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Smart Buoys and Sustainable Tuna Fisheries

How Monitoring Technology Supports Food Security, Transparency, and Responsible Management

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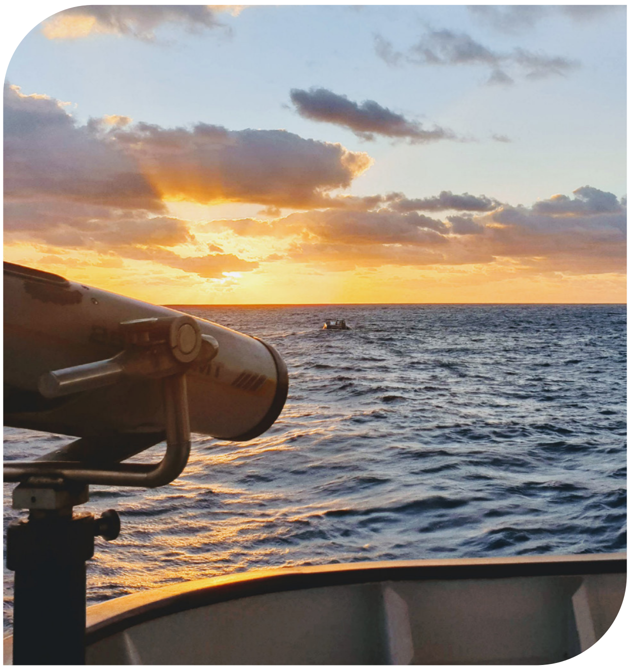
Executive
Summary

Tropical tuna is a cornerstone of global food security, providing an affordable and nutritious source of protein to millions of people worldwide. The majority of this tuna is harvested by purse seine fisheries operating across the Atlantic, Indian, and Pacific Oceans under international management frameworks.

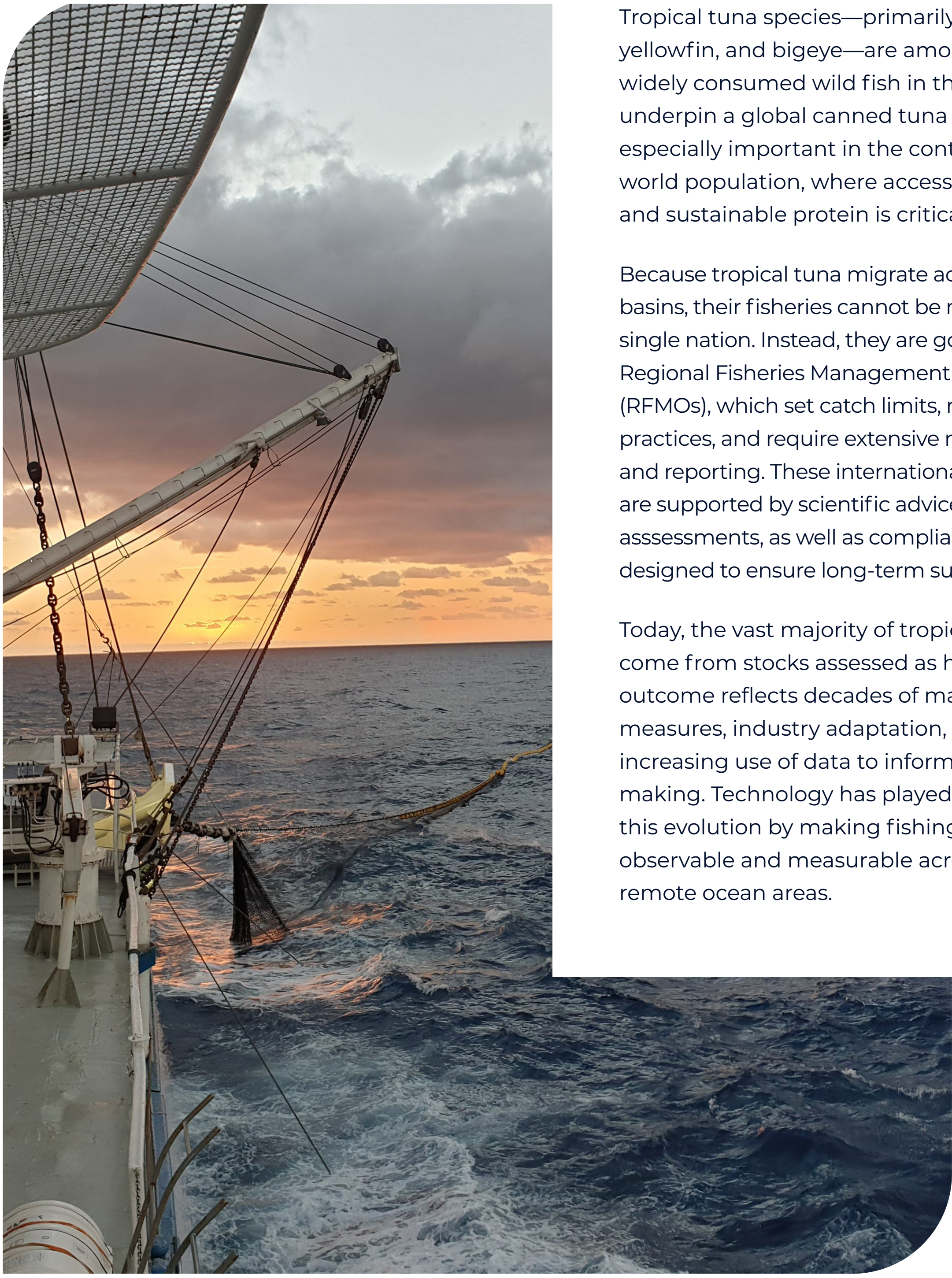
A defining feature of modern tropical tuna fisheries is the use of drifting Fish Aggregating Devices (dFADs) monitored by satellite-connected echosounder buoys and supported by digital platforms. These technologies provide real-time information on the location and movement of dFADs and the presence of tuna beneath them, enabling more efficient and selective fishing operations.



Public debate has increasingly focused on the environmental risks associated with dFADs, particularly in regard to the fate of these devices. This document explains how, through technology, these fishing tools can both mitigate environmental risks and guide informed decision making at sea.

