Becht Foundation | UK MPA Project

April to July 2022

Emerging Technology Assessment, a UK MPA Pilot

The UK MPA Project

Becht Foundation

The UK MPA Project is a collaboration between the Becht Family Charitable Trust and OceanMind. The project works with key partners responsible for Marine Protected Area (MPA) protection assurance and enforcement to identify a range of new Monitoring, Control and Surveillance (MCS) tools for use in English waters. This partnership aims to provide deterrent-by-detection solutions that are cost effective, high impact and scalable, and therefore can be applied to MPAs around the globe.

The project will increase the visibility of activity in the United Kingdom's MPAs. To achieve this, OceanMind will introduce a suite of previously unused tools to the relevant UK authorities, with the aim of highlighting risk areas and supporting MCS efforts within MPAs.

CONTENTS

ACRONYMS

AIS	Automatic Identification System
BFCT	Becht Family Charitable Trust
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
EO	Electro Optical
EVLOS	Extended Visual Line of Sight
IFCA	Inshore Fisheries and Conservation Authorities
I-VMS	Inshore - Vessel Monitoring System
MPA	Marine Protected Area
MCS	Monitoring, Control and Surveillance
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
OSC	Operational Safety Case
SAC	Special Area of Conservation
SAR	Synthetic Aperture Radar
VMS	Vessel Monitoring System
VLOS	Visual Line of Sight
UAV	Unmanned Aerial Vehicle
UK	United Kingdom

Marine Protected Areas

An MPA is a clearly defined geographical space, recognized, dedicated and managed to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN).

There are 91 Marine Conservation Zones (MCZ) in waters around England which are designated to protect important species, habitats, and ecological processes.

There are 656 Special Areas of Conservation (SACs) that contain animals, plants and habitats that are considered rare, special, or threatened within Europe.

Due to the central role of migratory bird populations in European ecosystems, 275 Special Protected Areas are designated for their protection.

Project Overview

Whilst not all MPAs have management measures in place, many of those that do have challenges with effective MCS. The Becht Family Charitable Trust (BFCT) UK MPA project has been working to help address this issue, with the aim of increasing the visibility of activity within UK MPAs, including that of non-compliant behaviour, by trialling a suite of tools previously unused by UK authorities.

In cooperation with the Marine Management Organisation (MMO) and the Inshore Fisheries and Conservation Authorities (IFCAs), OceanMind conducted a pilot to test how emerging technology and artificial intelligence can support MCS efforts within MPAs and help to define risks and improve risk mitigation across those in the UK.

Five sites were selected based on ecological features, fishing activity, non-compliance concerns and existing management measures. The group of sites was chosen to represent different variations including fully inshore (within 6 NM), fully offshore (beyond 6 NM), and straddling sites (across either the 6 NM or 12 NM boundary). This variety ensures that the chosen locations represent the range of different sites in UK waters that could benefit from remote sensing support.

Technology Pilot

During this pilot of the project, OceanMind have trialled a suite of technologies to understand the most cost-effective and results-driven way to ensure compliance and increase protection of vital marine habitats.

OceanMind gathered information about activities in the selected MPAs using:

- Vessel tracking positional information from Automatic Identification System (AIS) and the identity of a vessel.
- Artificial Intelligence to support analysts in efficiently and effectively monitoring risks. Vessel Monitoring System (VMS) and Inshore Vessel Monitoring System (I-VMS) data was processed through machine learning algorithms.
- Remote Sensing – Electro-optical (EO) and Synthetic Aperture Radar (SAR) – satellite imagery allows analysts to detect vessels which are not transmitting positional information.
- Unmanned Aerial Vehicle (UAV) short and long range systems were investigated to support patrol efforts, and monitoring and surveillance of remote sites.

Timeline of Analysis

January 2022
- CAA License Application Process starts.

April 2022
- EO Speculative Tasking begins on all sites
- Eddystone Drone Launch Site Assessment
- EO Tasking begins over Lundy MPA (10 weeks)
- Machine Learning Analysis on VMS and I-VMS Data on all sites (01Jan-26Apr).
- SAR Begins over South Wight MPA (5 Weeks)
- SAR Begins over Wight-Barfleur MPA (7 Weeks)
- SAR Begins over West of Walney MPA (8 Weeks)

May 2022
- EO Tasking begins over South Wight MPA (10 weeks)
- SAR Begins over Eddystone, Plymouth Sound to Start Point MPA (5 Weeks)
- SAR Begins over Lundy MPA (6 Weeks)

June 2022

July 2022
- Drone Flights at West of Walney MPA
- CAA BVLOS License Approval Received
- VMS and I-VMS Data Received (26Apr-31Jun) Machine Learning Analysis incomplete.
- AIS Analysis on all sites (31Mar-31Jun)

October 2022
- Drone Flights on Eddystone Scheduled

Vessel tracking

Automatic Identification System (AIS)

Whilst AIS use is not widespread by fishing vessels in the UK, it did provide useful insight into general activity levels, particularly in relation to larger vessels. During the pilot, AIS analysis was used in conjunction with satellite imagery in order to corroborate and better understand vessel activity.

Vessel Monitoring System (VMS) & Inshore Vessel Monitoring System (I-VMS)

Approximately 6 months of VMS data for all vessels operating in English waters and I-VMS data for vessels operating in the Devon and Severn IFCA District was obtained for analysis by the ML algorithm*. Around 1.5 million data points were provided for more than 2,000 vessels. All of this data was run through OceanMind's ML algorithm in order to generate alerts of fishing activity.

*OceanMind were provided with anonymised data and could not identify individual vessels. Information provided in additional to vessel tracks included vessel size, gear type and nationality only.

Machine Learning

Big Data Analysis

The 2,318 VMS and I-VMS vessel tracks which were monitored created nearly 1.3 million data points. It would require significant resources for human analysts to effectively monitor all these tracks.

OceanMind's Machine Learning (ML) algorithm was trained on AIS data in the UK and is able to analyse all tracks for factors including vessel type, fishing activity, and possible risks (alerts) in real time.

These alerts enable analysts to focus on vessels exhibiting potentially non-compliant activity inside restricted areas, facilitating more efficient monitoring.

Machine Learning

Breaches of technical and gear related restrictions are difficult to detect efficiently with satellite imagery, particularly over sites with complex muti-use byelaws. ML can be used to distil millions of vessel tracking data points to identify potential fishing activity within restricted byelaw areas.

OceanMind's ML algorithm has been developed using a variety of time-domain pattern matching techniques. The machine has been trained to produce a model of vessel behaviour which the pattern matchers then use to infer behaviour in new, previously unseen, data. Training requires a lot of example tracks and has been achieved by using many years of AIS data from tens of thousands of vessels. Machine Learning can be used to very quickly infer vessel behaviour. It allows to identify areas of interest in vessel tracks based on location, i.e. inside a restricted byelaw area which requires further investigation.

