Electro-Optical analysed spatial distribution of vessels, Isles of Scilly

Remote sensing techniques in support of seagrass meadows

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LIFE Recreation ReMEDIES (*LIFE18 NAT/UK/000039)*

Reducing and Mitigating Erosion and Disturbance impacts affecting the Seabed.

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Executive summary

High resolution Electro Optical (EO) data has emerged as a crucial tool in the realm of remote sensing for vessel detection in relation to environmental management. EO data, derived from satellite and aerial imagery, enables researchers and environmental managers to obtain detailed information about vessel type, location, and activity over an Area of Interest (AOI). This capability is vital for monitoring the anthropogenic pressures on fragile marine environments, facilitating effective conservation efforts, and ensuring sustainable use of marine resources.

EO data's ability to capture high-resolution imagery provides a comprehensive view of the AOI, making it possible to distinguish between different types of vessels based on size, shape, and other visual characteristics. This differentiation is essential in understanding the variety of boating activities taking place and assessing their respective impacts on important ecosystem assets such as seagrass meadows. The impact of boating, and particularly anchoring, on seagrass meadows is a critical concern for environmental managers. The integration of EO data into environmental management practices offers a proactive approach to mitigating the negative impacts of boating on seagrass meadows.

The LIFE Recreation ReMEDIES project, led by Natural England, aims to protect sensitive seabed habitats, including seagrass (*Zostera marina*) beds, which are easily damaged and slow to recover. This analysis will make a vital contribution to the aims of the LIFE Recreation ReMEDIES project by providing evidence on the impacts of boating activity on seagrass. To assess the spatial distribution of vessel detections in relation to seagrass meadows, OceanMind undertook a historical analysis of available EO imagery over the Isles of Scilly, United Kingdom, between 2017 and 2021. OceanMind obtained commercial EO imagery from Digital Globe for analysis period between May 2017 and October 2021. If imagery was unavailable or covered by cloud, OceanMind supplemented the commercially obtained EO images with open-sourced EO images from the European Space Agency's (ESA) Sentinel-2 constellation.

The Isles of Scilly AOI experiences a high level of recreational boat traffic. In total, 2184 vessels were detected across 27 high-resolution EO images between 2017 and 2021. The vessel detections were highest during the summer months of July and August, with moderate detections in images obtained in May, June and October. The results of this study highlight the threat that boating activity can have on the vulnerable seagrass habitats across the Isles of Scilly Complex. In total, 237 detections, or ~ 15% of total detections, were observed over the subtidal (Zostera sp.) seagrass meadows. Of these 237 detections, 195 (82.3%) were observed to exhibit anchoring behaviour.

Boating related damage to seagrass meadows can come in the form of propellor scarring, anchor damage or mooring scour. These activities can lead to habitat loss, reduced biodiversity, as well as erosion and sedimentation. To mitigate the impacts of boating, anchorage, and mooring on seagrass meadows, it is recommended to use a combination

of Advanced Mooring Systems (AMS) and No-Anchorage Zones. These specifically designed mitigation measures can be used to prevent seabed scouring and minimize the damage to seagrass meadows (AMS) or protect the seagrass meadows from direct physical damage entirely (No-Anchorage Zone). Further monitoring and research on boater behaviour and effectiveness of conservation measures will help inform adaptive management strategies that will continue to improve the conservation methods.

The use of high-resolution EO data serves as a powerful tool for vessel detection and environmental management in areas such as the Isles of Scilly, United Kingdom. Despite its limitations, EO data provides critical insights into boating activities and their impacts on seagrass meadows, enabling more effective conservation strategies. As technological advancements continue to enhance the resolution and availability of EO data, its role in protecting fragile marine ecosystems will undoubtedly become increasingly significant.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Introduction

High resolution Electro Optical (EO) data has emerged as a crucial tool in the realm of remote sensing for vessel detection in relation to environmental management. EO data, derived from satellite and aerial imagery, enables researchers and environmental managers to obtain detailed information about vessel type, location, and activity over an Area of Interest (AOI). This capability is vital for monitoring the anthropogenic pressures on fragile marine environments, facilitating effective conservation efforts, and ensuring sustainable use of marine resources.

As technological advances in remote sensing capabilities progress, EO data is becoming an increasingly viable tool, replacing more costly and time-consuming data collection methods (Kanjir and others, 2018). EO data's ability to capture high-resolution imagery provides a comprehensive view of the AOI, making it possible to distinguish between different types of vessels based on size, shape, and other visual characteristics (Bannister & Neyland, 2015). This differentiation is essential in understanding the variety of boating activities taking place and assessing their respective impacts on important ecosystem assets such as seagrass meadows. Furthermore, the geospatial positioning data embedded within EO imagery allows for precise tracking of vessel movements over time (Wang and others, 2021). By continuously monitoring these movements, environmental managers can identify behaviour patterns, such as frequent anchoring in specific areas, which may pose a risk to seagrass habitats.

However, the effectiveness of EO data for vessel detection is subject to certain limitations (Kanjir and others, 2018). The resolution of the sensor is a primary factor, as higher resolution imagery can provide more detailed and accurate information. However, higher resolution imagery often come with increased costs and data processing requirements. Additionally, weather conditions significantly impact the quality and usability of EO data. Cloud cover can obstruct the sensor's view of the AOI, leading to gaps in the data and potentially missed detections. In regions like the Isles of Scilly, where weather conditions can be highly variable, these limitations pose a challenge to consistent monitoring efforts. Moreover, the seasonality on the island affects the number of vessel detections, with peaks typically occurring during warmer months when recreational boating activity increases. Consequently, the number of vessel detections can fluctuate significantly with changes in cloud cover and sensor resolution, as well as the seasonal variations in boating activity on the islands.

