Shape

Description automatically generated with medium confidence

Simon Oiry

PhD student

Laboratoire ISOMer  
UFR Sciences et Techniques

Email: oirysimon@gmail.fr

*Remote Sensing of Environment*

**Editor-in-Chief**

Dear Editor-in-Chief, 2th may 2024

I hope that the following research article will be considered for publication in *Remote Sensing of Environment*:

**Discriminating Seagrasses From Green Macroalgae in European Intertidal areas using high resolution multispectral drone imagery.**

Intertidal seagrass meadows provide a wide range of ecosystem services to humanity. Seagrass meadows are particularly vulnerable to the intensification of human activities in coastal areas, facing direct impacts from anthropogenic pressures. This has led to a worldwide decline and fragmentation of these critical habitats. In turn, both the fragmentation and reduction of these habitats can significantly undermine the ecosystem services that seagrass meadows provide. The critical role of seagrass meadows and the diverse ecosystem services they offer have spurred the development of enhanced global and regional initiatives to monitor Essential Oceanic Variables (EOVs) like seagrass composition, and Essential Biodiversity Variables (EBVs) including taxonomic diversity, species distribution, population abundance, and phenology of seagrasses. Traditionally, seagrass status indicators have been determined through in situ measurements. Yet, obtaining these measurements in intertidal zones is notoriously difficult.

Remote sensing techniques have been proven effective in complementing in situ sampling, allowing for the near real-time and consistent retrieval of seagrass EOVs and EBVs over extensive meadows.

However, this technique faces limitations in accurately mapping vegetation when taxonomically distinct species have identical pigment compositions.

This study addresses critical gaps in the remote sensing of coastal ecosystems, particularly in distinguishing between seagrass and green macroalgae in heterogeneous intertidal zones—a challenge that conventional satellite remote sensing techniques struggle to overcome due to their limited spatial and spectral resolution.

Our research utilizes high-resolution multispectral imagery from unmanned aerial vehicles (UAVs) equipped with a ten spectral band sensor mirroring those of the MSI sensor of Sentinel-2 satellites. The findings from our nine drone flights across diverse intertidal habitats in France and Portugal demonstrate the precision of our deep learning classifier, which achieved an overall accuracy of 94% in discriminating between five taxonomic classes of intertidal vegetation. This underscores the capability of multispectral remote sensing combined with a Neural Network classifier to accurately differentiate between types of vegetation that share similar pigment compositions.

This seagrass research was carried out, as part of a wider project, to fill a large data gap in the current literature. Seagrass ecosystems provide a range of socio-economic and ecological services. The European Union has emphasised the importance of seagrasses, with the Water Framework Directive highlighting them as indicators of ecosystem health. This has led to extensive conservation, monitoring and assessments of seagrasses across the EU. However, while seagrasses occur in both inter and subtidal zones, there have been consistent biases towards relying on subtidal seagrasses in these assessments; yet intertidal seagrasses form a vital link between terrestrial and marine ecosystems. This bias in monitoring has likely been driven by the inaccessibility of most intertidal seagrass areas, which often form huge meadows across mud flats, where incoming tides and soft, deep sediment make *in situ* fieldwork both difficult and highly dangerous. Subsequently, this has led to intertidal seagrasses being either ignored or grouped amongst subtidal seagrasses for continental scale assessments. Furthermore, due to their climate regulatory and coastal protection potential, seagrasses are the subject of many conservation and restoration projects globally. Therefore, overlooking such an important habitat, covering at least 127,921 km2 globally, will hamper efforts to fight climate change. Intertidal seagrasses are also tidally subjected to both marine and terrestrial climatic conditions, which, in turn, mean that their annual variation, especially at high latitudes, will be driven by a combination of terrestrial and marine seasons. Intertidal seagrasses in high latitudes have been shown to follow strong seasonal patterns of above ground growth, yet when included in large scale estimates of seagrass trends or inventories these seasonal patterns have been ignored or assumed to be consistent across latitudes. Satellite imagery offers a unique avenue for evaluating remote and otherwise inaccessible locations throughout all seasons. Its long-term archives provide access to invaluable historical data. As remote sensing methodologies increasingly permeate the public domain, so does our capacity to conduct equitable and transparent scientific investigations on spatiotemporal scales that had never been considered until now. Sentinel-2 imagery, as open-access, pre-processed datasets, serves not only the specialised user communities but also extends its utility to the broader public, media and educational sectors. This accessibility fosters innovation and underpins a broad spectrum of societal benefits.

Here we show how large the variation in intertidal seagrass trajectories is across 6 intertidal seagrass sites spanning over 15° of latitude. This was shown using a combination of novel machine learning neural-network modelling tools to classify, in almost real-time. The **I**ntertidal **C**lassification of **E**urope: **C**ategorising **R**eflectance of **E**merged **A**reas of **M**arine vegetation with **S**entinel-2 (ICE CREAMS v1.0), a neural network model trained on over 300,000 Sentinel-2 pixels to identify different intertidal habitats, was applied to the open-access long term archive of systematically collected Sentinel-2 imagery to provide 7 years (2017-2023) worth of intertidal seagrass dynamics in 6 sites across Western Europe (471 Sentinel-2 Images). With an accuracy of 82% across ~12,000 validation pixels, we were able to show the interannual trajectories in intertidal seagrass meadows across Europe. Modelling the clear intra-annual variation allowed us to show how some seagrass beds are changing over time in their extent, while others stay stable or fluctuate.

Global efforts to tackle climate change by monitoring, managing and restoring blue carbon habitats, such as mangroves, saltmarshes and seagrasses, have increased significantly in recent years. These efforts are returning varying results, but intertidal seagrasses, in particular, lack comprehensive estimates of extent, with mangrove and saltmarsh habitats being far more emphasised. Intertidal seagrass assessments have, as mentioned above, been overlooked, and currently have only been carried out at regional to subregional scales. As part of the wider project as the current work, we aimed to solve this lack in continental scale intertidal seagrass monitoring. This started by testing whether the multispectral resolution of Sentinel-2 would be sufficient to distinguish green macrophytes, this was accomplished by Davies, et al., 2023. *Remote Sensing of Environment* 290. Drone imagery were taken, assessed and analysed as part of training data acquisition for the ICE CREAMS model, presented here, and these results will soon be submitted to *Remote Sensing of Environment* by Oiry et al. Here we present a remote sensing method, utilising Sentinel-2 multispectral surface reflectance alongside drone acquired habitat data to build a neural network model. Then use this model as an example of trajectory assessment of intertidal seagrass covering continental scales.

For consideration of this manuscript, we would suggest the following reviewers:

* Heidi Dierssen for their expertise on coastal remote sensing and optics. Email: Heidi.dierssen@uconn.edu
* Nicolas J. Murray for their knowledge of using remote sensing for monitoring changes in coastal ecosystems. Email: [murr.nick@gmail.com](mailto:murr.nick@gmail.com)
* Richard Unsworth for their knowledge of seagrass assessments, monitoring and the importance of this habitat. Email: [r.k.f.unsworth@swansea.ac.uk](mailto:r.k.f.unsworth@swansea.ac.uk)

If we can be of assistance for further referee suggestions, please do not hesitate to contact me.

The first author Bede Ffinian Rowe Davies is also the corresponding author, and the work described, the production and authorship conform in every respect to Nantes University’s policies on ethical and responsible behaviour in research. We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission to *Remote Sensing of Environment*.

We look forward to hearing from you in due course.

Yours sincerely,

Bede Ffinian Rowe Davies

On behalf of all co-authors