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Proceeding Paper

Drone-Based Spatio-Temporal Assessment of a Seagras Meadow: Insights into Anthropogenic Pressure †

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Abstract: *Zostera marina* L. is a flowering plant of great ecological interest as a breeding, nursery, and feeding place for many species. However, its spatial location implies strong competition with human uses (boating, fishing, etc.). Regular monitoring at a very high spatial and temporal resolution by a drone has been initiated to study the spatio-temporal and ecological dynamics of the seagrass meadow. Three drone campaigns per year were carried out in 2021 and 2022, totaling six spatial models. A pixel-oriented classification was performed to determine the overall envelope and to analyze the fragmentation of the meadow, which is likely caused by anchorage. A yearly loss of 465.18 m^2 was measured (envelope area) and a difference of 12.15 m^2 was observed between 2021 and 2022 (fragmented envelope area).

Keywords: seagrass; drone; machine learning

1. Introduction

Seagrass meadows play a key socio-ecological role as attested by the ecosystem services they provide to society in terms of their support, supply, regulation, and cultural services [1].

Protected by international, European, and local acts, *Zostera marina* L. meadows, made up of a marine flowing plant (angiosperm), are subject to considerable human pressure related to their geographical distribution: abrasion of anchor chains tied to recreational boat fishing [2], trawling due to professional fishing, and trampling due to foot fishing at low tide [3].

Regular, annual, and seasonal monitoring is required to study and explain the seagrass meadow dynamics. Satellite monitoring techniques, such as Sentinel 2, have demonstrated their ability to identify seagrass meadows, but at the expense of a coarse spatial resolution [4].

Fine spatial and temporal resolution is required to study coastal habitats. Drones provide this opportunity and are able to deliver natural color images (Red-Green-Blue; RGB) at a centimeter scale [5].

This study is part of the European Life Impact project, which aims to assess the disturbance/stress caused by human activity on a subtidal seagrass bed through an image machine learning classification algorithm. The aim of this study is to monitor the surface evolution and fragmentation of the seagrass meadow on a fine spatial and temporal scale using a drone.

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2. Materials and Methods

2.1. Study Site

The study site was at La Varde (48°40′59 N; 1°59′13 W) in the commune of Saint-Malo in Brittany on the subtidal seagrass meadow, *Zostera marina* L. (Figure 1).

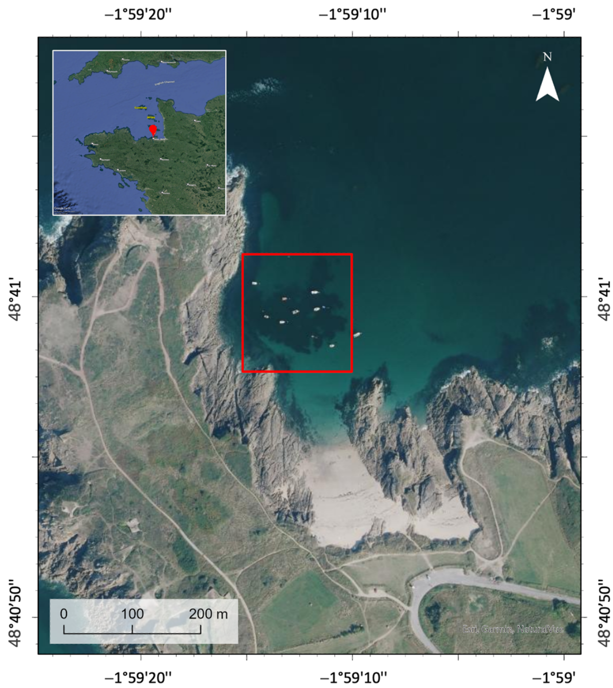


Figure 1. Map of the study area (red rectangle).

2.2. Data Collection

Three drone campaigns per year were carried out between 2021 and 2022. DJI's P4 Pro V2 drone equipped with a 20 M pixel camera was used to collect 188 Red-Green-Blue images (Figures 2 and 3). A flight plan that was created previously provided 80% front overlapping and 70% side overlapping. The drone flew at a constant height of 50 m.

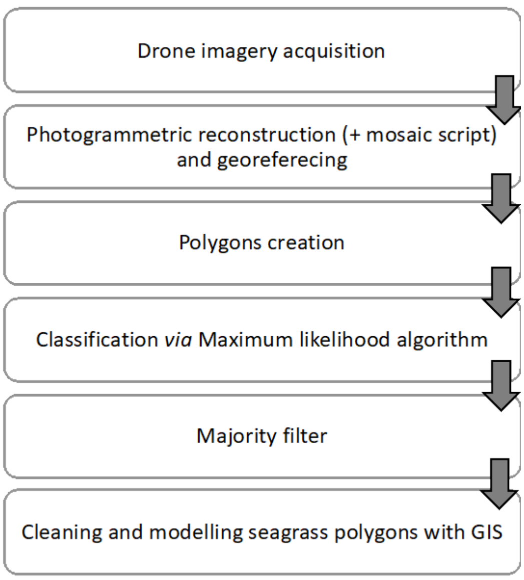


Figure 2. Methodology workflow.