The impact of boating, and particularly anchoring, on seagrass meadows is a critical concern for environmental managers. Seagrass meadows are highly productive ecosystems that provide numerous ecological benefits, including serving as nurseries for fish, stabilizing sediment, and sequestering carbon, forming important habitats in the sub-littoral and intertidal zones (Duffy, 2006; Howard-Williams, 2022). However, they are also highly susceptible to physical damage from boating activities (Collins, Suonpää &

Mallinson, 2010; Chen and others, 2007; Jones & Unsworth, 2016). Anchoring can cause direct damage to the seagrass by uprooting plants and creating scars on the seabed, which can take years to recover. Additionally, the turbidity caused by propeller wash and anchoring can reduce light availability for seagrass photosynthesis, further stressing these vital habitats.

The integration of EO data into environmental management practices offers a proactive approach to mitigating the negative impacts of boating on seagrass meadows. By providing either historical or near real-time monitoring capabilities, EO data allows for the timely identification of high-risk areas where boating activity is concentrated. Environmental managers can then implement targeted measures, such as designating no-anchoring zones or installing advanced mooring systems (AMS), to protect vulnerable seagrass meadows. Additionally, the data can be used to inform stakeholders and the boating community about the importance of seagrass conservation and encourage responsible boating practices.

The LIFE Recreation ReMEDIES project, led by Natural England, aims to protect sensitive seabed habitats, including seagrass (*Zostera marina*) beds, which are easily damaged and slow to recover. This analysis will make a vital contribution to the aims of the LIFE Recreation ReMEDIES project by providing evidence on the impacts of boating activity on seagrass. To assess the spatial distribution of vessel detections in relation to seagrass meadows, OceanMind undertook a historical analysis of available EO imagery over the Isles of Scilly, United Kingdom, between 2017 and 2021.

Methods

Area of Interest

The Isles of Scilly located approximately 28 miles off the southwestern tip of Cornwall, UK, encompass over 200 islands and islets, with only five inhabited. The archipelago, covering around 16 square kilometres, is designated as a Special Area of Conservation (SAC) under the EU Habitats Directive. This designation aims to protect its unique and critical habitats, including the seagrass meadows of *Zostera marina*. These seagrass meadows are vital for biodiversity, offering habitat and breeding grounds for various marine species and contributing to water quality and coastal stability.

As a SAC, the Isles of Scilly are subject to stringent conservation measures to preserve the ecological integrity. The seagrass meadows, in particular, are of significant interest due to the physiochemical (e.g., water quality), ecological (flora and fauna), climatic (e.g., mass stabilization & flood protection) and cultural (e.g., health & wellbeing benefits) services that they provide (Howard-Williams, 2022). The designation under the Conservation of Habitats and Species Regulations 2017 (as amended) ensures that any activities within the area, such as boating, fishing, and tourism, are managed to minimize impacts on these sensitive habitats. Conservation efforts by organizations such as Natural England focus on monitoring and protecting of these seagrass meadows to maintain the health and biodiversity of the marine environment in the Isles of Scilly.

Data Collection

OceanMind obtained commercial EO imagery from Digital Globe for analysis period between May 2017 and October 2021. The high-resolution EO imagery from Maxar Technologies, Digital Globe has a 0.5m resolution, with spatial coverage of the AOI, dependent on satellite orbit positioning and weather restrictions, coverage was between 15 – 25km x 5 – 180km. Priority was given to commercial Digital Globe imagery between 01st May – 30th September of a respective year.

If imagery was unavailable or covered by cloud, OceanMind supplemented the commercially obtained EO images with open-sourced EO images from the European Space Agency's (ESA) Sentinel-2 constellation. ESA Sentinel-2 imagery provides variable resolutions depending on the area and ranged from 10/20/60 m resolution imagery on a repeat cycle of five days with a tile size of up to 110 km^2. An image resolution of 20m was selected and pansharpened for improved detection capabilities. Pansharpening is a process of merging high-resolution panchromatic and lower resolution multispectral imagery to create a single high-resolution colour image.

While the Isles of Scilly cover about 75% of a Maxar Technologies Digital Globe imagery, the larger spatial coverage of the ESA Sentinel-2 images result in an AOI coverage of up to 10% of a Sentinel- 2 imagery. Table 1 highlights the variability in cloud coverage over the

Isles of Scilly AOI from Sentinel-2 imagery and the limitation in vessel detection capabilities. A low-cloud coverage imagery provides suitable conditions for vessel detection. A high-cloud coverage imagery reduces the visibility of the AOI and restricts the vessel detection capabilities.

Table 1: Examples of the influence of cloud cover over the Isles of Scilly AOIs from Sentinel-2 images.

Satellite Image	Cloud Cover (%)	AOI	Figure references
Sentinel – 2; low cloud cover	0.1	Bar Point, St Mary's	Figure 1
Sentinel – 2; High cloud cover	43.8	None	Figure 2

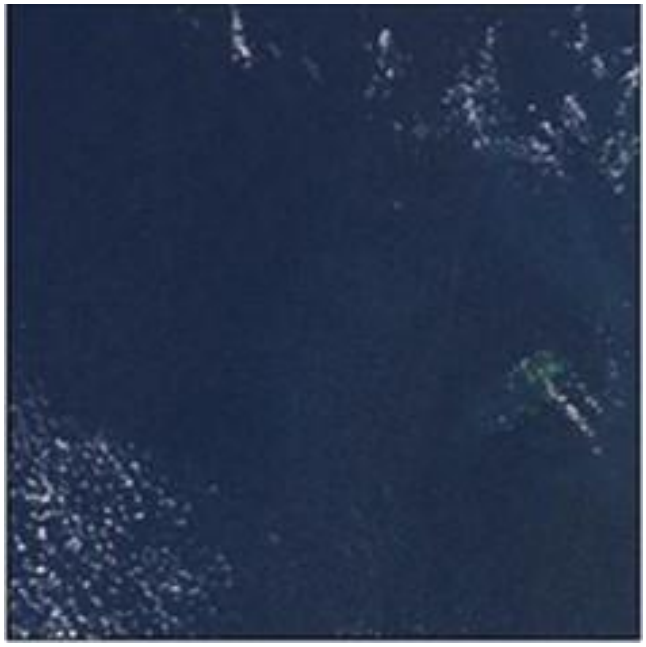

Figure 1: Sentinel-2; low cloud over (0.1%) at Bar Point, St Mary's Isles of Scilly © 2021 Copernicus Sentinel

