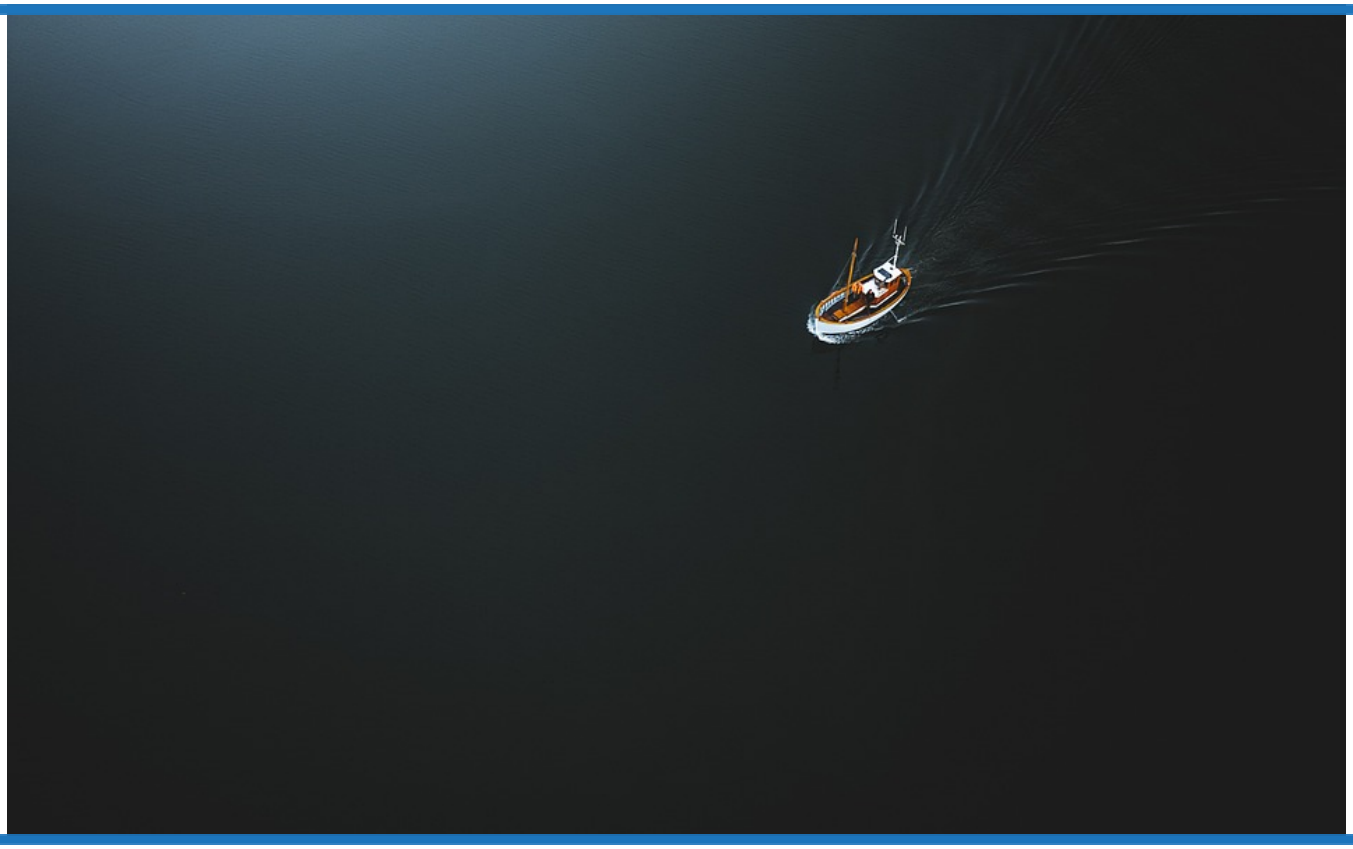
2023 Update Report of Satellite Technologies and Opportunities for Fisheries



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Executive Summary

In the past year, the space industry has continued to grow at a remarkable rate. Satellites are becoming smaller and lighter, allowing organisations and researchers worldwide to build and deploy their innovative ideas effectively and affordably. There have been significant developments around connectivity at sea, with industry leaders such as SpaceX releasing maritime-specific technology.