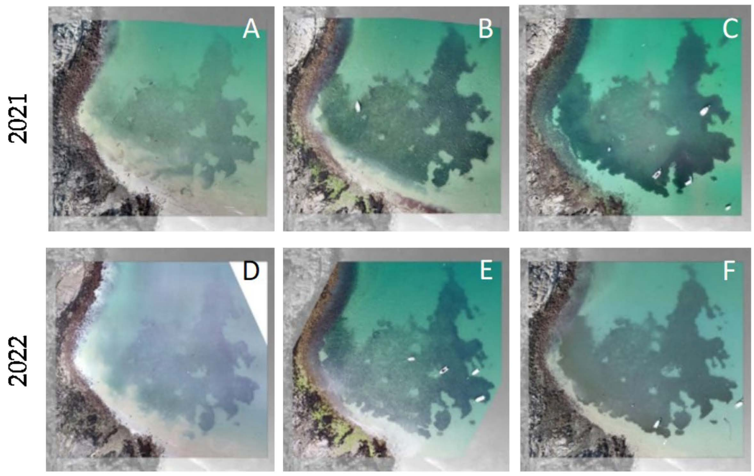


Figure 3. Orthomosaics Red-Green-Blue of the seagrass meadow of La Varde on 1 March 2021 (**A**), 27 May 2021 (**B**), 6 September 2021 (**C**), 3 February 2022 (**D**), 16 May 2022 (**E**) and 11 October 2022 (**F**).

Six ground control points were distributed over the terrestrial part of the survey area and geolocated using a GNSS RTK Emlid reach RS2+.

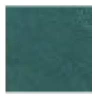
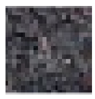
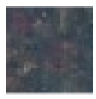
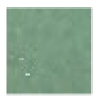
During the same timeframe as the drone surveys, underwater truths were collected by snorkeling.

2.3. Machine Learning Algorithm

Six classes were identified: immersed seagrass, emerged/immersed macroalgae, emerged/immersed sediment, and emerged rock (Table 1).

A machine learning algorithm, namely the probabilistic maximum likelihood, was employed.

Table 1. Classes identified to classify the study site.

Class Name	Thumbnail
Immersed seagrass	
Emerged macroalgae	
Immersed macroalgae	
Emerged rock	
Immersed sediment	
Emerged sediment	

3. Results and Discussion

3.1. Classification Results

The overall accuracy of the machine learning classification (ML) reached 73.31%, 87.82%, 90.3%, 65.83%, 73.35% and 84.03% in March, May and September 2021 and in February, May and October 2022, respectively.

Seagrass identification is better in spring and summer, and more imprecise in winter. These results corroborate the phenology of the seagrass meadows; they are more sparse in winter, with increasing density in spring, and full flowering in summer [6].

3.2. Annual and Seasonal Dynamics

Results have revealed a 465.18 m^2 loss in the seagrass meadow on an annual scale between 2021 and 2022 (Table 2).

Table 2. Annual evolution of the seagrass meadow (in m^2).

Year	Area (m^2)
2021	15,138.25
2022	14,673.07

Analysis of the results on a seasonal scale highlights a shrinkage of the meadow during the winter period and an expansion during the summer period, i.e., a differential of 382.4 m^2 between March and September 2021, and 370.64 m^2 between February 2022 and October 2022 (Figure 4). These temporal variations might be explained by the sensitivity of the *Zostera marina* L. species to variations in sedimentation and turbidity, which are more pronounced in winter due to the higher level of hydrodynamism at this period of year [7].

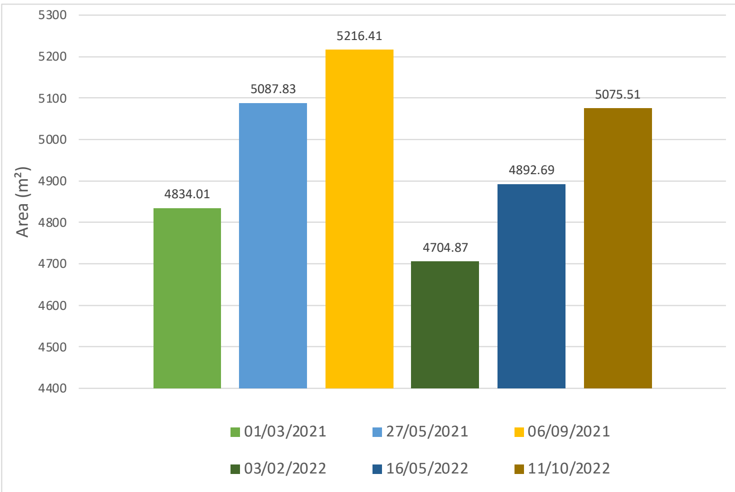


Figure 4. Histogram of the seasonal variation in the envelope of the seagrass meadow at La Varde (Saint-Malo).

