence overtopping occurrence. Other influential factor for overtopping occurrence was the morphology and seawall crown elevation which allowed identification of possible vulnerable areas that might experience overtopping; once the empirical and numerical models were applied, they delivered accurate assessment vulnerable areas at risk.

Videoimaging has provided useful information regarding various aspect of the research such as construction of intertidal bathymetry (used in DEM construction, for slope and wall foot calculation) and for validation of the number of overtopping events predicted correctly by the models.

Both the empirical and numerical models performed well. At a low computational cost, the empirical model is a suitable forecasting method for urban areas with more profiles that present high hazard levels which would reduce False rate. At a higher computational cost XBeach was more accurate at correctly predicting overtopping than the calibrated empirical model and at predicting profiles that present no hazard levels.

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Using Citizen Science to map shoreline change in a mesotidal urban beach #CoastSnapCadiz

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ABSTRACT
CoastSnap is an international initiative to study the evolution of beaches through Citizen Science. It is implemented in more than 44 countries, with Cadiz being the 5th station in Spain, and the first one outside Galicia region. The position of the coastline is obtained through images taken and shared by citizens using their mobile phone from a fixed station. Subsequently, these images are processed following a standard methodology (Harley et al. 2019), obtaining shoreline position accurately and at a very low cost. The CoastSnapCadiz station (@coasnuca) is located at Santa Maria del Mar urban beach (Cadiz). The present study covers a time period of more than 7 months (from 16th October 2020 to 31st May 2021), having received a total of 419 photographs, most of them (66%) by email. The trend of participation has been increasing month by month, with April being the month with the highest number of photographs shared (86 images). From a geomorphological point of view, during the first 5 months of 2021 a fluctuation in the dry beach width has been observed, with a final accreting trend of 0.85 m per week.

KEYWORDS
Coast Snap Cadiz, shoreline, mesotidal beach, Citizen Science, photographs

INTRODUCTION
Beaches are extremely dynamic ecosystems subject to both terrestrial and marine agents. In recent decades there has been a trend towards coastal occupation and development that increases vulnerability to potential coastal hazards. In order to address this problem, it is necessary to assess, monitor and manage the coast in an integrated manner. It is therefore essential to investigate the morphological changes and evolutionary trends of the coasts in order to understand the complexity of these environments.

Monitoring systems are used to study beach morphological changes. Traditional beach monitoring methods such as RTK-DGPS, LiDAR, terrestrial laser scanning or video monitoring require specialised knowledge and skills by those involved in the data collection, as well as sophisticated and expensive equipment. Moreover, nowadays there is an increasing need for more horizontal management policies in the coastal zone that integrate different stakeholders. Therefore, an increasing number of scientific projects and studies are using Citizen Science methodologies [Conrad and Hilchey, 2011]. Citizen Science is understood as scientific research and monitoring projects in which members of the public collect, classify, transcribe or analyse scientific data on a voluntary basis. [Bonney et al., 2014]. Thus for systems monitoring, Citizen Science can provide long-term data at low cost. At the same time, scientists need to establish a feedback mechanism that promotes conservation and knowledge of the coast. The rationale is that a better understanding of coastal environment by citizens will make them appreciate it more and feel part of it. In this context and with the proliferation of smartphones and social networks, the international project for community monitoring of beaches, CoastSnap, was initially developed at the University of New South Wales (Australia) (Harley et al., 2019).

MATERIALS AND METHODS
The study area is the urban beach of Santa Maria del Mar, in the city of Cadiz (SW Spain). The beach is located in the outer part of the Bay of

Cadiz, with a NNW-SSE orientation and an extension of approximately 900 m. It is an artificially nourished beach, bounded by two groins. The tide has a semidiurnal character and a spring tidal range of approximately 3 m.

The community takes pictures of the beach with their smartphones from a fixed point (CoastSnap station). The station consists of a low-cost and easy to- install infrastructure, where a stainless steel stand and a sign explaining the procedure can be found.

These images are shared through social networks indicating the date and time they were taken and using a specific hashtag, for this work #CoastSnapCadiz. These images are then collected and stored together with their metadata (person who sent the photograph, date and time, quality of the photograph, platform where it was sent). To obtain the scientific data, the software developed by Harley et al. (2019) was used, which consists of an initial processing of the images and a georectification by means of ground control points (GCPs). Once the image has been georectified, the shoreline is drawn using the software's toolbox. To detect the edge of the shoreline, the toolbox relies on the difference in the red and blue colour channels of the points located on the dry sand and the ocean (Harley et al., 2019).

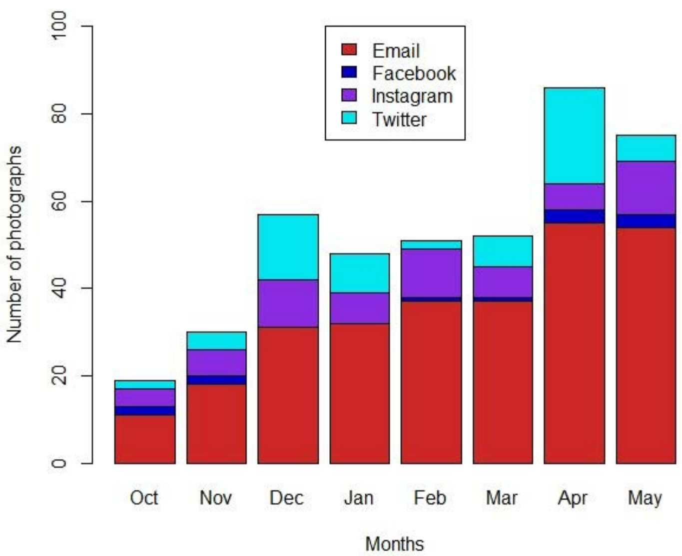

Figure 1. Evolution of the number of images received per month and contribution of each social network.

In order to study shoreline evolution, it is necessary to compare photographs with similar tidal level (tolerance), so there is a need to perform some simple tidal corrections (Harley et al., 2019). Once the shoreline has been tidally corrected and using the toolbox, it is possible to obtain the evolution of the beach.

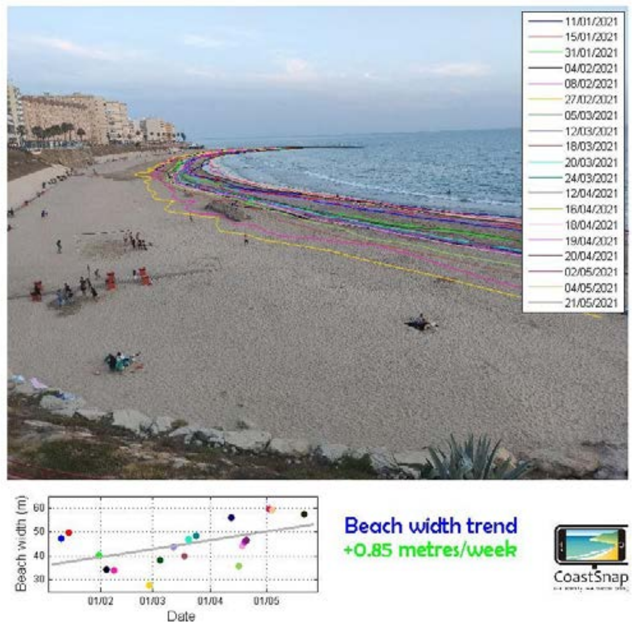

Figure 2. Evolution of the beach over the first 5 months of 2021

RESULTS AND DISCUSSION

The study covered a period of approximately 8 months (16th October to 31st May) after the installation of the station, in which a total of 419 images were received by 81 different individuals, from which a total of 350 shorelines were obtained. This represents a contribution rate of 5.17 images per individual and an average of 1.7 images per day, although there are two local champions who have sent 101 and 95 images each. The trend of photo submissions has been increasing throughout the study period (Figure 1), with April being the month with the highest number of contributions (86 images).

Most of the images were shared via email (66%), followed by Twitter and Instagram (16% and 15%, respectively). Images shared via Facebook accounted for only 3% of the total. Instagram is the social network with the largest number of followers and the highest feedback.Initial results obtained from the system allow to estimate the evolution of the beach during the first 5 months of 2021. The period from January to May was chosen for the study, because there are not enough images with the selected tidal range in the first months of the project. The starting image has a tidal height of 0.53 m above datum and a tidal tolerance of 0.1 is selected (i.e. only shorelines between 0.63-0.43m are compared) and a time period of 5 months. The results are presented in Figure 2, where the different positions of the shorelines of interest can be seen. Throughout the first 5 months of 2021 the dry beach has increased its width by an average of 0.85m per week. This result is consistent with the fair weather conditions recorded in this period.

CONCLUSIONS

Community participation in CoastSnap Cadiz beach monitoring program has been increasing over the study period, with almost one photograph on each survey day. As the results of both the evolution of the beach and the participation have been obtained, they have been published on the different social networks.

From a morphodynamic point of view, the implementation of a CoastSnap station has been useful to observe the evolution of the shoreline. However, a larger amount of images is needed to obtain accurate data due to the tidal range.

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Modelling upwelling index in the Southwest Coast of Portugal

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ABSTRACT
Oceanic upwelling regimes help to regulate marine temperature and promote nutrient circulation between the deep oceans and the coastal environment. This process is crucial for the biological productivity of coastal zones and might be affected by climate change. It is predominantly driven by atmospheric and oceanic circulation, which are ultimately driven partly by wind stress and oceanic currents, respectively. Time series analysis of oceanographic variables might provide valuable insights regarding the status and future scenarios of marine ecosystems within the context of climate alterations. Although the importance of time series analysis for the upwelling index data has already been recognised, the insufficient literature reviews have a detrimental impact on decision making about the methods used in this type of analysis. This work explores the use of time series decomposition methods on a daily upwelling index time series (2012-2018) from the Southwest Coast of Portugal at São Vicente Cape. Classical decomposition and the Seasonal-Trend decomposition based on Loess (STL) were applied to the upwelling index time series. Their performance was evaluated using some accuracy measures

KEYWORDS
upwelling index, time series analysis, decomposition methods, southwest coast of Portugal.

INTRODUCTION

Upwelling events are essential drivers of productivity in coastal areas. Understanding its dynamics is important to manage the coastal ecosystems and predict its occurrence.

A time series is defined as a series of measurements made over a certain period (Hyndman & Athanasopoulos, 2020). One of the main goals in time series analysis is to build a mathematical model that better describes the sampled data (Schumway & Stoffer, 2014). Although the importance of time series analysis for the upwelling index data has already been recognised (Lorentzen, 2014; Vantrepotte & Mélin, 2010), the low number of literature reviews have a detrimental impact on decision-making about the methods used in this type of analysis.

This research proposes the use of two time series decomposition methods applied to the upwelling index: classical decomposition and Seasonal-trend decomposition based on Loess (STL). Their performance was evaluated using well-known accuracy measures such as the root mean squared error (RMSE) and the mean absolute error (MAE).

METHODS

Upwelling index (UI)

The upwelling index time series was provided by the Instituto Español de Oceanografía (assessed on http://www.indicedeafloramiento.ieo.es/index1_es.php) and was calculated using sea level pressure of the MeteoGalicia WRF atmospheric model following Bakun (1973) methodology. The equivalent horizontal (U) and vertical (V) components of local winds were measured daily on a six-hour interval from 2012 to 2019.

UI transformation

Transformations and adjustments are tools used to remove known sources of variation or make the pattern along with the data more constant. The use of simpler patterns can make modelling easier and create more accurate forecasts (Hyndman & Athanasopoulos, 2020). A transformation was performed to the initial UI dataset according to the methodology introduced by Box & Cox (1964) and modified by Bickel & Doksum (1981). The latter transformation was chosen once it allows for negative values and is defined as in the following expression:

$$w_t = \begin{cases} \log(y_t) & if\ \lambda = 0 \\ \frac{sign(y_t)|y_t|^{\lambda}-1}{\lambda} & otherwise' \end{cases}$$

UI value at time t, t=1,…,N. To ensure that the transformation works with negative values, λ must be positive. The best value of λ was estimated according to
Guerrero (1993).

UI decomposition

Decomposition methods are commonly used to separate the time series into components. The trend component (T_t!, t=1,…,N) can be noticed when there is a continuous increase or decrease, not always linear, in the data (Hyndman & Athanasopoulos, 2020). The seasonal component (S_t!, t=1,…,N) is a repeated pattern that is always of a fixed and known period. It occurs when a time series is affected by seasonal factors, such as a day of the week or the time of the year, with the seasonal period always remaining constant, along with the time horizon (Hyndman & Athanasopoulos, 2020). Lastly, the remainder component (R_t!, t=1,…,N) is everything that does not fit inthe other components (Hyndman & Athanasopoulos, 2020). When the seasonal fluctuations, or the variation around the trend are approximately constant over the time horizon then an additive model is used (Coghlan, 2018; Hyndman & Athanasopoulos, 2020). This model is described as:

$$y_t = S_t + T_t + R_t,$$

where Y_t represents the observation at time t, with t=1,…,N.

In the classical decomposition, the seasonality is described by seasonal periods (m), such as m = 12 for monthly data. The first step is to apply the moving average smoothing to estimate T_t. A moving average of order m can be represented by m-MA and written as:

$$\hat{T}_t = \frac{1}{m}\sum_{j=-k}^{k} y_{t+j},$$

where m = 2k + 1, and T_t C is the estimated trend at time t, t=1,…,N, (Hyndman & Athanasopoulos, 2020). The detrended time series is calculated by $Y_t - T_t$ @!, t=1,…,N. The S_t is estimated by averaging the detrended values for each m. The seasonal component, e.g., for monthly data, will be the average of all detrended values in a month, with these values being adjusted until they add to zero. The remainder component is obtained by $R_t = Y_t - T_t - S_t$, t=1, ..., N.

Another decomposition method is the STL, proposed by Cleveland et al. (1990). This filtering procedure works by applying the locally weighted regression smoother (Loess) on the data, and it is useful when estimating nonlinear relationships. In this method, the trend and the seasonal window can be defined by the user. The number of consecutive years to calculate each value in the seasonal component is referred to as the seasonal window (Hyndman & Athanasopoulos, 2020). Within the values in a window, weights are calculated for each data point based on their distance from a chosen point. The closest value has the largest weight, and the weights decrease as the distance from the data point increases (Cleveland et al., 1990). More information about STL decomposition is found in Cleveland et al. (1990).

Error measures

Error measures are used to evaluate the accuracy of the models and compare different models. The residuals (e_t, t=1,…,N) are calculated from the difference between the observed value at time t (Y_t) and the fitted value (Y_t) at time t, t=1,…,N. The accuracy measures that are based only on e_t , t=1,…,N, can be called scaledependent errors and are used to make comparisons with the same units (Hyndman & Koehler, 2006). The most used scale-dependent measures are the mean absolute error (MAE) and the root mean square error (RMSE), where:

$$MAE = mean(|e_t|)$$
$$RMSE = \sqrt{mean(e_t^2)},$$

with t=1,…,N.

Statistical Software

All the statistical analysis was performed using the R software version 4.0.3. R Core Team (2020) and the packages fpp3 (Hyndman, 2021) and forecast (Hyndman et al., 2021).

RESULTS AND DISCUSSION

The upwelling index UI time series for the Southwest coast of Portugal (Cape St. Vicent) is presented (Fig. 1), with positive UI values indicating favourable upwelling conditions.

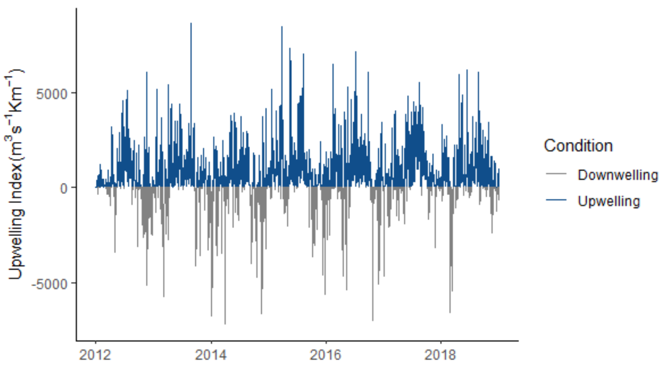

Figure 1. Daily time series of upwelling index.

Due to the variability of the data, the Box-Cox transformation modified by Bickel & Doksum (1981) was applied using λ “ = 0.89 as the optimal parameter (Figure 2).

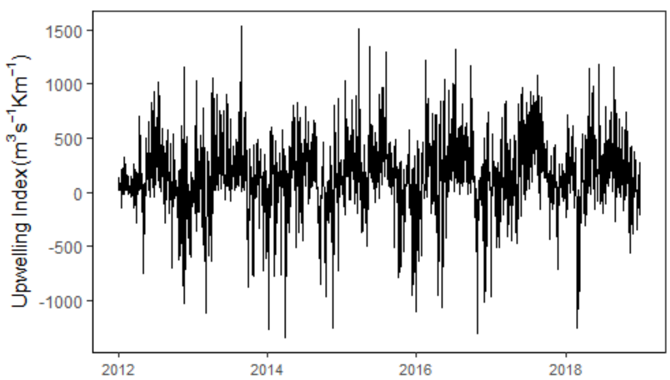

Figure 2. Transformed UI with λ = 0.78.

The classical decomposition model was fitted to the transformed daily UI data (Fig 3).

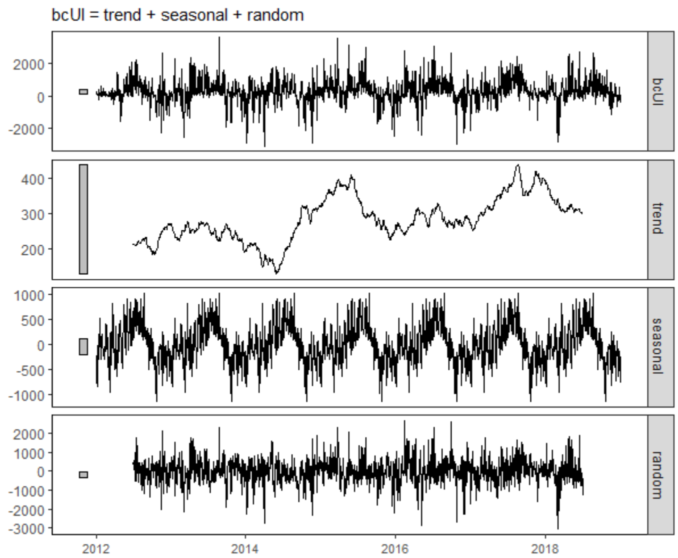

Figure 3. Classical decomposition of transformed daily UI.

Fig. 4 shows the STL decomposition, fitted to the transformed daily UI data.

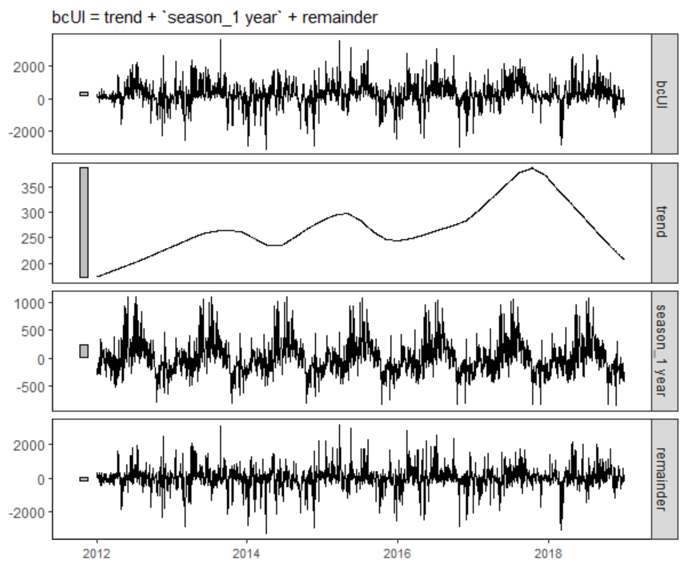

Figure 4. STL decomposition of transformed daily UI.

Both decompositions exhibit similar behaviour. In the decomposition plots, the grey bars at the left of the panel represent the relative scales of the components. The larger bar at the trend component represents a small variation compared to the variation in the data. The large bars in the trend panels indicate that the time series exhibits a small relative trend, whilst the short bars on the seasonality panels show a strong seasonality. Although a break is observed in the trend component between 2014- 2015, it is possible to identify an overall increasing trend in the UI values during the study period. The trend component, on the STL plot, presented a significant visual difference from the last decompositions, with a smoother plot. This smoothness can be linked to the model being robust to outliers.

One of the most challenging tasks in time series analysis is selecting the best model. Table 1 presents the values of the accuracy measures in order to compare the performance of the methods. STL decomposition shows the best performance since the error measure MAE is lower, although the difference is very small and the difference between the RMSE values is negligible.

Table 1. Accuracy measures

	RMSE	MAE

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Coastal Hazard Evolution under Different Wave Climate Change Scenarios in Ria Formosa, Portugal

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ABSTRACT
Coastal areas are being threatened by various effects of climate change mainly due to changes in coastal forcing: sea level rise, waves, tides, and storminess, whose spatial and temporal variations are very high. There is a need to translate these changes into potential hazard levels to serve as fundamental information for disaster risk assessment. The aim of this study is to assess the changes in potential overwash and (episodic) erosion hazards resulted from wave climate change to the barrier islands of Ria Formosa, Portugal. A regional scale assessment (~1 km scale) on the probabilistic hazard levels was carried out by using phase 1 of the Coastal Risk Assessment Framework (CRAF), for both present situation and climate change scenarios (RCP4.5 and RCP8.5) and data of wave parameters from six Global Circulation Models (GCMs). The present hazard levels agree with findings from the existing literature. Based on trends analysis in the future potential changes of hazard levels, a slight decrease in hazard level for RCP4.5 scenario from 2010 to 2050 and RCP8.5 scenario from 2050-2099 was observed although hazard level estimations for RCPs were found to be highly influenced by large variations of wave input parameters among different GCMs.

KEYWORDS
coastal hazards, climate change, storms, flood, erosion, overwash, CRAF.

INTRODUCTION
Among the various effects of climate change (Morim et al., 2019; Vousdoukas et al., 2017), sea level rise and changes in wave climate and intensity of floods can cause adverse economic loss and impose higher risks for valuable ecosystems in low-lying coastal areas. Under a high emission scenario, nearly 40% of the world's coastline is likely to be exposed to robust changes in at least two variables of offshore wave climate change (Morim et al., 2019). Globally, little attention has been given to assessments related to the projected future changes in wave climate (with relatively less understanding and quantifiable uncertainties on it than other climate parameters such as temperature, precipitation or sea level rise), despite its implications to the impact on the functioning of many industries and ecosystems in the coastal regions (Bricheno & Wolf, 2018; Hemer et al., 2013; Morim et al., 2019). This is also no exception for Ria Formosa, an economically and ecologically important coastal lagoon in the southern coast of Portugal.

This study aims to provide an initial assessment on the evolution of hazard levels in association to different wave climate scenarios, by defining possible future hotspot areas, related to erosion and flooding hazards at the barrier islands of Ria Formosa, and by comparing them with the current hazard levels. The hotspots are identified at a regional scale (1km resolution) using present wave input data and future climate change projection data. The results from this study, identifying critical zones (hotspots) for coastal hazards considering present and future scenarios, will be able to provide a valuable input for better decision-making process in management and planning of the coastal lagoon.

MATERIALS AND METHODS
Ria Formosa is situated in the southernmost part of the Portuguese coast, within the Gulf of Cadiz. It has a longshore extension of about 60 km and extends up to 6 km from the mainland in the vicinity of Cape Santa Maria (Figure 1). The lagoon system is protected from the direct action of the sea by two peninsulas –Ancão at the western end, Cacela to the east– and five barrier islands

(Barreta, Culatra, Armona, Tavira and Cabanas), separated by six tidal inlets spatially distributed to produce a cuspate shoreline of the barrier system (Ferreira et al., 2016a).

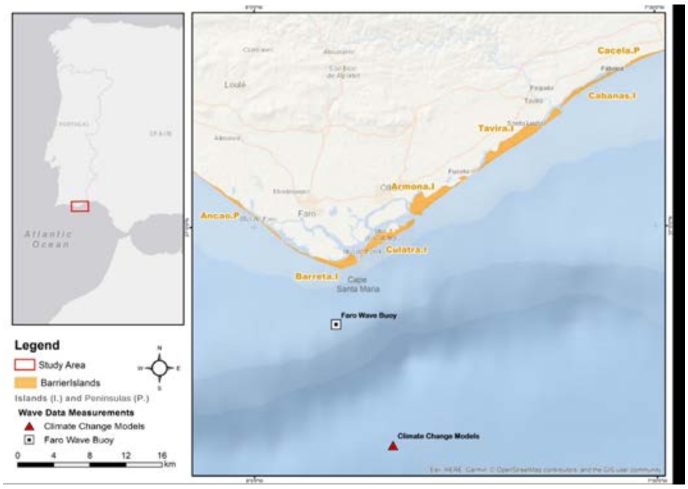


Figure 1: Location of the barrier islands, wave buoy (square) and grid point of the model data (red triangle)

Probabilistic present and future hazard levels at regional scale were calculated using phase 1 of Coastal Risk Assessment Framework (CRAF) and considering 2 only wave climate changes maintaining the current sealevel.

The coast was subdivided into different sections of 1 km, and 59 sections were obtained. For each of the sections, morphological data for the representative 'worst case scenario profile' (wcs hereafter) were retrieved using a topo-bathymetric Lidar DTM of 2011. Storm events were identified by using the threshold wave parameters relevant to the study area, and by using POT analysis.

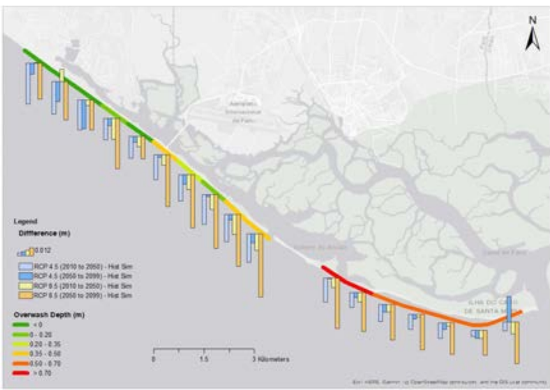
The hazard indicator values associated with the wcs profile were calculated for all the storm events identified for various datasets. Those include measured wave data and different scenarios of future wave projections from 6 different GCMs for RCP4.5 and RCP8.5 pathways, divided into two decadal periods (2010-2050 and 2050-2099). 1-D parametric models were applied as in the Phase 1 of CRAF tool (Ferreira et al., 2016b; Plomaritis et al.,2018; Viavattene et al., 2018). The overwash depth above the dune crest and shoreline retreat were used as overwash and episodic erosion hazard indicators respectively. Generalized Extreme Value Distribution was applied to define the hazard levels in probabilistic terms using 10 years and 50 years return periods (RP).

RESULTS AND DISCUSSION

The assessment for the current hazard level using wave buoy measurement data shows that Faro Beach (Middle section of Ancao Peninsula), Barreta Island, eastern parts and the western end of Culatra Island (Ilha do Farol), middle sections of Tavira island, and most of the Cabanas Island and Cacela Peninsula are the most critical spots in terms of overwash hazard (see Figure 2 as an example). For erosion, the western end of Barreta Island, middle sections and western end of Culatra Island (Farol), western parts of Tavira Island and the majority of Cabanas Island and Cacela Peninsula (similar to overwash) show high hazard levels (this does not imply them as high risks areas).

The present hazard levels observed among different sections along the barrier islands seem to be in agreement with the available literature and assessment to date (Almeida et al., 2011; Plomaritis et al., 2018).

In terms of potential future changes in hazard level, there is not a clear and common trend among the scenarios and the models, due to high variations in the hazard levels (see Figure 2), which might be greatly influenced by large variability of individual input wave parameters from the GCMs and their behaviours. For the majority of the coastline, the difference between hazard levels, averaged over the RCPs scenarios and historical simulations, shows a potential slight decrease for both RCP4.5 and RCP8.5 scenarios, respectively for the 2010-2050 and 2050-2099 periods.



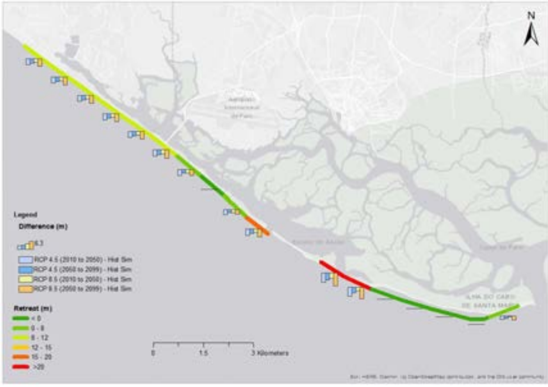


Figure 2: Probabilistic hazard levels for the present (single line feature along the coast) and potential changes (bar charts along each section) for RP 10 years for Overwash Hazard (upper panel) and Erosion Hazard (lower panel in Ancao Peninsula and Barreta Island. Bars pointing seawards mean a possible decrease of hazard level in relative future scenario than present, while bars pointing landwards a possible increase.

CONCLUSIONS

The methodology applied showed reliability for hazard level estimation to a larger extent but with some overestimation. This can be improved by better adjustments to the input wave data. Wave parameters can be modified in a way to be more representative of the physical system. More statistical or dynamic downscaling efforts can lead to more reliable estimation of the future wave projections, e.g. carrying out a bias correction for a single representative parameter than for the three parameters separately. For a complete estimation of future hazard hotspots, the effect of sea level rise and morphological changes of the coast influenced by longerterm dynamics should also be incorporated. According to currently available studies in the area, sea level rise predictions tend to prevail over the effects of wave storminess changes on the local sea levels and can be a crucial factor for shoreline retreat and overwash increase. Similarly, it should be noted that in some areas, complex morphological changes from other processes can, sometimes, influence the hazard levels to a larger extent than the changes in wave climate conditions. The results provide a critical part of necessary information needed for decision making in risk management and adaptation in coastal areas of the Ria Formosa.

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Cliff Vulnerability Assessment on Rocky Coasts in southern Portugal

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ABSTRACT
Rocky cliffs are widely distributed around the world's coasts and are subject to natural and anthropogenic pressures. The coastal evolution and erosional processes of the southern Algarve coast in Portugal have been previously studied. However, a detailed analysis of the relationship between lithological characteristics and cliff vulnerability to erosion is lacking. Therefore, in this work we focused on lithological facies variation and structures of the cliffs from Olhos de Água to Albandeira. We combined a variety of data, including those derived from traditional field-based and laboratory analysis, remote sensing (UAV image analysis) and photogrammetry. We identified multiple key forcers concerning cliff vulnerability to erosion: high vertical facies variation, intense karstification, multiple notches and marine caves. Furthermore, our lab analysis revealed differences in CaCO3 content for each lithofacies, resulting in alternating rock strength and leading to the formation of multiple structural notches into the cliff face. A classification of cliff vulnerability was developed based on a combination of these lithological and geomorphological factors. The sector Arrifes - Galé was classified as most vulnerable; Sector Galé - Armação de Pêra Bay was classified as least vulnerable in the study area.

KEYWORDS
Cliff erosion, driver mechanisms, lithology, remote sensing, Portugal

INTRODUCTION
The research on evolution and processes of rocky coastal cliffs is of major importance as these environments experience great natural and anthropogenic pressures and are highly sensitive to climatic changes or extreme events (Inman & Nordstrom, 1971; Davis, 2013;). Several studies have been conducted concerning these matters and are precisely summarized by Naylor et al., (2010). However, thorough research on driver mechanisms with respect to the physical substrate is needed. This involves the examination of cliff features such as lithology, karstification, morphology and structures such as bedding, faults and joints (Trenhaile, 2002; Boye & Fiadonu, 2020).

Rocky cliffs can be observed throughout most of the world's coastlines. Compared to sandy shorelines, the evolution of rock coasts is rather slow, but a loss of material is irreversible. Erosional processes on rocky coasts depend on multiple factors, including lithological properties of the exposed rocks, physical (wave impact, mass movements), chemical (karstification), biological and anthropogenic (infrastructure, tourism) parameters (Kelletat, 1989; Summerfield, 1991; Bird, 2008; Prémaillon et al., 2018). Rocky sea cliffs can consist of different lithologies (lithofacies) with mechanically and chemically stronger (therefore more resistant to weathering) and weaker rock units. "Resistant" in this context means strength of the exposed rock or the resistance to physical, chemical and biological weathering (Moura et al., 2011; Sunamura, 2015; Bird, 2016). Due to these differences in resistance to erosional processes, some lithofacies may erode faster than others, which eventually leads to a partial recession of the cliff and to the formation of arches and sea stacks. These formations are further supported by the presence of discontinuities such as faults, joints and fractures, as they provide a greater surface for erosion to act on (Komar, 1976; Emery & Kuhn, 1982; Bird, 2016).

The objectives of this study are to characterize different lithological units and structures and to associate lithological properties (dimensions and features) with cliff vulnerability to erosion throughout the study area. Furthermore, we tested whether the used tools are suitable and constructive for research on cliff vulnerability to erosion in the southern
Algarve.

MATERIALS AND METHODS

The area under study is defined by the about 40 km long coastal stretch between Olhos de Água and Albandeira in the southern Algarve, Portugal and was divided into six sectors according to respective lithological characteristics (Figure 1). To investigate possible associations between certain parameters and cliff vulnerability to erosion and to obtain the necessary data, a multi-tool approach was implemented. This included fieldwork to explore lateral facies variation and geomorphological features, laboratory analysis of rock samples (CaCO3 content), coupled with UAV (unmanned aerial vehicles) image analysis, and photogrammetry.

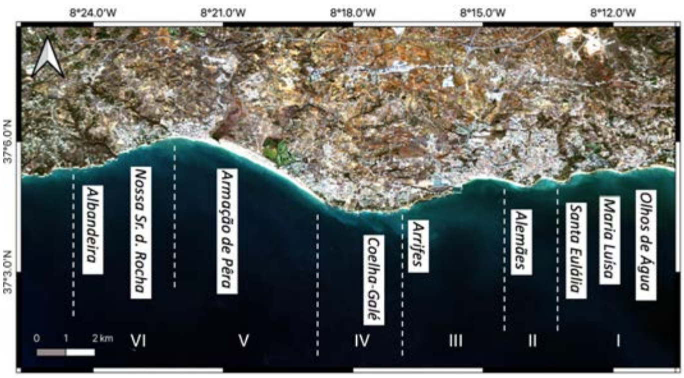

Figure 1: Study area in the southern Algarve, Portugal, identifying six sectors (STOCK 2020, ESA 2019).

The main purpose of the field survey was to observe the present cliff face, its geomorphological and lithological characteristics, structures and karst features. This included the identification and description of both lateral and vertical facies variation and their contact zones. Moreover, the extent of discontinuities, notches and marine caves in the cliff face, the presence or absence of shore platforms as well as rivulets reaching the shore were noted. In addition, rock samples were collected from each identified lithotype along the coast, whenever changes were detected.

The performed work in the laboratory focused on the quantification of CaCO3 content of each collected sample. According to Hulsemann, (1966) and Lamas et al., (2005), an efficient method for this purpose is the determination of
released CO2 after the reaction with hydrochloric acid (HCl). This was performed with a Bernard Calcimeter.

With the aim to quickly understand the lateral facies variation between coastal sectors, pictures were taken along the coast with both, a ground based digital camera (Panasonic Lumix GH4) and an UAV (DJI Spark). These images allow a better perception of the vertical and horizontal evolution of the cliffs' layered structure as well as the identification of cliff features.

For better visualization of the study area and to quantify geomorphological features (e.g., sinkholes), the captured UAV images were further processed in AgiSoft Metashape.

This software allows the three-dimensional reconstruction of the two-dimensional information contained in the images and the creation of orthomosaics and digital elevation
models (DEM).

RESULTS AND DISCUSSION

The results from field work showed vast differences in lithology, number of vertical facies, distribution of discontinuities as well as shore platform and beach width throughout the entire study area (Figure 2). For instance, Coelha and Albandeira displayed nine vertical lithofacies, whereas Alemães only showed three. A high abundance of faults and karst features could be detected in Alemães and Coelha. Multiple notches and marine caves were found in Maria Luísa. The widest beaches and shore platforms were observed in Armação de Pêra and Santa Eulália.

The highest average CaCO3 content values were detected at Albandeira (77,9%), followed by Santa Eulália (73%), Olhos de Água (59,7%) and Maria Luísa (56,6%), while the lowest average CaCO3 content could be found in the cliffs of Alemães (39,68%) (Figure 3). The CaCO3 content analysis provided valuable information as it is directly linked to rock strength and hence, resistance to erosion.

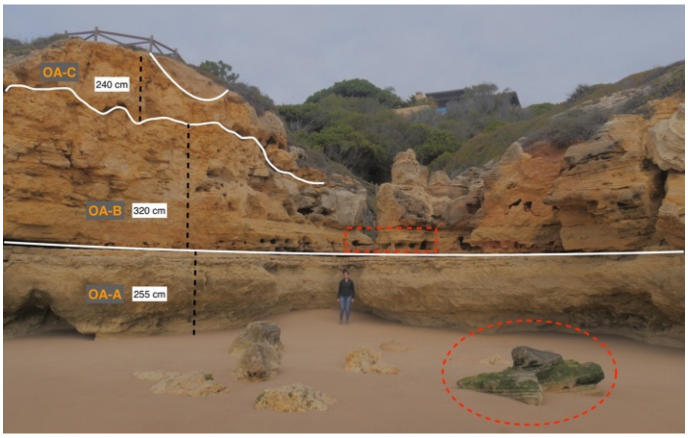

Figure 2. Cliff photograph of Olhos de Água showing lithofacies (OA-A, -B, -C), layer thicknesses, karst features (red squared) and elements of rockfall (red circled) (STOCK, 2019).

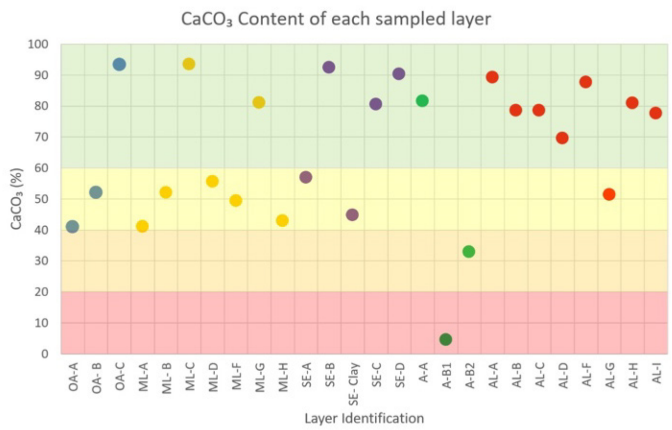

Figure 3. CaCO3 content of each sampled lithofacies organized from east to west with distinctly coloured dots according to the locations.

The outputs from AgiSoft Metashape established the possibility to observe cliff features from different and usually inaccessible angles. The created 3D model (Figure 4) helped to identify the overall morphology as well as minor scale features such as evidence of rock fall events, sinkholes and sediment fans, as well as to measure cliff heights.

Figure 4. 3D model of the cliffs near Maria Luísa displaying sinkholes and shore platforms (STOCK 2019).

After integrating the previous results, sector IV exhibited the highest vulnerability to erosion, mainly due to a high number of vertical facies and karstic features. Followed by the sectors I, II, III and VI. The lowest vulnerability was detected in sector V. The results are in accordance with previous research by Nunes et al. (2009) and Bezerra et al. (2011) who identified similar locations being exposed to drivers for erosional processes. Their research, however, was mainly based on parameters like wave energy and height and cliff exposition.

CONCLUSIONS

The parameters that primarily determine cliff vulnerability to erosion in the study area are lithological properties (vertical facies variation, CaCO3 content), discontinuities in the rock (faults, joints, karst features), notches, marine caves, wave exposure, as well as width of beaches and shore platforms. The approach using multiple tools and data sources showed potential for assessing cliff vulnerability to erosion. Particularly fieldwork with a thorough description of cliff properties and a lithological analysis and interpretation unveiled important results. Through this, the parameters of interest could be precisely analysed and combined for an overall assessment of vulnerability to erosion. However, an appropriate and detailed parametrization of the studied factors is needed to develop a profound vulnerability assessment of the southern Algarve cliffs. This is of high value as this coastal zone is subject to excessive touristic pressures.

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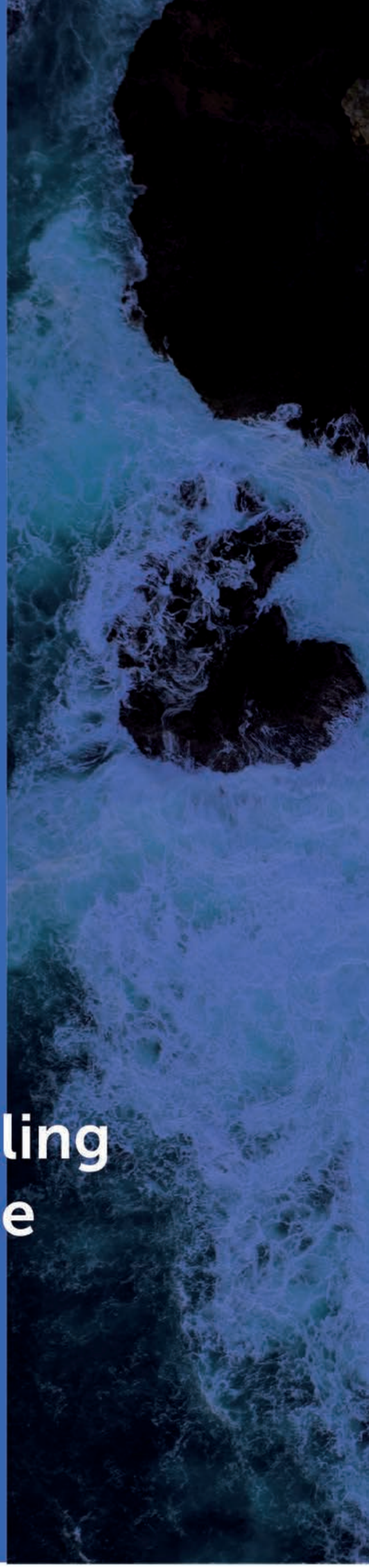

2. Observation and modelling systems for monitoring the marine environment

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UCA Universidad de Cádiz

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SEA-EU

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Comparing water level values in the Guadalquivir River estuary and the Gulf of Cadiz continental shelf from a numerical model, satellite altimetry and in-situ data

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ABSTRACT

The hydrodynamic model Delft3D was implemented in the Guadalquivir River estuary and the adjacent continental shelf, and was forced with tidal constituents and river discharge. Along-channel in situ observations of water level were compared with the model output under normal (low) and high river discharge conditions. The mean determination coefficients values were 0.88 and 0.78, during low and high discharge events, respectively. Model simulations were able to reproduce the over-elevations induced by the low-salinity plume at the estuary mouth and its adjacent inner shelf during periods of high river discharge (> 400 m3/s from the head dam). These over-elevations were previously identified with altimetry data. The effect of the plume is relevant to the dynamics of water mass (and suspended material) exchange between the estuary and the continental shelf, and should be considered for coastal management.

KEYWORDS

delft3D model, estuary, Guadalquivir, river discharges, coastal altimetry, sentinel-3a.

INTRODUCTION

The Guadalquivir River (GR, hereinafter), with a length of 650 km, is the largest river in Andalusia (South of Spain) and is also the only navigable one. Its estuary is limited by the port locks located in the city of Seville. The tidal wave reaches the lock, establishing the head of the estuary at 89 km upstream from the river's mouth. The daily river discharges, measured in the Alcala del Rio dam, show a wide variability, ranging between 0 and 3600 m3/s, according to the Guadalquivir River Hydrographic confederation (data from 1993 to date; https://www.chguadalquivir.es).

Figure 1. Study area where the Delft3D model was implemented and observation points used in the calibration (tide gauges, purple tacks; Sentinel-3A track, pink line).

Previous works have analysed the influence of GR discharges in the sea level variability of the Gulf of Cadiz using tide gauges and altimetry data (Gómez-Enri et al., 2012; Laiz et al., 2013). In this study, the hydrodynamic model Delft3D was implemented, in the river estuary and the adjacent continental shelf (Figure 1), to study the influence of the river discharges in the sea level variability with higher spatial resolution.

MATERIALS AND METHODS

The Delft3D hydrodynamic model, developed by Deltares (https://oss.deltares.nl/web/delft3d), is a model suit composed of several modules. For this study, the FLOW module was used to simulate the hydrodynamics resulting from tidal forcing under different river discharge scenarios. The model was forced by daily average river discharge (https://www.chguadalquivir.es/saih/), 14 tidal harmonics (https://www.tpxo.net/global/tpxo9-atlas), and salinity (Criado-Aldeanueva et al., 2006). Bottom friction was parameterized using the Chezy formula, with a space variable bottom coefficient (Díez-Minguito et al. 2012).

Water level calibration was performed by comparing the results obtained with in-situ tide gauge (Figure 1) data (Álvarez et al. 2001, Navarro et al., 2011), using different statistics: Pearson's correlation coefficient (r), coefficient of determination (R2), and Skill score (SCI). The comparison was done during events of low discharges, to calibrate the model (normal flows lower than 50 m3/s discharged from the Alcala del Río dam), and high discharges (flows higher than 400 m3/s), to validate.

In addition, a qualitative comparison of the water level obtained with the model and the Sea Level Anomaly (SLA) obtained with the Sentinel-3A altimetry (part of the Copernicus mission operated by ESA and EUMETSAT) (Figure 1) during high discharge events was carried out. To compare with the altimetry, the tidal signal was removed in the model data (Eq.1). In the case of Sentinel-3A, the high posting rate, 80 Hz, equivalent to a distance of ~85 m between two consecutive along-track measurements, was used to calculate the SLA (Eq. 2).

Model_WL_corr= Water Level – Tidal Prediction (Eq.1)

where Water Level is the water level measured by the model and the Tidal Prediction is calculated with a classical harmonic analysis (Pawlowicz et al., 2002) from the model data.

S3A_SLA = Orbit – Range – Range corrections - Geophysical corrections – Mean Sea Surface (Eq. 2)

where Orbit is the distance between the satellite's centre of mass and the reference surface (ellipsoid WGS84), Range is the retracked distance between the instrument and the mean-reflected surface, obtained using the SAMOSA+ retracker (Ray et al., 2015), Range corrections include the dry and wet tropospheric effects from the European Centre for Medium-range Weather Forecasts (ECMWFs) models and the ionospheric correction from the Global Ionospheric Maps (GIMs) of the Jet Propulsion Laboratory, the Geophysical corrections include: the tidal corrections from the TPX09 model (Egbert & Erofeeva, 2002), and the sea state bias (SSB) correction which was replaced by a correction using five percent of the significant wave height, because the SSB correction is not available at 80 Hz in the ESA GPOD service (Fenoglio-Marc, et al. 2015; Gómez-Enri et al. 2018; Aldarias et al. 2020), finally, the Mean Sea Surface used is the DTU15 (Andersen & Knudsen, 2009).

RESULTS AND DISCUSSION

When comparing the time series of water level obtained with the Delft3D model and the in-situ tide gauges, results show a good fit within the river estuary, both during periods of low discharge and high discharge.

Table 1. Comparison of the model and the tide gauges water level time series during low (high) river discharge events.

Table 1. Comparison of the model and the tide gauges water level time series during low (high) river discharge events.

	Tide gauges	r	R^2	SCI
Mouth to head ↓	Chipiona	0.97(0.97)	0.95(0.94)	0.22(0.23)
	Bonanza	0.97(0.97)	0.94(0.94)	0.23(0.25)
	Cepillos	0.96(0.96)	0.93(0.92)	0.26(0.27)
	beta1	0.96(0.97)	0.92(0.94)	0.31(0.27)
	beta2	0.96(0.95)	0.92(0.91)	0.32(0.33)
	Yeso	0.92(0.85)	0.85(0.72)	0.57(0.62)
	beta3	0.95(0.86)	0.91(0.74)	0.50(0.57)
	Horcada	0.91(0.82)	0.83(0.67)	0.57(0.62)
	beta4	0.96(0.87)	0.92(0.76)	0.48(0.54)
	beta5	0.93(0.83)	0.86(0.69)	0.54(0.60)
	Olivillos	0.90(0.79)	0.80(0.63)	0.60(0.64)
	beta6	0.89(0.79)	0.79(0.63)	0.57(0.63)
	Butano	0.91(0.82)	0.83(0.68)	0.51(0.58)

Close to the river mouth, the coefficients of determination were above 0.8 (Figure 2) (Table 1). At the upstream-most tide gauge stations, the coefficients of determination presented lower values and the model underestimated the sea level values.

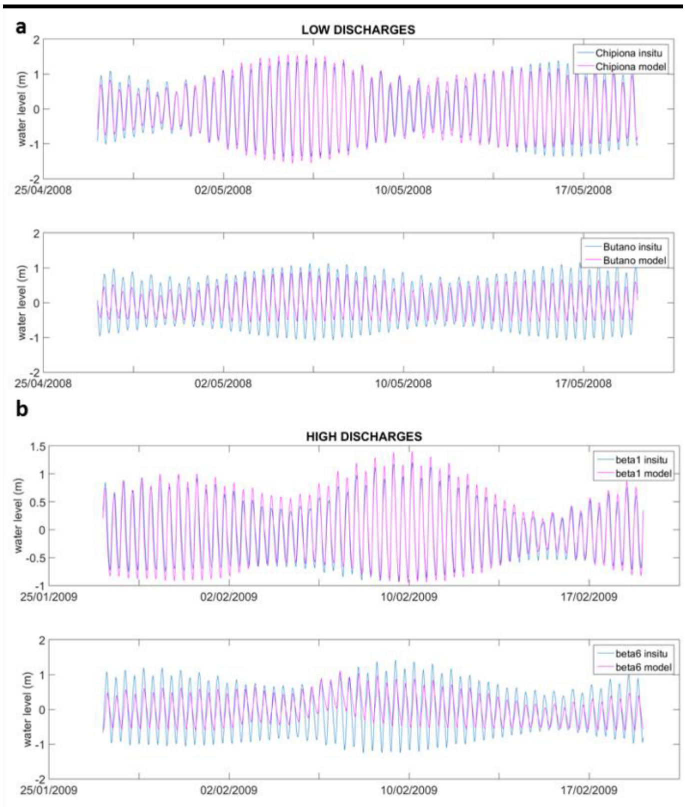

Figure 2. Comparison between model output and tide gauges data during a low discharge, Chipiona and Butano, (a) and a high discharge event, beta 1 and beta 6 (b).

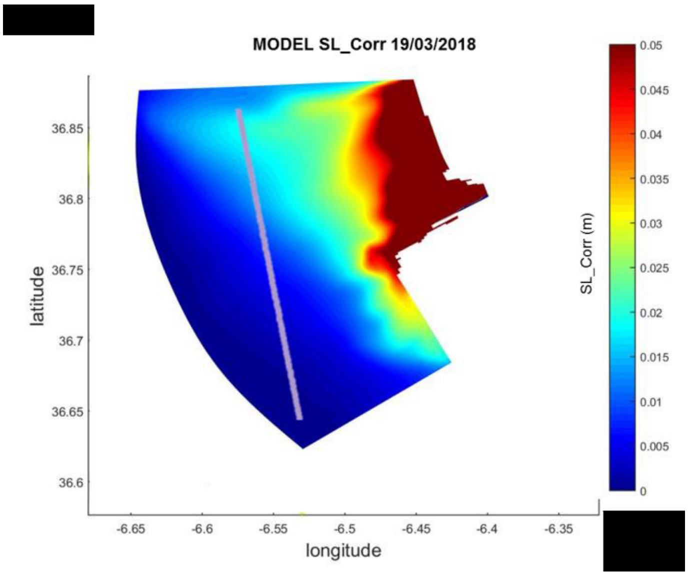

Figure 3. Map of WL_corr (m) in the model continental shelf during a high discharge event.

On the shelf, an increase in the water level elevation is observed during high discharge events in the model, corresponding to the low-salinity plume from the river discharge (Figure 3). This increase seems to be limited to an area close to the river mouth, as suggested by previous studies (Laiz et al, 2013). Qualitatively, a correspondence along the altimetry track seems to exist (Figure 4), but further investigations are necessary to confirm this.

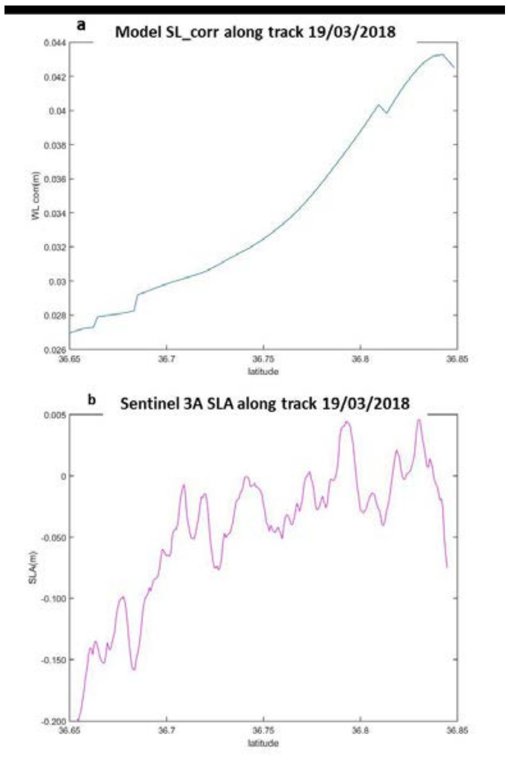

Figure 4. Qualitative comparison between (a) model WL_corr and (b) Sentinel-3A SLA along altimetry track.

CONCLUSIONS

The Delft3D model has showed to be a good tool to study the influence of the Guadalquivir River discharges in the sea level variability on the Gulf of Cadiz continental shelf. Complementary to the in-situ and altimetric data, this tool provides a higher spatial and temporal resolution. Nevertheless, further calibration is needed to correctly represent the tidal variation on the upstream of the river.

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Do current-driven dispersal and habitat patchiness explain local benthic diversity in the Mediterranean basin?

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ABSTRACT

Local patterns of biodiversity depend on several factors. When examining the diversity of benthic species that have colonized artificial substrates deployed on the seabed, it results from the establishment of various species inhabiting different habitats from adjacent areas as well as from distant regions thanks to current-driven larval dispersal. Early colonization is hypothesized to be mainly influenced by two interacting factors; the first being the variety of habitat patches found near the artificial structure as well as in remote locations. The second interacting factor is the diversity of origins of the colonists, which can be brought to the artificial structure by highly variable marine currents. When colonizers potentially come from a high diversity of spatial origins, characterized by a wide variety of habitats, species/genetic diversity is expected to be higher. We test this hypothesis in a pilot study in the Mediterranean coast, using Autonomous Reef Monitoring Structures (the structures to be colonized), photo-analyses (method to assess species diversity) and dispersal modelling combined with habitat mapping. When comparing richness and shannon index as derived from the ARMS and the dispersal/habitat model, we find a significant correlation ($p < 0.05$) between the Z-Score Shannon Indices when separating the surveyed regions into 2 datasets Despite the low number of data (that we are currently increasing), the present study suggest that current-driven dispersal of propagules and habitat patchiness control to a certain degree the spatial structure of benthic populations.

KEYWORDS

benthic communities, marine connectivity, diversity indexes, current-driven dispersal, habitat, management and conservation.

INTRODUCTION

Local patterns of biodiversity depend on several factors that include: interspecific relationships (prey-predator interactions, competition for food or space, etc.), and abiotic factors (temperature, substrate and currentsdriven dispersal) (McGlynn, 2010). When examining the diversity of benthic species found on artificial substrates (initially free of life) that were deployed on the seabed, two successive steps can be distinguished. The first step is the colonization of the structure, that consists in the establishment of various species from adjacent areas or from distant regions thanks to current-driven larval dispersal. The second step results in the species survival in the artificial structure which depends on local environmental conditions and on biotic interactions. The present work focuses on the first step; being that the colonization is mostly influenced by two interacting factors, the variety of habitats (both nearby the artificial structure as well as in remote locations) and the diversity of origins of colonists, which can be brought to the structure by marine currents (Cowen et al., 2007). This study focuses on the benthic communities and habitats of the Mediterranean Sea and their dispersion of larvae by ocean currents, assuming they are passively transported by water flow (i.e., neglecting larval behavior). Although it is well recognized that physical connectivity should influence intraspecific diversity (genetic structure) (Cowen & Sponaugle, 2009), the similar reasoning predicts that currents should also influence the species diversity of a recently-established community. Our hypothesis is that when colonizers potentially come from a diversity of spatial origins, characterized by various habitats and thus specific species assemblages, species diversity is expected to be higher. The benthic communities that colonized the artificial structures may come from surrounding sites, but also from very distant sites thanks to larval dispersal, especially for highly dispersive species.

MATERIALS AND METHODS

We investigate the colonization of Automated Reef Monitoring Structures (ARMS), which are artificial structures to monitor hard-bottom benthic biodiversity (Zimmerman & Martin, 2004), through photo-analyses (method to assess species diversity) (Williams et al., 2019) and habitat-dispersal modelling (Rossi., 2014; Ser-Giacomi et al., 2015). The Autonomous Reef Monitoring Structures (ARMS) are artificial structures to monitor hard-bottom benthic biodiversity (Zimmerman & Martin, 2004). Each ARMS unit is composed of nine 22.5 cm × 22.5 cm PVC plates and spacers stacked in an alternating series of open and closed formats, attached to a 35 cm × 45 cm base plate. There were 84 ARMSs deployed in the Northwest Mediterranean Sea and the Adriatic Sea at 13.7–24 m depth in Summer 2018. The 8 sampling regions were in Murcia (Spain), Banyuls (France), Marseille (France), Villefranche (France), Calví (France), Palinuro (Italy), Livorno (Italy) and Rovinj (Croatia). The ARMS units were installed by divers and submerged for approximately 12 months, depending on the region. Subsequently, ARMSs were recovered and returned to the laboratory, where they were dismantled and processed. Each plate surface was gently brushed to remove mobile fauna without detaching sessile organisms. Plates were kept in seawater aerated with bubblers until photographs were taken. Community composition was inferred from photographs in all the plates for each ARMS. The photo-analysis was performed with the use of the CoralNet software which is a online resource for benthic images analysis (Williams et al., 2019). Each photograph was divided into 16 squares, and four points were randomly selected within each square. The organisms present at each point were identified to the lowest possible taxonomic level. Relative abundances were calculated through the percentage of coverage of each taxa in all ARMSs, and afterwards, Taxa Richness and Shannon's diversity Indices (Shannon, 1948) were calculated.

The Lagrangian Flow Network (LFN; Ser-Giacomi et al., 2015) is a biophysical model used to evaluate connectivity and understand the structural complexity of marine populations. By coupling Lagrangian transport, Network Theory and habitat cartography (Rossi et al. 2020), it allows characterizing larval dispersal by ocean currents (Rossi et al., 2014). Larvae of different pelagic durations were modeled as passive tracers advected in a simulated oceanic surface flow from which a connectivity matrix was constructed. The connectivity matrix provided the probability of exchange of individuals between nodes (i.e. a subdivision of the oceanic domain) of the grid; if the matrix is column - normalized, then the matrix element rij gives the probability that an individual in population i came from population j. With an ensemble of connectivity matrices (simulating different pelagic larval durations and release times) that were aggregated, we computed a probabilistic backward dispersal plumes resuming the colonization process occurring during the deployment of ARMSs for each of the 8 regions.

