Seagrass mapping in two mudflats in the Auray River
About a rapid evolution of seagrasses

Simon Oiry[a,*], Bede Ffinian Rowe Davies[a,*]

[a] *Nantes Université, UR 2160, F-44000 Nantes, France, Institut des Substances et Organismes de la Mer, ISOMer, 2 chemin de la houssinière, Nantes, 44300*

Abstract

Maps of seagrass in two sites in the Auray River. These two sites were studied by Maxime Daviray during his PhD. Seagrass appeared very quickly during his PhD. This work aims to describe this rapid evolution of seagrasses.

Keywords: Remote Sensing, Sentinel-2, Seagrass

The data and scripts used for this work can be found here.

1. Materials & Methods

1.1. Seagrass mapping using Sentinel-2

To map the seagrass extent over time, the Sentinel-2 constellation was used. Level-2 images, which are already orthorectified and atmospherically corrected, were downloaded from the Copernicus Platform [1]. For most years, one low-tide, cloud-free image per year—closest to the period of peak annual seagrass biomass at this latitude—was selected. However, during the sampling years (2021–2022), all available low-tide, cloud-free images were used to characterize seagrass phenology. In total, 21 images were used (Table 1).

*Corresponding author

Email addresses: `oirysimon@gmail.com` (Simon Oiry), `bedeffinian@gmail.com` (Bede Ffinian Rowe Davies)

Table 1: Acquisition dates of Sentinel-2 images used to map seagrass in the Auray River mudflats. Tide times were obtained from SHOM and correspond to the tides at the Locmariaquer tide gauge, located approximately 2 km from the study sites. All usable images (i.e., cloud-free and at low tide) during the sampling period (2023–2023) were downloaded. For other years, a single image per year was used, selected based on the date of maximum seagrass extent.

Acquisition Date (UTC)	Low Tide Time (UTC)	Time Difference with Low tide
2016-11-03 11:12	12 : 08	- 00 : 56
2017-10-04 11:08	09 : 09	+ 01 : 59
2018-09-29 11:08	12 : 43	- 01 : 35
2019-09-14 11:06	10 : 28	+ 00 : 38
2020-08-04 11:06	10 : 45	+ 00 : 21
2021-10-08 11:09	11 : 18	- 00 : 09
2022-01-21 11:12	12 : 30	- 01 : 18
2022-03-07 11:09	13 : 19	- 02 : 10
2022-03-17 11:08	09 : 59	+ 01 : 09
2022-03-22 11:06	12 : 59	- 01 : 53
2022-06-15 11:06	10 : 40	+ 00 : 26
2022-06-30 11:06	11 : 01	+ 00 : 05
2022-07-15 11:06	11 : 19	- 00 : 13
2022-07-30 11:06	11 : 17	- 00 : 11
2022-08-29 11:06	11 : 27	- 00 : 21
2022-11-12 11:13	12 : 26	- 01 : 13
2023-01-12 11:13	13 : 34	- 02 : 21
2023-02-20 11:11	10 : 34	+ 00 : 37
2023-06-05 11:06	10 : 55	+ 00 : 11
2023-09-03 11:06	12 : 28	- 01 : 22
2024-08-08 11:09	12 : 32	- 01 : 23

The *Intertidal Classification of Europe: Categorising Reflectance of Emerged Areas of Marine vegetation with Sentinel-2* model has been applied to each Sentinel-2 image (ICE CREAMS, [2]). It is a neural network classifier designed to identify and discriminate intertidal vegetation in Europe. Pixels of the Magnoliopsida class (seagrasses) have been isolated, and the Normalized Difference Vegetation Index (NDVI, [3]), a commonly used remote sensing biomass proxy for vegetation, has been employed. The equation of [4] have been used to transform NDVI values into Seagrass Percent Cover (Equation 1). Only pixels with SPC values above 20%, corresponding to high biomass pixel have been considered in order to avoid confusion with other class of vegetation.

$$SPC = 172.06 \times NDVI - 22.18 \quad (1)$$

Maps and analysis have then been performed using the *Terra* package of R, in a *Tidyverse* workflow [5, 6].