Over the Start Point to Plymouth and Eddystone SAC the primary risk to the site was identified to be vessels illegally fishing with bottom towed gear in the byelaw areas. Within this site, the ML algorithm identified vessels with tracks and speeds associated with fishing activity (bottom towed gear), including instances that indicated potential unauthorized activity within a byelaw area.

These instances were reported to the competent authority for further investigation to determine fishing activity from additional sources (logbook data, catch returns etc).
In order to increase efficiency of overall analysis, the ML algorithm could be altered to incorporate more detailed gear types within its processes.

OceanMind's ML engine also applies an additional filter to identify missing or anomalous data points by interpreting the context around the positions. These can be an indication of a faulty VMS unit which may require servicing.

MACHINE LEARNING ALERTS

FISHING INSIDE AREAS OF INTEREST	387
POTENTIAL FISHING IN RESTRICTED AREAS	45
VESSELS REPORTED	**25**

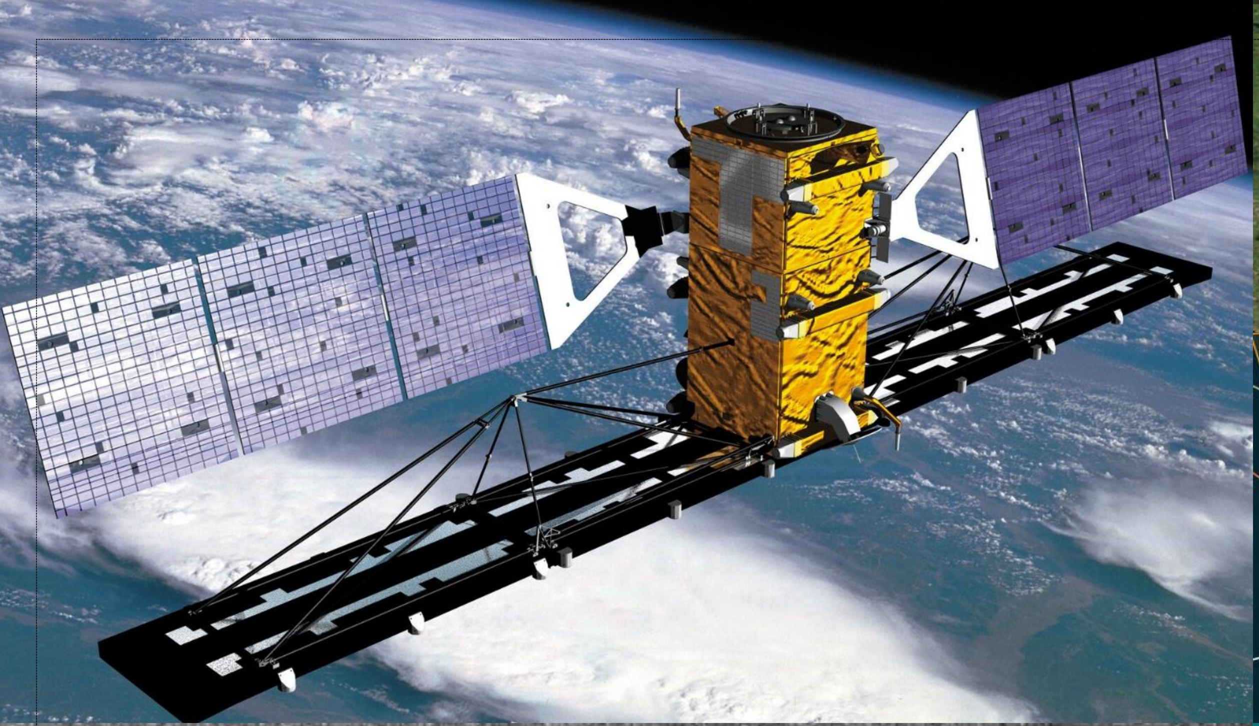
Vessel Tracking | Conclusions

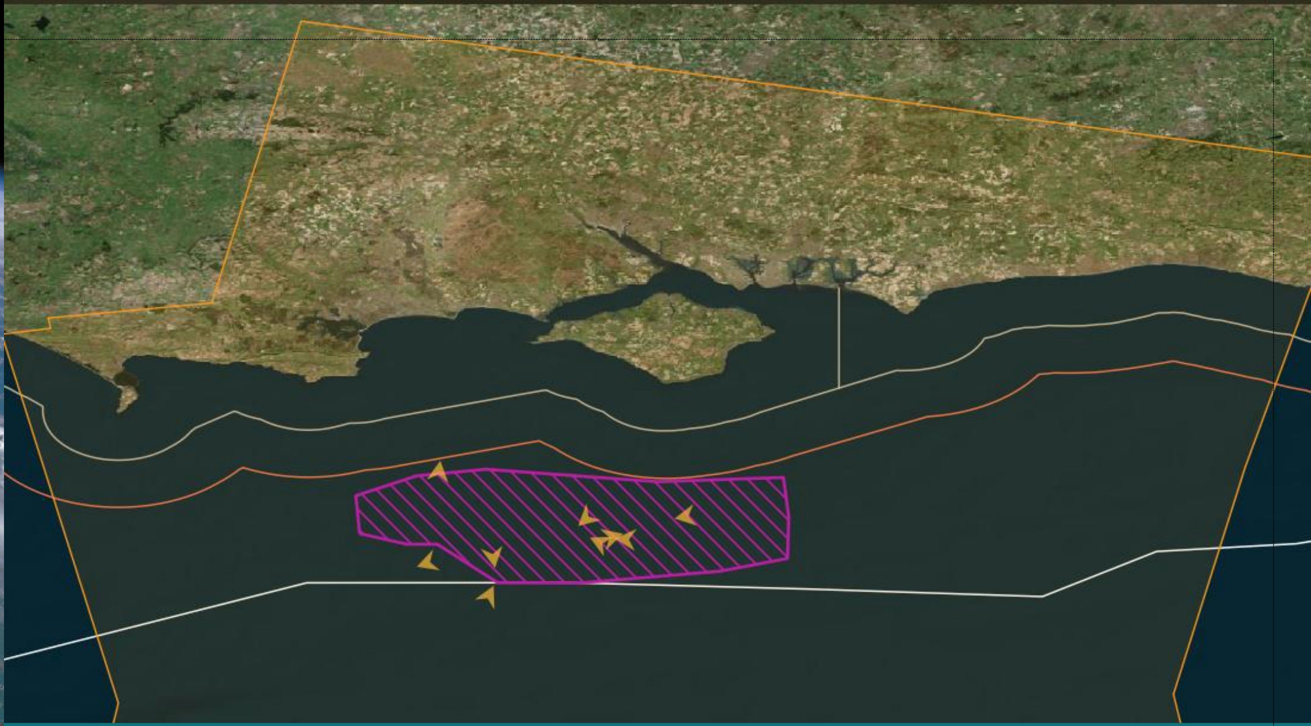
ML and AIS analysis can identify potentially non-compliant activity within restricted byelaw areas around the UK coastline.

