GSMA

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Advancing Sustainable Fisheries with Digital Technologies: The Gulf of Thailand

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Contents

Key concepts and definitions

Concept	Definition
Bycatch	The incidental capture of non-target species of fish and undersized target species, and/or of vulnerable charismatic species such as dolphins, turtles, and seabirds. Bycatch can either be discarded or, in the case of non-target species, retained for sale.
Fishery	A unit determined by an authority or other entity that is engaged in raising and/or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of the activities.[1]
Sustainable fisheries management	The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives.[2]
Illegal, unreported and unregulated (IUU) fishing	The Food and Agricultural Organization (FAO) uses the following definitions of illegal, unreported and unregulated fishing: **Illegal fishing:** Fishing activities that are i) conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations; ii) conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organisation but operate in contravention of the conservation and management measures adopted by that organisation and by which the States are bound, or relevant provisions of the applicable international law; or iii) conducted in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organisation. **Unreported fishing:** Fishing activities i) which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or ii) undertaken in the area of competence of a relevant regional fisheries management organisation which have not been reported or have been misreported, in contravention of the reporting procedures of that organisation. **Unregulated fishing:** Fishing activities i) in the area of application of a relevant regional fisheries management organisation that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organisation, or by a fishing entity in a manner that is not consistent with or contravenes the conservation and management measures of that organisation; or ii) in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law.
Sustainable fishing	Sustainable fishing means leaving enough fish in the ocean, respecting habitats, and ensuring people who depend on fishing can maintain their livelihoods. Sustainable fishing ensures there will be enough marine and freshwater wildlife in the future.[3]

1 FAO. (2025). FAO Term Portal: Fisheries.
2 Cochrane, K.L. (2002). A Fisheries Management Guidebook - Management Measures and Their Application. FAO.
3 Marine Stewardship Council. (n.d.). What is sustainable fishing?

Concept	Definition
Stock assessment	The scientific process of collecting, analysing and reporting on the condition of a fish stock and estimating its sustainable yield. Stock assessments are the backbone of sustainable fisheries management. Stock assessment models are mathematical and statistical techniques used to analyse and understand the impact of fisheries and environmental factors on fish stocks. The more data that is available, the better stock assessments are. Limited data cannot yield an assessment of current stocks and can only help assess stock size relative to previous years, while more comprehensive data can facilitate index-based modelling of stocks to estimate the maximum sustainable yield of fish.[4]
Marine capture fisheries	The practice of catching fish in the ocean.
Maximum sustainable yield (MSY)	A harvesting model used to calculate how much one can fish from a certain stock without depleting it. Its purpose is to define the largest catch (yield) that can be taken from a fish stock, over an indefinite period, while still leaving enough fish in the sea to ensure a sustainable stock development (i.e. enough mature fish to reproduce the maximum level, year after year).[5]
Overfishing	Depleting fish stock due to excessive fishing.
Marine protected area	A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.[6]
Regional Fisheries Management Organisation (RFMO)	International organisations that establish binding measures for conservation and sustainable management of highly migratory or straddling fish species.[7]

Abbreviations

AI	Artificial intelligence
AIS	Automatic Identification System
API	Application programming interface
ASEAN	Association of Southeast Asian Nations
CPUE	Catch per unit effort
EEZ	Exclusive economic zone
FAO	Food and Agriculture Organization of the United Nations
FMC	Fisheries Monitoring Centre
GPS	Global Positioning System
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IoT	Internet of things
IUU fishing	Illegal, unreported and unregulated fishing
IVMS	Inshore Vessel Monitoring System
MPA	Marine protected area
NFC	Near Field Communication
PSMA	Agreement on Port State Measures
REM	Remote electronic monitoring
RFID	Radio Frequency Identification
RFMO	Regional Fisheries Management Organisation
SEAFDEC	Southeast Asian Fisheries Development Center
VMS	Vessel Monitoring System

4 NOAA. (n.d.). Stock Assessment Model Descriptions.
5 Stockholm University Baltic Sea Centre. (2019). Factsheet: Understanding MSY.
6 Day, J., Dudley, N., Hockings, M., Holmes, G., Laffoley, D., Stolton, S., Wells, S. and Wenzel, L. (eds.) (2019). Guidelines for applying the IUCN protected area management categories to marine protected areas. IUCN.
7 European Commission. (n.d.). Regional fisheries management organisations (RFMO).

Executive summary

Context

The Gulf of Thailand is a vital marine ecosystem that supports a variety of fisheries essential for livelihoods and food security in bordering nations, including Cambodia, Malaysia, Thailand and Vietnam. This region, however, is grappling with significant challenges to marine life, such as declining fish stocks, overfishing, and the impacts of climate change. Coastal communities and domestic and export markets reliant on fisheries are becoming increasingly vulnerable as the marine ecosystem degrades due to these challenges, posing threats to socio-economic stability.

Sustainable fisheries manage and harvest stocks to ensure their long-term productivity, maintain healthy populations, protect ecosystems, and secure marine resources for future generations.

In the Gulf of Thailand, sustainable fisheries management is hindered by knowledge gaps about stock status, illegal, unreported, and unregulated (IUU) fishing, and financial and human resource limitations. This is further complicated by the transboundary nature of many stocks, which necessitates regional cooperation. However, efforts to collaborate are often hampered by geopolitical sensitivities and reluctance to share data, creating significant obstacles to effective management.

Key challenges facing sustainable fisheries management

Key barriers to sustainable fisheries management in the Gulf of Thailand include:

- **Knowledge gaps:** Lack of robust data on stock assessments and fishing practices limits the ability to implement effective management measures.
- **Overfishing and IUU fishing:** Facing pressure from reduced stocks and driven by the imperative to maximise their catch, both industrial and small-scale fishers have little incentive to accurately report catch data, reduce bycatch or curb IUU fishing practices in the absence of effective monitoring and control measures by regulatory authorities.
- **Limited capacity in fisheries management:** Fisheries departments face challenges in accessing training and resources to improve existing management systems, which remain mostly undigitised and slow-moving.
- **Affordability and digital skills:** Small-scale fishers face financial constraints as well as literacy and digital skills gaps in accessing digital tools that could enhance the visibility, sustainability and market competitiveness of their fishing activities.

Digitalisation as part of the solution

Digital technologies offer transformative potential for better fisheries management through tools including Vessel Monitoring Systems (VMS), electronic logbooks, mobile catch apps and traceability systems to address data gaps, enhance monitoring of fishing activities and improve compliance with fisheries laws and regulations. However, their success relies on aligning technology with existing governance and management structures, building local capacity, incentivising adoption and ensuring affordability and accessibility for small-scale fisheries.

Given the complexity of the problem, targeted pilots that respond to priority information needs to improve sustainability can demonstrate benefits to stakeholders and build momentum for scaling-up, while cross-national and regional collaboration can further amplify the benefits of digitalisation.

Headline recommendations for stakeholder groups

Key recommendations for actors interested in adopting digital technologies for more sustainable fisheries include:

Governments: Develop policy frameworks to ensure secure data use to overcome trust barriers, explore subsidies for technology development and adoption, and support local research and innovation.