The total extent of each site/date is represented as an absolute area, taking into account the seagrass density of each pixel.

$$\text{Extent}_{s,d} = \sum_{i=1}^{N_{s,d}} A_{\text{pixel}} \cdot D_i$$

where:

- $\text{Extent}_{s,d}$ is the total seagrass extent at site s and date d
- $N_{s,d}$ is the number of pixels classified as seagrass at site s and date d
- $A_{\text{pixel}} = 100\ \text{m}^2$ is the area of one pixel
- D_i is the seagrass density of pixel i (scaled from 0 to 1)

2. Results

2.1. Evolution of the spatial distribution of seagrasses over time

The time series of the seagrass percent cover between 2016 and 2024 shows an overall increase in meadow extent at both sites (Figure 1). From 2019 onwards, the meadows became denser at Fort Espagnol, particularly in the northern part of the mudflat. At Kerouarc'h, the meadow was limited to small, sparse patches between 2016 and 2019. However, from 2021 onward, the seagrass meadow experienced a rapid expansion, covering almost the entire mudflat.

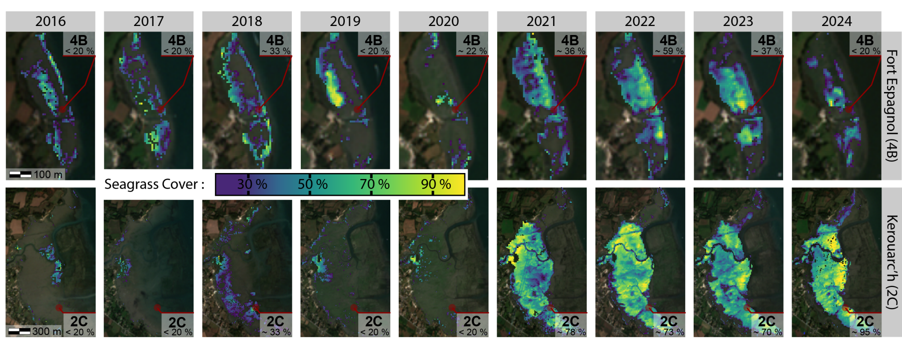

Figure 1: Time Series of Seagrass Percent Cover from 2016 to 2024 in Fort Espagnol and Kerouarc'h, two sites along the Auray River. Red points represent sampling stations: 4B - 47.616°N, 2.953°W; 2C - 47.583°N, 2.955°W. Labels are showing SPC values for each Site/Year.

2.2. Evolution of the extent and density of the meadow over time

Figure 2 A) shows the temporal evolution of seagrass meadow extent at both sites. From 2016 onwards, the extent steadily increased, reaching a maximum in 2021 at Fort Espagnol and in 2022 at Kerouarc'h. The only exception to this trend occurred in 2020, due to the presence of green algae overlaying the meadow, which led to an underestimation of its actual extent in the satellite imagery. After reaching their respective peaks, the extent slightly declined at both locations in the following years.

Figure 2 B) shows the density of meadow over time. Cover remained relatively stable from 2016 to 2020, then increased sharply at both sites, reaching a maximum average of 72% per pixel at Kerouarc'h in 2024 and 54% at Fort Espagnol in 2023. In 2024, however, a marked decline in density is observed at Fort Espagnol, despite the extent of the meadow remaining relatively high.

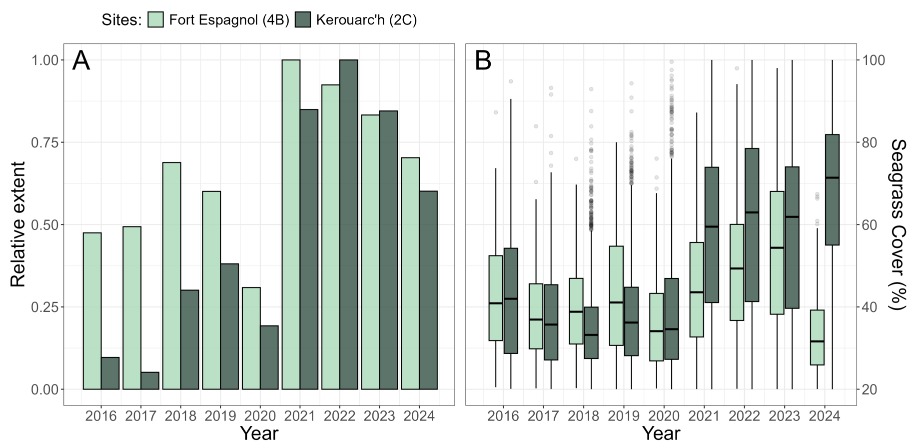

Figure 2: Description of the evolution of seagrass over time. A - Relative seagrass extent of each site. A value of 1 means maximum extent of the time serie for the site. B - Boxplot of the density of seagrass for each site at each date. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). Whiskers are to 1.5 * IQR (Inter-Quartile Range) from the hinge.