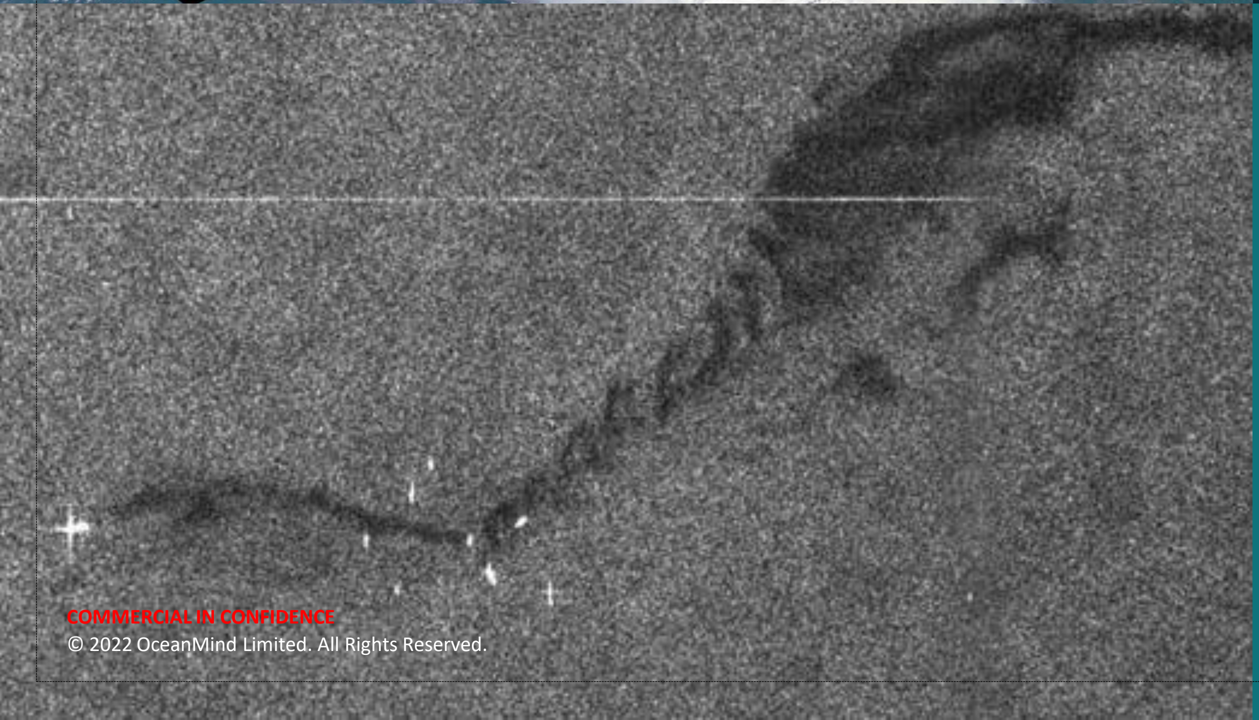
Alerts generated using data from the vessel tracking pilot show that ML is highly effective when analysing vessel tracking data sets. This is particularly true for I-VMS which has more data points per hour than VMS; VMS data transmissions are often too infrequent to accurately determine if unlicensed activity has occurred within closed areas. In some instances, AIS analysis identified behaviours in closed areas which were not detected through VMS alerts, due to the lower transmission rate of VMS vs AIS.

For sites where there are complex closed areas and multiple fishing vessel operations, ML can provide an efficient monitoring method for enforcement officers to generate alerts of likely fishing activity over byelaw areas for further investigation.

Based on the risks identified in the project, it is recommended that ML is applied to I-VMS data upon completion of the national rollout. This would allow to efficiently and effectively identify any non-compliant activity which occurs within the restricted byelaw areas, particularly vessels that are operating with bottom towed gear in areas closed to this activity. This will reduce the resource burden on governmental organisations and support efficient fisheries management.







Synthetic Aperture Radar

Utilization of micro-wave reflections from objects of higher density than their surroundings.

Top-Left | Graphic of the RadarSat-2 Satellite used in this pilot. (Copyright: European Space Agency)

Top-Right | Case Study over the Wight Barfleur SAC (purple), showing the area over which SAR was acquired (orange) and detections (arrows). (Data provided by MDA, Satellite Image: Microsoft

Lower-Left | Other uses for maritime monitoring include oil spills. The example in the image shows a vessel collision off the Belgium coast. (Copyright: European Space Agency)

Statistics

342,990 km² of area covered between April 2022 and July 2022.

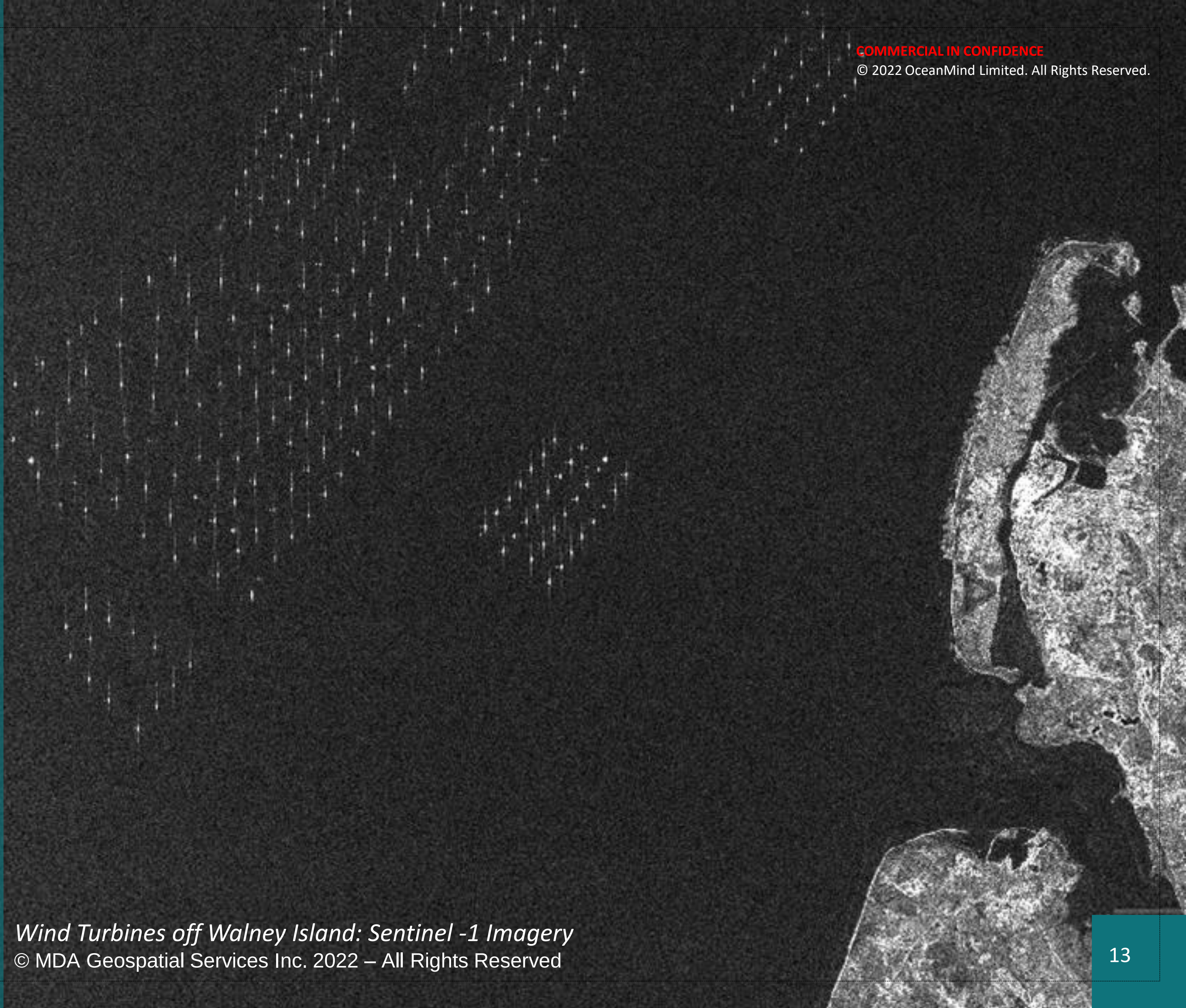
46 images collected.