Figure 2: Sentinel-2; high cloud cover (43.8%) © 2021 Copernicus Sentinel

EO image selection was dependent on availability and cloud coverage. If no EO images were available whereby the AOI was not significantly cloud-free, additional imagery was analysed for those areas (e.g., Sentinel – 2 imagery in 2018). Once the imagery was selected over the AOI, the images were analysed using the online Maxar Technologies Digital Globe, SecureWatch platform or downloaded in the case of ESA Sentinel-2 images. The images were reviewed at a magnification level of 20m. When a vessel was detected in

an image, the detection was recorded geospatially (latitude and longitude), with an assigned confidence level (Table 2) and classification (Table 3). The confidence level is an indication of how accurately an analyst can confirm the presence of a vessel. The different available resolutions and associated analytical confidence is show in Table 2. The images in Table 2 highlight the distortion of a catamaran sailing vessel under various EO image resolutions. As the resolution increases from 20m to 0.2m, the ability to detect vessels and the associated confidence that what is being detected is accurately identified, increases as well. Vessels detected at a lower resolution are more difficult to identify accurately.

Table 2: Variable analyst confidence in vessel detection capability with different EO image resolution.

Satellite	Resolution	Confidence for targets above 5 m	Confidence for targets below 5 m	Figure references
WorldView - 03	0.3 - 0.4 m	Very High	High	Figure 3
WorldView - 02	0.5 - 0.6 m	High	Medium	Figure 4
WorldView - 02	0.7 - 20 m	Medium	Low	Figure 5
Sentinel - 2	20 m	Low	Not detectable	Figure 6

Figure 3: A WorldView-03 (0.3-0.4 m resolution) satellite image of a vessel in the Isles of Scilly. ©2021 Maxar Technologies.

Figure 4: A WorldView – 02 (0.5-0.6 m resolution) satellite image of a vessel in the Isles of Scilly ©2021 Maxar Technologies.

Figure 5: WorldView 02 (0.7-20 m resolution) satellite image of a vessel in the Isles of Scilly ©2021 Mazar Technologies.

Figure 6: Sentinel-2 satellite image of an unidentified vessel 'V' in the Isles of Scilly ©2021 Copernicus Sentinel.

Vessels were categorised into different size and type classes (Table 3). These classes were chosen based on the vessel detection confidence and the potential risk they pose to seagrass meadows. All vessel detections were classified into one of nine codes. The vessel codes, a brief description, and accompanying examples from EO imagery can be seen in Table 3.

Table 3: Vessel identification codes from EO imagery.

Code	Explanation	Figure Ref
V	V is an unspecified target detected within Sentinel – 2 images. These targets are usually larger than 10 m. Targets above 30 m may be identified by type and therefore not categorised with V.	7a and 7b
S	S are small targets without engines, or Personal Watercraft (PWC, e.g., Jet Ski). When the activity could be identified these targets, activity may be listed as Recreational (R).	8a and 8b
SE	Small Engine boats that do not have any sheltered structure and do not exceed 6 m.	9a and 9b
ME	Medium Engine boats are between 6 – 10 m in size and usually have only a small, sheltered structure.	10a and 10b
LE	Large engine vessels are without a sailing mast above 10 m.	11a and 11b
MS	Sailing boats below 24 m are considered MS.	12a and 12b
SC	Sailing Catamarans are between 15 – 25 m in size with a single mast. There were some catamarans within this size category without a mast, which were still considered here.	13a and 13b
LS	Large sailing vessels are all vessels above 24 m. This category was very rarely observed.	14a and 14b

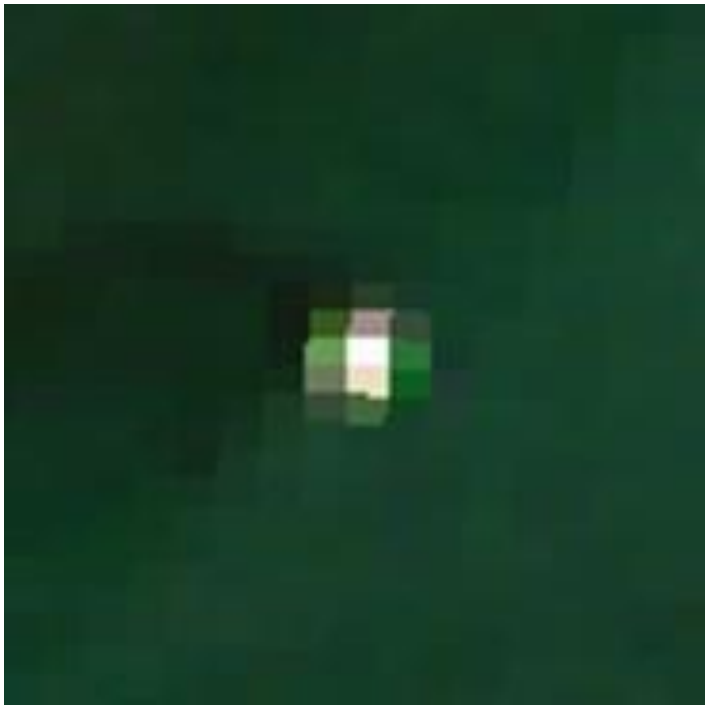

Figure 7a: Sentinel-2 satellite image of an unspecified vessel 'V' in the Isles of Scilly ©2021 Copernicus Sentinel.