The benthic habitats evaluated in the present study comes from the EMODnet Seabed Habitat website (https://www.emodnet-seabedhabitats.eu). We compute relative abundances of habitats for each node of each backward plume with the use of the EMODnet Seabed Habitat categories. Finally, we computed an index of diversity combining habitat and dispersal routes using the same formula (i.e. Shannon index) as we did the taxonomic diversity from photographs. These habitat diversity indices were processed and compared to the taxa diversity indices. By evaluating the relationship between both variables, our main aim is to assess whether benthic biodiversity depends on habitat-specific dispersal.

RESULTS AND DISCUSSION

The results obtained though the photo-analyses in different countries presented slightly different ranges of results, with the Italian and Croatian regions having a different level of diversity compared to the French and Spanish regions. It was proposed to separate this dataset of 8 regions into 2 datasets, being the first dataset includes the French regions and the Spanish region (Murcia) being named as Western Mediterranean sites and the second dataset including the Italian regions and the Croatian region (Rovinj) named as Central Mediterranean. Also, the species diversity and the habitat diversity had results of different magnitudes, so to understand better the magnitude of correlation of those variables we performed a z score normalization before looking for correlations. Then we found significant positive linear correlations between the Shannon indices assessing the diversity of taxa and habitat, respectively, for both datasets. Consequently, the Habitat Shannon Index increases, the Shannon Index for the community structure also increases. The figure 1 presented the regression lines for the 2 separate datasets and its main correlation results are synthetized in the Table 1. From the correlations presented in Table 1 the Shannon Index with the Z score presented significant results due to the low p-values and high R squared encountered in both datasets analyzed. When analyzing the table 1 it is possible to observe that the correlations are significant at the 5 % significant level (i.e., the probability of a null regression line slope is lower than 0,05).

Here, we proposed, for the first time, a methodology to study how dispersal affect biodiversity. It combines diversity assessment of benthic communities through the photoanalyses of colonized artificial structures and physical dispersal mode-

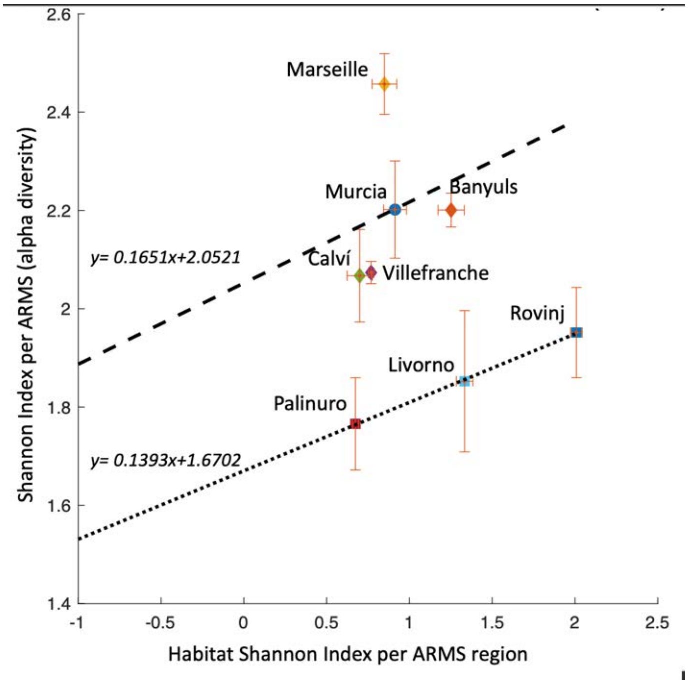

FIGURE 1 - SCATTER PLOT WITH 2 REGRESSION LINES OF THE SHANNON INDEX PER REGION AND THE HABITAT SHANNON INDEX; REGRESSION LINE 1 IS THE REGRESSION LINE FOR THE WESTERN MEDITERRANEAN REGIONS; REGRESSION LINE 2 IS THE REGRESSION LINE CENTRAL MEDITERRANEAN REGIONS. TABLE 1 - THE PRESENT TABLE INTEGRATES THE; P- VALUE AND R SQUARED FOR THE SHANNON INDEX ANALYSED IN 2 DATASETS;

Shannon Index (Z score)

Region	Western Mediterranean	Central Mediterranean
P-value	0.0503	0.0206
R squared	0.717	0.999

lling with habitat maps. The positive correlations confirm the accuracy of the data obtained through two those state-of-the-art. However, this correlation was obtained based on a splitting the data set in two groups, which was justified by the different levels of diversity found on different regions through the photoanalyses and also according to richness and biodiversity measures encountered in the literature (Cahill et al.,2018, UNEP/MAP, 2012, Coll et al., 2010).

This growing field of study shows great potential for seascape analyses, moreover, for further analyses it would be recommended to perform more extensive statistical comparisons between the diversity indices for the 8 surveyed regions for a better understanding if they are statistically different within each other, before correlating the final results. Moreover, the statistical weakness of the present study is due to the low number of observations. We are currently processing data from other years and regions to add more data points in order to increase the statistical power of the correlations. Moreover, the EMODnet dataset, used to assess the habitat of the colonists has a heterogenic resolution which is more precise in some regions than the others present in this study and that can affect the final habitat diversity results. Also, it would be interesting to consider the results from the community composition to weight the Pelagic Larval Duration results according with the dispersal traits of the species assemblages found on the ARMS. An interesting project could be evaluating ARMS colonization in shorter deployment duration (e.g. 1 month) since the 1 year deployment could be too long so that the community structure would not be affected by other local factors such as the trophic interactions in ARMS.

CONCLUSIONS

The present study effectively evaluated the community composition using ARMS through photo-analyses. The use of the Lagrangian Flow Networks was very useful to analyze habitat patches and larvae sources into the ARMS. The EMODnet network presented a wide range of habitats that allowed these analyses to be performed.

Among the conclusions backed up by both modelling and community composition analyses, our study suggests that to a certain degree lower diversity is expected along the Western Italian Coast and higher in the Spanish and French Mediterranean Coasts. Also, the North Adriatic Sea presented high taxa diversity and also habitat diversity since it presents a more confined circulation.

Although it is well recognized that physical connectivity should influence local intraspecific diversity, the same logic predicts that currents should also influence the species diversity of a community, the present study suggests that that current-driven dispersal of propagules and habitat patchiness control to a certain degree the spatial structure of benthic populations.

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A holistic approach to assess the spatial distribution and dispersion of the European anchovy (Engraulis encrasicolus) early stages in the Gulf of Cadiz during the summer of 2016

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ABSTRACT
Variability in the recruitment of small pelagic species highly depends on their early life stages spatial distribution and drift history. In this study, two different modelling approaches were used to address the potential factors affecting the recruitment variability of the European anchovy in the Gulf of Cadiz (GoC) after an apparent anomalous episode in 2016. First, distance-based linear multivariate techniques were used to characterize the anchovy spawning areas. Second, Lagrangian simulations were conducted to simulate the early life stages passive dispersal during the 2016 most intense spawning peak, which coincided with a persistent coastal countercurrent event. The distance-based analysis indicated that Chlorophyll is the environmental variable that best characterized the spawning areas with a 3-day time-lag. The Lagrangian simulations showed that most of the particles were transported to the western Portuguese coast, suggesting an increase in the connectivity between that region and the GoC. Although different environmental processes taking place during ontogenetic stages, along with overfishing, can explain part of the variability observed in the anchovy recruitment, events such as the development of coastal countercurrents during the spawning season could partly explain the observed anchovy increase on the western Portuguese coast and decrease in the GoC one year later.

KEYWORDS
Engraulis encrasicolus, anchovy early stages, Gulf of Cadiz, Lagrangian transport, ROMS, connectivity

INTRODUCTION
The European anchovy is a small pelagic species, fast growing, and short-lived (3 to 4 years) (ICES, 2010) that represents the most abundant species in the Gulf of Cadiz (GoC) (Baldó et al., 2006). Its spawning period in the GoC spans from early spring (March-April) to early autumn (September-November), linked to the increase in sea surface temperature and stratification (Baldó et al., 2006). Its main spawning and nursery areas in the GoC are the nutrient-rich Guadalquivir (Baldó and Drake, 2002; Baldó et al., 2006; González-Ortegón et al., 2015) and Guadiana (Chícharo et al., 2001; Morais et al., 2009) estuaries. Overall, this species is highly sensitive to the environmental conditions and ecosystem changes (Chícharo et al., 2001); thus, assessing the relationship between the anchovy early stages abundance in the main spawning regions and the environmental variables is crucial to

identify the drivers that determine their survival.

Previous studies suggest that the horizontal dispersion of anchovy early stages in the GoC is mainly determined by the surface currents (Catalán et al., 2006) during the first 10 days after spawning. Thus, and, considering the complex and variable surface circulation in the region, a thorough comprehension of the eggs and larvae passive transport between the spawning and the nursery areas could be key to understand the anchovy recruitment. In fact, the abundance of anchovy in the GoC has declined by 66% during the last decade (Uriarte and General, 2018). Although intense fishing could be the main reason for this decrease, the succession of low recruitments due to unfavourable environmental conditions could largely contribute to this decline (Larkin, 1996). Moreover, changes in the anchovy spawning zonation have been reported in the GoC (Baldó et al., 2006), which could also impact on the species recruitment. In fact, during August 2016, the highest egg densities were sampled further west than normally (Figure 1) (ICES, 2017).

The hypothesis of this study is that the westward displacement in the spawning spatial distribution under an intense easterly event that triggered a persistent coastal countercurrent, could contribute to decrease the anchovy recruitment in the GoC while increasing it in the western Portuguese region. Consequently, the objectives of this work are: (a) To analyse the effects of various environmental factors on the anchovy early life stages abundance and horizontal distribution in the GoC, and (b) to study the effect of a specific surface currents' regime on their passive transport.

MATERIAL AND METHODS

Sampling

Anchovy eggs were collected in the GoC during the ECOCADIZ 2016 campaign between July 31 and August 11, 2016 from the R/V Miguel Oliver using a CUFES (Continuous Underway Fish Egg Sampler) to estimate the abundance (Casaucao et al., 2021).

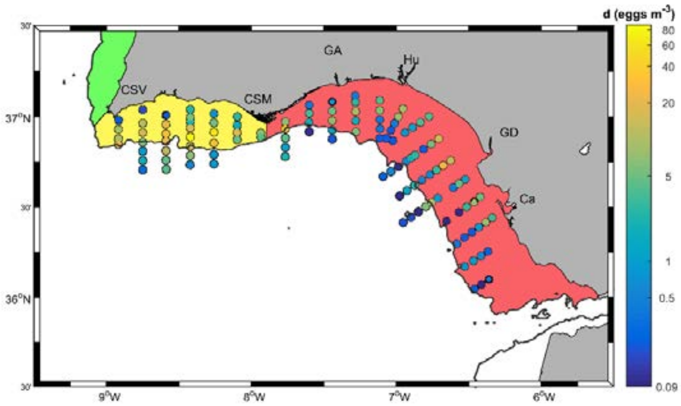


Figure 1. Map of the densities of anchovy eggs sampled at each station (Coloured dots) and areas defined to evaluate the results from the Lagrangian simulation (see more details in Casaucao et al., 2021).

Remote sensing and wind data

Daily means of chlorophyll-a (Chl-a), sea surface temperature (SST) and wind data products were downloaded for the study area (see more details at Casaucao et al., 2021).

Numerical model

The currents data were obtained from the high-resolution hydrodynamic model Regional Ocean Modeling System (ROMS) to study the transport of the first stages of anchovy within the GoC and its dispersion along the Iberian coast (see more details in Laiz et al., 2020 and Casaucao et al., 2021).

Statistical analysis

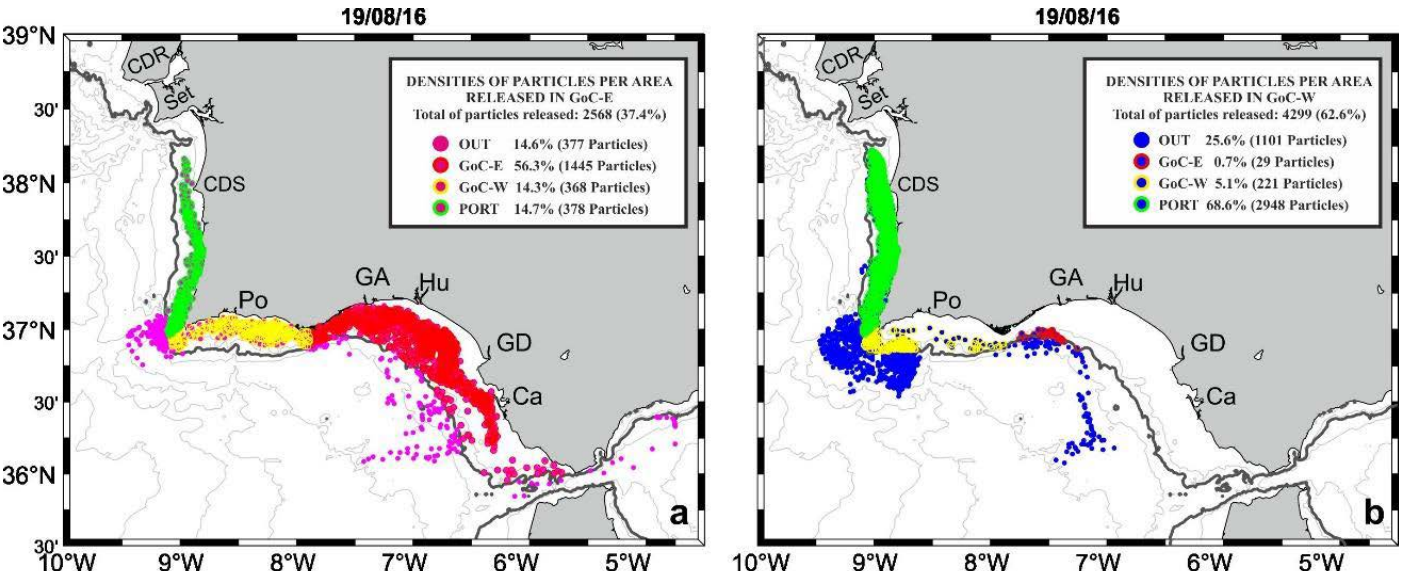
The univariate and non-parametric multivariate techniques of the distance-based linear modelling package (DistLM) contained in PRIMER 6.1 (Plymouth Routines in Multivariate Ecological Research, Anderson et al., 2008) were used to explore the anchovy eggs density in the GoC and tested against environmental variables.

RESULTS AND DISCUSSION

The highest egg densities (16.2-87.9 eggs m–3) seemed to concur with the largest chlorophyll-a values of the GoC western shelf (0.21 mg m–3), showing a positive and significant correlation (Spearman's $r_S = 0.48$, $P < 0.001$). Moreover, a DistLM showed that the Chl-a with a lag of 3 days explain a 31.32% variation in the abundance of anchovy eggs. This could probably indicate that, before any spawning process occurs, anchovy adults require suitable environmental conditions such as high chlorophyll-a concentrations.

The particle trajectories showed a preferential westward transport, consistent with the onset and intensification of the coastal countercurrent by easterly winds, which caused a westward advection of warm surface water, as well as the Lagrangian particles (Figure 2). The accumulation of particles after ten days of simulation would be ordered from highest to lowest as: on the Portuguese western shelf (48.4%), on the GoC eastern shelf (21.5%), off the shelf (21.5%) and on the GoC western shelf (8.6%) (Figure 2). Hence, the simulation results suggested a potential gain of anchovy along the western coast of Portugal. In fact, while an increase in landings was documented a year later in the region West of Portugal (ICES, 2018), the abundance of anchovy in the GoC was lower, with a 30% reduction in catches (Uriarte and General, 2018). In contrast, the simulation results also suggested that a smaller percentage of particles (21.5% of the total particles released) were exported out of the continental shelf and, therefore, far from the area where the individual has the most suitable resources to ensure their survival (ICES, 2018). The results obtained in this study suggested that these changes in catches could be due to the existence of periods of intense easterlies and a persistent coastal countercurrent at the time of spawning (Casaucao e al., 2021). This could affect recruiting and larval connectivity, probably explaining part of the above-mentioned reduction in anchovy in the GoC and its increase West of Portugal.

In terms of the retention capacity of each of the continental shelves, results from the Lagrangian simulation indicated that the GoC western shelf had a considerably lower retention capacity (5.1%) (Figure 2, b) than the eastern shelf (56.3%) (Figure 2, a) during the study period. This could be related not only to the narrower width of the western shelf, but also to the intensity and persistence of the coastal countercurrent within that shelf. Keeping these results in mind, we could suggest that a change in the spatial distribution of the anchovy eggs spawning, resulting in a higher density of eggs west of Cape Santa Maria under an intense and long lasting coastal countercurrent, would lead to an increase in the connectivity between the GoC and western Portuguese region during the studied period (Casaucao et al., 2021).



CONCLUSIONS

The environmental variable that best characterized the spawning areas was chlorophyll-a with a lag of 3 days,. Under intense countercurrents, the early life stages of the European anchovy spawned in the GoC can be transported to the Portuguese western coast and, to a lesser extent, offshore to the Atlantic oligotrophic waters. This transport increases the connectivity between the GoC eastern and western shelfs, and between the region from Cape San Vicente to the west coast of Galicia, if the coastal countercurrent is prolonged over time,or if the anchovy eggs spawning region is mainly located over the GoC western shelf. The dispersion pattern could explain why a year later there was a gain in anchovy on the Portuguese western coast and losses in the GoC. In order to get a better understanding of how spawning, hatching or survival are being affected by changes in oceanographic conditions, it is necessary to study more years.

AKNOWLEDGEMENTS

The authors thank the IEO, the crews of the R/V Miguel Oliver for technical assistance on the field. ATM acknowledges project 'SARDINHA2020' (MAR-01.04.02-FEAMP-0009), from the Programa Operacional MAR 2020 (Portugal).

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Environmental forcing on blue whiting year-class strength in the Porcupine bank (NE Atlantic)

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ABSTRACT
The highest abundance of age-0 blue whiting Micromesistius poutassou in the Porcupine Bank since 2001 was observed in 2020. Various environmental parameters, namely chlorophyll concentration, surface salinity, temperature, ocean currents, and wind data were used to study their potential impact on the blue whiting eggs and larvae survival. Our results showed that in 2020, during the blue whiting-spawning season (March-April), the calm wind situation along with weaker ocean currents above the Porcupine Bank helped to accumulate phytoplankton biomass, thus promoting secondary productivity. The optimal salinity concentration, as well as surface temperature during this time, helped the buoyancy of eggs and larvae to the food-rich surface, thus improving the larval condition and enhanced the survival rate, which in turn resulted in the highest year-class recruitment since 2001.

KEYWORDS
blue whiting, recruitment, 0-group, survival, chlorophyll, salinity, temperature, wind mixing index, ocean current.

INTRODUCTION
The Porcupine Bank (ICES Divisions 7c and 7k) is located at the western edge of the north-eastern Atlantic shelf west of Ireland, between 51-54°N and 11-15°W (Thébaudeau et al., 2016), and comprises a major spawning area for blue whiting Micromesistius poutassou (Risso, 1827). In this region, blue whiting spawn during March and April between 300 to 600 m depth (Hillgruber and Kloppmann, 1999); however, most larvae occurr within the upper 40 m (Kloppmann et al., 2002). Although temporal and spatial match and mismatch of fish larvae with their potential prey organisms, as well as prey abundance, are considered the main factors regulating the year-class strength in marine fish populations (Lasker 1975), different environmental forcings also influence the survival rate of larvae and thus, the year-class recruitment. Lasker (1975) and Lewis et al. (1994) showed that strong wind-mixing disrupts layers of high prey concentrations and reduce the energy transfer efficiency from phytoplankton production to higher trophic levels. Hillgruber and Kloppmann (1999) showed that during high storm activities, larvae survival is poor due to turbulence-induced malnutrition. Miesner and Payne (2018) showed that the optimum salinity window for blue whiting spawning is between 35.3-35.5 PSU. Therefore, it is evident that different environmental forcings play a vital role in the survival rate of blue whiting larvae.

In 2020, the abundance of year-class recruits (total lenght < 20 cm) of Micromesistius poutassou was the highest in the record from 2001-2020, implying that there must be some environmental conditions in the spawning season which determined the high survival rate of the larvae. Therefore, in this present study, we test the hypothesis that the exceptional year-class strengh of Micromesistius poutassou in 2020 is related to the optimal environmental conditions in the spawning season (March-April). In particular, we describe how the sea surface temperature, salinity, chlorophyll (as a proxy of biological productivity), wind mixing index and ocean currents influence the high year-class recruitment in 2020.

MATERIALS AND METHODS

A Spanish bottom trawl research survey has been carried out annually (September) since 2001 in the Porkupine Bank (Figure 1) to study the distribution, relative abundance and biological parameters of commercial fish. The survey covered an area extending from 12° W to 15° W longitude and from 51° N to 54° N latitude, following the standard methodology for the IBTS North Eastern Atlantic Surveys (ICES, 2017). Bottom trawls were carried out on board the R/V Vizconde de Eza, a stern trawler of 53 m and 1800 Kw, using a Baca-GAV 39/52 with a cod-end mesh size of 20 mm. The insets in Figure 1 show the in situ data of the abundance and distribution of year-class blue whiting recruits in 2020.

To analyse the impact of environmental forcing on fish abundance, satellite remote sensing L4 product of chlorophyll-a concentration (hereafter CHL) as well as sea surface salinity (hereafter S), temperature (hereafter SST) and ocean currents data from the IBI numerical model were downloaded from the Marine Copernicus Service (https://marine.copernicus.eu/) for 2020. The ERA5 wind field at 10 m was downloaded from the Copernicus Climate Data Store (https://cds.climate.copernicus.eu/). The wind mixing index (hereafter WMI) was calculated as the cube of wind speed, following Cuttitta et al. (2006). SST and WMI anomaly maps were calculated.

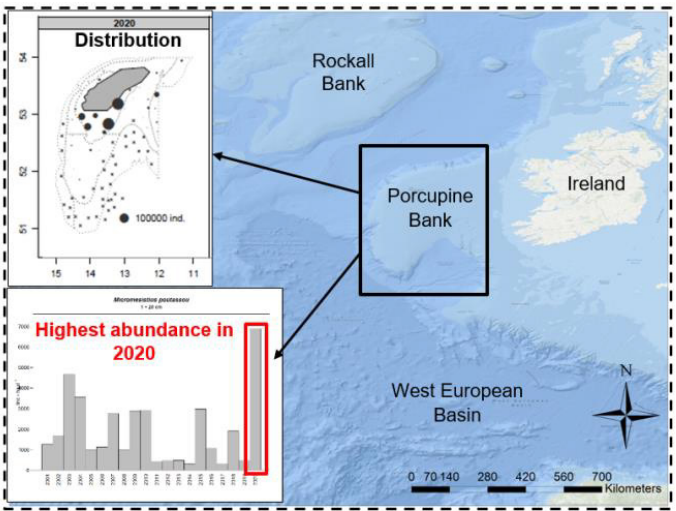

Figure 1. Study area map showing the location of Porcupine Bank along with the abundance and distribution of year-class blue whiting recruits in 2020.

RESULTS AND DISCUSSION

The concentration of CHL in the ocean is considered as a proxy of phytoplankton biomass that can be related to fish production. CHL concentrations above 0.2 mg/m3 indicate the presence of sufficient planktonic life to sustain fisheries (Butler, 1988). Though it is evident from Figure 2 that during March 2020, the concentration of CHL was limited to the coast of Ireland implying lower productivity offshore, in April, the concentrations increased largely above the Porcupine Bank, which created favorable conditions for primary and secondary productivity, thus, benefiting blue whiting larvae with a favorable feeding environment.

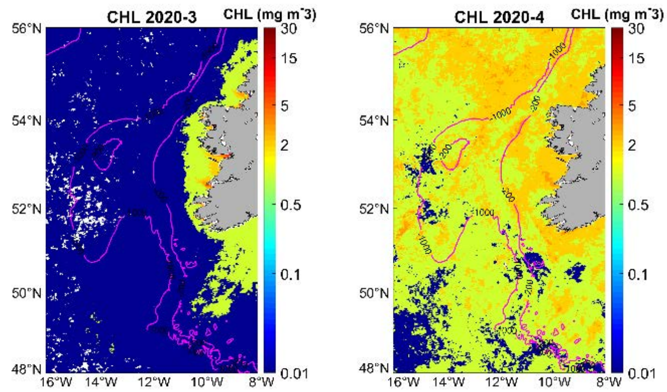

Figure 2. Monthly means of CHL concentrations during March and April 2020.

Blue whiting eggs are positively buoyant at their initial stage and their density increases during egg development, which helps them to maintain a stable bathypelagic distribution (Adlandsvik et al., 2001). Blue whiting larvae passively ascend through the water column towards the food-rich surface (Adlandsvik et al., 2001). However, the buoyancy of eggs and larvae and their vertical distribution are affected by the water density. Changes in salinity and temperature, thus in water density, can alter the ascent of larvae from their spawning depth towards the food-rich surface waters which are critical for their survival (Miesner and Payne 2018). During the 2020 spawning period, above the Porcupine Bank, the salinity ranged from 35.3-35.5 PSU (Figure 3) which is exactly the optimum salinity window for blue whiting spawning (Miesner and Payne 2018). Furthermore, the SST anomaly maps (Figure 4) showed negative anomalies during March that began to move from zero to slightly positive anomalies in April, implying that the water density of this region was becoming favorable for the blue whiting larvae, helping them to ascend passively through the water column to reach the surface where they could feed.

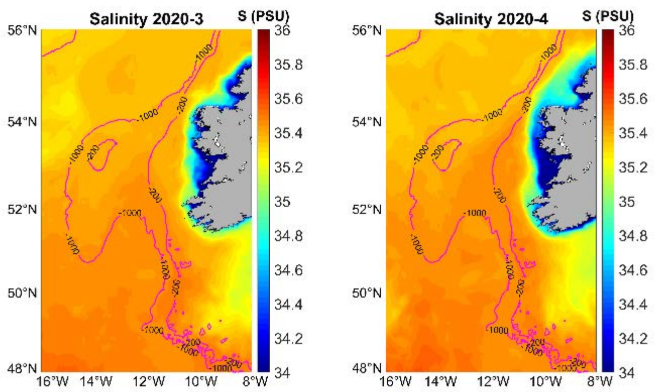

Figure 3. Monthly means of S during March and April 2020.

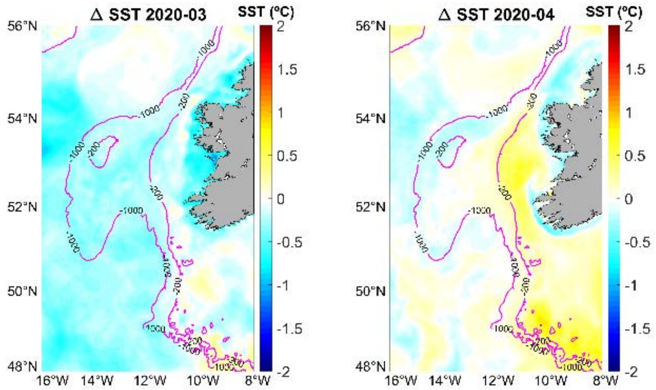

Figure 4. SST anomaly maps in March and April 2020.

Figure 5 shows the WMI anomalies whereas Figure 6 shows the mean ocean current velocity during the spawning season. It is evident that during this time, WMI anomaly was negative, implying a calmer than average situation. Moreover, above the Porcupine Bank, the ocean current was weaker than the northern and southern parts of the bank. Both environmental conditions resulted in higher prey concentrations and better feeding opportunities/success for blue whiting larvae, ensuring better larval conditions and enhanced survival during the critical first life span.

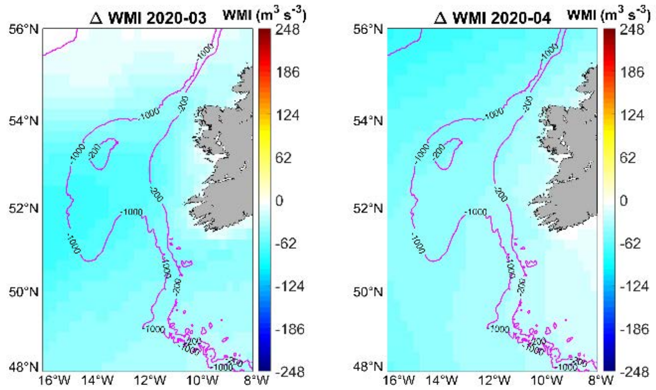

Figure 5. WMI anomaly maps in March and April 2020.

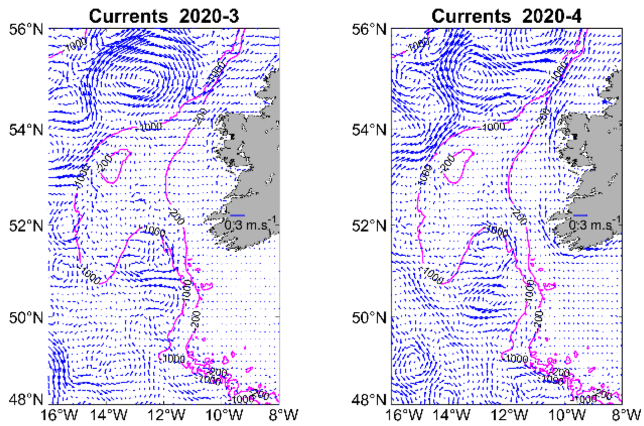

Figure 6. Monthly mean surface current maps in March and April 2020.

CONCLUSIONS

The calmer oceanic environment as a result of weak ocean currents and calm winds over the Porcupine Bank helped accumulate phytoplankton biomass thus triggered secondary productivity in this region, which in turn improved the availability of prey organisms. During this time, optimal salinity concentrations, as well as surface temperature, helped larvae to ascend to the food-rich surface and hence led to better feeding success. All these environmental forcings improved the condition of blue whiting larvae resulting in higher larval survival rates and consequently greater recruitment success in 2020.

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The Use of Combined in situ and Remote Sensing Datasets to Derive Phytoplankton Dynamics: Contributions to the Management of Blue Growth Sectors.

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ABSTRACT
This study explores the applications of ocean colour remote sensing to monitor phytoplankton dynamics for the management of Blue Growth sectors in coastal regions such as the South of Iberian Peninsula. The ocean colour sensors (OCS) assessed are Moderate Resolution Imaging Spectroradiometer (MODIS), Visible Infrared Imaging Radiometer Suite (VIIRS) and, Ocean and Land Colour Instrument (OLCI). These datasets are compared with in situ for Chlorophyll-a concentrations (Chl a, herein). Chl a derived using MODIS > in situ Chl a, and VIIRS estimated Chl a ≥ in situ Chl a. OLCI's standard algorithms, maximum band ratio semi-analytical algorithm (OC4ME) and Neural Network (NN) derived Chl a with values such that OC4ME > NN, and NN estimates of Chl a < in situ Chl a. The water-leaving reflectance spectra rw(l) retrieved by OCS is compared to the samples representing different in situ phytoplankton communities. The shapes of the spectra indicate that rw(490) < rw(510) for the samples collected on 12/02/21 and 16/10/20, characterised by very high presence of Nanophytoplankton, while rw(490) > rw(510) for the sample 11/03/21, entailed by majority of Diatoms. Future studies should also explore the contributions of other water constituents and cell sizes to the overall shapes of rw(l).

KEYWORDS
blue whiting, recruitment, 0-group, survival, chlorophyll, salinity, temperature, wind mixing index, ocean current.

INTRODUCTION
Blue Growth sectors are often at risk from the changes in phytoplankton dynamics (Burford, 1997) and harmful algal blooms (HABs) (Getchis et al., 2017). Ocean colour remote sensing (OCRS) is an increasingly important tool to study and monitor these phenomena (Le Traon et al., 2015), with the objectives of preventing economic losses and to safeguard public health. The hypothesis is that the integration of the freely available ocean colour data can help to detect changes in phytoplankton communities including HABs. The selected ocean colour sensors (OCS) can be compared with in situ measurements, investigating for their suitability for detecting Chl a and phytoplankton variations. This study aims to advance the Strategic Objectives of the Portugal Space 2030, European Green Deal (2019-24), and the United Nations' 2030 Agenda for Sustainable Development Goals (UNSDGs) number 8: Decent Work and Economic Growth and 14: Life Below Water.

MATERIALS AND METHODS
The study site is located in the eastern side of the Faro-Olhão inlet, off Ria Formosa in southern Portugal (Fig. 1). The sampling period is from 01/09/20 to 15/04/21 (6.5-month) and the seawater collection was done by a volunteer who sampled at about 7°51'55.67"W

36°57'52.88"N. Given the proximity of the study area to the shore, satellite data was subjected to coastal contaminations and had to be acquired from a reliable location than the seawater collection area.

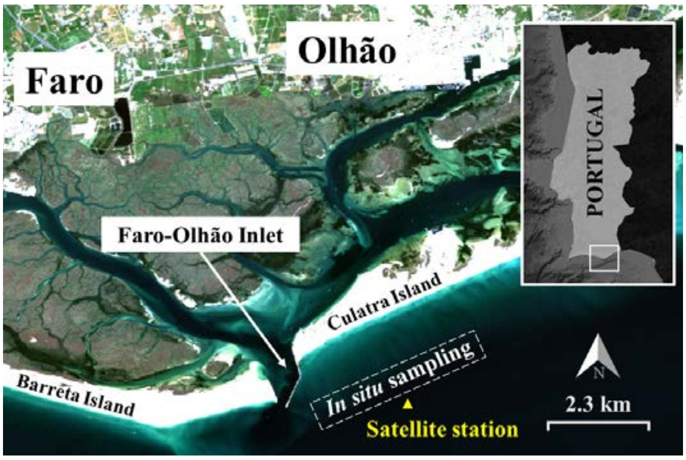

Figure 1. A map of the study area at Ria Formosa. "In situ sampling" is an approximate area for seawater collection. "Satellite station" represents a pixel (yellow triangle) where the satellite datasets were acquired. Source: Copernicus Sentinel data 2021, processed by ESA.

Level-2 satellite images are downloaded from NASA's portal for MODIS and VIIRS, and Copernicus Online Data Access, CODA for OLCI. The images corresponding to the distinct algorithms (Chlor_a, OC4ME and NN) were processed using the software SeNtinel's Application Platform (SNAP) for quality control and to obtain Chl a values from a pinned location (i.e. "satellite station"). Intersensors/algorithms comparisons were performed using determination of coefficient (R2), mean absolute (*) and biased (*) percentage differences (over the total number of coincident days between sensors, N). Satellite and in situ measurements were compared using scatter plots.

The shapes of water-leaving reflectance, rw(l) for sampling days matching different in situ phytoplankton communities are compared. Due to the low Chl a typically observed during winter at the study area (Brito et al., 2012), rw(490) and rw(510) are low due to water absorption. Hence, the shapes may reveal (if any) associations with the main contributing groups and toxigenic/non-toxigenic phytoplankton (Blix et al., 2019; Brockmann et al., 2016).

Seawater samples were collected for Chl a determination through spectrophotometry (Parsons et al., 1984 and references herein). Utermöhl method (1958) was used to identify the main contributing groups and toxin-producing phytoplankton.

RESULTS AND DISCUSSION

Inter-sensors/algorithms comparisons support that OLCI sensor is feasible, with R2 = 0.79 between its standard algorithms, OC4ME and NN, along with ± 3h overpassing difference to seawater collection (Fig. 2).

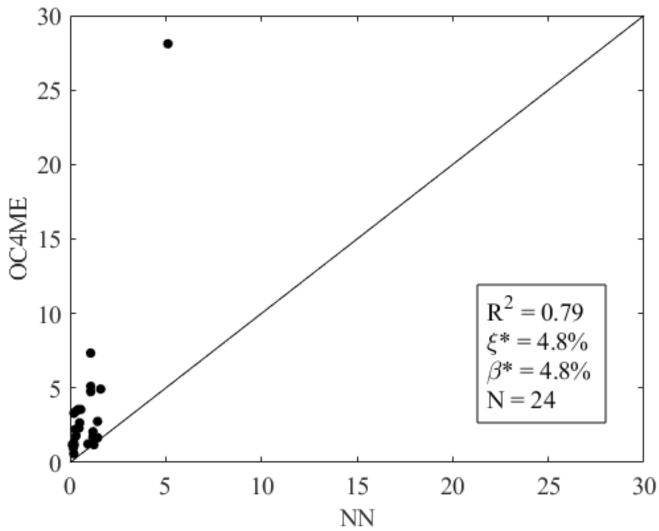

Figure 2. Inter-algorithms comparison between OC4ME and NN from OLCI sensor.

The comparison between the OCS and in situ Chl a (Fig. 3) shows that MODCA (MODIS, Chlor_a algorithm) > in situ; VRSCA (VIIRS, Chlor_a algorithm) ≥ in situ; OLCOC (OLCI, OC4ME algorithm) > OLCNN (OLCI, NN algorithm); and OLCNN < in situ. In general, OC4ME > NN, as OC4ME is not designed for complex waters conditions, where coloured dissolved organic matter (CDOM) and total suspended matter (TSM) influence the absorption of Chl a (Doerffer and

Schiller, 2007). Although NN is more sensitive to TSM, it can underestimate Chl a (Blix et al., 2018), as also found in this research. Due to the short period of study, only 7 matchup days were successful, as other images were discarded due to clouds and coastal contaminations.

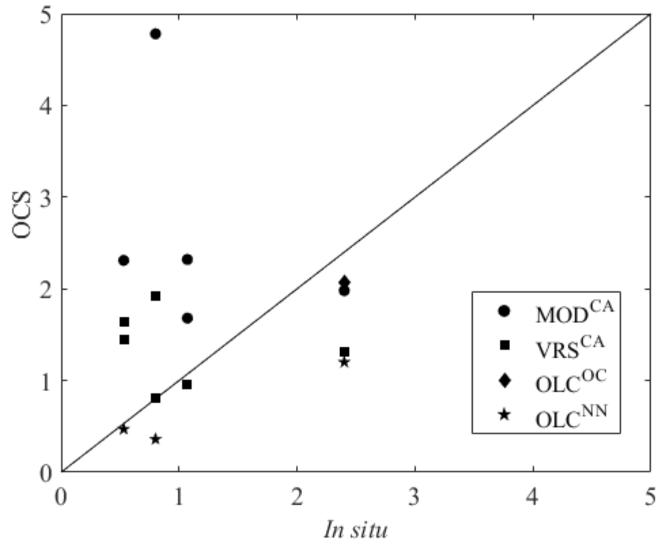

Figure 3. Comparison of Chlorophyll-a concentrations (mg.m-3) during coincident days; MODCA = MODIS, Chlor_a algorithm; VRSCA = VIIRS, Chlor_a algorithm; OLCOC = OLCI, OC4ME algorithm; OLCNN = OLCI, NN algorithm.

The rw(l) spectra extracted from OLCI may indicate a relationship between the shapes of rw(l) of matching sampling days to the different phytoplankton communities identified (Fig. 4). The samples 12/02/21 and 16/10/20 show rw(490) < rw(510), whereas the opposite is observed for 11/03/21.

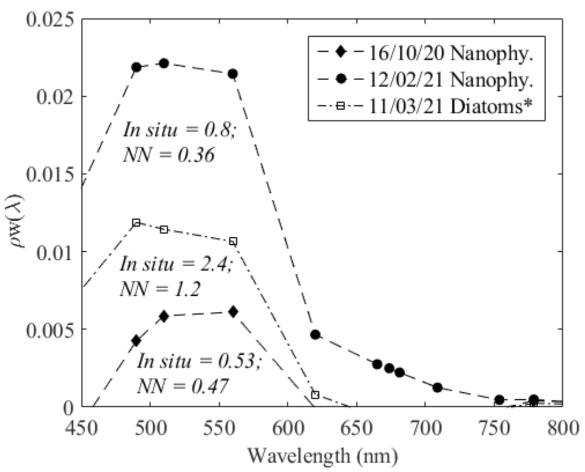

Figure 4. Water-leaving reflectance, rw(l) spectrum view from OLCI sensor on the available matchup days corresponding to phytoplankton communities; in situ and NN estimates of Chl a (mg.m-3) are stated per sample; Nanophy. = Nanophytoplankton; *Majority non-harmful species, Leptocylindrus minimus. Nanophytoplankton (2-20 μm) contributed to 87% and 89% of the total phytoplankton per samples collected on 12/02/21 and 16/10/21. Whereas, the sample collected on 11/03/21 is characterised by 63% Diatoms, with the majority of non-harmful species, Leptocylindrus minimus at 2.1 x 106 cells per litre.

The toxin-producing Pseudo-nitzschia spp. (a common HAB genus in the area) was also detected: 16,760 cells.L-1 (0.82% of 16/10/21 sample), 20,020 cells.L-1 (1.4% of 12/02/21 sample), and 1,180 cells.L-1 (0.032% of 11/03/21 sample), which are all well below the safe levels set by the Portuguese Institute of Sea and Atmosphere (IPMA) under its National Monitoring System of Bivalve Molluscs (SNMB).

In situ Chl a retrieved from the samples were 0.8, 0.53 and 2.4 mg.m-3, while the OLCI method (using NN algorithm) estimated 0.36, 0.47 and 1.2 mg.m-3 respectively. These are well below the reference condition of 5.3 mg.m-3, used to indicate an overall "High Status" amongst the Portuguese coastal water lagoons (EC, 2008; Carletti and Heiskanen, 2009). Moreover, Chl a does not necessarily reflect the presence of toxigenic/non-toxigenic phytoplankton as observed in the study area. The Chl a (both in situ and NN) for 11/03/21 > 12/02/21 but the abundance of toxin-producing, Pseudonitzschia spp. is identified up to 17x higher in the latter.

CONCLUSIONS

This study aimed at determining if OCRS can be used to detect phytoplankton variability and HABs, in coastal waters where Blue Growth sectors are found. OLCI's NN algorithm works best in complex waters compared to OC4ME, probably because it accounts better for the influences of CDOM and TSM on the absorption by Chl a. However, NN is susceptible to underestimations with in situ measurements. The differences in the rw(l) spectral shapes may indicate different phytoplankton communities. We find that rw(490) < rw(510) in samples with high abundance of Nanophytoplankton, while the opposite behaviour occurs when Diatoms dominate. In addition, the presence of toxin-producing Pseudo-nitzschia spp. (common to the region) was detected and was well below the safe levels. In fact, Chl a measured from both in situ and OCS do not necessarily reflect the presence of toxigenic/non-toxigenic phytoplankton as identified in this study. Future studies should investigate the contributions by other water constituents to the overall spectral rw(l) shape. The links between in situ Chl a concentration, cell sizes and HAB/non-HAB, to OCS can be better understood with more datasets gathered over broader spatial and temporal scales.

AKNOWLEDGEMENTS

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Comparison of UAS and Sentinel-2 Multispectral Imagery for water quality monitoring in the Iberian Pyrite Belt (SW Spain)

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ABSTRACT
Unmanned Aerial Systems (UAS) and satellites are used for monitoring and assessing the water quality of surface waters. UAS provides ultra-high spatial resolution and flexible temporal resolution, while satellites offer time-series data and worldwide coverage. Combining both sensors in a joint tool may scale local water quality retrieval models to regional and global scales by translating UAS-based models to satellite imagery. The present study assesses whether Sentinel-2 (S2) data can complement UAS data acquired by MicaSense RedEdge-MX Dual sensor for inland water quality monitoring in mining environments affected by Acid Mine Drainage (AMD). S2 data was processed with Case 2 Regional Coast Colour (C2RCC) and Case 2 Regional Coast Colour for Complex waters (C2X) atmospheric correction (AC) processors. The results showed C2RCC and C2X performed better for acidic greenish-blue and non-acidic greenishbrown water bodies concerning the UAS data than for acidic dark reddish-brown waters. However, significant differences in reflectance between MicaSense RedEdge-MX Dual and both S2 AC processors have been detected.

KEYWORDS
Acid mine drainage, abandoned mine, water monitoring, UAS, Sentinel 2, multispectral sensor

INTRODUCTION
Remote sensing techniques have gained popularity in the last years and the improvement of the sensors in terms of spectral, spatial, and temporal resolutions have increased their use for analysis and monitoring in different fields of study. Lately, Unmanned Aerial Systems (UAS) have grown as an innovative platform for acquiring ultrahigh- resolution images at low altitudes, providing both high spatial centimeter-scale and flexible temporal resolution, at an increasingly affordable price. At the same time, recently launched satellites from the Copernicus Sentinel-2A/B (S2) mission (by the European Space Agency, ESA) can also provide a medium spatial resolution (maximum 10 m) with a revisit frequency of five days (at the equator) but delivering global coverage. Each of these data platforms is generally used separately even though it is known that they can be complementary and have strong synergies (Emilien et al., 2021).

This study focuses on the comparison of reflectance data acquired by UAS and by S2 in small water bodies affected by acid mine drainage (AMD) at different extents. For this study, two atmospheric correction (AC) processors were selected to be applied on S2 data: Case 2 Regional Coast Colour (C2RCC), and Case 2 Regional Coast Colour for Complex waters (C2X). Therefore, the main objective is to examine whether S2 data can complement (or replace) UAS data, for inland water quality monitoring in mining environments.

MATERIALS AND METHODS
Two abandoned mining sites in the Tharsis mine complex, located in the Iberian Pyrite Belt (Huelva, Spain) were selected as sampling sites (Figure 1). This mine complex including 10 water

bodies Embalse Grande (EG), Sierra Bullones (SB), Filón Centro (FC), Filón Norte (FN), TH18, Mina Lagunazo (ML), Embalse Lagunazo (EL), Laguna Lagunazo A, B and C (LLA, LLB, LLC). EG and EL are greenish-brown clean water reservoirs used for agricultural purposes. ML is an acidic greenish-blue reservoir. LLA, LLB, LLC, TH18, FC, FN, and SB are acidic dark reddish-brown waters.

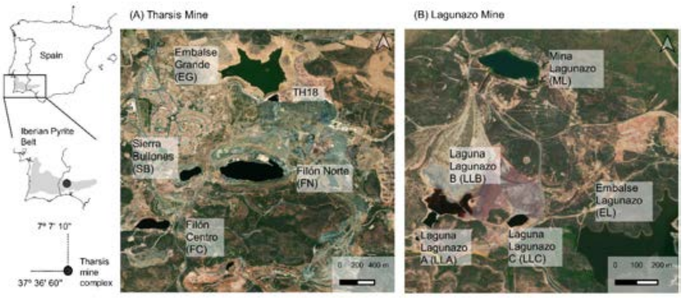

Figure 1. Location of the Tharsis mine complex that include the Tharsis Mine (A) and the Lagunazo Mine (B) with the respective water bodies.

The UAS DJI Matrice 210 V2 data acquisition was carried with the sensor MicaSense RedEdge-MX Dual on October 7th, 2020. The sensor has 10 bands capable of obtaining information in the coastal blue 444 nm, blue 475 nm, green 531 nm, green 560 nm, red 650 nm, red 668 nm, red edge 705 nm, red edge 717 nm, red edge 740 nm, and near-infrared (NIR) 842 nm. For the S2 data, the October 8th overpassing day was elected. The S2 Level 1C product was acquired from the Copernicus Open Access Hub (https://scihub.copernicus.eu/) and was processed to Level-2A with the C2RCC and C2X processors (Brockmann et al., 2016). The bands coincident with the UAS were resampled to 10 m in SNAP - ESA Sentinel Application Platform v 8.0 using the upsampling method bilinear. The bands used were coastal blue 443 nm, blue 490 nm, green 560 nm, red 665 nm, rededge 1 704 nm, rededge 2 740 nm, and NIR 865 nm. The satellite imagery was then reprojected to WGS 84 / UTM zone 29N with nearest neighbour interpolation to match the UAS data.

The UAS data was resampled and aligned in QGIS software to match the satellite pixel size of 10 m employing the bilinear interpolation method. To compare the results of both sensors datasets, for each waterbody six pixels reflectance values (10x10 m) were extracted randomly from the UAS and S2 imagery. Only the central pixels of the water body were chosen, meaning that pixels with only water cover were used.

The correlation between the UAS data and the atmospherically corrected S2 data was evaluated on a band-by-band basis to determine the strength of the relationship between both sensors. For this purpose, a linear model was fitted to the UAS-S2 image pair and the coefficient of determination (R2) was calculated and compared. Besides, a pixel-by-pixel and band-by-band comparison was performed as a graphical output of the analyzed reflectance values. To validate the consistency of both sensors, the band-by-band root mean square error (RMSE), mean absolute error (MAE), and bias between all the UAS resampled pixels and the corresponding S2 data were calculated. Then, the compatibility of the spectral data from the UAV bands and the S2 bands was analyzed through statistical methods. The non-parametric paired-sample Wilcoxon signed-rank test was applied to compare the mean difference of reflectance values from UAS data with the S2 data band-by-band. This test is an alternative to paired t-test since the data has no normal distribution according to the results obtained by the Shapiro-Wilk test. The test will indicate whether there is a statistical difference between the two means of UAS and S2 data.

RESULTS AND DISCUSSION

AMD-affected waters have a complex composition due to their physicochemical characteristics (mean pH of 1.72 and mean EC of 535 mS cm-1) which are also observed in their different colors. Based on the general shape of the spectral signature, greenish-blue and greenish-brown water bodies (ML and EG) showed a good agreement between sensors. In general, the differences between UAS and S2 measurements are pronounced at the coastal blue and NIR bands, while the reflectances between the blue, and red-edge 2 bands are more consistent. For the dark reddish-brown waters (LLA, LLB, LLC, TH18, FC, FN, SB), the shape of the spectra seems to vary depending on the sensor and atmospheric correction procedure, showing a lack of consistency in the form of the spectral signature obtained by both sensors (Figure 2).

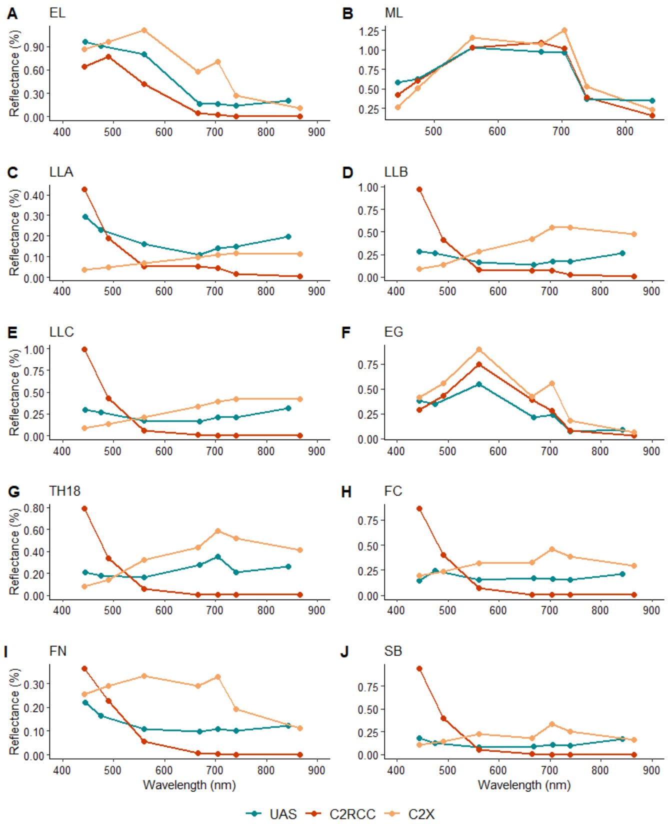

Figure 2. Reflectance spectra collected in October 2020 with UAS and Sentinel-2 bands obtained with C2RCC and C2X atmospheric correction processing.

To assess the consistency of both sensors, Figure 3 shows the statistical analysis applied to the coincident bands: R2, RMSE, MAE, and bias, per band and per AC. It can be observed that UAS vs C2RCC performed better than UAS vs C2X. The R2 obtained from comparing UAS orthomosaics and C2RCC were higher than those obtained with C2X for the bands between the green and NIR. There is a weak relationship between the two sensors for both AC processors for the NIR band and there is an extremely weak relationship for the coastal blue band whose R2 is the lowest of all bands. For the regression between UAS and C2RCC data, the results suggest that while more than 70% of the variation in the green, red and rededge1 bands can be explained by the linear model, the remaining variation might be due to the differences such as acquisition dates, the spectral bands, bandwidth of the sensors, radiometric correction, among others (Figure 3 (A)) (Sozzi et al., 2020; Zabala, 2017).

Regarding the coastal blue band, C2X values were closer to the UAS data than C2RCC (Figure 3 (B, C)). The bias values of C2RCC show negative values between 443 nm and 490 nm, indicating an underestimation of the reflectance obtained by this AC processor, while C2X shows positive values indicating an overestimation of the reflectance values (Figure 3 (D)). For the green, red, rededge1, and rededge2 bands, C2RCC values were generally closer to the UAS data. C2RCC shows a low positive bias, while C2X has negative values. Finally, in the NIR band, both atmospheric corrections have similar RMSE and MAE values. C2RCC increases the bias in the NIR band and C2X decreases it.

The results obtained by the band-by-band and pixelby-pixel comparison agree with the statistical analysis, C2RCC data is more similar to the UAS data than C2X. However, despite the strong correlation found in the green, red and rededge1 bands for C2RCC, a significant difference in reflectance, between UAS and S2, was found with the Wilcoxon signed-rank test based on a band-by-band comparison (p-value<0.001). The p-value indicates strong evidence against the null hypothesis, as there is less than a 5% probability the null is correct. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted. The only nonsignificant difference from the whole analysis was found in the blue (p-value=0.214) and NIR band (p-value<0.680) for both AC processors. This means that the differences in the reflectance values should be considered when combining data from both sensors since these could have further consequences in developing multi-scale models. The poor agreement between sensors may arise from different causes such as the spectral bands of the sensors, the bandwidth of the sensors, radiometric correction, the atmospheric conditions, adjacency effects (Sozzi et al., 2020; Zabala, 2017). One important factor is the acquisition date, there is one day difference between the UAS and S2 data, even though it is not much, the environmental variables could modify the spectral response of the sensor.

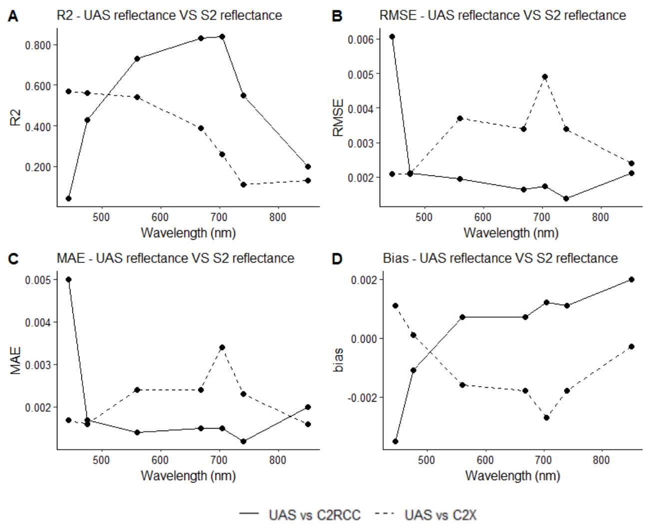

Figure 3. Band by band summary of statistics. (A) R2, (B) RMSE, (C) MAE, (D) bias. UAS data of October 7th and S2 data of October 8th, 2020.

Few studies have analyzed the correlation of bands between MicaSense RedEge sensor and S2. Regarding the water environment, a good agreement in the shape of the spectral signature of a drinking water reservoir affected by eutrophication for both sensors has been recently proven (Castro et al., 2020), which makes possible the development of multi-scale monitoring tools. It is important to mention, that the water bodies analyzed in this study (EG, EL, ML) with similar spectral signatures to the one studied by Castro et. al (2020) have shown coherence between the shapes of the spectral curves of both sensors. However, the red AMD-affected water bodies did not show coherence in the results. For this reason, further study to determine the cause of such difference in the sensors' responses is recommended. A possible explanation is that the spectrum of the AMDaffected water is not within the training database of the AC processors or the spectrum is out-of-scope of the algorithm definition, giving a reflectance spectrum with large deviations from the UAS data (Brockmann et al., 2016). Thus, new AC should be designed for this peculiar type of water. Due to the complexity of these water bodies also the water constituents must be studied once they affect the reflectance signature.

CONCLUSIONS

Considering that the UAS data is a low altitude remote sensing tool with ultrahigh spatial resolution (8 cm) that is not affected by the atmosphere (and that field spectroradiometric measurements were not performed), the UAS data was considered as the ground truth reference source for the reflectance. The results suggest that even though C2RCC showed a better performance than C2X compared to the UAS data, there is a significant difference in reflectance, between MicaSense RedEdge- MX Dual and the AC processors which should be considered when combining data from both sensors since this could have further consequences in developing multiscale models. The results obtained may be considered preliminary due to the limited in situ database and the lack of field radiometric measurements to validate the performance of the UAS sensor and the AC processors.

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Harmful Algae Blooms on the Portuguese coast: cross-checking events with remote sensing ocean colour data for coastal management

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ABSTRACT
Phytoplankton are essential for the feeding of commercially important bivalves, crustaceans, and fish. However, in some situations, the proliferation of algae can cause serious economic losses for aquaculture, fishing and tourism and have major environmental and human health impacts. Increases in the occurrence of toxic phytoplankton blooms in Iberian waters have been reported. Earth Observation can provide important information about the spatial and temporal distribution and the destination of blooms, with scales not available for conventional monitoring techniques. The present work aims to take advantage of public databases (Harmful Algae Event Database (HAEDAT)) to correlate the ocean colour data, also publicly available, (EUMETSAT's Copernicus Marine Data and NASA Ocean Colour Web) with the detection of the occurrence of harmful algal blooms (HABs) proliferation. From the analysis of the HAEDAT database, it was possible to observe that in Portugal, from 1987 to 2019, there were 630 HABs events, with Diarrhetic Intoxication by Shellfish (DSP) syndrome. The images were extracted from different ocean colour sensors (2016-2019) for periods coinciding with the HABs events in recent years to identify patterns in the development and destination of flowering, to assist in coastal management.

KEYWORDS
HABs, Earth Observation, ocean colour, coastal management, Portugal.

INTRODUCTION
Microscopic planktonic algae are essential foods for the feeding of commercially farmed bivalves, crustaceans, and fish. In most cases, algal blooms are beneficial for aquaculture and wild fishing. However, in some situations the proliferation of algae, so-called HABs, can have negative effects, causing impacts on human health and economic losses (for example, aquaculture, tourism) (Petterson et al, 2013).

Increases in the occurrence of some toxic phytoplankton blooms and the appearance of species never mentioned in Iberian waters have been reported, which may be related to the increased use of coastal waters for aquaculture, anthropogenic eutrophication, and the transport of toxic microalgae in the ballast waters of ships (Leal & Braga, 2014; Petterson et al., 2013).

Earth Observation (EO) could provide important insights regarding spatial and temporal spread and fate of the blooms, with scales not available for the conventional monitoring techniques (Leal & Catarina, 2014).

Recent data availability in public sources might allow for interesting scientific comparisons, and thus capitalizing the investment on regular monitoring programs and EO platforms.
The aim of this work is to take advantage of publicly available databases [HAEDAT, EUMETSAT's Copernicus Marine Data and NASA OceanColor Web] and to evaluate its usefulness to assess the frequency and dispersion of HAB events in the Portuguese coast. This work contributes to the ultimate goal of checking the feasibility of integrate EO data with regular monitoring programs data to produce insights regarding coastal water quality management.