Collaboration between technology providers, fishing fleets and regulators will be crucial for finding applicable and scalable solutions for achieving sustainability goals.

01 Tropical Tuna, Food Security, and Governance



Tropical tuna species—primarily skipjack, yellowfin, and bigeye—are among the most widely consumed wild fish in the world. They underpin a global canned tuna supply that is especially important in the context of a growing world population, where access to affordable and sustainable protein is critical.

Because tropical tuna migrate across entire ocean basins, their fisheries cannot be managed by any single nation. Instead, they are governed through Regional Fisheries Management Organizations (RFMOs), which set catch limits, regulate fishing practices, and require extensive monitoring and reporting. These international systems are supported by scientific advice and stock asssessments, as well as compliance mechanisms designed to ensure long-term sustainability.

Today, the vast majority of tropical tuna landings come from stocks assessed as healthy. This outcome reflects decades of management measures, industry adaptation, and the increasing use of data to inform decision-making. Technology has played a central role in this evolution by making fishing activity more observable and measurable across vast and remote ocean areas.

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Healthy stocks

Due to effective management, nearly all tuna stocks are currently healthy, and 99% of tuna landings come from stocks that are not overfished.

97.9%

Catch is Tuna

97.9% of the catch in each dFAD-set is target tuna. Bycatch of other marine life is only about 2%, and vulnerable species (sharks, turtles, etc.) are <0.2% reflecting highly selective fishing.

>50%

Lower carbon footprint

Tuna caught through purse-seine fishing has less than half the carbon footprint of land-based protein or other fishing gears.[1][2]

100%

Monitored

Most modern purse-seine fleets have 100% observer coverage: every trip is monitored by human or electronic observers, and all vessels share positions with regulators in real time. This ensures full traceability and accountability.

Figure 1. Global importance of tropical tuna for food security

1 McKuin, B., Watson, J. T., Stohs, S., & Campbell, J. E. (2021). Rethinking sustainability in seafood. *Elementa: Science of the Anthropocene, 9*(1). https://doi.org/10.1525/elementa.2019.00081
2 Parker, R. W. R., Vázquez-Rowe, I., & Tyedmers, P. H. (2015). Fuel performance and carbon footprint of the global purse seine tuna fleet. *Journal of Cleaner Production, 103*, 517-524. https://doi.org/10.1016/j.jclepro.2014.05.017

02

Why FADs Exist - What Satellite Buoys Do

WHY FADS ARE USED

Tuna naturally aggregate around floating objects. Long before modern fishing technologies existed, fishers observed tuna gathering beneath logs, dead whales, drifting debris, or other floating materials. Drifting Fish Aggregating Devices (dFADs) replicate this natural phenomenon and provide predictable aggregation points in open-ocean environments where free-swimming tuna schools are otherwise difficult and costly to locate.

Importantly, dFADs do not draw tuna from long distances, nor do they catch tuna themselves. They simply make existing aggregation behavior visible and accessible in a controlled way.

THE ROLE OF SATELLITE BUOYS

Modern dFADs are typically monitored using satellite-connected buoys equipped with GPS and acoustic sensors. These buoys serve exclusively to monitor dFADs at sea and provide remote information for fishers. That is, they do not actively attract fish or directly increase catch.

Among others, satellite buoys provide information on:

- the geographic position and drift trajectory of a dFAD,
- estimates of fish biomass beneath it,
- and temporal patterns in aggregation.

This information allows vessels to make informed decisions about whether to visit a dFAD, whether to fish on it, or whether to avoid it altogether. For managers, buoy data provides unprecedented visibility into fishing activity at sea.

Discussions around dFADs and echosounder buoys have often focused on numerical limits, restrictions, or prohibitions. While such measures play an important role in fisheries management, they do not fully capture the potential of technology-enabled monitoring to support responsible fishing practices. Satellite buoys and associated digital tools shift the focus from counting devices to maintaining visibility, accountability, and the ability to intervene when risks arise. In this context, satellite buoys should be understood as essential tools for further improving dFAD fishing.

Satellite buoys maintain traceability by enabling the monitoring of every deployed dFAD