The ocean covers 70% of the Earth's surface, making in-situ measurements and monitoring costly and impractical. Remote sensing technology solves this problem by providing comprehensive and frequent measurements across the globe. We review further applications of this, including detecting emissions from single vessels, monitoring the carbon cycle, and identifying and quantifying the impacts of illegal and unregulated fishing. We also highlight the vast benefits of a simple data collection effort from UK fisheries to improve fishing practices, help calibrate the satellites monitoring our oceans and improve traceability across the supply chain.

Introduction

This report provides a further update to the comprehensive review of available space technology and remote sensing methods for the Scottish fishery industry (FIS037) and the 2022 update review undertaken by Space Intelligence. Here, we take a look at the most recent advancements in the sector, including (1) the rise of small satellites, (2) how a data collection effort across UK fisheries can improve fishing practices and aid in the digitisation of the industry, and (3) how satellite technology can promote crew safety and the decarbonisation of the industry.

Increasing connectivity in our oceans

American aerospace company and industry leader SpaceX have recently announced 'Starlink Maritime.' Starlink Maritime is a new high-speed satellite service designed to provide a fast and reliable internet connection to vessels anywhere at sea. Internet access is provided through a number of satellites orbiting the Earth connected to a ground-based station. The service promises to be faster and more reliable than current satellite-based internet providers, with speeds of up to 300 Mbps.

The availability of this offers a positive outlook for many members of the maritime industry. Fishing vessels in remote areas will now have instant access to the latest weather forecasts, fishing information, and other relevant news, as well as being well digitally connected to the supply chain, where they may send relevant information like catches to the mainland.

Small satellites

Small satellites are often deployed in constellations of tens to hundreds, all working together to achieve their project-specific goals. As opposed to regular large satellites, constellations create a network of small satellites to provide global coverage, increase revisit times and enhance data collection.

On 15th March 2023, the UK government released a new policy paper stating that illegal, unreported, and unregulated (IUU) fishing remains one of the biggest threats to our oceans[1]. Among impacts on ocean ecosystems, communities, and the global food supply, the UK Government estimates IUU fishing is worth £10-20 billion per year.

Small satellites are one of the most promising emerging technologies to prevent and dissuade the practice of IUU. Many small satellites are equipped with high-resolution

[1] UK Government. 2023. Illegal, unreported, and unregulated fishing: Action Alliance pledge. Retrieved from https://www.gov.uk/government/publications/illegal-unreported-and-unregulated-fishing-action-alliance-pledge/illegal-unreported-and-unregulated-fishing-action-alliance-pledge

imaging sensors that can monitor maritime activities. A dramatic use-case emerged in 2020, where researchers used four different satellite technologies to identify hundreds of vessels of Chinese and North Korean origin fishing illegally in waters between Japan, Russia, and North Korea and South Korea[2]. By combining data from Automatic Identification Systems (AIS), Synthetic Aperture Radar (SAR), the Visible Infrared Imaging Radiometer Suite (VIIRS), and high-resolution optical imagery, they were able to identify these vessels and estimate the species, weight, and cost of their illegal fishing practices, amounting to over $440 million of caught Japanese flying squid (*Todarodes pacificus)*.