Regional bodies such as intergovernmental organisations: Promote data-sharing agreements and joint enforcement initiatives to increase regional collaboration on transboundary stocks and IUU fishing measures.

Fisheries technology providers: Develop and encourage the adoption of hybrid VMS, electronic logbooks and mobile apps, and AI-based analytics for cost-effective monitoring to drive progress in scalable, impactful digital technologies for the sector.

Donors and development partners supporting the blue economy: Support capacity building and infrastructure development to enable technology rollout, facilitate pilots that demonstrate the value of specific digital interventions, and make sustainable investments in fisheries management systems.

1. Introduction

1.1 The impact of unsustainable fishing on marine resources

Unsustainable fishing is a growing threat to global stocks, driven by multiple factors, including climate change, increasing consumption of aquatic food, destructive fishing practices, and inadequate regulation and enforcement of IUU fishing. Overfishing and IUU fishing have significantly depleted fish populations, destabilising marine ecosystems and jeopardising the livelihoods of communities reliant on fishing for food and income. The United Nations Food and Agriculture Organization (FAO) monitors over 500 stocks globally, and estimated that in 2024, over 37% of stocks were overfished.[8]

IUU fishing presents a significant challenge to sustainable fisheries. Difficult to monitor and combat, IUU fishing accounts for 11-19% of global fisheries production, causing economic losses estimated between $10 billion and $23.5 billion annually.[9] IUU fishing undermines efforts to manage stocks responsibly, and disproportionately affects coastal fishing communities.

Climate change, which disrupts marine ecosystems and alters oceanic conditions critical to fish habitats, is further exacerbating these challenges. Rising ocean temperatures affect the growth, reproduction, and migration of many fish species, forcing tropical species to seek cooler waters, shifting traditional fishing areas. This destabilises fishing economies and increases competition for resources. Ocean acidification, caused by increased carbon dioxide absorption, further impacts marine life, particularly shellfish that rely on calcium carbonate for their shells. This disruption cascades through food chains, threatening the balance essential for fish populations to thrive. Additionally, changes in ocean currents, salinity, and oxygen levels create further habitat stress, often favouring some species over others and diminishing biodiversity.

The combination of these factors threatens the sustainability of stocks. In response to these challenges, there has been a concerted global effort to implement sustainable fishing practices. Governments, industry, and NGOs are working together to establish sustainable fisheries management measures to preserve stocks and protect marine ecosystems.

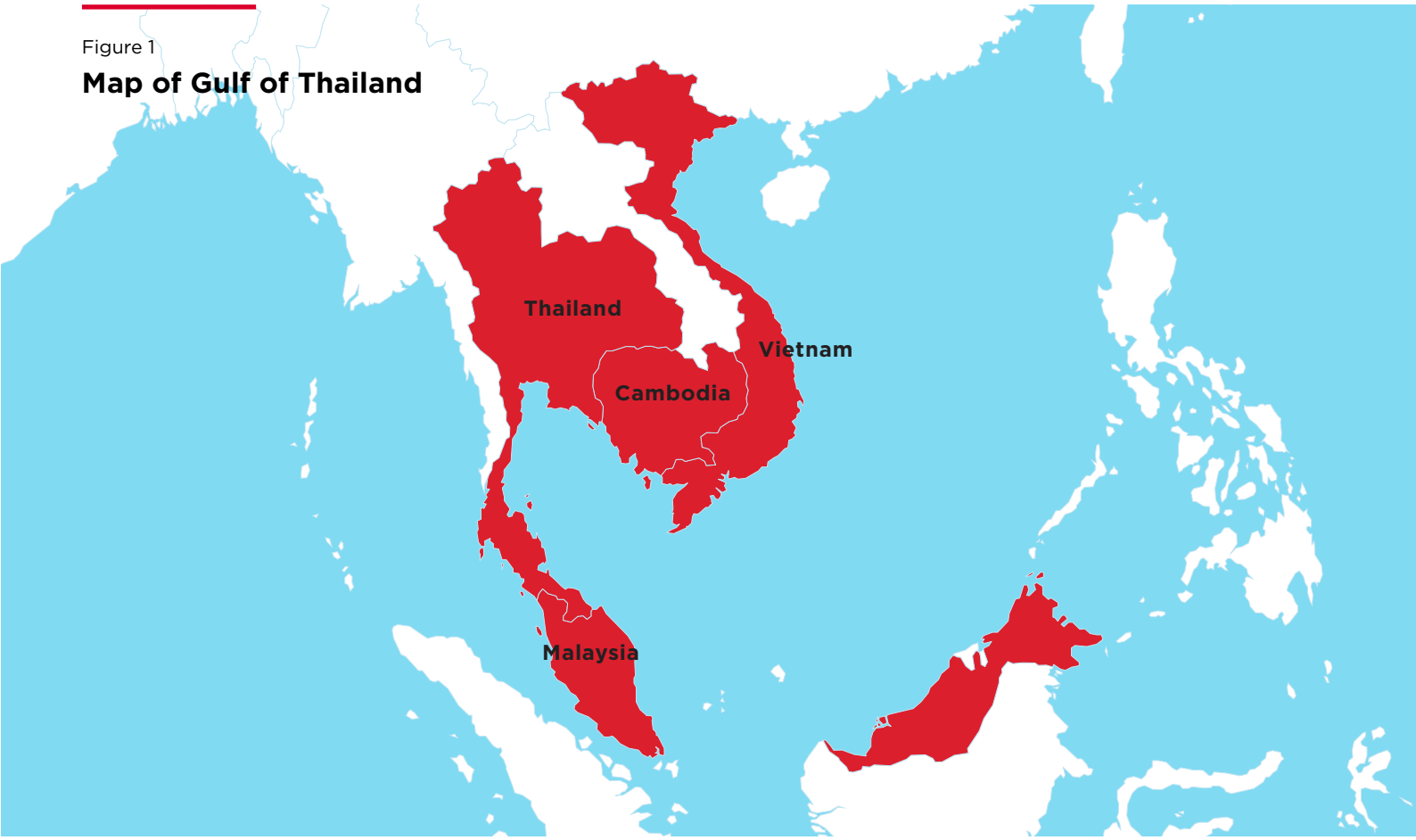
8 See Marine Stewardship Council website. Overfishing.
9 See World Wildlife Fund website. Illegal, Unreported and Unregulated Fishing.

1.2 The importance of fisheries in the Gulf of Thailand

The Gulf of Thailand, a body of water connected to the South China Sea, is bordered by Thailand to the northwest and west, Malaysia to the southwest, and Cambodia and Vietnam to the northeast. These shallow waters are home to diverse fisheries, ranging from small-scale operations to large-scale industrial enterprises.