- 31 Extra-Fine (6 m resolution)
- 15 Ultra-Fine (3 m resolution)

54 'dark' (non-transmitting on AIS) vessel detections* within the MPA and surrounding 3 NM buffer.

517 detections correlated with AIS transmissions.

***Detections** were passed to MMO for cross-referencing with the definitive VMS to investigate non-compliance



Wind Turbines off Walney Island: Sentinel -1 Imagery

Synthetic Aperture Radar

Advantages

- Effective at characterizing larger targets
- Reliable detection algorithms
- Predictable and advanced planning
- Independent of weather conditions

Application in the UK

- Strategic Historical & Risk Assessments

Disadvantages

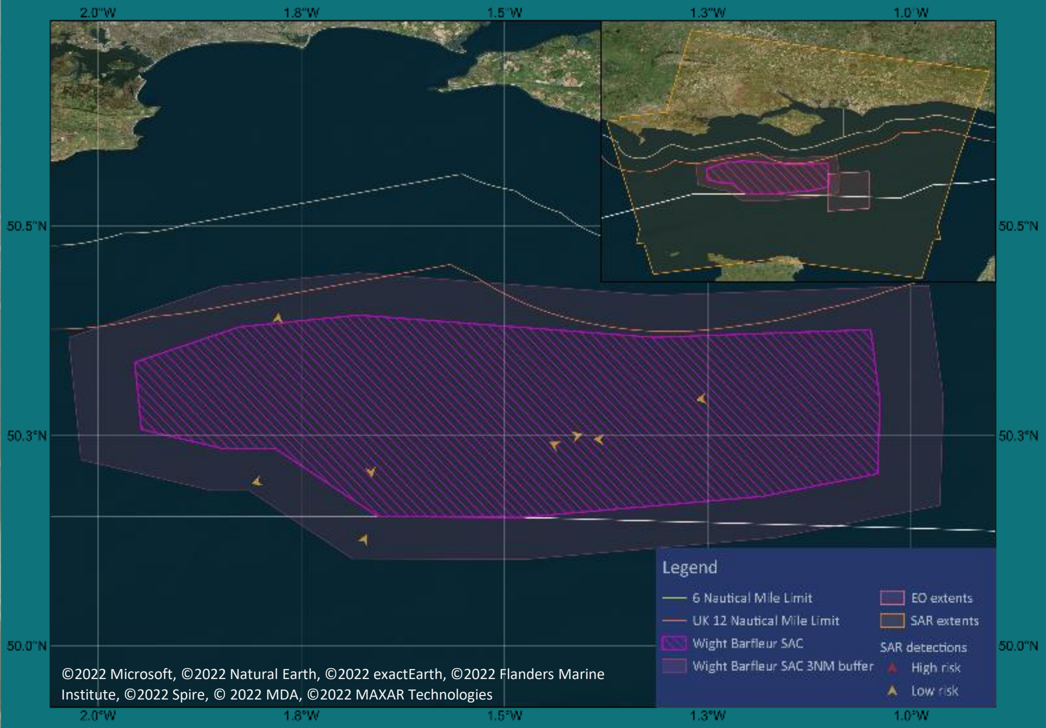
- Vessel identity, type and risk can often not be defined
- Size estimation is dependent on object density and incidence angle
- Turn around too slow for real time enforcement capabilities
- Proportion of the image inside the area of interest is smaller than the extent
- Only useful for areas where vessels persist over time

SAR & AIS Case Study | Wight Barfleur

The Wight Barfleur pilot demonstrates how SAR can be used to detect 'dark vessels' in large offshore sites. When combined with AIS analysis, this information can be used to support site use assessments.

A total of 8 XF (Extra Fine) SAR images were collected over the SAC between April and July 2022. AIS vessel tracking data could be correlated with the majority of detections (86 of 107 detections) within the SAC and 3 NM buffer. Not using AIS, particularly in such a heavily trafficked area like the English Channel, increases the risk of collision and potential environmental damage.

Swaths extending outside the SAC gave insights into activities within the surrounding waters. Additionally, the proximity to the South Wight SAC meant that SAR swaths could provide coverage over both areas, encouraging cross-organisational efficiencies between the Inshore IFCA and offshore MMO managed areas.



Of the 21 'dark vessel' detections within the SAC and surrounding 3 NM buffer, only 8 had sizes and profiles which aligned with possible fishing vessels. These detections ranged in size between 44 – 154 m and could not be correlated with AIS transmissions. The detections were reported to the competent authority for situational awareness. It is possible that they were transmitting on VMS.

Further checks to confirm identities would support investigations into levels of fishing activity within the SAC. This information can be used to support site assessments and be taken into consideration for potential management measures and associated enforcement activities.