Figure 7b: A satellite image of an unspecified vessel 'V' in the Isles of Scilly ©2021 Copernicus Sentinel.

Figure 8a: An image of one or two small ‘S’ vessels or personal watercraft in the Isles of Scilly. If they are identifiable, they are then maybe classified as Recreational ‘R’ ©2021 Maxar Technologies.

Figure 8b: This is a satellite example image of one or two small 'S' vessels or personal watercraft in the Isles of Scilly. If they are identifiable, they are then maybe classified as Recreational 'R' ©2021 Maxar Technologies.

Figure 9a: This is a satellite example image of Small Engine (SE) boats that do not have any sheltered structure and do not exceed 6 m ©2021 Maxar Technologies.

Figure 9b: This is a satellite example image of Small Engine (SE) boats that do not have any sheltered structure and do not exceed 6 m ©2021 Maxar Technologies.

Figure 10a: This is a satellite example image of Medium Engine (ME) boats between 6 to 10 m in size and usually have only a small, sheltered structure ©2021 Maxar Technologies.

Figure 10b: This is a satellite example image of Medium Engine (ME) boats between 6-10m, and usually featuring a small, sheltered structured in the Isles of Scilly ©2021 Maxar Technologies.

Figure 11a: This is a satellite example image of large engine (LE) vessels are without a mast and are larger than 10m ©2021 Maxar Technologies, seen in the Isles of Scilly.

Figure 11b: This is a satellite example image of large engine ‘LE’ vessels are without a mast and are larger than 10m ©2021 Maxar Technologies, seen in the Isles of Scilly.

Figure 12a: This is a satellite example image of Sailing boats ‘MS’ below 24 m, seen in the Isles of Scilly ©2021 Maxar Technologies.

Figure 12b: This is a satellite example image of Sailing boats ‘MS’ below 24 m, seen in the Isles of Scilly ©2021 Maxar Technologies.

Figure 13a: This is a satellite example image of Sailing Catamarans ‘SC’ are between 15-25 m in size with a single mast, seen in the Isles of Scilly ©2021 Maxar Technologies.

Figure 13b: This is a satellite example image of Sailing Catamaran 'SC' are vessels between 15-25 m in size with a single mast. Although some were observed to be without a mast but were still classed as this type of vessel in the Isles of Scilly ©2021 Maxar Technologies.

Figure 84a: This is a satellite example image of large sailing vessel ‘LS’ observed in the Isles of Scilly ©2021 Maxar Technologies.

Figure 14b: This is a satellite example image of large sailing vessel ‘LS’ observed in the Isles of Scilly ©2021 Maxar Technologies.

In conjunction with vessel type (Table 3), the activity of the detection was assessed where possible (

Table 4). The activity classifications were selected based on visible vessel behaviour. The activities were divided into four classifications, representative of the behaviour, and was

inferred as either recreational (R), anchored[1] (A), moving (M) or stationary (S). If there was no activity visible, the detection was considered as stationary (S). Some activity unrelated to risks for seagrass meadows were spelled out (e.g., docking).

Table 4: Vessel activity codes and explanation.

Code	Explanation	Figure Reference
R	**R**ecreational activity describes a high confidence detection, where a small (excluding PWC) target is used recreationally.	15a and 15b
A	An **A**nchor (or float) is visible near the vessel.	16a and 16b
M	Any target where a wake suggest that the target is **M**oving.	17a and 17b
S	Any target which is **S**tationary without any evidence of anchoring or moving.	18a and 18b

[1] Without any prior knowledge on the locations of the pre-established moorings, any vessels observed to be attached to an anchor or mooring was classified as Anchored (A) in this analysis.

Figure 15a: This is a satellite example image of Recreational activity 'R' describes a high confidence detection where small, excluding Personal Watercraft targets, is being used in the Isles of Scilly ©2021 Maxar Technologies.

Figure 15b: This is a satellite example image of Recreational activity 'R' describes a high confidence detection where small, excluding Personal Watercraft targets, is being used in the Isles of Scilly ©2021 Maxar Technologies.

Figure 16a: This is a satellite example image showing a vessel, in the Isles of Scilly, either using an anchor 'A' or a float visible near the vessel ©2021 Maxar Technologies.

Figure 16b: This is a satellite example image showing a vessel, in the Isles of Scilly, either using an anchor 'A' or a float visible next to the vessel ©2021 Maxar Technologies.

Figure 17a: This is a satellite example image of a satellite image showing a target, which is moving 'M' and causing a wake, in the Isles of Scilly ©2021 Maxar Technologies.

Figure 17b: This is a satellite example image of a satellite image showing a target, which is moving and causing a wake, in the Isles of Scilly ©2021 Maxar Technologies.

Figure 18a: This is a satellite example image of a satellite image showing a stationary 'S' vessel without any evidence of anchoring or movement ©2021 Maxar Technologies.

Figure 18b: This is a satellite example image of a satellite image showing a stationary 'S' vessel without any evidence of anchoring or movement ©2021 Maxar Technologies.

