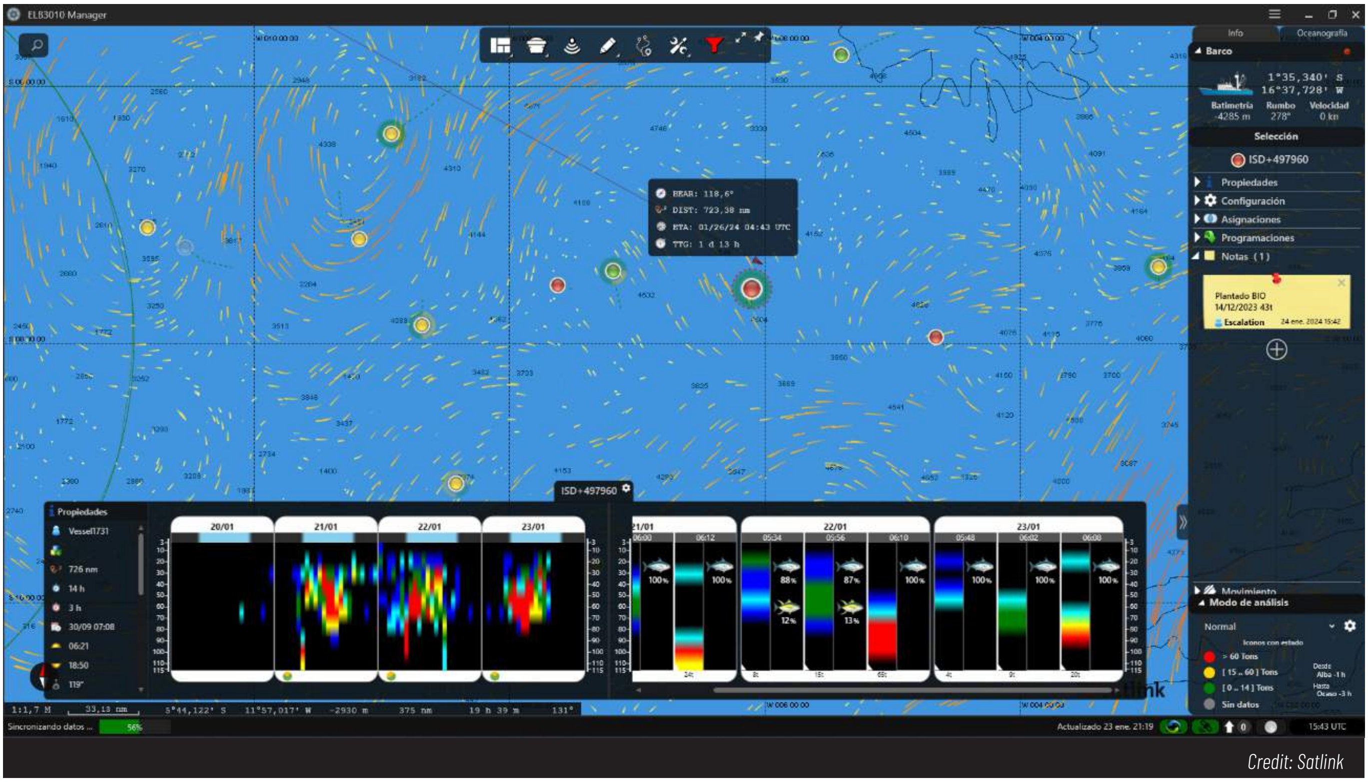
Smart technologies towards a new era in sustainable fishing

By Kathryn Gavira-O'Neill

Modern fishing vessels, equipped with advanced technology and sensors, are at the forefront of sustainable fishing. Information on oceanographic conditions allows fishermen to observe and understand the environment they will encounter at sea, while smart technologies allow them to focus on their target species, increase their selectivity and comply with fishing quotas, saving time, fuel, and resources while at sea. Furthermore, comprehensive data collection systems such as electronic monitoring, enhance transparency, compliance, and the provision of reliable data for researchers. The integration of advanced technologies in the fishing fleet has not only facilitated safer navigation, optimized fishing operations and increased traceability, but has also become increasingly relevant for scientists studying marine ecosystems. As technology evolves, the future promises exciting possibilities for managing the ocean's resources.



Credit: Satlink

On board nearly any fishing vessel today, you'll see at least one screen with multi-coloured maps indicating the oceanographic conditions across entire swathes of the ocean.

The bridge on any fishing vessel today looks very different to what it was like a few decades ago. Even the simplest vessels at sea nowadays have GPS capability, automatic identification system (AIS), radar, or fish-finders and echo-sounders to help them sail safely or locate a good catch.