Figure 1

Map of Gulf of Thailand



Fishing has long been a cornerstone of economic activity and sustenance in the Gulf of Thailand, delivering significant social and economic benefits. Thailand holds jurisdiction over 63% of the Gulf's waters and, similarly to Vietnam and Cambodia, relies heavily on fisheries for livelihoods, nutrition and economic growth. In Malaysia, marine capture fisheries form the backbone of fish production, playing a crucial role in both the economy and food security.

The Gulf of Thailand hosts a large and varied fishing fleet. According to the Southeast Asian Fisheries Development Center (SEAFDEC),[10] approximately 95,000 fishing vessels, both powered and non-powered, operate in the region. These vessels can be broadly categorised into small-scale (artisanal) and large-scale (industrial) operations, each of which plays a key role in supporting regional economies and communities.

However, the fisheries sector faces mounting challenges. The volume of fish caught in the Gulf surged after the 1960s as industrial fishing expanded, but has been in decline since the 1980s, despite increased fishing effort. This decline points to the depletion of fish stocks.[11] While overfishing remains a significant driver,[12,13] other factors such as coastal development, pollution and climate change also contribute to the problem.

10 See SEAFDEC website (accessed 16 January 2025).
11 Sea Around Us. (2024). Catches by Taxon in the waters of Thailand (Gulf of Thailand).
12 Environmental Justice Foundation. (2015). Overfishing and pirate fishing perpetuate environmental degradation and modern-day slavery in Thailand.
13 Kingdom of Cambodia, Ministry of Agriculture, Forestry and Fisheries. (2015). Law on Fisheries of Cambodia.

To address these challenges, effective fisheries management is essential. Sustainable practices are imperative to preserve the Gulf of Thailand's productivity and marine biodiversity. Transitioning fisheries from unsustainable to sustainable practices stands to benefit all nations bordering the Gulf of Thailand, as their economies, food security and livelihoods are directly tied to its health. Additionally, high-value markets, including the European Union, are increasingly requiring export nations to demonstrate sustainable fisheries management, adding further incentives for reform.[14,15]

1.3 Key elements of sustainable fisheries

Sustainable fisheries manage and harvest fish stocks to ensure long-term productivity while maintaining healthy fish populations, protecting ecosystems, and securing marine resources for future generations.

The sustainability of fisheries is dependent on numerous activities in the fisheries value chain, from fishing to primary processing, aggregation for sale, storage, transportation and trade. Besides activities in the fisheries value chain, external factors also affect fish stocks. Coastal development, for example, impacts the health of coastal fish stocks. For this report, we focus on one element of the fisheries value chain: fishing activity. The two core elements of sustainable fisheries management during the fishing stage of the fisheries value chain include understanding existing fish stocks and conserving them, and combating IUU fishing.

Stock assessments

Sustainable fisheries management measures rely on robust data about stocks, which can vary widely depending on factors such as regional capacities in data collection, which stock is being assessed (e.g., tuna, mackerel, tilapia), and the level of commitment to marine conservation. It involves collecting and analysing data and reporting on the condition of stocks to estimate sustainable yields i.e. how much of a stock can be fished to maintain the population in the long run. Using mathematical and statistical models, these assessments evaluate how fishing and environmental factors are affecting fish populations.[16]

Data-limited models: In situations with limited data, such as only catch or landing data, simpler models provide guidance on maximum allowable catches but cannot estimate stock size or identify whether overfishing is occurring.[17]

Index-based models: These more advanced models incorporate both "fishery-independent" data (e.g., survey data) and "fishery-dependent" data (e.g., logbooks from commercial and small-scale fisheries). This combined data supports more reliable stock assessments and better fisheries management.[18]

At its most basic, three types of data are needed for stock assessments, including data about stocks; that is, there must be a means of monitoring and collecting data about stocks made available for analysis, as well as the accuracy and timeliness of that data, over time, so that deviations and changes to stocks can be observed.

Stock assessment is also not a one-off activity and requires an ongoing process of monitoring. Regular and consistent information is needed about the biology and ecology of fished species, stock structure and abundance, fluctuations in the population and changes to the amount and efficiency of fishing.

Stock assessments have advanced considerably, as advances in computing capacity has allowed the construction of more meaningful models that increasingly also integrate environmental and ecological data to better understand the interactions between environmental parameters that often govern stock productivity, and ecological interactions that influence stock sustainability.

It is important to note that for tropical species found in the Gulf of Thailand, biological parameters used in stock assessments are often unreliable, making it even more difficult to accurately evaluate stock status.

14 IUU Watch. (n.d.). Map of EU carding decisions since the EU IUU Regulation entered into force.
15 Ocean and Coastal Futures. (2024). EU Proposes Revision of Tools to Tackle Unsustainable Fishing by Non-EU Countries.
16 NOAA. (n.d.). Stock Assessment Model Descriptions.
17 Ibid.
18 Ibid.

Control and enforcement

IUU fishing is a pervasive global issue, spanning small-scale, near-shore activities to large-scale, long-distance industrial operations. According to the UN Food and Agriculture Organization (FAO), IUU fishing represents one of the greatest threats to marine ecosystems[19] and undermines national and regional efforts to achieve sustainable fisheries. It is estimated that IUU fishing accounts for as much as one-fifth of global fisheries catches, representing up to $23.5 billion every year, with overall economic losses estimated to be $50 billion.[20,21]

Box 1
What constitutes IUU fishing?

The FAO's definitions of IUU fishing includes the following:

Illegal fishing

Activities conducted:

- By national or foreign vessels in a State's jurisdictional waters without permission or in violation of its laws and regulations.
- By vessels flying the flag of a State that is part of a regional fisheries management organisation (RFMO) but contravening its conservation and management measures or international law.
- In breach of national or international laws, including obligations under RFMO agreements.

Unreported fishing

Activities that:

- Are not reported or are misreported to the relevant national authority, violating national laws or regulations.
- Occur within an RFMO's area of competence without proper reporting, in contravention of its procedures.

Unregulated fishing

Activities that:

- Are conducted by vessels without nationality or those flying the flag of a non-RFMO member State, in contravention of RFMO conservation and management measures.
- Occur in areas or involve fish stocks lacking applicable management measures, contrary to States' responsibilities under international law for conserving marine resources.

19 FAO. (2025). Illegal, Unreported and Unregulated (IUU) fishing.

20 Financial Transparency Coalition. (2022). Half of industrial IUU fishing vessels operate in Africa, majority Chinese and European – new report.

21 Beyond economic impacts, IUU fishing exacerbates environmental pressures on already overfished stocks and is often associated with other criminal activities, including drug trafficking, arms smuggling and modern slavery.

Illegal industrial-scale fishing is often systemic, linked to organised crime, and attracts significant attention, research and investment. As a result, industrial and high-seas fishing has become increasingly regulated and monitored with initiatives such as the Agreement on Port State Measures (PSMA). The PSMA is the first binding international agreement that entered into force in 2016 to specifically target IUU fishing by preventing vessels engaged in IUU fishing from seeking entry to ports to land their catches outside of their own State.[22] In this way, the PSMA reduces the incentive of such vessels to continue to operate, while it also blocks fishery products derived from IUU fishing from reaching national and international markets.