Results

The Isles of Scilly AOI experiences a high level of recreational boat traffic. In total, 2184 vessels were detected across 27 high-resolution EO images between 2017 and 2021. The vessel detections were highest during the summer months of July and August, with moderate detections in images obtained in May, June and October. Across all years, 2021 (811 detections), 2019 (651 detections) and 2017 (435 detections) had the highest number of detections whilst 2018 (123 detections) and 2020 (164 detections) had the lowest

number of detections. The low detections in 2018 can be attributed to lower resolution of the Sentinel-2 images used for this period. However, the low detections in 2020 were a likely result of the COVID-19 pandemic, whereby outside activity was restricted which resulted in fewer vessel detections.

The EO detection density across the 12 different AOIs which make up this study is evident in Figure 19 and Figure 20. Figure 19 highlights the detection density in relation to Isles of Scilly AOIs, with darker colours representing a greater number of detections. Further evident in Figure 19 are the vessel detections in relation to the Isles of Scilly seagrass meadows. In total, 237 detections, or ~ 15% of total detections, were observed over the seagrass meadows. Most of these detections (149 or 63%) were observed over the St Mary's seagrass meadows, whilst 58 (25%) detections were observed over the Eastern Isles seagrass meadows and 31 (13%) were observed over the Tresco seagrass meadows. Of these 237 detections, 195 (82.3%) were observed to exhibit anchoring behaviour. Only 8 detections over the seagrass meadows were observed to be moving (3.4%), whilst a further 34 detections (14.3%) were stationary.

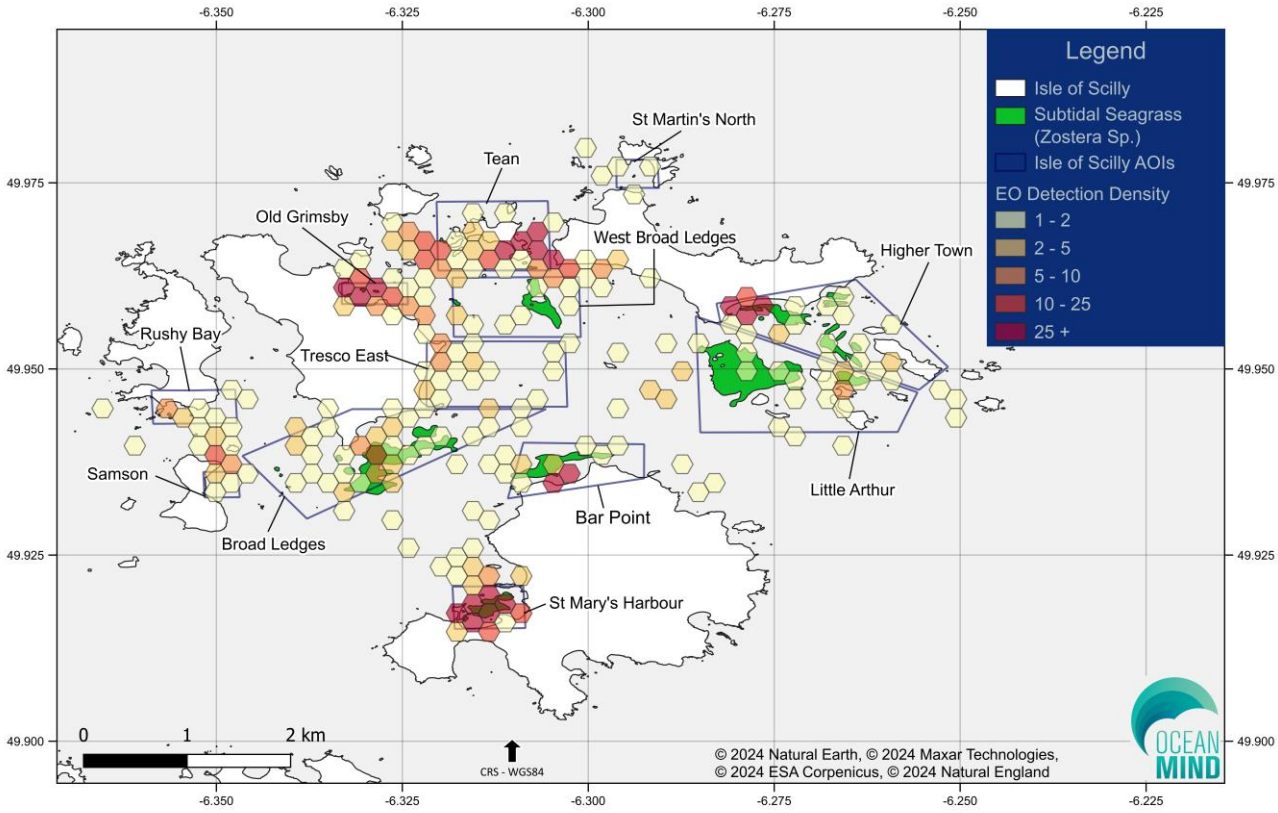

Figure 19: A map highlighting the vessel detection density derived from electro-optical imagery over the Isles of Scilly AOIs. The subtidal seagrass (Zostera sp.) has been mapped showing the vessel detections in relation to these vulnerable ecosystems.

Of the 195 detections that were observed to be anchored over seagrass meadows (Figure 19), the majority of these (44%) were classified as medium engine (ME) vessels, and a

further 24.6% were classified as small engine (SE) and 13.3% as large engine (LE). It is notable that vessels with an engine are more likely to physically damage the seagrass meadows through propeller scarring in shallow waters in conjunction with the disturbances from the anchor itself.

A total of 1856 (85%) of all detections were observed within the 12 Isles of Scilly AOIs (Figure 20). Only 328 (15%) of detections were observed outside of the AOI boundaries. St Mary's Harbour had the highest number of detections. The highest numbers of detections occur in bays with port structures (Figure 19 & Figure 20). The area around St Mary's Harbour (595) had the highest number of detections, followed by Old Grimsby (386), Higher Town Bay (295) and Tean (236).