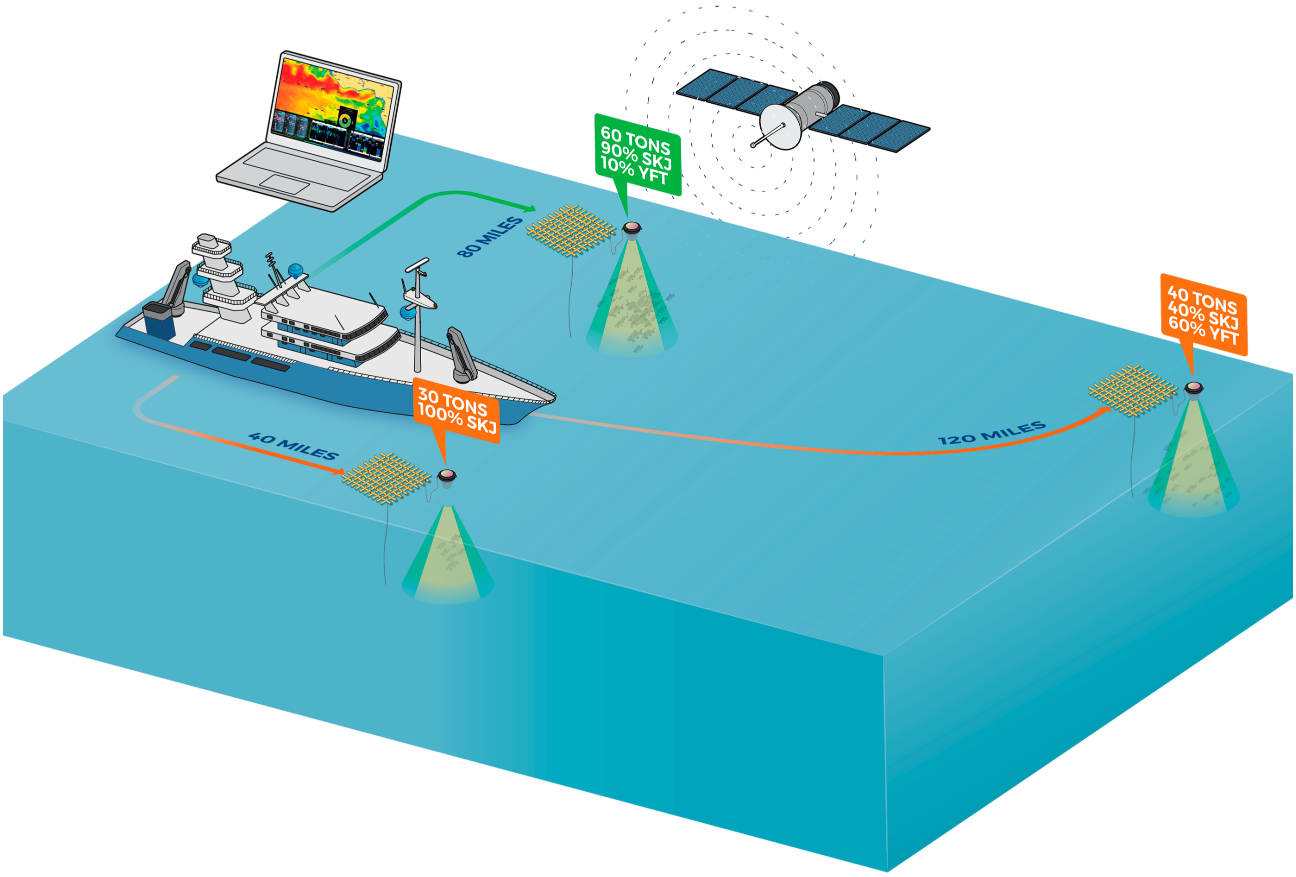


Figure 2. How satellite buoys are used by fishing vessels at sea

03 Efficiency, Selectivity, and Environmental Performance

Access to accurate, real-time information fundamentally changes how fishing operations are conducted. Improved efficiency does not mean increased fishing pressure; total catches remain constrained by RFMO-set limits. Instead, efficiency means reaching those limits with less wasted effort.

By using buoy data:

- vessels reduce time spent searching blindly,
- fuel consumption declines,
- non-target species can be avoided.

Lower fuel use translates directly into reduced greenhouse gas emissions. As a result, tropical tuna purse seine fisheries rank among the most carbon-efficient methods of harvesting animal protein from the ocean.

LOW CO2 FOOTPRINT

(Liters of fuel per ton of tuna)

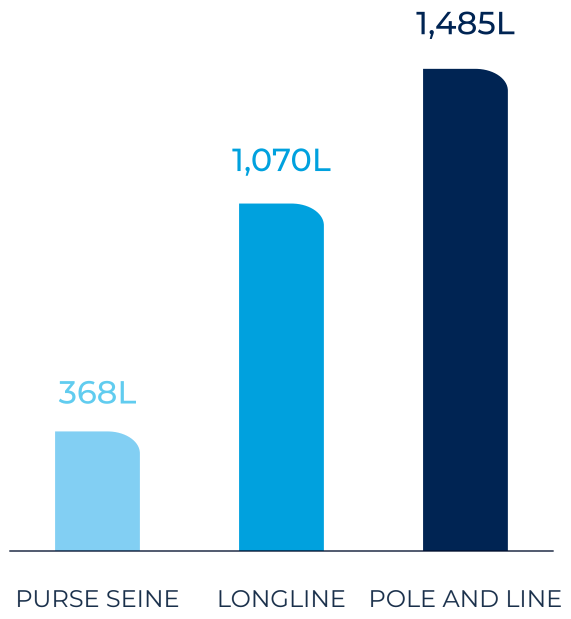
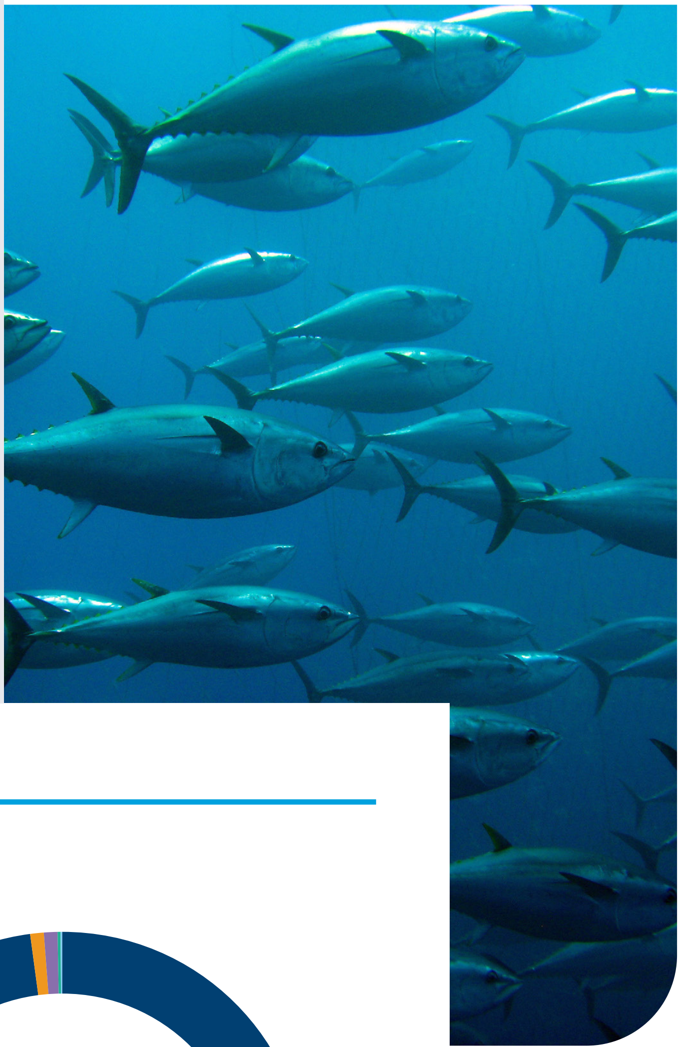


Figure 3. Fuel use per ton of tuna by fishing method

Better information also improves selectivity. When data suggest low biomass or presence of species other than tuna, vessels can choose not to fish. Over time, this has contributed to very high proportions of target species in purse seine catches and extremely low interactions with sensitive species.