More industrialized vessels are equipped with advanced technological systems, from camera networks that relay detailed information about every set to relevant authorities, to high-resolution computer screens displaying colourful maps of the ocean's temperature, or the areas where plankton blooms occur. Increasingly developed acoustic equipment informs fishing vessels of what species are present and available to catch. The skills a successful fisherman needs today extend beyond management of crew, and of the vessel, to knowing how to keep up to date, as well as adopt and use all the latest tools that technology providers put at their disposal.

The increased flow of information that technology brings has not only shed light on the best areas for fishermen to set their nets, but also has widespread benefits for managers and regulators, who can now keep track of where and how vessels are operating at sea. From a compliance perspective, this has obvious advantages: those who operate responsibly now have the tools to show that they have nothing to hide, and those that don't no longer have excuses to hide behind.

Beyond compliance, data on fishing activities is invaluable to the scientists responsible for evaluating the health of fish stocks and the potential impacts of different fishing methods on the species that are being caught. These researchers are tasked with the challenge of modelling the entire population of species that we only see a small part of. Pelagic species, such as commercially valuable tropical tuna or billfishes, are particularly difficult to study, as they migrate over huge areas, often deep in the water and out of reach of any research vessel. However, with improvements in satellite connectivity, and advances in the technology used at sea and on-board, we are gaining valuable insight into the ecology of these species and how to best protect their populations into the future.

A tech revolution: from the bridge

In the early days of tuna purse-seining, around the 1980s, most tropical tuna was caught in "free-schools". These are generally large schools of tuna which swim at the surface of the ocean, unassociated to any particular floating object. Finding, and catching, these free-schools is not easy, as they move at high speeds throughout enormous areas of the ocean. To find them, vessels typically employ spotters that scan the ocean's surface with giant binoculars in search of tell-tale splashes or movement.

Today's vessels also use sophisticated bird-radars, which detect any birds that could be travelling with the school of tuna, opportunistically feeding on baitfish or other species being chased by the school. The best bird-radars might have a detection range of up to 32 miles, although typically they operate at less than that, and a spotter with good eyesight on a day with calm seas might be able to detect fish up to six miles away. These might seem like very long ranges, but when you're searching for fish that can move across entire oceans, it's hardly enough.

In the past, fishermen could rely on information handed down from fathers to sons or stick to certain fishing grounds and seasons year to year, but in the context of climate change, fishing grounds that historically have been productive may no longer be so. Today's satellite remote-sensing technology provides information on the oceanographic conditions present across entire oceans, allowing fishermen to observe and understand the environment they will encounter at sea, even before getting there.

Through satellite remote sensing, we can receive daily maps of sea surface temperature, model ocean currents at nearly any depth, or monitor the areas where plankton blooms, and consequent food-webs, develop. On board nearly any fishing vessel today, you'll see at least one screen with multi-coloured maps indicating the oceanographic conditions across entire swathes of the ocean. By learning to interpret these maps in the context of a species' habitat preferences, fishermen have reduced their search areas to the places where conditions are most favourable for the species they are targeting, increasing their chances of finding them through other methods like bird-radars or spotters.

As well as free-school fishing, tuna purse-seiners also catch "associated schools": having noticed that schools of tuna could often be found associated to floating agglomerations of twigs and roots, or logs, that drifted out to sea from rivers and estuaries, fishermen started deploying man-made structures (also called Fish Aggregating Devices, or FADs). In the early 90s, fishermen started tracking these floating objects using increasingly sophisticated technology to improve their chances of catching tuna. Initial tracking devices carried only radio communications, while today's FADs are monitored with satellite-linked GPS buoys equipped with one or two echosounders, permitting fishing masters to remotely monitor the exact location of their FADs as well as receive real-time estimates of the amount; and in some cases even the species of tuna present at each one. These devices have revolutionized the way vessels find fish, allowing them to reduce their searching time while maximizing catches.

Furthermore, FAD sets are much more likely to be successful than free-school sets; according to data from the Spanish Institute of Oceanography, between 1990 and 2019, more than 40% of the free-school sets of the Spanish fleet in the Indian Ocean were null and no tuna was caught; whereas the same was true for less than 6% of FAD sets[1]. Likewise, the volume of tuna caught is on average, 10% higher on FAD sets than on free-school sets[2]. In addition, by being able to assess the amount of fish at any given FAD remotely, fisherman can plan their trips more efficiently, targeting only FADs with larger potential catches, thus reducing searching time and fuel-use. Of course, this has benefits in terms of the carbon footprint of purse-seine fleets, and a recent study presented at the Indian Ocean Tuna Commission[3] found that, by tonne of tuna caught, the carbon footprint of FAD fishing trips was less than half that of trips focused on free-school tuna fishing; but also in terms of reducing bycatch, as larger schools of tuna have a proportionately smaller amount of bycatch[4].