3.3. Fragmentation Analysis

Seagrass meadow fragmentation was measured (fragmented envelope area) and highlights a difference of −12.15 m^2 between 2021 and 2022.

In addition, two ecological anchorages (InnoBlanc and InnoRouge) have been installed in the seagrass zone, with the particularity of reducing the scraping of the seabed. Over the 2021–2022 study period, the results of seagrass fragmentation revealed that 10% and 7% of fragmentation is attributed to InnoBlanc and InnoRouge respectively, and that 34% and 47% of fragmentation is driven by traditional anchorages REF01 and REF02, respectively (Figures 5 and 6).

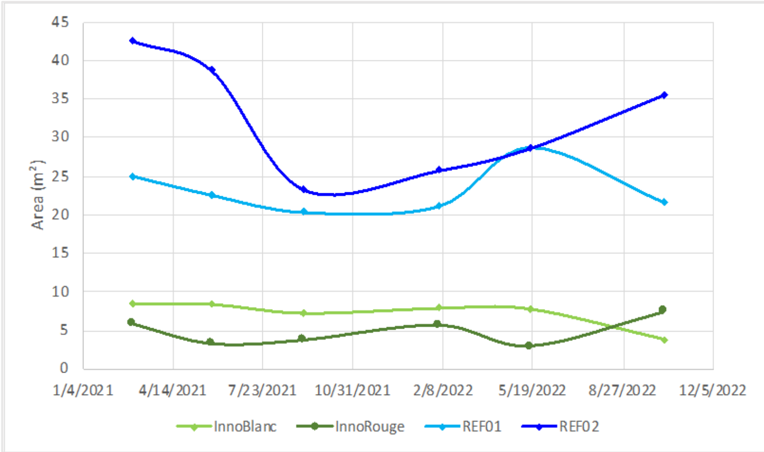


Figure 5. Diagram of the surface evolution of seagrass fragmentation as a function of the type of anchorages: traditional in blue and ecologic in green.

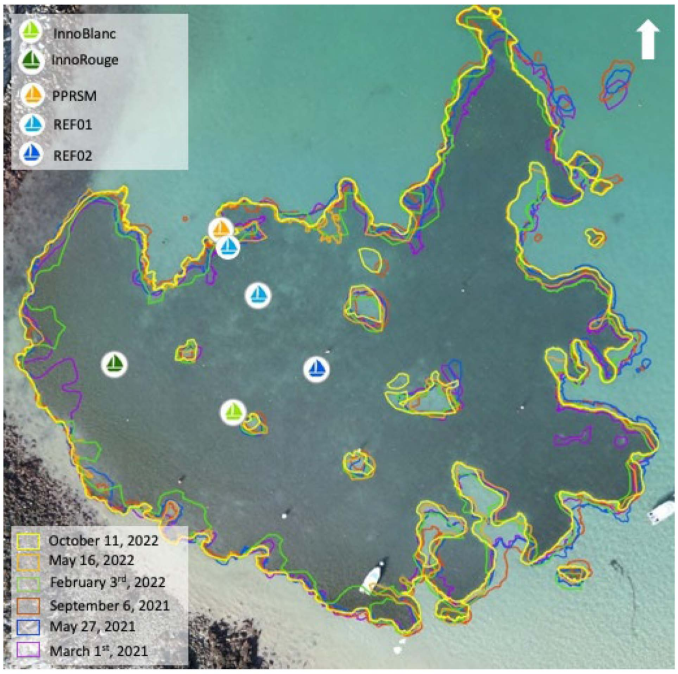


Figure 6. Map of the seagrass meadow fragmentation, innovative anchor vs. traditional anchor.

Regarding fragmentation, the seagrass meadow recovery can be explained by the protection measures adopted, such as restricting fishing on foot and setting up ecological anchorages.

4. Conclusions

The evolution of the seagrass meadow at la Varde (Saint-Malo) has been evaluated thanks to monitoring carried out three times a year in 2021 and 2022 by a drone equipped with an RGB sensor. Based on the easy-to-transfer maximum likelihood algorithm, the overall accuracy was evaluated, and the seagrass meadow envelope was extracted, representing a loss of 465.18 m^2 between 2021 and 2022. Subsequently, based on this information, the analysis of the anthropogenic impact on the meadow revealed a significant difference between two types of anchorages (traditional and ecological) with consequences for the fragmentation of the meadow: 36 m^2 and 172 m^2 in 2021, and 35 m^2 and 161 m^2 in 2022 between ecological and traditional anchorages, respectively.

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Conflicts of Interest: The authors declare no conflicts of interest.

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