2.3. Monthly cover of seagrasses

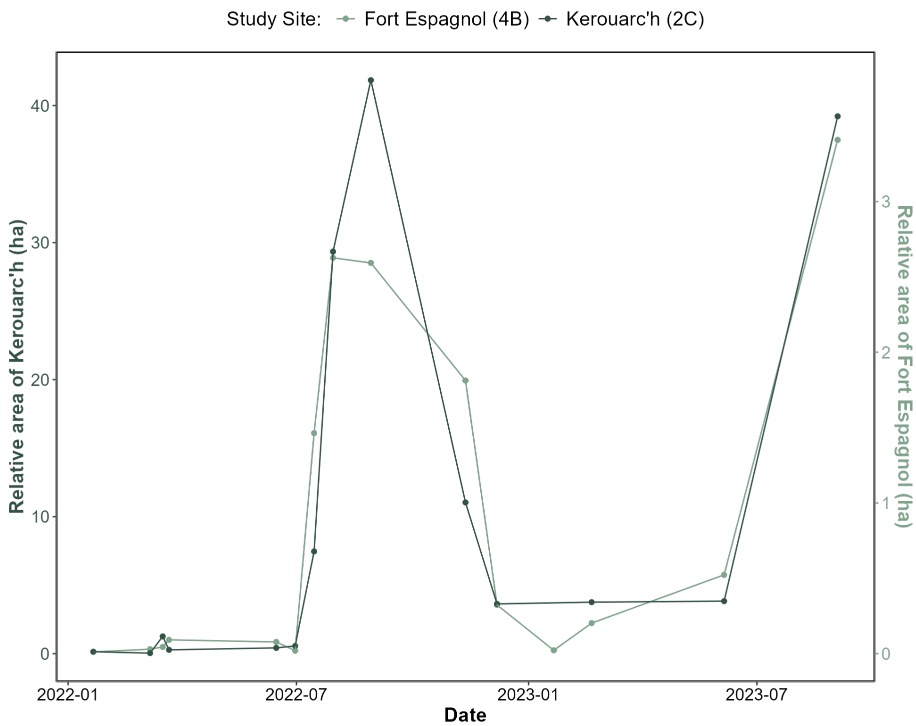

Figure 3: Evolution of the seagrass cover at Kerouarc'h and Fort Espagnol during 2022 and 2023

Figure 3 shows a strong seasonal variation in seagrass cover at both sites. Seagrass cover is nearly absent during winter and begins to increase in early summer (July), reaching peak extent and density around September. Kerouarc'h hosts the largest meadows, covering more than 40 hectares on August 29, 2022, while Fort Espagnol reaches a maximum extent of 2.5 hectares during the same period.

References

[1] Copernicus, Copernicus open access hub, accessed: 2024-07-16 (2024). URL https://browser.dataspace.copernicus.eu/

[2] B. F. R. Davies, S. Oiry, P. Rosa, M. L. Zoffoli, A. I. Sousa, O. R. Thomas, D. A. Smale, M. C. Austen, L. Biermann, M. J. Attrill, A. Roman, G. Navarro, A.-L. Barillé, N. Harin, D. Clewley, V. Martinez-Vicente, P. Gernez, L. Barillé, A sentinel watching over inter-tidal seagrass phenology across western europe and north africa, Communications Earth & Environment 5 (1) (2024) 382. doi:10.1038/s43247-024-01543-z. URL https://doi.org/10.1038/s43247-024-01543-z

[3] J. W. Rouse, R. H. Haas, J. A. Schell, D. W. Deering, et al., Monitoring vegetation systems in the great plains with erts, NASA Spec. Publ 351 (1) (1974) 309.

[4] M. L. Zoffoli, P. Gernez, P. Rosa, A. Le Bris, V. E. Brando, A.-L. Barillé, N. Harin, S. Peters, K. Poser, L. Spaias, et al., Sentinel-2 remote sensing of zostera noltei-dominated intertidal seagrass meadows, Remote Sensing of Environment 251 (2020) 112020.
URL https://doi.org/10.1016/j.rse.2020.112020

[5] R. Hijmans, terra: Spatial data analysis. r package version 1.7-39, The R Foundation for Statistical Computing (2023).

[6] H. Wickham, Easily install and load the 'tidyverse', R package version 1 (1) (2017).