MATERIALS AND METHODS
The HAEDAT database (IOCHAB, 2020) was analysed from 1987 to 2019, to find out which

HABs events (classified according to the toxins produced) have occurred more frequently in Portugal. The year of 2018 was selected for further analysis since it was the one with most events recorded in Portuguese coastal waters. Considering the dates and locations where the events occurred (a total of 10 regions considered), the satellite images corresponding to these periods and geographic locations were selected for the analysis and processing in the Sentinel Application Platform (SNAP) software version 7.0.0. Images were extracted from three ocean colour sensors:

• Ocean and Land Colour Instrument (OLCI) - Sentinel-3 Marine Copernicus Online Data Access (CODA) Web Service (data previous to November 29th, 2017, were downloaded from the CODArep portal, as recommended by EUMETSAT);
• Moderate Resolution Imaging Spectroradiometer – AQUA (NASA Goddard Space Flight Center (GSFC) (http://oceancolor.gsfc.nasa.gov/));
• Visible Infrared Imager Radiometer Suite (VIIRS) – Suomi-NPP (NASA GSFC (http://oceancolor.gsfc.nasa.gov/)).

Only the satellite images that presented the lowest percentage of contamination by clouds or other quality flags were chosen for the analysis: in the case of MODIS and VIIRS, the images with flags mentioned in NASA GSFC (https://oceancolor.gsfc.nasa.gov/atbd/ocl2flags/) were identified and in the case of OLCI the images with flags recommended in the Matchup Protocols (EUMETSAT, 2019) were identified.

After compiling the images that met the quality criteria, by zones and dates, and analyzing the chlorophyll a concentration (Chla), the images was confronted with the biotoxin concentration data in bivalve tissues collected in these locations, available online (https:/ /www.ipma.pt/pt/bivalves/biotox/) through the National Bivalve Mollusk Monitoring System, in charge of the Marine Biotoxins Laboratory of the Portuguese Institute of the Sea and Atmosphere (IPMA). The analysis was made for different regions: Coast of Viana do Castelo, Matosinhos, Figueira da Foz, Lisbon, Setúbal, Aljezur, São Vicente, Lagos, Faro and Tavira, having selected from these, 3 main areas for further case study analysis (Figure 1) – Viana do Castelo, Matosinhos (identified as L1 and L2 in Figure 2 respectively) and Setúbal.

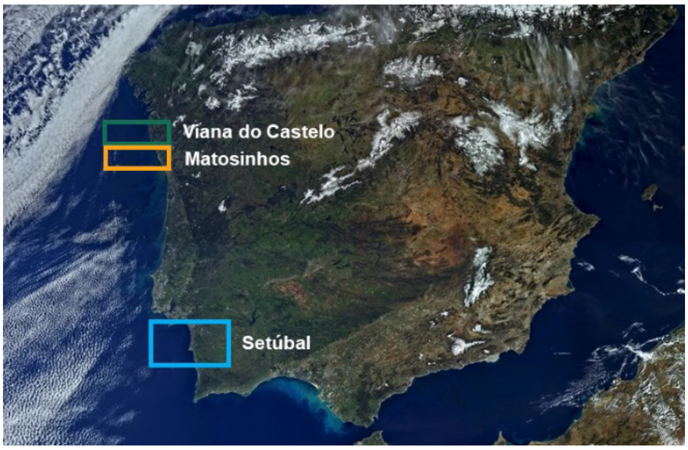

Figure 1. Study regions in the Portuguese coast (contains Sentinel-3 OLCI [01-03-2016] image, processed by ESA).

RESULTS AND DISCUSSION

From April 6, 2018, to July 19, 2018, HAEDAT recorded a HAB event that triggered a quarantine of bivalve harvesting in the coastal zone from Viana do Castelo to Matosinhos. According to HAEDAT, the observed toxic event was associated with the species Dinophysis acuminata, which can induce the DSP. In approximately the same period (from May 1, 2018, to May 19, 2018), an increase in Chla was observed in the MODIS-Aqua (OC3 algorithm) and VIIRS Suomi-NPP (OC-3V algorithm) Chla satellite images (Figure 2), where Chla values were reached above 8 mg.m-3.

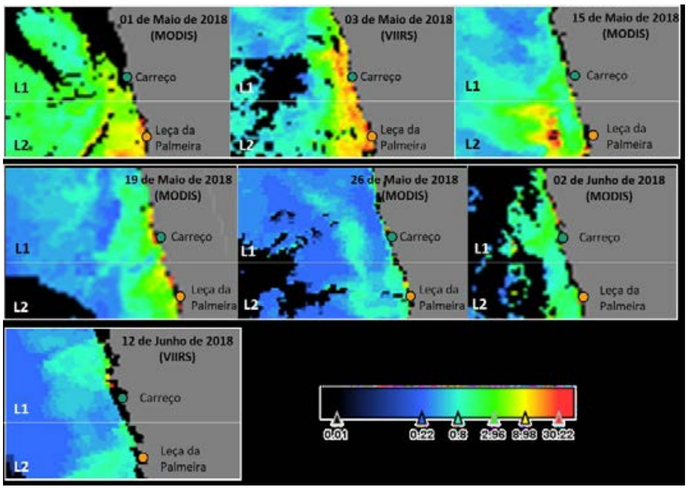

Figure 2. Level 2 satellite images of chlorophyll a from MODIS-Aqua (OC3 algorithm) and VIIRS-Suomi NPP (OC-3V algorithm) showing the development of an algal bloom between May and June 2018 covering two regions Viana do Castelo (L1) and Matosinhos (L2).

In Figure 3, it is possible to observe the values of biotoxin concentrations over the period in which the images were extracted (in which the bioindicator considered was Mytilus spp. (mussel), as it had the highest concentrations of biotoxin) highlighting that for the 21st of May 2018, for the study area, the highest concentrations of DSP (215 µg AO equiv / Kg) were obtained, values that were above the legal limits.

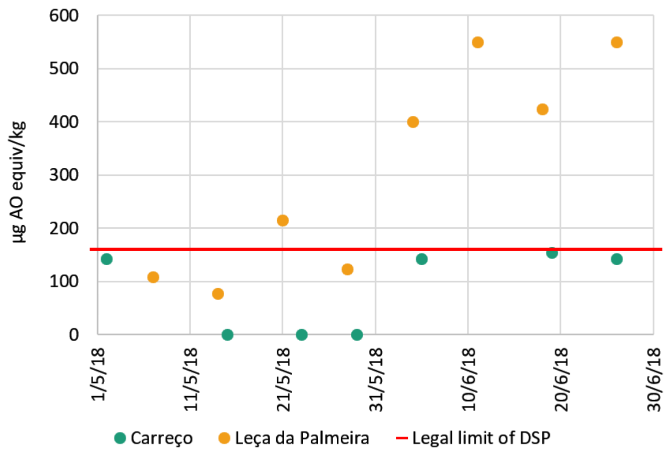

Figure 3. DSP biotoxin concentrations (µg AO equiv / Kg), taken from the IPMA, between May and June 2018. The red line represents the maximum legal biotoxin concentration, from which the ban on bivalve harvesting in the area is triggered.

From May 18, 2018, to July 6, 2018, HAEDAT registered a HAB event that triggered a quarantine of bivalve harvesting in the coastal area of Setúbal. According to HAEDAT, the toxicity observed was associated with the species Dinophysis acuminata, which can induce the DSP Syndrome. In the same period, a bloom was observed in the EO images (Figure 4), which lasted from May 1, 2018, to May 13, 2018, with Chla values above 8 mg.m-3.

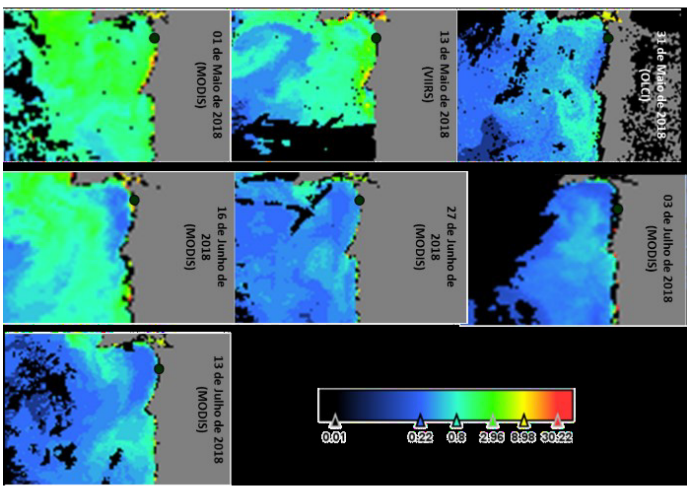

Figure 4. Level 2 satellite images of chlorophyll a from OLCI-Sentinel-3A (OC4ME algorithm), MODIS-Aqua (OC3 algorithm) and VIIRS- Suomi NPP (OC-3V algorithm) showing the development of an algal bloom between May and July 2018 in the region of Setúbal.

In Figure 5, it is possible to observe the biotoxin concentration values for the same period in which the images were extracted. The highest concentrations of DSP were obtained on May 17th, 2018 (160 µg AO equiv / Kg), being above legal limits. The considered bioindicator was the Donax spp., as it was the one that presented the highest DSP concentration values in the tissues.

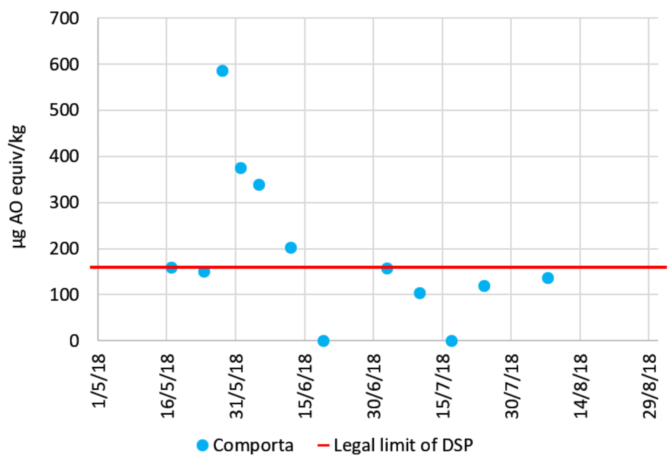

Figure 5. DSP biotoxin concentrations (µg AO equiv / Kg), taken from the IPMA, between May and August 2018. Where the red line represents the maximum legal biotoxin concentration, from which the ban on bivalve harvesting in the area is triggered.

CONCLUSIONS

In general, when comparing the levels of biotoxins associated with the presence of the species Dinophysis acuminata (potentially causative of DSP syndrome), with the ocean colour remote sensing images, it is observed that these toxin-producing phytoplankton communities develop during high chlorophyll episodes were also detected by remote sensing. It was also possible to observe that, for the areas of Viana do Castelo and Matosinhos, there is a delay of approximately 1 month between the bloom formation observed in the images and the recording of the appearance of high toxicity in bivalves. For the Setúbal area, a delay between bloom formation (high values of Chla) was also observed in the images and the recording of bivalves contaminated by DSP biotoxins, but smaller – of approximately fifteen days.

This work explored the applicability of ocean colour data provided by EO platforms to study the occurrence and spatial dispersion of HABs on the Portuguese coast. These data have the potential to be used as complementary tools for coastal water quality assessment and management, but they also reinforce the importance of maintaining existing monitoring programs on a regular basis, especially as some types of HABs may not be easily distinguishable by EO.

Future studies include the extraction of spectral signature data (reflectance and absorption spectra) from the satellite images, in order to study possible significant changes in the optical properties of water associated with changes in phytoplankton communities. This will be particularly relevant in the case of successions to communities with significant presence of potentially harmful phytoplankton groups.

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Spatial and seasonal dynamic of intertidal microphytobenthos in a tropical estuary using Sentinel-2 multispectral satellite images

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ABSTRACT
Intertidal mudflats are some of the most productive coastal ecosystems in part due to the activity of the photosynthetic microbial community at sediment surface (microphytobenthos, MPB). MPB dynamics depend on the interaction of several physico-chemical variables in short temporal and spatial scales. Remote sensing, when compared to traditional in situ sampling, allows to study large intertidal areas, and with increased observational frequency. MPB dynamics have been investigated mostly in temperate estuaries, whereas studies in tropical estuaries are scarce, even by traditional methods. Here, we investigated the spatio-temporal dynamics of MPB biomass using NDVI as a proxy in the Nicoya Gulf, one of the most productive estuaries worldwide, using Sentinel-2 images from 2018-2020. Our results suggest that MPB NDVI was highest in the western part of the estuary most likely due to the increased nutrient availability and sediment deposition in this part, and in the upper shore due to decreased turbidity and reduced grazing pressure. A clear seasonal pattern was observed with highest MPB NDVI in late wet and early dry seasons. Therefore, the elevated temperature and irradiance reached in Nicoya estuary during dry season could inhibit growth of MPB in contrast to what is observed in high latitude temperate estuaries.

KEYWORDS
Remote sensing, Nicoya estuary, benthic microalgae, cover, biomass, NDVI, environmental factors.

INTRODUCTION
Intertidal mudflats are highly productive ecosystems that harbour a great variety of primary producers (e.g., seagrass, microphytobenthos (MPB), macroalgae, etc.) (Underwood and Kromkamp, 1999). MPB is the photosynthetic microbial community that inhabit in the photic layer of coastal sediments and can contribute up to 50 % of benthic primary production in intertidal ecosystems (Haro et al., 2020). MPB also provides important ecosystem services, such as surface stabilization against sediment erosion and resuspension, carbon and nutrient fluxes buffering, organic matter cycling, blue carbon sequestration and direct source of food for grazers. MPB spatial and temporal distribution is affected by several physicochemical variables at different temporal and spatial scales. Sediment structure, rainfall, temperature, tidal exposure, photoperiod can changes at daily, monthly and seasonal scales affecting MPB biomass (Jesus et al., 2005; Haro et al. 2019). Remote sensing approach based on the normalized difference vegetation index (NDVI), used as proxy of microphytobenthic chlorophyll-a (Rouse et al., 1973; Serôdio et al 2005). is an ideal too for monitoring spatio-temporal distribution of MPB (Oiry and Barillé, 2020). Previously, MPB dynamics have been studied, in temperate

systems, using this approach from SPOT (Brito et al., 2013), Landsat (Daggers et al., 2018), MODIS (Savelli et al., 2018; Van der Wal et al., 2010) and Sentinel-2 satellite images (Daggers et al., 2020; Oiry and Barillé, 2021).

In this work, we used Sentinel-2A/B satellite images with 10 m spatial resolution, and 2-5 days temporal resolution to investigate spatial and temporal distribution of MPB, in the tropical Nicoya estuary, Costa Rica, one of the most productive estuaries worldwide (Soria et al 2017). Our aim was to describe the distribution of MPB biomass in the estuary and determine whether the patterns observed in temperate estuaries are valid as well in a tropical system.

MATERIALS AND METHODS

The Nicoya estuary is characterized by two seasons (wet and dry) and high nutrient load from Tempisque river (Seguro et al., 2015; Gómez et al., 2019). In order to study the spatio-temporal dynamic of MPB biomass in Nicoya estuary (10° N, 85° W), 24 Sentinel 2, Level - 2A satellite images, acquired at low tide and cloud free conditions, were processed in Sentinel Application Platform (SNAP) to extract "MPB NDVI", a proxy of MPB biomass (NDVI pixel-1) for the entire study period, 2018-2020. Sen2cor atmospheric correction was used to convert L1C into L2A. No other small primary producers grow in the intertidal area of the gulf. MPB biomass were filtered between 0 - 0.4 NDVI and mapped, clearly distinguishing adjacent mangrove forests (Brito et al., 2013; Oiry and Barillé, 2021). Moreover, 6 Level – 1C images collected at high tide were processed for water quality parameters (chlorophyll-a, Chl-a, and total suspended matter, TSM) using C2RCC processor (Doerffer and Schiller, 2007) in 2020.

The study area was arbitrarily divided into four sections, and five sea level classes (SL) across the intertidal range to analyse the spatial variability of MPB. MPB NDVI was estimated on a daily basis using a sine function (Mansfield & Smith 1984; Haro et al 2019) to investigate its relationship with meteorological data (rainfall, temperature, and irradiance). Sediment fines and water quality parameters (Chl-a and TSM) were also analysed for 2020.

Mean MPB NDVI was computed for each section and SL class range in QGIS. Statistical and significant tests were computed using analysis of variance (ANOVA) and Tukey HSD post hoc tests in R and Excel.

RESULTS AND DISCUSSION

MPB NDVI varied both spatially and seasonally across the Nicoya intertidal mudflat despite the high nutrient availability year-round (Seguro et al., 2015, Soria et al., 2017). The highest MPB NDVI was observed at northwestern section, whereas the lowest at the south-eastern part of the estuary with differences being significant (Figure 1a). The currents in the inner part of the bay circulate in an anticlockwise manner with marine oligotrophic waters entering from the north and fresh water from the Tempisque flowing principally from the southern part of the estuary (Lizano and Alfaro, 2004; Pelage et al., 2021). This high nutrient availability and fine sediment deposition is probably sustaining the higher MPB NDVI in this part of the estuary.

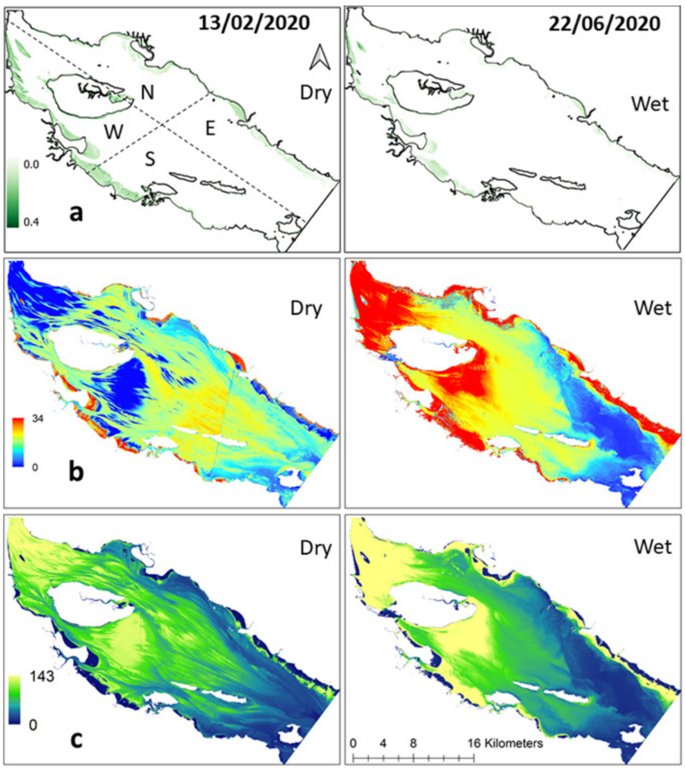

Figure 1. Examples of maps indicating the spatio-temporal variations of MPB NDVI pixel-1, a proxy of MPB biomass, in the intertidal zone for the four studied sections, North (N), West (W), South (S), East (E) (a), and concentrations of Chlorophyll-a (b) and total suspended matter (c) in the water column of Nicoya estuary for 2020.

Along the intertidal gradient, MPB NDVI was higher in the upper shore (Figure 2), similarly to what has been observed in temperate estuaries (Brito et al., 2013; Haro et al., 2020). In temperate estuaries the higher biomass upper shore has been linked to the higher light availability and lower grazing pressure. In Nicoya Gulf, light does not vary significantly during the year and should not be considered a limiting factor, although the high turbidity could limit growth under emersion. In addition, other variables such as grazing could be the main driving factors resulting in the distribution observed. Apart from sea level, sediment grain size is also a factor determining MPB spatial dynamics, mainly due to its relation to organic matter and nutrient availability in fine sediments. Here, a positive and significant relationship was observed between MPB NDVI and sediment fines percentage (Pearson coefficient =0.38; $p < 0.05$; n=542).

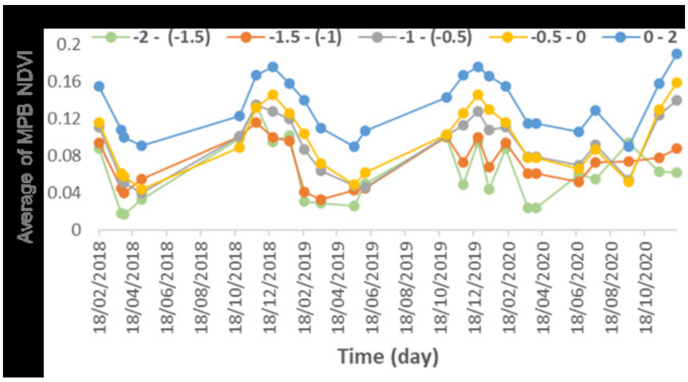

Figure 2. Temporal evolution of average MPB NDVI per sea level range, expressed as MPB NDVI pixel-1, in the intertidal zone of Nicoya estuary for 2018-2020.

On a temporal scale, a clear seasonal pattern was observed for the MPB NDVI with maximum values in late wet and early dry seasons. This seasonal pattern differs from that observed in temperate estuaries located at different latitudes where highest biomass is observed in spring and summer, with higher temperatures and lower precipitation (Van der Wal et al., 2010; Brito et al., 2013; Savelli et al., 2018). Here, the estimated daily average of MPB NDVI showed a positive relationship to precipitation, and surprisingly negative to temperature and irradiance (Figure 3). Precipitation may contribute positively to MPB growth due to the transport of nutrients and fine sediment from the river, whereas air temperature and high irradiance may thermo- and photo-inhibit MPB growth in the Nicoya estuary. Therefore, even though it is generally considered that temperature and irradiance are stable year-round and are not limiting in tropical systems, compared to temperate systems, hence their high productivity, it seems that MPB communities are negatively affected by the combination of these variables at high levels.

In addition, a positive relation between water column surface Chl-a and TSM, and MPB NDVI were found (Figure 1), possibly suggesting that the same abiotic factors could affect both water column and sediment primary producers. In addition, MPB and sediment could be resuspended into water column from intertidal mudflat during the wet season as observed in temperate systems (Brito et al., 2016).

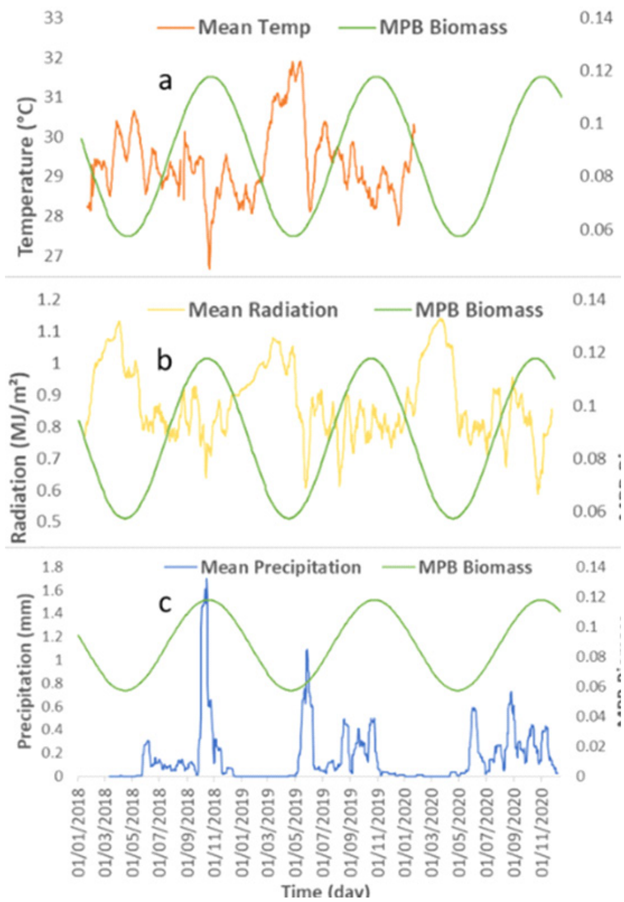

Figure 3. Daily average of air temperature (ºC) (a), irradiance (MJ m-2) (b) and precipitation (mm) (c) (primary axis-y) and estimated average MPB biomass (estimated as NDVI pixel-1) in the intertidal area of Nicoya estuary (secondary axis-y) from 2018 to 2020 (axis-x).

CONCLUSIONS

Sentinel-2 satellite images used here allowed to investigate spatial and temporal dynamics of MPB NDVI, a proxy of MPB biomass, in Nicoya estuary intertidal mudflat. MPB NDVI varied clearly in space and time over the period study. MPB NDVI was highest near the estuary head where most of the nutrients from the river are found and in late wet and early dry seasons, when nutrients are still abundant, but temperatures and irradiance are not that high to inhibit MPB growth. Overall, the results show that MPB in this tropical estuary shows characteristic patterns, in part different from the ones in temperate estuaries. The results will have to be validated with in situ data on MPB biomass. This type of studies has to be extended to more systems to determine global patterns and the contribution of MPB biomass and productivity to these systems productivity.

AKNOWLEDGEMENTS

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On the applicability of remote sensing techniques to detect soil salinization in the Mekong Delta, Vietnam

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ABSTRACT
Track changes in salinity with reliable information is needed for proper and timely decisions. This research aims to evaluatethe applicability of the most common vegetation indices (VIs) derived from MODIS and Landsat data to assess soil salinity in the coastal zone of the Mekong River Delta. The results indicate that VIs that include near-infrared (NIR) and shortwaveinfrared (SWIR) bands cannot be used to reliably track salinity because of the geographically typical presence of ponds for the intensive aquaculture activity, which affects the signal acquired by Landsat and MODIS. Consequently the VIs correlate with the water percentage coverage rather than with other vegetation properties related to possible salinization. However the brackish water aquaculture ponds in the coastal area coincide with the highly saline land. Therefore, for the specific case of the Mekong Delta, the detection of ponded areas along the coast somehow corresponds to the detection of medium to highly saline areas. We developed two new indices based on the behavior of the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI) that can be effectively used to detect ponded and nonponded areas and, eventually, can be used to quickly separate highly saline from inner freshwater lands.

KEYWORDS
MODIS, Mekong Delta, Landsat 8, soil salinity, vegetation indices, water coverage.

INTRODUCTION
Soil salinization is a global issue that affects more than 100 countries distributed in all continents and regions (Shahid, Zama and Heng, 2018). In the Mekong River Delta, Vietnam, soil salinization is one of the most devastating environmental issues that has a great impact on agriculture (United Nations, 2016). Salt-affected soil area in the Mekong Delta has been predicted to increase due to increasing saline water intrusion under the impacts of climate change, reduced river flows from upstream dams and land subsidence due to groundwater overexploitation (GDLA, 2017). Therefore, monitoring salinity to track its changes is needed in order to take proper and timely decisions and anticipate further degradation trends securing sustainable land use and management.

In this study, we investigate the applicability of remote sensing techniques in soil salinity assessment. In particular, the research aims to (1) evaluate the applicability of common vegetation indices (VIs) derived from MODIS and Landsat data to assess soil salinity; (2) investigate the impact of ponded areas, typical of the shrimp farming practices, on the radiometric signals and consequently on VIs; and (3) develop new indices to quickly separating saline wetlands from the freshwater environment.

MATERIALS AND METHODS
The research used the MODIS 8-day composite surface reflectance products (MOD09Q1 and MOD09A1) collected in the period 29 February - 29 April 2016 to compute VIs and tasseled cap transformation. Resulting values were correlated

to soil salinity data provided by the Soil Science Department, Can Tho University. Specifically, the electrical conductivity of saturated soil-paste extract (ECe) were retrieved from 181 soil samples collected at 0 - 20 cm of depth in four coastal provinces in April, 2016. Linear regression models were used to investigate the correlation between ECe and (i) Near-Infrared Band, (ii) Normalized Difference Vegetation Index (NDVI), (iii) Enhanced Vegetation Index (EVI), (iv) Soil Adjusted Vegetation Index (SAVI) and (v) Vegetation Soil Salinity Index (VSSI), (vi) Brightness and (vii) Greenness. A hierarchical cluster analysis with euclidean distance method was also performed on the salinity data sets to group them according o salinity levels. Together with the total samples, these groups were then separately investigated for the correlation with the above VIs.

In order to investigate the influence of ponds on the radiometric signals, the correlation between NDVI and NDWI across ponded, mixed and non-ponded land cover types were investigated. Moreover, the Random Forest Classifier (RF) was applied to estimate the water coverage. To identify water coverage of the pixels, grids were created over the study area. Intersections fallen into the water surface were counted for water coverage. For MODIS image, 103 regions of interest (ROIs) were sampled, of which 22 were non-ponded, 43 were mixed, and 38 were ponded. For Landsat 8 images, a total of 99 ROIs were sampled, of which 31 were non-ponded, 29 were mixed, and 39 were ponded.

The correlation between the selected VIs derived from MODIS and Landsat data and water coverage was checked with water coverage in both freshwater and saltwater areas. Similarly to the RF sampling approach, water coverage of MODIS data was collected for inland and coastal areas with 200 and 348 samples, respectively. For Landsat data, the water coverage samples were 171 for the inland area and 205 for the coastal area. Two new indices based on the coupled behaviors of NDVI and NDWI have been developed to quickly detect ponded surfaces from non-ponded areas. The indices for MODIS (D1) and Landsat data (D2) are shown in equation 1 and 2, respectively.

$$D1 = NDVI \times NDWI \times \frac{NDVI-NDWI}{NDVI+NDWI}$$

$$D2 = \frac{NDVI^2 - NDWI^2}{NDVI^2 + NDWI^2}$$

RESULTS AND DISCUSSION

1. Spatial distribution of soil salinity from the ground-truth datasets

The cluster analysis applied to the 2016 soil salinity dataset retrieved 3 clusters according to salinity levels, including (1) Cluster 1 = non to moderately saline (ECe from 1.13 to 9.68 mS/cm), (2) Cluster 2 = highly saline (ECe from
10.6 to 24 mS/cm), and (3) Cluster 3 = very highly saline (ECe from 25.4 to 54.5 mS/cm). We found that their distribution is not random but linked to the territory characteristic. Specifically, both magnitude and variance of soil salinity increases when moving toward the coastline, especially within a buffer of 30 km from the coastline. Besides, the high salinity samples are mostly recorded in the shrimp farms and their adjacent areas **(Figure 1).**

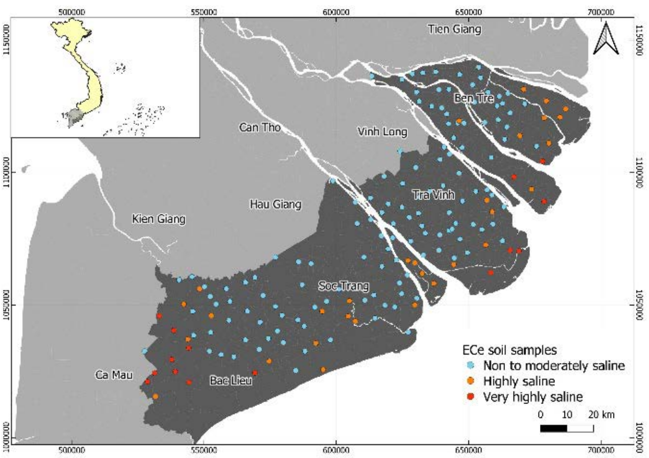

Figure 1. Distribution of soil salinity in the Mekong Delta in April 2016.

2. Applicability of satellite data to soil salinity assessment

The correlations of salinity with VIs derived from MODIS data were investigated for all the training dataset and for each salinity cluster mentioned above (Table 1). We found that VIs derived from MODIS data present a poor correlation with soil salinity (R-square from 0.19 to 0.28).

The highest R-square is observed between soil salinity and Greenness, while the lowest is recorded for Brightness. Cluster 1 and Cluster 3 have very low correlations between ECe and all the VIs. Cluster 2 has higher has slightly higher correlations than other clusters with the highest R-square recorded for Greenness, EVI and NDVI (0.3394, 0.3357 and 0.3202, respectively). On the other hand, a study of Nguyen et al., 2020 investigated the correlations between VIs derived from Landsat 8 data and soil salinity in February 2017, which are much more promising than those obtained with MODIS data (R-square from 0.41 to 0.80)
(Table 1).

Table 1. R-square of soil salinity and VIs derived from 2016 MODIS data and Landsat8 2017 data.

VIs	MODIS 2016 All samples n=136	Cluster 1 n=98	Cluster 2 n=24	Cluster 3 n=14	Landsat-8 vs 2017 data n=29 (Nguyen et al., 2020)
NDVI	0.2149	0.0246	0.3202	0.0697	0.4108
NIR	0.2519	0.0166	0.1636	0.0579	0.8011
SAVI	0.2639	0.0214	0.2148	0.0042	0.6245
VSSI	0.2029	0.0066	0.0797	0.0621	0.7149
EVI	0.2498	0.0309	0.3357	0.0874	
Greenness	0.186	0.015	0.3394	0.0041	
Brightness	0.2813	0.0313	0.1203	0.0487	

In order to understand if the VIs response is dominated by salinity or by the presence of ponds, we compared the correlation between NDVI and water coverage obtained for (1) fresh water and for (2) salt water environments (Table 2). In general, VIs derived from both MODIS and Landsat- 8 data strongly correlate with water coverage. For MODIS data, all VIs in coastal areas have strong correlations to water coverage with R-square greater than 0.5 while those in inland freshwater area have lower correlations (less than 0.335). On the other hand, the correlations of VIs derived from Landsat-8 data to water coverage are strong in both areas. Therefore, our results show that, regardless of salinity concentration, VIs have strong correlations with water coverage in both freshwater and saline environments. Besides, the spatial resolution does not strongly impact the relationship when the correlations are high in both Landsat 8 and MODIS data.

Table 2. R-square of water coverage and VIs derived from MODIS and Landsat-8 data

VIs	MODIS Coastal ponded areas	MODIS Inland ponded areas	Landsat 8 Coastal ponded areas	Landsat 8 Inland ponded areas
NDVI	0.5372	0.3209	0.6239	0.7017
NIR	0.6093	0.3137	0.4812	0.6979
EVI	0.5457	0.3355	0.6001	0.6974
SAVI	0.6213	0.3222	0.5472	0.6945
VSSI	0.5312	0.2882	0.3459	0.693
Brightness	0.5033	0.1318	0.4139	0.6872
Greenness	0.6276	0.2195	0.5876	0.6923

3. New indices for detecting water coverage in the Mekong Delta

In this study, we develop robust indices based on NDVI and NDWI to detect aquaculture area, which can be easily applied. D1 index derived from MODIS data tends to increase when moving from ponded to non-ponded areas.

Hence, a threshold 0.0059 for D1 is determined to separate non-ponded from the other classes (Figure 2). Similarly, the values of D2 index derived from Landsat 8 data increases with the decrease in water coverage. Therefore, a threshold of -0.07 is set for D2 to create a mask of nonponded and mixed pixels (Figure 3).

In the Mekong Delta, about 861,459 ha of the Mekong Delta is dedicated to aquaculture (Seijger et al., 2019), which goes along with the high density of aquaculture ponds in the coastal zone. As shown by our analyses on the salinity distribution across the study site, which are in agreement with the maps available in literature, the ponded areas correspond to the areas with the highest salinity.

Therefore, for the specific case of the Mekong Delta, the detection of ponded areas along the coast somehow corresponds to the detection of medium to highly saline areas. In this sense, the indices based on Landsat and MODIS data developed in this study can be considered useful to quickly separate highly saline areas from freshwater lands.

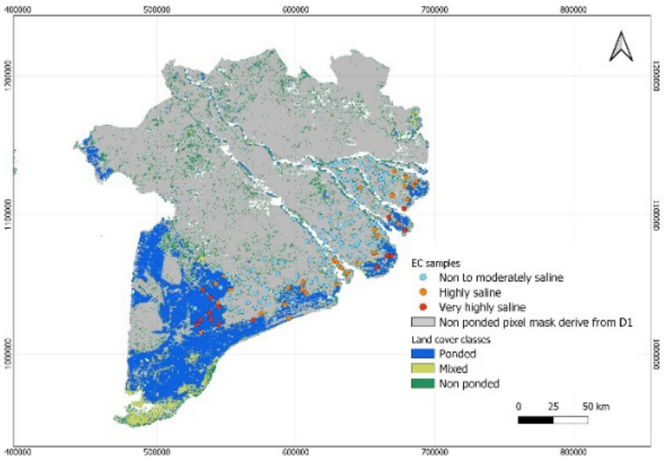

Figure 2. RF water coverage classification map of the Mekong Delta overlaid by non-ponded mask derived from D1.

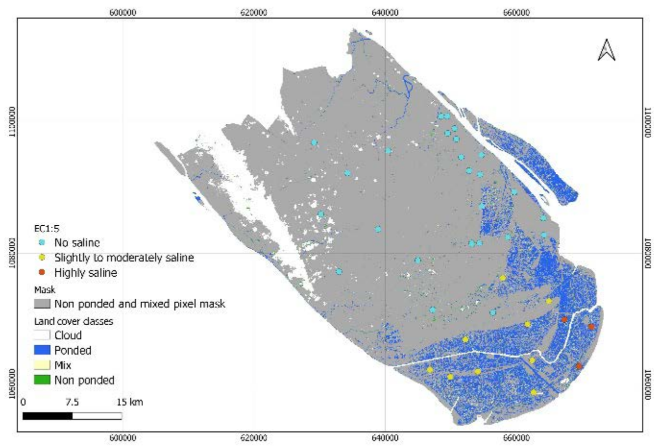

Figure 3. RF water coverage classification map of Tra Vinh overlaid with non-ponded and mixed pixel mask derived from D2.

CONCLUSIONS

The Mekong Delta ponded areas in the coastal zone tend to be salted, because of the brackish water shrimp farming practices and seawater intrusion. On the other hand, non-ponded areas are still dominated by freshwater since they are further away from the coastline and are characterized by freshwater presence. Remote sensing can be effectively used to detect the presence of standing water and ponds on land, as shown by our RF classification results and the D1 and D2 indices that we developed based on the behaviors of NDVI and NDWI. Eventually, these indices can be useful to quickly distinguish brackish and saline water aquaculture ponds present in the coastal zone of the Mekong Delta from inland freshwater lands.

On the contrary, we find that NDVI and other VIs cannot be used to reliably track salinity because of the presence of ponds that “mask” any possible signal coming from the salinity presence. Therefore, to properly assess soil salinity in the Mekong Delta, it is suggested to further investigate methods other than the use of VIs coming from satellite data at low to medium spatial resolution (30 m for Landsat and 250 m for MODIS), because pixels include the ponds that are typical of the Mekong Delta. It is therefore suggested to limit the use of these satellite data to inland areas or at least to apply them in agriculture and aquaculture areas separately. Besides, higher spatial resolution such as IKNOS, Quickbird or WorldView-2 might improve the accuracy of the assessment by excluding pixels with mixed ponded/non-ponded areas.

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Impact of Land Use Land Cover (LULC) Variation on Hydrological Fluxes in Karasu Basin

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ABSTRACT
The growing trend of urbanization, agricultural lands and non-stationarity of climate necessitates the importance of understanding the spatiotemporal changes in hydrologic fluxes with variation in land use for effective management of water resources. Physically distributed models are widely used due to their ability to capture spatiotemporal variations and use of physically based-equations to describe hydrologic processes, although with some model uncertainties associated with its output. This study explored the effect of Land Use Land Cover changes on hydrological fluxes in Karasu basin by simulating the fluxes from 1990 to 2012 with 1990 and 2012 Coordination of Information on the Environment (CORINE) LULC maps using the mesoscale Hydrologic Model (mHM). The results revealed a decrease in total annual evapotranspiration, base flow, recharge flow by 551.47mm, 428.03mm and 423.38mm respectively between both scenarios but an increase in direct runoff was observed in the 2012 LULC scenario due to slight increase in urban areas and deforestation in the basin. The result of this study provides useful information for planning and development department, disaster management autho rities, city government, policymakers, and other stakeholders involved in the sustainable management of water resources in Karasu basin.

KEYWORDS
Lulc, mhm, corine, hydrologic modeling.

INTRODUCTION
Despite the ubiquitous nature of water, its availability for consumption and economic activities is limited by a wide range of factors. The exponential increase in population is spiking the global rise in water demand, which is worsened by anthropogenic activities that compromises the quality of the available resources. The potential water resource available for human use and management in a region is represented by the average runoff in such region (Dingman, 2015). The runoff amount depends on meteorological, morphological components of the region and greatly influenced by land use. The changes in land use and land cover causes variations in water yield in form increase in discharge, decrease in infiltration and groundwater recharge (Measho et al., 2020).

Urbanization is largely considered one of the primary cause of Land Use Land Cover (LULC) change which causes landscape degradation and increases extent of impermeable surfaces (Atak & Tonyalo lu, 2020). Impervious surfaces such as roads, buildings reduces infiltration, increases runoff yield and reduces time taken to reach peak flow (Jacobson, 2011), which significantly affects streamflow, flood frequency, magnitude and timing of evapotranspiration and global climate (Patidar & Behera, 2019). In addition to LULC changes, non-stationarity of climatic variables contributes immensely to the uncertainty in hydrological processes and influences the distribution of water on the earth surface.

The complex inter-relationship between hydrological components such as precipitation, evaporation, infiltration, transpiration and runoff complicates the study of hydrological cycle and hydrological response (Dwarakish & Ganasri, 2015). This is worsened by human interventions in form of urbanization, which intensifies land use dynamics and further leads to varying hydrological response thereby affecting the amount of water available for human use and management in a watershed. For proper management of these resources, the simulation of LULC scenarios to observe the implications of human triggered events on hydrological processes becomes imminent. The impacts of LULC change on hydrology at watershed scale has become an important research topic in studying human-environment interaction (Briones et al., 2016).

This study is aimed at observing the impact of LULC variations between 1990 and 2012 on the hydrological processes in Karasu basin, Turkey, using a fully distributed physically distributed model. The mesoscale Hydrologic Model (mHM) was preferred as the model of interest due to its Multiscale Parameter Regionalization technique, which accounts for sub-grid variability in the basin physical characteristics. Previous researches related to this study focused on the use of conceptual models, which provides little information about the spatial distribution of fluxes in the basin. We adopted the use of CORINE land cover maps to characterize and identify the land cover changes in the basin.

MATERIALS AND METHODS

In order to obtain land cover variations between the studied periods, we analyzed 1990 and 2012 CORINE land cover maps of Karasu basin, Turkey. CORINE land cover (CLC) is the first land cover map in Europe based on photographic interpretation of satellite images for the years 1990, 2000, 2006, 2012 and 2018, producing the CLC 1990, CLC 2000, CLC 2006, CLC 2012 and CLC 2018 products respectively. The main advantage of the CORINE Land Cover (CLC) inventory is its frequent update by European countries, although the level of detail of the source data is a limitation (Cie lak et al., 2020). The mesoscale Hydrologic model (mHM) was then used to create case 1 and case 2 scenario experiments involving 1990 and 2012 CORINE land cover maps respectively, which were reclassified to suit the model requirement. This involved simulation of hydrological processes and predictions of monthly evapotranspiration, recharge, base flow, direct runoff and discharge from 1990 to 2012, using optimized parameters obtained after calibration of the model. mHM is a physically distributed hydrologic model that uses numerical approximations and conservation of physical laws while simulating hydrological processes between 1990 and 2012. The fundamental data for setting up the model are classified into meteorological data, morphological data, land cover data and gauging data, which were obtained from E-OBS, MODIS, CORINE, GlobcoverV2, SRTM, and European soil database, Harmonized world soil database.

RESULTS AND DISCUSSION

LULC Dynamics in Karasu Basin

Global population increase is on the rise and has been triggering various activities to meet human needs, putting pressure on available resources. The planning and management of water resources require adequate knowledge about the influence of human activities on land cover characteristics across the years and its implication on water distribution on the earth's surface. Karasu basin is not an exception to LULC changes. Based on the level one CORINE nomenclature, the dominant land cover characteristics in the basin are artificial surfaces consisting of urban fabrics, industrial, commercial, transportation areas, mining sites, dumping sites, construction sites, green urban areas, and leisure facilities.

The basin is also characterized by Agricultural areas such as arable land, non-irrigated arable land, permanently irrigated land, pastures, complex cultivation patterns, and land principally occupied by agriculture with significant areas of natural vegetation. The forest and semi-natural areas part of the basin consists of broad-leaved trees, coniferous trees, mixed forests, natural grasslands, beaches, dunes, bares rocks, glaciers, and perpetual snow. Waterbodies are also present in the basin and increased in extent over the studied periods. Anthropogenic activities and other environmentally induced stresses often lead to the conversion of land covers from one class to another, which affects the complex interactions of hydrologic processes. Based on the land cover change detection, we noticed some variations in the extent of the various land cover classes. The artificial surfaces in the basin increased from about 69km2 to 74km2, mainly in built-up areas, road networks, airports, and mineral extraction sites. The rise in built-up areas is usually directly proportional to population increase, which affects environmental balance by overexploitation of natural resources and escalating waste management issues. Classification of a place as urbanized based often gets complicated, begging how densely populated with industries and humans the area has to be. Some authors proposed to use impervious thresholds to classify catchments, which was later crucified by researchers based on the absence of a universally accepted imperviousness estimation technique. Elga et al., (2015) then suggested that a catchment is considered as urban if hydrological fluxes in the areas are significantly affected by the local anthropogenic impacts. The increase in urban land cover probably justifies the reduction in agricultural and forested lands in the basin. In addition to this, the increase in the glacier and perpetual snow in the basin increased in 2012, which also could be responsible for the loss of croplands and other agricultural establishments in the basin.

Hydrological Fluxes in the basin

The effect of LULC changes on hydrological fluxes in Karasu basin was simulated by creating scenario experiments involving case 1 and case 2 using 1990 and 2012 CORINE land cover maps respectively to predict hydrological variables from 1990 to 2012. The total annual actual evapotranspiration, base flow and recharge simulated in case 1 exceeded those simulated in the case 2 scenario. These variables decreased by 551.47mm, 428.03mm and 423.38mm respectively in the basin scale but with significant changes in the spatial distribution. However, from the same table, the total annual direct runoff in the case 2 scenario exceeds that of the other land cover scenario by 1019.6mm. This could be because of the reduction in forest areas and urbanization that occurred throughout the simulation period, which increases paved surfaces and thereby decreasing percolation, and further allow more movement of water on the surface.

Additionally we explored the spatial distribution of the fluxes by estimating the differences between the total annual fluxes between the two cases. From the figure, it can be seen that the spatial difference in the total annual direct runoff between the two scenarios ranges between -706mm and 894mm, despite the small difference in the total annual direct runoff. The change in actual evapotranspiration ranges between -23.89mm and 19.65mm, while change in recharge ranges between -14.20mm and 8.66mm and the change in base flow ranges between -14.36mm and 8.56mm.The presentation of spatial maps of outputs attributed to physically distributed hydrologic models is one of the advantages of the model. This in reality helps to identify region in the basin with anomalous and significant processes that affects the whole basin and upon which attention can be focused.

Considering the difference in annual discharge simulated between case 1 and case 2. The maximum annual change in discharge was approximately 8.79m3/s in 2011 and minimum change of about 0.17m3/s in 2006. The mean annual change in discharge was 2.53m3/s with 9 years above the average and the rest 14 years below this average. A sudden increase in the difference was seen between 2001 and 2003, followed by a sharp drop until it reached its minimum in 2006. Afterwards, a steady rise and fall was observed from 2006 until the maximum difference was obtained in 2011.

CONCLUSIONS

The importance of total runoff (discharge) estimation in watersheds cannot be over-emphasized since it represents the portion of water that is available for use and upon which management is focused (Dingman, 2015). It should be made known that runoff in the context of this discussion also refers to the simulated discharge presented in the result section above, and these terms are used interchangeably to mean the water available for planning. Global rise in population is associated with increased urbanization and demand for more resources to meet necessary needs. The analysis of the selected land cover maps of the study area showed slight variation in the spatial extent of the land cover classes. These variations in land cover classes are responsible for changes in the hydrological fluxes observed in the simulations. Human interventions and some natural events that occur overtime influence hillslope, channel processes, and affect the hydrological processes in basins.

Based on the reference land maps utilized to study land cover dynamics in Karasu basin, it is obvious that the study area had experienced some land cover changes especially in the extent of urban, forest and agricultural areas. The nature of these dynamics are interconnected to most of the classes. The land cover maps confirmed the reduction of forest and agricultural areas and expansion of urbanized areas, although not huge due to insignificant anthropogenic disturbance in the basin. It was observed from this study that increase in extent of impervious surfaces caused by expansion of urban areas and reduction in forest areas could be responsible for decrease in evapotranspiration, base flow and recharge in the basin while the discharge simulated increases. The result of this study provides useful information for planning and development department, disaster management authorities, city government, policymakers, and other stakeholders involved in the sustainable management of water resources in Karasu basin.

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Surface transport and distribution of trace metals through the Strait of Gibraltar

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ABSTRACT
Trace metals can either act as an essential element for the development of life or as a toxic inhibitor. This study was carried out to find out whether these metals, pollutants or not, can reach areas of great ecosystemic value within the Gulf of Cadiz and the Alboran Sea. For this purpose, the factors that influence their temporal variability and spatial distribution were addressed. Trace metals concentrations were sampled at the sea surface during the campaigns STOCA, MEGAN and MEGOCA and were studied along with temperature and salinity. Results indicate that trace metals present an offshore and eastward gradient, and that they are conditioned by variations in the wind field and in the ocean surface circulation. In this way, intense and persistent easterly winds hamper the connection between the Gulf of Cadiz and the Alboran Sea, which in turn diminishes the trace metals concentrations in some places. However, under these same conditions, in other locations (e.g., Estepona upwelling, or near Djbouti Bank) trace metals can be retained by the presence of submesoscale structures, inducing their accumulation or removal by phytoplanktonic organisms, leading in this case to an increase in primary production.

KEYWORDS
Trace metals, contaminants, easterlies, biological activity, Gulf of Cadiz, Alboran Sea

INTRODUCTION
The main source of trace metals in the Gulf of Cadiz (GoC) is the discharge of the surrounding rivers: Tinto, Odiel, Guadalquivir and Guadiana (González-Ortegón et al., 2019). In particular, mining activities in the Iberian Pyrite Belt heavily contaminates these rivers (Nieto et al., 2006). Furthermore, near Guadalquivir, there is a marine dump where dredged material is deposited periodically, changing ecosystems permanently (Donázar-Aramendía et al., 2020). These metal concentrations produce a plume of contamination near the coast that extends southeastward towards the Strait of Gibraltar (SoG) (Elbaz-Poulichet et al., 2001). Thus, when the metal-enriched Spanish shelf water reaches the Atlantic inflow, can act a source of trace metals into the Alboran Sea (AS) (Boyle et al., 1985; van Geen et al., 1988; Laiz et al., 2020). Nevertheless, this connection through the SoG can be interrupted due to intense and persistent easterly winds (Bolado-Penagos et al., 2020), causing changes in the Atlantic flow, altering the surface circulation of the AS (Bolado-Penagos et al., 2021), and affecting high productivity areas such the Estepona upwelling (Sarhan et al., 2000). In this way, the hypothesis of this work is as follows: the processes controlling the distribution of trace metals through the SoG are associated with the direction and intensity of surface currents and zonal winds, as well as with biological activity, and their knowledge is fundamental to manage the coastal and industrial anthropogenic impacts.

MATERIALS AND METHODS
The area of study includes the easter part of the GoC, the SoG and the western AS (Figure 1). In these places, wind speed and surface currents velocity were used to study the surface circu-

lation variations related to atmospheric forcing. The surface current velocity data were retrieved from the High-Frequency Radar antennas system installed on the SoG coastal margin, as well as from the SAMPA model, both data are available at OpenDAP system from Puertos del Estado. In addition, wind data (at 10 m height) was obtained from the ERA5 meteorological reanalysis (https://www.ecmwf.int/) for the study area; finally, daily images of chlorophyll-a concentration (OCEANCOLOUR_ ATL_CHL_L4_NRT _ OBSERVATIONS_009_037) were downloaded from Copernicus Marine Service (https://marine.copernicus.eu/) and match with the dates of the in-situ campaigns. The in-situ data (trace metals and CTD profiles) were acquired as part of the STOCA (in the GoC - Figure 1a), MEGAN and MEGOCA (in the SoG and AS - Figure 1b) campaigns carried out between September and October 2015. Trace metals (Table 1) were acquired at 5 m depth, under ultra-clean conditions described in more detail in Tovar-Sánchez (2012).

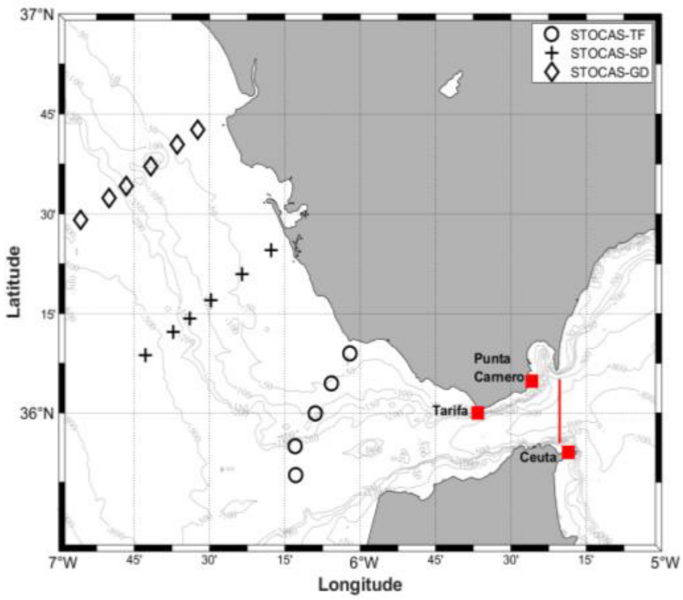
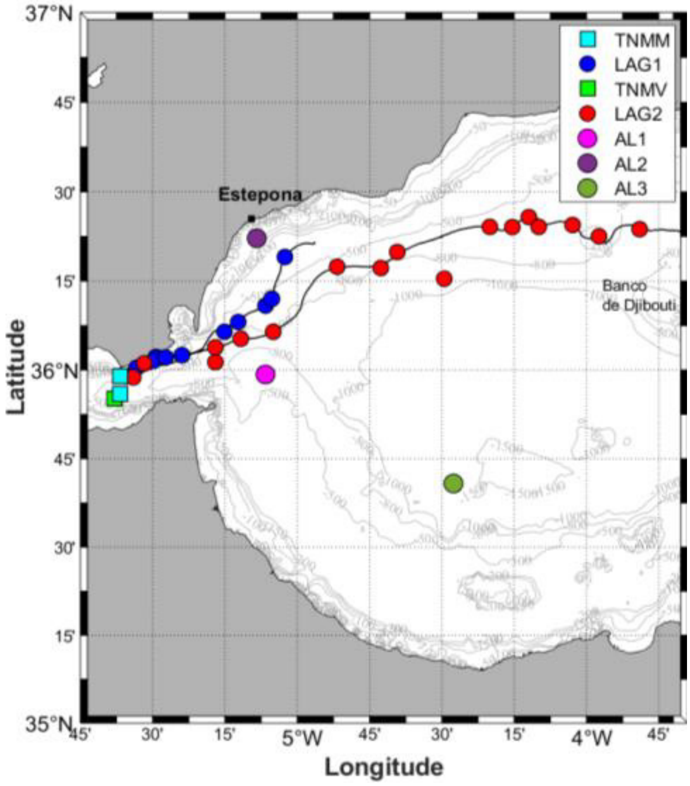


Figure 1. (a) Sampling points Guadalquivir, Sancti Petri, Trafalgar (GD, SP, TF, respectively) (STOCA campaign), and High Frequency radar antennas' (red squares) location.

(b) Sampling points in different phases: Lagrangian neap and spring tide (LAG1, LAG2, respectively), Alboran cycles (AL1, AL2, AL3) and Tarifa Narrow neap and spring tide (TNMM, TNMV) during MEGOCA and MEGAN campaigns.



RESULTS AND DISCUSSION

In the GoC, trace metals concentrations present a coastal and longitudinal eastward gradient: i.e., the highest values are obtained in the coastal points of the GD transect (Table 1) and decreased towards the TF transect, as shown in Figure 2 for Fe. These higher concentrations found in GD belong to the Spanish shelf water (Figure 3). On the other hand, high concentrations obtained in the AS coastal locations (Table 1), are related to changes in mesoscale structures (Renault et al., 2012) and submesoscale structures linked to the atmospheric forcing (Bolado-Penagos et al., 2021), which act as retention areas, thus facilitating the accumulation of metals. In addition, the lack of biological activity in AL2, due to the displacement of the Estepona upwelling (Sarhan et al., 2000) and to non-optimal conditions for photosynthesis (Bartual et al., 2020), show that the metals' distribution is controlled by advection. However, in the open ocean, these retention areas allow for water fertilization, phytoplankton growth (Bartual et al., 2020; Bolado-Penagos et al., 2021) and a subsequent decrease in the surface metal concentration, as is the case of LAG2 central points (Figure 2). Nevertheless, other areas of the AS, which are oligotrophic, such as AL3, do not show such an increase in surface chlorophyll-a despite having intermediate Fe concentrations (Figure 2). Finally, the lowest concentrations in the Atlantic flow samples (TN and AL1) are associated with Surface Atlantic Water (SAW), characteristic of stations located offshore and with a low concentration of metals (Laiz et al., 2020).

Table 1. Maximum and minimum values for the whole survey

	MAX	MIN
Fe (nM)	AL2 = 60.12	SP = 0.64
Co (nM)	GD = 0.75	TNMV = 0.04
Cu (nM)	GD = 16.81	AL1 = 1.73
Cd (nM)	GD = 0.35	LAG2 = 0.12
Mo (nM)	TNMV = 122.05	AL2 = 102.11
Ni (nM)	AL2 = 4.13	TF = 2.26
Pb (nM)	TF = 0.67	AL1 = 0.02
Zn (nM)	GD = 26.51	TNMV = 0.00

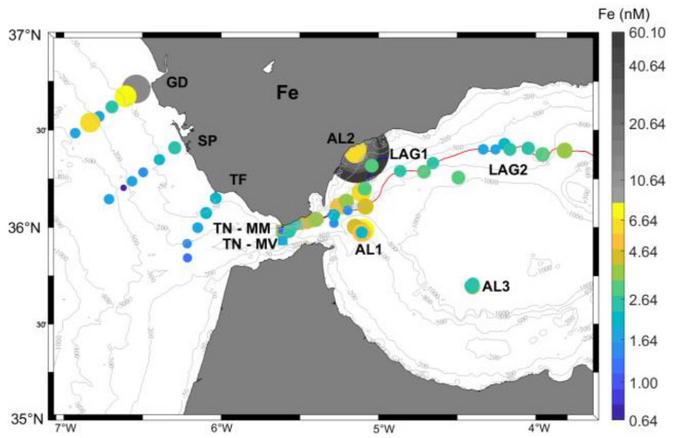


Figure 2. Concentrations of Fe (nM) for the whole survey.