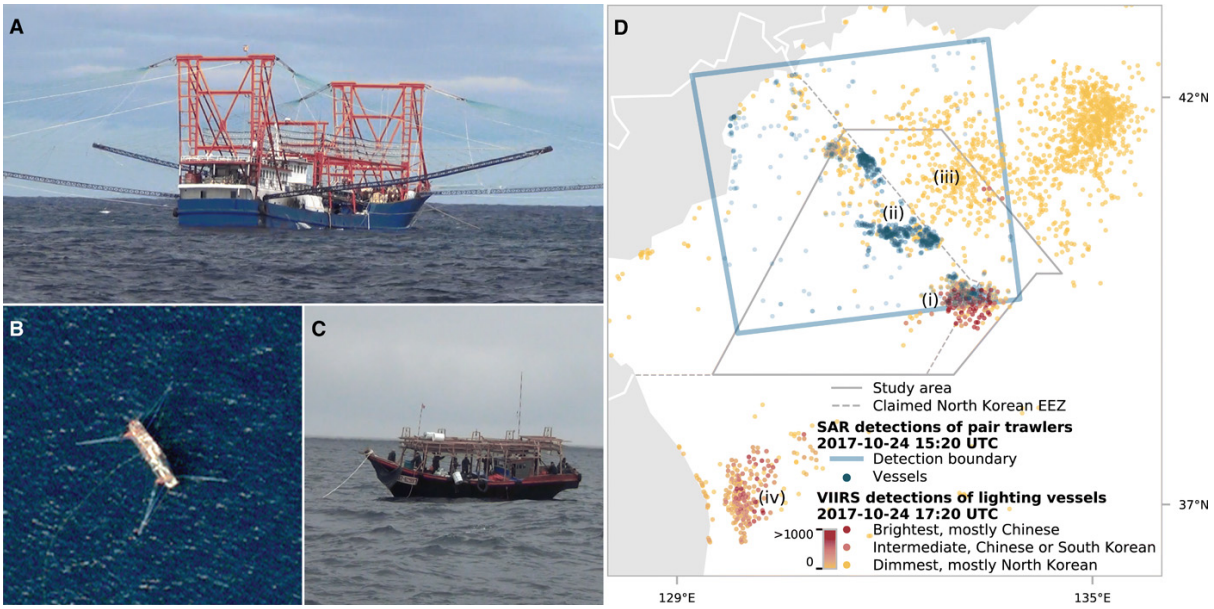

Figure 1: Satellite technology detects illegal fishing practices. (A) shows a Chinese lighting vessel near North Korean waters (photo taken by authorities), (B) shows the vessel observed from a Planet SkySat satellite, (C) shows a North Korean lighting vessel in Russian waters (photo taken by authorities), and (D) shows vessel detections by Synthetic Aperture Radar (SAR) and Visible Infrared Imaging Radiometer Suite (VIIRS). Image sourced from: Park et al. (2020), doi: 10.1126/sciadv.abb1197.

Ada Space, a Chinese technology company, is planning to launch a network of 192 small satellites to live-stream satellite imagery of the Earth[3]. Ada Space will use artificial intelligence to process the data in real-time and provide users with an app to view the imagery. While live streaming satellite imagery isn't a brand new idea, ADA Space's unique combination of AI optimisation, a user-friendly app, and 1 metre image resolutions represents a significant advancement over current technology such as NASA Worldview, which also provides live streaming but at a much coarser resolution of 250 metres. There are various use cases in the fishing industry for this technology, such as identifying IUU vessels and live storm and weather tracking.

[2] Jaeyoon Park, et al., Illuminating dark fishing fleets in North Korea. *Sci. Adv.* **6**, eabb1197 (2020). DOI: 10.1126/sciadv.abb1197

[3] Jones, A., 2021. ADA Space raises $55.6 million in Series B round. SpaceNews. Available at: https://spacenews.com/ada-space-raises-55-6-million-in-series-b-round/

Digitisation of fisheries

Data collection

One of the primary objectives of FIS036, a digital roadmap of Scotland's fisheries, was increasing data collection within the industry. The UK's fishing fleet is expansive, and equipping each vessel with a small sensor to collect various types of data would provide the industry with invaluable information to optimise fishing operations, promote the sustainable management of marine resources and environments, and provide ground truth data to satellites observing our oceans.