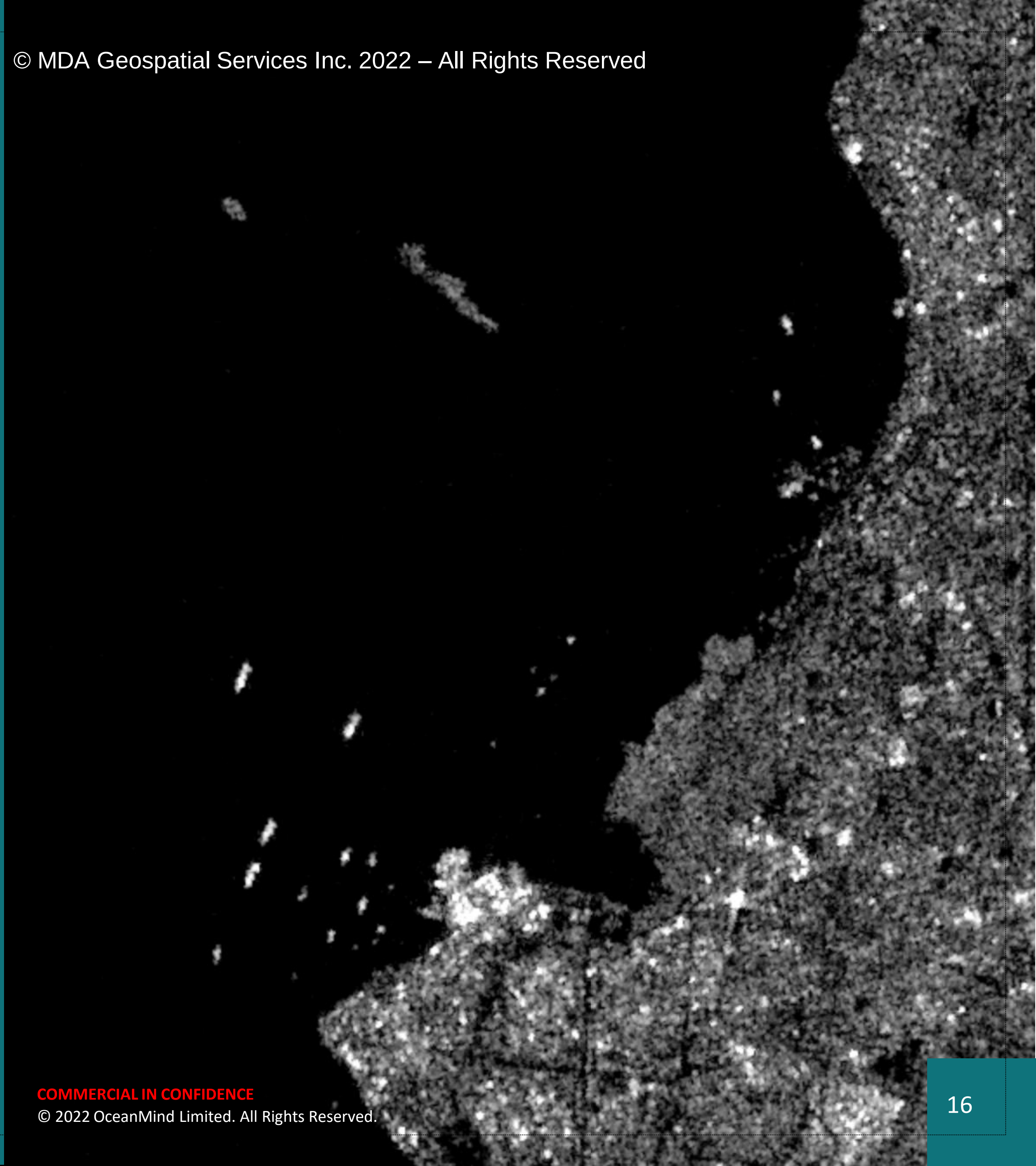
Synthetic Aperture Radar | Conclusions

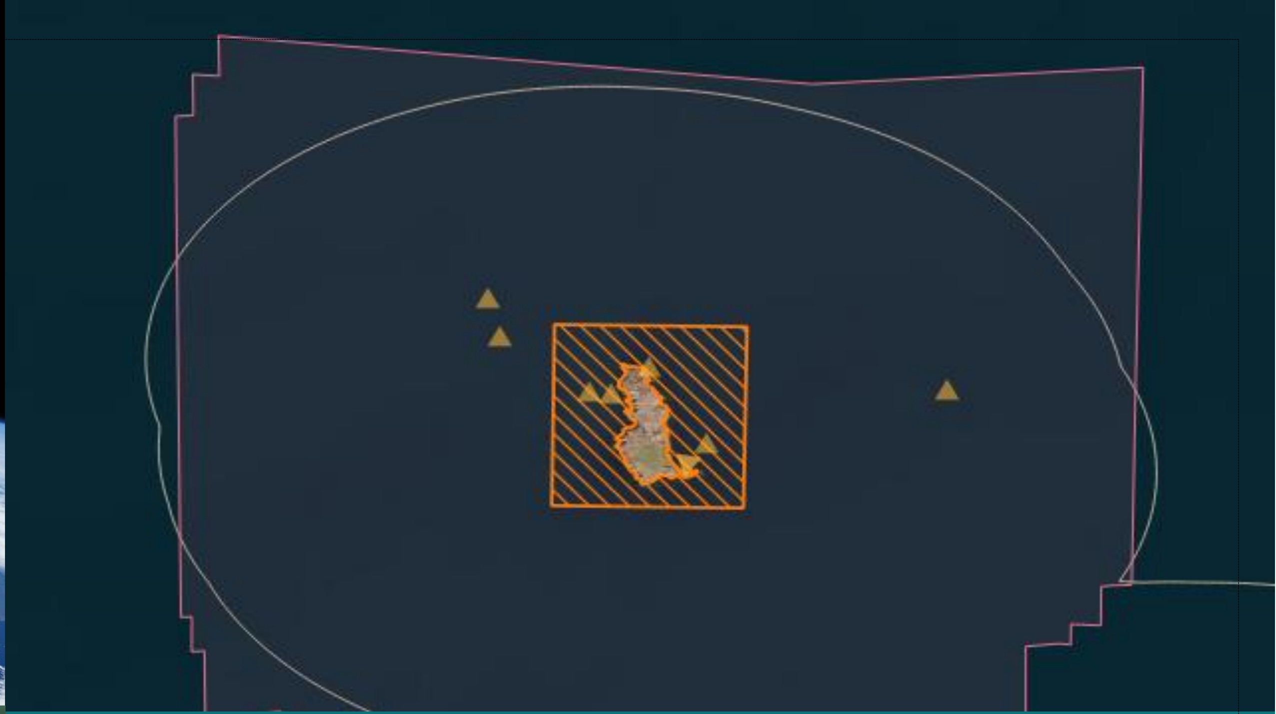
SAR applications within the UK maritime areas could be an efficient tool for site assessments, but are less able to assist with patrol support on individual sites.

Commercial SAR with resolutions between 3 – 6 m is very effective at detecting 'dark vessels' and can even provide some indication of vessel type for larger detections. The sizes and shapes of small to medium size detections are not always well defined and vessel types cannot be determined accurately. This limitation restricts the use of SAR for identifying specific vessel types in high traffic coastal areas, where many vessels may have the same size profile, such as yachts, pleasure vessels, and small fishing vessels. Resolutions can be increased but may be less cost effective or the swath extent may not fully cover the MPA.

In the UK, the majority of vessels operating in coastal waters do not show persistence over time on consecutive collection days. Due to the time requirements between acquisition and processing of imagery, SAR cannot effectively assist live patrol support within the UK coastal maritime space, however, insights can aid patrol planning.