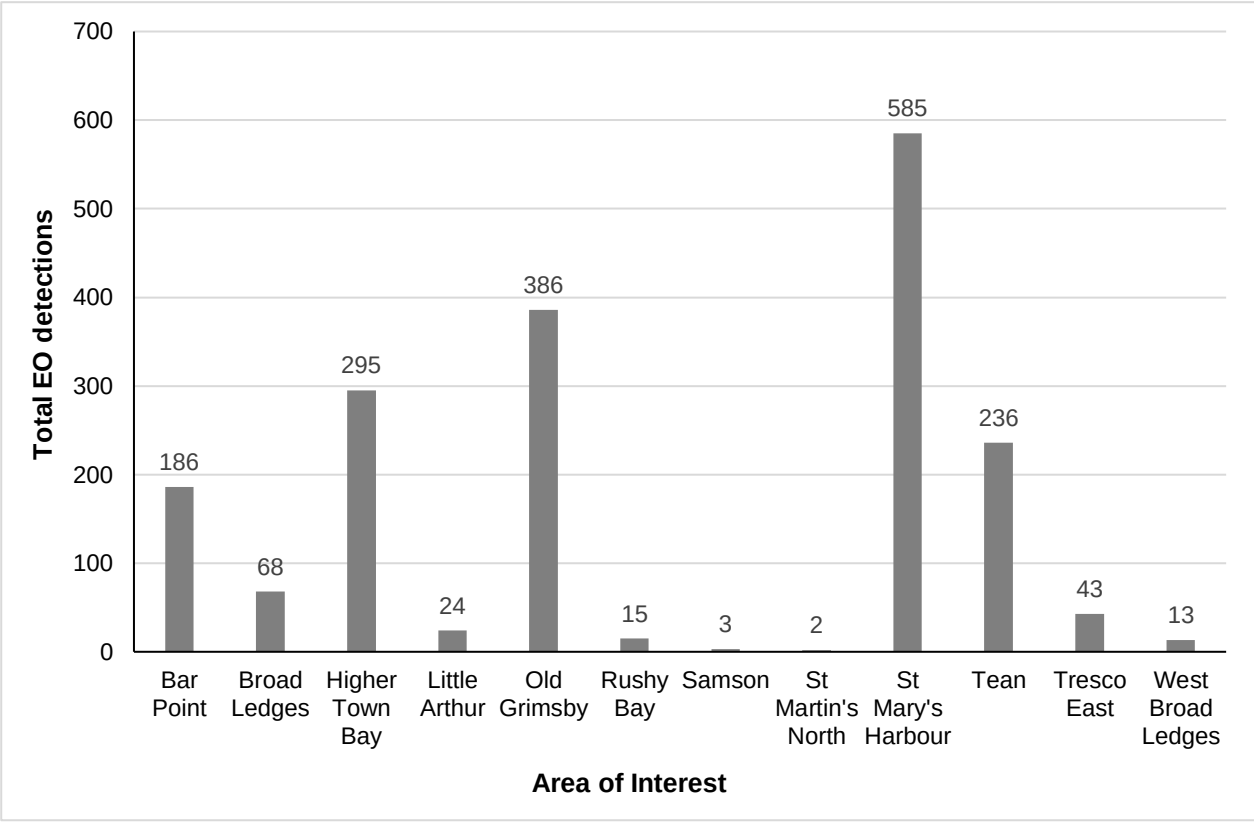

Figure 20: Plot of the total electro-optical detections across the twelve Areas of Interest (AOIs) across the Isles of Scilly used in this study.

Due to the high detection rate in ports and bays most detections were either on anchor or stationery. Across all the detections, as seen in Figure 21, a total of 955 (43.7%) vessels were observed to be anchored (A) whilst 941 (43.1%) of detections were classified as stationary (S). In some instances, stationary vessels may be under anchor, but this was not clear in the imagery. Moving targets were scattered around most AOIs with a slightly over proportional representations (moving targets/all targets in the AOI) in Broad Ledges, Tresco and Tresco East. As seen in Figure 21, only 132 (6%) of vessel detections were actively moving (M) in the imagery, whilst a further 41 (1.9%) of detections were

undertaking recreational activity whilst 115 (5.3%) were classified as “Other,” which was given to vessels that were docked in a harbour (106 detections) or stranded on a beach (9 detections).