Managing success: technology for policy makers

The substantial shift towards FAD fishing, which today brings in more than 20% of all tropical tuna caught globally, has raised concerns from environmental groups regarding impacts on fish populations, on non-target or bycatch species, and on the marine environment in the form of pollution.

However, researchers recognize that technology can actually be the key to addressing many of these concerns[5]. For example, regulators can push for more selective fisheries by encouraging vessels to use echo-sounder buoys that incorporate estimates of species composition, enabling vessels to better adhere to fishing quotas and avoid catching non-target species[6]. In terms of reducing marine pollution, echo-sounder buoys can integrate warnings to avoid FAD loss at sea or send their position to local shore-based partners, to be intercepted and avoid impacts to coastal environments. Indeed, just as the fishery has evolved with the advent of satellite buoy technology, so have the regulations around their

[1] *Báez, J. C., Ramos, M. L., González Carballo, M., Pérez San Juan, A., Déniz, S., & Sierra, V. (2020). Updating the statistics reported for the EU-Spain purse seine fishing fleet in the Indian Ocean (period 1984-2019) and the effects of the COVID-19 pandemic on the port sampling activity in Victoria (Seychelles).*

[2] *Wain, G., Guéry, L., Kaplan, D. M., Gaertner, D., & O'Driscoll, R. (2021). Quantifying the increase in fishing efficiency due to the use of drifting FADs equipped with echosounders in tropical tuna purse seine fisheries. ICES Journal of Marine Science, 78(1), 235-245. https://doi.org/10.1093/icesjms/fsaa216*

[3] *Cabezas Basurko, O., Castresana, J., Grande, M., & Santiago, J. (2023). Energy Efficiency of the Purse Seine Fishery: FAD vs Free Swimming Schools Strategy.*

[4] *Dagorn, L., Filmalter, John D., Forget, F., Amandè, M. J., Hall, Martin A., Williams, P., Murua, H., Ariz, J., Chavance, P., Bez, N., & Hilborn, R. (2012). Targeting bigger schools can reduce ecosystem impacts of fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 69(9), 1463-1467. https://doi.org/10.1139/f2012-089*

[5] *Pons, M., Kaplan, D., Moreno, G., Escalle, L., Abascal, F., Hall, M., Restrepo, V., & Hilborn, R. (2023). Benefits, concerns, and solutions of fishing for tunas with drifting fish aggregation devices. Fish and Fisheries. https://doi.org/10.1111/faf.12780*

[6] *Moreno, G., Boyra, G., Sancristobal, I., Itano, D., & Restrepo, V. (2019). Towards acoustic discrimination of tropical tuna associated with Fish Aggregating Devices. PLoS One, 14(6), e0216353. https://doi.org/10.1371/journal.pone.0216353*

Buoy technology can provide estimates of species composition, enabling vessels to better adhere to fishing quotas and avoid catching non-target species.

usage. While in the early 2000s, fleets could employ as many FADs as they wanted, now there are specific rules around how many FADs each vessel can actively monitor at any given time; and even how many echosounder buoys can be purchased per year, varying slightly depending on the relevant Regional Fisheries Management Organization (RFMO). Technology providers report these numbers directly to authorized parties, providing a way of monitoring fishing effort.

However, the data and tools available to regulators extends well beyond monitoring FADs, as now there are technological solutions in place to gain a comprehensive understanding of how fleets operate. One such solution that has garnered a lot of attention in recent years is electronic monitoring (EM), which comprises real-time monitoring systems installed on-board. These EM systems integrate cameras, gear sensors and GPS to provide a complete overview of vessels' fishing activity at sea. They are designed to enhance the work on-board that fishery observers do; monitoring catch composition, bycatch, and adherence to regulations; and providing a more accurate and reliable record of fishing operations.

EM's biggest draw is its potential for increasing observer coverage, particularly in fleets where it is difficult to deploy on-board fishery observers. However, each EM system gathers immense amounts of data, creating some concern for policymakers, which have to develop standards and minimum data requirements for processing data from these systems. Without a doubt, recording on-board activity isn't enough; consequently, Artificial Intelligence (AI) and advanced Machine Learning models are being developed to respond to stakeholder's concerns, process information and deliver practical results. For example, videos recorded by EM systems on tuna fishing vessels can already be run through AI servers which accurately identify when a vessel is fishing; the species being caught with over 95% accuracy; whether they are a target or bycatch species; and provide estimates of the total amount of fish that is brought on board.