Regular schedules could also inform historic and strategic assessments to assess the use and potential risks to both new and established MPAs over time, particularly when combined with vessel tracking data. High risk areas or hot-spots can then be targeted with other monitoring methods, such as electro-optical imagery or UAVs to provide a more comprehensive picture of activity.





Electro Optical

Optical imagery from space utilizing infrared to ultraviolet spectrum to detect vessels or environmental conditions.

Top-Left | Graphic of the Sentinel-2 EO Satellite (Copyright: European Space Agency)

Top-Right | Case Study over the Lundy SAC (orange), showing the area over which EO was acquired (purple) and detections (triangle).

Lower-Left | Other uses for maritime monitoring could be the monitoring of sea grass meadow growth. The example in the image shows vessels mooring among seagrass.

Statistics

17,591 km² of covered area between April 2022 and July 2022.

23 images collected

- > 200 vessel detections
- 15 risk detections identified

30 detections were inside MPAs.

80 % of detections could not be correlated to an AIS identity.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High Resolution Electro-Optical

Advantages

- Identification of individual vessels
- Vessel types and activities can be determined
- Has a wide range of use cases

Application in the UK

- Strategic Historical & Risk Assessments
- Evidence for Monitoring and Control Plans

Disadvantages

- Dependent on low cloud cover
- Unpredictable planning
- High costs for tasking imagery
- Turn around too slow for enforcement capabilities
- Only useful for areas where vessels persist over time

Electro-Optical Case Study | Lundy

The value and utility of EO imagery in terms of intelligence gathering was clearly shown, particularly for the following reasons.

Understanding site use: EO images showed where vessels were active and the key anchoring points in the MPA.

Being able to identify individual vessels: Using information provided previously, analysts were able to confirm the identity of specific vessels within the MPA. This highlights the possibility of replicating this in other areas where expert local knowledge can be applied.

Being able to identify likely vessel activity: The resolution of imagery is high enough to assess likely vessel activity. This was shown both in the vicinity of Lundy and in other MPAs where trawling occurred.

Providing a quantitative dataset of the whole site: The data obtained gives a quantitative and objective view of activity over the area. This can be used to inform management, patrols, impact assessments and to understand if there is a requirement for regulation.

Ground truthing | The color photograph was taken from Lundy island on the same day that satellite imagery was obtained. The same vessels are detected in the satellite imagery. This allowed for the vessel identity to be verified.

Electro Optical | Conclusions

High resolution EO imagery was a highly effective remote sensing technique when tasked over small, multi-use MPAs.

High resolution EO imagery proved to be an effective tool for identifying targets as small as a jet ski and determining likely activity of vessels, such as anchoring, fishing and transiting.

Cloud cover was initially expected to be a limiting factor for collecting clear imagery, however this proved not to be the case, perhaps due to the time of year of the pilot. The utilisation of EO significantly increased surveillance coverage compared to traditional patrolling alone. This could represent a more economical equivalent to patrol vessel surveillance for remote or inaccessible locations.

This remote sensing technique can give insight into both vessel type and activity, as well as identifying site feature extents e.g. sea grass meadows, for effective contribution to site risk and management assessments.

Although this remote sensing technique can support MCS, it should not be used in isolation. It was possible to maintain reasonable coverage of the Lundy MPA (25 % overall) during the monitoring period, however the area has various catch restrictions and technical measures that cannot be monitored with this type of remote sensing. More traditional measures, such as monitoring landings and logbook information would still be required.

Unmanned Aerial Vehicles

Unmanned Aerial Vehicles (UAVs) were investigated for their value as a complementary tool to satellite remote sensing methods employed across the UK MPA project.

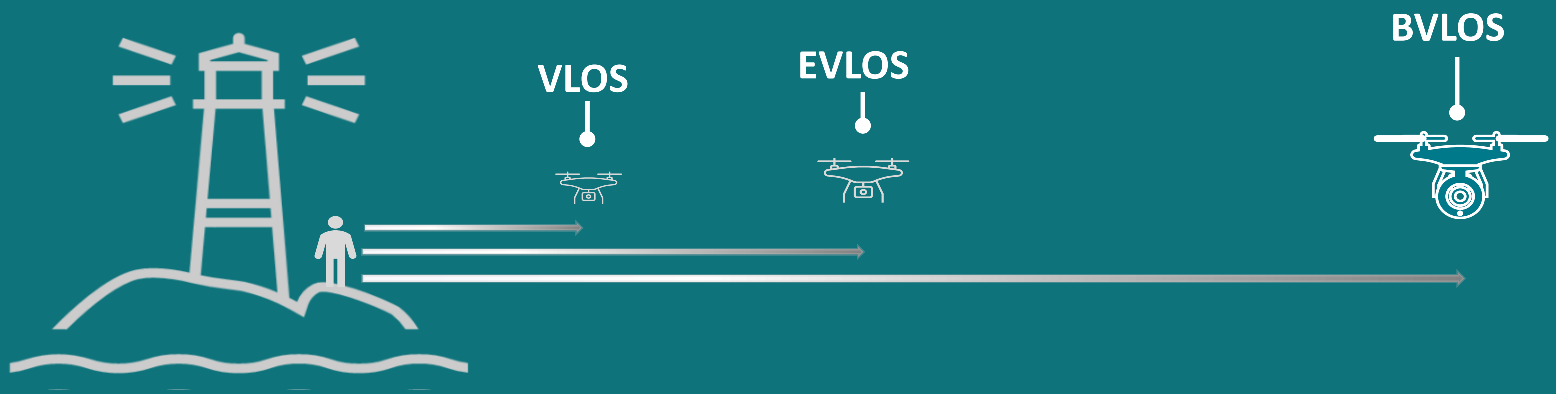
UAV flights in inshore areas showed that there may be benefits to using UAV technology to facilitate fisheries monitoring. The use of UAVs may improve health and safety when operating in high-risk tidal areas and habitats. They can identify and record individuals and vessels. Furthermore, gear markings inspections can be improved using the units. A wider shift towards painted buoys may further increase the suitability of UAV technology in MCS.

Most of the work required for a successful deployment of a UAV is preparatory – before the start of the flights – and includes obtaining regulatory approval, preparing the equipment, and selecting a suitable take-off and landing location.

Sites selected for drone flight testing were West of Walney for quadcopter and Eddystone for offshore flights (fixed wing).

Flying Beyond Visual Line of Sight

License and capabilities



VLOS | Visual Line of Sight

0 - 500 m

Drone must remain within visual line of sight to the Pilot and cannot fly higher than 120 m.

Specific permissions are not usually required for these operations. Though the pilot may require certification.

EVLOS | Extended Visual Line of Sight

500 - 1,000 m

Trained observers are used to extend the line of sight of the pilot, connected via radio communications.

Permissions may be required from the Civil Aviation Authority.