In parallel, dFAD designs have evolved. Non-entangling and increasingly biodegradable materials are becoming standard, reducing risks to marine life and minimizing long-term environmental footprint. Monitoring technology plays a key role in ensuring these improvements are effective by enabling tracking and recovery.



HIGHLY SELECTIVE FISHERY

(% Catch in dFAD sets)

- TARGET SPECIES **99.7%**
- OTHER TUNA **0.9%**
- OTHER BONYFISH **0.9%**
- SHARKS **0.2%**
- BILLFISHES **0.1%**
- RAYS **0.0%**

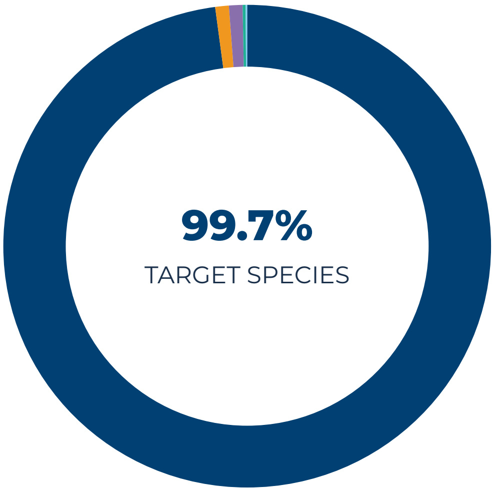


Figure 4. Catch composition in typical dFAD-associated sets

04 Accountability, Traceability, and Compliance

Tropical tuna purse seine fisheries operate under some of the most comprehensive monitoring systems in global fisheries.

Every purse-seine vessel carries a VMS (Vessel Monitoring System), a GPS transmitter that sends the boat's location to government authorities at least every hour. Unlike AIS (the public ship tracking system, designed for avoiding collisions, which can be turned off), VMS is mandated by law and cannot be easily disabled without alerting authorities. Fisheries patrol centers around the world receive these signals and can see if a vessel strays into a closed area or an unauthorized zone.

Few sectors in the global seafood industry provide the level of traceability and data availability seen in industrial tuna purse-seine fisheries

In addition to position tracking, there is 100% observer coverage on nearly all industrial purse seiners. That means that for every trip, either a human observer is on board, or cameras are recording activity on deck. These systems contribute to scientific monitoring, recording catch data as well as validating that crews are complying with best-practice measures for the treatment of sensitive species, among other objectives. By contrast, many other fisheries have little or no direct monitoring, while tuna fleets have embraced full monitoring.

Satellite buoys add another layer of traceability, as buoys automatically indicate where and when a dFAD was deployed, as well as its drift and trajectory, information which is shared directly with management bodies.

Together, these systems create a data rich fishery, and fleets contribute huge amounts of information to regulators. Through collaboration, industry and regulators can ensure that accountability is maintained and that rules are based on science and data.

Beyond echosounder buoys, purse-seine fleets employ monitoring systems that strengthen accountability, compliance and traceability