A sensor, such as the ENKI sensor in development from Safety Net Technologies[4], can be attached to fishing equipment and automatically measure several variables such as depth, temperature, and motion. The table below lists the variables a simple sensor can measure and their various applications within the industry.

Measurement	Applications

Location (GPS)	• Traceability
	  ○ Verify locations of catch, etc.
	• Crew safety
	  ○ Relay location data to authorities in emergency situations

Depth	• Determine fishing depth
	  ○ Different fish species live at different depths, depth measurements and datasets could help fisherman target specific species more effectively
	• Regulation compliance
	  ○ In some fishing zones, there might be depth restrictions[5]. Depth measurements can help fishermen ensure and verify they are complying with these regulations

Motion	• Detecting fish capture
	  ○ A change in acceleration of a sensor on fishing gear could indicate that a fish is struggling against the gear. Acceleration measurements can alert the fishermen when to withdraw the gear.
	• Optimising retrieval
	  ○ Understanding patterns in acceleration may aid in determining the best time and method to retrieve the gear

Temperature	• Locating fish
	  ○ Different species of fish prefer different temperatures, salinity, DO and pH. Monitoring these variables can help fishermen target specific areas and understand trends such as feeding patterns and migration routes
	• Monitoring water quality
	  ○ Significant changes in salinity could indicate pollution

Salinity	
Dissolved oxygen (DO)	

[4] SafetyNet Technologies, 2023. *Enki - SafetyNet Technologies*. [online] Available at: https://sntech.co.uk/products/enki/

[5] European Commission (2022) Deep-sea fisheries. Available at: https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/deep-sea-fisheries_en#documents

pH	events such as runoff from land or a spill ○ Low DO and changes in pH levels can indicate poor water quality such as pollution or environmental issues[6] ● Monitoring climate change ○ Real time and expansive ocean temperature measurements are important for monitoring changes in ocean temperatures ○ Changes in salinity can indicate large-scale environmental changes such as melting ice caps, changes in sea level and changes in precipitation patterns[7] ○ Changes in DO can indicate large scale environmental changes such as global warming and acidification[8] ○ Oceans are becoming more acidic due to increasing levels of carbon dioxide in the atmosphere. Changes in pH can impact marine life like shellfish and coral reefs ○ Measurements of these variables would be very important as input data for ocean and climate computer models ● Regulation compliance ○ In some areas, fishing restrictions on sea temperature[9], salinity, DO and pH might apply. Measurements of these variables can help fishermen ensure and verify they are complying with these restrictions ● Detecting hypoxic zones ○ Hypoxic zones are areas of low DO, which can lead to "dead zones" where most marine life cannot survive[10]. Monitoring DO can allow fishermen to avoid these areas and protect catch from these conditions

The table above lists just a few of the potential applications of these measurements. These measurements act as ground truth data, providing high-accuracy data for their respective times and locations. Satellite sensors indirectly measure many of the same variables from space, often deriving the values from electromagnetic radiation such as infrared. The exact relationship between this radiation and oceanic properties is complex; hence calibrating the sensors with these in-situ measurements is essential for the accuracy and reliability of these satellite measurements.

A study detailing numerous satellite sensors for measuring water quality parameters such as water temperature, salinity and dissolved oxygen highlighted the importance

[6] Kulkarni, S.J., 2016. A review on research and studies on dissolved oxygen and its affecting parameters. *International Journal of Research and Review*, *3*(8), pp.18-22.

[7] Durack, P.J., Wijffels, S.E. and Matear, R.J., 2012. Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *science*, *336*(6080), pp.455-458.

[8] Matear, R.J. and Hirst, A.C., 2003. Long-term changes in dissolved oxygen concentrations in the ocean caused by protracted global warming. *Global Biogeochemical Cycles*, *17*(4).