By contrast, IUU fishing in small-scale fisheries typically involves individual boat owners fishing in restricted areas or engaging in damaging practices, such as using explosives, poisons or micro-nets, or encroaching into marine protected areas (MPAs). Governance gaps and weaker reporting requirements exacerbate the problem of monitoring small-scale fisheries. Unlike industrial vessels, small-scale fisheries often lack sufficient legal obligations for reporting catches.

Poor management and spatial conflicts also create governance vacuums, fostering unregulated fishing at both industrial and small-scale levels.

Effective sustainable fisheries management therefore requires rigorous monitoring of both large- and small-scale fishing operations to prevent overfishing, illegal activity in MPAs, and destructive practices like bottom trawling in coastal waters, as well as effective enforcement mechanisms to deter violations of IUU fishing laws and regulations.

22 FAO. (2025). Agreement on Port State Measures (PSMA).

Status of sustainable fisheries in the Gulf of Thailand

Three of the four countries bordering the Gulf of Thailand are ranked in the bottom third of countries for sustainable fishing (Table 1). The Yale Environmental Performance Index for the fisheries category[23] measures the health and sustainability of fisheries by country. The category is comprised of five indicators: fish stock status, fish catch discarded, fish caught by bottom trawling and dredging (domestically and across the global ocean), and the Marine Trophic Index, which measures fishing down the food chain and indicates the biological productivity of an ecosystem. In 2024, Cambodia ranked 129th, Malaysia 79th, Thailand 102nd and Vietnam 133rd out of a total of 141 countries.

Table 1: Gulf of Thailand fisheries environmental performance rank in the Yale environmental performance index (EPI) in 2024

Country	Indicator	Rank	Score (1=worst and 100=best)	Change in score over 10 years
Cambodia	**Fisheries**	**129 out of 141 countries**	**31.8**	**1.6**
	Fish stock status	85 out of 109 countries	23	3.9
	Fish catch discarded	31 out of 137 countries	86.7	13.7
	Bottom trawling in EEZ	132 out of 137 countries	12	0.1
	Bottom trawling in global ocean	136 out of 141 countries	15.4	1.9
	Regional Marine Trophic Index	51 out of 136 countries	52	-48
Malaysia	**Fisheries**	**79 out of 141 countries**	**52**	**-0.1**
	Fish stock status	44 out of 109 countries	51.5	2.2
	Fish catch discarded	29 out of 137 countries	87.8	0.2
	Bottom trawling in EEZ	92 out of 137 countries	39.4	-0.3
	Bottom trawling in global ocean	105 out of 141 countries	41.3	-0.6
	Regional Marine Trophic Index	75 out of 136 countries	48.7	-4.0
Thailand	**Fisheries**	**102 out of 141 countries**	**44.2**	**-1.9**
	Fish stock status	62 out of 109 countries	38.8	-14.4
	Fish catch discarded	38 out of 137 countries	79.2	0.5
	Bottom trawling in EEZ	102 out of 137 countries	31.5	-0.4
	Bottom trawling in global ocean	118 out of 141 countries	33.3	-0.2
	Regional Marine Trophic Index	25 out of 136 countries	60.9	6.4
Vietnam	**Fisheries**	**133 out of 141 countries**	**29.4**	**-2.9**
	Fish stock status	3 out of 109 countries	98.2	-1.8
	Fish catch discarded	118 out of 137 countries	31.8	-1.9
	Bottom trawling in EEZ	134 out of 137 countries	9	-3.2
	Bottom trawling in global ocean	137 out of 141 countries	13.3	-3.5
	Regional Marine Trophic Index	115 out of 136 countries	29	-3.3

Source: Yale EPI[24]

23 Environmental Performance Index. (2024). Fisheries.
24 Ibid.

Indicators:

Fisheries: The fisheries issue category measures the health and sustainability of the world's fisheries. It is made up of five indicators: fish stock status, fish catch discarded, fish caught by bottom trawling and dredging (domestically and across the global ocean), and the Marine Trophic Index. As data is only available for marine fisheries, landlocked countries are not scored in these indicators.

Fish stock status: The percentage of a country's total catch from overexploited or collapsed stocks, considering all fish stocks within a country's exclusive economic zone (EEZ). As continued and increased stock exploitation leads to smaller catches, this indicator sheds light on the impact of fishing practices within its EEZ. A score of 100 indicates that none of a country's fish catch comes from stocks that are overexploited or collapsed, and a score of 0 indicates worst performance. Data is from the Sea Around Us.

Fish catch discarded: The proportion of a country's total catch in the global ocean that is discarded, instead of landed and used. This indicator serves as a proxy of bycatch and thus of untargeted and wasteful fishing practices. A score of 100 indicates that none of a country's fish catch is discarded, and a score of 0 indicates worst performance. Data is from the Sea Around Us.

Bottom trawling in EEZ: The proportion of the total catch in a country's EEZ caught by any country using bottom trawling and dredging. This indicator measures whether countries allow bottom trawling in the marine regions under their jurisdiction. A score of 100 indicates that no fish are caught with bottom trawling inside a country's EEZ, and a score of 0 indicates worst performance. Data is from the Sea Around Us.

Bottom trawling in global ocean: The proportion of a country's total catch across the global ocean caught by bottom trawling and dredging. This indicator measures how much countries use bottom trawling, either in their own waters, those of other countries, or in the high seas. A score of 100 indicates that the country catches no fish with bottom trawling, and a score of 0 indicates worst performance. Data is from the Sea Around Us.