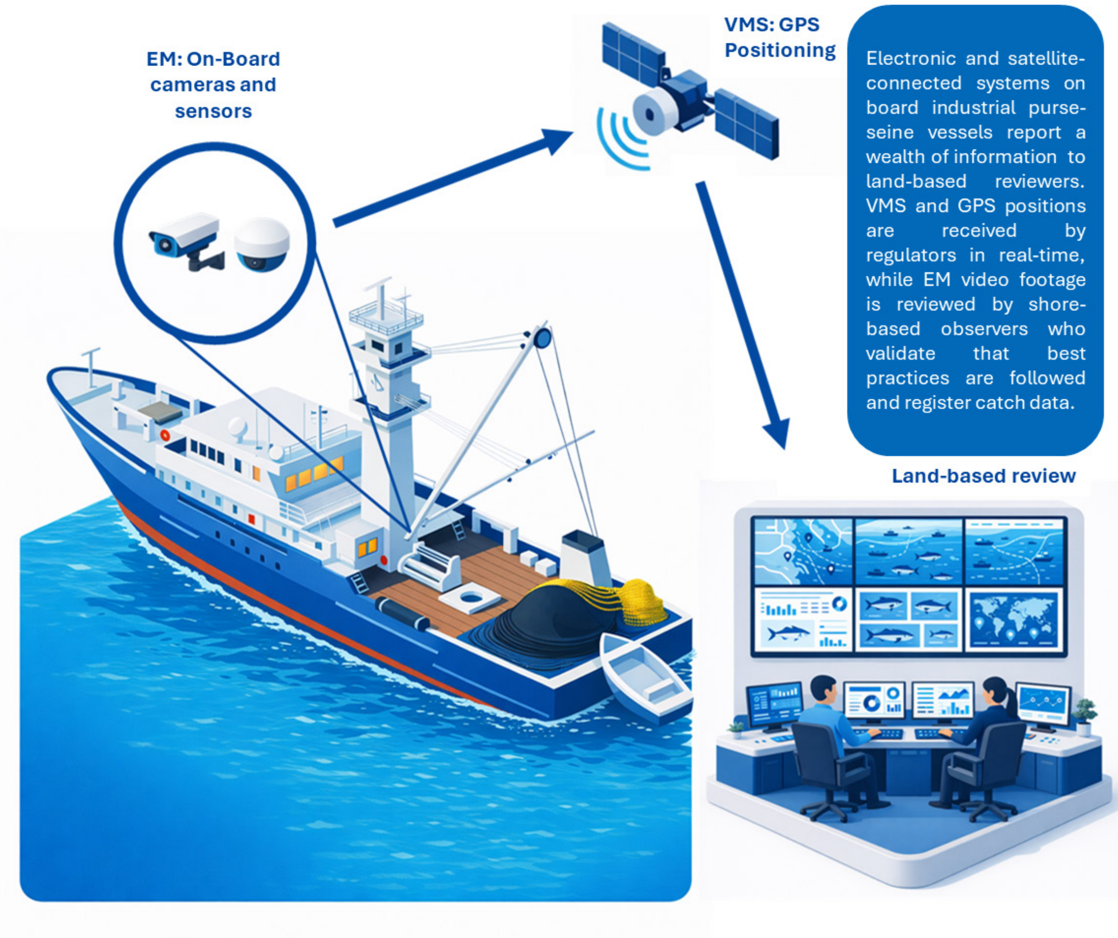


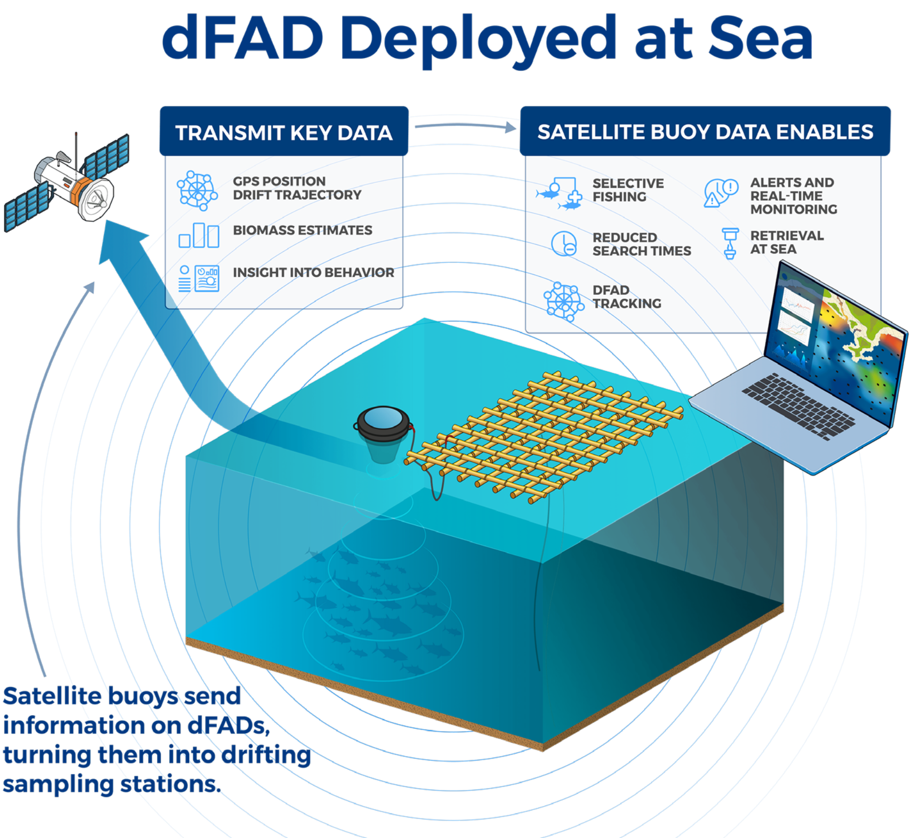
Figure 5. Vessel Monitoring System (VMS) or Electronic Monitoring (EM) for traceability in tropical purse-seine fisheries.

05 The Digital Layer: From Buoy to Decision

Satellite buoys are most effective when integrated into broader digital ecosystems. Modern software combines buoy data with vessel information, regulations and oceanographic information to support responsible decision-making.

Advances in data processing and artificial intelligence further improve interpretation of acoustic signals, helping distinguish between commercially relevant tuna, non-target species, and background noise. While these tools do not replace human judgment, they enhance situational awareness and reduce uncertainty.

Crucially, digital platforms also enable early identification of dFADs drifting toward sensitive areas, creating opportunities for intervention before impacts occur.



These platforms allow operators to:

- visualize dFAD positions and drift paths,
- integrate environmental conditions such as currents and temperature,
- prioritize actions based on risk and relevance,
- and coordinate recovery of dFADs.

Figure 6. From floating object to informed decisions: the digital dFAD ecosystem

06 A Critical Issue: Minimizing Impacts and Supporting Recovery

Public concern around dFADs often centers on the potential environmental impact of devices that cannot be recovered. This concern is legitimate and is an active area of improvement for fishing fleets, technology providers and regulators.

The GPS positioning capability of satellite buoys attached to dFADs provides a feasible way for monitoring dFADs over their entire lifespan. However, current regulation places limits on the number of satellite buoys that can be transmitting their positions, regardless of whether they are actively being used to guide fishing operations, or whether they are being tracked for scientific purposes or to protect coastal ecosystems.

Supporting recovery of dFADs at sea, is both complex and essential. To achieve a practical solution, a potential solution may be to consider differentiating between operational dFADs or buoys which are being actively monitored by fishing vessels; and buoys which are kept active solely for tracking purposes or to support scientific research. To achieve this, feasible and fair sources of funding will need to be identified, and benefits and concerns for different stakeholders will need to be put in the balance.

Fostering recovery of dFADs at sea depends on:

- Clear and comprehensive objectives when establishing regulations
- Consideration of operational constraints around dFAD use
- Consultation with industry players and technology providers to find “what is possible”
- Sustainable and scaleable solutions to support increased retrieval

FAD WATCH & CIRCULAR ECONOMY

In certain coastal areas, tropical tuna purse seine fleets, together with satellite buoy providers, have partnered with NGOs and local organizations to demonstrate how tracking dFADs through satellite buoys can enable timely recovery. These initiatives, named FAD Watch programs, use the positioning capability of satellite buoys together with digital geo-fences, to share real-time information with local organizations. These partners can then retrieve the dFAD while it is at sea, avoiding damage to reefs and coastlines.

Several FAD Watch initiatives are underway around the world, and all buoy providers collaborate to maximize their success. In addition, leading technology providers are running circular economy programs for recovered recovered buoys, taking sustainability a step further.