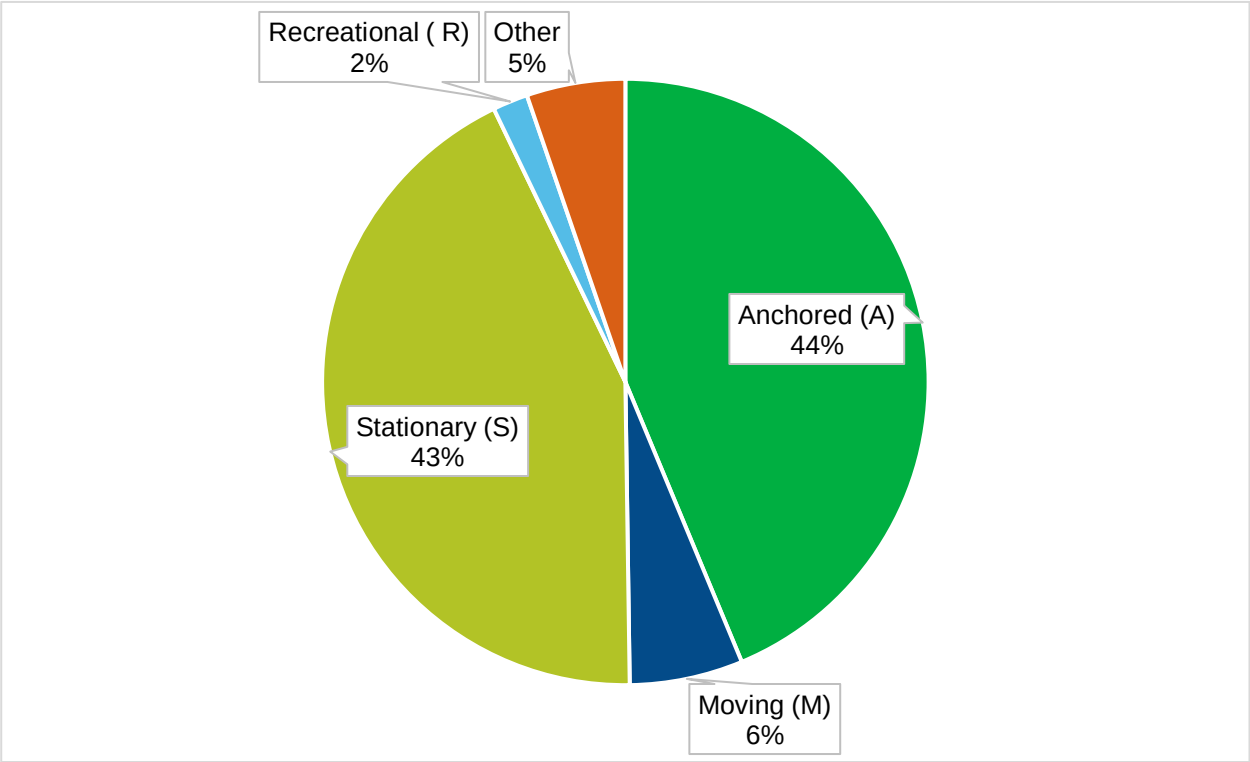

Figure 21: Diagram highlighting the proportion of vessel activity among the 2184 detections observed in Electro - Optical imagery over the Isles of Scilly, 2017 – 2021.

Across the analysis, each detection was assigned a vessel identification letter according to the shape and profile of the detection, in conjunction with the clarity of the image, in relation to the classification rigour in Table 3. Many detections, 1491 or 68.3%, were observed to be vessels with an outboard motor engine whilst 224 (10.3%) were classified as sailing vessels. In total, 249 (11.4%) of detections were unspecified targets whereby the resolution of the Sentinel-2 images restricted the ability of the observer to accurately determine the shape and profile of the vessel (Figure 22). As seen in Figure 22, which depicts the total number of detections across vessel types, the vessel types with the greatest number of detections are the medium engine (ME) and small engine (SE) detection categories. The small targets (S) which do not have an engine, or are private watercraft (PWC), make up 220 detections and the fourth highest detection category. The highest category of sailing vessels are the sailing boats below 24m in length (MS), whereby 197 detections were observed across the period.

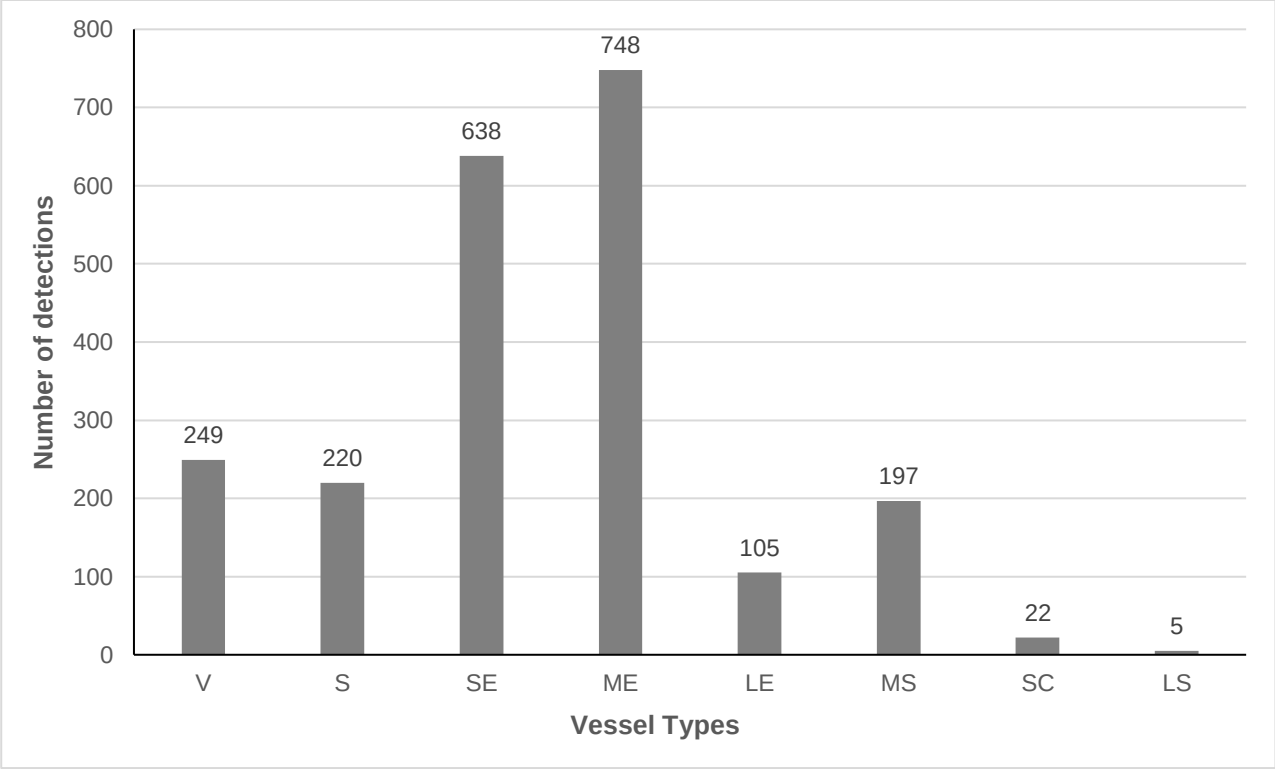

Figure 22: Vessel classifications from 2184 detections observed in Electro - Optical imagery over the Isles of Scilly, 2017 – 2021.