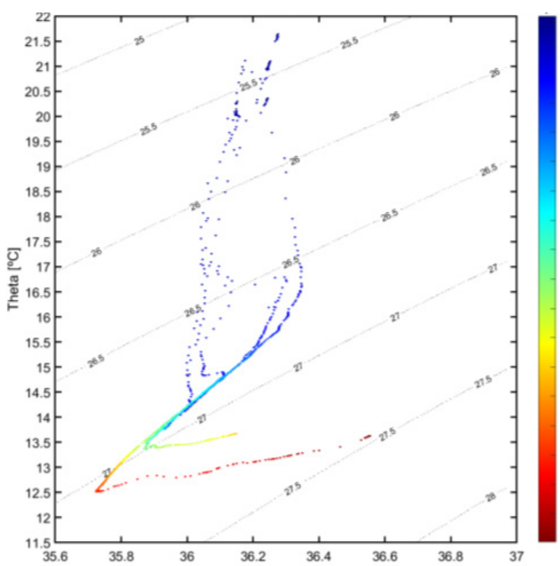


Figure 3. Temperature-Salinity diagram in GD transect.

CONCLUSIONS

Regardless of the origin of these metals, their transport depends on factors such as the intensity and direction of wind and surface currents, as well as the presence of meso- and submesoscale structures and the biological activity associated with them. Advection and processes related with atmospheric forcing would favor the retention of metals in areas where the water mass residence time is longer. Therefore, biological activity will control the accumulation or consumption of these metals. These phenomena will occur depending on the type of metal, the abundance of phytoplankton, and the conditions for photosynthesis. Thus, trace metals concentration between the GoC and the AS implies changes in the productivity, especially in coastal areas where concentrations of these metals are greater than offshore.

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Assessing the sensitivity of seagrass landscaping as a nature-based solution in the coastal belt of Emilia Romagna

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ABSTRACT
Nature based solutions (NBS) have been proposed as a feasible and effective solution to protect the coastlines. NBS such as seagrasses have high capability to attenuate the waves, thereby achieving effective coastal protection. To evaluate the sensitivity of seagrass along the Emilia-Romagna Coastal belt we designed a combination of landscape design with wave modelling simulations. The WW3 model was modified by including the modified bottom dissipation stress due to submerged vegetation, thereby incorporating the NBS as a potential mechanism for wave amplitude reduction. The seagrass species 'Zostera marina' was chosen in this study and comparisons using different seagrass landscaping structures showed that seagrass is capable to reduce the wave energy in the study area. Most importantly, the study points out to the fact that the landscaping of the seagrass is an important aspect for achieving wave energy reduction at the coast apart from the vegetation characteristics.

KEYWORDS
NBS, seagrass, wave dissipation, zostera marina, landscaping, wave energy, wave attenuation.

INTRODUCTION
The Emilia-Romagna coastline is highly prone to storms and erosion (Armaroli & Duo, 2018; Armaroli et al., 2019) mainly due to its heavily urbanized coastal area and due its low-lying characteristics. In this context the seagrass can be considered as a highly potential naturebased solution, which has the capacity to mitigate the impact of storms and related coastal erosion. Over the past few decades, numerous field and laboratory studies have been performed to determine the effects of vegetation on wave attenuation (Maza et al., 2013; Ondiviela et al., 2014; James et al., 2021). As reported in Procaccini et al. (2003), Zostera Marina is present along the central Adriatic coasts, and it could really exist along the coast if the mean wave heights are less than 0.4m and a mean percentage of surface irradiance is greater than 33% (Hirst et al., 2017). The influence of seagrass landscaping in attenuating the wave energy at any coast is an important aspect to be considered in the modelling studies. The seagrass species 'Zostera marina' was chosen in this study and comparisons showed that this seagrass is capable to reduce the wave energy in the study area. The sensitivity of seagrass landscaping was evaluated with respect to different landscape designs along the Emilia-Romagna coasts.

MATERIALS AND METHODS
The study was conducted across the Emilia-Romagna costal belt and to simulate the waves the unstructured WW3 model was implemented. Validation of the model was carried out with an available wave station for 10 years and skill was shown to be very good (Umesh et al., 2021) An along-shore seagrass belt in the Bellocchio area was inserted first in WW3 as shown in Figure 1.

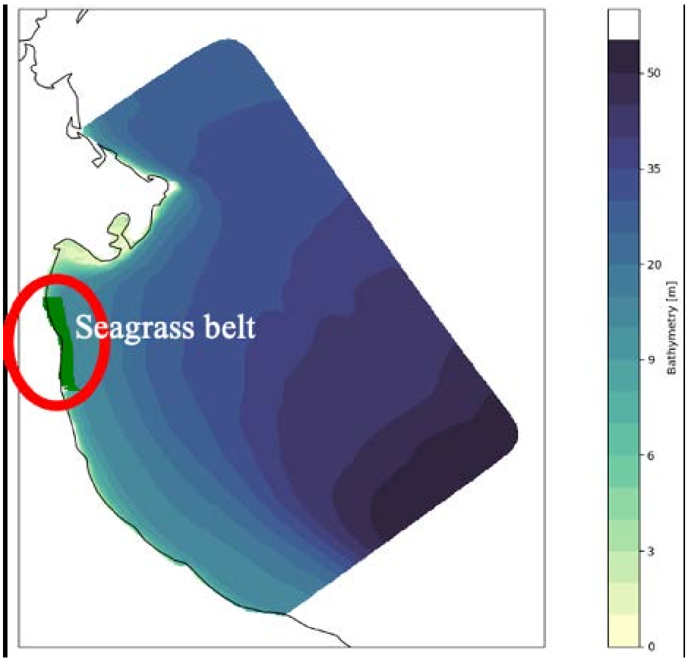

Figure 1. Bathymetry and seagrass belt position in the Bellocchio beach.

To include the NBS, the WW3 model was improved by incorporating the modified bottom dissipation stress due to submerged vegetation. For that, the SHOWEX (Ardhuin et al., 2003) bottom friction formulation in WW3 model (WW3DG, 2016) used in the present study was modified by incorporating the dissipation due to vegetation with the wave damping due to vegetation (Dalrymple et al. 1984, Mendez and Losada, 2004) term as adapted from the nearshore model SWAN.

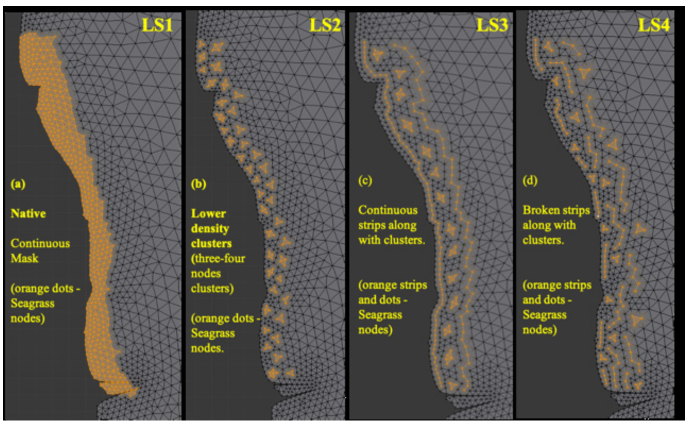

Figure 2. Seagrass (Maskveg) landscape designs for the Bellocchio beach.

The seagrass was incorporated with different landscape design across the coast (2-10m, as shown in Figure 2). The four different types of landscape (LS) designs implemented are:

• Native – continuous mask (denoted as LS1)
• Lower density clusters (three-four nodes clusters, denoted as LS2)
• Continuous strips along with clusters (denoted as LS3)
• Broken strips along with clusters (denoted as LS4).

The physical characteristics of the seagrass species used in the experiments were adopted from Mazzella et al. (1998) and they considered both Cymodocea Nodosa and Zostera Marina. LS1 experiments were attempted with both seagrass species but results showed that Zostera Marina produced larger wave amplitude reduction and all the other experiments were done with Zostera Marina only.

RESULTS AND DISCUSSION

Different combination of experiments were executed to test the sensitivity of the model to the different designs along with the two types of vegetation namely Cymodocea nodosa and Zostera marina. LS1 (Figure 2a) being the native uniform mask, to test the sensitivity of the design, at first a comparison of wave spectra with uniform distributions of Cymodocea Nodosa and Zostera Marina was made, which showed that Zostera Marina was more capable in producing greater reduction in energy along the coast. During January and March 2017, at Stations 1 and 2 (Figure 3), it is noted that the short period waves have completely dissipated for all the three seagrass landscapes (LS2, LS3 & LS4) with higher attenuations achieved with the broken strips along with clusters arrangement (LS4) as evident from Figure 3(d) at Station 2. The comparison of wave spectra points out the importance of the landscape design of seagrass in such studies to choose an ideal arrangement of vegetation at a coastal location.

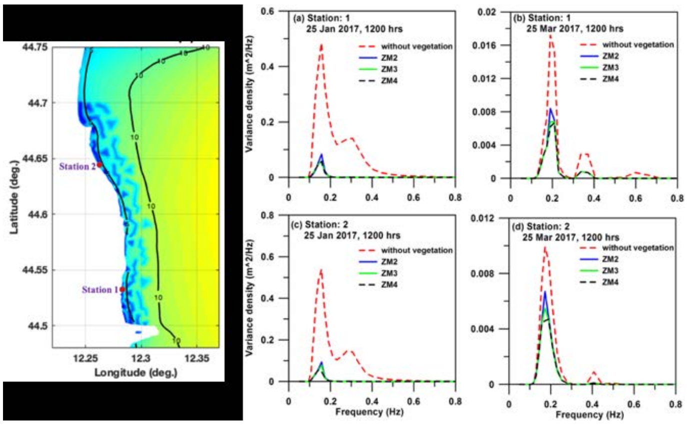

Figure 3. Comparison of wave spectra with different distributions of Zostera Marina (ZM) (January & March 2017). ZM2: ZM with LS2 design, ZM3: ZM with LS3 design, and ZM4: ZM with LS4 design.

Furthermore, the influence on high density and lowdensity vegetation scenarios, together with physical characteristics of seagrass (height and width of the seagrass) shows the sensitivity of the results thereby showing reduction of wave energy as obtained with different degrees by all NBS scenarios.

CONCLUSIONS

This study provided new insights into the applicability of seagrass as a potential mechanism in reduction of wave energy in any coastal area. A combination of broken vegetation stripes and clusters were seen to be effective in reduction of wave energy at the coast in comparison to other landscape designs. The wave height comparisons with and without vegetation showed a considerable reduction in vegetated wave heights. The Zostera Marina seagrass applied for the Emilia-Romagna coastal belt was found to be efficient in reduction of wave energy (> 50%). The limitation being that the experiments were done with rigid seagrass and in the future, we look for advanced parameterization using flexible seagrass.

AKNOWLEDGEMENTS

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The influence of coastal currents on the movement patterns of Argyrosomus regius (Asso, 1801) along the northern shelf of the Gulf of Cadiz

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ABSTRACT
Meagre Argyrosomus regius (Asso, 1801) is a large oceanodromous teleost fish. Despite being highly targeted by coastal fisheries, its movement patterns are still not fully understood. In this study, we implement an innovative approach to explore the relationship between meagre movement patterns and coastal currents. We combined movement data obtained with biotelemetry with ocean currents data gathered with Acoustic Doppler Current Profilers (ADCP) to infer the influence of ocean currents on the movement patterns of meagre. Movements were tested against alongshore coastal currents, near-bed temperature from ADCP and cross-shore movements related to unfiltered ADCP data. Fish detections were mainly concentrated from July to November, with few detections occurring during the winter and spring months. Our results suggest that meagre prefer to move westward with westward flows (WFs) during the summer and swim against equatorward flows during the spring. Yet, movements patterns were not associated with cross-shore currents. Movements were closely linked to temperature, which is governed by WFs during the upwelling season. These results provide a preliminary insight on the influence of coastal currents on the movement patterns of meagre, contributing better to understand the spatial ecology of this important species.

KEYWORDS
acoustic telemetry, alongshore currents, tagging, eastward flows, westward flows

INTRODUCTION
Meagre Argyrosomus regius (Asso, 1801) is a large oceanodromous teleost fish. Meagre populations are vulnerable to fishing pressure because they mature late, are long-lived, attain large sizes, form spawning aggregations and are highly-priced fish. Their coastal movements patterns are not well identified, and existing information is mostly based on the fisheries data. Water currents can have a significant effect on fish movement. Therefore, more reliable information on meagre migrations is essential and beneficial for fisheries management and conservation attempts. The study objective is to investigate if there is any relationship between meagre movements and ocean currents in the northern shelf of the Gulf of Cadiz (GoC).

MATERIALS AND METHODS
Acoustic Doppler Current Profiler (ADCP) data and acoustic telemetry data were collected on the northern shelf of the GoC from December 2018 to November 2020. ADCPs data were obtained from 5 deployments at 3 stations, and data were processed following the procedure described in Garel et al. (2016). Fish movements were inferred from acoustic telemetry. Twenty-eight passively captured meagre (at the tuna trap located offshore Fuseta - 37.017º N, -7.708º W) were tagged with Vemco V16 acoustic transmitters and an array of Vemco VR2W acoustic receivers deployed throughout the Algarve coast was used to monitor their presence. The time difference and distance between all consecutive detections was calculated. Meagre movements were analysed in relation to alongshore coastal currents, seasons, association with near-bed temperature from ADCP and cross-shore movements related to unfiltered ADCP data. Statistical analyses were carried

out to infer the relationship between fish movement patterns and coastal currents. Data handling and statistical analyses were carried out in MATLAB 2020b (MATLAB, 2020) and R 4.0.3 (R Core Team, 2020).

RESULTS AND DISCUSSION

The coastal currents observations from three ADCP moorings show bidirectional alongshore current pattern throughout the year. Alongshore currents are one order of magnitude larger than across-shore currents. Due to these frequent current direction changes, meagre movement cannot directly be related to seasonal currents patterns on the northern shelf of the GoC.

In the present study, acoustic detections were mainly concentrated from July to November, with very few detections occurring in the winter and spring months. This was probably due to fish being in deeper overwintering areas located far away from acoustic receivers, as showed by Bovim (2020). Meagres ecological niche limits meagres to the continental shelf, and thus their long-range movements are predominantly parallel to the shore. Previous studies on the migration patterns of meagre on the GoC were based on catch statistics (González-Quirós et al., 2011; Prista et al., 2013) and otolith composition (Morales-Nin et al., 2012) and support the results of the present study.

Meagre movements that took a short time (< 7 days) were associated with coastal currents data. Along-shore movements of meagre show a significant relationship ($p < 0.001$) between meagre movement direction and season. In the summer and spring seasons, meagres swim westward than eastward. The season does not seem to play a role in whether meagre swim against or with the currents. During the summer and spring seasons, meagre movements are mainly associated with westward flows (WFs), whereas in Autumn and Winter seasons, meagre movements are mainly associated with eastward flows(EFs). However, it should be noted that this result was obtained from limited observations (37 movements) and should be confirmed by more observations.

Wilcoxon test results showed a significant difference ($p < 0.001$) between meagre movement direction and the temperature. Meagre movements were associated with high mean temperatures of WFs compared to the EFs, and westward movements were associated with higher temperatures than eastward movements. However, the temperature trend has no significant difference ($p=0.221$) between fish movements direction. During summer, WFs bring warm waters, and EFs brings upwelled cold water (Garel et al., 2016). However, WFs are not associated with warmer water in winter. Meagres were observed to migrate to deep areas, usually warmer than shallow shelf areas, during the winter and spring months (Bovim, 2020), thus explaining the limited number of detections during the winter and early spring. When the upwelling season (May-October) is resumed, WFs increases the temperature by bringing warm and faster flows to the shelf. The degree of temperature variation (ΔT) may influence meagres preference of temperature. According to observations, meagre movements associated with WFs had hightemperature variation compared to the EFs. Bovim (2020) showed that most of the time, meagres stayed in temperatures between 14°C – 16.9°C, which is closer to their lower limit (13°C). The northern shelf of the GoC has lower water temperatures due to coastal upwellings (García-Lafuente et al., 2006), and meagre may not be able to move within their preferred temperature range. As WFs are associated with higher temperature variation, meagre may change swimming direction and follow the warm mass.

Cross-shore movements of meagre were not associated with weak across-shore currents suggesting that tides do not influence inshore/offshore movements. Given the limited data available, these results should be considered preliminary and interpreted with caution. The acoustic receiver network was mainly limited to nearshore shallow water areas, preventing meagre detection in deeper waters. Multiple receivers in APPA and Sagres TEL acted as gates, but other stations had only one receiver. ADCP data had data gaps, and most of the time, data were available from a single station resulted in that assumption of the homogenous current direction in the GoC. Future studies could benefit from an enlarged array of acoustic receivers, particularly in deeper areas of the shelf. Coastal current monitoring can be improved by simultaneously deploying ADCPs in the western and eastern shelves of the northern shelf of the GoC.

CONCLUSIONS

In this study, we implemented an innovative approach to explore the relationship between meagre movement patterns and coastal currents on the northern shelf of the GoC using biotelemetry and ADCP data. Although preliminary, our results suggest that meagre prefer to move westward with WFs during summer and swim against EFs during spring. Moreover, current inversion and temperature variation associated with coastal currents significantly influenced their movement direction. Meagre movements patterns are closely linked to temperature, which is governed by WFs during the upwelling season. Meagre cross-shore movements were not associated with weak across-shore currents. With the continuation of biotelemetric and ADCPs data collection, future studies should aim to further improve the knowledge on the influence of coastal currents associated with meagre movement patterns.

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Intertidal Topography Mapping Using the Waterline Method from Sentinel -2 Images of Inner Bay of Cadiz

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ABSTRACT
Intertidal bay is characterized with dynamic behavior and supports a complex mixture of highly productive and biodiverse habitats. Being an intertidal Bay, the inner Bay of Cadiz always experiences vulnerable and dynamic coastal ecosystems. Thus, it demands recurring observations. It is often challenging in terms of cost and time constraints to do continuous monitoring and mapping of the inaccessible large scale intertidal flats. Therefore, topography mapping generated from remote sensed imageries is logistically and financially sound over conventional ground-based surveying. The main objective of this study is generating intertidal topography map of the Inner Bay of Cadiz. To produce the map, an improved waterline method is applied using Sentinel 2 images, from the year 2015 to 2020. The best fit filter with adjacent perimeter is calculated and performed to extract the waterline. Besides, to measure the accuracy of edge detection method in all tidal conditions, three transect lines are drawn in upper, lower and middle basin. Average distance between the observed and calculated waterline is calculated for those transects and the values are 4.3m, 2.2m and 1.9m respectively. This research findings can be applied to estimate intertidal morphological changes and might be suitable to investigate the mechanisms of water and sediment interexchange.

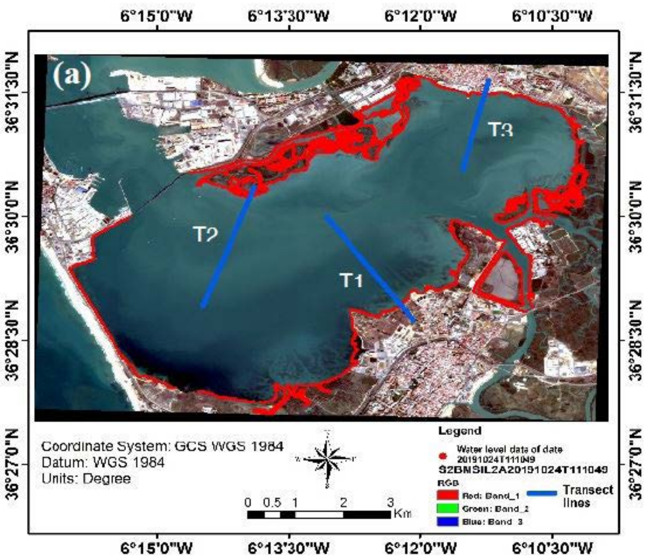
KEYWORDS
intertidal flats, topography, dem, waterline method, sentinel 2 images.

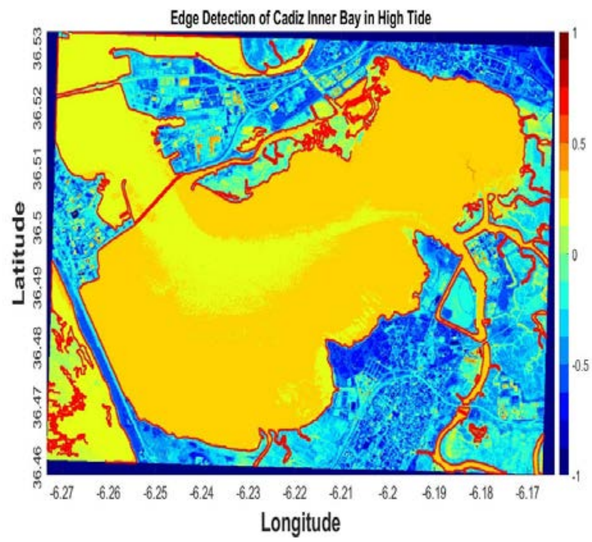
INTRODUCTION
Intertidal flats are considered as interim ecosystems linking both marine and terrestrial areas and pose a significant contribution to ecosystem function and land resource potential. Due to the constant domination of the tidal processes, these dynamic coastal ecosystems possess a complex mixture of highly productive and biodiverse habitats, ranging from extensive tidal mudflats, sandy beaches, fringing coral reefs, steep rocky cliffs (Bishop-Taylor et al., 2019) to a large community of migratory shorebirds (Granadeiro et al., 2007; Kober & Bairlein, 2009; Luijendijk et al., 2018). However, human interceding such as settlements, establishment of the port and various infrastructures, coastal development, land reclamation, dredging, upstream dams, changes in river sediment balances, along with sea level rise and coastal erosion due to climate change, put these regions among the world's most vulnerable and threatened ecosystems (Bishop-Taylor et al., 2019). Lately, Murray et al., (2019) revealed that global intertidal flats have been decreased by 16% between the year 1984 and 2016. Hence, changes in tidal flats can be a major a major indicator to track and monitor environmental changes and sea level rise (Chen & Chang, 2009; Xu et al., 2016a) which requires a recurring feasible observing process in terms of cost.
Developing intertidal topography maps using remote sensing technology can be an affordable approach to overcome this kind of constraints. Based on remote sensing data, many studies (Li et al., 2014; Mason et al., 2010; Ryu et al., 2008; Xu et al., 2016b) presently came up with the waterline method to be the most effective and

accepted approach for Digital Elevation Model (DEM) generation of intertidal flats. The present study aims at generating intertidal DEM of the inner bay of Cadiz, considering the tidal variation using the waterline method from Sentinel-2 images and to find the best fit edge detecting filter to extract the waterlines.

MATERIALS AND METHODS

The study area covers the shallow inner bay of Cadiz which is a highly diversified tidal dominating bay (Fig.1). The waterline method can be divided into the following four steps. a) Detecting the waterlines in a time series of several remote sensing images, showing different water levels: Automated Water Extraction Index (AWEIsh) is used to extract the waterlines. The processing scheme is as follows: Sentinel 2 MSI Level 2A/2B> Read> Resample> Subset> Reproject> BandMaths (AWEIsh Computation)> write. This process was done using ‘Graph Processing Tool, graph builder’ in SNAP software. Later, those AWEI images was binarized using ‘Otshu method’ (Otsu, 1979) using MATLAB. b) Estimating the geographical position of each point in each waterline of the binarized AWEI images. The MATLAB function ‘pixcenters’ is used extract the geographical information.
c) Combining this values with water level information retrieved from the tidal gauge data for each point of each waterline at the time-date of the Satellite image was MATLAB function ‘interp’.
d) Three different transect lines (T1, T2 and T3) (Fig.1) at three different points of the Inner Bay have been considered to examine the average distance between the observed and calculated waterline and to examine how concentrated the data is around the line of best fit between two data sets; e) finally, interpolating the resulting grid of contour lines to a DEM mapping. The DEM point clouds were then interpolated using the cubic interpolation method in MATLAB. Two different types of data were used in this study: Satellite images, in total 65 cloud free Sentinel-2 multi-spectral instrument (MSI) level2A and 2B images from the year 2015 to 2020 were used to extract the waterlines and tide gauge data was used to determine the height (elevation) of the extracted waterlines. Those images were preprocessed to make unified datasets of same spatial resolution of 10 m and rectified to the world geodetic survey 1984 (WGS84) datum using SNAP software.





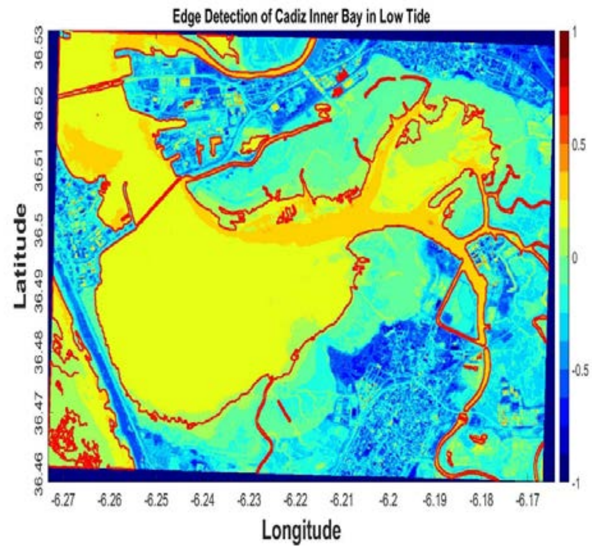


Fig 1 Study Area. (a) Edge detection process using Sentinel-2 images showing three transects.
(b) Edge detection in Inner Bay of Cadiz in High tide (c) Edge detection in Inner Bay of Cadiz in Low tide.

RESULTS AND DISCUSSION

As shown in Fig. 1, the waterlines are extracted from Sentinel 2 images after the edge detection. In general, the Sentinel-2 derived topographic data agree well with in situ measurement along the three transects (T1, T2 and T3) lines those were drawn at three different points of the Inner Bay. The average distance is calculated over each of these three transects and the values of which executed. To assign the water-level to each point of the waterlines linear interpolation was performed using the are 6.6m, 4.7m and 4.4m, respectively. Using the tidal data, water level that corresponds to the date of the satellite images are calculated (Fig. 2) and it shows an obvious uneven spatial distribution of the instantaneous water level field. This indicates that the waterline method based on Sentinel-2 images can be used for topographic mapping of large-scale tidal flats such as the Inner Bay of Cadiz. Finally, the assembled waterlines (DEM point clouds) were interpolated, using the cubic interpolation techniques to generate intertidal DEM of Inner Bay of Cadiz (Fig 3). A potential problem with the waterline method is that it assumes that temporal changes of the tidal flats are very small and slow (Zhao et al., 2008). In this study area, the average distance of the three transects is approx. 0.3 pixels, that refers to the gentle topography of the intertidal zone (Liu et al., 2013). Therefore, the topography of the tidal flats of this area may change quickly in a short period. In this study, noisy (nonwatery pixels that corresponds to other surrounding small objects) images and images with similar sea level were removed manually. Nonetheless, in future studies these two features should be further addressed, especially to determine the optimal required number of waterlines (that may depend on a prior knowledge of the intertidal slope) and lastly to define more adequate criteria for images selection (for limiting the redundancy).

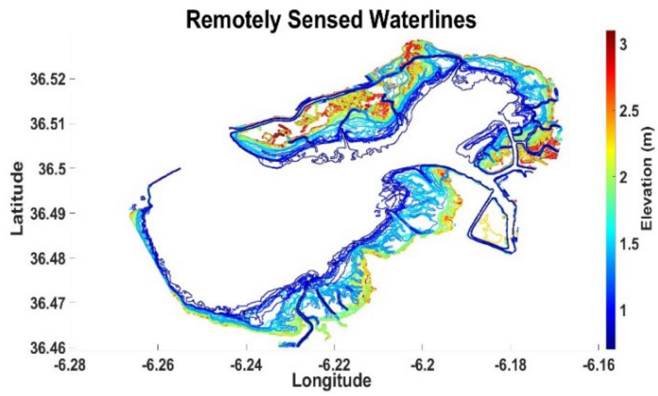


Fig 2 Remotely sensed waterlines with assigned water level of the corresponding satellite images

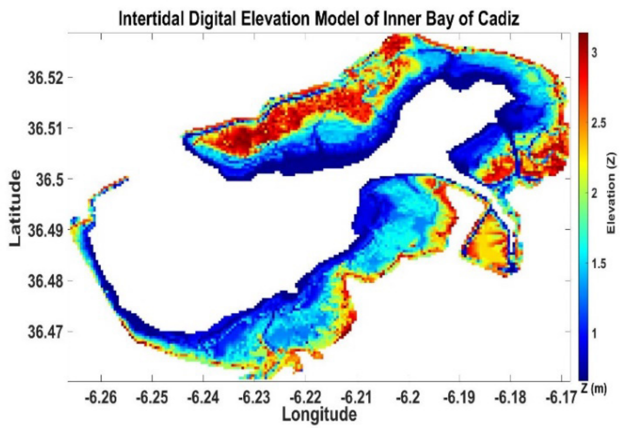


Fig 3 Illustration of generated Intertidal Digital Elevation Model (DEM) of the Study area

CONCLUSIONS

This study presents a first attempt for intertidal DEM generation of inner bay of Cadiz, using the waterline method by analyzing Sentinel-2 images. Comparing to the previous studies, a major alternation is done to the waterline method in the edge detection process. Here, the best fit filter is used to detect the waterline, but the postprocessing of extracted waterlines is done manually. Salameh (2020) suggested a solution for this by adding the combination of k-means segmentation and active contouring, in order to get an accurate and faster automatic post-processing of waterlines. The findings of this study may further be used to derive any type of geographic planning or large-scale architectural planning in this basin. Moreover, this model can also be used to delineate topography mapping of tidally-influenced coastal environments globally in broader aspects and can also answer to the exact rate of sea level rise adjusted by sediment driven seabed elevation. In future, validation along with accuracy assessment of the generated DEM can broaden up the scope of the application of this research findings to address the potential coastal risks and ecological habitat mapping in coastal areas.

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Nature based solutions to contrast coastal erosion and flooding: numerical modeling application

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ABSTRACT

Recently, the use of nature to combat loss of biodiversity and climate change has grown significantly. Nature based solutions (NBSs) appear as an innovative approach that is the focus of the OPEn-air laboratories for Nature based solutions to Manage environmental risks (OPERANDUM) project financed by the European Union's Horizon 2020 research and innovation programme. Here, the application of two different NBSs to mitigate coastal flooding and erosion in Bellocchio Beach (Lido di Dante, Emilia-Romagna Region, Italy) are presented. The first one consists of an artificial sand dune reinforced with a natural, biodegradable structure (NBS1) while the second involves seagrass fields slightly offshore (NBS2). Through numerical simulations and an innovative multi-model and multiscale modelling system the impacts on the coast are investigated. In the framework of climate change, present conditions and future scenarios are simulated with the morphodynamic model XBeach to test the reliability of the implemented NBSs first separately and then combined. Incipient results indicate no further improvement in reducing beach erosion when the artificial dune was combined with the seagrass fields relative to when the seagrass alone was used. As an upcoming step, the combination will be further investigated under more extreme conditions.

KEYWORDS

Nature based solutions, XBeach, coastal modelling, mitigation measures, long-term scenario, present, future.

INTRODUCTION

Nature based solutions (NBSs) address key societal challenges through the protection, sustainable management and restoration of both natural and modified ecosystems. Recently, the use of this innovative approach increased significantly with local and regional projects currently undergoing to evaluate distinct NBSs. Among them, the European funded OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks (OPERANDUM) project focuses on coastal-related measures.

Thus, the present work intends to evaluate the implementation of two different NBSs designed to mitigate the impacts of storm surges and coastal erosion.

The study area is the Bellocchio beach located in the Emilia-Romagna region (Northeast of the Italic peninsula facing the Adriatic Sea).

The first NBS (NBS1 in the OAL-Italy) consists of an artificial sand dune reinforced with a structure of natural, biodegradable material. It is designed in front of a vegetated residual natural dune while the second NBS (NBS4 in the OAL-Italy) consists of benthic seagrass fields just offshore. Both implementations intend to decrease/cease local erosion and hidering flood phenomena. The OPERANDUM Project aimed to realize the artificial dune at the Bellocchio beach. However, the severe damages caused by a heavy storm occurred in november 2020 lead to the impossibility of building the dune on the beach. It was therefore necessary to define a new site for the real implementation of the experiment, not mentioned in this paper. Contrariwise, the second NBS (seagrass) has been only modellized.

STUDY AREA

As previously mentioned, the study area is located at Bellocchio Beach, Lido di Spina in the Emilia Romagna littoral. Coastal flooding and localized erosion are known to affect the region as a consequence of high waves and/or storm surges normally associated with Bora (northeast) or Sirocco (south-east) winds.

A sediment deficit is observed in the region partially due to a low incoming supply coming from the Reno river. The dominant alongshore current is oriented northwards resulting in a net sediment transport directed to the same direction. (Aguzzi et al., 2016).

In the coastal stretch of Bellocchio, the grain size ranges from medium sand to silt moving seaward as mentioned in Aguzzi et al. (2016). Although its shape has been flattened, a residual natural dune is located on the beach.

MATERIALS AND METHODS

In order to appropriately evaluate the designed NBSs, a high space-time resolution is required. Hence, a multimodel strategy is developed with pertinent coupling between different numerical models. Initially, the hydrodynamic model SHYFEM (Umgiesser et al., 2004; Ferrarin et al. 2008; Bellafiore and Umgiesser, 2009) provide the sea-level taking into account the astronomical tides, atmospheric pressure and winds. Alongside, WAVEWATCH3 (Tolman 2009) is used to calculate the wind wave parameters. Finally, using the sea-level outputs from SHYFEM and the wave outputs from WAVEWATCH3, the morphodynamic model XBeach (Roelvink et al., 2009) is used to assess morphological changes in the coastal areas. The multi-model approach aims at evaluating the efficiency of the NBSs in protecting the coast from flooding and erosion under current (2010-2019) and future scenarios (2040-2049).

Since long-term morphological modeling needs considerable computational time, in order to avoid excessively long simulations and oversized output, a schematization of model inputs together with acceleration techniques is applied for both present and future 10 years scenarios. This methodology allows to simulate the morphological evolution over large periods (years) with less computational effort. For an in depth description of the method, please refer to Lesser (2009) and Walstra (2013).

XBeach is set-up via an automated succession of stationary (for mild conditions) and surfbeat (for more significant waves) simulations. These simulations constitute a 24 class representative wave climate. Moreover, a morphological acceleration factor (morfac) is set for each simulation being defined based on a fixed amount of hydrodynamic time per simulation (24 hours). Figure 1 depicts the model bathymetry used for long-term simulations.

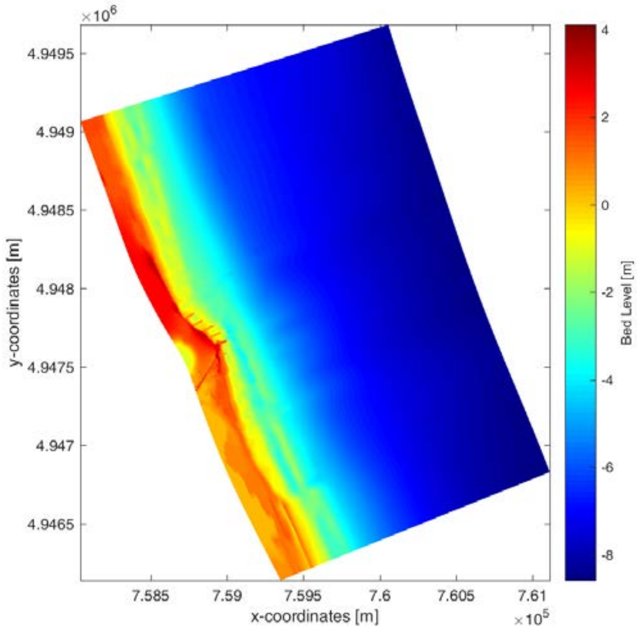

Figure 1. XBeach bathymetry

Both present and future runs of XBeach are based on the same initial bathymetry developed on the basis of topo-bathymetric surveys carried out in winter 2020. As mentioned above, waves and sea level inputs for XBeach are obtained from the present and future runs of the models WAVEWATCH3 and SHYFEM. For each scenario (present and future) four morphological simulations are performed; 1) baseline scenario (without NBS), 2) run with NBS1, 3) run with NBS2 and 4) run with the combination of NBS1 and NBS2.

Results of the long-term XBeach simulations are analyzed in terms of coastal erosion of the beach located around the artificial dune by means of volume calculations and maximum coastal flooding.

Volume analyses focus on the areas surrounding the planned artificial dune and is divided in two sections: in front of the dune towards the sea (frontNBS hereinafter) and behind the projected dune including the residual natural one (backNBS). The volume analyses refer to a common baseline (at the -2m quota) and involve comparing the initial and final bathymetries of the 10-yearly simulations.

RESULTS AND DISCUSSION

The results for current (2010-2019) and future scenarios (2040-2049) are presented here. Simulations without NBS for both scenarios are taken as the baseline run.

Present scenario

In the baseline run (2010-2019), a general decrease in beach elevation is observed for the entire coastal stretch with a special emphasis in the northern area where the artificial dune will be located. The general decrease in beach elevation is expressed by the formation of erosional escarpments similar to those currently observed in this area. The natural vegetated dune is only slightly affected by the flooding with a little loss of sediments. Additionally, the shoreline remains almost unchanged in front of the projected artificial dune while southwards a shift towards the sea is observed.

When the artificial dune is used in the simulations, it is possible to visualize a decrease of marine inland incursion implying on a reduced risk of flooding in the backNBS area. It is important to emphasize that the NBS1 executive project for the real world implementation includes an additional wooden filter protection for the frontal and lateral parts of the artificial dune. However, NBS1 is modelled as a hard-structure due to limitations in XBeach schematizations and results in a localized erosion around the north head of the projected dune. The aforementioned filter has been designed exactly to avoid the effects seen if a hard-structure is used.

A marked improvement is seen when the seagrass fields are implemented. The overall erosion is reduced to 1/3 with respect to the baseline scenario for the frontNBS area. No variation is observed within the backNBS area indicating that the natural vegetated dune is not affected by wave action and, therefore, by erosion. Furthermore, the results do not show significant improvements with combining the NBSs when compared to the implementation of seagrass alone.

Future scenario

Similarly to the baseline run for the current scenario, the baseline coastal run forced with waves and sea levels predicted for the period 2040-2049 shows that the whole coastal stretch is affected by an evident decrease in beach elevation resulting in the formation of an erosional slope and a tendency to shift the shoreline seaward. However, because of an average rise of about 0.30 m in forecasted sea levels with respect to present conditions, the impacts are more intense for the 2040-2049 scenario. In this case, the effectiveness of the artificial dune in protecting the territory behind is more evident.

The main benefit offered by the artificial dune is a net eroded volume reduction of about 24% with respect to the baseline run. As expected, the seagrass buffer effect on waves causes an effective mitigation of erosion in the backNBS area of approximately 93%.

Finally, as for the current scenario results, no further improvements in reducing the erosion of the vegetated natural dune are produced by the combination of the 2 NBSs compared to the simulation with the seagrass fields alone. The greater effect in terms of runup decrease can be associated with the seagrass implementation.

CONCLUSIONS

The reduction in wave intensity obtained with the seagrass alone scenarios provides greater benefits in terms of erosion mitigation and flood reduction. In general, the higher the attenuation of the incoming wave conditions, the lower the pressures on the beach.

The NBSs efficiency in contrasting coastal flooding and erosion is more evident in the future scenario as a consequence of higher sea levels. As expected, the artificial dune tends to hinder the most intense marine flooding events.

In a general way, no further improvements are demonstrated by the combination of the 2 solutions. However, It must be considered that long-term morphological modelling requires an input schematization which excludes single storm events. On that account, further investigation on the effectiveness of the NBSs combination under intense storms will be performed.

ACKNOWLEDGEMENTS

This work is performed in the context of the OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risks (OPERANDUM) EU H2020 project. This project "OPERANDUM" has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776848.

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Uncertainty in coastal prediction: application of the ensemble technique to coastal modelling

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ABSTRACT
The multi-model approach, integrating meteorological, oceanographic and coastal processes, is typically adopted to provide warnings of coastal flooding. Recently, an increased use of ensemble approaches have been observed as they allow for quantifying uncertainties associated with numerical forecasting which is not possible with deterministic schemes. This paper presents an integrated "Cloud-to-Coast" ensemble modeling framework made-up of a cascade of models reproducing the complex interactions among wind, waves and transport processes. Such modelling framework consists of the Emilia-Romagna Early Warning System (EWS), operational at the Hydro-Meteo-Climate Service of the Regional Agency for Prevention, Environment and Energy of Emilia-Romagna Region (Arpae-SIMC). The aim of the study is to investigate the propagation of uncertainties in the reproduction of a sea storm by generating an ensemble of different meteorological scenarios. The ensemble approach is then extended to the morphological model

KEYWORDS
forecast uncertainties, ensemble forecasting, coastal modelling, XBeach, storm events.

INTRODUCTION
Coastal Early Warning Systems are essential to mitigate the impacts of sea storms on people and properties from coastal flooding, allowing for effective emergency plans.

Despite the extensive developments in all the branches of numerical modeling and forecasting the prediction of coastal flooding is affected by large uncertainties (Baart et al. 2011; Zou, 2009). The pure deterministic approach adopted in numerical forecasting is not able to associate by itself a level of uncertainty to the forecasts. For this reason the ensemble approach is being increasingly used in weather forecasting (Park et al.,2008).

The present work investigates the propagation of uncertainties along a forecasting chain that comprises weather, oceanographic and coastal models through the ensemble approach, focusing on their influence on the assessment of coastal vulnerability.

The analysis of both meteorological and morphological modeling uncertainties on coastal vulnerability assessment was carried on through a preliminary study of 2 test cases of sea-storms that occurred in the autumn-winter 2015-2016. Uncertainties were introduced in the modelling chain in the meteorological fields and as an innovative step in the morphological inputs (bathymetry).

MATERIALS AND METHODS
The modelling framework of the EWS for coastal storm hazard operational at the Arpae-SIMC was followed. It consists of a cascade of meteorological, oceanographic and coastal models and provides a forecast up to 72 hours ahead of sea level along the entire coastal region.

The ensemble approach was applied to the coastal modeling chain in order to reproduce two storms occurred in Autumn-Winter 2015-2016. The two events covered respectively the periods

20-24 November 2015 and 27 February- 2 March 2016.

16 different weather scenarios were propagated towards the coast using the meteorological Limited Area Ensemble Prediction System COSMO-LEPS (Marsigli et al. 2001, Montani et al. 2011) aiming on studying meteorological uncertainties. Moreover, the ensemble technique was also applied to the morphological forecast by re-run the coastal model XBeach (Roelvink et al., 2009) along different topo-bathymetric beach profiles.

Overall, a meteorological (perturbations in the weather model) and a morphological ensemble system (perturbation in the coastal model) were developed and compared.

Forecasts of the meteorological model in terms of wind speed and mean sea level pressure were analyzed and compared with the observations. Moreover, waves parameters and sea levels were investigated at different stations.

Finally, the coastal impacts analyses focused on 3 significant coastal indicators: shoreline retreat, maximum runup and eroded volumes above the mean sea level for a coastal stretch located near the municipality of Cesenatico

(Emilia-Romagna, Italy). Ensemble metrics were based on ensemble mean and spread. Moreover, comparisons between the root-mean square error of the ensemble mean (RMSE) and the ensemble spread (SPRD) were performed. When the ensemble spread is lower than the RMSE, the ensemble system is "under-dispersed". On the other hand, for ensemble spread greater than the RMSE, the ensemble members are considered "over-dispersed" around the mean and the system is "unconfident". This index comparison gives an indication of the consistency of the ensemble forecasts.

RESULTS AND DISCUSSION

In the first storm, 20-24 november 2015, an underestimation of the wave height and of the sea level peak is observed when the meteorological perturbations are propagated (Figure 1).

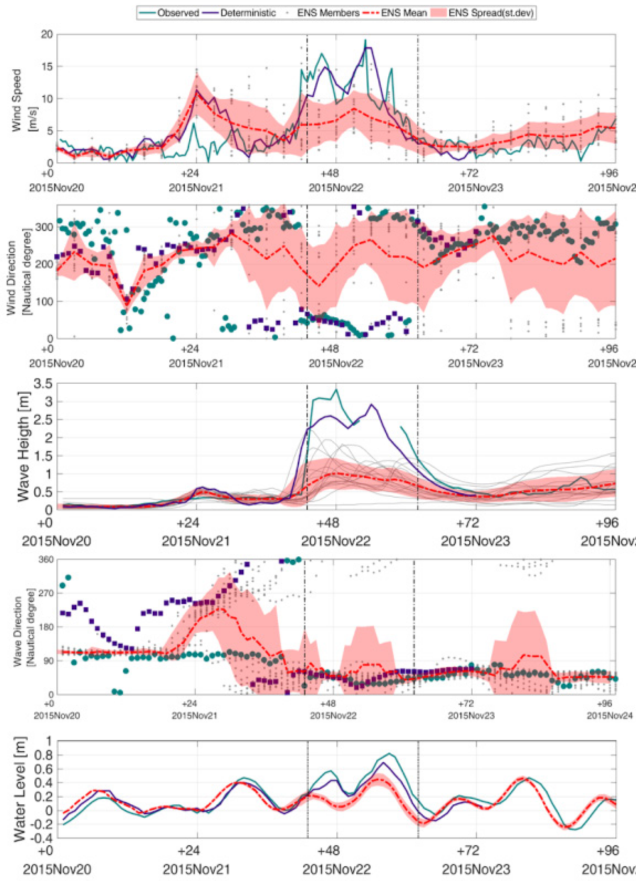

Figure 1. Observed and modeled variables for the period 20-24 November 2015, meteorological ensemble. Starting from the upper panel: 10 m wind speed, wind directions, wave height, wave direction and sea level. Green lines and dots: observations. Deterministic forecasts are depicted in purple, ensemble members in grey, ensemble mean in red and the filled pink area is the ensemble spread.

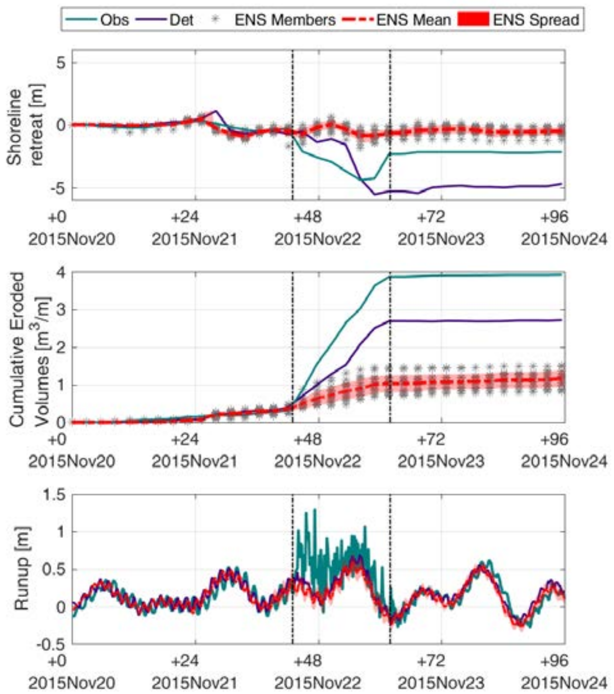

Figure 2. Observed and modeled coastal variables for the period 20-24 November 2015, meteorological ensemble. Starting from the upper panel: shoreline retreat, eroded volumes and runup.

However, during the peak of the event, the mismatch between the RMSE and the SPRD becomes evident in particular for the eroded volumes indicating that the ensemble system is under-dispersed.

When the morphological uncertainties are introduced in the bathymetry inputs, a marked divergence between the ensemble members starting from the peak of the event is observed (Figure 3). The highest SPRD obtained in shoreline retreat forecasting is 2.92 m, considerably higher than the value observed in the meteorological ensemble. For eroded volumes, a highest value of about 1.39 m3/m is forecasted. Moreover, in this case the SPRD is higher than the RMSE for all coastal variables indicating that the morphological ensemble system for the first storm is overdispersed.

For the second storm, 27 february-2 march 2016, the intensity of the wave height is better predicted by the meteorological ensemble fields leading to a good representation of the morphological variations. Due to spacing reasons, figures for the period 27 february-2 march 2016 are not displayed here.

For both erosion, shoreline retreat and runup, the SPRD tends to be in good agreement with the RMSE when uncertainties in meteorological files are introduced. Contrariwise, a remarkable deviation of more than 1m among the RMSE and the SPRD for shoreline retreat can be seen for the morphological ensemble system. Also in this case, the SPRD is higher than the RMSE meaning an overdispersed ensemble.

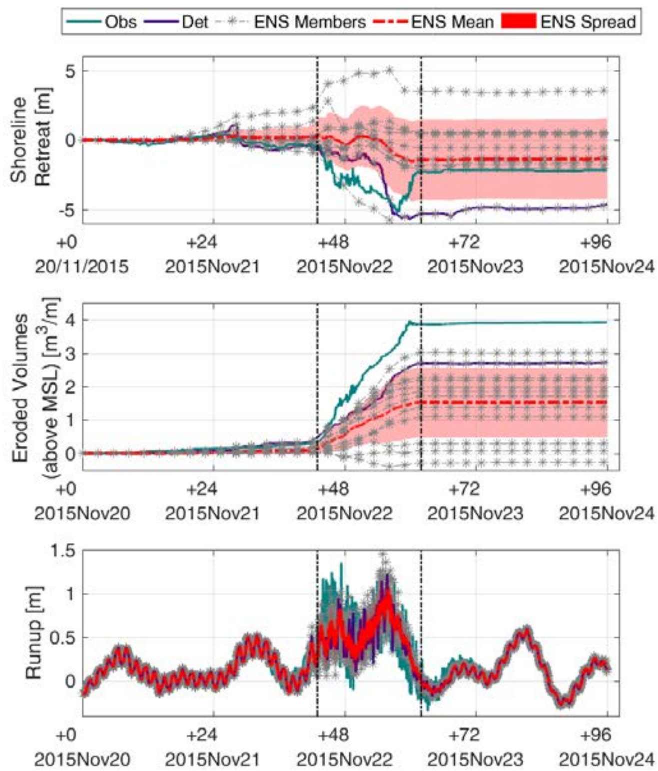

Figure 3. Observed and modeled coastal variables for the period 20-24 November 2015, morphological ensemble. Starting from the upper panel: shoreline retreat, eroded volumes and runup.

CONCLUSIONS

This study investigated the applicability of the ensemble technique to a multi-model chain composed of meteorological, oceanographic and coastal models. The analyses showed that the sources of uncertainty are associated to different inputs and can propagate in coastal impacts.

The ensemble approach allows better understanding of uncertainties associated with forecasts and can be easily extended to coastal forecasting.

The results show that uncertainty in weather fields is dominant for coastal forecasting but the uncertainty related to the input bathymetry can cause a large variability in coastal erosion, shoreline retreat and wave runup.

Coastal impacts in fact are more sensitive to beach bathymetry perturbations than to the meteorological one. For all the coastal variables, the ensemble spread produced by the morphological uncertainty is larger than the meteorological one. Moreover, the comparison between the RMSE and the SPRD highlights that the ensemble system with meteorological perturbations tends to be under dispersive while when the uncertainty related to the input bathymetry are included, the system is instead over dispersed.

The different nature of the investigated storms lead to different behaviours of the ensemble system, in both meteorological and morphological uncertainty investigation. It must be considered that each storm presents different features in terms of intensity, duration and winds. The ensemble performance depends on the storm's predictability. As expected, the spread of coastal output variables is strongly correlated to waves and sealevel variability (boundary conditions).

Results suggest the possibility to improve the forecasting system performance by introducing a morphological ensemble based on the input bathymetry.

ACKNOWLEDGEMENTS
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Saltmarsh fragmentation in a mesotidal estuary: implications for medium to long-term management

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ABSTRACT

Saltmarshes worldwide have suffered major losses in their extent and associated ecosystem services. The salt marshes of San Vicente de la Barquera estuary (N Spain) are a clear example of this, with a drastic reduction in their occupied surface over the last 60 years. In this study, regional and local factors have been studied to identify possible causes of salt marsh deterioration in order to develop appropriate management measures according to the evolution of the system. They have been studied in a spatial context by means of detailed maps of change in vegetation cover combined with topographic data. The results may support the evidences of salt marsh decline in this estuary. No clear pattern of vegetation loss/gain in relation to elevation has been identified. However, evidences have been found of physical stress within the salt marsh, which lead to the fragmentation of the habitat.

Despite the lack of sedimentary input to this area, which means that there is no effective adaptation to regional factors as SLR, based on literature it may be concluded that the human interventions during the 20th century diminished the resilience of the system. The study intends to demonstrate the importance of both natural and human forcing factors when describing salt marshes evolution for a proper development of management strategies.

KEYWORDS

Salt marshes, estuaries, eco-geomorphology, resilience, nature-based solutions.

INTRODUCTION

Salt marshes are low-land systems directly connected to coastal and river dynamics, depending on vegetation for stabilization. Salt marshes are especially relevant for their role in natural coastal defence (Ganju, 2019). Because of this, it is important to quantify long-term changes to understand the processes and timescales driving the evolution of the salt marshes in order to recover or to maintain the ecosystem services they provide. Besides natural processes, the changes derived from anthropic actions play a crucial role in the evolution of these systems, needing also to be monitored.

Recently, saltmarsh conservation and restoration are part of the philosophy of “nature based solution” for coastal management as these systems play an important role in reducing the impact of increasing coastal pressures causes (Bouma et al., 2016).

In the present work a study of the origin of the changes and decline/disappearance of salt marshes in San Vicente de la Barquera estuary has been carried out. The main objective is to identify the hypothesis that better explains San Vicente de la Barquera estuary evolution. Furthermore, possible spatial patterns related to feedback interactions between salt marshes and their abiotic environment will be also investigated.

MATERIALS AND METHODS

The study site is located in the Cantabrian coast, the North-Atlantic region of the Iberian Peninsula. The San Vicente de la Barquera (SVB) estuary includes wide tidal flats, favouring the development of salt marshes and mudflats. The SVB is a tide-dominated totally-mixed estuary (Flor-Blanco et al., 2015), located in a mesotidalsemidiurnal coast with a Mean Spring Tidal Range (MSTR) of 3.94 m. The sediment input in this estuary is low, with a limited river flow and the external coastal inputs conditioned by the configuration of the coast.

Regarding the specific ecosystem services that the salt marshes of SVB provide, they can be summarised in: resources supply (extractive fishing), cultural services (tourism and leisure activities) and regulation services (energy and morphosedimentary regulation and biological control).

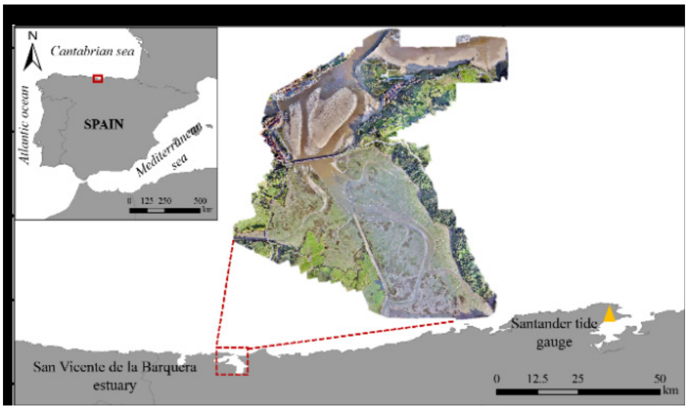

Figure 1. Location of San Vicente de la Barquera estuary (N Spain) and location of the Santander tide gauge (yellow triangle). An orthomosaic of the estuary is showed.

To cope with the main objective, data from a previous work (Aranda et al., 2020), namely 7 geomorphological diachronic maps of the salt marshes over the last 60 years (1956, 1988, 1997, 2003, 2010, 2014 and 2017) have been used as initial data. By overlapping consecutive geomorphological maps, six different maps of vegetation change have been developed. Different analysis of changes in the saltmarsh and tidal flats over the last 60 years together with a patch size distribution analysis over the study period have been carried out with data from the above-described data sources. Furthermore, the causes of change are going to be studied. For that, a sea level data series from the nearby Santander tide gauge from 1993 to 2018 has been used, together with a Digital Terrain Model (DTM) of the zone to identify variations on the inundation duration and exposure frequency in the tidal flat over the study period based on Balke et al. (2016) model. Lastly, as anthropogenic impacts may also have contributed to salt marsh evolution, scientific literature and technical reports of interventions made in this estuary have been reviewed.

RESULTS AND DISCUSSION

As a preliminary result, the spatio-temporal analysis of the SVB salt marshes reveals that the saltmarsh is switching into mudflats (Figure 2), as most of the surface occupied by salt marshes is lost in the last 60 years. When analysing the patch size distribution over the years to explain salt marshes evolution, a log-log relationship is expected to be found, which could explain the fragmentation of the system. Thus, the patch size distribution will confirm the signs of saltmarsh fragmentation.

On the other hand, the time series of the Santander tidal gauge (1993-2018) used to calculate changes in the duration of the inundation and the exposure frequency in the estuary, showed small changes over time. The complete time series reveals that there is an oscillation of the curves over time. In any case, the direct consequence of this change could be that the elevation necessary for vegetation to be exposed and settle up increases.

The combination of the change maps with the DTM of the zone helped to develop a map of exposure frequency in the tidal flats, which can be used as a proxy for a saltmarsh expansion probability map.

Finally, local factors seem to be more relevant in the deterioration of the salt marsh than the regional ones, based on bibliography. Both, drying processes since the middle of the 20th century and an ulterior recovery of the dried surface (Ho-

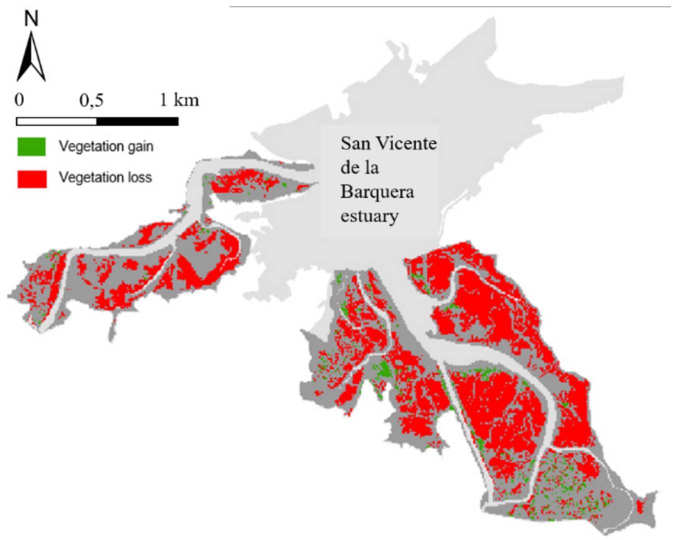

Figure 2. Preliminary map of vegetation gain and vegetation loss at the intertidal area of San Vicente de la Barquera estuary since 1956.

yos Cordero, 2018), lead to strong changes in the configuration of the saltmarsh, together with dredgings works for navigation repeated over time.

CONCLUSIONS

The applied methodology demonstrated to be very useful in the analysis of the eco-geomorphological evolution and the functioning of the salt marshes, providing information about the processes controlling saltmarsh development in the last years. Thus, the merging of sequential 2D information with topographic data allows to verify if the detected trend in the salt marshes will persist over time. On the other hand, the study of the interaction between biological and geomorphological processes on these systems demonstrates to be crucial when describing changes in a long temporal scale.