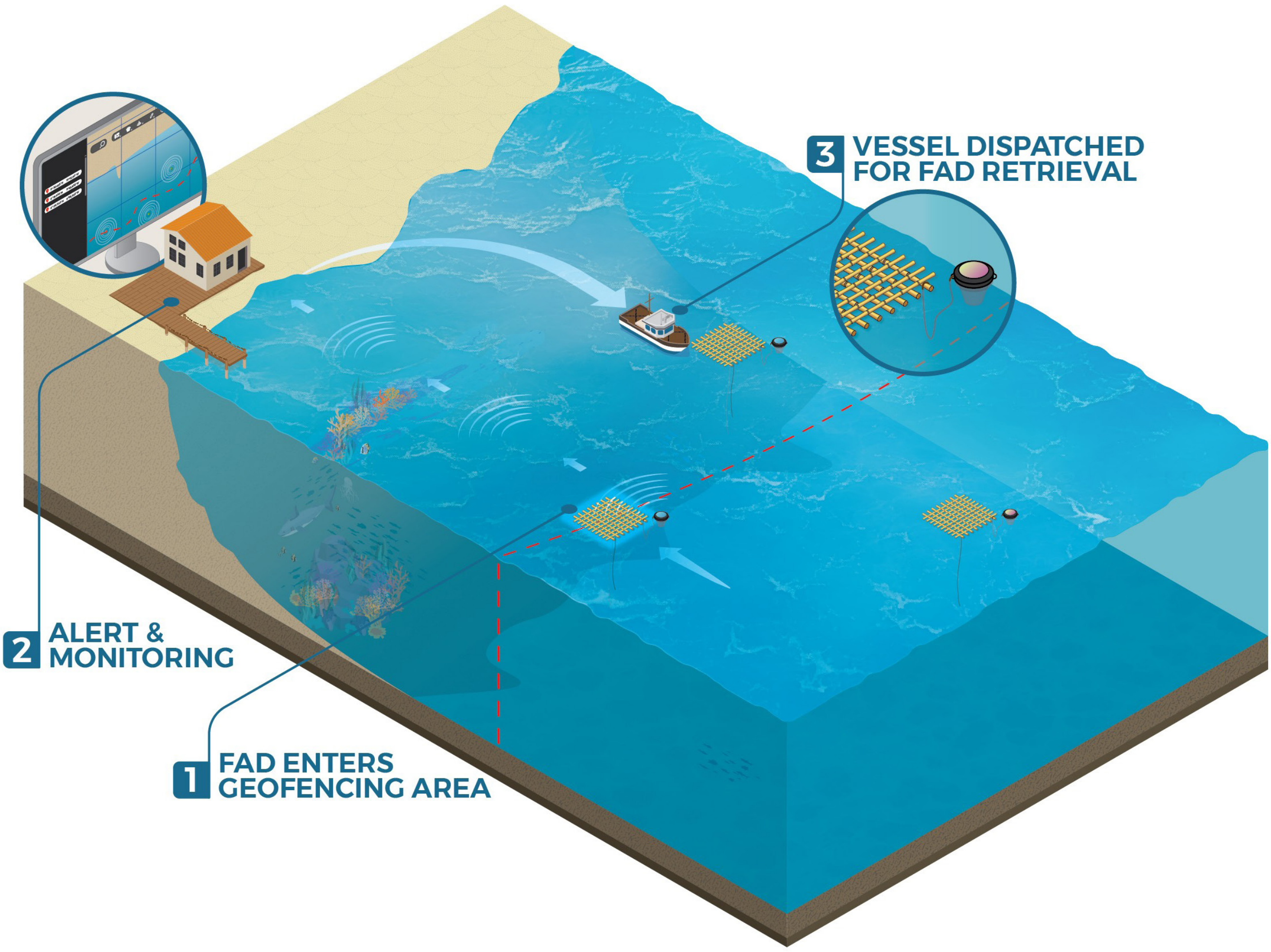
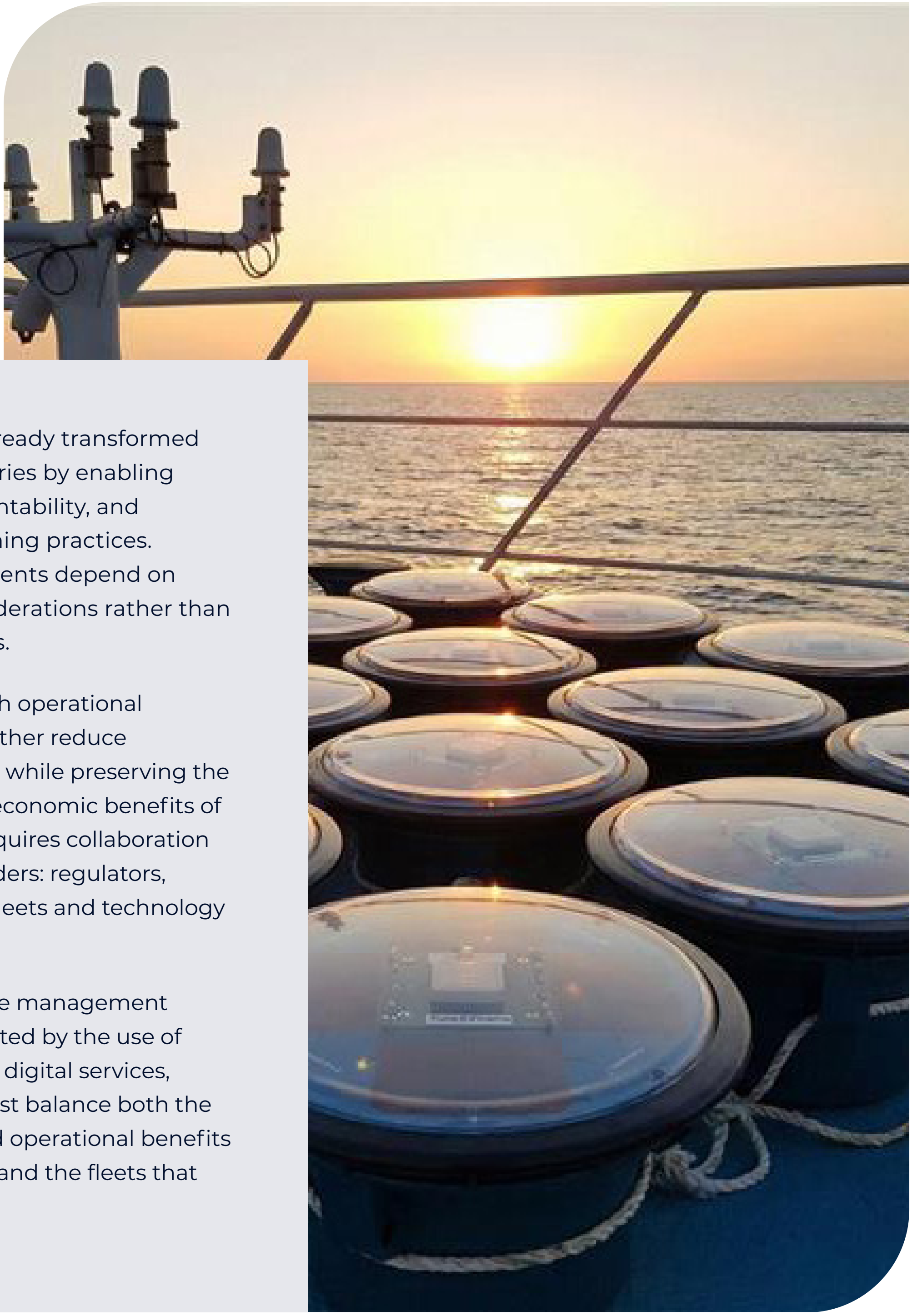