[9] Lubejko, M. and Parker, J. (2022) A Review of Temperature-based Fishing Restrictions. Maine: Maine Department of Inland Fisheries & Wildlife, Fisheries and Hatcheries Division. Available at: https://www.maine.gov/ifw/docs/Issue%20Profile_%20A%20Review%20of%20Temperature%20based%20Fishing%20Restrictions_Final.pdf

[10] Kraus, R.T., Knight, C.T., Farmer, T.M., Gorman, A.M., Collingsworth, P.D., Warren, G.J., Kocovsky, P.M. and Conroy, J.D., 2015. Dynamic hypoxic zones in Lake Erie compress fish habitat, altering vulnerability to fishing gears. *Canadian Journal of Fisheries and Aquatic Sciences*.

of in-situ measurements for the accuracy and performance of these instruments[11]. They state that these satellite sensors require extensive calibration procedures using in-situ data, which is often very costly to obtain. An extensive data collection effort from the UKs fishing fleet would be very beneficial to the performance of these satellite sensors. The resulting datasets would be highly useful in applications within fisheries such as deriving historical and projected fishing locations.

While this extent of data collection is a relatively new concept in the fishing industry, there could be potential in the future for fisheries to receive compensation for their efforts in this critical data-gathering process.

Traceability of product

Product traceability remains one of the most pressing consumer-facing challenges in the fishing industry. Effective traceability measures assure the consumer of quality, safety, and the product's sustainable and legal sources.

The ever-increasing connectivity at sea that Starlink Maritime and other services provide through satellite technology ensures that capturing traceability information is simpler than ever. Catches can be verified in real-time with location data, photographs, and data collected and sent directly to the next step in the supply chain. Each catch could have its unique ID number and a digital timeline illustrating the product's journey from catch to store.

As also mentioned in FIS036, QR codes can be placed on seafood products to provide this information and promote traceability at the consumer level. Some companies have already begun utilising this technology by providing digital identities on their seafood products. For example, members of the Norway Seafood Organisation took part in an industry wide collaboration to increase transparency in their supply chain by collecting data such as catch location and time and providing it to the consumer through a QR code placed on their products[12]. Vessels and sensors often have GPS tracking units that can record the locations of all activities from departure to the point of return and processing. The lightweight characteristics of GPS devices, and global coverage provided by satellites, mean this simple traceability system can be moved and used anywhere on the planet.

[11] Gholizadeh, M.H., Melesse, A.M. and Reddi, L., 2016. A comprehensive review on water quality parameters estimation using remote sensing techniques. *Sensors*, *16*(8), p.1298.
[12] Blank, C. (2022) 'Seafood industry raises bar on transparency and sustainability', Supermarket Perimeter, 21 April. Available at: https://www.supermarketperimeter.com/articles/8049-seafood-industry-raises-bar-on-transparency-and-sustainability

Crew safety

In the case of emergencies such as accidents or distress situations at sea, satellites play an important role in search and rescue operations to ensure crew safety. Satellite communication systems enable distress signals to be transmitted to land, facilitating timely response and coordination of the rescue authorities.

One of the earliest examples of this was the COSPAS-SARSAT system, launched in 1982, which utilises satellites and ground facilities to detect and locate the signals of distress beacons. While this technology remains effective, connectivity at sea is ever-improving with more satellites in the sky. Furthermore, with constellations of small satellites and live streaming services such as the ADA Space project, satellite imagery could also be used to locate and assist vessels in distress. This could be especially effective upon the unlikely failure of a vessel's distress beacon.

Decarbonisation of the industry

The impacts of climate change and the pursuit of net zero emissions are more apparent than ever. While essential for global trade, an EU article stated that global shipping contributes to over 3% of emitted greenhouse gases[13]. The article also provides innovative solutions to decarbonise the industry, including new fuel types and fume removal from the atmosphere. However, an essential aspect in pursuing net zero emissions is the availability of reliable data to back up these decarbonisation efforts.