As for fishermen, the main concern focuses on their privacy being invaded. It should be noted that EM systems only record fishing activity and include features that protect the identity of the crews, such as real-time face blurring, completely safeguarding the crew's privacy. Furthermore, while EM also provides significant advantages over on-board observers (can't be coerced, operates 24x7, data can be audited and validated *a posteriori*), it shouldn't replace them entirely.

Biologists placed on board are still important for gathering biological samples, such as otoliths or fish gonads, which provide crucial data for assessing a species' life history, and thus modelling fish stocks. Indeed, a combination of both EM and on-board observers not only generates employment opportunities on-shore, but also improves on-board working conditions and safety for these professionals as they move away from a compliance role, to a purely scientific one. In essence, combining EM and on-board observers can be the most effective approach for gathering comprehensive and reliable data for scientists to carry out their work in modelling fish populations, enabling them to provide sound advice to regulators.

Governments around the world, such as Solomon Islands, Cyprus and Sweden, to name a few, have been quick to recognize the potential of this solution, with numerous successful projects in many different fisheries (long-line, pole-and-line, purse-seine, etc.) and oceans, demonstrating that EM is the best approach for collecting data and monitoring fishing activity. Recently, the latest update of the EU Common Fisheries Policy brings forward EM systems for fishing vessels of 18 meters or more that may pose a risk of non-compliance with the landing obligation, which aims to encourage fishermen to avoid unwanted catches, and for which there will be an adaptation period of four years[7].

[7] *Regulation (EU) 2023/2842 of the European Parliament and of the Council of 22 November 2023*

From the bridge of today's vessels, a great deal of information can be obtained to enhance safer navigation, provide a better understanding of the ocean environment, or optimize fishing operations.

Overseeing our oceans: data for science

The integration of advanced technologies in the fishing fleet has not only facilitated safer navigation and optimized fishing operations but has also become increasingly relevant for scientists studying marine ecosystems. Remote sensing and satellite technology has allowed researchers to gather data on entire oceans, gaining crucial insights into how conditions vary over time and from place to place, particularly in the face of climate change. However, *in-situ* data is still relatively rare, expensive, and difficult to obtain by traditional research vessels and methods. For this reason, the scientific community is beginning to look to the fishing industry as a partner for gaining knowledge about the ocean. Leveraging the technological solutions used by vessels, such as on-board sensors, or echo-sounder buoys, it becomes possible to substantially increase the data available to scientists at a fraction of the cost.

For scientists focused on modeling entire populations of highly migratory pelagic species like tropical tuna (particularly difficult to study due to their enormous range and mobility), data from technology can be especially relevant. In much the same way echo-sounder buoys aid fishermen in finding the best areas to fish, they can also provide scientists with large-scale insights into where tuna populations are located throughout the entire ocean, regardless of whether a vessel is there fishing. With the advent of Artificial Intelligence, data scientists, in collaboration with technology providers, are developing ways to process the information provided by these buoys to better understand the habits and behaviour of the tuna around FADs; or to inform stock assessments through a buoy-based abundance index. This novel source of information has already been adopted by the Inter-American Tropical Tuna Commission (IATTC) and the International Commission for the Conservation of Atlantic Tunas (ICCAT), the RFMOs responsible for regulating tuna fisheries in the eastern Pacific and Atlantic oceans, respectively.

Beyond fisheries, scientists have been looking into the applications of data collected from vessels and their equipment. Trajectory data from FADs can provide valuable *in-situ* information on ocean currents, validating oceanographic models of the ocean which are used across the world in predicting the transport of bio-geochemical materials, or analyzing the relationship between ocean and atmosphere in the face of climate change. Fishing vessels, and their gear, can serve as "platforms of opportunity", acting almost as mobile weather stations by including additional sensors monitoring temperature or atmospheric pressure, and then integrating that information into atmospheric and weather models. As satellite communications improve, data can be sent in near-real time, reducing latency and improving the reactivity of these models to real-life conditions at sea. In turn, fishermen, who also use information derived from 3D modelling of the ocean, can see the direct benefit of their collaboration, obtaining higher resolution and more trustworthy information with which to plan out their activity.

Without a doubt, technology is revolutionizing the way we view and interact with the world across the board. From taking the guesswork out of fishing, to improving safety at sea and managing ocean resources, solutions nowadays allow for what we could only dream of just a few years ago. Coupled with advanced data processing capabilities which are only now showing their full potential, the best word to describe the future of technology in respect to how we interact with the ocean is "exciting".

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