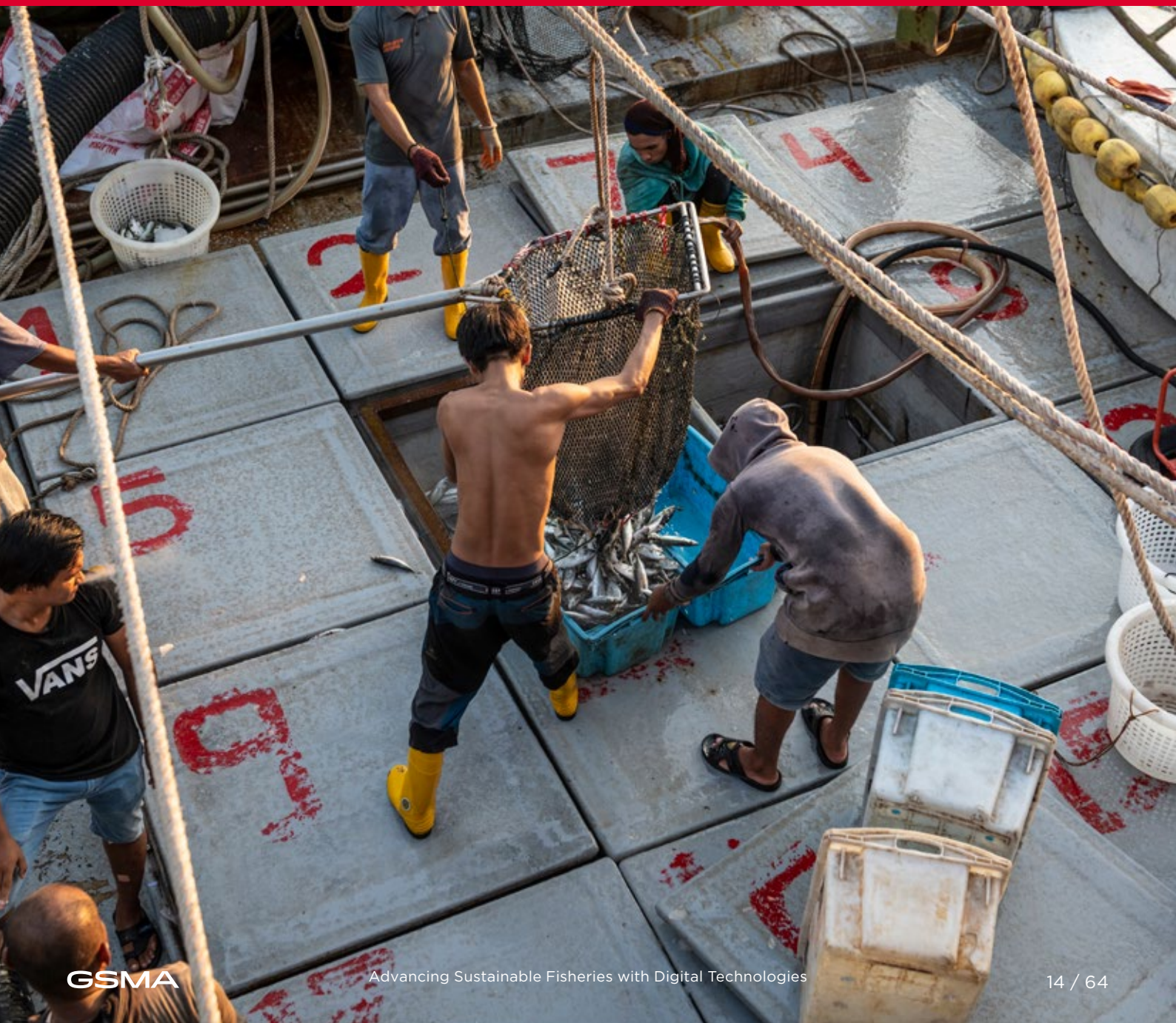
Marine Trophic Index: A measurement of how fast the trophic level of fish stocks changed over the last decade. The decline of the trophic level of fish catches is a phenomenon commonly known as fishing down the food web.

These rankings indicate serious challenges with sustainable fisheries management, with all four countries ranking particularly low in bottom trawling, an unselective industrial fishing method that damages the seabed, and Thailand and Vietnam registering reduced fish stocks in the last 10 years.

The role of digital technologies

Digital technologies are playing an increasingly important role in fisheries management globally and offer significant potential to improve sustainable fishing in the Gulf of Thailand. By enhancing data collection and control and enforcement mechanisms, these technologies support better stock assessments and can help to combat IUU fishing. Key innovations include the use of mobile and other digital devices for more accurate and efficient data collection, and exchange of data on catch sizes and other parameters critical for stock assessment models. AI-powered cameras can assess catch sizes and species composition with greater accuracy and efficiency than manual observations. Mobile and satellite connectivity and remote sensing technologies enable real-time tracking of fishing vessels to help monitor illegal activity and ensure compliance with regulations. Onboard sensors and IoT devices are deployed to detect the type of fishing gear being used and monitor environmental conditions in the ocean, aiding enforcement efforts and sustainable practices, and data collected from sensors and satellites provides insights into ocean health and supports ecosystem-based fisheries management.

2. Research objectives and methodology



2.1 Research objectives

This study identifies opportunities to leverage digital technologies for improved stock assessment and the monitoring of IUU fishing in the Gulf of Thailand, with the aim of enhancing the sustainability of its fisheries.

The study underscores the importance of regional cooperation in employing digital technologies to improve data sharing, which is critical for accurate stock assessments. It provides insights for regional and national fisheries managers and regulators on how digital tools can enhance the monitoring, assessment and control of fishing activities, thereby fostering more sustainable marine capture fisheries. Additionally, the report outlines best practices for integrating digital technologies into stock assessment and monitoring efforts, and explores opportunities for transboundary collaborations to harness these tools for effective fisheries management.

For donor and development partners, the study highlights resource and capacity gaps that need to be addressed to strengthen sustainable fisheries management in the Gulf of Thailand. It also offers a broader understanding of how digital technologies can contribute to fisheries sustainability globally, informing support and funding initiatives to optimise the use of these tools.

Private sector technology startups developing digital solutions for the fisheries sector will find insights into opportunities for technology innovation and deployment that could support sustainability in the Gulf of Thailand and low- and middle-income countries (LMICs) worldwide.

The report also highlights adoption challenges that must be addressed, paving the way for more effective implementation of these technologies and their integration into fisheries management systems.

2.2 Research methodology

This study uses a range of research methodologies as outlined in Figure 2.

Figure 2

Research methodology and process

Desk research

Extensive literature review incorporating industry, academic and grey literature to identify key challenges with stock assessments and IUU fishing in the Gulf of Thailand.

Landscaping

Landscape analysis of the role of mobile and digital technologies in supporting sustainable fisheries and the specific role they can play in curbing IUU fishing and fish stock monitoring.

Key informant interviews

Forty interviews with regional and global players to understand the current state of play in technology adoption, including:

- Fisheries regulators
- Commercial fishing companies/associations
- Small-scale fisheries/ associations
- NGOs advocating for sustainable fisheries
- Regional fisheries coordination bodies
- Technology providers
- Development and donor partners.

Validation

Field visits with relevant stakeholders in two countries to validate findings.

The research integrates insights gathered through a comprehensive desk review, landscape analysis, and interviews with 40 regional experts. These experts represent a diverse range of stakeholders, including fisheries departments, regional coordination bodies, technology providers, NGOs, government advisers, multilateral organisations, donors and development partners focused on sustainable fisheries management. Additional perspectives were obtained from the GSMA M4D roundtable held in Thailand in September 2024 and from field visits.

Through landscape analysis and stakeholder interviews, we identified key challenges hindering sustainable fisheries in the Gulf of Thailand.

We also examined existing regional collaborations on stock assessment, and control and enforcement efforts. Leveraging these findings, we explored the potential of digital technologies to enhance stock assessment and control and enforcement. This included evaluating current technologies in relation to the specific needs of Gulf of Thailand fisheries, highlighting their strengths, weaknesses and suitability.

Our analysis highlights opportunities for technology adoption and identifies critical barriers that must be addressed to advance the sustainability of fisheries management in the region.

Scope

This study focuses on mobile-based, digital, i.e. web-based, and emerging technologies, which include AI and ML, IoT, drones, satellite imagery, robotics and blockchain.

While military and maritime security agencies use a number of remote sensing technologies, such as radar and sonar technologies, to monitor fishing vessels to manage IUU fishing, these are not within the scope of this study.