Besides, the origin of the fragmentation process is going to be assessed at regional and local scales. Local actions seem to be the most direct causes of change in the salt marsh, by modifying coastal and riverine dynamics and, therefore, diminishing the resilience of the system to future threats. All of them could have led to a current patched configuration of the saltmarsh that contribute to the stress of the system. Thus, although the data do not provide a definitive solution to the ultimate cause of degradation, they allow to discard some causes and to focus future efforts on others that seem to be the most influential. In this sense, results shown in the present work provide different tools to understand the mechanisms controlling salt marsh evolution, allowing to target management measures, so that the ecosystem services that these systems provide can be maintained.

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Impacts of coastal tourism in seagrass ecosystems and human wellbeing in the Bay of Cadiz (Spain, SW)

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ABSTRACT
Seagrasses are a unique group of flowering plants present in the Bay of Cadiz that provide multiple benefits to coastal inhabitants and tourism users, including provisioning services (food), regulatory services (erosion regulation, water purification, and waste treatment), and cultural services (relaxation and amusement). On the other hand, mass tourism has negatively impacted the Bay of Cadiz since the economic benefits generated have been obtained at the cost of the touristic destination's environmental and socio-cultural balance.

Consequently, a long-term study (2000-2020) was performed to know the trend in seagrasses meadows covering remote sensing images analysis to characterize the Z. noltei meadows extension trend. Moreover, several coastal tourism activities caused by coastal tourism, such as cruise tourism, beach tourism, and changes in population and use of land, were analyzed as pressures to the changes in the Z. noltei meadows.

The results showed a decrease in the Z. noltei meadows from 32.64 ha (in the year 2000) ha to 16.27 ha (in 2020). Therefore, we conclude that a loss in the Z. noltei area means a loss in the ecosystem services it provides and, thus, a worsening in human wellbeing for the Bay of Cadiz' population and coastal tourism itself.

KEYWORDS
DPSI(W)RM, coastal tourism, seagrasses, remote sensing, Bay of Cadiz

INTRODUCTION
More than 40% of the world's population lives within 100km of the coast, in cities with more than 100,000 residents (Barragán & de Andrés, 2015). The marine environment provides many economic activities like fishing, transportation, and tourism, among other activities. Because of the growth and development of coastal communities, the density of people and infrastructure have increased in highly ecologically sensitive areas causing the deterioration of the coastal and marine ecosystems (El-Naggar et al., 2021).

Tourism in Spain is an activity of vital economic and social importance. It is one of Spain's main economic activities, a driver of economic and social development. In 2017 it performed 11.8% of GDP and in 2018 sustained 13.5% of the employment, 2.6 million direct jobs (OECD, 2020).

Seagrasses are essential ecosystems with a high value due to their incredible diversity (Reynold et al.,2018). They constitute the base of the benthic communities' food web, an essential food source for megaherbivores, and provide shelter for many animals, including commercially and recreationally important fishery species (Ruiz et al., 2015). Moreover, seagrasses' photosynthetic activity sequestrates carbon dioxide from the atmosphere binding it as organic matter, and as a product of it, they oxygenate the water (Nordlund et al., 2016). They are responsible for 20% of the global carbon sequestration in marine sediments despite occupying 0.1% of the ocean surface (Duarte et al., 2013). Unfortunately, seagrass habitats have disappeared worldwide at a rate of 110 km2/year between 1980 and 2006 (Waycott et al., 2009), with an estimated 14% of seagrass species experiencing an elevated risk of extinction. Their most widespread threats are habitat disruption and fragmentation, eutrophication, climate change, water turbidity, pollutants, coastal development, and species introduced (Lillebø et al., 2011). On the other hand, Seagrass ecosystems provide multiple benefits to coastal inhabitants and tourism users, including provisioning services (food), regulatory services (erosion regulation, water purification, and waste treatment), and cultural services (relaxation and amusement). Thus, the maintenance and protection of seagrasses will conserve the water quality and other resource values that can attract tourism (Bujang et al., 2016). Nevertheless, tourism-related activities generate stress continuously and damage the fragile seagrass ecosystems, which are already impacted (Daby, 2003).

MATERIALS AND METHODS

The study was carried out in the Bay of Cadiz, a sub-region of Andalusia (Spain), located in the Iberian Peninsula southwest. The Bay of Cadiz is a shallow macrotidal and sheltered embayment of approximately 12,000 ha, composed of five important urban areas: Cádiz, San Fernando, Puerto Real, El Puerto de Santa María, and Chiclana de la Frontera. All these cities conform to one of the highest dense urban areas in Spain. It has 425,527 inhabitants, being Cadiz one of the cities with the highest population density of Andalusia: 116,027 inhabitants or 9,597.4 inhab./km2 (INE, 2019).

Coastal tourism activities (CTAs) generate a threat flow to seagrasses ecosystem services (SES), human wellbeing, and coastal tourism (CT) itself. The term threat can be regarded as the risk of ES reduction, partial or permanent loss of provision due to a single or multiple anthropogenic effects (Drius et al., 2019). In this study, threats include the ideas of pressure and impact conceptualized in the DPSI(W)R(M) (Driver - Pressure - State - Impact - Well Being - Response) framework. The DPSI(W)R(M) framework provides a cause-consequence connection between the anthropogenic activities and the environmental processes in a simple descriptive method, organizing the collected data. (Cooper, 2013; Elliott et al., 2017). Thus, all the DPSI(W)R(M) steps were followed, considering the information gathered from literature, official reports, and satellite data. In this study, CT was identified as the Driving forces and CTAs as past and present Pressures. The differences in seagrass coverage/NDVI from 2000 to 2020 was the State of change, considering the background information and the potential Impacts, namely those associated with the ES provided by seagrasses and its potential for Human Well-being. Finally, there were outlined possible Responses from the scientific/academic point of view in the scope of maintenance and preservation of the ES provided by the seagrass communities in the Bay of Cadiz.

RESULTS AND DISCUSSION

The results obtained by the DPI(W)R(M) revealed how CT through CTAs impacts the Z. noltei meadows in the Bay of Cadiz from 2000 to 2020. Moreover, the analysis may suggest that CT is degrading Z. noltei in the Bay of Cadiz. Therefore, the loss of ecosystem services worsens human wellbeing in the Bay of Cadiz.

The number of visitors and overnight stays is increasing every year in the Bay of Cadiz, and their presence is concentrated in August for national visitors and October for foreigners. This seasonality is associated with further deterioration of the environment, job insecurity, and overprices during the high season. If the tourist demand in the Bay of Cadiz were distributed equitably throughout the year, the environmental damage caused by the overcrowding and concentration of actual tourist flows would not occur (Ramón & Abellán, 2014)
In addition, this rises in CT trigger an increase in the CTAs. For example, the Bay of Cadiz's port has had a positive evolution in the number of cruise passengers in the last two decades, rising 27.1%, which contributed economically to the Port Authority but generated environmental impact as solid waste production, air emissions, and greywaters usually discharged overboard

illegally (Klein, 2011). Moreover, recreational boating increased since the beginning of the study period. All types of boating can physically damage vegetated benthic species such as seagrass meadows. Remarkably, the propellers of motorboats can break the structures like the plant shoots and the repeating action of ripping out shoots by an anchor that can ultimately wipe out the seagrass meadow (Hansen et al., 2018). Furthermore, swimming, surfing, and SCUBA diving are the most regular holiday activities worldwide. This type of tourism directly impacts seagrasses, like chemical pollution for the use of sun creams or physical damage, when non-experienced divers cause stirring up of sediments (Burns & Davies, 2020; Collins et al., 2010; Honey & Krantz, 2007).

On the other hand, the increase of population and the urbanization process in the Bay of Cadiz were a considered pressure for Z. noltei meadows. The population grew 1.6% on average in the Bay of Cadiz from 1996 to 2019, but it was not equal to all bay's cities. While in Cádiz (the capital city), it decreased by 22.8%, in other cities such as Puerto Real, closer to the Z. noltei meadows, increased a 17.2%. In addition, from 1999 to 2015, the agroforestry system decreased a 16.33% giving way to the urban and industrial land, increasing 13.95% in the same period. However, urbanization decreases the ability of the land to retain nutrients, increases erosion, sedimentation, and nutrient runoff, resulting in a reduction in vegetated benthic species (Roman et al., 2020).

The retrospective analysis of Z. noltei showed a decrease in the Z. noltei seagrass between 2000 and 2020, from 32.64 ha to 16.27 ha. In addition, the most density Z. noltei meadows showed a significant decrease in the surface from 23.11 ha (2000) to 2.88 ha (2020) (Adjusted-R2 = 0.65; p-value 0.005). Moreover, the analysis indicated that the decline took place in the upper intertidal and increased in the lower intertidal zone. The variable visitors presented the highest significant correlation (Adj-R2 = 0.61; p-value < 0.05), followed by nutrients, especially for phosphates concentration (Adjusted-R2 = 0.54; p-value < 0.05). The rest of the anthropogenic and chemical variables measured at the Bay of Cadiz did not consistently correlate with the meadows' long-term trend. This might be caused for the lack of data in remote sensing images as anthropogenic and chemical variables.

Thus, a loss in Z. noltei area means a loss in SES and a loss in human wellbeing. In this sense, the loss of seagrass meadows in the Bay of Cadiz could affect the coastal and offshore fisheries, affect Blue flag award recognition, increase CO2 and CH4 into the atmosphere, raise flood hazards, and a loss of tourism, among other disadvantages to human wellbeing (de los Santos et al., 2020; Egea et al., 2019; Unsworth et al., 2018)

In response to the DPSI(W)R(M) theoretical framework and considering the benefits of seagrasses, and the loss of SES that injured human wellbeing in the Bay of Cadiz requires an integrated coastal management response. In Spain, the public administration is responsible for dealing with the problems towards sustainable development that enhance society's wellness. For example, the regional government of Andalusia has the Tourism Quality Plan 2014-2020 (Junta de Andalucía, 2014). This plan promotes sustainability as a management model, respectful of the environment and of those who promote it.

CONCLUSIONS

The increase in CT and consequently in CTAs in the Bay of Cadiz has led to the infrastructure development which this type of tourism requires and, therefore, the degradation of the bay's coastal ecosystems, of which this research focused on the Z. noltei seagrass meadows. Seagrass ecosystems play a fundamental role in human wellbeing, e.g., food through fisheries, erosion control, carbon sequestration, recreation, and tourism. Quantifying these services allows knowing their contribution to human wellbeing and justifies its conservation. Our results suggested that Z. noltei meadows are decreasing in the Bay of Cadiz because of the increase in CTAs. Thus, a loss in Z. noltei area means a loss in SES and human wellbeing.

However, it is unlikely that the analyzed variables are responsible for Z. noltei cover reduction, despite the number of visitors and the concentration of the nutrients. This highlights the fact that other variables affect Z. noltei dynamics, such as benthic macroinvertebrates or herbivory. All these possibilities suggest further research and urge the continued mapping of Z. noltei mapping and studying the pressure to this ecosystem.

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Diet composition and seasonal variations of mysid Mesopodopsis slabberi in Guadalquivir river estuary and its potential use in aquaculture

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ABSTRACT

Feeding habits and seasonal diet variations of mysid Mesopodopsis slabberi were investigated based on fatty acid analysis over a two year period at Guadalquivir river estuary. M. slabberi show high level of essential fatty acids, EPA (16.29-21.23 %), and DHA (13.05-17.26 %), through the study period. Significant variations through seasons were observed, showing highest EPA and DHA values in May and July.M. slabberi present a high content of LC -3 FA, being the essential fatty acids EPA and DHA the two most representative PUFAs through study period, obtained mainly from the consumption of diatoms, dinoflagellates and bacterial loop components. In order to evaluate potential use as a new resource in aquaculture, we study M.slabberi ability to increase natural EPA and DHA after being fed with experimental microalgae and rotifer diets. We observed a reduction of EPA and DHA content from natural wild high presence of 19.62 and 14.42 % to 9.89 and 5.35% in culture M.slabberi, respectively, after 15 days experimental culture. Nutritional evaluation acid profile of M. slabberi in the estuary suggests a great potential to be used as food source in aquaculture, although it is necessary to investigate more in an adequate maintenance of the culturing conditions.

KEYWORDS

Mysid, Mesopodopsis slabberi, Fatty acids

INTRODUCTION

Mesopodopsis slabberi (Van Beneden, 1861) is one of the most common mysids in estuaries and coasts of the North Atlantic and the Mediterranean Sea (Biju et al., 2009). It is one of the most abundant species of Guadalquivir Estuary community, where it plays a key role as prey of many fish and crustacean decapod species, some of high commercial interest, channeling energy from low to high trophic levels (Vilas, Drake, & Fockedey, 2008). Despite it is considered widely omnivorous, feeding habits and key food sources of M. slabberi are not well known. In order to unravel M. slabberi diet, basal trophic resources and its nutritional quality we analyzed its seasonal fatty acid composition as trophic markers.

Because of its high nutritional quality, we consider M. slabberi as a possible alternative to complement nutritional requirements in aquaculture. Fishmeal and fish oil replacements in aquaculture requires alternative searches and more sustainable fatty acids enrichment sources (Copeman et al., 2009; Glencross, 2009). Dietary requirements of essential fatty acids, in particular DHA, play a critical structural role in the early stages of development of marine organisms. The presence or absence in M. slabberi of essential fatty acids increase the nutritional value of the product and improve its quality as an alternative prey. We carried out several feeding experiments to study M. slabberi possible fatty acid trophic enrichment and its potential culture.

MATERIALS AND METHODS

The study was conducted in the Guadalquivir river estuary between 2019 and 2020 years. A zooplankton net was used to capture the mysids and separated in the laboratory by stages (adults and juveniles). The experiment consisted on following changes of mysid fatty acid composition as a function of known diets. They were carried out in aquariums for a period of 15 to 21 days feeding with microalgae Tetraselmis chuii and the rotifer Brachionus plicatilis. Fatty acid analyzes were carried out by a Shimadzu GC 2010-Plus gas chromatograph following methodologies by Cañavate et al. (2021). Individual FAMEs were identified by reference to authentic standards well-characterized as fish oil. Nutritional quality index based on FA (FA-NQI) were made following (Cañavate, 2019) method, given the importance of FA relationship in marine trophic networks.

RESULTS AND DISCUSSION

Mesopodpsis slabberi present an average total lipid content ranging between 11.48 and 19%, finding highest contents during spring-early summer. No differences were found between stages. Fatty acid profile of wild mysids points PUFAs as most abundant fatty acid type, with an average of 48.72 ± 3.20%, not showing significant differences between stages or seasons (Table 1). M. slabberi was found relatively rich in eicosapentaenoic acid (EPA; 20:5 n–3) and docosapentaenoic acid (DPA; 22:5 n–3).

Stage	Day	Diet	EPA	DHA	SFA	MUFA	PUFA	FA-NQI
Tetra	0	F2	2.64	0.42	34.21 ± 2.82	30.28 ± 1.93	32.78 ± 4.05	64.31 ± 3.17
Rotifer	0	F2	4.88	1.37	24.28 ± 2.92	26.07 ± 4.33	37.90 ± 3.41	42.40 ± 2.63
M.slabberi	0	Natural	19.62	14.42	34 ± 3.72	14.5 ± 1.09	48.72 ± 3.20	294.01 ± 17.09
M.slabberi	7	Tetra	12.95	10.07	33.92 ± 1.64	20.78 ± 1.20	42.06 ± 2.47	175.19 ± 5.88
M.slabberi	15	Rotifer	9.89	5.68	31.34 ± 0.55	23.82 ± 0.90	39.66 ± 0.02	134.51 ± 1.49

Table 1. Essential fatty acids in M. slabberi in their natural state and fed from experimental microalgae Tetraselmis chuii and rotifer Brachionus plicatilis. Values are present in percentages of fatty acids by groups: Saturated fatty acids (SFA), Monounsaturated fatty acids (MUFA) and Polyunsaturated fatty acids (PUFA). Nutritional index as denoted as FA-NQI.

Fatty acids multivariate analysis (principal component analysis PCA; Figure 1) and comparison with FA known sources composition shows how main food sources of M. slabberi might be Dinoflagellates, Diatoms and bacterial loop components. Feeding preferences shift seasonally; during spring M.slabberi adults and juveniles are positively correlated with diatoms typical fatty acid markers (16: 2n3 and 16: 3n4) and dinoflagellates (18:2n6 and 18:3n4), while during summer show a greater preference for dinoflagellates. During early autumn both adults and juveniles seem prefer diatoms, ahead of components of the bacterial loop (15:0 and 16:0).

Feeding experiments resulted in a reduction of essential fatty acids EPA and DHA form present in natural mysids (19.62 and 14.42% for EPA and DHA respectively) to cultured mysids content after 15 days fed with Tetraselmis diet (12.95 and 10.07 % for EPA and DHA respectively) and Tetraselmis enriched rotifers (9.89% and 5.68 % for EPA and DHA respectively). Results suggest that the type of diet greatly influences the content of essential fatty acids in M.slabberi and it is doesn´t seem able of increasing EPA and DHA values from low nutritional sources. Besides, significant differences were observed on the nutritional indices based on FA between individuals captured in the natural environment (294.01 ± 17.09) and individuals fed with both experimental diets (p-value<0.05), Tetraselmis chuii (175.19 ± 5.88) and Rotifer (134.50 ± 1.49) after 15 days culture (Table 1).

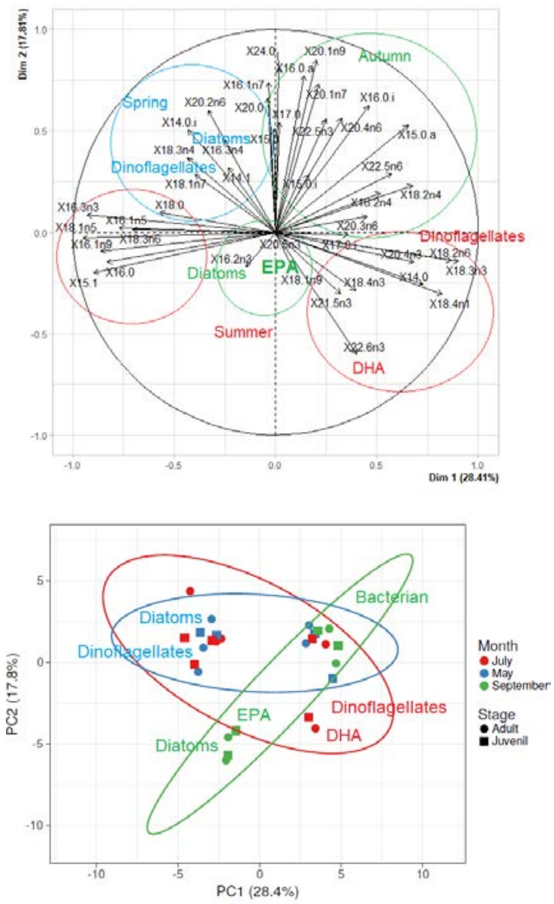

Figure 1. Fatty acids seasonal variations of M.slabberi 2019-20. Upper plot identifies fatty acids distributed through seasons of study period, marked as colors; Spring (Blue), Summer (Red) and Autumn (Green) and main fatty acids detected; Scatter diagram (below) shows same PCA analysis but showing mysids samples by factors Season as and Stage.

CONCLUSIONS

Mesopodopsis slabberi present a high content of LC -3 FA, being the essential fatty acids EPA and DHA the two most representative PUFAs through study period, obtained mainly from the consumption of diatoms, dinoflagellates and bacterial loop components. Diet composition results describe M. slabberi as a wide niche omnivorous which channels carbon and energy from basal trophic primary producers and detritus to upper trophic levels. It agrees with its role of key prey for most abundant secondary consumers in the estuary, many of them fish juveniles which uses the estuary as a main nursery and essential fish habitat. Its FA-nutritional index value is high in natural environment, but M.slabberi FA-NQI is reduced after continuously fed with low EPA and DHA diets.

M. slabberi fatty acid composition reported in this study suggests that this species has a great potential as live prey for fish, crustaceans and cephalopods aquaculture. However, further studies are needed to optimize culturing appropiate diet to potentially be used as a reliable, high-quality, live food or even as part of artificial diets in aquaculture.

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The Ostrom's Social-Ecological System Framework modified for Urban Ecosystem Assessment

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ABSTRACT
Social-ecological systems are composed of a complex network of natural and anthropic variables that interact with each other and produce a specific outcome that can affect the health of the ecosystems or human well-being. Ostrom's Social-Ecological System (SES) Framework aims to understand the complexity of these systems and provide helpful information for their management. Cities or urban agglomerations must be studied as an SES where nature and the citizens interact daily. Nonetheless, there are a few tools or information for studying urban ecosystems, their services, and their relationship with anthropic elements inside urban areas. This research aims to provide a modified version of Ostrom's SES framework to study urban ecosystem services, especially in coastal areas. The city of Cádiz was selected as a study area, and the SES variables were identified, described, characterised, and related between them. Thanks to the elaborated methodology, the interactions between the environment and the citizens were identified and their outcomes defined. This tool allows the gathering and analysing of information to adapt policies, management resources, and projects under the Ecosystem-based management approach.

KEYWORDS
social-ecological systems, ecosystem services, urban ecosystems, urban planning, environmental management.

INTRODUCTION
Cities are ecosystems composed of artificial or anthropogenic elements and many natural environments (rivers, urban green areas, coastal zones, and many others) that interact with humans and impact their well-being. [1]. Integrating cities as part of the natural environment respects human beings' role as drivers of change. Humans are also dependent on those ecosystems and their critical role in maintaining and improving well-being by the ecosystem services they provide [2], [3]. There is a close relationship and interdependence between ecosystem services and their use and accessibility with human well-being. For this reason, the historical development of cities has concentrated in areas with high species richness and endemism, mainly concentrated along coastlines and near large river systems. Unfortunately, urban growth and sprawling are associated with the loss of ecosystems and their services, especially for the unorganised and unplanned development in past centuries [4], [5]. The protection, restoration, and ecosystem services management have proven to bring multiple and synergistic benefits to socio-environmental justice [2], [6]. The presence, use, and conservation of ecosystems near and within urban centres are necessary to improve resilience, sustainability, and citizens' well-being; therefore, it is essential to include and monitor ecosystem services programs and projects during the urban planning process [7], [8]. The Social-Ecological System approach (SES) has been under development for over 50 years. An SES is a: "Multilevel system that provides essential services to society such as the supply of food, fibre, energy and drinking

water" [9]. A social-ecological system has interactions between social and ecological units that are mutually dependent and intertwined at multiple scales. It includes a set of defined resources and the necessary entities for its management [10]. Ostrom (2009) has developed a framework for understanding a particular system's main aspects according to a set of subsystems and variables that characterise the systems and their interactions. The SES theory specifies that users can develop institutions, regulations, or even cultural practices to govern the common resources without the need for privatisation or extensive government oversight [11].

Therefore, this research aims to provide a modified version of Ostrom's SES to assess urban ecosystems. This methodology would give urban or environmental managers valuable insights into the interrelationship between anthropogenic and natural variables with the main goal of gathering helpful information for policies, environmental projects or urban planning.

STUDY AREA

The municipality of Cádiz has an extension of 12 km2 [12] and a population of 116 027 for 2019, and it presents a declining population rate. [13]. The municipality of Cádiz is characterised by a close relationship with the bay and the coastal areas. It has commercial ports, marinas, and sun and beach tourism activities. It is considered a city of services and commercial activities, but it also has an important industrial sector and port activity. [14], [15]. Due to its geographical conditions, the municipality of Cádiz can be affected by storm surges and coastal flooding, especially in the southern salt marshes and swamp areas. In general, the city of Cádiz has exhausted its ability to grow several decades ago due to the presence of coastal ecosystems. [14]. The Bay of Cádiz Natural Park was established in 1989 and integrated into the Natura 2000 program in 1992. In 2015, the marine bottom was also set as a protected space under Natura 2000. [16]

MATERIALS AND METHODS

Based on Ostrom's SES Framework, this study focuses on ecosystem services as the common pool resource. To be precise, the resource under exploitation by the influence of the users and social and political settings. From this point of view, the following factors were considered for the characterisation of the first-level subsystems:

• Resource System: The city of Cádiz is the SES under study. Therefore, the resource systems include the urban and natural systems found in the selected geographical area. The main economic sectors must be identified, the system's boundaries established, the area and the population quantified, and identified the city's facilities.

• Resource Units: This research aims to monitor urban ecosystem services. The resource units are all the ecosystems and their services inside the resource system. For the identification of the ecosystem services, this research uses the Common International Classification of Ecosystem Services (CICES) from the European Environment Agency (2018) and the Millennium Ecosystem Assessment (2003).

• Governance system: This research aims to provide a tool for urban planning. The governance system will focus on those responsible for urban planning and the elaboration of spatial planning plans.

• Users: The users are the population and visitors of the city.

• Related ecosystems: Related ecosystems are closer than 10km from the city's defined geographical boundary, and the users can enjoy them regularly.

• Social, economic, and political settings: National and regional politics and strategies can affect urban planning and natural areas

RESULTS AND DISCUSSION

After analysing the interactions between the SES, it is fair to determine that the City of Cádiz has exerted significant pressure on the city's ecosystems and those nearby. Cádiz does not have many urban green areas, limiting its capacity to provide ecosystem services. Only 7%

of urban green areas correspond to parks, gardens, and beaches and dunes. According to the recorded population in 2016, the city has only 4,55 m2 per capita of urban green areas, half of the minimum recommended and a lot less than the desired 50 m2 per capita to improve human well-being [17] [12], [15], [18]. Nonetheless, the areas provide multiple cultural services, especially the beach and dunes, due to the recreational activities that increase the appeal of Cádiz as a holiday city for "beach and sun" tourism. The Cádiz Bay, the Atlantic Ocean and the salt marshes provide an important recreational and ecotourism space for the city's citizens. Due to the small amount of urban green areas, there is not much space to support biodiversity or provide shelter for vulnerable species inside the city's limits reducing its genetic diversity, decreasing its capacity to control plagues or other diseases. This trend implies a reduction of ecosystem services for pollination and biodiversity. The small urban green areas limit climate regulation capacity. The urban green areas are mostly in the historical centre in the far northwest of the city; therefore, carbon sequestration and local temperature control are very limited. The soil's permeability is minimal due to the extent of urban infrastructure, provoking an increase in runoff, urban flooding, and the aquifer's disequilibrium. The beach supports fish stock and habitat for marine species and food supply, providing cultural ecosystem services in recreational fishing. The coast also permits nautical navigation, which represents an industrial activity in Cádiz, and once more, provides recreation services in the form of nautical sports. The city is also vulnerable to coastal flooding, and for this reason, the city has historical coastal defences to substitute the loss of ecosystem services by the urbanisation process [12]. Other ecosystem services have human-made substitutes that come from other regions. For example, there is no recording of urban agriculture in Cádiz at present. Therefore, besides some fish caught in the bay, all the food in the city is imported from other regions. The drinkable water supply comes from the Sierra de Cádiz, so there is no freshwater supply in the city or wells for drinkable water consumption. [19], [20]. For sewage assimilation, the city of Cádiz uses a wastewater plant located in San Fernando, outside the city limits; nonetheless, some industrial wastewater disposal from the port has been registered in the Cádiz Bay. [21]. For waste disposal, the city depends on facilities in the municipality of Chiclana de la Frontera. [15], [19], [22].

Under the awareness that cities are social-ecological systems that have complex relationships between their components and the reciprocity between ecosystems and the humans, this research acknowledges the complexity of studying cities as a unique system but also recognises the importance of understanding the environmental and social needs of an urban system [23], [24]. Therefore, this research used the SES Framework as an analytical tool to characterise and understand the relationships in Cádiz with their ecosystems and ecosystem services. This framework helped identify the ecosystem and its services and described the citizens' connections with them, the threats and pressures to human well-being, and the main reason the threats and pressures exist. Thus, the framework allows for a better understanding of the city's needs. It can help develop a more holistic urban plan that uses nature-based solutions and improved ecosystem services for a more sustainable and resilient city. The employment of the SES framework for analysing complex systems has been underway in the last 20 years with multiple examples and case studies due to its methodological flexibility [10], [11], [25]–[28].

SES framework for urban system analyses must be further developed to gain accessibility to the urban managers, especially if combined with other environmental frameworks like ecosystem services [27]. The ecosystems and the ecosystem services were detected using the urban land cover and analysed using the CICES list of ecosystem services. The ecosystems detected have been very similar to other studied urban ecosystems with the added particularity that Cádiz is located in the coastal zone, adding their own set of ecosystems and their services [26], [29]

CONCLUSIONS

This research concluded that Cádiz is highly dependent on the ecosystems and their services. For example, the city has a significant economic and cultural dependency on water and coastal ecosystems. Also, as in many cities worldwide, fossil fuels for private and public transportation, both inland and sea, have negatively affected air quality [30]. This environmental impact can have a direct effect on human health and well-being. Therefore, urban green areas' presence and development are essential for urban ecosystems due to the various services provided to their population, including air quality control [17].

Furthermore, like any other city, Cádiz requires the external supply of provisioning services like food, timber and freshwater [31]. Therefore, urban green areas provide regulating services, although unfortunately, the extension of urban vegetation is limited. Concerning cultural services, the urban green areas and coastal zone are essential ecosystems that directly influence human well-being, making their enjoyment a priority for improving the quality of life inside the city boundaries [6].

The SES framework is a flexible tool to study the relationships in a complex system. Cities need to be understood as an intricate social-ecological system with essential interactions with their variables to implement a more holistic and integrative management approach that could lead to more sustainable and resilient cities.

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Mapping Ecosystem service flow in Ungwana bay, Kenya

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ABSTRACT
A major obstacle to mapping Ecosystem Services (ES) and the application of the ES concept has been the inadequacy of data at the landscape level necessary for their quantification. This study proposes that understanding and mapping services through cost-effective and accessible materials and methods are key to contributing to the sustainable management of natural resources in developing countries. Therefore, this study aims to assess the flow of ES in the mangrove ecosystem of Ungwana Bay in the North coast of Kenya, by adopting the Land Use Land Cover (LULC) matrix approach. The study characterized the LULC classes present in the study area, identified the most important ES, and collected data on expert opinions via a survey on ES flow supplied by the mangrove ecosystem. A qualitative and quantitative analysis of the expert scoring produced a LULC matrix that when integrated with the LULC maps shows the spatial distribution of ES flow. The assessment indicates very high flow (5.0) for the regulating and supporting services, high flow (4.0) for the cultural services and medium flow (3.0) for the provisioning services as supplied by mangroves. In addition, the analysis indicates there are sixteen (16) major ES supplied by the mangrove ecosystem of Ungwana bay as per the year 2021. This study highlights the importance of the mangroves as a coastal ecosystem and how the visualization of the spatial distribution of ES flow using maps can be useful in informing natural resource management. In addition, the study shows the possibilities of using freely accessible materials and methods in ES assessment studies lacking in developing countries.

KEYWORDS
Mapping, Ecosystem service flow, Mangrove, Kenya.

INTRODUCTION
Coastal ecosystems are some of the most productive systems on earth (Conservation International, 2019), being the planet's life-support systems for the human species and all other forms of life (MEA, 2005). Among these systems, are the mangrove ecosystems that provide a wide range of goods and services to both nature and society, being viewed at local, national and global scales (UNEP, 2020). However, the dual trends of local and global population growth and increase in consumption rates have led to the increasing demand for coastal ecosystem services (ES). Between 1985 and 2005, the world lost about 35% of mangrove forests declining faster than tropical forests and coral reefs (Giri, 2016). Based on these global concerns, the concept of ES has gained popularity in research because of its ability to integrate both inter and intradisciplinary research and linking environmental and socio-economic concepts (Burkhard et al., 2009). The concept has been applied in assessments such as the Millennium Ecosystem Assessment (MA, 2005). Therefore, this research study is very relevant to this conference in Water and Coastal Management (WACOMA) goals of using natural sciences knowledge to address societal challenges pertinent to coastal communities.

This research aims to assess the flow of ES in the mangrove ecosystems of Ungwana bay, adopting Burkhard et al., (2009) LULC matrix. Further, this study advocate for the use of free and cost-effective mapping materials that can be useful to carry out ES assessments in developing countries.

MATERIALS AND METHODS

The study was conducted in Ungwana bay, on the North coast of Kenya focusing on the mangrove ecosystem that has been influenced highly by land conversion into salt harvesting ponds (Kamau, 1998; Bundotich et al., 2009; GoK, 2015). The study focuses on the southern part of the bay on areas of Mto-Kilifi and Ngomeni mangroves characterized by a wide shallow embayment in front of river Tana and Sabaki (Lang'at, 2008).

This study relied highly on freely accessible satellite remotely sensed data from Sentinel-2 satellite missions. In addition, the study applied open-source GIS software such as the semi-automatic classification plugin (SCP) in QGIS in processing LULC maps. A survey was conducted to collect data from experts* on the flow of ES in the study area. Through qualitative and quantitative analysis, the scored ES flow matrix data was integrated with the LULC maps to show the spatial distribution of ES in the study area.

RESULTS AND DISCUSSION

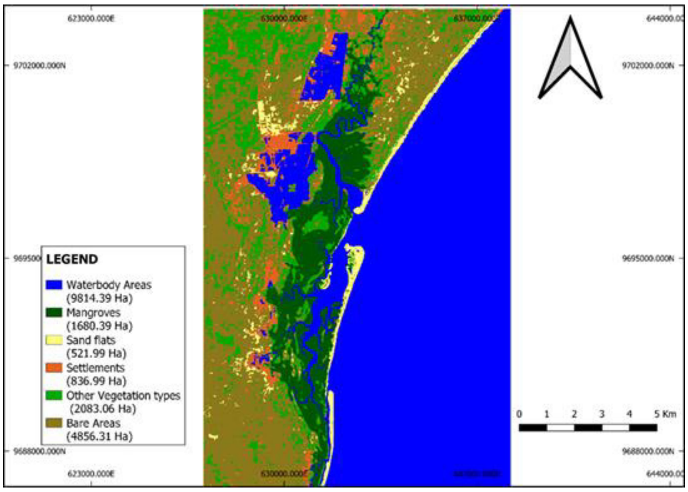
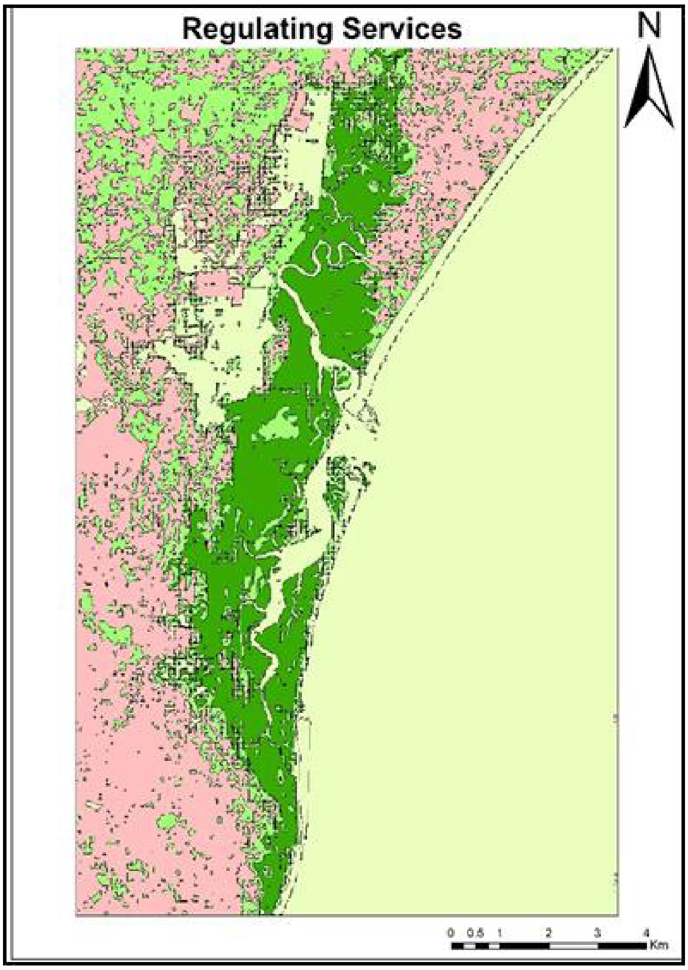


Figure 1. LULC classification using SCP plugin of a 2021 Sentinel-2 acquired satellite image showing the LULC classes present in the Mto-Kilifi area.

The LULC classification process resulted in six (6) LULC classes present in the study area (Figure 1) including the calculated area of each class in hectares (see legend). This LULC map lays the foundation for ES assessment by identifying the classes present in a landscape, then a matrix scoring can be conducted based on the classes. Therefore, a good quality high-resolution satellite imagery such as the one provided by Sentinel-2 multi-spectral satellites is significant in this kind of study.

The compilation of the survey responses indicated there are sixteen (16) ES supplied by the mangrove ecosystem of Ungwana bay. They include: - provisioning services (wood products, fuel, fresh water, fisheries, local employment, medicinal plants, wild food &honey), regulating services (carbon sequestration, water purification, shoreline protection, preservation of biodiversity), supporting services (sediment trapping, nutrient cycling), cultural services (recreation & tourism, cultural heritage, education & research).



* those in the academia, government and non-government organizations working with mangroves and the community members living and/or working adjacent to the mangrove ecosystem of the study area.

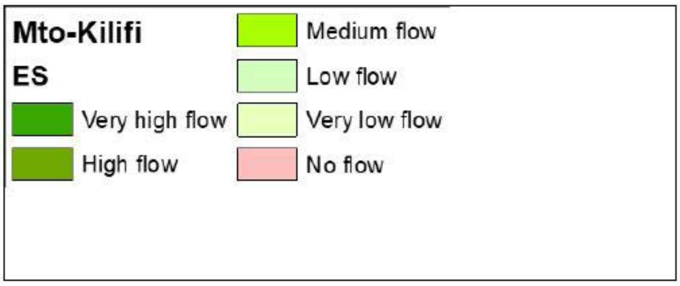


Figure 2. Spatial distribution map of the regulating services in the Mto-Kilifi subset of the study area. The legend describes different levels of ES flow on a scale of 1-5 with the mangrove area indicating a very high flow (5.0-dark green).

Figure 2 is the result of the integration of the LULC map in Figure 1 and the matrix expert scoring. The figure is showing the flow of only regulating services supplied by the mangrove ecosystem of Ungwana bay as an example.

The mangrove indicates a very high flow (dark green), the water bodies which include the ocean, the creeks and flooded salt ponds indicate very low flow (grey-green), the bare areas and settlements indicate no flow (rosy color) and areas covered by other vegetation types other than mangrove indicating medium flow (peridot green) of the regulating services. This kind of results emphasizes the importance of mangroves as a coastal ecosystem with the highest flow among the landscapes assessed (Maes et al., 2011; Kauffman and Donato, 2012; Conservation International, 2019).

The most appealing concept about the LULC matrix (sometimes referred to as ES matrix) approach has been its simplicity, flexibility in application in data-scarce regions (Burkhard and Maes, 2017). Therefore, such preliminary results support the hypothesis that using free and accessible materials and methods in mapping the flow of ES in data-scarce areas is key for the sustainable management of resources.

CONCLUSIONS

Most developing countries are highly reliant on natural resources; hence, integrated natural resource management is key in ensuring sustainable development. Nonetheless, such nations lack the necessary tools such as biophysical databases on the potential of different landscapes to supply ES. Therefore, the application of cost-effective and resourceful approaches such as the LULC matrix in curbing data availability challenge is significant in populating such databases with needed information. More so, the approach like in this study can use freely accessible materials for ES assessment eliminating the problem of cost. Further, the LULC approach relies on the input of experts which is a form of stakeholder participation, a significant element of sustainable development. Besides, the visual aspect of the spatial distribution maps of ES flow can be important in enhancing communication between researchers and stakeholders.

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Proposal for the Restoration of tidal Marshes on the left bank of the Guadalquivir Estuary: Trebujena Marshes.

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ABSTRACT
The marshes of the Guadalquivir River Estuary are ecosystems that have suffered marked impacts from anthropic actions such as intensive agriculture, animal husbandry and aquaculture. As a result of these actions, the marshes on the left bank of Trebujena have lost their natural functioning as a result of the construction of dams and other artificial infrastructures that prevent the tidal flooding of these ecosystems. Therefore, this work proposes management measures under the approach of nature-based solutions for a proposed tidal restoration of the marshes in the area. The pilot Restoration proposal of the Adventus marsh in analyzed with the aim of proposing action guidelines for the restoration of marshes on a larger scale. Using the ArcGis 10.4 tool, cartographic information on socioeconomic and administrative activities and risk of flooding in the area of the left bank of Trebujena was analyzed. Potential restoration areas in the estuary were identified from aerial images of the 1956 American flight and observations in the field. This information was complemented with the recommendation of specific management measures and with an analysis of the ecosystem services offered by the tidal marshes, emphasizing that the Restoration of Marshes is an interesting measure to mitigate the effects of climate change in coastal areas, as these blue carbon ecosystems are important given the ecosystems services they offer such as water purification, flood risk reduction, carbon sinks and nursey grounds for fisheries that are important for human well-being.

KEYWORDS
restoration, salt marsh, management, nature-based solutions

INTRODUCTION
The Guadalquivir Estuary, with an approximate lenght of 110 km, extends from the Alcalá del río dam to its mouth in the Broa Sanlúcar, in the waters of the Atlantic Ocean.The estuary is a transition zone between the fluvial and marine environments, differentiated from the rest of the upstream river sections by the influence of the sea, which marks the dynamics of the estuary and therefore the mixture of fresh and salt wáter. The marshes of the Guadalquivir river estuary are ecosystems that have suffered marked impacts due to the anthropic actions carried out in that area. The main interventions that gave rise to the current state and morphology of the estuary are: cutting of river channels to maintain navigability to Seville, drainage and filling of large extensions of marshes to accommodate intensive greenhouse agriculture, rice cultivation, fisheries, aquaculture, urban developments and their infrastructures, adn an extensive network of roads and paths on both sides of teh main channel of the estuary. From these interventions, the flooded area has been reduced by 85% and the total intake of fresh wáter by 60%. As a result, the estuarine marshes today are isolated from the main wáter course (Llope, 2017).

The purpose of this work is to collect and synthesize knowledge about the restoration of marshes from the pilot restoration carried out in the Adventus marsh (Trebujena), in order to propose recommendations and proposals for restoration on a larger scale based on nature- based solutions.

MATERIALS AND METHODS

The study area is located in the Guadalquivir Estuary, specifically in the area of the left bank of the municipality of Trebujena. In this area, it is proposed to carry out marsh restoration in different areas (Fig 1), and in turn the Adventus marsh is located, which is a pilot restoration initiative that we use as a reference to propose potential areas to restore.

The activities for this work in the indicated area were the following:

1) Cartographic analysis of flood risk and state of the marshes in 1956.
2) Cartographic analysis of Potential Restoration Zones on the Left Bank of Trebujena.
3) Meetings with different stakeholders on restoration processes and ecosystem services (WWF-Plegadis- IFAPA-CSIC)
4) Analysis ecosystem services in salt marshes

RESULTS AND DISCUSSION

Restoration proposal in the study area (Fig. 1). Different areas for restoration in the estuary area are proposed on the map. The ecosystem services of the marshes are presented in Table 1. These benefits could be important to mitigate the effects of climate change and water purification problems, among others.

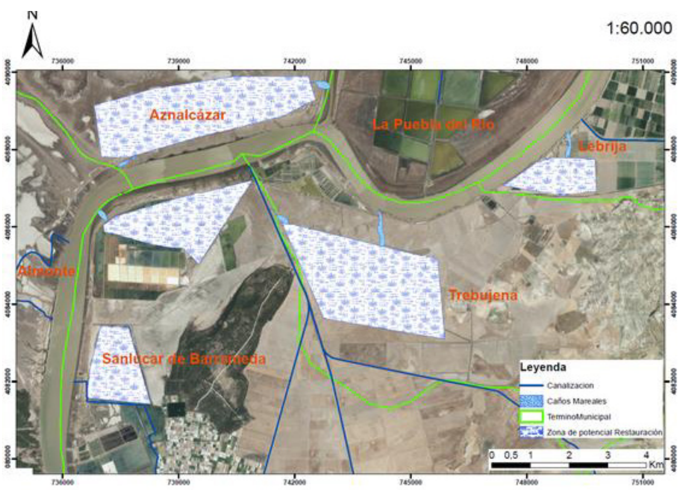

Figura 1. Proposal for the restoration of salt marsh of áreas on the left bank of Trebujena.

Environmental System	Clasification	Environmental Services
Salt Marsh	Support	Spaces for the development of living beings (hábitat) Wastewater assimilation Infrastructure transport Primary production
	Provisión	Food Biochemistry Aquaculture Forage
	Regulation	Climate regulation Water treatment Regulation of disturbances Pollination Erosion control Air purification
	Cultural	Investigation Esthetic Education Recreational and ecotourism Iconic species

Table 1. Ecosystem services of the Marshes.

CONCLUSIONS

The restoration of tidal ecosystems is an interesting alternative to mitigate the effects of climate change in coastal áreas. To the eventual risk of floods estimated within the next few years for the area of the left bank of Trebujena, this restoration initiative for the marshes through the opening of the tidal channels, is projected as an alternative consistent with nature-based solutions.

Different management criteria must be taken into account to develop a large-scale marsh restoration. Among the criteria to be taken into account, it is necessary to consider legal, administrative, socio-economic activities and considerations of land use in the area to be restored.

The ecosystrem services offered by tidal marshes are important for human well-being. Problems such as wáter quality, fishing and the risk of floods that affect the estuary area could be solved with the restoration of the ecosystem services that the marsh offers.

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Whale watching as ecotourism in Sagres, Portugal - It is possible?

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ABSTRACT
Whale watching brings advantages to whale and dolphin conservation by increasing economic benefits to stakeholders, reducing whaling activity and enhancing interest and environmentally responsible behaviors of tourists. However, the increase of whale watching services to meet the increasing demand of those who want to see the animals in the wild causes negative issues for the whales, other marine animals and the marine environment. This puts into question whether whale watching may be considered as ecotourism. Understanding the profile of tourists, their satisfaction and perception of whale watching tours, as well as their valuation of the ecosystem services is important to help operators and managers respond to the market while better protecting natural values. The "willingness-to-pay" questionnaire was used to assess these important factors. The analysis relies on a sample of 104 whale watchers collected during September 2019, in Sagres (Portugal). The results show: (i) most of the respondents were foreigners; (ii) most were seeing cetacean in the wild for the first time; (iii) they strongly disagreed with keeping whales in captivity; (iv) they strongly disagreed with whaling. The findings were that (i) operators could consider a combination of whale and coastline watching; (ii) the interpretation section of the tours could be improved; (iii) the environmental education content of the tours could be increased.

KEYWORDS
Whale watching, satisfaction, perception, willingness - to - pay, tourist's characteristics, ecotourism.

INTRODUCTION
Coastal tourism, including ecotourism, is an important sector in Blue Growth strategies of many nations, such as European countries and increasingly important in developing countries, such as Vietnam. However, the increase of coastal tourism, such as whale watching tourism, may have a negative impact on the target animals, the marine environment and benefits to the local people. Coastal managers need to reconcile the growth of coastal tourism with ecosystem protection to encourage ecotourism and benefit from the value of this ecosystem service.

Tourism relies on many non-material ecosystem benefits such as aesthetics or sense of wellbeing. However, it is difficult to assess the value of ecosystem services (Small et al., 2017), especially the non-material value of ecosystems. Common approaches include the contingent valuation method (Cheng et al., 2019), especially using willingness-to -pay (WTP) questionnaires (Farr et al., 2014) and the travel cost method (Zhang et al., 2015).

Furthermore, ecotourism is difficult to define. The term "eco" depends on the "environmental awareness and responsibility of stakeholders, especially operators and tourists (Goodwin, 1996). However, because tourism is an experience service, it also depends on tourist demand and the value of the ecosystem to them. Therefore, it is important for authorities and operators to understand the profile of tourists, their motivation, satisfaction and their perception on the value of the ecosystem services. The information could help operators and regulators to meet the market's demand while protecting the environment (Cheung & Jim, 2014).

Studies of individual, environmental attitudes, environmental knowledge, age, education level in relation with the eco-oriented levels exist (Higham, 2008). Most of the studies were done by questionnaire and interview. Results of these studies show that ecotourists would use ecotourism products multiple times (Mehmetoglu, 2007), pay more for conservation (Guerreiro, 2016) and to learn more about the environment and ecosystem (Lück, 2015).

Whale watching is an emerging type of coastal tourism that is normally promoted as "ecotourism". However, this sector does not altogether fit the concept of ecotourism. Only a small part of the operators of whale watching boat tours proactively teach more about whales (Lück, 2015). Many whale watchers would pay more towards whales and dolphin conservation (Fatima et al., 2012).

The economy of Algarve, Portugal, largely depends on excellent natural conditions. Whale watching tourism, mostly dolphin watching, is a very popular activity in the Algarve that is a well-known coastal destination. However, there is a great lack of knowledge about this popular economic activity. This research based on a case study in Sagres (Algarve, Portugal) to identify how sustainable management of whale watching tourism may be investigate profiles of dolphin watchers; (2) value the cultural ecosystem services; and (3) define potential solutions for better ecotourism practices in the dolphin watching activities in the area.

The study focuses on the following 3 research questions:

(1) What are the characteristics of the dolphin watchers in the area?
(2) How do they value the ecosystem services of whale watching?
(3) How could dolphin-watching ecotourism improve in the area?

MATERIALS AND METHODS

Research area

Sagres is one of sites in the Algarve where tourists take part in dolphin watching tours. The watching activity normally reaches its peak during summer months around June to September. Tourists generally pay 35 euro for a 1.5-hour boat tour.

Data collection

Close - end questionnaires were sent out via email to tourists who took part in dolphin watching tours operated by the Mar Ilimitado company in the period 07 September – 08 October 2019 and expressed their willingness to answer the online survey. Questionnaires were sent to only 1 representative per group. A total of 104 interviewquestionnaires were completed from the 233 emails sent.

The questionnaire included questions on tourists' profile, motivation, satisfaction and a WTP question for whale conservations and 3 other WTP questions for more environmentally friendly tour services (to learn more about ecosystem; to have a longer tour to see coastline; and to improve boat facility or reduce in the number of passengers on a boat).

Data analysis

Descriptive statistical measures such as the mode, median, were used.. Additionally, to investigate if there is an association between level of WTP (for conservation and for a more environmentally friendly tour services) and tourists, the chi-square test and the spearman correlation coefficient (rs) were applied in case of nominal and ordinal variables, respectively. All the statistical analyses were performed using the statistical software SPSS version 26.0, and a 5% level of significance.

RESULTS AND DISCUSSION

Results

Tourist profile and visit information

The demographic profile of the tourists during the research period was characterized. Most whale watchers in Sagres are foreign (>93%), well-educated (with university and higher degree) (87.4%), and between the ages of 18-60 (>93%). Their incomes are higher than medium income (>65.3%). Most of respondents were multiple-destination tourists. Most of them stayed in Sagres less than 7 days (81%). The travel group information was: 46.15% of them traveled as a couple; 37.5% of them traveled with their families, 8.56% respondents traveled with their friends, the remaining traveled alone or with an organized group.

Tourist motivation and experience
45.2% of respondents were watching whales and dolphins for the first time. Natural values of Sagres including landscape, seascape, weather, beaches were the main reasons for the visit. 8% of respondents visit Sagres for whale watching only. Seeing whales and dolphins were the main reasons for the boat trips, (>81%). Some of them (17.5%) wanted to learn more about whales and dolphins while taking part in the boat trips.

Tourist perception on whaling and whale watching
Respondents strongly disagreed with commercial whaling (>98%) and keeping whales in captivity (55.8%) Many respondents enjoy the tour even if they could not see whales and dolphins (57.7%). Only 40.4% of the total respondents would only enjoy the tour a little if they did not encounter whales during boat trips.

Tourist's WTP for conservation and Potential solutions for more environmentally friendly tours
87.5% of them would pay average 6.16 € for whale and dolphin conservation. The variable of WTP for conservation did not show any association with most variables relating to the variable of tourist characteristics, except the variable of tourist experience and and perception on commercial whaling. A significant statistical correlation between the WTP for conservation variable and previous experience variable was found by chi-square test (t=8.649, p-value=0.013 and Phi=0.308). Additionally, the correlation between Perception_commercial whaling variable and WTP for conservation variable was very weak and negative (rs = -0.218) but statistically significative (pvalue = 0.038 < =0.05).

Respondents showed they are happy with tour facilities. They would not pay more to improved boat facility and a reduction in the number of passengers on boats. However, 38.5% of respondents would pay more for a better environmental interpretation when taking part in boat watching tours. 71.2% of respondents would pay more to have a longer tour and see more of the coastline. Those who want to learn more about whales, tend to pay more for education sector during boat watching trips (t = 11.304, p-value = 0.004 < 0.05).

Discussion
The tourist profile was quite similar to general tourists profile in the Algarve at the same time of the year. To specify, in the period of September – October, a majorities of tourists in Algarve are foreigners; respondents tend to travel as a couple or with their friend(s) in the Barlavento (including Sagres) subregion than the number of those who travel with their families (Turismo do Algarve, 2016). The results showed a similar demographic profile to whale watchers in previous research, (Gonçalves et al., 2012). Most of respondents are foreigners, middle-aged and well-educated (Bentz et al., 2016). They have a relatively high income (Parsons et al., 2003) and the rate of repeat whale watchers was slightly over half of the total respondents (Meadows, 2002 cited in Shapiro, 2006).

The Algarve is well-known for sun, beach, landscape and natural value (Turismo do Algarve, 2016), it is easy to understand that most of respondents came to Sagres to enjoy the natural value here. The reason for taking part in boat trips in this study was to see whales, beinh similar to previous studies (Hoyt & Hvenegaard, 2002); only some of tourists joining whale watching trips or join naturebased tourism/ ecotourism services want to learn more about ecosystem (Sheena et al., 2015) or whales (Lück, 2015); and encountering whale is still important to the success of boat watching trip (Chen, 2011).

The WTP value for conservation is in the range of 10-25% of the total ticket value for conservation, which is similar to the percentage of ticket value that whale watcher would pay more, in Croatia (Batel et al., 2014).

CONCLUSIONS

The tourists taking part in dolphin watching tours in Sagres have a similar profile to whale watching tourists in other areas. Generally, they are well-educated, foreign, middle-age and having high income. They were multidestination tourists who showed a strong disagreement with keeping whales and dolphins in captivity and whaling.

87.5% of respondents would add 6 EUR to their ticket value for whale and dolphin conservation. About 39 % of them would pay more for improved environmental interpretation. About 71% of them would pay for a longer tour to see coastlines in Sagres, as the area is well-known for its beautiful coastline. Hence, operators and coastal managers in the area could consider the solution of a combination of dolphin watching tours and coastal tours. They may also continue to improve the environmental interpretation during the tours. Fund for whale and dolphin conservation could be collected as part of an increase in the ticket value.

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A proposal for MPAs participation in areas beyond national jurisdiction: the case of Macaronesia

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ABSTRACT
The Ocean is the largest ecosystem on the planet, supporting millions of people's livelihood. Marine protected areas (MPAs) are key to guarantee Ocean resilience. About 62% of the Ocean surface coincide with areas 200 miles from coastlines, called areas beyond national jurisdiction (ABNJ). However, MPA in ABNJ are only 1,18% of the high seas. Stakeholder involvement is a keystone in governance process. Especially in Macaronesia, with the need for compatibility between human activities and conservation, through the synergetic engagement of the local-maritime community. The present paper aim to develop a proposal of a well-managed MPA in ABNJ context, through expert consultation. The proposal was compared with Macaronesia region study case. Results show that there is not only one integrated international body to fully addresses the range of problems to be tackled, to treat it models as Conference of Parties seems to be more adequate. Considering Macaronesia region specificity, the conclusion is that select local focal points in each archipelago to enhance the local maritime community is essential. Furthermore, it would be necessary to implement Working Groups, rotative between archipelagos, to address different solutions for local conservation practices. Invest in clear communication is fundamental since the very beginning to guarantee visibility and transparency.

KEYWORDS
Marine Protected Areas, Areas Beyond National Jurisdiction, Stakeholder engagement, participation.

INTRODUCTION
The Ocean is the largest ecosystem on the planet, supporting millions of people's livelihood (FAO,2018). Last decades have witnessed a steady increase of threats and pressures towards the Ocean (FAO,2018). One of the keys to protect this vital environment are the area-based management tools (ABMT), as Marine Protected Areas (MPAs) (UNEP-WCMC and IUCN, 2018).

About 62% of the Ocean surface coincide with areas 200 miles from coastlines, called areas beyond national jurisdiction (ABNJ) (FAO, 2018). However, MPA in ABNJ are only 1,18% of the high seas (UNEP-WCMC and IUCN, 2021). An adequate legal framework is necessary to ensure the sustainability of the BBNJ (Collins et al. 2020).

A UN Preparatory Committee (PrepCom) has been working on a draft proposal to an international legally binding instrument (ILBI)1 under the UN Convention on the Law of the Sea (UNCLOS, 1982) on the conservation and sustainable use of marine biological diversity in ABNJ (Wright et al., 2019). One of the main goals of the current document is to regulate ABMT, including MPAs.

1Revised draft text of an agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. Available at https://undocs.org/en/a/conf.232/2020/3

In this draft document, released in January 2020, traditional knowledge of indigenous peoples and local communities are considered part of the stakeholder group.

Engaging communities in a dynamic, participative process is a core element for MPA success (Rasheed & Abdulla, 2020). The importance of traditional knowledge and maritime community in the MPA in ABNJ management cycle is well established and understood as necessary (Mulalap et al., 2020).

Macaronesia is a region is composed of Small Islands, stressing the need for compatibility between human activities and conservation through the synergetic engagement of stakeholders and the local population (Calado et al., 2014). In addition, the Macaronesia region is an excellent study case because of their engagement in working together as an outermost region to conserve marine biodiversity.

The aim of this paper is to develop a proposal of a well-managed MPA in ABNJ context, through expert consultation. Moreover, this paper want to answer if it is possible to develop a proposal for MPAs participation in ABNJ on Macaronesian context.

MATERIALS AND METHODS

The methodology of this work is based on questionnaire to experts survey to develop a proposal of a well-managed MPA in ABNJ context. The proposal was compared with Macaronesia region study case, in order to point some applicable suggestions to manage the area.

A set of key actors involved in the ABNJ discussion were selected for their knowledge and ability to explain area-based management tools (ABMT) participation in this context, it is important to point that this is a new field and there is a small number of specialists working in the area. At first, the “BBNJ Working Group” was identified as the leading specialists on the topic, a group that later became the Preparatory Committee (PrepCom) (Rochette et al., 2015). Then, nine extra contacts were added to the list as a suggestion from the foremost experts’ group and considered all equability the gender and undeveloped countries approach (UN, 2019). Guided by the previous steps, twenty-four questions on a semi-structured questionnaire survey were carried on a mix of yes/no/maybe, select among choices, scale ranking, and open-ended questions. The online survey tool “Google Forms” was selected as the robust platform to pursue the questionnaire and gather results easier and be answered from anywhere, making the process more accessible; besides, the output is easily interpreted (Sandhya et al., 2020). Each block of questions sought to evaluate three central questions: (i) Is it possible to create an International Body for ABMT (centred in an Ecosystem-Based Management)? (ii) How should be the local maritime community involvement during all management cycle? (iii) How to conduct participative management in MPAs in ABNJ?