Figure 7. FAD Watch programs bring together industry, NGOs and buoy providers

07

Aligning Technology, Policy, and Outcomes



Technology has already transformed tropical tuna fisheries by enabling traceability, accountability, and more selective fishing practices. Further improvements depend on institutional considerations rather than technological ones.

Aligning policy with operational constraints can further reduce environmental risk while preserving the food security and economic benefits of the fishery. This requires collaboration across all stakeholders: regulators, scientists, fishing fleets and technology providers.

The comprehensive management of dFADs is supported by the use of satellite buoys and digital services, and regulation must balance both the environmental and operational benefits of this technology and the fleets that use them.

08 Expanding the Impact: Benefits for Local Fisheries, Ocean Science, and Conservation

While originally designed for industrial tuna fisheries, smart satellite buoys are evolving into autonomous, multi-sensor platforms with applications that extend far beyond a single species or sector. Their ability to provide continuous, real-time oceanographic data makes them a shared resource for coastal communities, scientific research, and environmental monitoring.

8.1 EMPOWERING LOCAL AND ARTISANAL FISHERIES

Small-scale fisheries provide over 50% of the fish consumed directly by humans but often lack access to real-time environmental data. Smart buoy technology bridges this gap, offering safety and efficiency benefits to local fleets:

SAFETY AT SEA:
Access to real-time weather and current data helps small vessels anticipate hazardous conditions and avoid dangerous navigation zones, directly reducing accident risks.

EFFICIENCY FOR MULTI-SPECIES:
Beyond tuna, buoy data on temperature and currents helps locate small pelagics (sardines, mackerel) and other species. Studies in the Pacific Islands have shown that access to this oceanographic information can increase daily catch efficiency by 10–25% for local fishers.

GEAR SECURITY:
GPS tracking allows artisanal fishers to monitor their own passive gear, reducing loss and preventing “ghost fishing”.