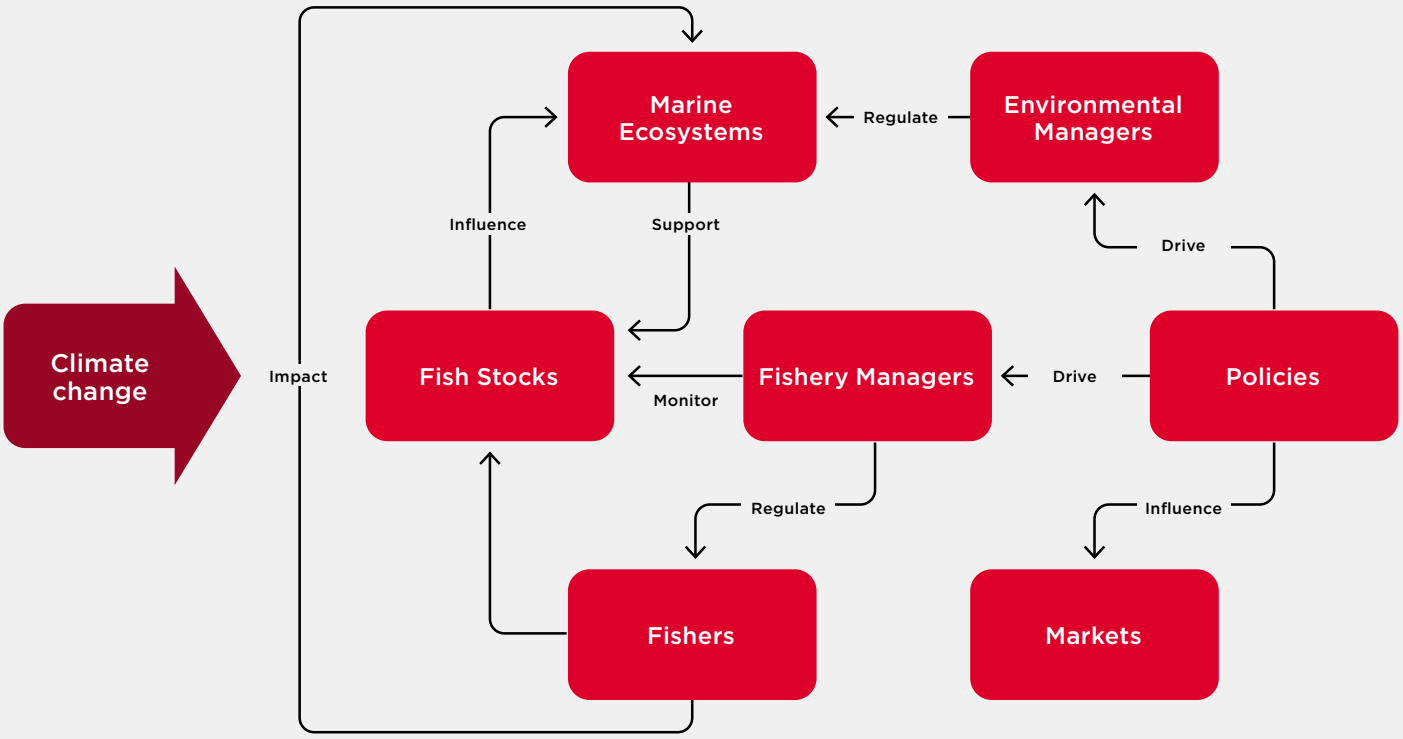
Research approach

While digital technologies can play a key role in improving fisheries management, we take the approach that their success hinges on effective integration into existing fisheries management systems (Figure 3).

The introduction of digital technologies offers fisheries managers access to better information, which can significantly improve decision-making, but the effectiveness of these technologies depends on the overall functionality of the fisheries system to maximise their advantage. Misaligned policies, harmful market incentives, climate change and other systemic challenges may hamper sustainable fisheries management despite digitalisation, in the absence of good governance.

Figure 3

A generalised model of a fishery system



Source: Howell Marine Consulting

3. Digital technologies for sustainable fisheries management

3.1 Challenges facing sustainable fisheries management in the Gulf of Thailand

Sustainable fisheries management in the Gulf of Thailand faces significant challenges, which include:

- **The scale and diversity of fisheries:** The Gulf of Thailand is home to tens of thousands of fishing vessels operating along its extensive coastlines. This immense scale, coupled with the diversity of fisheries—particularly inshore, small-scale operations that are vital for coastal livelihoods—makes monitoring fishing activity exceptionally difficult. Capacity constraints within fisheries departments hinder the collection of accurate and timely data, further complicating effective management.
- **Knowledge gaps and data limitations:** Effective fisheries management depends on robust biological, ecological, social and economic data. This data is essential for informed policymaking, assessing environmental impacts, and monitoring compliance with regulations. However, data collection in the Gulf of Thailand often remains paper-based, particularly for inshore fleets. Additionally, data is frequently stored on disconnected platforms, limiting its utility for policy decisions or evaluating the effectiveness of management measures.
- **Regional cooperation gaps:** While regional platforms like the ASEAN Network and the Association of South-East Nations (SEAFDEC) promote collaboration, transparency and data-sharing between nations bordering the Gulf of Thailand remains limited. Significant disparities exist in policy approaches and management capacities across countries, hindering cohesive, cross-border strategies for sustainable fisheries.
- **Complexities of multi-species fisheries:** The Gulf's demersal trawl fisheries i.e. g fisheries that drag nets on the ocean floor, an unselective method that damages the seabed, and catch multiple species simultaneously, create a significant management challenge. Each species has unique lifecycle characteristics and responds differently to fishing pressures, yet selective fishing is difficult, and these species are often captured in the same trawl. Therefore, multi-species assessment approaches are necessary, but are challenging for all nations globally. Current methods and capacities to conduct stock assessments vary widely across the region.
- **Control and enforcement limitations:** IUU fishing continues to undermine sustainability in the Gulf of Thailand. While regulatory frameworks exist to combat IUU fishing, enforcement is constrained by limited resources and insufficient oversight, particularly of inshore fleets. Small vessels, which play a critical role in fisheries sustainability and ecosystem protection, often operate with minimal visibility, contributing to overfishing and habitat degradation.