RESULTS AND DISCUSSION

The results and discussion of the current paper will be separated into three main blocks divided by objectives, instruments, and resources necessary to develop a proposal of a well-managed MPA in ABNJ context.

1. Objectives

The experts (100%) recognise the importance of traditional knowledge and maritime community in the MPA in ABNJ management cycle. To do so, it must to be well established and is understood as necessary.

The conservation of BBNJ challenges were pointed out by the experts. For example, it is hard to address Monitor, Control, Surveillance (MCS) (Warner, 2014). Besides it, including water column on protections measures is still a not clear path.

Today area-based management tools (ABMT), including MPAs, in ABNJ are conducted inside a patchwork of different international bodies (UNEP-WCMC, 2018). Most of the experts (66.7%) believe that creating an International Body to legislate in AMBT focused on Ecosystem-based management as governance principles. This competent body could assist in the coordination, set some standards, or oversee and put in place MCS.

The experts pointed that the current BBNJ negotiations seem to indicate that the Conference of Parties (COP) model, inside the Regional Seas Programmes, could be the best version to centralise, organise, mobilise, and engage current international institutions to build integrated projects in ABNJ (Collins et al., 2020). It is crucial to count on a scientific and technical body, too (Wright et al., 2019).

One expert wrote that "the Treaty needs flexibility and a suite of options to best react to the ecological and political realities of each proposed area so that the result is a network of ecologically connected and properly protected MPAs that are representative and preserve sufficient marine life to ensure the ocean can provide for all future generations to come".

The environmental centred approach is even more necessary to protect BBNJ (UNEP-WCMC, 2018). Macaronesia region has a dynamic interconnection and must be understood as environmental-based solutions. The region, if well managed, could become an example of a marine corridor by creating political awareness of issues relating to ABNJ.

2. Instrument

The main instrument that should take place in an ABNJ context is a regular forum to debate ABMT management globally and locally. The Conference of Parties (COP) model inside the Regional Seas Programmes is a potential permitting authority in this context (Collins et al. 2020). Experts highlighted that is essential to ensure the effectiveness of the current institutions based on science.

All experts believe that stakeholders must be included in all MPA management cycle. The "whole process needs to be transparent, open and inclusive" (expert survey), all stakeholders must have a chance to express their opinion. Therefore, it is essential to leave the guidelines text space to "the possibility and acknowledge that other forms of knowledge are relevant" (expert survey). The results show that the importance of stakeholder engagement established until so far with the International documents in ABNJ analyses.
An effective local engagement still lacks the ABNJ context in the conservation practices (Christie et al., 2017). Mobilisation and capacitation are key factors to enhance empowerment during the process (Xavier et al., 2018). The experts agree (91,6%) that capacitation is crucial to guarantee stakeholder participation.

Engage local maritime community goes beyond communication, as it is crucial to guarantee permanent assistant in boundary organisations (Blanchard et al., 2019).

The Working group was selected by the experts as an applicable tool towards MPAs objectivities. The Working groups can be rotative between archipelagos, facilitating exchange between stakeholders and contributing to community engagement (Xavier et al., 2018). To address different solutions into local problems, it is essential to adjust and adapt (IUCN, 2008).

Experts agree that it is crucial to communicate from the beginning of the meetings' objectives and participative forum (Rasheed & Abdulla, 2020). To build trust and reduce or align expectations during the process. Specialists pointed all the importance of explain how the process steps of the participatory process will be.

To follow the COP and Working groups process, it could be implemented Observatory with academic members. An Observatory could help implement an adaptative programme, working closely with MPAs Network to guarantee the protection and resilience of BBNJ (Blanchard et al., 2019).

3. Resources

Engage and maintain the local maritime community during the management process is essential, as explained above. To accomplish it, human resources are a decisive factor (Rasheed & Abdulla, 2020). On a value scale (zero to five), the importance of exchanging knowledge between local maritime communities during the MPA process was most valued as three and four (33.3% each). Each Macaronesia archipelago has its peculiarity and different governance systems (García-Sanabria et al., 2019). Select local focal points in each archipelago to enhance the local maritime community can be a crucial action.

Everyone surveyed (100%) believe that the meetings can be transmitted online. To spread the information, the Internet is one of the main tools (website, App, online forums transmission), but should not be limited to that.

In the specific case of ABNJ, transparency is pointed out by the experts as an essential issue to be addressed in international bodies. There are gaps in undertaking how communication will be passed for the maritime community. Then, to build clear guidelines, considering the entire management cycle, is necessary to really involve all stakeholders.

Usually, the challenges of a well-executed participatory process are the lack of resources and governance (political support) (Rasheed & Abdulla, 2020). It is essential to highlight that more extended finance programs are necessary. Tackling economic terms, an MPA in ABNJ can be profitable, and it is an opportunity to enhance governance (Blasiak et al., 2016). The MPA can effectively bring social, ecological, and economic benefits (Christie et al., 2017).

In the Macaronesia study case, the explorations of whale watching increase is an important economic use of the Ocean. MPAs in ABNJ can help to protect and guarantee a healthy environment for those mammals (Evans, 2018). In that sense, an MPAs coherent Network could promote economic value while supporting environmental protection (e.g., create an environmental fund and collect taxes from visitors in the archipelagos).

CONCLUSIONS

It was possible to conclude the importance of leave open an opportunity to maritime community manifest in MPA in ABNJ. Moreover, is time to acknowledge that other forms of knowledge are relevant.

The Conference of Parties (COP) model, inside the Regional Seas Programmes, could be the best version to centralise, organise, mobilise, and engage current international institutions to build integrated projects in ABNJ.

Considering Macaronesia region specificity, the conclusion is that select local focal points in each archipelago to enhance the local maritime community is essential. Furthermore, it would be necessary to implement Working Groups, rotative between archipelagos, to address different solutions for local conservation practices. Throughout the process, it will be necessary to carry out conflict management with all the stakeholders who work in the region.

Using tourism investment to capacity building for popular participation and training local focal points is an alternative to ensure resources for a longer duration project. Invest in clear communication is fundamental since the very beginning and during the entire process. Bring visibility and transparency to the project and next steps help maintain the community engagement.

In conclusion, it is possible to develop a proposal for MPAs participation in ABNJ on Macaronesian context, based on experts consultation. But still, some new research is necessary in to embrace the participation and engagement in ABNJ in larger scales. Specially taking in account that until so far, no integrated body address the range of problems to be tackled, and a Conference of Parties still only a proposal.

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Strategic environmental sensitivity mapping for oil spill contingency planning in the Peruvian marine-coastal zone

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ABSTRACT
Major oil spills can cause significant impacts on marine-coastal zones, particularly on areas with a high oil spill risk which combine a high oil spill hazard and a high environmental sensitivity. In this sense, a straightforward multicriteria methodology is proposed to determine the second factor of the oil spill risk, namely the strategic environmental sensitivity (SES), in 68 areas covering the entire Peruvian marine-coastal zone. The process comprises the weighted integration of physical, biological, and socioeconomic indicators selected based on their relevance in marine oil spills and the Peruvian context. To demonstrate the SES applicability, an oil spill risk assessment at a screening level is performed in a selected area with current oil production activities. The oil beaching likelihood of worst-case discharge scenarios modelled in January 2021 is used to determine the hazard, while a matrix relating the SES and hazard determines the risk. The results can be used as a decision-support tool to enhance the oil spill contingency planning in Peru, especially on high-risk areas. In addition, the proposed methodologies can be adapted to different local and international contexts and scales.

KEYWORDS
Oil spills, strategic sensitivity mapping, contingency planning, marine-coastal zone, Peru

INTRODUCTION
Major accidental oil spills can cause significant ecological and socioeconomic impacts on marine-coastal zones. The Deepwater Horizon oil spill in the Gulf of Mexico in 2010 is a clear example by having caused the oiling of thousands of kilometers of shoreline, the death of more than a million biological organisms, and more than US$ 20 billion in economic losses (NRDC, 2015; NOAA, 2017). In a context where oil is expected to remain as one of the main energy sources in the world for at least twenty more years (IEA, 2020), it becomes necessary to use tools that help reduce the overall oil spill risk of an operation, country, or region, particularly to support the oil spill contingency planning (OSCP) for the preparedness and the rapid response to major oil spills whose areas of potential impact can cover from national to even international territories, and where the decision-making process of what to protect or clean up first or later is a difficult task. One decision-support tool used by the oil and gas (O&G) industry is the environmental sensitivity maps, adapted over the years to assist both responders and decision-makers according to their needs and the spill tiers. Specifically, strategic environmental sensitivity maps determine the most sensitive sectors and help strengthen the response strategy in high-risk areas—those with a high oil spill hazard and a high environmental sensitivity (IPIECA, IMO & IOGP, 2012).
Countries like Peru are not exempt from being affected by these unfortunate events at any time, since a large part of its maritime domain is used for O&G exploration and production and maritime trade (Perupetro, 2021; UNCTADSTAT, 2021). It

is therefore critical to develop decision-support tools to help reduce the consequences of oil spill contingencies coming from these oil-related activities.

METHODS

Strategic Environmental Sensitivity (SES) Assessment

The entire Peruvian marine-coastal zone was divided into 68 sectors, considering political-administrative units and four distance ranges to the coastline: 0-20, 20-50, 50-100, and 100-200 nautical miles. In parallel, a comprehensive data gathering and document review on publicly available online sources was carried out to identify the main sensitive resources to oil spills in the study area. As a result, physical, biological, and socioeconomic sensitivity indicators (PSI, BSI, SSI) were constructed based on the criterion that the more highly sensitive features on a sector, the more sensitive a sector is (Table 1). The sensitivity of the features in each indicator was incorporated as a relative sensitivity level (RSL) ranging from 1 to 9, 1 referring to the lowest sensitivity and 9 to the highest.

Table 1. Sensitivity indicators per environmental component

Component	Indicator	Sub-indicator	Formula
Physical	PSI_1: Shoreline types	none	$\frac{\sum(S_i \times RSL_i)}{S_S}$ *S: length of shoreline in km; i: shoreline type (ESI); S: sector*
	PSI_2: Depth ranges	none	$\frac{\sum(D_i \times RSL_i)}{D_S}$ *D: number of pixels i: depth ranges; S: sector*
Component	**Indicator**	**Sub-indicator**	**Formula**
Biological	BSI_1: Protected/ recognized biological sites	none	$\sum RSL_i$ *i: biological sites*
Socioeconomic	SSI_1: Coastal localities	none	P_S *P: total coastal population; S: sector*
	SSI_2: Fisheries and aquaculture	$SSI_{2.1}$: Fishing grounds	$\frac{RSL_{S,i} + RSL_{S,j}}{2}$ *i: fish capture volume; j: fleet presence; S: sector*
		$SSI_{2.2}$: Fish landing sites	F_S *F: average annual total fish landing volume in metric tons; S: sector*
		$SSI_{2.3}$: Mariculture sites	$\sum RSL_i$ *i: mariculture sites*
	SSI_3: Recreational beaches	none	$\frac{RSL_{S,i} + RSL_{S,j}}{2}$ *i: beach importance; j: surf importance; S: sector*
	SSI_4: Water intakes	none	V_S *V: total volume of seawater extracted in tons per year; S: sector*
	SSI_5: Ports	none	$\sum RSL_i$ *i: ports*

The sensitivity indicators and sub-indicators were used to obtain the strategic sensitivities of the physical, biological, and socioeconomic components (SPS, SBS, SSS). Prior to any calculation, raw results were normalized, and outliers were managed by constructing five class intervals with the non-null minimum and maximum result among sectors. A categorical-numerical scale was then applied to the five class intervals: very low (1), low (3), moderate (5), high (7), and very high (9). Sectors with a null result were automatically assigned a null value (0). In addition, sensitivity indicators and sub-indicators were weighted considering two scenarios (W): (1) they hold an equal weight (conservative scenario), and (2) they hold different weights based on the theoretical framework on surface oil spills and the Peruvian ecological and socioeconomic context. The Analytical Hierarchy Process (AHP) proposed by Saaty (1987) was used for this process.

$$SPS = \sum(N_{PSI_i} \times W_{ij}) \; ; SBS = N_{BSI_i} \times W_{ij} \; ; SSS = \sum(N_{SSI_i} \times W_{ij})$$

To obtain the overall Strategic Environmental Sensitivity (SES) per sector, the strategic sensitivities per environmental component were weighted considering four scenarios: (A) SPS = SBS = SSS (conservative scenario); (B) SPS > SBS and SBS; (C) SBS > SPS and SSS, and (D) SSS > SPS and SPS. As with the sensitivity indicators, the results per component were normalized prior any calculation using the same categorical-numerical scale.

$$SES = (N_{SPS} \times W_k) + (N_{SBS} \times W_k) + (N_{SSS} \times W_k)$$

Screening Oil Spill Risk (R) Assessment

To demonstrate the SES applicability, a screening oil spill risk assessment was performed in the northern coastal sector A1 (Tumbes), where offshore oil production activities are carried out. Ten worst-case discharge oil spill scenarios (OSS) from these activities were modelled in January 2021, given the relevance of the summer season in northern Peru (Fig. 1). To include the effect of the variability of metocean conditions, OSS were modelled on MEDSLIK-II every three days, reaching a total of eleven 7-day (168 h) simulations run per OSS. Oceanographic data derived from the 1/12° hourly global surface analysis fields of the Copernicus Marine Environment Service (CMEMS) and atmospheric data from the 1/10° 6-h High-Resolution global model (HRES) of the European Center for Medium-Range Weather (ECMWF).

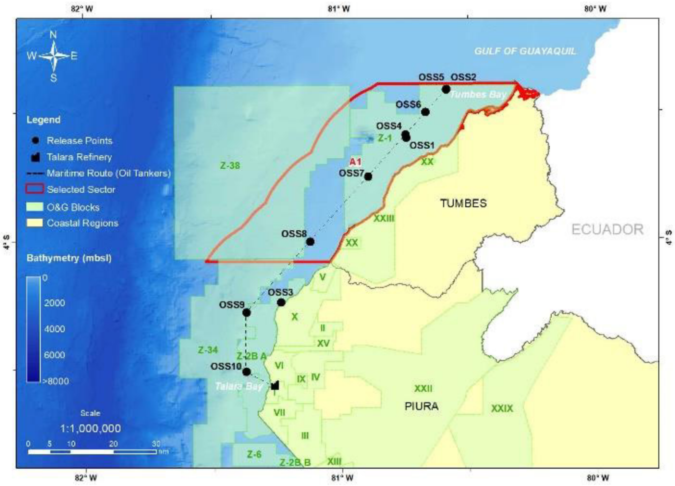

Figure 1. OSS release points in sector A1

The methodology proposed by Lyubartseva et al. (2015) was simplified to obtain the screening oil spill hazard level (H) in sector A1. As a result, the likelihood frequency of oil beaching events (B), expressed as the oil stranding probability considering all simulations run in January 2021 for all OSS (M = 110), was applied. Beaching events were selected since they represent the biggest threats to sensitive resources in the marine-coastal zone. A beaching event was a positive count when the spill, after the 168 simulation hours, covered a coastline of more than one kilometer regardless of the stranded oil concentrations. Finally, H ranged between 0 and 1 (Table 2).

$$H = \frac{1}{M} \times \sum_{0}^{M} B$$

Table 2. Screening oil spill hazard (H) scale

H	Description
[0 , 0.2>	Very Low
[0.2 , 0.4>	Low
[0.4 , 0.6>	Moderate
[0.6 , 0.8>	High
[0.8 , 1.0]	Very High

The screening oil spill risk level (R) was then determined by relating the screening oil spill hazard level (H) and the strategic environmental sensitivity level (SES), following a 5x5 matrix (Table 3).

Table 3. Oil spill risk matrix

		SES				
		Very Low	Low	Moderate	High	Very High
H	Very Low	Low	Low	Moderate	Moderate	Moderate
	Low	Low	Moderate	Moderate	High	High
	Moderate	Low	Moderate	High	High	Very High
	High	Low	Moderate	High	Very High	Very High
	Very High	Low	Moderate	High	Very High	Very High

Source: Adapted from the European Commission Notice on Reporting Guidelines on Disaster Risk Management, Art. 6(1)d of Decision No 1313/2013/EU.

RESULTS AND DISCUSSION

Northern coastal sectors, followed by central coastal sectors, obtained the highest SES, in contrast with southern coastal and offshore sectors which obtained the lowest (Fig. 2). Specifically, sectors A1 (Tumbes), J1 (central Lima), and L1 (northern Ica) obtained the highest SES, confirming the well-known relevance of their ecological, socioeconomic, and scientific attributes, and validating the functionality of the SES methodology.

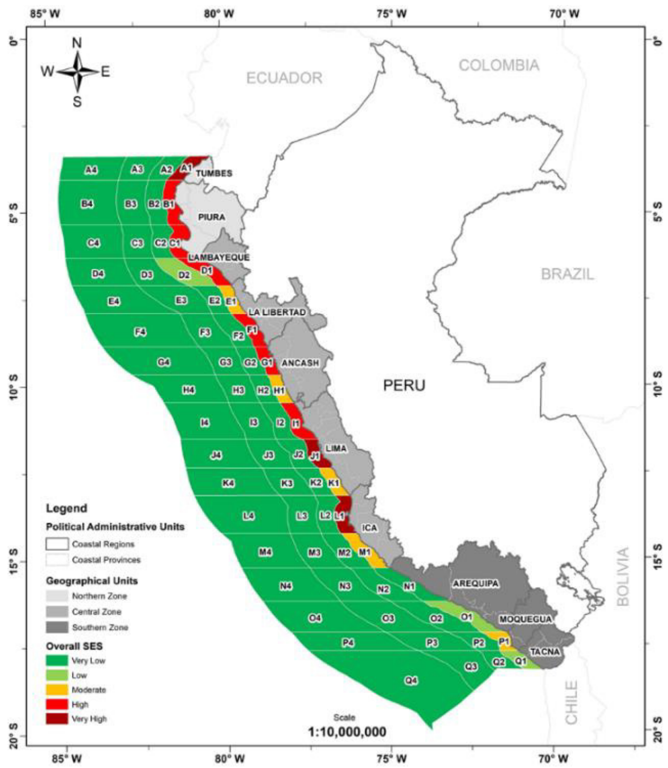

Figure 2. Overall SES in the Peruvian marine-coastal zone

The selection of relevant independent indicators was appropriate to obtain a more realistic SES with the least duplicity of results. They can be improved by including a ground-truthing process, temporal and spatial data not available during the assessment, a seasonality factor, and an oil spill coping capacity indicator. On the other hand, the assignment of weights framed under the Peruvian ecological and socioeconomic context, was also essential for a more accurate SES assessment. Participatory methods incorporating various stakeholders could enhance the weighting process. In addition, normalization and the management of outliers using a categorical-numerical scale were pertinent to ease the comparison between sectors. Normalized results should be understood as a relative sensitivity between sectors and not as a sensitivity given by national or international standardized absolute scales. Likewise, lower sensitivity levels do not mean the absence of highly sensitive resources in a sector, but a lower number of them when compared to other sectors based on the spatial and temporal scale of the present SES assessment.

Regarding the screening oil spill risk assessment, only ten simulations, among the 110 simulations run in January 2021, reached the shoreline of sector A1, indicating a very low H and a moderate R. This screening assessment represents an applied example of what could be done using the SES results. A more comprehensive risk assessment aiming to identify high-risk sectors in the entire Peruvian marine-coastal zone is deemed necessary for a more robust National OSCP. Some improvements for the proposed risk methodology include increasing the number of scenarios, release points, simulation lengths, and temporal ranges of meteocean conditions, and including other current and future oil-related activities.

Finally, the proposed methodologies are straightforward and easily replicable in different ecological and socioeconomic contexts and geographical scales, given its low number of indicators and the simple inherent statistics applied.

CONCLUSIONS

The SES of the entire Peruvian marine-coastal zone was determined following a straightforward multicriteria methodology. This decision-support tool—not available at a national level in the past—can be used in the oil spill contingency planning by supporting the identification of high-risk areas, or in other relevant processes such as the integrated coastal zone management, the marine spatial planning, or the contingency planning of other liquid contaminants.

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Analysis for Integrated Management of Ria Formosa Coastal Lagoon using DAPSI(W)R(M) framework

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ABSTRACT
Ria Formosa lagoon has become a popular hotspot due to its highly productive ecosystem services, providing fisheries and landscapes, attracting many tourists, and rich diversity of species. However, the impacts of human activities have altered the ecosystem. The complex nature of the lagoon has made it challenging to address the environmental issues the lagoon is facing. DAPSI(W)R(M) framework has been used as a tool to create a causal network between the many activities and the multiple acting pressures in the system and the resulting impacts on the environment. Several activities have been identified as adversely impacting the ecosystem, as well as multiple collective pressures from the accumula-tion of several activities' partial pressures. Managers and decision-makers can use the knowledge produced by this study to select and determine the best way to address environmental issues, whether from the source or mitigating the im-pacts.

KEYWORDS
DAPSI(W)R(M), Ria Formosa, integrated management, management framework, lagoon

INTRODUCTION
Coastal lagoons are one of the most highly productive ecosystems, with primary production ranging to be on par with renowned upwelling areas reaching over 500 g C m–2 yr–1 (Kennish, 2016). Being situated between the open sea and landmass creates a transition between the two domains. This has formed unique conditions that gave rise to complex types of environments within the same lagoon. The gradient created by the varying deposits, hydrology, and ecology forms a highly diverse and resili-ent ecosystem (Cataudella, Crosetti and Massa, 2015). Due to the lagoon's complex environment and high biodi-versity constrained within a small region, it can provide essential direct and indirect ecosystem services, as well as supporting many human activities from fishing to tour-ism and forming a historical and cultural heritage (Barbier et al., 2011; Basset et al., 2013; Newton et al., 2018).

Nevertheless, lagoons face many issues, varying from resource scarcity and degradation to climate change and biodiversity loss (Vitousek, 1997). Researchers and man-agers realised the need to cover several perspectives to completely represent lagoons in a holistic, integrative multi-sectorial approach, accounting for the social and ecological systems' interactions to address these convo-luted environmental issues. DAPSI(W)R(M) framework offers such a solution (Binder et al., 2013; Elliott et al., 2017). Therefore, the aim of this study is to analyse and assess the Ria Formosa lagoon for the human activities and its consequences using the DAPSI(W)R(M) frame-work as a social-ecological framework.

MATERIALS AND METHODS
Study Area
Ria Formosa is a shallow mesotidal lagoon formed within a barrier island system on the southern coast of Portugal (Figure 1). The lagoon is enclosed within five barrier islands and two spits, with six inlets to the sea. The Ria Formosa

lagoon covers an area of around 100 km2, with its unusual triangular shape stretching 55 km across from east to west, 6 km from north to sou-th, and an aver-age depth no more than 2 m (Ja-cob and Cravo, 2019; Sousa, Boski and Pereira, 2019). Ria Formosa lagoon holds a very high so-cioeconomic value, as it is capable of supporting fisheries, aquacultures, shellfish farming and salt production. The lagoon's surrounding area also hosts various forms of agriculture production and animal rearing to a lesser extent. Real estate plays a big role in the sur-rounding economy, as well as tourism and recreation, employing a sig-nificant part of the local population, direct-ly or indirectly (Bebianno et al., 2019; Sousa, Cunha and Ribeiro, 2020).

Figure 1 Ria Formosa lagoon in the south coast of Portugal.

Literature and data were collated from peer-re-viewed articles to reports and news article based on a sensitive "rapid" systematic search strate-gy using relevant key-words, either separately or concurrently, and adjusted according to the search engine database requisites in-cluding Google scholar, ScienceDirect, Web of Knowled-ge, and Google, as inspired by the PRISMA me-thod (Page et al., 2021). The lagoon's name is ex-plicit-ly searched in combination with the relevant aspect of interest, like activities and pollution, where several syno-nyms of the keyword were used. The documents were then screened based first on the title, then the abstract, followed by the introduction. The final screened docu-ments were then analysed thoroughly, and information was extracted per the DAPSI(W)R(M) framework ele-ments.

DAPSI(W)R(M) management framework

DAPSI(W)R(M) framework is used to gather, visualise, and understand the issues in the Ria Formosa lagoon and to help in how they can be resolved (Patrício et al., 2016; Elliott et al., 2017). All information gathered can be sys-tematically filled into the Framework's elements in a standar-dised causally linked way and analysed for holis-tic management. Drivers are considered the pri-mary societal basic human needs, as proposed by Maslow, arranged in a five-tier hierarchy pyra-mid (Maslow, 1943). They form the driving force behind many socioeconomic human Activities. Activities, in turn, translates into Pressures, which are the mechanisms of change that can impact and alter the lagoon system to varying degrees. Pressures then act upon the natural environment imposing a State change. These changes can be in physiochemical or ecological properties of the lagoon system. The State changes in the natural system reflect on society as Im-pacts (on Wel-fare). Responses (as Measures) are taken after considering the whole causal chain and left for man-agers and relevant authorities to make an informed deci-sion (Fisher, Turner and Morling, 2009; Turner et al., 2015; Elliott et al., 2017)

RESULTS AND DISCUSSION

Following the DAPSI(W)R(M) framework metho-dology, over 150 literature documents were analy-sed, and its contents were categorised and stan-dardised to fit within the framework elements.
Following the causal links (Figure 2), it was seen that the main driver behind many human activities is basic biological and physiological need. Howe-ver, self-actualisation needs led to the most dama-ging activities in the lagoon, like tourism. Activities resulting from human needs create pressure on the lagoon system. Extraction of living resources, coastal infrastructure, and tourism and recreation are the most extensive sectors in the lagoon and consequently had the most widespread activities (Bolman et al., 2011; Jongbloed, Jak and Bol-man, 2013). In particular, urban development has been the most dam-aging activity, especially sin-ce many illegal and legal houses are constructed

over the dune fields, and an in-creasing value of real estate for tourism is driving them further (Ceia et al., 2010). It has intensified the pressures acting on the lagoon system and has put existing hou-sing in hazardous state. Pressures due to urban development range from water pollution to trophic chain disturbance. This signifies how far-reaching are its impacts throughout the whole ecosystem (Newton et al., 2020).

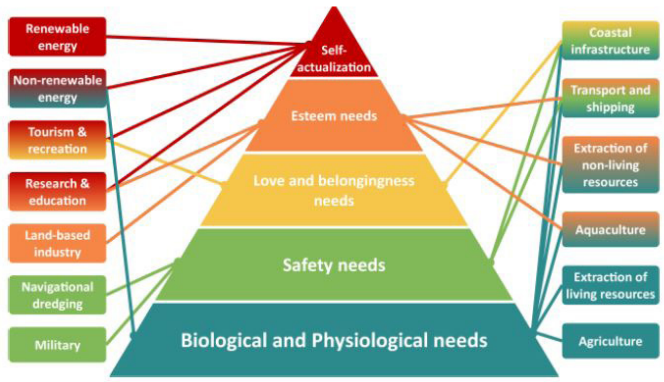

Figure 2 Excerpt from the constructed Ria Formosa DAP-SI(W)R(M) framework showing Drivers in the middle and the relevant Activity sector that it influences on the sides, colour coding of the Activity sector depends on the Driver colour, a mixed colour indicates multiple drivers.

While each activity contributes partially to each pres-sure by varying degree, the collective pres-sure from all the activities is greater than the sum of its parts. This is clearly seen by activities affecting the lagoon's sediment, where individua-lly their contribution may be minor, de-creasing the load, and resuspending already settled sed-iments, imposing a higher collective pressure on the whole lagoon (González-Wangüemert, Domínguez-Godino and Cánovas, 2018). Si-milarly, water pollution and trophic chain modi-fication and disturbance pressures exhibits the same features (Rocha et al., 2013; Cruzeiro et al., 2015). In fact, they are considered as the most damaging pressures, due to the number of components and processes they alter within the marine ecosystem for state change, affecting almost every element of the eco-system's com-ponent and all the ecosystem's processes. It is also worth noting that sediment resuspension and loss pressure, has the biggest state chan-ge impact on the ecosystem's component (Ca-baço, Ferreira and Santos, 2010). These state changes in the marine ecosystem translate into changes in the intermediate and final natural ecosystem services through highly sophisticated interac-tions within the environment. Moreover, exogenic pres-sures, originating from outside the lagoon, would further compound with the current existing endogenic pressures, aggravating the state changes within the lagoon.

Through the built human capital, communities utilise these services for their goods and benefits. Following the causal chain, these negative state changes in the envi-ronment have a considera-ble impact on the livelihoods of the surrounding population, whether in the form of loss of emplo-yment or lost potential opportunities (Teixeira et al., 2014). This impact also extends beyond the physical monetary realm and includes mental and spiritual wellbe-ing and the local heritage.

CONCLUSIONS

Lagoons are one of the most rewarding ecosys-tems, providing services directly and indirectly that sustain hu-man livelihoods and wellbeing. However, conflicting inter-ests and overexploita-tion of the ecosystem's resources have degraded these services and reduced the stability of the lagoon system to recover. DAPSI(W)R(M) fra-mework has proven to be a powerful tool to tra-ce human activities to their drivers and impacts on the ecosystem, following a causal chain. De-cision-makers can use the produced results to identify issues in the Ria Formosa lagoon and how it is interlinked with the driving causes and their con-sequent effects, providing a better cour-se of action to resolve the selected issues based on the framework's elements.

It is suggested that an intervention is needed, particu-larly towards the water pollution and tro-phic chain modifi-cation and disturbances pres-sures, at particularly pres-sured sites. The action can be directed towards the pres-sures them-selves or the contributing activities. In the latter case, it is preferred to deal directly with the most impacting activities. For water pollution pressu-re, a more efficient and higher level of wastewa-ter treatment is need-ed, as well as connecting off-network houses. The farming practices must improve to control and reduce the exces-sive usage of fertilisers. For trophic chain modification and disturbances pressures, increasing the selectivity of the fishing gear and raising fishermen capacity and aware-ness are necessary to decrease the collateral damage produced while fishing and setting the aquaculture grounds.

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Implications of Offshore Wind Energy Developments in Coastal and Maritime Tourism and Recreation

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ABSTRACT
Offshore Wind Farms (OWF) are being developed seen as the right investment to meet climate change targets while bringing autonomy and development to many countries around the world. However, as any other large energy facility, these developments may have external effects on other marine users, especially the ones dependent on marine space and its seascape, such as Tourism and Recreation. A thorough systematic literature review of the past 5 years is performed, as an Impact Analysis tool, to answer how OWF influence Coastal and Maritime Tourism and Recreation and its possible impacts, evaluating public and scientific awareness on and worries about the subject. OWF are found to affect tourism and recreation with prospect of decreasing local welfare and number of visits to these coastal areas with turbines in the horizon, depending on local and development characteristics and management applied. The possible implications change within development stages and are already studied as part of the obligatory Environmental impact assessment for OWF. However, parameters seem to be lacking public sensitivity and participation. The negative predicted impacts are strongly connected to lack of integration between local tourism and recreation stakeholders and OWF developers. Appropriate Tourism Impact Assessment seems necessary for coastal areas with a high density of tourism and recreational activities to be involved in OWF plans.

KEYWORDS
Offshore Wind energy, Tourism, Recreation, Coastal Management, Marine Spatial Planning, Impact Assessment

INTRODUCTION
About two-thirds of the world's population live within 60 kilometres of the coast, and almost half of the world's cities with more than one million people are sited in estuaries, while a significant number of countries have more than 70% of their population living within 100 km of the coast, as shown on Figure1. Consequently, for the past half century, population growth and the consequent energy demand increase drove massive efforts have been made and more are needed to reduce CO2 emissions and reach the 17 Sustainable Development Goals (SDGs) adopted in 2015 by all United Nations Member States. The Sustainable Development Goals 14 – Life Below water - declares that the increase of economic benefits from the sustainable use of marine resources is a target to be fulfilled until 2030. Despite its remarkable progress in the past decade, the gap between the promise of energy for all and the with 800 million people remain without electricity and access to clean cooking fuels remains, as stated by the UN progress report 2019(UN, 1954). Consequently, the number of renewable energy (RE) developments, especially Wind and Solar parks, increases every year.

Wind energy has record installations around the word, with China planning to build 30GW Offshore Wind Farms by 2030 and Europe breaking installation records both on and offshore in Germany, the UK, France, Belgium, Ireland, and Croatia, summing in Europe 3,148 MW of offshore wind energy capacity (GWEC, 2019). The

GWEC report also states that by the end of 2017, nearly 84% (15,780 MW) of all offshore installations were located in the waters off the coast of eleven European countries and according to 2018 Global Wind Report, UK, Germany, China, Denmark, Netherlands, Belgium, Sweden, Vietnam, Finland, Japan are the top10 countries in cumulative Offshore wind capacity in 2017, leaving Ireland in 13th position with 25 MW.

Moreover, according to the statistical office of the European Union (Eurostat), in 2017 over 13 million people in the European Union (EU) were employed in economic activities related to tourism. Nearly 8 million of these people worked in the food and beverage industry, while 2 million were employed in transport, and industries that rely almost entirely on tourism employed 3.6 million people in the EU (European Union, 2019).

Through a robust literature review, the study aims to answer these hypotheses using the results of international cases in a general analysis focusing on a semi-systematic literature review that considers positive or negative impact by finding concrete proofs of effect, as changes on visitor's numbers and decrease in recreation stakeholder's income, but also behavioral changes and fears that can interact with and even change decision-making processes and installation of the OWF. Besides the main impact results obtained focusing on the 6 main hypothesis, open discussions will be developed based on other factors found relevant along the papers analyzed.

MATERIALS AND METHODS

- A modified structure based on the one developed by the report "The economic impacts of wind farms on Scottish tourism" (Scottish Government, 2008), which's core is a large international literature review and a spatial analysis, will be used to study the possible impacts generated by the sitting of OWF in areas where tourism and recreational activities are developed.

The current methodology differs from the base study and other studies by including recreation as a main actor on the analysis and not as included on general tourism, including papers published in different fields and performing a global review. Therefore, by expanding the search methodology used in this study, the current paper seeks a wider range of results in a more restricted Wind energy study.

In addition, according to Siddaway et al. (2019) rules for systematic reviews, to perform the current literature, review the degree of progress of the approached problem must be established, identifying relations, contradictions, gaps, and inconsistencies and comment it, not only summarize it, while showing implications for practice and policy and bringing recommendations and what is expected from the subject when talking about the directions of the related research. According to Snyder (2019), a semi-systematic literature brings an overview research of the field overtime in a broad range of research questions through qualitative and quantitative research articles checking the state of knowledge in the related source's themes.

Therefore, following these methodological definitions, the present work review's is developed as semi-systematic narrative meta-synthesis (SSNMS).

RESULTS AND DISCUSSION

The papers found in this analysis work as indicators of the relationship between the sectors, being the review consequently considered an Impact analysis. Thus, its results are presented as descriptions of the papers offerings and contents that answer the research questions, becoming indicators produced according to the methodology.

Using the previously explained methodology, the chosen combinations of keywords were searched on both Scientific Search Platforms, Scopus and on WOS and, at first, 202 papers were found as result.

Among the results papers containing general studies and papers containing applied study cases were found, providing a wide range of answers, opinions, and experiences. The importance of informing and even advertising successful pilot plants is seen as vital to create the positive relationship between tourists and locals with wind farm projects, as discussed by the paper a.107(Johansen, 2019). In that meaning, also the importance of seeing and real wind farms and having contact with is seen to generate positive future impact, as seeing land-based and Offshore Wind Farms increases the acceptance for future developments. This public behaviour normally analysed on residents for implementation is proved to work also for tourists and recreationists on by the papers, with a strong statement about that on Westerberg et al. (2015).

The existence of impact was analysed as proposed, showing the main conclusion of the study about the OWF influences on Marine and Maritime Tourism and Recreation. The Yes response shows papers in which the influence of OWF is felt by the stakeholders involved and by the sector itself, in the different methodologies and parameters used in each analysis, while the No response shows the papers in which this influence was considered non-existent or not relevant. As many papers had answers that fluctuate between Yes and No in more holistic analysis, the parameter neutral as also used, as stated in the methodology, to show papers that as a conclusion show both results.

Public reaction depends on developers and government assessment of costs, potential risks, and benefits OW projects, information on distance and visual elements of the wind turbines, as they frequently do not have enough knowledge of their impacts and benefits. Westerberg et al. (2015) finds that socio-demographic factors are consistent and do correlate positively with age and income whilst the evidence of the impact of education on preferences is mixed, higher educated respondents being less sensitive to the installation of Offshore Wind Farms at 5 and 8 km from the coast.

Chen et al. (2015) studying stakeholders in Taiwan in a sample composed mainly by fisherman and aquaculture farmers, finds that the respondents' cluster with higher approval rates of OWFs and attendant benefits of OWFs, have relatively lower age, lower experience, and higher educational level.

According to the review produced by Brownlee et al. (2015) the general acceptance of offshore wind decreases with increases in education, income, and age, having male respondents found to be less positive toward offshore wind. Female respondents being more affected by landscape and visual impact is a result present, in higher or lower degrees all along the results. For example, female respondents prefer solar energy due to considering it less damaging to visual landscape and are more likely to feel annoyed by wind turbines noise, while male respondents support wind energy use.

But Firestone et al., (2018) shows that behaviour predictions using demographic factors are not a black and white parameter when divide their analysis highlighting the differences among the effects of demographic variables in the general attitude toward wind power and finds that, even Block Island and Rhode Island being front neighbours and deeply connected communities with similar incomes and educational level, the place attachment is different and a factor much more relevant to this study. Islanders are more likely to support the project and have higher values on place related variables than near ocean coastal respondents. Hence, within these spatial impacts, one of the important results found is the relation between islands and OWF impact on tourism and seascape.

A large majority of the results is kept mostly between 15 and 20 km from shore (Bonar et al., 2015; Christoforaki & Tsoutsos, 2017; Depellegrin, 2016; Nichifor, 2016) with few papers going further on 30km (Griffin et al., 2015). For example, accounting that OW turbines indeed do decrease slightly the tourism in the region if they are visible (Nichifor (2016) uses the 16 km difference between turbines and shore from Lilley et al. (2010) study as the minimum distance to avoid unwanted impacts for this sector. In addition, for Smith et all. (2018), the small geographical nature drives "everyone in the community knows one another" also concentrating the marine recreation sectors geographically, what makes the findings in these areas more direct and the analysis can be performed with greater ease than on other areas. This effect can be especially seen in islands. The analysis on UK's islands performed by De Groot & Bailey (2016) shows how island are specially an attractive location for second homeowners, retirees, and tourism. These island's specificness are highlighted for example on the papers that analyse Block Island Wind Farm (BIWF), first offshore wind farm in the United States, as shown on its related papers analysed in the study.

Another interesting point analysed is the relation between submarine OWF Power Cables and Recreational fishing and boating (Firestone, Bates, et al., 2018). The study shows that, even presenting comments from the population related to the way transmission cables affect tourism and recreation due to visibility and security matters, these comments come from respondents not familiar with cables existence, also having an overall response of No Effect of the OWF cables for Safety of people in water (67%) and Safety of people on beach (72%).

When developing the analysis about the type of impact existent in the papers is searched and marked in the research as YES on the previous analysis. Here, more than half of the results show OWF being connected to negative impacts being that the main finding. But as negative and positive on this matter are not black and white subjects, these results will be described here divided in their classification for better understanding.

CONCLUSIONS

As the society grows, more will the sectors in land, coastal and offshore environments share space and therefore dialog. Especially when it comes to sectors so deeply involved in intrinsic needs as energy and leisure, the idea of an ideal site or ideal situation for the sector must be the best combination for all sectors involved, for all marine users and stakeholders.

In the academic view of the matter, as a result of the analysed literature, a big knowledge gap still exists on publications specifically analysing the impact of Offshore Wind farms on Coastal and Maritime Tourism and Recreation. Although most general offshore Impact Analysis papers suggest no evidence of a serious negative economic impact of wind farms, the study here developed shows that a negative perspective is the major outcome when analysing the sitting of OWF under the perspective of Tourism and Recreation.

Tourism itself can be a danger due to unplanned growth of hotels and tourism facilities and structures to diminish the traffic congestion on coastal roads with little regard to visual impacts or local architecture, Induced development pressures aimed at meeting tourist needs, loss of habitats and of biodiversity such as the typical case of dune destruction and even extinction or pressure on turtle's nesting sites, unsustainable exploitation of natural resources, including excessive abstraction of drinking water and the consequent lack of sewage and effluent treatment and disposal for the highly increased seasonal population and multiple negative impacts in traditional communities where local populations are outnumbered by tourists (European Environment Agency, 2015). Research from the United States indicates that when demand for beach access exceeds infrastructure capacity, coastal resources and the quality of visitor experiences may be compromised, threatening sustainable tourism management and the long-term economic viability of tourism destinations (Snider et al., 2015). Another example is recreational fishing that relies significantly on the availability of large sport fish such as marlins, swordfish and sailfish that need a complex ecological chain to survive and can undermine itself and other sectors if an uncontrolled number of recreationists and lack of information take place (United Nations, 2016).

The impacts found in the literature show a number of cases where the turbines generated decrease of visitation and consequent negative impact on tourism local revenues (directly and indirectly among the chain of stakeholders), but positive and negative changes in beach behaviour, being the impacts most times shown as a triggered by visual perception/landscape intrusion and by place attachment/place dependency and other emotional generated negative responses more then by the physical impacted related to security risks or activities allocation. On the other hand, a large majority of the relevant papers analysed show, as mitigatory or direct positive impact, the possible negative influence as being only dependent of management to be prevented and become neutral or even beneficial to tourism and recreation.

The result presented shows the importance of analysing the type of impact evaluated in the review during the development of Wind farms. The impact generated by OWF on C&M Tourism and Recreation is found to be highly inconsistent throughout the different coastal areas in the world, changing significantly according to type of development, community, and area's physical characteristics. Every OWF project has its unique effects, positive and negative, and that is taken into consideration in the analysis. On the other hand, the literature proves that more the merrier works on amount of information regarding the OWF and acceptance levels.

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Adaptive Management of Environmental Challenges in West African Coastal Lagoons: Case of Ghana

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ABSTRACT
Coastal lagoons are complex environments that, among others, provide valuable ecosystem services for human wellbeing. This research provides an environmental assessment of eleven Ghanaian lagoons along the Gulf of Guinea and delivers management options that can support decision-makers. A socio-ecological framework (Drivers (D), Activities (A), Pressure (P), State (S), Impact (I) on welfare (W), and Response (R) as a Measure (M)) was adopted for the analysis. Results show that basic biological and physiological needs such as food and shelter, social status and dominance, financial self-reliance, and self-actualization are the drivers of fishing, farming, salt extraction, mangrove harvesting, industry, sand, and stone mining, among others. These activities have introduced pressures of selective extraction of fish, birds, and plant species, and salt and sand, the introduction of heavy metals, organic materials, and smothering of substrates. These pressures caused changes in the environment by decreasing the oxygen rate and increasing the biochemical oxygen demand, organic matter, nutrients and pathogens, heavy metals, and reducing lagoon areas and biodiversity. Thus, ultimately impacting human welfare, such as loss of revenue, employment, and seafood provision. Enforcement, re-afforestation, Liquified Petroleum Gas and green farming are recommended as management measures to improve the sustainability of these ecosystems.

KEYWORDS
Socio-ecology; Fishing; Farming; DAPSIWRM; Impact.

INTRODUCTION
Coastal lagoons are vulnerable and dynamic ecosystems with rich biodiversity that, among others, support essential ecosystem services worldwide (Agbekpornu et al., 2016; Mahapatro et al., 2013). Their vulnerability stems from the value and benefits they provide and their proximity to local communities and industries, leading to excessive dependence (Brinks, 2017; Finlayson et al., 2000).

The majority of coastal lagoons in Ghana have not been spared the negative effect of anthropogenic activities including, peri-urban and urban development, waste disposal, mineral extraction, etc., resulting in the characterization of some as dead zones (Armah et al., 2010; Entsua-Mensah et al., 2000). Although few of the coastal lagoons (e.g., Muni-Pomadze, Keta, Sakumo, Songhor lagoons) in Ghana have Ramsar designation under the Ramsar Convention due to their international importance (Ramsar, 2014), they are not free from human activities (Armah et al., 2010; Entsua-Mensah et al., 2000). The Ramsar Convention is an international convention that ensures the conservation and wise use of wetland including, coastal lagoons worldwide (Ramsar Convention Secretariat, 2016). This study aims to analyze the Drivers (D), Activities (A), Pressures (P), State changes (S), Impacts (I) on human welfare (W) and to provide the Response (R) as Measures (M) (DAPSI(W)R(M)) for 11 coastal lagoons (El Mahrad et al., 2020; Elliott et al., 2017) in Ghana. Although DAPSI(W)R(M) has definition discrepancy limitations, its adoption for this study is because of its capacity to highlight all aspects of the anthropogenic activities and their effect on both the ecosystem and society (Gari et al., 2015).

MATERIALS AND METHODS

Benya, Fosu, Narkwa, Muni-Pomadze, Oyibi, Korle, Sakum II, Kpeshie, Mukwe, Songhor, and Keta lagoons in Ghana were studied. Through extensive search, we sampled data from peer-reviewed research papers, thesis, reports, conference proceedings, and online news sources with systematic methods adopted from Van Cauwenberghe et al. (2015), Khamis et al. (2017), and El Mahrad et al. (2020). Based on the search guides, a total of 72 publications significant to the study, spanning periods between 1977 to 2020, were retrieved. Relevant information in the data gathered was collated and analyzed with a socio-ecological framework. The socioecological framework highlights the Drivers (D), Activities (A), Pressure (P), State (S), Impact (I) on Welfare (W), and Response (R) as a Measure (M) known as DAPSI(W)R(M) (Elliott et al., 2017). DAPSI(W)R(M) evolved from Drivers-Pressure-State-Impact Responses (DPSIR), which was an initiative of Rapport and Friend (1979).

RESULTS AND DISCUSSION

Coastal lagoons in Ghana, by their locations, have in the last century suffered the consequences of human activities, pressures, and state change, due to human drivers and the failure of management measures to address the problem cohesively.

The desire for food and shelter to ensure survival. Societal status, and dominance to influence decisionmaking in families and communities. Self-actualization through financial self-reliance in a country where 23 % of the population live below the poverty line is a human activity driver in the studied lagoon (Ghana Statistical Service, 2018; Vowotor et al., 2019). Similar findings were made by Fiandra (2019) and El Mahrad et al. (2020).

Due to the drivers, fishing with dragnet, traps, mosquito nets, gillnets, and cast net, bottles, chemicals are rife in the studied coastal lagoons in Ghana (Figure 1) (Addo et al., 2014; Dankwa et al., 2016).

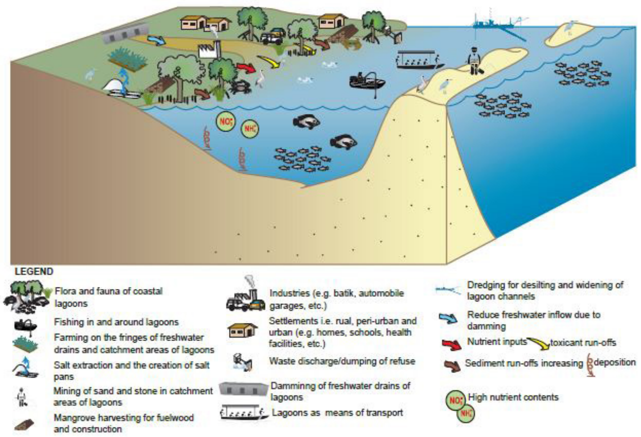

Figure 1: Activities and their effects on studied coastal lagoons in Ghana

Vegetable, crop, and animal farming along the freshwater drain of the studied lagoon are common phenomena due to the available water and arable land. Salt extraction, sand and stone mining, hunting of waterbirds, mangrove and reed harvesting, industrial and residential development, transportation, and damming of freshwater drains are also taking place within the studied lagoons (Agbemehia, 2014; van Leeuwen et al., 2018).

Fishing activities have brought to bear the pressure of selective extraction of T. guineensis, Mugil cephalus, Callinectes amnicola, Penaeus notialis, Crasostrea tulipa, Tympanotonus fuscatus. The average fishing rate is between 1 to 36 kg fisher-1 hr-1 (Dankwa et al., 2016; Ntiamoa-Baidu, 1991). Pressure from the removal of
mangrove species and degradation of vegetation (e.g., 0.53 km2 yr-1 at Muni lagoon) and introduction of invasive species (e.g., water hyacinth in Fosu) (Ametefe, 2016; Environmental Protection Agency of Ghana, 2020). Salt extraction, sand and stone mining, introduction of heavy metals, hydrocarbons, pesticide, pathogens, organic materials, increased sediments and nutrients runoffs (e.g., phosphorous 19.1 to 90.4 kg day-1) (Bentum et al., 2011; Porter et al., 1997).

The state of dissolved oxygen levels in the studied lagoons including Benya, Mukwe, Korle and Sakumo II are below 2 mgl-1 due to pressure from human activities within their catchment area (Ar-

mah et al., 2012; van Leeuwen et al., 2018). The biochemical oxygen demand (BOD) in studied lagoons such as Benya, Fosu, Korle,
Songhor Sakumo II, and Kpeshie have become high (> 3 mgl-1) due to the discharge of effluent and runoff from agriculture activities. Although the BOD of the other studied lagoon were low, there is evidence of anthropogenic impact (Amuzu, 1997; Avornyo, 2017). The majority lagoons studied have become enriched in organic matter, ammonia (> 0.2 mgl-1) and nitrate higher than WHO's guidelines (Eshun, 2011; World Health Organization, 2011). Heavy metal concentrations in the studied lagoons are above USEPA standard for saline environment due to the anthropogenic activities (US EPA, 2019). The size (i.e., area and depth) and waterflow of
the studied lagoons due to damming and construction activities (e.g., housing, bridges and railways) (Kondra, 2018; Nixon et al., 2007). Excessive fishing, hunting, harvesting and pollution have contributed to the loss of biodiversity.

The quantity and quality of lagoon fish and leisure available have declined. Fish is the cheapest source of protein in Ghana, especially for coastal dwellers. However, due to anthropogenic pressure and the resultant change in lagoon state, the availability of fish as food has been affected as the current quantity and sizes of fish from coastal lagoons have reduced (Lamptey and Ofori-Danson, 2014). Sakumo II and Fosu lagoons, for instance, are experiencing little fishing activities due to low fish catch and fish size (Baffour-Awuah, 2014).

Flooding, outbreaks of cholera, malaria, and urinary schistosomiasis have increased. For instance, residents within the catchment areas of Korle, Sakumo II, and Keta lagoons have been experiencing severe flooding during the rainy season because the lagoons have become shallow due to siltation and pollution (Boadi
and Kuitunen, 2002; van Leeuwen et al., 2018). The spiritual and cultural significance of lagoons is on the decline due to reduction in quantity of fish and size of lagoon.

Pungent smell and reduction in aesthetics due to heavy pollution of Fosu, Korle, Kpeshie, and Benya lagoons in Ghana have reduced their appeal as leisure centers (Boadi and Kuitunen, 2002). Although laws, restoration projects, taboos, and customs are in place, the status quo remains. Hence, measures including the use of liquified petroleum gas in place of mangrove, enforcement, re-afforestation, green farming, among others, were suggested.

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Bio-based plastics are not always biodegradable, and biodegradable plastics are not always bio-based: which cause concerns for the marine environment?

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ABSTRACT
Non-biodegradable conventional plastics are ubiquitous. Scientist are alarming the detrimental impacts of these plastics on the environment while biodegradable plastics replacements are now picking up in the polymer science. Not all the biobased plastics are biodegradable in fact they behave as the conventional plastics. Since, the lack of data on the toxicity of biodegradable plastics leads to another crucial concern as on the conventional plastics. Current status of scientific studies and publications on biodegrable plastics and their impacts on marine environment was analyzed through Bibliometrix metadata analysis tool and found that scientific production annual growth rate was 58.49%. Several countries closely watch the issues cause by the biodegradable plastics too. If the biodegradable plastics are not completely degraded, they leave their remnants that cause severe threat to the aquatic environments. Therefore, an integrated continuous investigation is essential to evaluate the subsequent toxicity of bio-based biodegradable plastics in marine environment.

KEYWORDS
biodegradation, bioplastics, toxicity, marine environment.

INTRODUCTION
Unprecedented loading of plastics into the oceans is a desperate menace to the marine biota and its' ecosystem services to humans and other associated communities. The mass plastic production leading to an exponential increase of single-use items waste disposal took place in the 1950's approximately and accumulation of these slowly degrading materials raise severe concerns on the eco-toxicological effects to the biota either in the terrestrial and aquatic environment.

To tackle the long term persistence of the plastics, the need for compostable plastics have been increased and resulted in the production of biodegradable plastics. Figure 1 shows the concept of the biodegradable plastics from petroleum and bio-based plastics. Not all biobased plastics are biodegradable and not all biodegrable plastics are bio-based (Krieger, 2019). It is only in the very recent years that scientists have been centering their attention on biodegradable plastics and very few reviews seems existing. The composing units of bioplastics and biodegradable additives in conventional plastics have potential cascading eco-toxicological impacts to the marine biota. (Palsikowski et al., 2018). In addition, microplastics from biodegradable plastics also reported the impacts on marine organisms (Green et al., 2016). The aim of this discussion to understand the status of the scientific articles and the way forward to focus on the eco toxicological studies to identify their potential threats to the environment.

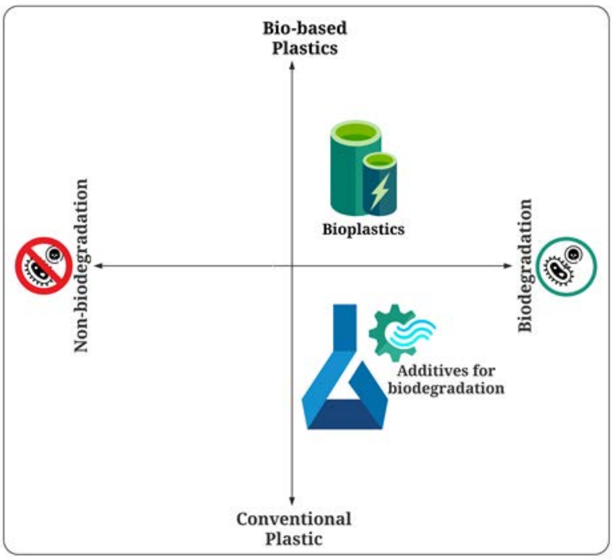

Figure 1. Conceptual diagram of biodegradable plastics

MATERIALS AND METHODS

Bibliometrix, an R-tool for comprehensive science mapping analysis (Aria, M. & Cuccurullo, C., 2017) was used to understand the current trends of publications on impacts of biodegradable plastics in aquatic environments. The following keyword thread was used to pinpoint the articles published during 2000 to 2021 in Scopus. "biodegradable plastic*" OR bioplastic* OR "bio-based plastic*" AND "marine organism*" OR mussel* OR "aquatic environment".

RESULTS AND DISCUSSION

There were 45 articles found via the keyword thread in the Scopus. Then the most relevant articles were filtered and 26 selected. The annual scientific production growth rate is 58.49%. It shows that the biodegradable plastics are getting more concern among the scientist. Italy, Sweden and China are the major countries contribute the scientific work on these plastics. It emerges that plastics currently on the market as biodegradable products do contribute to plastic pollution if they are lost or not properly dumped. They do not degrade completely in the environment, and in case they do it not as quickly as thought leading to potential harmful effects to ecosystems. Also, the environmental features (i.e. seawater vs freshwater) greatly influence this phenomenon, thus requiring more specific studies.

Further, bioplastic products contain a number of chemicals used as additives, similar to conventional plastics (Gunaalan et al. 2020). Some of these, for example Bisphenol A, are known to have endocrine disrupting effects on marine fauna (Canesi and Fabbri, 2015). However, most additives are not declared by producers and poorly investigated at the moment.

Studies well demonstrated toxicity for freshwater invertebrates (Zimmermann et al., 2020). Few ecotoxicological assays have been performed on marine organism ascidian, mussels by using conventional, and bioplastics (Khalid et al., 2021; Manfra et al., 2021) where the functional activities were downregulated by the bioplastics.

The few data available on the existence of biodegradable plastics in the marine ecosystem can construct the platform for research opportunities to fill the knowledge gaps that solve the mystery of their suitability to tackle marine plastic pollution.

CONCLUSIONS

Biodegradable and bioplastics should need an crucial concern on their eco-toxiocological impacts on marine organisms since their behaviour and fate in the aquatic enviromment is unclear since there is no global standards or norms currently available for their disposal in the aquatic environments.

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Amount, sources and composition of sedimentary organic matter, and associated influences on sedimentary mercury in an impacted estuarine system, Mobile bay, Alabama

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ABSTRACT
Estuaries are hotspots of organic matter (OM) production and transformation. This study investigates the amount, source, and composition of surficial sediment OM in a river-dominated estuary – Mobile Bay, AL, USA – using stable isotopes and molecular biomarkers. Overall, carbon to nitrogen ratios (7.14 ± 2.78, n=58) and 13C of total organic carbon (-27.98 ± 1.56, n=58) show that C3 plants and marine algae are the two primary sources for sedimentary OM. 13C values increase along a salinity gradient, suggesting a gradual reduction of river-delivered terrigenous OM from the river mouth to the inner bay. Preliminary sediment Hg concentration data (0.0173 ± 0.1809 mg/kg, n=14) do not significantly correlate with Total Organic Carbon (r = 0.48, p = 0.079) or Total Nitrogen (r = 0.48, p = 0.086). Molecular biomarkers are also being analyzed to provide more detailed insight into the origin, type, and fate of OM and how these factors influence distribution of Hg in Mobile Bay sediments.

KEYWORDS
Sedimentary Organic Matter, Stable Carbon Isotope, Stable Nitrogen Isotope, Estuary, Biomarker, Mobile Bay

INTRODUCTION
Estuaries are dynamic and productive systems that provide essential ecosystem services. Estuaries receive inputs from diverse sources such as terrestrial and marine environments [1], and they are hotspots for organic matter (OM) production and processing [2]. Therefore, studying OM dynamics in estuaries is crucial to enhancing understanding of the sources and fate of OM along the river–estuary–ocean margin, which has important implications for water quality, aquatic habitat conditions, and carbon budgets at the land-ocean margin.

Processes regulating OM in estuaries remain poorly understood owing to their complexity. Multiple OM sources (e.g., marine algae, marsh plants, riverine and anthropogenic inputs) and environmental drivers (e.g., river discharge, tidal change) are simultaneously involved. The Mobile Bay Estuary has been impacted by accelerated human activities, representing many such systems in the northern Gulf of Mexico and other coastal regions. To date, the primary factor(s) and process(es) that control the source, transformation, and preservation of OM in Mobile Bay sediments remain unidentified.

The nature of OM in estuarine sediments also plays a role in the distribution of toxic metals, including Hg. The distribution of Hg has been reported to be influenced by organic matter content, with studies [3] reporting correlation between sediment TOC and Hg concentrations. Other studies [4] have observed that the composition and quality of sedimentary OM influence the distribution of Hg differently.

Unraveling the complexity of estuarine OM dynamics requires the application of multiple geochemical tracers. Stable carbon isotopes have been extensively used to distinguish OM sources in aquatic ecosystems; however, different sources can have overlapping 13C values, which often makes result interpretation difficult. Molecular biomarkers can provide more detailed and unambiguous source information, as different biological sources produce distinct suites of molecules resistant to biodegradation and diagenesis.