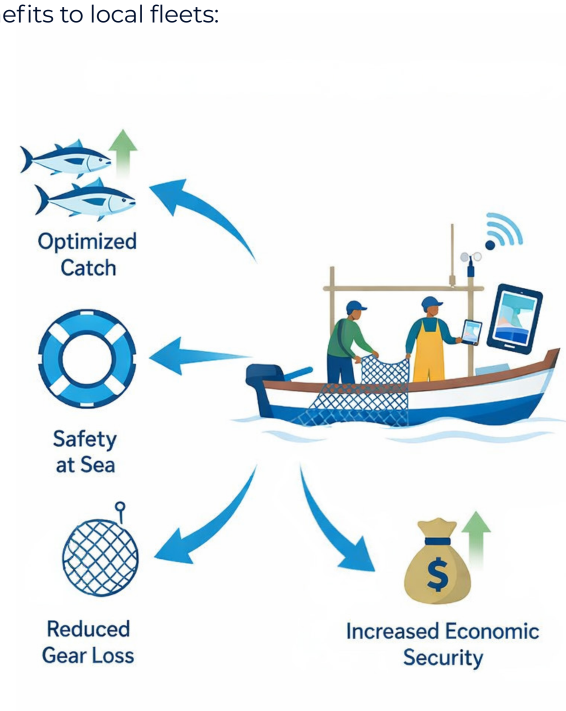


Figure 8. Bridging the technological gap for local fisheries and ocean science

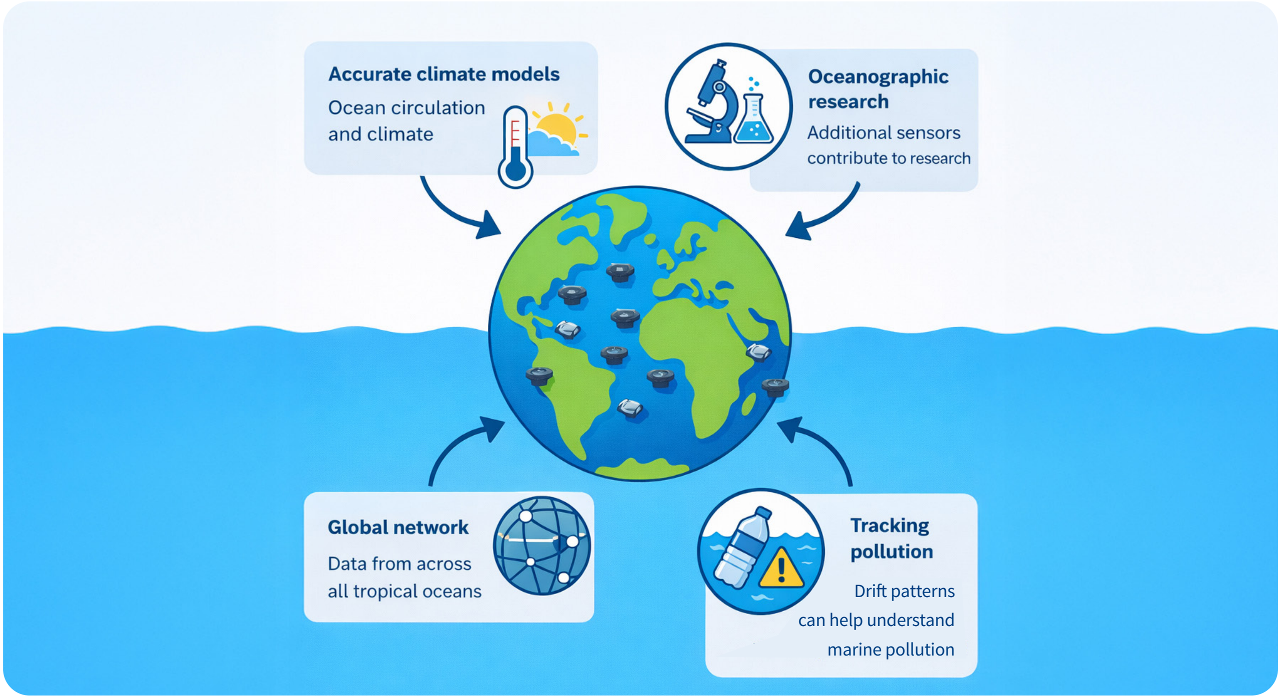


Figure 9. Data from satellite buoys can be applied to research beyond the dFAD fishery

8.2 MULTIFACETED APPLICATIONS FOR OCEAN OBSERVATION

Beyond their role in supporting fisheries, every active buoy functions as an independent, drifting oceanographic station. These devices provide a unique platform to collect vital data in vast, remote areas of the ocean where research vessels rarely venture, with the potential to enable diverse environmental monitoring applications.

CLIMATE & WEATHER:
Buoys can measure in-situ conditions, feeding critical data into global climate models and weather forecasting systems.

BIODIVERSITY & ECOSYSTEMS:
Acoustic sensors provide unique insights into the behavior of non-target species and the overall health of the pelagic ecosystem.

OCEAN CIRCULATION:
Data from drifting buoys can feed into ocean circulation models and understanding of basin-wide transport mechanisms.

Selected readings

1. **FAO (2022)**. *The State of World Fisheries and Aquaculture.*
2. **ISSF (2023)**. *Best Practices for Fish Aggregating Device Management.*
3. **FAO (2024)** *The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action.*
4. **Moreno et al. (2019)**. *Echo-sounder buoys as scientific tools for biomass estimation under drifting FADs. Fisheries Research.*
5. **Parker et al. (2018)**. *Fuel use and greenhouse gas emissions of world fisheries. Nature Sustainability.*
6. **Pew Charitable Trusts**. *Drifting Fish Aggregating Devices and Marine Ecosystems.*
7. **Dagorn, L., Holland, K. N., Restrepo, V., & Moreno, G. (2013)**. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? *Fish and Fisheries*, **14**(3), 391–415. https://doi.org/10.1111/j.1467-2979.2012.00478.
8. **Dagorn, L., Holland, K. N., Itano, D. G., & Sancho, G. (2013)**. Fish aggregating devices as scientific platforms for fisheries management. *ICES Journal of Marine Science*, 70(7), 1427–1436.
9. **FAO. (2021)**. *Abandoned, Lost or Otherwise Discarded Fishing Gear (ALDFG).* FAO Fisheries and Aquaculture Technical Paper No. 523. Rome: Food and Agriculture Organization of the United Nations. ISBN 978-92-5-106196-1
10. **ISSF. (2023)**. *Recommended Best Practices for Managing Fish Aggregating Devices (FADs).* ISSF Technical Report 2023-10. International Seafood Sustainability Foundation, Washington, DC.
11. **ISSF. (2024)**. *Status of the World Fisheries for Tuna: November 2024*. ISSF Technical Report 2024-7. International Seafood Sustainability Foundation, Washington, DC.
12. **Macfadyen, G., Huntington, T., & Cappell, R. (2009)**. *Abandoned, Lost or Otherwise Discarded Fishing Gear*. UNEP Regional Seas Reports and Studies No. 185; FAO Fisheries and Aquaculture Technical Paper No. 523. Rome: UNEP/FAO.
13. **Moreno, G., Dagorn, L., Sancristobal, I., & Itano, D. (2016)**. Fish aggregating devices (FADs) as scientific platforms. *Fisheries Research*, **178**, 122–129. ttps://doi.org/10.1016/j.fishres.2015.09.021
14. **Parker, R. W. R., Blanchard, J. L., Gardner, C., et al. (2018)**. Fuel use and greenhouse gas emissions of world fisheries. *Nature Sustainability*, **1**, 563–572. https://doi.org/10.1038/s41893-018-0130-x
15. **Richardson, K., Hardesty, B. D., & Wilcox, C. (2021)**. Global estimates of fishing gear loss and associated ecological impacts. *Reviews in Fish Biology and Fisheries*, 31, 1–29.
16. **Roemmich, D., Riser, S., Owens, W. B., et al. (2019)**. On the future of Argo: A global, full-depth, multidisciplinary ocean observing system. *Frontiers in Marine Science*, 6, 439.
17. **Secretariat of the Pacific Community (SPC). (2021)**. *Fisheries and oceanographic information for the Pacific Islands region*. Noumea, New Caledonia.
18. **The Nature Conservancy (TNC). (2022)**. *Climate-resilient fisheries: Data-driven solutions for coastal communities*. Arlington, VA.
19. **UNESCO. (2021)**. *United Nations Decade of Ocean Science for Sustainable Development (2021–2030): Implementation Plan*. Paris: UNESCO
20. **United Nations. (1995)**. Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement). New York: United Nations.

Note to the Reader

These references represent a selective entry point into a broad and evolving body of scientific and policy literature. They are provided to support informed discussion of the issues addressed in this document and do not imply endorsement of specific policy positions.

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