BVLOS | Beyond Visual Line of Sight

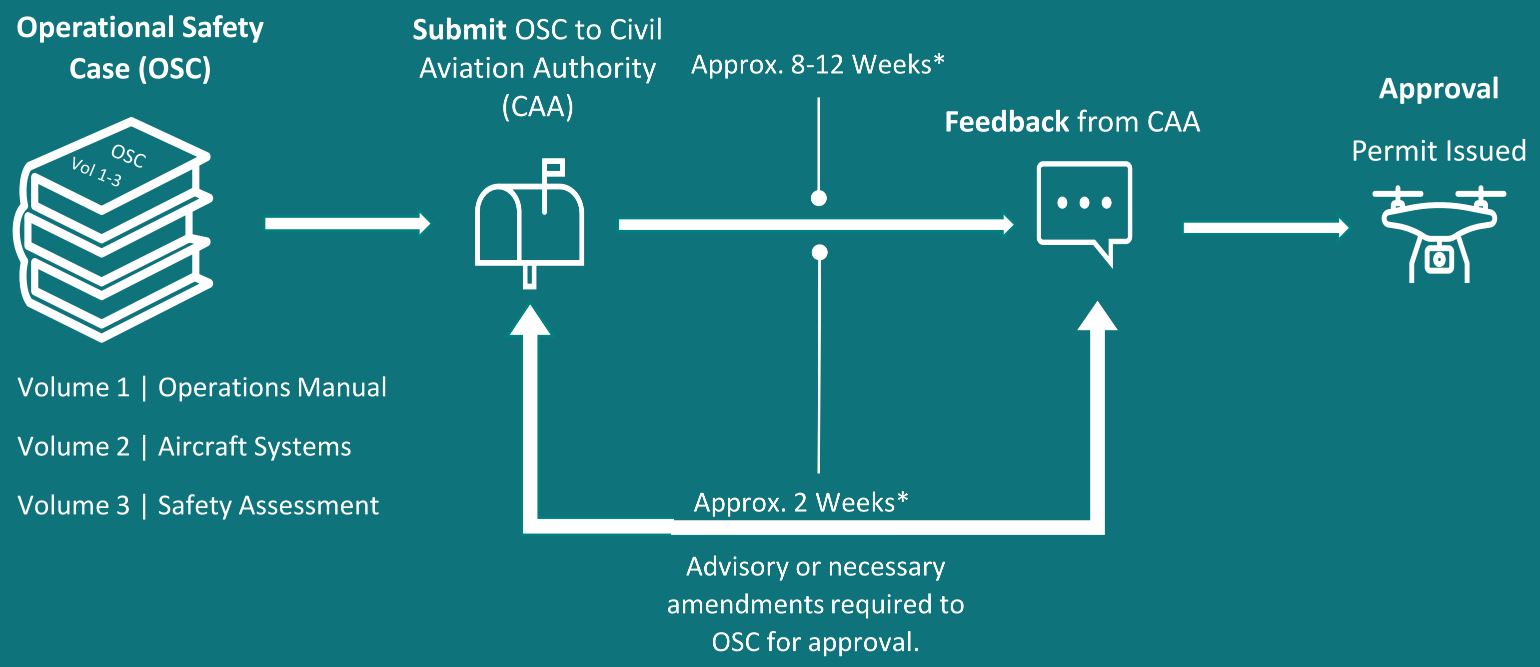
1,000 - 30,000 m

Drones can be operated beyond the line of sight of the pilot and observers.

Operations are most commonly conducted in segregated airspace which is typically provided by a Temporary Danger Area.

Permits and approval must be sought from the Civil Aviation Authority.

Operational Safety Case for BVLOS Utilization in the UK



Volume 1 | Operations Manual

Volume 2 | Aircraft Systems

Volume 3 | Safety Assessment

Further information on how to apply for an OSC can be found here:

CAA CAP 722: Unmanned Aircraft System Operations in UK Airspace - Guidance.

CAA CAP 722A: Unmanned Aircraft System Operations in UK Airspace – Operating Safety Cases

*There is no mandated timeframe for the CAA to respond to, review or issue OSC drone permissions. Times are given here as a guide for project planning and if drone permissions or permits are required for operations, then an OSC should be initiated at the earliest opportunity.

Fixed Wing Drone Take-off Site Selection

Site requirements for a successful operation

Regulatory constraints

Satisfying CAA requirements for safe BVLOS flights, including flying in non-populated areas, below 2,000 ft, and in controlled airspace qualified for BVLOS UAV flights (for example a permanent danger area or a temporary one).

System performance constraints

Satisfy environmental requirements that could limit system performance:

- clear line-of sight communication from the ground to the aircraft
- low electromagnetic interference on the frequencies used for communication with the drone
- space for clear take-off, climb, approach and landing

Local approval constraints

Obtain approval from land owner to fly from the selected location

Operational performance constraints

The site needs to provide easy operation, so the time deployed is spent - as much as possible - flying instead of completing logistics.

Site Assessment | National Coast Watch Station Rame Head

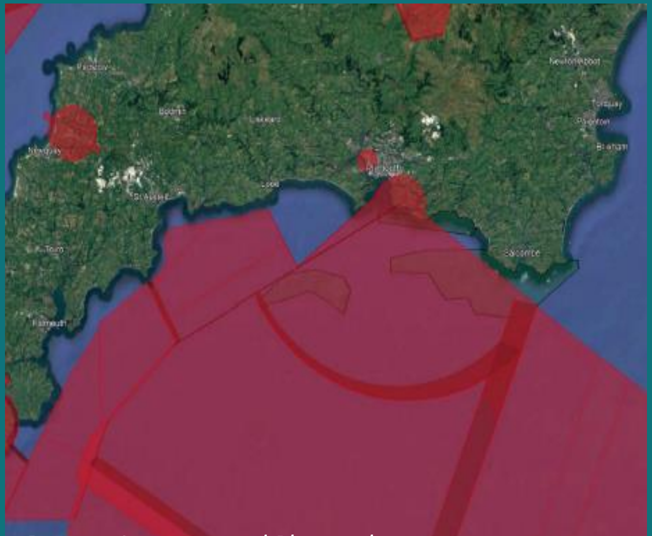
NCW Station Rame Head Take-off Location

Site requirements for a successful operation

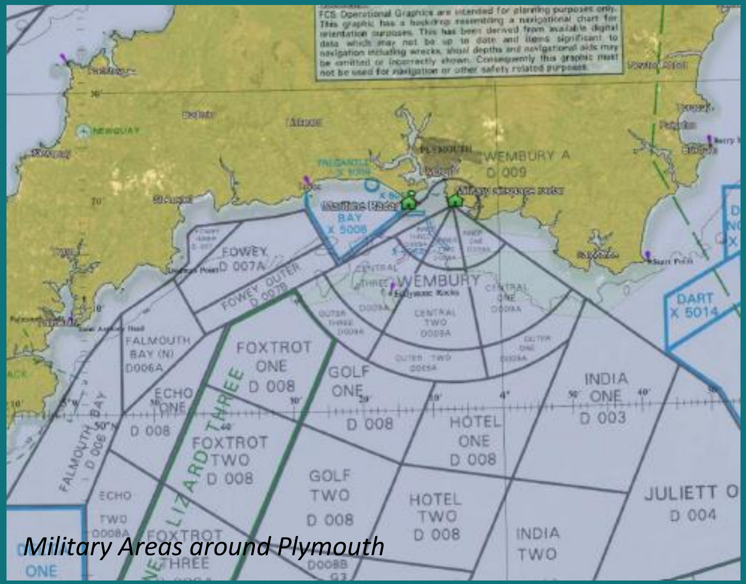
Proximity to maritime area of interest
This site is located 12 km away from the Eddystone protected area which is within range of the drone.