Conclusion and Recommendations

The results of this study highlight the threat that boating activity can have on the vulnerable seagrass habitats across the Isles of Scilly Complex. In total, 237 detections, or ~ 15% of total detections, were observed over the subtidal (Zostera sp.) seagrass meadows. Of these 237 detections, 195 (82.3%) were observed to exhibit anchoring behaviour. The high proportion of anchored motorised vessels detected over the seagrass meadows underlines the susceptibility of these areas to boating damage. There were significantly more detections in July and August compared to September and June. Furthermore, commercial imagery needs to be tasked or available, the availability of which is dependent on other parties historically requesting imagery over the area, which varied through the period of the analysis.

Boating related damage to seagrass meadows can come in the form of propellor scarring, anchor damage or mooring scour (Collins, Suonpää & Mallinson, 2010; Chen and others, 2007; Jones & Unsworth, 2016). Propeller scarring occurs when boats travel through shallow waters, whereby the propellers can cut into seagrass meadows, causing physical damage to the plans which can lead to reduced seagrass cover and fragment the habitat. Dropping anchors onto seagrass meadows can uproot plants and disturb the sediment. Repeated anchoring in the same area can create barren patches within the seagrass meadow, leading to habitat fragmentation (Unsworth and others, 2017). Furthermore, traditional mooring can cause scouring as chains drag along the seabed and with the movement of tides and boats, resulting in patches of disturbed, damaged or dead seagrass (Unsworth and others, 2017).

These activities can lead to habitat loss, reduced biodiversity, as well as erosion and sedimentation (Jones and Unsworth, 2016). Seagrass meadows are critical habitats for a variety of marine species. Damage from boating activities can lead to a loss of habitat for fish, invertebrates, and other marine organisms that rely on seagrass for food and shelter. Physical damage to seagrass meadows because of boating activity can therefore result in decreased biodiversity. Seagrass meadows, such as those prevalent in the Isles of Scilly, support complex food webs, and their degradation can lead to the decline of species diversity and abundance (Ashley and others, 2020). Furthermore, seagrass meadows help stabilize the seabed. Damage to these meadows can increase erosion and sedimentation rates, which can further degrade the habitat and affect water quality (Hansen and Reidenbach, 2012).

It is difficult to compare the activity around the seagrass meadows by year, as satellite imagery was not frequently obtained. The EO imagery available in 2017, 2019 and 2021 had greater coverage than the imagery available in 2018 and 2020. High cloud cover in 2018 challenged the feasibility of the analysis further. The covid pandemic influenced the vessel activity in 2020 further and may have had impacts on the operations in 2021 due to

the number of tourists visiting the Islands or other social economic effects. However, the proportion of activity in the respective AOIs does not change significantly.

As a SAC, the Isles of Scilly are subject to stringent conservation measures to preserve their ecological integrity. The seagrass meadows are of significant interest due to their role in supporting diverse marine life, including fish, invertebrates, and birds (Howard-Williams, 2022). The designation under the Habitats Directive ensures that any activities within the area, such as boating, fishing, and tourism, are managed to minimize impacts on these sensitive habitats. Conservation efforts by organizations such as Natural England focus on monitoring and protecting these seagrass meadows to maintain the health and biodiversity of the marine environment in the Isles of Scilly. It is recommended that future monitoring in this area is used to explore the vessel anchorage hotspots to inform targeted conservation efforts to help protect these vulnerable ecosystems.

Future monitoring through EO imagery can be obtained throughout the year, where available, to inform suitable areas for mitigation measures. To mitigate the impacts of boating, anchorage, and mooring on seagrass meadows, recommendations include the use of a combination of Advanced Mooring Systems (AMS) and Voluntary No-Anchorage Zones (VNAZ). These specifically designed mitigation measures can be used to prevent seabed scouring and minimize the damage to seagrass meadows (AMS) or protect the seagrass meadows from direct physical damage entirely (No-Anchorage Zone). In the UK, VNAZ have been implemented in areas such as Studland Bay in Dorset in 2021 and Osborne Bay in the Isle of Wight in 2024. These bays have been observed to exhibit high levels of vessel activity whereby the seagrass beds have shown signs of damage from anchoring and mooring pressures.

Further recommendations could include the implementation of “No Wake Zones,” whereby reducing the speed that boats travel over sensitive areas to prevent damage, erosion and fragmentation (Chen and others, 2007). Further educating boaters about the importance of seagrass habitats and promoting best practices for anchoring and mooring can help reduce inadvertent damage. For further educational information on best practices for anchoring and mooring, see educational resources such as the Green Blue Green Guide to Anchoring. These considerations of boating compliance would need to be implemented in conjunction with Advanced mooring Systems and No-Anchorage Zones to provide a holistic approach. Further monitoring and research on boater behaviour and effectiveness of conservation measures will help inform adaptive management strategies that will continue to improve the conservation methods.

The use of high-resolution EO data serves as a powerful tool for vessel detection and environmental management in areas such as the Isles of Scilly, United Kingdom. Despite its limitations, EO data provides critical insights into boating activities and their impacts on seagrass meadows, enabling more effective conservation strategies. As technological advancements continue to enhance the resolution and availability of EO data, its role in protecting fragile marine ecosystems will undoubtedly become increasingly significant.

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