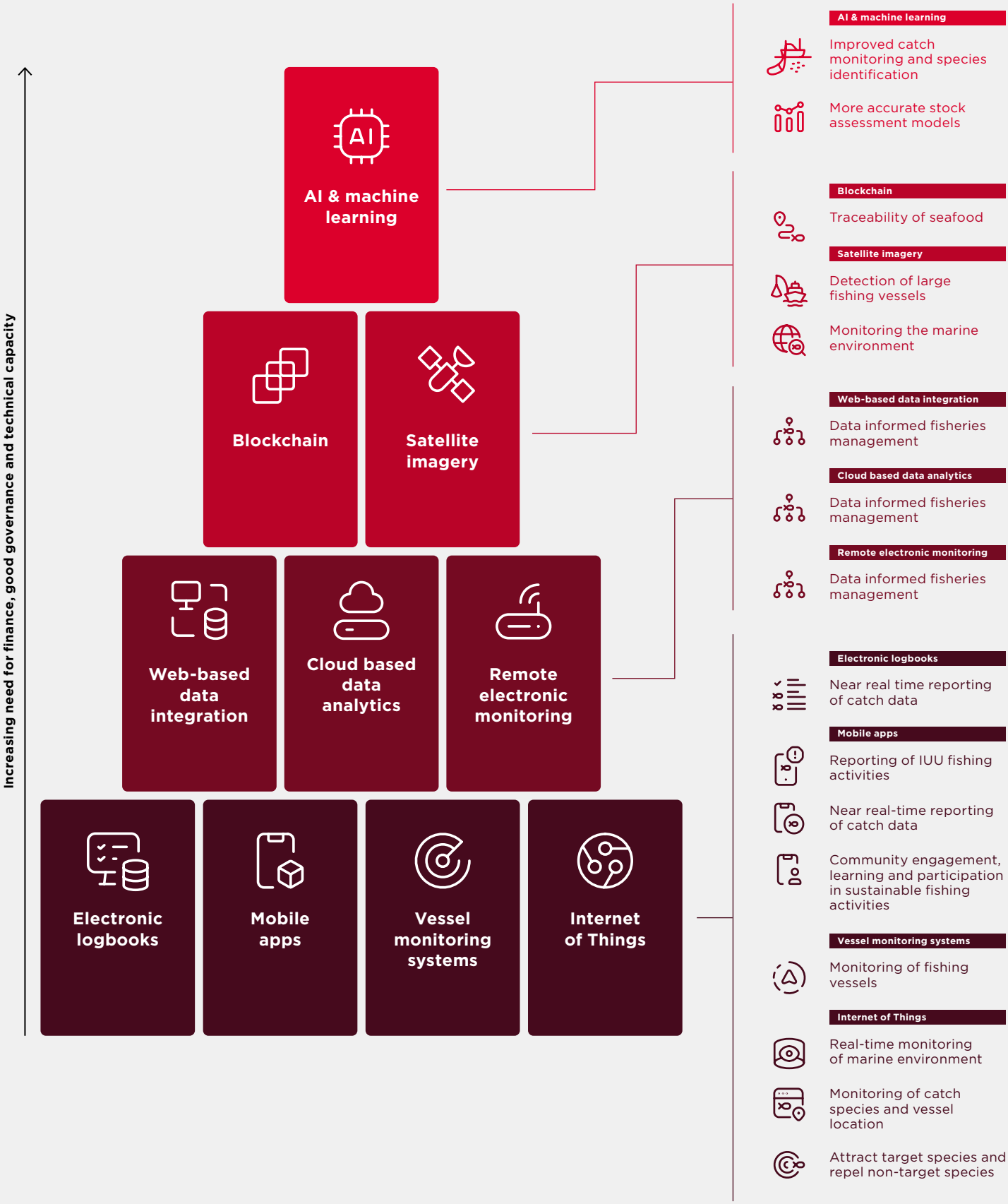
3.2 The role of digital technologies in overcoming challenges

Digital technologies have the potential to address sustainable fisheries management challenges, providing countries bordering the Gulf of Thailand with the data and tools to improve fisheries management by improving stock assessments to establish more data-informed and adaptable fishing quotas, monitoring IUU fishing, supporting regional collaboration, and enhancing environmental sustainability (Figure X).

Figure 4 captures key digital technologies and associated use cases that are being increasingly applied to sustainable fisheries management around the world and offer the potential to help address sustainability challenges faced in the Gulf of Thailand. These are divided into categories by increasing complexity of implementation.

Figure 4

Digital technologies and their key use cases for sustainable fisheries



Source: GSMA Mobile for Development

3.2.1 Digital tools for stock monitoring and assessments

The status of stock assessments in the Gulf of Thailand

Stock assessments aim to provide reliable estimates of stock abundance[25] to inform decision makers about the need for and design of fisheries management measures.

Data on the majority of stocks in the Gulf of Thailand are limited, and those that exist are often dated. For example, the last comprehensive survey of stocks in Cambodia was conducted in 2019, so there is a knowledge gap about the current status of stocks to guide fisheries management policy. Generally, commercial stocks are better managed and understood because of their market value and often as data is more readily available from industrial fisheries. By contrast, small-scale fisheries are often unregulated, or poorly regulated, and therefore little is known about the practices and impact of small-scale fisheries on fish stocks and the wider environment.

Assessing multispecies fisheries is an additional challenge for the Gulf of Thailand. Multispecies assessment methods seek to address some of these limitations, but are challenging and most advanced in regions with high levels of collaboration, expertise and experience, and where there are large volumes of supporting data from long-term monitoring initiatives. While Thailand has progressed in multispecies assessments, lack of data-sharing and coordination on stock assessment data between the countries bordering the Gulf of Thailand, makes accurate stock assessments even more difficult.

Weak enforcement of fisheries regulations further exacerbates these challenges, with detrimental impacts on coastal fishing communities, who are no longer able to sustain their livelihoods and struggle with food security due to stock depletion.

Moreover, stock assessment in the countries bordering the Gulf of Thailand varies considerably, from significantly more robust measurement in Thailand and Malaysia, to more nascent and limited assessments in Vietnam and Cambodia. A high-level overview of stock monitoring for the four countries follows.

High level assessment of stock monitoring in the countries bordering the Gulf of Thailand

Thailand

Thailand leads the way in stock assessments and fisheries monitoring in the Gulf of Thailand, particularly for primary stocks. Regular data collection is conducted through surveys focusing on key categories: anchovy, demersal, and pelagic stocks. Pelagic stocks, which include oceanic species such as tuna, mackerel, and sardines, play a crucial role in marine food systems and are vital for maintaining ecosystem health.

The Department of Fisheries (DOF) in Thailand carries out stock assessment surveys using government-operated vessels. These surveys are supplemented by data from industrial fishing activities. However, manual data collection is still prevalent at ports, which limits coverage and results in incomplete records, as it captures only a portion of vessel landings.

25 Bouch et al,.(2021). Comparative performance of data-poor CMSY and data-moderate SPiCT stock assessment methods when applied to data-rich, real-world stocks. ICES Journal of Marine Science. Volume 78.

Malaysia

Stock assessments in Malaysia are conducted by the Department of Fisheries, Malaysia (DOFM) and involve manual data collection at various fishing ports, including both government and private facilities. Data collection is integrated across district, state, and federal levels, but challenges remain in ensuring comprehensive coverage, especially for small-scale fisheries. Most data are entered manually or through basic systems.

Cambodia

Compared to Thailand and Malaysia, Cambodia's fisheries data collection system is significantly less developed. The Fisheries Administration (FiA), operating under Cambodia's Ministry of Agriculture, Forestry, and Fisheries, serves as the primary agency for fisheries data collection. At the sub-national level, the Marine Fisheries Research and Development Institute (MaFReDI) oversees fisheries management, while the Fisheries Administration Cantonment (FiAC), under FiA, is tasked with fisheries oversight and regulation at the provincial level. However, the fisheries administration faces considerable capacity constraints.