While there has been plenty of research into monitoring emissions from space, detecting emissions from single vessels is much more complex. In 2020, for the first time, researchers could monitor nitrogen dioxide plumes from individual ships using data from the Copernicus Sentinel-5P satellite[14]. The satellite detected these emissions using the TROPOspheric Monitoring Instrument (TROPOMI) onboard. The TROPOMI is a spectrometer that measures the intensity of light, allowing it to detect different chemical substances in the atmosphere. Weather conditions need to be favourable for accurate measurements from this sensor. In the article above, the experiment time and location were chosen based on cloudless weather conditions.

Earth's carbon cycle describes the process in which the atmosphere, geosphere, biosphere, pedosphere and hydrosphere exchange carbon. The ocean is an

[13] King, A. (2022). Emissions-free sailing: Full steam ahead for ocean-going shipping. Horizon Magazine. Retrieved from https://ec.europa.eu/research-and-innovation/en/horizon-magazine/emissions-free-sailing-full-steam-ahead-ocean-going-shipping

[14] Georgoulias, A.K., Boersma, K.F., Van Vliet, J., Zhang, X., Zanis, P. and de Laat, J., 2020. Detection of NO2 pollution plumes from individual ships with the TROPOMI/S5P satellite sensor. *Environmental Research Letters*, *15*(12), p.124037

essential factor in the carbon cycle, acting as one of the primary sinks regulating atmospheric carbon dioxide concentrations. Central to this is the ocean biological pump (OBCP), which details several processes which transfer carbon from the surface to deep in the ocean. A study in 2021 described how remote sensing is one of the most effective ways to monitor the OBCP and produce a satellite-based carbon budget for the ocean[15].

By measuring electromagnetic radiation at different frequencies and resolutions, carbon pools and fluxes can be located and quantified. For example, pools of carbon, such as zooplankton, aquatic animals which consume phytoplankton, can be identified using Light Detection and Ranging (LiDAR) methods from space. In this study, they also highlight the importance of field measurements from vessels at sea to complement these satellite observations, stating that the "development, evaluation, uncertainty, computation and calibration of satellite remote sensing algorithms for carbon pools and fluxes are highly-dependent on *in-situ* observations."

The fishing industry is a source of carbon emissions. Still, with a data collection effort like that mentioned in this report, fisheries could be a critical factor in monitoring the OBCP and carbon cycle. This could lead to a better understanding of the position of UK fisheries within the ocean's carbon budget and allow the industry to contribute to understanding and mitigating the impacts of climate change.

Summary

This report provides a further update to the review on satellite technology and opportunities for Scottish fisheries in 2021, and the update report undertaken by Space Intelligence in 2022. In this report, we discuss some of the exciting new advancements taking place within the satellite industry, looking closer at how satellite technology and remote sensing can continue to detect and even quantify the impacts of illegal and unregulated fishing, estimate carbon emissions from single vessels and monitor the ocean carbon cycle.

We also investigate how the UK fishing fleet can participate in an extensive data collection effort using a simple sensor attached to their fishing gear or vessel. Fisheries can collect data on oceanic properties such as water temperature, depth, motion, and location. This data not only optimises fishing operations but can serve other purposes too. First, it can provide ground truth data to satellites, enhancing the accuracy and reliability of their sensors for measuring oceanic variables. Second, it would contribute to our understanding of climate change and allow fisheries to take part in a collective effort to tackle it. Furthermore, these datasets would be highly useful for consumer-facing traceability applications such as digital timelines of a product's journey from catch to store.

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[15] Brewin, R.J., Sathyendranath, S., Platt, T., Bouman, H., Ciavatta, S., Dall'Olmo, G., Dingle, J., Groom, S., Jönsson, B., Kostadinov, T.S. and Kulk, G., 2021. Sensing the ocean biological carbon pump from space: A review of capabilities, concepts, research gaps and future developments. *Earth-Science Reviews*, *217*, p.103604.