Proximity to danger area / Military areas
The coastal area around Plymouth is covered in danger areas, established to permit military exercises by restricting access to the airspace.

The Eddystone Reef MPA fully intersects with one of the danger areas. The take-off location is 500 m away from the danger area, making it suitable for BVLOS operation without the need for a temporary danger area to transit to the permanent one.



Danger Areas around Plymouth



Military Areas around Plymouth

Site Assessment Continued

Site requirements for a successful operation

Local electromagnetic emissions

The site houses a maritime radar, and is 8 km away from the military airspace radar on Wembury Point. These radars could generate interference with the radio equipment on the drone and disrupt communications, particularly the high power airspace radar.

Operational Logistics

The aircraft must also have a clear 100 m unobstructed straight line, headed into the wind, to be able to transition from hover to cruise on take-off. The site has almost 280 degree clearance around the take-off location with no obstructions. The area is easily accessible and well serviced; the station can provide recharge of the aircraft and equipment batteries.

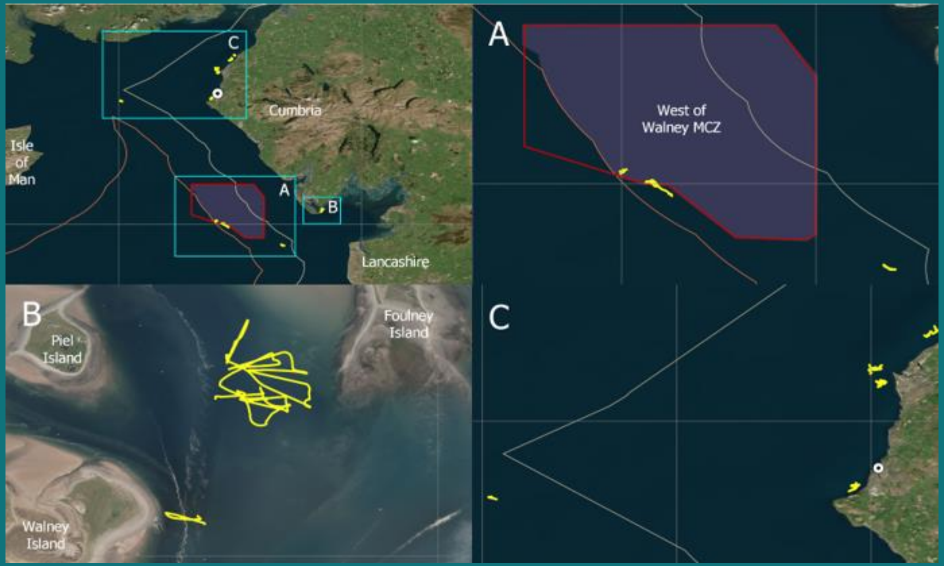
Military Airspace Radar on Wembury Point

With thanks to the skipper of the potting vessel GIRL MIA

UAV Flights | West of Walney

The various applications of UAV technology tested using a vessel-launch approach from 29Jun-01Jul2022 demonstrated clear benefit to monitoring, control and enforcement activities both within the boundaries of the West of Walney MCZ, and across the wider North West IFCA district.

The key risk identified to the West of Walney MCZ – vessels towing mobile bottom gears (which is prohibited throughout the whole site up to the 12 NM limit) – was not encountered during the test flights. However, trials using a potting vessel demonstrated that a small UAV unit (capable of being launched from a patrol vessel in offshore areas) can allow observation and recording of footage of active fishing operations such as hauling of gear.



Legend
UK 6 Nautical Mile Limit
UK 12 Nautical Mile Limit
MCZ Boundary
MCZ Byelaw Area
UAV Tracks 29Jun2022-01Jul2022
NW Protector Berth (Whitehaven)

Image A | *Flights over the West of Walney MPA and Lune Deep Feature*
Image B | *Flights to support scientific shellfish surveys around Foulney Island and Walney Island seal colony*
Image C | *Gear Markings and vessel activity observations*

Vessel-launched UAVs have the potential to identify and observe vessels and gear markings, as well as contributing to scientific assessments of important habitats and protected areas.

It is likely that launching a patrol vessel in an area has a deterrence effect, additionally the use of UAVs is likely to increase the overall deterrence effect.

North West IFCA have subsequently invested in a drone for future operations. This additional asset will support both seaborne and foot patrols within the district.

UAV Flight Statistics

- UAV flight time was 151 minutes across 15 flights.
- The longest flight-time of the quad-copter was 17.1 minutes over a total distance of 6 km.

Conclusions

The Role of Vessel Tracking in the Management of Marine Protected Areas

The high accuracy of vessel tracking systems provides insight into activities of vessels operating within UK waters and beyond. Data gaps, limited legislation on the requirement to carry AIS and potential tampering with units, creates a necessity for remote sensing technologies to detect associated targets to these limitations.

Effective Monitoring through Machine Learning

The role of machine learning in MCS has grown in recent years. It allows analysts to effectively monitor large numbers of fleets and their activities. The algorithm used by OceanMind successfully determined gear types and periods of potential use in restricted areas. Monitoring resources were lowered ten-fold compared to traditional requirements.

Shining a Light on 'Dark Vessels'

All sites had detections which were not correlated to AIS data. Depending on the site location and size different types of remote sensing have been shown to be best suited for monitoring. However, the turn around time between image acquisition and reporting appears to be too slow to effectively deploy patrol assets. This is due to the nature of daily fishing operations in UK waters, which are likely to not persist over multiple days.

An eye in the sky

The deployment of UAVs can be a cost effective way to monitor inshore MPAs and simultaneously create a deterrence effect. The advancements in resolution and range allows a potential overview of sights up to 30 km. This range is currently limited by VLOS regulations, which needs to be addressed in order to monitor MPAs effectively. Current alternatives include drones with a large zoom or to launch the drone from a patrol asset.

UK MPA Management

While fishing vessels demonstrated a relatively high level of compliance, it is worth recognising that single offenses in protected areas can have huge environmental impacts. Improving the robustness of associated legislation could increase detection of offenses and compliance. Advancement in technologies can support agencies and safeguard the sustainability of UKs fisheries and ecosystems.

For further information, please contact: analysts@oceanmind.global

Special thanks to the Skipper and Crew of the NW PROTECTOR for supporting the UAV trials in the West of Walney MPA