The objectives of this study are twofold. First, we will assess the amount, sources, and composition of sedimentary OM in Mobile Bay. This will answer the questions "what are the sources of sedimentary OM?" and "how do the sources and composition of sedimentary OM vary in response to hydrological and biogeochemical drivers?". Second, we will investigate the influence of sedimentary OM on the distribution of Hg in Mobile Bay.

MATERIALS AND METHODS

Study Site

Our study site, the Mobile Bay Estuary, has been called "America's Amazon" due to its diverse biological communities and associated habitats, such as oyster reefs, tidal wetlands, and submerged aquatic vegetation. Mobile Bay is situated at the northeast Gulf of Mexico and the fourth largest river system in the United States – the Mobile River system with a mean annual discharge of 1,750 m3/sec (62, 000 ft3/sec). The watershed of the Mobile River system drains an area of more than 110,000 km2 (43,000 mi2), including more than two-thirds of the State of Alabama, the northwestern section of Georgia, and the northeastern portion of Mississippi and Tennessee [5], [6]. The total surface area of the Mobile Bay estuary is approximately 1,070 km2 (413 mi2), and depths in the bay generally range from less than 1 m (3 ft) to over 9 m (30 ft) [5], [6].

Mobile Bay has a larger proportion of fine-grained sediments compared to other estuaries in the northern Gulf of Mexico due to the large deltaic buildup at the head of the bay, which traps coarser sediments delivered by rivers. This abundance of fine-grained sediments is of environmental significance, providing large surface areas to absorb organic and inorganic contaminants [5]. Organic and inorganic contaminants can negatively impact water and ecosystem quality, bioaccumulate through the aquatic food chian, and impact seafood safety and public health.

Sampling

The sampling program for this study started in June 2020, and it is expected to run for two years. Using a 4 km by 4 km grid, ninety-six (96) surface sediments samples have been collected so far at water depths of 0.88-11.16 m using an Ekman stainless steel dredge sampler (6"x6"x6"). The sediment samples were stored in pre-combusted glass jars and preserved on ice until delivered to the lab, where they were kept in the freezer until being lyophilized. Water quality parameters at the water column-sediment interface were taken at each sediment sampling station using a YSI Pro Plus multimeter.

Bulk OM Analysis

About 5 g of each freeze-dried sample were acidified with aqueous 10% HCl to remove inorganic carbon. Depending on the organic matter content, about 5–100 mg of each sample was wrapped in a tin capsule and analyzed for Total Organic Carbon (TOC), Total Nitrogen (TN), and 13CTOC and 15N of TN on using a Costech Elemental Analyzer (ESC 4010) coupled with a Thermo Scientific Delta V plus Isotope Ratio Mass Spectrometer in a Finningan Conflo IV. The carbon isotope compositions of all samples are reported using the standard notation (‰) relative to PDB. The measurement precision is estimated to be ±0.1‰ based on multiple NBS-19 standards and replicate measurements. This analytical process will be repeated for the potential OM end members, which are currently being oven dried.

Total Hg

Sediment total mercury concentrations are determined using a Brooks Rand MERX-T DP CVAF mercury analyzer, following USEPA Method 245.7 [7]

PRELIMINARY RESULTS AND DISCUSSION

Sources of Organic Matter

Sediment TOC values range from 0.02 to 2.36%, with no apparent spatial trend. Several samples, especially those with a high sand content, yield low TOC, while the clay-rich samples, mostly dark-colored, have higher TOC contents.

The 13C values of TOC (13CTOC) range from -27.98‰ to -23.088‰, with an increasing trend along the bottom water salinity gradient (Fig. 1A). Sediment samples from high-salinity areas are enriched in 13CTOC a noticeable depletion towards the bayhead. C3 vascular plants have more depleted 13C values (< 25‰) compared to freshwater and marine algae which can have very broad 13CTOC range (22‰ to 28‰) [1], [8]. On the other hand, the C/N ratio decreases along the salinity gradient (Fig. 1B), and C/N ratios of algae and bacteria are lower than those of marsh and terrestrial plants (Fig. 2). These trends show a continuous reduction of terrigenous OM from the Mobile river mouth to the inner bay.

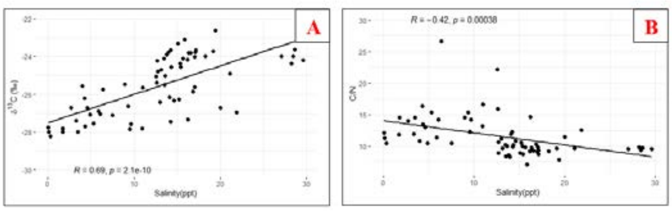

Fig. 1: Scatterplot A) of 13CTOC and B) C/N ratio versus bottom water salinity in surface sediments of the Mobile Bay

To further constrain the sources of sedimentary OM, we plotted 13CTOC against C/N (Fig. 2). The plot shows that the two primary sources contributing to sedimentary OM in Mobile Bay are terrestrial C3 plants and marine algae.

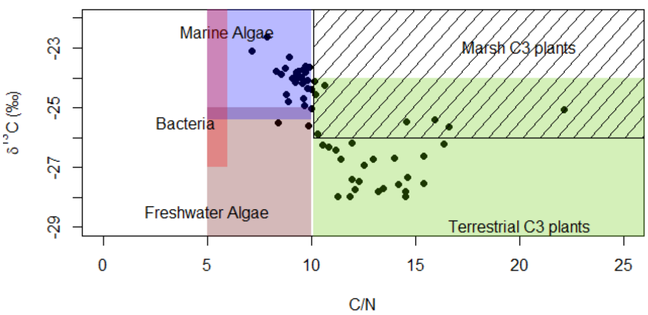

Fig. 2: Cross-plot showing the range of 13CTOC and C/N ratios of sedimentary OM in Mobile Bay sediments. End-member ranges (bacteria, algae and plants) are from [9] and [10].

Organic Matter vs. Hg

None of the organic parameters show significant correlations with sediment Hg concentrations (TOC, Pearson r= 0.48, P= 0.079; TN, r = 0.48, P = 0.086; 13CTOC, r = 0.13, P = 0.67 and C/N, r = 0.1, P = 0.73; n=14). However, the relatively low p values related to TOC and TN suggest that significant correlations may emerge with more data.

ONGOING DATA COLLECTION

Although stable isotope and elemental compositions provide insight into potential sources of sedimentary OM in Mobile Bay, the overlapping signatures of potential sources limit the resolution of source apportionment. Therefore, we are analyzing molecular biomarkers, which can resist biodegradation and give unique signatures of precursor organisms. These characteristics of molecular biomarkers will reveal the specific sources and compositions of sedimentary OM in our study area.

Additionally, we are analyzing the bulk parameters of potential endmember OM sources from our study site, including terrestrial plants, marsh plants, inland sediment, phytoplankton, and zooplankton. We will build a mixing model using water quality parameters, biomarker data and bulk parameters of sediment and endmembers. Finally, we will be analyzing the Hg concentrations of more sediment samples for to further investigate the influence of OM from different sources on the Hg distribution in the Bay.

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Ecologicalstatusofbenthiccommunitiesafteralongstoryof trade-offbetween conservation and exploitation in the Goro Lagoon,northernAdriaticSea

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ABSTRACT
Coastal lagoons are among the most disturbed ecosystems in the world,yet shaping unique communities of inhabiting fauna and providing many ecosystem services. Goro Lagoon in the North Adriatic-coast (Emilia Romagna Region,Italy) is a lagoon of economic importance (shellfish aquaculture) and conservational interest(Ramsarand UNESCO heritage site).The aims of this study were to assess benthic assemblages in the Goro Lagoon and to analyze the changes of their structures comparing data from 1984/85 campaign with present data (2020/21). In this study, four stations (FV, BM, GO and CS) of the lagoon were sampled for macrobenthos and sediment in two periods(October 2020 and March 2021). Each of these stations was chosen to represent areas of the basin with different hydrographic and sedimentological characteristics. Macrobenthic assemblage structures resulted different in the four stations with seasonal variations. The differences in assemblage structures could be best explained by the distribution of finesand (Rho=0.425).Compared with the published literature,macrobenthic assemblage structures of the present-day had low species diversity but also a smaller number of tolerant and opportunistic species as well, indicating a slight improvement in ecological quality.

KEYWORDS
Goro Lagoon, Parco del Delta del Po, macrobenthic community, ecological shift, Adriatic Sea, brackish lagoon assemblages

INTRODUCTION
Coastal lagoons are defined as transitional aquatic ecosystems between the land and sea, characterized by semi-isolation from the sea by a natural barrier; i.e., a sand barrier, land spit or a similar kind of land mass, having one or more inlets to have restricted exchange of water, sediment and organisms with the adjacent ocean area (Pérez-Ruzafa etal., 2019). The European continent has the lowest percentage of lagoonal coverage in the world (5.3% of total continental coast); thus, the lagoons are considered Priority Habitats for conservation under the European Habitats Directive (Herbert etal., 2019). In the Mediterranean region, there are a total of 400 coastal lagoons along an area of 6400 km2, however, only about 50 lagoonal systems have been studied for their hydrodynamic or ecological status (Pérez-Ruzafa et al., 2019).

Coastal lagoons are highly productive systems. They support a unique set of aquatic life (marine, brackish and freshwater) with a greater variety in species diversity, high density and exclusive community structures. On the other hand, these ecosystems are heavily exploited by about 40% of the population inhabited within 100 km of the world's coasts for a broad set of ecosystem services i.e., provisional, regulatory, supporting and cultural (Newton etal., 2014), thus being most anthropogenically threatened as well.

In its synthetic report, the Millennium Ecosystem Assessment recorded that, wetlands are the most damaged and lost ecosystems of all the other ecosystems globally, and the consequence is declining diversity of the species that depend on both freshwater and coastal waters for their survival. Thus, long-term monitoring and sustainable management of these ecosystems has been a highly discussed topic in the recent years. Many studies have done with experimenting various types of management strategies to effectively manage coastal lagoonal systems using different tools that are often coupled with biological and ecological characteristics of the ecosystem such as primary productivity, secondary productivity, benthic assemblages, etc. (Casini etal., 2015).

Sacca di Goro in the northern Adriatic coast in Emilia- Romagna Region of Italy, is a small restricted, microtidal coastal lagoon, which has been protected by the Ramsar Convention and also as a UNESCO Heritage Site and Sites of Interest by the European Community (Viaroli et al., 2005). Nevertheless, a larger part (~10 km2) of the lagoon's surface is exploited for intensive aquaculture of Manila clams (Ruditapes philippinarum) (Zaldívar et al., 2003). It has been well-documented in many literatures to have anthropogenic disturbances from the manipulation between conservation and exploitation, every now and then (Reizopoulou etal., 1996; Ponti etal., 2009; Abbiati et al., 2010; Pitacco et al., 2020), thus affecting the consistency and community structure of its macrobenthic fauna. Hence, this study highlights the importance of assessing and long-term monitoring of biodiversity and ecological status of macrobenthic community of Sacca di Goro in order to understand the impacts of these manipulations on their assemblage and community structure, eventually to protect the ecosystem in degraded areas, to plan restoration and to avoid future conflicts between relevant stakeholders.

MATERIALS AND METHODS

Sacca di Goro (Lat: 44.78 – 44.83 and Lon: 12.25 – 12.33) is a coastal lagoon positioned in the southern part of the Po River Deltaic System in the Emilia-Romagna Region (Italy), with a total surface area of around 35 km2 and a total volume of 51 million m3 (Maicu et al., 2021). In this present study, four stations were sampled (Foce Volano (FV) (Lat: 44.82, Lon: 12.27), Centro Sacca (CS) (Lat: 44.83, Lon: 12.30), Gorino (GO) (Lat: 44.79, Lon: 12.36) and Bocca Mare (BM) (Lat: 44.80, Lon: 12.32)) in two periods (October 2020 and March 2021) for benthic macro fauna and sediment. These stations were the same sampled in past (Reggiani, 1988) and were chosen to represent areas of the same sub-basins with different hydrographic and sedimentological characteristics. The sampling protocols were best match with the old study. Benthic macrofauna samples were sampled using a Wildo Box-corer (15×15 cm2), sieved through a 500 µm mesh size, collected into pre-labelled, clean plastic jars and preserved with 90% Ethanol. A sub-sample of sediment from the same Wildo Box-corer was simultaneously collected into a small plastic vial and stored immediately under 4°C after bringing to the laboratory.

Sediment samples were analyzed for grain size (>250 µm coarse sand, 250-63 µm fine sand, <63 µm silt and clay (Wentworth Scale)) and organic matter (OM) content (Loss on Ignition method). Macrobenthic communities have been analyzed by univariate indices (species richness (S), total abundance (N), species diversity as Hill's N1 and evenness as Hill's N10) and multivariate methods. Macrobenthic community structure were based on Bray-Curtis similarity of square root transformed data. The resulting pattern was graphically displayed using nMDS (non-metric multi-dimensional scaling). To assess the spatial-temporal variability of benthic assemblages and environmental variables, a two- crossed factors experimental design was adopted with two fixed factors: the first factor "Station" with four levels (FV, BM, GO and CS), and a second factor "Period" with two levels corresponding to the two dates in which samples were collected. Then, the relationships between multivariate assemblage structures and subsets of sediment variables were assessed using the BIOENV procedure. All the analyses were performed using PRIMER 7 with the PERMANOVA+ add-on package.

RESULTS AND DISCUSSION

The environmental characteristics measured by sediment variables showed significant differences among the four stations. FV, the westernmost part of the lagoon was characterized by the highest fraction of coarse sand, the highest fraction of OM content and relatively lower fractions of fine sand and mud (silt & clay). GO, the easternmost part of the lagoon was characterized by a higher fraction of silt & clay, lower fractions of sand (coarse and fine) and OM. The central part of the lagoon CS had a higher content of silt & clay with a higher content of OM, and lower fractions of coarse sand and fine sand. BM, the lagoon mouth, which directly connected with the Adriatic Sea, was characterized with the highest fraction of fine sand of all stations, higher fraction of coarse sand but lower fractions of mud (silt & clay) and OM.

Macrobenthic community structure, defined by their species composition and relative abundances changed in space and time as evidenced by the nMDS plot where the sample points of each period formed two separated clusters and within each period the assemblage from each station appeared relatively well separated (Figure 1).

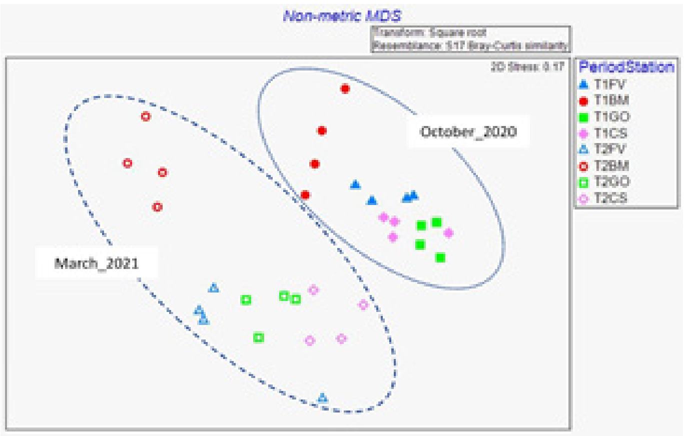

Figure 1: nMDS ordination plot representing the community structure at each station in two time periods on Bray-Curtis similarity of square root transformed data. (T1: October 2020, T2: March 2021, FV: Foce Volano, BM: Bocca Mare, GO: Gorino, CS: Centro Sacca)

The differences among the communities found in Goro Lagoon, can be attributed to the heterogeneity of hydrodynamic and environmental conditions that may determine different ecological zones. BIOENV results gave the highest correlation (Rho=0.425) with the distribution of fine sand fraction and second highest correlation with fine sand and OM content (Rho=0.384) for the structuring of macrobenthic communities. The macrobenthic communities in Goro Lagoon are dominated by the spinoid polychaete Streblospio shrubsolii(68-92% of specimens), followed by the nereid polychaete Hediste diversicolor (0-14.6%), Oligochaetes (0.1-9.5%), capitellid polychaete Heteromastus filiformis (0-8.5%), bivalves: Ruditapes philippinarum (0-9%); Lentidiummediterraneum (0-4.4%); Arcuatulasenhousia (0.03-3%), isopod Cyathura carinata (0-3.4%), and the amphipods: Microdeutopus anomalus (0-2.5%); Corophium orientale (0-4.8%), and the gastropod Hydrobiasp. (0-2.3%).

Comparing the present data with those from the study at the same stations carried out in 1984/85 (Reggiani, 1988), a significant ecological shift from 1984/85 to 2020/21 could be observed (Figure 2). In particular, station GO had a very unique and distinct community structure that was far well-separated from all the other stations in 1984/85, but more or less similar to all the other stations at present.

These shift was mainly due the dominance of species, such as Hydrobiasp., and small polychaetes: S.shrubsolii, Polidora ciliata, Ficopomatus enigmaticus, Capitella capitata, that are indicators of disturbance and specialized to inhabit organically enriched and reduced environments (Corazza, Mistri and Ceccherelli, 1989; Reizopoulou, Thessalou-Legaki and Nicolaidou, 1996; Munari and Mistri, 2008). The number of these tolerant and opportunistic species and their abundances has reduced in the present study suggesting that ecological quality of Goro Lagoon has been a bit improved throughout the past years and macrobenthic community has ecologically shifted towards a slightly better state.

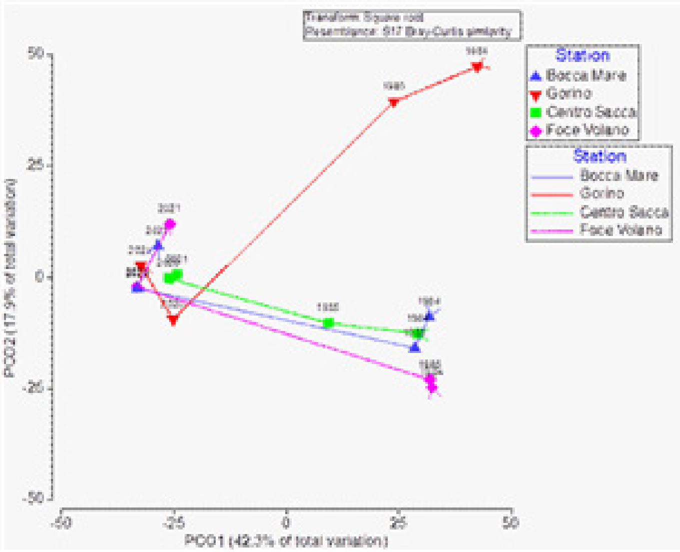

Figure 2: Results of the PCoA (principal coordinate analysis) for 1984/84 and 2020/21 macrobenthic community data on square-root transformed Bray-Curtis similarity

This improvement may be due to the cutting of the sand barrier at the lagoon mouth in 1992 in order to facilitate the water circulation inside the lagoon. After the construction of this canal, water quality improved, decreasing the frequency of eutrophication followed by dystrophy and anoxia. This can be attributed to the observation of present-day community structure at the lagoon which has been slightly improved according to the data.

CONCLUSIONS

From the present study, the spatial-temporal heterogeneity of the macrobenthic communities inhabiting the Goro Lagoon was highly evident, and the community mosaics matched the ecological zones derived by the sedimentary variables, in particular, with the distribution of fine sand fraction across the lagoon. Comparison with the past study allowed a better understanding of how the macrobenthic community structure had been changed in the long-term and to explore what kind of disturbances had caused the changes mentioned above. Thus, long-term monitoring of the ecosystems which are highly disturbed by such kind of anthropogenic influences plays a key role in maintaining a balanced trade-off between the conservation and exploitation in these ecosystems.

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Effects of bioplastic and tire rubber leachates on the Mediterranean mussel, Mytilus galloprovincialis ontogeny and physiology

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ABSTRACT
Bioplastics are one of the most valid alternatives to conventional plastics; however, their potential toxicity has been insufficiently studied. This study is the first to investigate the adverse effects of leachates from bioplastics (starch-based, SB; polylactic acid, PLA; bio-polyethylene terephthalate, BPT) and tire rubber (TR) on the Mediterranean mussel Mytilus galloprovincialis. Endpoints included fertilization, embryotoxicity and larvae motility/survival measured at 0.6 – 100% leachate concentration, and biomarkers of lysosomal/oxidative stress analyzed in adult mussels exposed to 0.6% leachates for 7 days. A preliminary HPLC-MS assessment revealed the presence of several chemicals in leachates including Bisphenol A (BPA) which is an endocrine disruptor, at concentrations ranging from 303.3 ng/L (BPT) to 4809.8 ng/L (TR). The embryo-larval development was the most significantly affected endpoint, with EC50 ranging from 4.61% (TR) to 45.81% (PLA) of leachate. The D-larvae survival was the least sensitive early stages endpoint, as none of the bioleachates affected it. Lysosomal membrane destabilization and lipofuscin accumulation were observed in adult mussels exposed to SB and TR. Glutathione S-transferase activity was increased by SB in digestive glands and by PLA in gills; SB caused a significant catalase activity increase in digestive gland. This study shows that additives released from conventional and bio-based materials can cause ontogenetic and physiological alterations in mussels.

KEYWORDS
Bioplastics, early life stages, biomarkers, marine mussels, additive leachates, BPA

INTRODUCTION
Intensive use and improper waste management strategies have caused the contamination of marine environment (Galloway, 2015). Currently, bioplastics are considered one of the most valid alternatives to conventional plastics and their production is expected to increase by 36% by 2025 (European Bioplastics Conference, 2020). More than 40% of bioplastics are not biodegradable (European Bioplastics Conference, 2020) and biodegradable bioplastics are not able to degrade at the required rate in different environments; in particular, the biodegradation potential is lower in the marine ecosystem (Bhagwat et al., 2020), which absorbs 93% of the world's plastic waste (Pathak et al., 2014). In this context, the weathering (fragmentation and degradation) of bioplastics after accumulation can lead to the leaching of various chemicals that can impact living organisms.

In the production phase, additives such as plasticizers, stabilizers, antioxidants (intentionally added substances, IAS) and by-products or degradation products (nonintentionally added substances, NIAS) are used to improve various properties of materials, or used as catalysts (Hahladakis et al., 2018; Muncke, 2009). Additives are mainly needed for those bioplastics that are directly derived from biota, such as cellulose and starch-based plastics (plants) or PLA (microorganisms), due to their weak physical properties (such as thermal stability) (Beach et al., 2013; Khan et al., 2017). Therefore, the role of bioplastic as an alternative to conventional plastics is being scientifically researched. In this study, the effects of three bioplastic leachates and one conventional polymer leachate on the Mediterranean mussel "Mytilus galloprovincialis" were investigated. Fertilization, embryotoxicity, motility and mortality tests were performed on early life stages; adult were exposed to the leachates to analyze different biomarkers (lysosomal membrane stability, LMS; lipofuscin, LF; malondialdehyde, MDA; glutathione-s-transferases, GST; catalase, CAT). The Mediterranean mussel "M. galloprovincialis" is considered as a bioindicator of microplastic pollution in coastal ecosystem because of its important role as a filter feeder, widespread distribution, high sensitivity to chemical pollutants (Fabbri et al., 2014), bioaccumulation potential, and sessile life (Widdows & Donkin, 1992). They also have hard shells and are easy to handle in the laboratory, which reduce the risk of contamination (Beyer et al., 2017; Setälä et al., 2016).

MATERIALS AND METHODS

The materials used to prepare leachates in this study were three bio-based plastics, starch-based bags (SB), polylactic acid glasses (PLA), bio-polyethylene terephthalate mineral water bottles (BPT) and a conventional polymer, i.e., tire rubber (TR). A plastic to water ratio of 80 g/L was used to prepare leachates in an incubator at 125 rpm for 14 days under dark conditions (Capolupo et al., 2020). The toxicity of the prepared leachates was studied on different life stages of M. galloprovincialis. Fertilization, embryotoxicity, motility and mortality tests were performed to assess the toxic effects of the leachates on early life stages (gametes, embryos and D-shaped veliger larvae) after exposure to different concentrations (0.6, 1, 2, 4, 6, 10, 20, 40, 60, 80 and 100%) of each leachate; a battery of biomarkers (lysosomal membrane stability, LMS; Lipofuscin, LF;
Malondialdehyde, MDA; Catalase, CAT; Glutathione Stransferases, GST) was used to determine the toxicity of 0.6% concentration of each leachate on adult mussels following 7 days of exposure. Controls using microfiltered seawater (0.22 μm) were run in parallel with each assay. All assays were performed at 16 ± 1 °C and the number of replicates (N) was specific for each bioassay.

RESULTS AND DISCUSSION

The concentration of BPA was higher in all the leachates (SB, PLA, BPT and TR) compared to control. It was 4809.8. ng/L in TR, 506 ng/L in SB, 338.8 ng/L in BPT and 303.3 ng/L in PLA. Other chemicals are under quantification. BPA is known as an endocrine disrupting chemical (EDC) (Rubin, 2011; Vandenberg et al., 2013) and is used in various applications such as food and beverage packaging, flame retardant, paper coating etc. (EFSA FIP, 2015). In invertebrates, BPA is known to cause endocrine related effects in several species, including marine mollusks (Canesi & Fabbri, 2015; Flint et al., 2012).

Embryonic development was the most sensitive endpoint in early life stages of mussels after 48-h exposure to SB (0.6 to 100%), TR (1 to 100%), PLA (6 to 100%), and BPT (1 to 100%). According to results, EC50 values for inhibition of embryonic development were reported in the range of 4.61-45.81% and ranked as TR<SB<BPT<PLA. Significant effects on egg fertilization were observed after 60-min exposure to SB (80 and 100%), BPT (100%), and TR (4 to 100%). EC50 values for gametes fertilization for SB, BPT and PLA were not within the range of concentrations tested; for TR, it was within tested concentrations (12.55% of the total concentration). Motility rate was reduced only at the highest concentrations of SB, PLA and TR leachates; survival rate (144 and 216h) of Dveliger was considered the least sensitive endpoint and was affected only by TR. EC50 values for larval motility and survival rate (144h and 216h) for SB, BPT and PLA were also not within the range of concentrations tested, TR leachate has effects with EC50 values within the tested concentrations of leachates. Lysosomal membrane destabilization and LF accumulation were detected in mussels exposed to SB and TR leachates. GST activity was induced by SB leachate in digestive glands and by PLA leachate in gills. SB leachate also caused a significant increase in activity of CAT in digestive glands; BPT leachate decreased the activity of CAT in both digestive glands and gills. However, no significant effect was observed on MDA content of mussels.

In early life stages tests on mussels, TR and SB showed stronger effects on embryonic development. However, gamete fertilization, larval motility and survival were significantly affected only by TR leachates in most bioassays. SB is the only bioplastic that had effects on most of the endpoints. This may be attributed to the complex mixture of chemicals released from this material. According to a study by Fabbri et al. (2014), BPA has the potential to significantly inhibit the embryonic development in M. galloprovincialis. Embryonic development was also severely affected by PLA and BPT. Recently, it has been documented that both PLA and BPA are capable of producing baseline toxicity (microtox) due to different chemical features they contain (Zimmermann et al., 2020). Usually, PLA is compounded with different chemicals to increase thermal stability and mechanical strength depending on the end use, so that composting of PLA requires specific conditions under industrial premises. Therefore, it cannot be biodegraded and remains in the environment until exposed to proper composting conditions (Jem et al., 2010). BPT also contained a high concentration of BPA compared to control. At the same time, it is not completely biodegradable (European Environmental Communications Guide, 2020). and may thus pose threats to living organisms.

In marine bivalves, the most representative biomarker of general stress is LMS (Martínez-Gómez et al., 2015; Aldo Viarengo et al., 2007) and in this study, destabilization of the lysosomal membrane was observed in hemocytes due to SB and TR. Both leachates contained high concentration of BPA. According to Canesi et al. (2005), BPA has potential to affect the stability of lysosomal membrane in M. galloprovincialis. TR containing higher concentration of BPA, induced a stronger effect on LMS compared to SB. This could also be related to the presence of benzothiazole and zinc in the leachate of tire rubber since both benzothiazole and zinc are known to affect the functionality of lysosomal membrane (De Wever & Verachtert, 1997; Giamberini & Pihan, 1997; Hietanen et al., 1988). Significant accumulation of lipofuscin in digestive glands of mussels was also observed by SB and TR Leachates. LF accumulation is a consequence of lipid peroxidation (A Viarengo & Nott, 1993). It may be the consequence of EDCs exposure (Canesi et al., 2008; Gu et al., 2020) like BPA, which showed highest levels in TR and SB leachates.

Overall, basal level activity of GST was higher in gills than digestive glands while opposite trend was reported for CAT, in line with previous studies (Capolupo et al., 2020, 2021; Sáenz et al., 2010). The presence of reactive oxygen species (ROS) induces lipid peroxidation in organisms (Pizzimenti et al., 2010) which stimulates the activity of antioxidant enzymes such as GST and CAT to maintain system via cellular homeostasis (Regoli & Giuliani, 2014). GST as antioxidant enzyme is widely known to detoxify various xenobiotics and by-products of oxidative metabolism. In case of SB leachate, our data suggest that ROS may significantly activate GST in both digestive gland and gills. According to Canesi et al. (2005, 2007), BPA is also capable of altering digestive gland and immune system functions. SB leachate may also contain other unidentified chemicals. According to Zimmermann et al. (2020), starch-based plastics have a higher number of chemical properties compared to other bioplastics. According to another study, the biopolymer “starch” is mostly used to produce packaging material, whose retrogradation can be a problem due to the presence of water. To prevent this, starch is plasticized with water and additives of low molecular weight to make it synthetic thermoplastic starch (Khan et al., 2017). Therefore, these chemicals may be responsible for higher effects induced by SB leachate.

CONCLUSIONS

This study was the first to investigate the adverse effects of bioplastic leachates in mussels. It also evaluated the effects of tire rubber, which is known to affect most endpoints in mussels. Embryotoxicity was considered the most sensitive endpoint for early life stage testing; LMS, LF and GST showed more changes as biomarkers of stress in adult mussels. Overall, SB leachate (among bioplastics) and TR leachate produced more stronger effects. In conclusion, data from this study show that chemicals leached by some bioplastics may cause similar ontogenetic and physiological alterations to those induced in mussels by leachates from conventional synthetic polymers, indicating the need for improving the level of chemical safety in the processes of bio-plastic manufacturing.

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Experimental evidence of how contamination might modify the shrimps' population dynamics and make them susceptible to spatial isolation

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ABSTRACT

Contamination is likely to affect the landscape composition, usually linked to ecological fragmentation, which may impact the distribution, persistence and abundance of species. In the current study, the estuarine shrimp Palaemon varians was exposed to copper (25 and 0.5 µg/L) simultaneously to predation signal and food to evaluate the organism's spatial distribution within a spatially heterogeneous landscape. All experimental landscapes were simulated in the Heterogeneous Multi Habitat Assay System (HeMHAS). As results, P. varians detected and avoided copper, however, predation signal shifted the response to preference over regions with conditions previously avoided, even if that meant to increase copper exposure. When confronted to move towards environments with high food availability, lower connectivity occurred among the shrimps' populations isolated by contamination and predation risk simultaneously. This indicate that contamination might: (i) trigger avoidance in shrimps, (ii) prevent the colonisation towards foraging areas, (iii) enhance the populations' isolation and (iv) make populations more susceptible to local extinction.

KEYWORDS

Spatial distribution, stressors, ecological fragmentation, HeMHAS.

INTRODUCTION

Landscape ecology studies the use of resources that are spatially heterogeneous and how organisms live, reproduce, disperse and interact within a landscape mosaic (Turner, 2005). Several factors, either natural or anthropogenic may cause ruptures in the connectivity changing the landscape composition (Fuller, et al., 2015), which is typically linked to ecological fragmentation, limiting the mobility of organisms among habitats and affecting the populations persistence (Holyoak, 2000).

Contamination has particularly shown to play an important element for the plasticity on habitat selection by aquatic organisms (Araújo, et al., 2020b). This role has received special attention with the novel methods of exposure to contaminants, in which the effects of contamination can be assessed from a landscape perspective. In this sense, organisms are exposed to a chemically heterogeneous scenario and then it is possible to assess how contamination affects the spatial distribution of organisms.

The aim of the present study is to evaluate the role of contamination (copper) on the connectivity loss among habitats and the consequences for the spatial isolation of populationsof the estuarine shrimp Palaemon varians. The HeMHAS (Heterogeneous Multi-Habitat Assay System) was used to simulate spatially heterogeneous landscapes. In order to provide more ecological relevance to the study, in addition to contamination as stressor, two factors were also simultaneously tested: fish kairomones (as predation signal) and food availability.

MATERIALS AND METHODS

The estuarine shrimp P. varians was sampled in the salt pond Salina La Esperanza (Puerto Real, Spain). This species is able to detect and avoid some contaminants (Araújo, et al., 2020b). Tests were performed in the HeMHAS, which comprises several independent compartments that can be connected to simulate environmental scenarios with different levels of connectivity among them (Fig. 1).

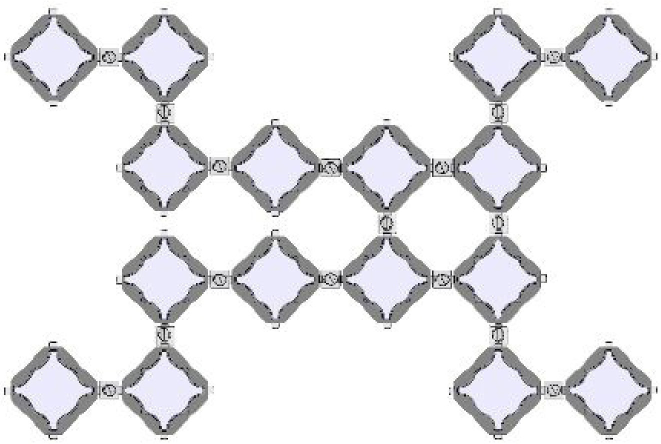

Figure 1: Spatial arrangement design of the experiments

Copper was used as reference substance due to its repellent effect previously observed in P. varians (Araújo, et al., 2020a). Two levels of contamination were used: low (0.5 µg/L) and high (25 µg/L), representing, respectively, an environmentally relevant concentration and a highly contaminated environment. As predator signal, it was used fish kairomones collected from filter of a recirculating aquaculture system culturing Seriola dumerili and Sparus aurata.

Different scenarios varying regarding the levels of contamination and presence of predators and food were simulated in the HeMHAS to create heterogeneous landscapes (Fig. 2). Experiments were conducted in darkness, under regulated temperature (~20°C) and the location of organisms was recorded each 30 min for 4 hours.

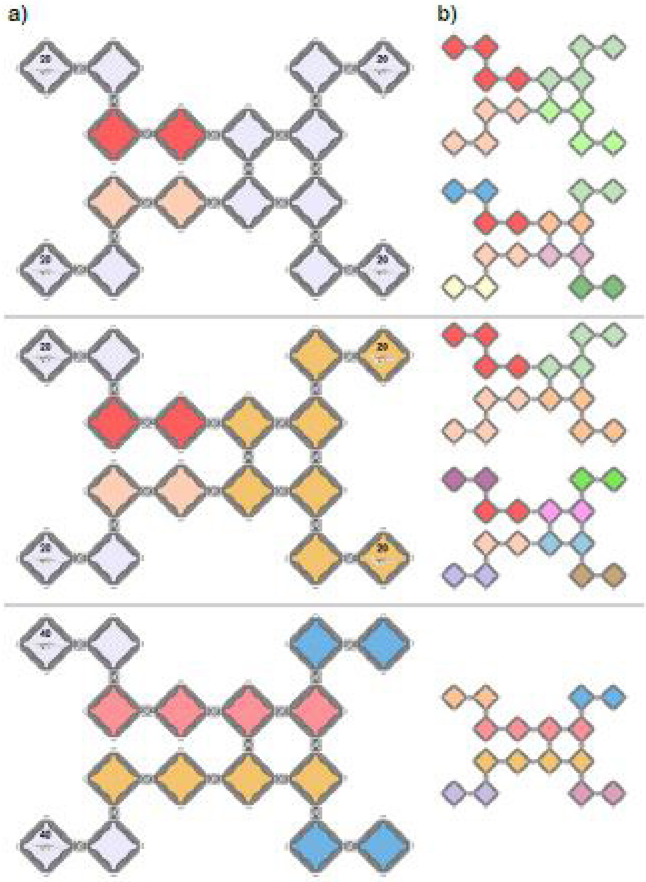

Figure 2: Experimental design of experiments. Column a): experiments with copper (up), copper vs kairomone (middle), and colonisation (down) experiments. Compartments colored in white: control water; red: 25 µg/L copper; light pink: 0.5 µg/L copper; ocher: kairomones; salmon: kairomones + 25 µg/L copper; blue: food. Column b): arrangement for data analysis in regions (4 compartments) and areas (2 compartments)

RESULTS

Fig. 3 shows that shrimps were able to detect copper and avoided the higher concentration, in the arrangement for areas (HCC in plot b) and for regions (HCC in plot a). With kairomones (plots c and d), the response changed: shrimps preferred the compartments with copper (HCC and LCC). This preference is discriminated in the plot d, since within the regions with copper influence, organisms preferred the areas without the contaminant (IHC and ILC).

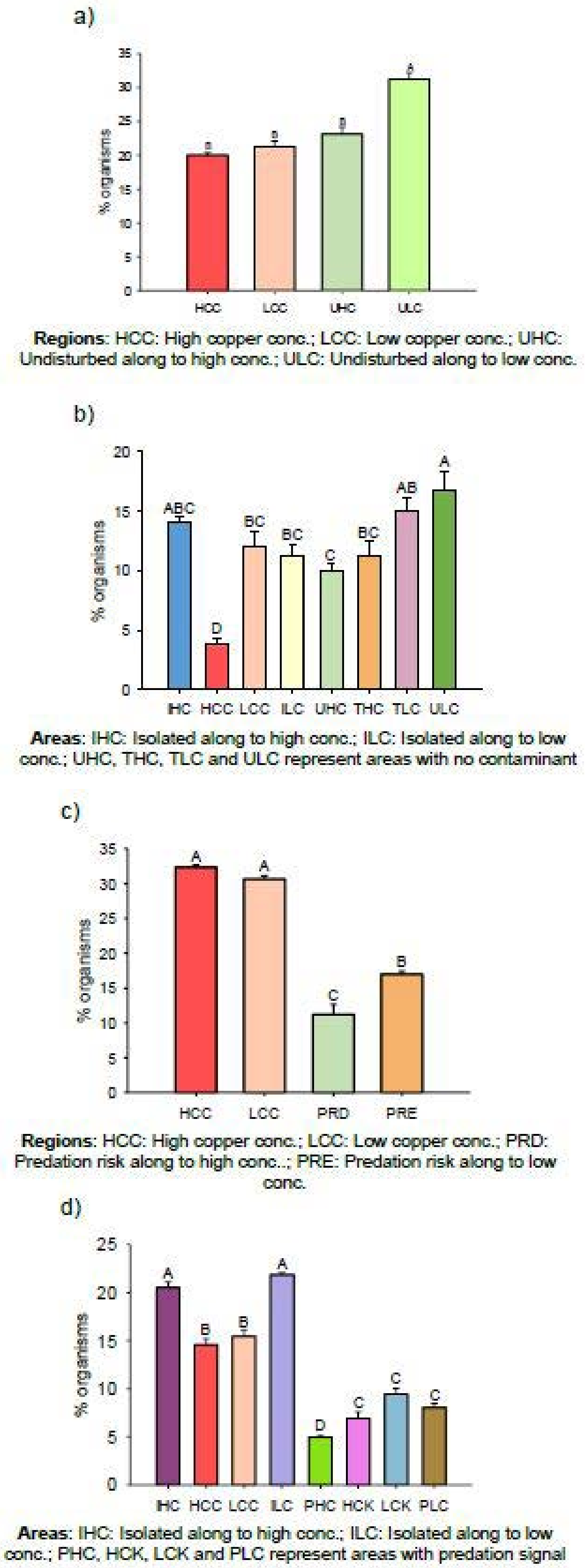

Figure 3: Distribution of organisms exposed to copper (a and b) and copper + kairomones (c and d). The columns' colors are coincident with the colors of arrangements for data analysis

For colonisation assays (Fig. 4), the shrimps were able to colonise the areas with food; although, higher (not statistically different) dynamic transit seems to occur in the region with kairomones and no copper (Fig. 4 plot b).

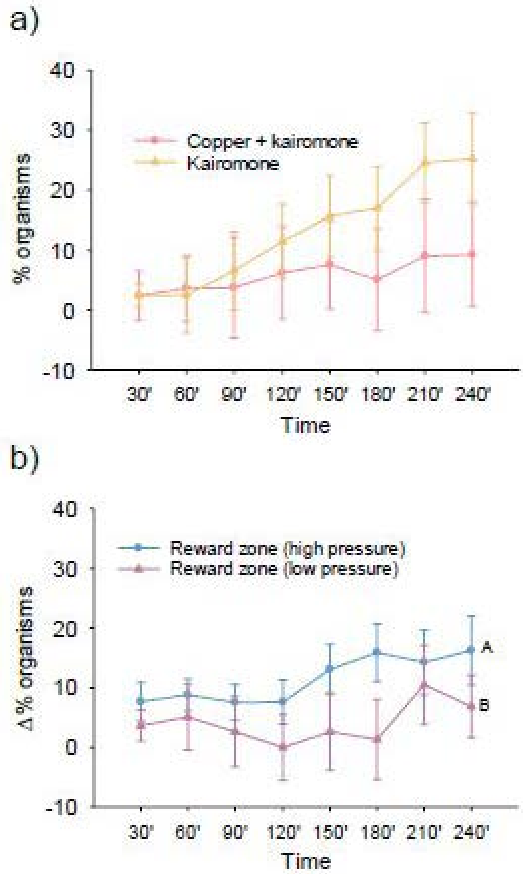

Figure 4: Population dynamic once exposed to stressors/ stimulus simultaneously. a) dynamic on disturbed regions, b) dynamic on reward areas with food. Letters A and B represent that the Δ% of organisms within reward areas under high pressure (influenced by the region with copper + kairomone) and low pressure (influenced by the region with kairomones only) at 240' were statistically different

DISCUSSION

The estuarine shrimp P. varians was able to detect and avoid copper; however, predation signal shifted the response to prefer the previously avoided regions influenced by copper, although the clean and undisturbed area within both regions was prioritized (Fig. 3). Although under forced exposure to copper fish might decrease the anti-predator response (Sovová, et al., 2014), under freechoice exposure assay system, Araújo, et al. (2020) found that shrimps make a balance between a minimal risk of predation with an acceptable contamination level at an acceptable energy-cost requirement. Considering that copper is harmful for the sensory system (Ferrari, et al., 2010), the exposure to copper may increase the organism's susceptibility to both toxic effects of the contaminant and the predation risk.

Furthermore, food requirements plays an important role as well. Organisms in starvation were able to reach areas with food crossing through a relatively high disturbed region, albeit the region with copper presence seemd to have a lower populational dynamic. Our results are similar to previous ones in which the authors suggest that contamination may suppose a barrier for foraging activities (Araújo et al., 2016: Islam et al., 2019). Due to the repellence caused by contamination, organisms are likely to underuse the habitat food resources, which provokes a chemical fragmentation of habitat and changes in the ecological balance at the landscape level.

CONCLUSIONS

The populations of shrimps avoided stressors, either chemical contamination or the signal of predator. Although populations tended to inhabit clean areas with available food, contamination can create a chemical barrier reducing the connectivity among populations. In summary, these results showed that contamination can trigger avoidance and prevent the colonisation, which might isolate populations making them more susceptible to local extinction.

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Early life development toxicity of cigarette butt leachates

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ABSTRACT
Even since cigarette consumption has become a popular practice, abandoned cigarette butts release different hazardous and carcinogenic chemicals after introducing into the aquatic environment by forming leachate and the pathway of these chemicals is complex, diverse, and still unknown. In the present study, three different brands including regular commercial cigarettes and hand-rolling cigarettes were artificially smoked and soaked in the seawater for 7 days to prepare the leachate. The concentration of different metals (Cr, Fe, Co, Mn, Cd, Zn, Cu, Ni, and Tl), BP3, Nicotine, and PAHs were determined from prepared cigarette butt leachates. Acute toxicity tests were carried out exposing organisms to different leachate dilutions (Control, 0.16,0.32, 0.64, 1.3, 2.56, 5.12, 10 and 16 butt/L). Fertilization and larval development of P. lividus, and S. aurata survival were the measured endpoints. The findings revealed metals, PAHs, and nicotine concentration were higher in cigarette butts' leachates compared with control concentration. The results of the bioassay exhibit brand-to-brand variation and a dose-response relationship between increasing leachate concentration and adverse effects ($p < 0.01$). Among the toxicity assay, larval development endpoint measured in P. lividus was the most sensitive ($p < 0.05$).

KEYWORDS
cigarette butts, leachate, marine environment, toxicity assay.

INTRODUCTION
Cigarette butts, which are also known as tobacco product waste (TPW), are ubiquitous and persistent. The International Coastal Clean-up reports from 2020 and 2019 campaigns showed that cigarette butts (CB) were the most collected items in environmental trash clean-ups worldwide (Ocean Conservancy, 2019; 2020). As these reports demonstrate, TPW is not just a local issue, TPW can easily be transported worldwide and arrive in marine environments. There is a growing concern about TPW littering since it is considered a potential health hazard to humans and ecosystems. Concerning hazard to humans, cigarette smoking kills 6 million people every year and it is expected to 8 million deaths by 2030 (Mathers & Loncar, 2006).

Regarding hazard to ecosystems, cigarette butts are made by nearly non-biodegradable plastic cellulose acetate filters which can release around 7000 chemicals and about 70 are carcinogens (USDHHS report, 2010). A proportion of these compounds are absorbed by the filters and kept in the cigarette butt when tobacco is smoked (Kurmus and Mohajerani, 2020; Torkashvand et al., 2020). The perplexing pathways of these released compunds, their adverse effects, fate and bioaccumulation in the marine ecosystem and human beings should be investigated. The present study addresses to determine the concentration of Nicotine, PAHs, the UV filter BP3 (Benzophenone) and metals (Cr, Fe, Mn, Co, Ni, Cd, Zn, Cu, TI) in cigarette butt leachates and to investigate the toxicity, the dose-response relationship, and associated risk concentration of cigarrte butts in marine environments, by using the bioindicator species Sparus aurata and Paracentrotus Lividus in early developing stages.

This research aimed to bring together the complexity of the issue to kick start a discussion on how to act in a coordinated way to reduce this type of pollution on beaches and other coastal and aquatic environments. We call for the attention of stakeholders for each part to reduce this environmental risk.

MATERIALS AND METHODS

Survival toxicity tests were ascertained from leachate prepared by using smoked cigarette butts from three different brands, Brand 1, 3 (Commercial cigarette), and Brand 2 (hand-rolling cigarette). Artificial smoking was performed following the methodology described by Micevska et al. (2006), Dieng et al. (2013), and in ISO 3308:2012(E) protocols. Leachate preparation was accomplished following Micevska et al., (2006). PAHs, BP3, and nicotine were analyzed following the methodology described by Pintado-Herrera et al. (2014). Target metals analysis was carried out by ICP-MS (ICAP-Q, Thermofisher).

Toxicity assessment was performed using dilutions of control (Control, 0.16,0.32, 0.64, 1.3, 2.56, 5.12, 10 and 16 butt/L) and all three brands' leachates to determine risk values and dose-response relationship. A control treatment (only seawater) was run in parallel. Toxicity bioassays of Paracentrotus lividus were performed according to (Fernández & Beiras, 2001) and (Beiras et al., 2012) and accommodated by national agencies EPA report (2009) and Environment Canada (2011). The survival toxicity test of Sparus aurata larvae was carried out according to the protocol from Díaz- Garduño et al. (2016) based on the OECD (2013) guidelines.

Statistical analysis (one-way ANOVA and Turkey's and Dunnett's test) was performed by SPSS/PC þ statistical package® (15.0), in order to find diffrences between control and leachates dilutions. The EC50, EC10 values were estimated using the PROBIT programme.

RESULTS AND DISCUSSION

No significant concentration of contaminants was found in control treatment. Among the metals, Mn, Fe, Ni, Cu, and Ti concentration exhibited higher values in commercial CB leachate. On the other hand, Cd concentration was found higher in hand-rolling CB leachate. Taking into consideration all the brands, leachates from commercial cigarettes exhibited higher contaminant concentrations. Moerman & Potts (2011), found higher metal concentration from unsmoked cigarette butt leachates than smoked cigarette butt leachates, showing metal loss during the smoking. Moriwaki et al. (2009) found the presence of Cd, Cr, Cu in cigarette butt leachate. Nicotine concentration also followed the same trend as metals, the result exhibited a higher presence of nicotine in the commercial CB leachate than in hand-rolling CB leachate (Brand 1> Brand 3> Brand 2). PAHs concentration revealed a reverse scenario considering metals and nicotine concentration. PAHs concentration was found higher in hand-rolling CB leachate than the leachates from other brands ($p<0,05$). Zumbado et al. (2019) found tobacco paper as a prominent source of exposure to emerging contaminants as the present study found a remarkable quantity of Benzophenone 3 in both commercial and handmade cigarette butt leachates.

Regarding the dose-response relationship, the fertilization assay showed a strong and significant relationship between the percentage of fertilization and cigarette butt leachate dilution ($p<0,05$). The rate of fertilization decreased with increasing concentration of leachate in the dilution and only 20% of eggs were able to be fertilized in the highest concentration of leachate (16 butts/L). Comparing the different brand toxicity and EC50 value for the assay, findings revealed that brand 3 (14.64%) is more toxic followed by brand 2 (13.33) and brand 1 (7.87). To investigate the cause of disturbance in fertilization assay, a negative control (filtered seawater) was performed. It revealed no significant difference in different dilutions. The fertilization rate in the control was 90% and in the negative blank was higher (92%) for any of the dilutions.

Larval development assay revealed the pluteus formation rate was successful in the control concentration (80%) and negative blank (79.5%). The study found interruption on bioassay from lower concentration (0.16-0.64 butt/L) and detrimental impacts like mortality and block on embryo larval development from higher concentration (1.3 to 16 butt/L) for commercial and hand-rolling cigarette butt leachate. In the highest concentration 70% of fertilized eggs unable to get developed (10 butt/L and 16 butt/L) for all three brands. But the findings were not unexpected because different species exposure from cigarette butt leachate revealed an almost similar result. Díaz-Garduño et al. (2016) found a similar response as the present study, from P. lividus exposure through a wastewater treatment plant effluent. Considering EC50 value for the assay, brand 3 (1.74%) is more toxic followed by brand 1 (1.83%) and brand 2 (3.18%).

The results revealed that Sparus aurata larvae survived in control (84%) and in negative blank treatments (80%). Survival values lower than 80% were determined in the lowest dilution of 0.16 butt/L for both commercial (Brand 1, 65.3 % survival rate) and hand-rolling brand (Brand 2, 38% survival rate). For all the brand Sparus aurata larvae exhibited 100% mortality after expose to 1.3 butt/L. Mortality was higher in hand-rolling cigarette than in the commercial cigarette butt leachates. EC50 value for the assay, revealed that brand 2 (0.15 butt/L) is more toxic followed by brand 1 (0.32 butt/L) and brand 3 (0.48 butt/L).

CONCLUSIONS

Cigarette butts are entering into the aquatic environment mostly in the marine environment as littered by smokers directly or discharged from municipal waste. The present study found a significant amount of different metals, nicotine, PAHs, and BP3 UV filter released from a smoked cigarette butts. Measured endpoints revealed that the presence of CB leachate can increase mortality, failure of fertilization, disturbance of embryo development stage, and even block in growth from different early development organism stages. The higher percentage of bioavailable metals and chemical leakage from smoked cigarette filters are indicative of possible future ecological disturbance. As the marine ecosystem is the largest ecosystem of the earth linking the human and other ecosystems in the food chain, it needs special attention and further research to analyze the pathways of toxicity and adverse effects on the ecosystem.

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6. Climate Change and Global Warning

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Climate Change Adaptation in Northern and Southern Europe: A Comparison of Adaptation Initiatives in Denmark and Spain

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ABSTRACT
Adaptation to sea level rise and climate change is a global issue that is increasingly affecting cities. While several studies have analyzed the number of adaptation responses implemented by cities at a local level, few have compared climate change adaptation responses and the factors that drive these responses between various countries with different political contexts. Our study collected data through a 19 question survey that was sent to 123 municipalities in Spain and 60 in Denmark. The survey instrument asked respondents to identify commmon adaptation measures referenced by EU literature that had been implemented by their municipality as well as 17closed-ended questions where participants qualified various barriers or drivers of adaptation. We utilized these responses to determine 1) the current level of adaptation in the two countries as well as 2) the significant variables that are either hindering or driving adaptation on a municipal level. Danish municipalities have implemented, on average, over twice as many adaptation measures as their Spanish counterparts. A linear regression model was employed to identify the significant factors associated with climate change adaptation. Analyses done with the model showed that in Denmark having "Access to information pertaining to climate change" and experience with "Assessments generated by the European Union Flood Risk Directive" were significant variables whereas in Spain "Political commitment of local leaders" is the only significant variable. This is due to the differing political contexts of the two countries and the presence of climate adaptation obligations imposed by the national government in Denmark and the lack of obligations in Spain. This study demonstrates the importance of the national political context in driving local adaptation and that climate change adaptation is a dynamic process whose drivers and obstacles may change over time.

KEYWORDS
resilience, climate change, adaptation, municipalities, flood risk directive

INTRODUCTION
The European Coastline is expected to be affected by various coastal hazards due to climate change (Church et al., 2018). It has been estimated that approximately 40% of the European Union's (EU) Gross Domestic Product (GDP) is generated in coastal regions. (European Union, 2020). Further, 40% of the EU's population lives within 50 km of the sea, with the number of residents residing in coastal regions rising to 100% in Denmark, Cyprus, and Malta (Eurostat, 2013). A large part of coastal development and population settlements are seen in urban areas – which at the international and EU level are increasingly rapidly. In 2018, 55% of the world's population was living in urban areas, and this number is expected to increase to 68% by 2050 (United Nations, 2018.) In non-percentage terms the urban population of the world has more than quintupled over the last 70 years with the global urban population increasing from 751million in 1950 to 4.2 billion in 2018 (United Nations, 2018.) In the European Union, 74.7% of citizens live in urban areas (World Bank, 2018). Many cities are located in coastal or riverine areas and will be exposed to various threats associated with climate change (Araos et al., 2016) In the EU, climate impact related losses already average over EUR 12 billion per year. Losses are not distributed evenly and disproportionately affect regions that are currently confronting other challenges like low growth or high youth unemployment (European

Commission, 2021).

According to the International Panel on Climate Change (IPCC), to better prepare coastal regions for risks and impacts, communities around the world have already begun to implement adaptation responses. These adaptation responses are important as it has been estimated that for every euro invested in flood protection, six euros are saved by avoiding costs arising from the damage (EC, 2013). These measures adapted by all levels of society are of critical importance as they protect investments, infrastructures, private property, and lives. While adaptation is a multi-level governance issue, it is predominantly cities that are tasked with the effort.

More recently, municipalities (or local government units) have increasingly been increasingly recognized for the critical role they have in climate adaptation (Measham et al., 2011) This is because it is at the local level where the action happens. Local governments are the public body to climate impacts and are most sensitive to the contextspecific and place-based nature of risks and vulnerabilities (Chu et al., 2015, Measham et al., 2011). Further, cities are located at the intersection of various scales of government and have been tasked with translating national policy and international commitments into local action (Heidrich et al., 2016). This study, through an email distributed survey and a linear regression model, will explore the number of adaptation measures (dependent variable) that municipalities in Denmark and Spain have implemented. It will then regress the number of adaptation measures against various factors or drivers (independent variables) that will also be collected through survey questions. The measures and factors to be included in the survey will be identified in two separate literature reviews.

MATERIALS AND METHODS

The main data collection tool for the research is an academic research survey that was designed to collect adaptation data from city respondents. Surveys can be a powerful method to assess adaptation as researchers can ask focused questions to identify progress or pinpoint factors for adaptation success, and survey-based studies have so far been important contributions to the study of urban adaptation (Araos et al, 2015). Several recent studies have collected necessary data from municipalities through email distributed surveys. This study will follow a similar method. (Jensen et al, 2016) conducted a climate change adaptation survey in 2016 where a 20 question questionnaire was sent via email to all 98 municipalities in Denmark.

Prior to survey creation two literature reviews were conducted to identify the dependent variable and the numerous independent variables. The dependent variable was an "adaptation score" that was based on the sum of 26 adaptation measures identified in the EU adaptation literature and cross-checked with Spanish and Danish adaptation guides and documents. This study adopted the terminology used by the EU to classify adaptation measures so that municipalities were more familiar with the various terms included in the survey. The 26 measures are included below and are divided according to the European Union classification of grey, green and soft measures as seen in Figure 1.

Grey Measures

- Dikes (elevated earthen structure constructed for flooding and erosion protection purposes).
- Groynes, rock gardens (artificial reefs), or breakwaters.
- Seawalls or jetties.
- Maintenance/upgrade of drainage system.
- Separation of drainage and sewer system.
- Raising existing defensive infrastructures.
- Temporary mobile protection (sand bags, temporary quay walls, partitions, etc.).
- Update existing buildings to make them floodable (Retrofitting).
- Other hard infrastructure

Green Measures

- Wetland, salt marsh or natural barrier creation.
- Dune restoration or Beach nourishment.
- Green infrastructure (Green roofs, animal corridors, permeable pavement, creation of parks, etc.).
- Floodplain restoration or accomodation (Renaturalization or "greening" of floodplain areas).
- Other green infrastructure not included in list

Soft Measures

- Climate change or sea level rise task force
- Sea level rise vulnerability assessment
- Flood, storm surge, or microburst assessment vulnerability hazard assessment.
- Adoption of new building codes or revision of building codes to be more resilient to flooding.
- Early warning system
- Participatory approaches
- Existing or adopted floodplain building regulation
- Existing or adopted shoreline setback construction
- Government acquisition of property at risk
- Awareness raising campaigns.
- Incorporation of climate change adaptation criteria and possibilities in general urban planning strategies (Mainstreaming).
- Other Soft infrastructure not included in list

Figure 1: Adaptation measures included in survey (Grey, Green, and Soft)

The independent variables aimed to explore the various drivers of climate change adaptation. Through a literature review, 17 independent variables were identified and included in our study. Every independent variable selected had been identified by at least one academic article as a "driver" of climate change adaptation. Including all of these variables in the same survey and later regressing them in the same model was not something that had been previously done in the academic literature – at least to the knowledge of the author. This gives an insight into the factors that are driving adaptation in two different countries with different political, geographic, and cultural contexts. Independent variables identified by the author included, but were not limited to: political commitment of local leaders to climate change adaptation, access to information, sufficient resources, assessments generated by the European Union Flood Risk Directive, and the capacity of the municipality to work across departments.

Two criteria for were established for municipalities to whom the survey would be distributed via email. These criteria were 1) that the city have a population between 20,000 and 200,000 people and 2) that the city have coastline within its jurisdiction. This criteria selection yielded 60 municipalities in Denmark and 123 in Spain. Email addresses for municipalities were found online and the survey was sent to the official most closely associated with climate change adaptation – normally the manager of the environmental department. The survey period lasted from mid March to early May of 2021. The survey was followed up and enforced with telephone calls to the environmental departments of every municipality.

RESULTS AND DISCUSSION

The final tally for completed responses (every question) was 33 in Spain and 15 in Denmark, which is a response rate of 27% and 25%, respectively. Respondents were informed that their responses would be anonymous so we will not include names in any part of the communication of our research. The average number of adaptation measures implemented by Danish Municipalities is 14.00 whereas this number is 6.36 in Spain. Danish municipalities identified over twice as many adaptation practices on a local level compared with their Spanish counterparts.

Additional survey questions were used to determine the various obstacles or drivers to climate change adapatation that were present in municipalities. In Figures 2 below the average response rate (1 to 5) for various questions were plotted against each other with the average of Danish municipalities plotted in blue and the Spanish municipalities in red.

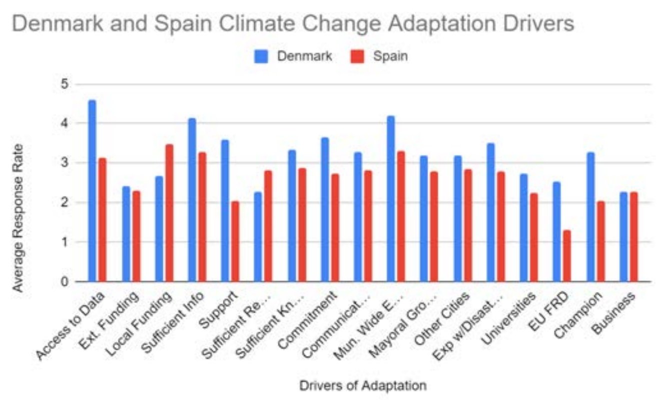

Figure 2: Climate change adaptation drivers in denmark and spain

Linear regression models were used to determine the importance of various drivers and obstacles of climate change adaptation. The first step of the model consisted in testing the dependent variable "level of adaptation (sum of the adaptation measures selected by the municipality with a max of 26)" against the 17 factors identified as drivers of climate change adaptation.

This was done in R using linear regression formulas and verified with Spearman's and Kendall's Rank correlation coefficient. The independent variables that were found to be significant ($P < 0.05$) through the regression formula and both correlation coefficients were further employed in the subsequent analyses. They are as follows:

Denmark: Access to sufficient information pertaining to climate change and assessments generated by the (FRD)Spain: External funding, Sufficient knowledge, Political commitment, Communication between municipality and national/regional government, Municipal wide efforts, and Previous experience with disaster events

The following variables continue being statistically significant even with population acting as a control:

• Denmark: Access to sufficient information pertaining to climate change and assessments generated by the European Union Flood Risk Directive.

• Spain: Sufficient knowledge, political commitment, and municipal wide efforts

When the significant independent variables are all included in the same models we find the following:

• Denmark: neither of the two variables is significant ($P < 0.05$) although the EUFRD has a lower p value than access to sufficient information

• Spain: only political commitment becomes a significant variable.

Access to Sufficient Information

Municipalities generally lack state-provided information about the impact of climate change. This encourages the hiring of engineering consultants who, may ignore the social context of municipal decisions (Crabbé, P., & Robin, M., 2006). Denmark has attempted to resolve this obstacle by providing all municipalities wirth both a data source (https://en.klimatilpasning.dk/tools/climate-atlas/) and information platform (https://www.klimatilpasning.dk/) pertaining to climate change adaptation. The platform provides municipalities with case studies, resources, tools, and guides for climate change adaptation. While not a requirement to use, our research suggests that those who do access it, end up using it and implementing adaptation measures. In Spain this information is more decentralized and its accessibility is more complicated due to shared responsibilities between the autonomous communities and the national government.

European Union Flood Risk Directive

The European Union Flood Risk Directive (Directive 2007/60/EC) entered into force in 2007. The Directive required EU Member States to assess, map, and take measures against flood risks. However, an analysis by (Priest et al., 2016) found that the effect of the FRD is highly variable among European countries.

A literature review of the two countries confirmed the findings of (Priest et al., 2016) as the two countries took very different approaches to the FRD. In 2011, the Ministries of the Environment and Transport of Denmark identified 10 flood prone areas while carrying out flood risk assessments. The 10 flood risk areas encompassed areas spread across 22 municipalities, of which all 22 had to prepare plans to reduce flood risk through mitigation and adaptation measures (Sorensen et al., 2017). These plans were an extra obligation for Danish municipalities on top of climate action plans that all municipalities had to approve before 2014. Contrary to Denmark, there was no obligation in Spain to incorporate FRD into municipal level measures.

Previous research (Berke, 1996) has found that state mandates accomplish that municipalities who would not have made plans otherwise make plans and that those who would make plans of higher quality than if there had been no mandate. Denmark's emphasis on requiring that municipalities comply with certain obligations has spurred adaptation at the municipal level. All municipalities in Denmark have certain obligations to comply with (Climate Action Plans and 2018 Spatial Planning Law), however those identified by the FRD had extra obligations and it is likely this has encouraged further adaptation.

Political Commitment

Previous research has also highlighted the importance of political commitment as a climate change adaptation driver. Research by (Anguelovski, I., Carmin, J., 2011) highlighted that successful (politically committed) municipalities will act in the absence of national or state level policies. In a survey of 156 municipalities (Shi et al, 2015) found that holding all else equal, a city with very high political commitment was 81 times more likely to plan for climate adaptation than a city with very low political commitment. Our survey builds upon these results – but with a small difference. Political commitment in countries without national obligations is a more important factor than in countries where obligations are present. The lack of obligations in Spain has created an ecosystem where political commitment of local leaders has become an important variable in determining whether or not adaptation occurs as the lack of guidance makes the leaders themselves the drivers of adaptation.

CONCLUSIONS

Our research investigated the role of 17 independent variables and whether or not they were statistically significant in fomenting the climate change adaptation process in Denmark and Spain. Our research methodology consisted in identifying every coastal municipality between 20,000 and 200,000 citizens in the two countries and sending a survey to the respective environmental departments of established municipalities. We chose municipalities and not businesses or regional governments as our research sample due to the important role municipalities play in climate change adaptation and the different levels of adaptation that can be found between municipalities with similar characteristics.

Danish municipalities have, on average, implemented nearly twice as many measures as Spanish municipalities. We believe that this can be attributed to the various centralized and organized approaches taken by the Danish national government. The Danish government, over the past decade, has facilitated the beginning stages of local climate change adaptation in Denmark through state mandated requirements at the local level. We theorize that these mandates coupled with the provision of accessible and utilizable information pertinent to climate change have spurred local adaptation in Denmark. Meanwhile in Spain, the lack of accessible, centralized information coupled with an absence of obligations originating at the national level have inadvertently conferred more “liberty” to the municipalities. This has created a situation where the most committed of political leaders are themselves the drivers of climate change adaptation. Below we have included our three main conclusions from our investigation:

Conclusion 1:

Information that is easy to access, utilize, and understand can spur climate change adaptation. Denmark’s efforts towards centralizing information pertaining to climate change (case studies, tools, etc) have made access to information a significant variable in climate change adaptation efforts.

Conclusion 2:

The municipalities identified by the Flood Risk Directive in Denmark had to comply with more state mandated obligations and this has fomented further adaptation at the municipal level in these municipalities.

Conclusion 3:

The absence of adaptation obligations in Spain has created a situation in which the more committed political leaders may be able to make more of a difference as their impact may be more profound in an ecosystem devoid of obligations enforced by the national government.

Conclusion 4:

As a country or city adapts and proceeds with climate change adaptation projects, the factors that drive future projects may change as well. For example, Denmark has implemented many more adaptation measures and the factors that drive these measures are different than in Spain that is characterized by less measures and a lesscentralized political system.

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Estimating the Blue Carbon Storage in an artisanal Saltpan: CO2 sink or source?

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ABSTRACT
Salt marshes are the second largest blue carbon (BC) sink among coastal ecosystems in the world. However, how salt marsh transformation for salt production affect to BC storage is still unknown. In this work, we studied BC stock in an artisanal saltpan in three ponds along a salinity gradient: seawater storage pond (40 ‰), evaporator (80 ‰) and crystallizer (200 ‰). Three sediment cores were collected up to 1 m of depth in each pond, and BC stocks were quantified. Moreover, CO2 fluxes were measured in sediment-water interface in winter using in situ benthic chambers. Evaporator (184 tCO2 ha-1) stocked up to 25% lower of BC than storage (253 tCO2 ha-1) and crystallizer (215 tCO2 ha-1) ponds. Paradoxically, the crystallizer in winter acted as a CO2 source, showing a net heterotrophic metabolism (-1.7 ± 1.4 mmol C m-2 d-1). On the opposite, storage and evaporator ponds were CO2 sinks with a net autotrophic metabolism (~ 5 mmol C m-2 d-1). Our results suggest that, while some salt ponds can act as carbon sources at specific times of the year, the transformation of natural marshes into saltpans entails a long-term net removal of carbon from coastal ecosystem, acting as carbon sink.

KEYWORDS
Primary production, CO2 fluxes, organic carbon, salt ponds, salt marsh, climate change

INTRODUCTION
Coastal wetland, e.g. mangroves, salt marshes and seagrass meadows, have the ability to sequester organic carbon (OC) in their biomass and in the sediment. Blue carbon (BC) ecosystems remove CO2 from the atmosphere by storing carbon in their living biomass through photosynthesis. A part of biomass is incorporated into the sediment as detritus, where is decomposed slowly under anaerobic conditions (Gulliver et al., 2020). The organic matter that is not remineralized remains stocked as OC in the sediment (autochthonous carbon). In addition, BC ecosystems have the ability to trap organic matter exported from adjacent ecosystems (allochthonous carbon) both in tidal flows and in terrestrial runoff, which they continually accrete within their sediments over time. The global interest in BC is based in its potential to remove CO2 and mitigate climate change (Duarte, Middelburg and Caraco, 2005; Macreadie et al., 2019). In salt marshes transformed by man to produce salt or fish, the natural processes are altered to be adapted to productive requirements, which depend on the final product. In case of saltpans, water is stored in shallow ponds to force progressive salt concentration by evaporation. This process creates a gradient of hypersaline ponds that determines the biogeochemical processes. Moreover, the alterations of the soil for the extraction of salt can expose the OC from the sediment to oxidation, increasing the emission of CO2 or other greenhouse gases (Spivak et al., 2019).

Determining if saltpans act as source or sink of carbon is critical to understand their impact (positive or negative) on coastal carbon sequestration capacity. However, information on carbon storage and sediment CO2 fluxes from altered salt marshes remains scarce. Here, we quantify BC stock and seawater-sediment CO2 fluxes in an artisanal saltpan. We hypothesise that BC storage change along the salinity and temperature gradients. Both, temperature and salinity, are factors that affect to (1) composition of the phototropic microbial communities in hypersaline unvegetated sediment surface, (2) oxygen solubility, and thus, (3) biogeochemistry of the sediment.

MATERIAL AND METHODS

This study was conducted in three ponds in an artisanal saltpan with different salinities, seawater pond (approximately 40 ‰), evaporator (80 ‰) and crystallizer (200 ‰), located in the Natural Park Cadiz Bay, (SW Spain). This salt pond is active at least since 1900. In 1994 the production of salt ceased, and for more than twenty years the saline remained inactive, until the year 2020, in which the extraction of salt was restarted.

Three sediment cores (6 cm diameter and 100 cm long) were collected per pond. The cores were first frozen for conservation, and sectioned at 2 cm intervals. The depth was corrected applying the measured compaction percentage. For that, we assume that the sediment compaction was linear (higher 40%) or logarithmic (lower 40 %) (Howard et al., 2014; Morton and White, 1997; (UICN, 2021). A linear expansion percentage (water content decreased linearly with the depth; Pearson coefficient = -0.51; n = 42) was also applied to correct the sediment expansion after freezing interstitial water content. Dry bulk density (DBD) was determined as the dry sediment weight divided by the initial volume. The organic matter (OM) was measured by loss on ignition (Heiri et al., 2001). Afterward, percentage of OC was estimated using a stoichiometric equation specifically was calculated for saltpans in Cadiz, that linearly related OM and OC (y = 0.0988x - 0.7476; Díaz-Almela et al., 2019). Finally, density of OC was calculated, and the BC stock was quantified (Howard et al., 2014; UICN, 2021).

To measure community carbon metabolism (through changes in dissolved oxygen –DO– concentration), we used benthic chambers (four incubations per sampling pond) with an oxygen-sensitive optode system (OXSP5 oxygen sensor spots; pyroscience). The sampling was carried out in winter (February 2021) when a higher biomass of phototropic microbial communities were expected in the unvegetated sediment surface (Haro et al., 2020). Daily rates of gross community production (GPP) were estimated from the difference in oxygen concentration between sunrise and 6 h after sunrise, extrapolating the result using the natural photoperiod (10h). Daily rates of community respiration (CR) were calculated from the difference between sunset and sunrise divided by the time lasted between both sampling, based on the assumption that respiration rate was constant during 24 h. Finally, net metabolism (NCP; mmol O2 m-2 d-1) was estimated as the difference between GPP and CR, and were converted to carbon units assuming photosynthetic and respiratory quotients of 1 (Egea et al., 2019).

Chlorophyll-a (Chl-a) concentration in the sediment was measured by extraction of 0.5 g of dry sediment in pure ethanol buffered with MgCO2, for 12h at 4ºC in darkness, centrifuged 4700 × g for 10 min, and spectra of the extracts were analysed in FLAME-CHEM spectrometers (Ocean Insight). Chlorophyll-a was estimated according to Ritchie, (2008).

RESULTS AND DISCUSSION

The OM content was lower in evaporator (9 - 17 %) than storage pond (13 - 20 %) and crystallizer (15 - 20 %). In the storage pond, the OM was higher in the first 10 cm (~20%), after decreasing gradually to 30 cm, and remained constant, about 13%, up to 1 m of depth. On the opposite, in evaporator and crystallizer, OM was homogenous along sediment core.

The vertical profiles of carbon density ranged from 0.01 to 0.03 g C cm-2 (Figure 1). Overall, carbon density was homogeneous along sediment core in all ponds. It could be due to sediment typology. The dry density ranged between 0.2-1.5, 0.2-1.4 and 0.4-0.9 g cm-3 for storage pond, evaporator and crystallizer, respectively.

Lower BC storage, in term of CO2, were observed in evaporator (184 tCO2 ha-1) compared to storage pond (253 tCO2 ha-1) or crystallizer (215 tCO2 ha-1). Currently, in the studied salt pond, the historic carbon stock in the crystallizer was similar than in storage pond. Our saltpan stocked an average of 217.2 ± 20 tCO2 ha-1. When we compare our results with specific carbon measurements made in the Cadiz Bay (Díaz-Almela et al., 2019), our BC stock was similar to that measured in low vegetated salt marshes (232.3 tCO2 ha-1), and lower than low unvegetated salt marshes (297.5 tCO2 ha-1), but higher that measured in other saltpans in the Cadiz Bay (active artisanal; 142.8 tCO2 ha-1; wet abandoned salina, 199.2 tCO2 ha-1; dry abandoned salina, 148.8 tCO2 ha-1; unpublished data; Díaz-Almela et al., 2019). In this sense our results suggest that the maintenance of saltpan activity may lead to an enhancement in the capacity of these ecosystems to store carbon.

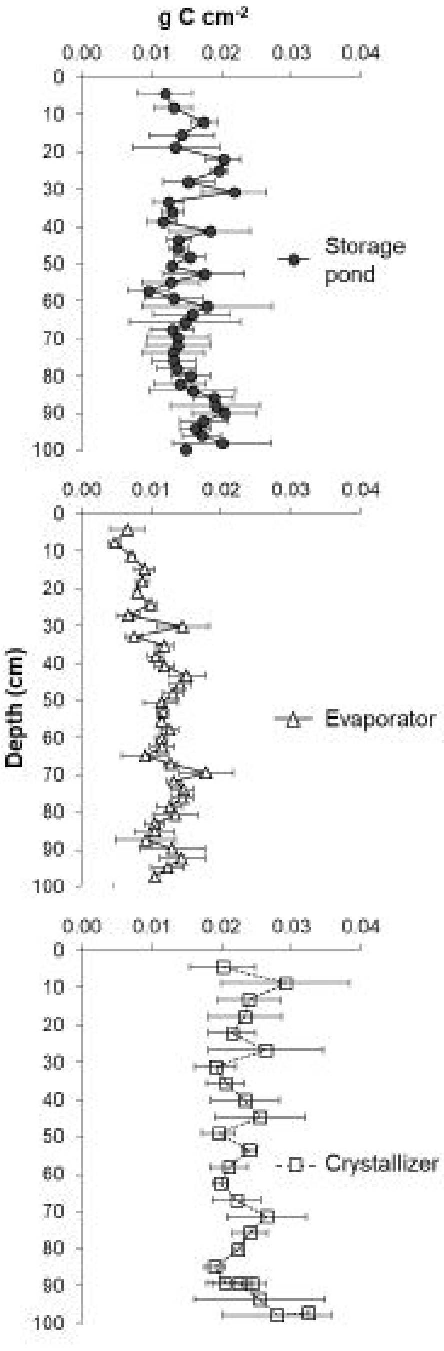

Figure 1. Vertical profiles of blue carbon storage (g C cm-2) in an artisanal salt pond: storage pond (black dots), evaporator (white dots) and crystallizer (discontinuous line). Data are presented as mean ± standard error.

Daily rates of NCP were 5.0 ± 3.6, 5.2 ± 1.0 and -1.7 ± 1.4 mmol C m-2 d-1 for storage, evaporator and crystallizer ponds, respectively. This means that storage and evaporator ponds showed a net autotrophic metabolism in February 2021 and hence, they may act as a potential CO2 sink. Meanwhile, crystallizer pond presented a heterotrophic metabolism, and then, it may act as a potential CO2 source. These values correspond to winter season. The seasonal variability of rates of production or consumption of oxygen must be taken into account. Moreover, autotrophic carbon only is a bit part of BC stock, and other factors such as the input of allochthonous carbon or the remineralisation of the captured carbon must be considered. In this sense, isotopic analysis to determine the external carbon origin might help to understand the net annual metabolism.

It must be pointed out that, in coastal system artificially managed by man, as saltpans, management factors as removing of sediments in crystallizers associated with salt extraction may expose sediments to oxidation, then promoting greenhouse gases emissions, and removing BC stock. In this sense, the dating of the sediments is essential to reveal possible alterations of the accretion rates. The absence of accretion in salt ponds, as consequences of removing sediment for salt exploitation, was observed by Gulliver et al., (2020) and Díaz-Almela et al., (2019).

The concentration of Chl-a was the double in the evaporator than in storage pond and crystallizer. However, autotrophic biomass in evaporator seems to be less productive (GPP = 0.14 mmol C mg chl-1 d-1) than storage pond (GPP = 0.52 mmol C mg chl-1 d-1). Rates of oxygen consumption were 37.7, 22.9 and 3.4 mmol C m-2 d-1 for storage pond, evaporator and crystallizer, respectively. Oxygen solubility in the sediment surface is affected by salinity increase, determining thickness of both aerobic and anaerobic layers in the sediment, which are keys in the sediment biogeochemistry.

CONCLUSIONS

This is one of first studies in which the BC stock has been quantified in artisanal saltpans. We have found differences in carbon storage and net metabolism among different ponds of the saltpan. Overall, the BC stock was lower in evaporator pond. When compared to natural marshes, storage ponds and crystallizer accumulate carbon to a similar or slightly less extent. However, these values are higher than those registered so far in active or inactive salt ponds. Moreover, we found autotrophic net metabolism of storage pond and evaporator in winter, whereas the crystallizer punctually showed a heterotrophic metabolism. Seasonal variability of NCP and allochthonous carbon must be integrated to fully understand the metabolic functioning of the saltpan. Nonetheless, this saline as a whole appears to be acting as a long-term carbon sink. More research is needed to fully understand how the alteration of natural regimes and the removal of sediments caused by salt extraction processes modify carbon balances in artificially managed salt marshes.

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Application of Managed Aquifer Recharge as a robust solution for salinization prevention in the Mekong Delta, Vietnam

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ABSTRACT
In coastal areas frequently affected by seawater intrusion, groundwater is a vital source for socio-economic development. Managed Aquifer Recharge (MAR) has been proposed as an adaptive strategy in groundwater management. However, knowledge and implementation of MAR in the Mekong Delta are still limited. This study proposes an infiltration pond system as a robust solution for salinization prevention in the Mekong Delta, Vietnam. The investigation from the literatures and the land cover map of the study area considering hydrogeological characteristics, fresh-saline interface, and freshwater demands showed that the transitional zone between freshwater agriculture and brackish water aquaculture in Soc Trang, Tra Vinh and Ben Tre provinces is optimal to implement an aquifer recharge/freshwater barrier scheme. Based on water budget balance approach and the vertical flow according to the Darcy's Law, the operation of the infiltration pond in Soc Trang province was estimated to yield a recharge rate of 151.74 m3/year and 303.82 m3/year per unit area (m2) of infiltration pond with an increased water level of 0.5 m and 1 m, respectively. In conclusion, MAR can be considered an alternative strategy in the integrated water resources management plan, together with current regulations, to reach a sustainable groundwater equilibrium and salinization prevention.

KEYWORDS
Infiltration pond, Managed Aquifer Recharge, groundwater, salinization.

INTRODUCTION
In the Mekong Delta, groundwater is an important water source for domestic, urban, irrigation, aquaculture and industrial supplies (IUCN, 2011). Continuous decline of groundwater head due to overexploitation has caused lateral saltwater intrusion, up-coning of brackish to saline groundwater under extraction wells and land subsidence (Erban, Gorelick and Zebker, 2014). Approximately 63% of the groundwater volume in the Mekong Delta is saline (Vuong, Lam, & Van, 2015). Natural recharge of groundwater is predicted to decrease both in the short and long term due to climate changes (Shrestha, Bach, & Pandey, 2016).

Managed Aquifer Recharge (MAR) has been proposed as an adaptive strategy in groundwater management, but knowledge and implementation of MAR in Vietnam and the Mekong Delta are still limited. To our knowledge, no research has investigated the potential of the Mekong Delta for MAR implementation with the infiltration pond method yet. Therefore, the aim of this work was to address the knowledge gap and provide a robust solution to groundwater management in this area The area proposed to install the pilot MAR project is Soc Trang, a coastal province of the Mekong Delta (Figure 1). The province is strongly affected by saltwater intrusion from the East Sea. Groundwater is a vital source of water supply for domestic, agricultural and aquaculture purposes. However, groundwater quantity and quality have been significantly degraded due to overexploitation and saltwater intrusion, posing a challenge to the sustainable use and management of groundwater in the area (Trang, Hang, Diep, An, & Tri, 2018).

MATERIALS AND METHODS
To achieve our goal, climate data of Soc Trang province were collected from AQUASTAT - FAO global information system (https://aquastat.fao.org/climateinformation-tool/), including monthly average precipitation and reference evapotranspiration for the period 1961 – 1990.

A simple water balance equation was applied to calculate the deficit or surplus in the water budget of the MAR site:

$\Delta W = P - ET - Sout - R \pm \Delta S$ (1)

where ΔW is the deficit/surplus, P is precipitation, Sout is the outflow of groundwater, R is surface runoff, ΔS is the change in soil moisture storage, and ET is the evaporation from the surface water. In this study, R is considered insignificant because of the flat elevation of the study site and the implementation of the MAR project over the sand dune with a high infiltration capacity. Besides, the soil water content is constant in steady-state conditions for the long term, therefore, ΔS is assumed to be zero. Moreover, Sout is also assumed to be zero for simplicity. Consequently, the simplified water balance equation becomes:

$\Delta W = P - ET$ (2)

Recharge rate in the unconfined aquifer was estimated based on Darcy's Law for steady flow:

$$v = -K \times \frac{\Delta h}{L}$$

(3)

Where v is the vertical flow (specific discharge; m/day), K is the hydraulic conductivity, L is the depth of the sandy aquifer, and Δh is the difference in head between the MAR pond surface and the surrounding aquifer. According to DWRPIS (2010), the average L is about 6 m and K is assumed to be 5 m/day. Δh is set to be 0.5 m (scenario 1) and 1 m (scenario 2).

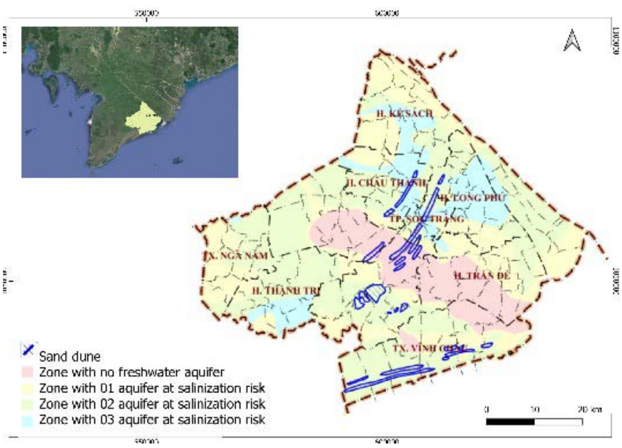

Figure 1. Soc Trang province and salinization risks in aquifers. Source: DWRPIS (2010).

A pilot MAR project using the infiltration method is suggested for the study site due to its low cost and simplicity in implementation. The conceptual model of the pond infiltration system is presented in Figure 2. The infiltration pond is set with a freshwater head higher than the current groundwater head to create a hydraulic gradient for infiltration of freshwater into the shallow aquifer. The water level in the infiltration pond is proposed to be kept constant at 0.5 m (scenario 1) and 1 m (scenario 2) from the surrounding water tableThe recharged freshwater is treated by the infiltration purification process and acts as a hydraulic barrier to mitigate local salinization. The infiltration pond system is recommended to be in places with permeable sandy paleodune deposits, allowing infiltration to shallow aquifer. In Soc Trang province sandy dunes are found in Long Phu, Vinh Chau, My Tu districts, and Soc Trang city and is represented in Figure 1 in transparent blue polygons

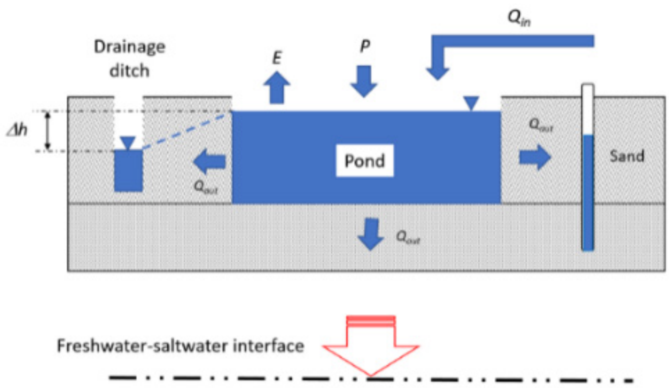

Figure 2. Conceptual model of MAR project using a pond infiltration system

Moreover, a literature review on the hydrogeological characteristics of the Mekong Delta was done to investigate potential locations for MAR projects based on the following criteria: (1) above the sea level; (2) connected with the aquifer (low permeable layer); (3) high water demands; and (4) saline water counteracting function.

RESULTS AND DISCUSSION

1. Conceptual model and water budget of the pilot MAR project and some management

considerations

The average precipitation and reference evapotranspiration during 1961 – 1990 are 1935 mm/year and 1455 mm/year, respectively. A hydrological deficit is found in the dry season, from January to April, while water surplus is recorded during the wet season, from May to December.. The operation of the infiltration pond in Soc Trang province would yield a recharge rate of 151.74 m3/year and 303.82 m3/year per unit area (m2) for scenario 1 and 2, respectively. With a typical infiltration pond of 5000 m2, a cumulative amount of aquifer recharge would yield up to 758,696 m3/year and 1,519,112 m3/year with increased water of 0.5 m and 1 m, respectively. With 0.5 m of water level increased in the pond, natural recharge from rainwater occurs from May to December and accounts for 14% of the total recharge amount, whereas, in the other scenario, that only contributes to 7%.

Reduced water abstraction in salinity risk areas and an exploitation rate of less than 20% of potential extraction capacity are current regulations to protect groundwater quality from salinization in Soc Trang province. In addition, freshwater import is suggested in the management scheme to tackle water shortage in some saline-affected areas (DWRPIS, 2010). However, the freshwater transfer cost is estimated to be 2 – 10 times higher than limiting saltwater intrusion into a coastal aquifer (Dillon & Arshad, 2016). Therefore, the integration of current regulations with suitable MAR infiltration ponds would help to reach a sustainable groundwater equilibrium and salinization prevention. Besides, the multipurpose use of infiltration ponds would benefit agriculture development with increased freshwater availability.

The location of the infiltration ponds should be in places with thick and laterally extended sand bodies. In case it is covered, excavation to reach the sandy aquifer would be required. Besides, the implementation sites should be located near water source and electricity sources, as well as access to roads to ensure a steady supply and limit potential transport costs.

Surface water is recommended to be a suitable source for recharge water. In Soc Trang province, surface water distributes widely from the extensive canals of the Hau River. The quality of surface water is acceptable; however, some places are affected by anthropogenic activities and saltwater intrusion. Further investigation on a suitable location to extract surface water for MAR water supply should be performed to mitigate related risks.

The maximum infiltration rate is recorded at the operation's start and gradually decreases over time (Nadee, Trelo-ges, Pavelic, & Srisuk, 2011). Therefore, regular maintenance of the infiltration pond to ensure infiltration is critical. Besides, longitudinal ponds (parallel to paleo-dune axes) are considered suitable in the study site to minimize evaporative water loss. A combination of multiple ponds in a system is advised to ensure a steady supply during maintenance.

Different studies have suggested MAR in the Mekong Delta as an adaptive strategy in groundwater management. However, knowledge and legal framework for the implementation of MAR in the Mekong Delta is still limited. Therefore, adopting and regulating MAR as a part of integrated water resources management should be promoted. In the future, specific site, water source and dimension of the recharge pond selections and cost-benefit of MAR should be further investigated using Geographic Information System, modelling and socio-economic tools.

2. Feasibility of MAR in the Mekong Delta for salinization mitigation

Implementing the MAR program using an infiltration pond system is technically feasible due to some hydrogeological characteristics of the Mekong Delta. The eastern coastal area is characterized by the presence of relict beach ridges parallel to the coastline, which were formed due to the progradation of delta deposits (Nguyen, Kim, Ta, & Tateishi, 2000). These bodies are laterally extensive, which might be important for local permeable aquifers and potential locations for managed aquifer recharge. In addition, the stratigraphy of different sections in the Mekong Delta shows specific locations with permeable sandy bodies directly at the surface or encased with low conductivity sediments. In the latter case, if the surface aquitards are thin, they might be dug to reach the aquifer below for recharge. The red polygons in Figure 3 indicate potential areas in the upstream (2) and the coastal areas (1) to implement infiltration ponds, which have elevation above sea level. The (2) zone is in a freshwater zone with high relief whereas the (1) zone is strongly dissected by many permeable sandy paleo-dune deposits (solid black).

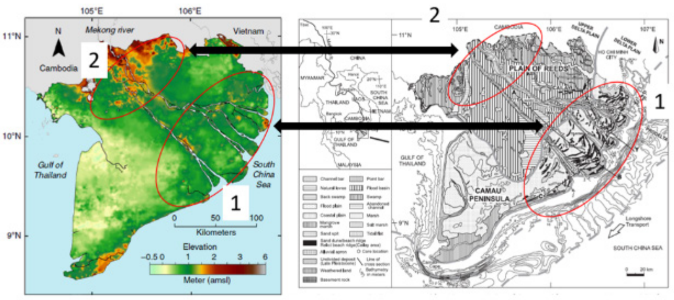

Figure 3. Potential areas for infiltration pond implementation

Water demands and secondary benefits should be considered in selecting the MAR site to optimize the investment cost and benefit of MAR (Alam, Borthakur, Ravi, Gebremichael, & Mohanty, 2021). The salinization in the Mekong Delta is frequently recorded in the coastal zone with the presence of brackish water aquaculture ponds. Therefore, the MAR project is recommended to be implemented in the transition area between salty and freshwater areas to create a freshwater barrier in the aquifer, preventing further saltwater intrusion. Besides, it could also sustain the local freshwater supply. Therefore, the transitional zone between freshwater agriculture and brackish water aquaculture in Soc Trang, Tra Vinh and Ben Tre provinces is the optimal area to implement an aquifer recharge/freshwater barrier scheme, considering hydrogeological characteristics, the fresh-saline boundary and freshwater demands (Figure 4).

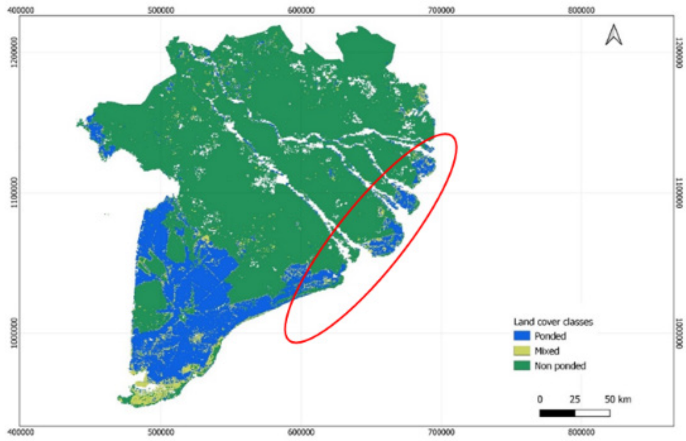

Figure 4. Optimal area for MAR implementation (red polygon)

CONCLUSIONS

Implementing an infiltration pond system is promising for counteracting salinization in shallow aquifers in the Mekong Delta at the local scale. The implementation of MAR using an infiltration pond system is technically feasible in the Mekong Delta, considering hydrogeological characteristics, the fresh-saline interface and freshwater demands. The transitional zone between freshwater agriculture and brackish water aquaculture in Soc Trang, Tra Vinh and Ben Tre provinces is optimal for implementing an aquifer recharge/ freshwater barrier scheme.

The operation of the infiltration pond in Soc Trang province would yield a recharge rate of 151.74 m3/year and 303.82 m3/year per unit area (m2) of infiltration pond with an increased water level of 0.5 m and 1 m, respectively. MAR can be considered as an additional strategy in the integrated water resources management plan, together with current regulations. Besides, the multipurpose use of infiltration ponds would benefit agriculture development with increased freshwater availability in the area.

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Inter-comparison of Standard Chlorophyll-a estimates from different Ocean Colour Sensors to detect a bloom of Leptocylindrus minimus at Southern Portuguese Coast

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ABSTRACT
This study explores the feasibility of using different datasets, from distinct ocean colour sensors (OCS) to monitor phytoplankton dynamics including harmful algal blooms (HABs), by means of the improved spatial-temporal coverage of satellite images. Standard Chlorophyll-a (Chl a) products from three OCS are compared with in situ Chl a during a rare spring bloom of non-toxin producing diatom species, Leptocylindrus minimus (2.1 x 106 cells per litre) identified offshore of Ria Formosa, Portugal. The OCS evaluated are Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Aqua/Terra satellites (Chlor_a algorithm), Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi/NOAA-20 (Chlor_a algorithm), and Ocean and Land Colour Instrument (OLCI) onboard Sentinel-3A (OC4ME and NN algorithms). The results show that Chl a estimates from OLCI-Sentinel-3A (OC4ME) and MODIS-Terra are the best representing in situ measurements, with differences <0.5 mg.m-3, while NN and VIIRS are varied with in situ by 0.85 and 0.73 mg.m-3, respectively. Standard remote sensing reflectance, Rrs( ) between sensors are somewhat comparable, with MODIS having more reflectance bands in the green spectrum due to high spectral resolutions. Level-2 satellite images of Chl a from all sensors confirm the spatial extend of the bloom, though in different spatial resolutions that is, OLCI > VIIRS > MODIS.

KEYWORDS
Ocean colour remote sensing, phytoplankton, HABs, Chlorophyll-a.

INTRODUCTION
Changes in phytoplankton dynamics and HAB events can pose serious risk to the Blue Growth (BG) sectors (Gatchis & Shumway, 2017) such as aquaculture and tourism, common in the coastal region of Algarve, Portugal. Coastal managers and stakeholders can utilise ocean colour remote sensing technology as a decision support tool to protect assets, maintain the quality for recreational uses, and food security (IOCCG, 2009). The hypothesis is that, an integrated management of BG should include the amalgamation of different OCS, so that the spatial-temporal distributions of the phytoplankton (including HABs) can be better understood.

To achieve this objective, a rare bloom event was investigated on 11/03/21, where Diatoms-dominated, nontoxigenic species, Leptocylindrus minimus (Gran, 1915) with an abundance of 2.1 x 106 cells per litre was identified, representing 56.8% of the total abundance. L. minimus is a common species found at Ria Formosa (Moita & Vilarinho, 1999) and considered as a non-toxin producing species, with no account of alert and danger levels set by the Portuguese Institute of Sea and Atmosphere (IPMA).

Further studies should look into the potential harms, as fish kills were associated with L.minimus blooms affecting the farmed salmon in south Chile, although the apparentnoxious effect was not confirmed (Clement & Lembeye 1991). Nashad et al. (2017) reported a bloom of 1.5 to 1.8 x105 L. minimus cells.L-1 in the coastal waters of SW India, also without toxic effects. Rensel and Whyte (2004) recommends response management actions in aquaculture when the species' abundance > 1 x 106 cells.L-1.

Using the standard Chl a product (as a proxy to phytoplankton biomass) from different OCS, the coincident datasets are compared with in situ Chl a concentrations. The satellite images are quantitatively used for expressing the spatial extend of the bloom. The Rrs( ) spectra are analysed to check the spectral signature of the L. minimus by the different OCS. The results can be used to understand the dynamics of an uncommonly reported single dominant species bloom at Ria Formosa.

The significance of this work includes advancing the Strategic Objectives of the Portugal Space 2030, European Green Deal (2019-24), and the United Nations' 2030 Agenda for Sustainable Development Goals (UNSDGs) number 8: Decent Work and Economic Growth and 14: Life Below Water.

MATERIALS AND METHODS

The approximate coordinates of the in situ station are 7°51'55.67"W 36°57'52.88"N, east of the Faro-Olhão inlet, off Ria Formosa in southern Portugal.

The satellite data was extracted away from the coast to minimize image contaminations. These were downloaded from NASA's portal for MODIS and VIIRS, and Copernicus Online Data Access, CODA for OLCI. OCS with a time window ±3h from the seawater collection was selected (±3h herein). The available OCS are: MODIS-Terra (MDT), VIIRS-Suomi (VRS), OLCI-S3A (both OC-4ME and NN, OC4 and NN herein, respectively), while MODIS-Aqua (MDA) and VIIRS-NOAA-20 (VRN) were also considered although the time window was >3h. For brevity, only the Chlor_a algorithm was considered for MODIS and VIIRS. SeNtinel's Application Platform (SNAP) software v.8 was used to extract standard Chl a products by 1x1 spatial window (centred at 7°50'26.83"W 36°58'6.87"N) due to non-homogenous conditions and the varied spatial resolutions between sensors.

Differences between satellite and in situ measurements were calculated as Chl_asatellite – Chl_ainsitu. OLCI water leaving reflectances were transformed into Rrs( ) by division with π. The shapes of Rrs( ) centred around the blue and green waveband were compared and assessed for the potentials for merging. As the wavebands were different to each OCS, these were expressed at Rrs(488) and Rrs(555) for MDT/A, Rrs(486) and Rrs(551) for VRS, Rrs(489) and Rrs(556) for VRN, while Rrs (490) and Rrs (510) for OLCI.

The seawater for Chl a determination and for phytoplankton counting was collected from the sea surface by a volunteer on 11/03/21 at 09:45 AM. In situ Chl a was determined by spectrophotometry (Parsons et al., 1984 and references herein), while phytoplankton enumeration was done using Utermöhl method (1958).

RESULTS AND DISCUSSION

The concentration of in situ Chl a was 2.05 mg.m-3 which is well below the pelagic values observed in a 40- year discontinuous study period in Ria Formosa by Brito et al. (2012), and the reference level of 5.3 mg.m-3 (EC, 2008). Chl a derived using OC4 and MDT best represented the in situ Chl a, with 2.07 and 1.98 mg.m-3, respectively. NN and VRS underestimated the in situ Chl a by 0.85 and 0.73 mg.m-3, respectively.

The differences may be due to the overall low Chl a (<5 mg.m-3) measured at the study area, which is the estimated threshold for increased vulnerability to the variations in coloured dissolved organic matter (CDOM) absorption and scattering when estimating Chl a using OCS (Gilerson et al., 2010). OC4 showed better agreement with in situ data on this day compared to NN. Although NN is more sensitive to CDOM and total suspended matter (TSM), it can underestimate Chl a (Blix et al., 2018), as also found in this research (NN < in situ).

Pahlevan et al. (2016) mentions that MODIS and VIIRS comparison with in situ in coastal areas can have errors up to 18%, with an estimated overall difference of <0.15 mg.m-3, although the value found for VIIRS in this study is 0.73 mg.m-3. MODIS has the advantage of having a higher spectral resolution, in which 4 bands are available in the green band compared to the other OCS. On the other hand, VIIRS could perform better because of improved calibration/validation results compared to MODIS and has a wider overlapping coverage (Scott & Werdell, 2019).

Inter-sensors Rrs( ) spectra are compared for the variations between ±3h, along with >3h for MODIS and VIIRS (Fig.1). The images for this particular sample, abundant with diatoms (63%), show similar trend in the blue and green bands, that is Rrs(490) > Rrs(510) for OLCI, Rrs(488) > Rrs(555) for MODIS, Rrs(486) > Rrs(551) for VRS and Rrs(489) > Rrs(556) for VRN. MDT/A has the longest difference in passing times (between 11:00 and 14:15, respectively) and their corresponding Rrs( ) shapes are most varied. VRS/N Rrs( ) shapes are very similar as they overpassed <1h apart. Additionally, Rrs( ) of VIIRS for Chl reflectances are different (VRS < VRN). These factors may affect the sensitivity in the acquisition of OC products and must be considered upon inter-sensor combination.

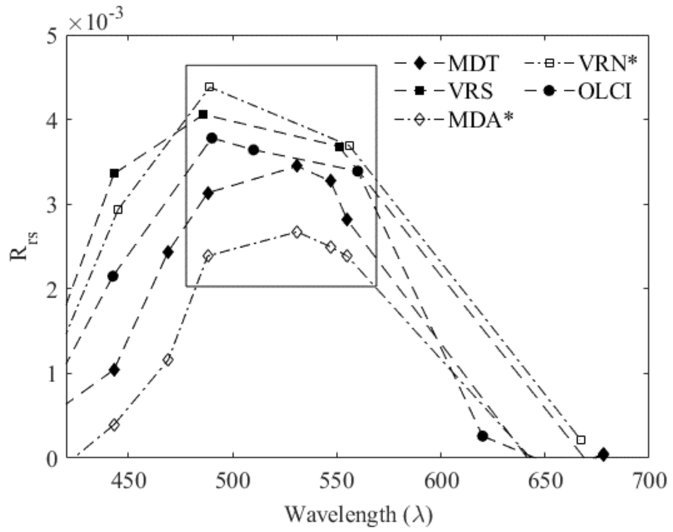

Figure 1. Remote sensing reflectance, Rrs( ) from MODIS, VIIRS and OLCI for 11/03/21; The box estimates the green wavebands; * >3h time window.

Non-continuous 5-day outlook of Chl a derived using OC4 are presented to track the progression of the bloom (Fig.2). OC4 is chosen as it has the highest resolution and smallest time window amongst the selected OCS, although lacked clarity due to clouds. The satellite images indicate a wide spread bloom between 0.8 to 3 mg.m-3 concentrated along the whole Algarve coast, then dispersed offshore.

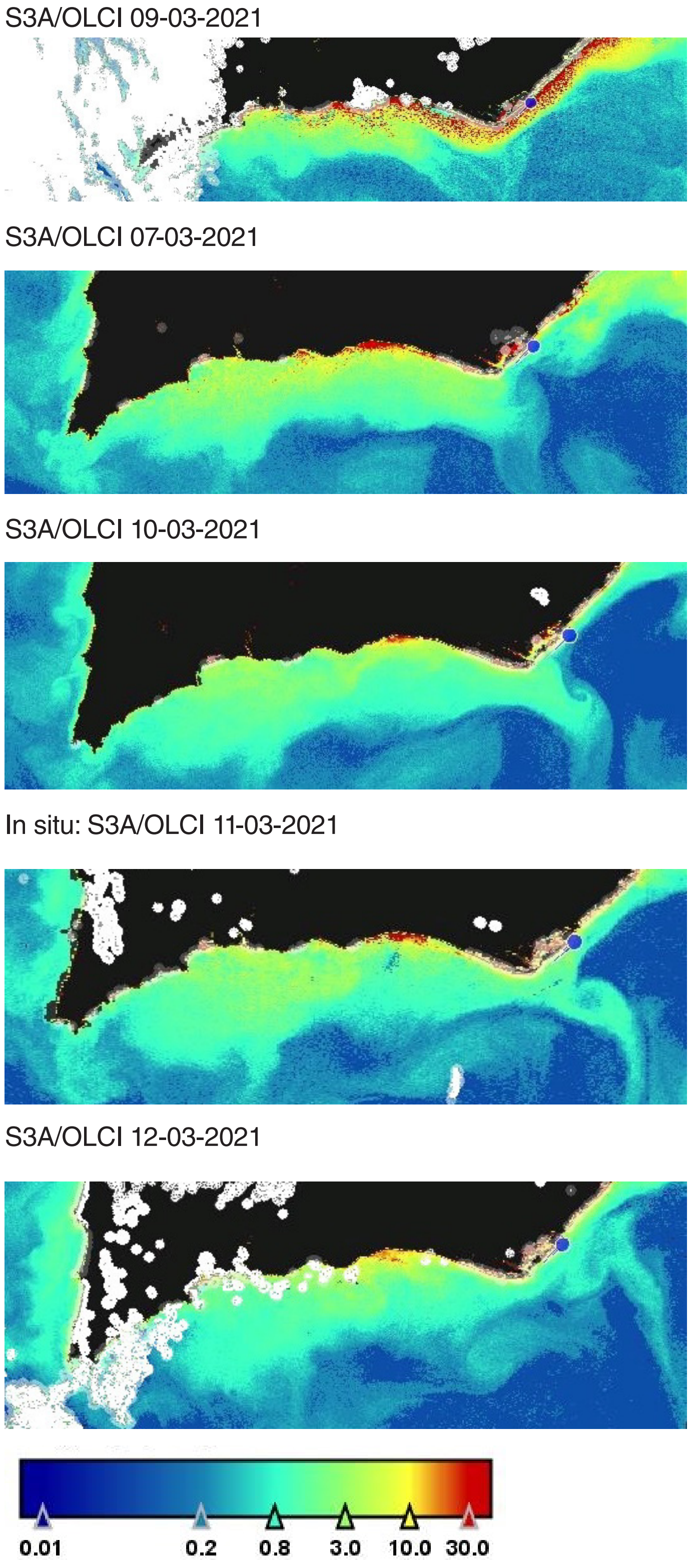

Figure 2. Non-consecutive 5-day outlook of full resolution L2 satellite images of Chlorophyll-a (mg.m-3) from OLCI using OC4ME algorithm; Seawater was collected on 11/03/21 at 09:45 AM from the pinned location; Clouds are shaded white and gray.

CONCLUSIONS

This study explored the feasibility of using datasets from different OCS to understand the progression of a rare L.minimus bloom. For 1-day scene analyses, OC4 and MDT may be feasible since the differences with in situ data were <0.5 mg.m-3 and the overpassing time difference between satellites is ~2h. Furthermore, the different wavelengths of Rrs( ) for VRS/VRN may not be suitable to be combined and represent Chl a. The shapes of Rrs( ) reveal the differences between the sensors, and that the time window is one of the factors to be considered when compositing the datasets and images. Although the visual comparison of the Chl a scene is varied in terms of spatial resolutions, in which OLCI > VIIRS > MODIS, the progression and extend of the bloom can be confirmed. These variations can be further studied using additional sampling stations over different conditions, so that intersensor calibration efforts can be achieved.

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Integrating remote sensing data to urban Ecosystem Services management

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ABSTRACT
Ecosystem services are benefits human beings obtain from nature that are indispensable for human well-being. Thus, it is imperative to manage natural ecosystems, especially inside or near urban areas, where the relationships and interactions between anthropic and natural variables intensify. Combining techniques, frameworks, and approaches is necessary to obtain a holistic approach for Ecosystem-Based management. This research focuses on integrating remote sensing techniques to monitor ecosystem services in land, air and water, specifically NO2 atmospheric emissions, Normalised Difference Vegetation Index, Total Suspended matter and Chlorophyll-a for water bodies. It was demonstrated that the utilised information from the satellite imagery was a reasonable, low budget and flexible tool for urban and environmental management. Furthermore, the integration of these techniques can represent better and more informed responses to environmental issues that are spatially distributed, given a clear advantage for spatial planning.

KEYWORDS
Ecosystem services, remote sensing techniques, normalised vegetation index, air quality, water quality, urban planning, environmental management, ecosystem-based management, sentinel, Landsat.

INTRODUCTION
The role of Ecosystem Services is related to their importance for human development and well-being. In the last decades, The Millennium Ecosystem Assessment Conceptual Framework Working Group (2003) defined ecosystem services as "The benefits people obtain from ecosystems". Therefore, it implies a close relationship and interdependence between ecosystem services, their use and accessibility with human well-being. According to the Millennium Ecosystem Assessment Conceptual Framework Working Group (2003), the ecosystem service framework has four categories: Provisioning Services, Supporting Services, Regulating Services and Cultural Services.
Human well-being factors are associated with ecosystem services like food security and shelter, reduced vulnerability to ecological shocks and environmental stress, raw materials for a good life, health and comfort, freedom and choice, and good social relations [1].

Natural systems like delta areas or the coastal zone promote human settlements and fast population growth. Simultaneously, this increases the pressure on natural areas that can damage ecosystem services' supply deteriorating human well-being [2]. Global, national, or regional socio-economic drivers can provoke a deterioration of the ecosystems and reduce the services they provide due to land change, pollution, agricultural runoff, urbanisation, and many other pressures. Conservation policies and natural protected areas should be established in the coastal zone to avoid the deterioration of these ecosystems. However, there seems to be a trend in the reduction of conservation policies [3]

Ecosystem-based management (EBM) responds to the need for integrating ecosystem service to management approaches. This method moves away from a single species or sector management approach to a more complex understanding of the interactions in a specific environment [4]–[6]. EBM has to manage human activity to maintain ecosystem services by restoring or preserving habitat quality, therefore successfully handling the target species without affecting non-target species [4]. For this purpose, EBM depends on tools, like remote sensing techniques, to measure the state of the ecosystems.

Remote sensing techniques are of great utility due to the spatial qualities of urban planning and ecosystem mapping. Thanks to the sunlight's reflected radiation from the earth's surface, it is possible to quantify several ecosystems' physical and biological characteristics. Some of these characteristics are land cover, biomass, water quality, vegetation, and other parameters [7], [8]

Land use is among the most utilised remote sensing techniques for identifying urban ecosystems and their services. The Normalised Difference Vegetation Index (NDVI), Land Surface Temperature (LST), and Leaf Area Index (LAI) [9] are measurements broadly used to monitor ecosystem services. Many other measurements are used for ecosystem service mapping using geographical information systems and remote sensing techniques; their selection depends on data availability and the study's objective [7]

The most mapped and studied urban ecosystem services are Regulating Services like climate regulation, air quality or water regulation, stormwater regulation, and wastewater purification. Cultural Services like recreation and aesthetics have been studied and monitored with remote sensing techniques due to the link with urban green spaces and the importance of nature for landscape appreciation and physical activity [9]. As for Provisioning Services, they can be mapped by monitoring urban agriculture sites or timber forests. Nonetheless, Provisioning Services are usually substituted in cities by outside sources [10]. The localisation and mapping of urban green spaces hold great importance due to the various ecosystem services found in green areas, the importance of accessibility for the population, and spatial distribution across a city [9], [11].

Currently, remote sensing techniques and geographical information systems are not sufficient to map all the ecosystem services, and when possible, direct measurements are preferable. These techniques provide an inexpensive and easily accessible tool for urban planners thanks to their ability to process large areas where direct measurements are not viable [7], [12]. Primary data from satellite imagery from Landsat and Sentinel programs provides free of charge satellite images that researchers and urban planners can use for ecosystem service monitoring.

STUDY AREA

The municipality of Cádiz has an extension of 12 km2 [13] and a population of 116 027 for 2019, and it presents a declining population rate. [14]. The municipality of Cádiz is characterised by a close relationship with the bay and the coastal areas. It has commercial ports, marinas, and sun and beach tourism activities. It is considered a city of services and commercial activities, but it also has an important industrial sector and port activity. [15], [16]. Due to its geographical conditions, the municipality of Cádiz can be affected by storm surges and coastal flooding, especially in the southern salt marshes and swamp areas. In general, the city of Cádiz has exhausted its ability to naturally grow several decades ago due to the presence of coastal ecosystems. [15]. The Bay of Cádiz Natural Park was established in 1989 and integrated into the Natura 2000 program in 1992. In 2015, the marine bottom was also set as a protected space under Natura 2000. [17]

MATERIALS AND METHODS

The ecosystem services measure in this research is air quality, urban green areas and water quality. Air quality or regulation is related to atmospheric emissions using NO2 as an indicator. For this process, Sentinel 5p data was used for April and August 2019 and April and August 2020. Urban green area cover related to cultural and regulating services. It was measured using the Normalised Difference Vegetation Index (NDVI) with Landsat 8 and Sentinel 2 data from August 2020 and August 2017. Finally, Sentinel 3 data with the OCLI instrument was used to measure Total Suspended Matter and Chlorophyll-a for water quality.

This research used QGIS Bucaresti 3.12, Python 3.7.9 and SNAP 7.0 for the data interpretation.

RESULTS AND DISCUSSION

For measuring atmospheric emissions, NO2 was selected as the compound to monitor due to its commonality as an urban health indicator. NO2 is a product of a secondary reaction of nitric oxide (NO) and volatile organic compounds. NO is positively related to combustion in motors for vehicles, making NO2 an excellent transportation pollution indicator [18]. The NO2 distribution is affected by many climatic variables, like wind and temperature, increasing the information's variability daily and seasonally [18]. This research demonstrated a reduction in NO2 between April 2019 vs April 2020. This reduction is related to the COVID-19 Pandemic mobility restrictions during April 2020 in Spain and worldwide.

In an area that experiences an intense wind regimen, like the province of Cádiz, the NO2 tends to disperse quickly, provoking less accumulation of gases in the area, and cloud interference can also provoke a loss of information. Furthermore, due to the satellite's movement, the sensor measures at a different time daily, provoking a small sample compared with ground-based measurement stations. The methodology also provides the vertical column density of the NO2, so it measures the amount per area in the troposphere, not only in the low parts of the atmosphere, where it is emitted and can affect human well-being. Therefore, ground-based measure stations are vital for corroborating the collected data and control atmospheric emissions, especially in high-density urban clusters. However, other research has proven the correlation between ground-based stations and satellite imagery, certifying remote sensing data's utility in monitoring atmospheric emissions [18]. One of the main advantages of remote sensing techniques to measure atmospheric emissions is that satellite imagery gives spatial information of atmospheric pollution that the ground-based stations cannot provide. This imagery has demonstrated the state's change in the atmosphere and can provide critical information for urban managers. Using this information, governments and managers can regulate emissions to improve human well-being. They can also measure the efficiency of nature-based solutions for air quality control based on ecosystem services.

For monitoring the change of state for urban green areas, this research used the NDVI, which showed an improvement in the city's vegetation rate between 2017 and 2020, demonstrating the utility of the NDVI as an indicator of urban green areas [19]–[23]. This improvement in vegetation relates to increased ecosystem services like pollination, carbon sequestration, climate regulation, biodiversity and many cultural services that improve human well-being [1]. The NDVI will vary seasonally due to its relationship with vegetation growth and health [20]. Therefore, an urban manager can create annual databases representing the variability of vegetation inside a city. This technique has the significant advantage of providing information about parks and gardens and isolated vegetation not related to land cover or use. A clear example is the iconic tree Árbol del Mora, located in Cádiz near the Caleta Beach (204089.7,4047966.6) with an NDVI higher than 0.5.

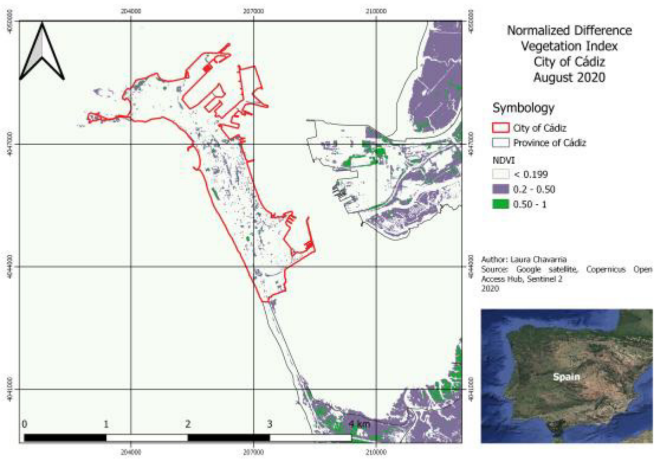

Figure 1. NDVI for the city of Cádiz using Sentinel 2 data

NDVI has already proven its capacity to indicate vegetation in crop and forest area [24]. Therefore, an urban manager will have the capacity to monitor projects of urban green areas. The NDVI can measure a vegetation increase that not necessarily mean modifying the land use, for example, city streets reforestation, the encouragement of private or communal gardens, green walls or rooftops, and other initiatives [25].

This research has proven the efficiency and utility of remote sensing techniques in measuring ecosystems and their services, especially for managers under a tight budget. For example, in Cádiz Bay, the chlorophyll and total suspended matter demonstrated higher values near urban areas. Although water quality samples should always be taken and analyse by a certified laboratory, this remote sensing technique can allow the manager to gather information at a much lower cost than the laboratory test. It can also prioritise testing areas to measure location with higher chlorophyll and suspended matter [26].

CONCLUSIONS

With remote sensing techniques, this research demonstrated that the anthropic variables had exerted pressure on the ecosystem services for all the selected matrices. However, most importantly, it demonstrated the utility and use of remote sensing techniques to measure ecosystem services variables, proving to be an excellent urban and environmental management tool.

The air quality seems to be the least impacted ecosystem service, primarily due to the wind and climate variables. Nonetheless, thanks to the decline in air pollution during the COVID-19 pandemic lockdown during April 2020, this research demonstrated that lower emissions are possible to accomplish and that remote sensing techniques are helpful and low-cost to monitor changes in this environment matrix.

There is an evident variation on chlorophyll and total suspended matter near the city of Cádiz, which indicates a probable influence on water quality. Therefore, using this remote sensing technique, urban and environmental managers can improve their testing methods and select better sample areas to represent the pollution in an established area.

Finally, the NDVI demonstrated to be an excellent index to measure urban vegetation. Although it does not have 100% accuracy, it detects vegetation changes that cannot be detected with land cover classification. For example, the NDVI detects trees and other isolated urban vegetation. It is also cost-effective compared to other, more accurate techniques to measure urban vegetation, making it an excellent urban management tool. This research demonstrated the need for more urban green areas inside Cádiz. Urban vegetation provides many ecosystem services, making the creation and maintenance of urban green areas a cost-effective technique to improve human well-being.

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