Stock assessments in Cambodia are sporadic and inconsistent, primarily due to gaps in technical expertise and jurisdictional ambiguities between ministries. The reliance on manual, paper-based data entry systems and the absence of real-time data capture tools further hampers effective fisheries management. Current data collection efforts depend on provincial offices aggregating catch logbook records from fishers[26], a process that is often unreliable and inconsistent.[27]

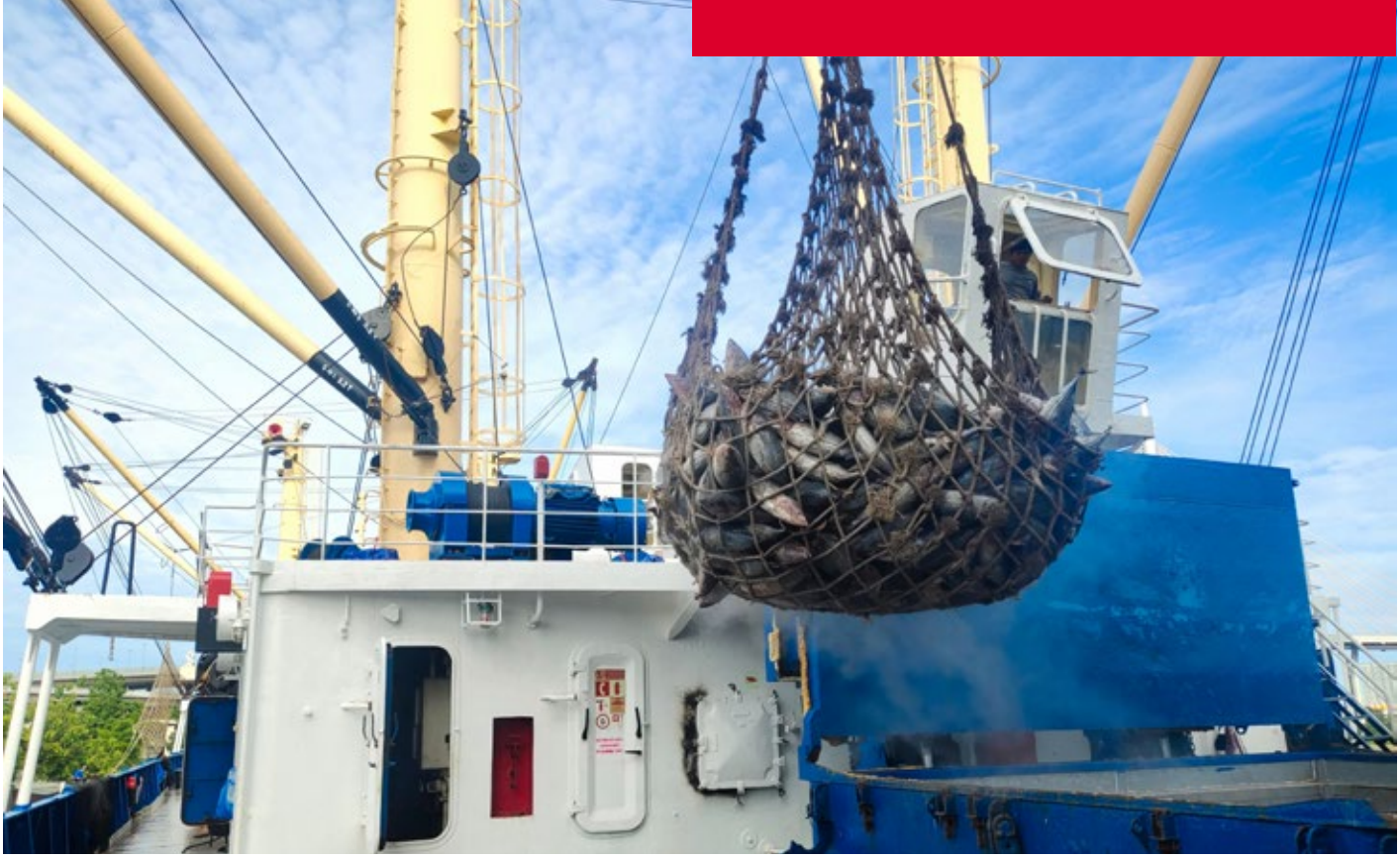
Efforts to improve stock assessments are supported by regional organisations such as SEAFDEC and the FAO[28], which are supporting the introduction of new assessment methodologies[29]. However, Cambodia's dependence on external funding and NGO-led training initiatives undermines the sustainability of its data management systems, leaving the country vulnerable to challenges in maintaining long-term improvements.

Vietnam

In Vietnam, stock assessments rely on data collected from fish landings at ports and information provided by onboard observers, particularly in key fisheries such as tuna. Despite these efforts, much of the data is still recorded manually and submitted to port authorities, leading to inefficiencies and potential data quality issues.

Although various data collection initiatives are in place, the methods and models used for assessments remain underdeveloped. Manual processes dominate, especially for smaller vessels, limiting the comprehensiveness of the data. Concerns about the reliability of fisheries data also persist, driven by issues such as underreporting and the inherent complexities of managing multi-species fisheries.

26 FAO. (2023). The status of marine fishery stock assessments in the Asian region and the potential for a network of practitioners.
27 Ibid.
28 SEAFDEC. (2022). Cambodia: Fisheries Country Profile.
29 Ibid.



Digitalisation for improved stock assessment

Digitalisation offers the opportunity to enhance fish stock monitoring by improving data collection processes and mechanisms for more data-informed fisheries management. Some key traditional processes for stock assessments for large fishing vessels can be improved by mobile and digital technologies.

Traditional data collection methods

Dockside monitoring

Monitoring fishing vessel movements and landings from the dockside is a key source of information about catches. Dockside monitoring can provide accurate measures of fish catch, supplemented by measurements of biological parameters, including the length, sex and age of fish, that can provide useful information for stock assessments.

Logbooks

Traditionally analogue and filled in by fishers by hand, logbooks tend to be carried aboard fishing vessels and are completed by the vessel master to provide a range of fishery-dependent data, including a record of the species, weight and/or number of each species, area caught, time and duration of fishing trips, which can then inform the calculation and monitoring of Catch per unit effort (CPUE), an indirect measure of the abundance of a target stock.

Fisheries observers

Fisheries observers are independent specialists deployed on board commercial fisheries vessels as part of at-sea monitoring programmes, contracted either by regulators or third-party contractors on their behalf. They have played a critical role in providing scientific data from commercial fisheries vessels for use in stock assessment and environmental monitoring. As fisheries regulations and legislated obligations increase the demand for data and greater coverage of fisheries, the use of at-sea observers has been challenged by methodological and budgetary limits, and safety risks of sending people to sea.

Digital data collection methods

Traditional tools using surveys, paper logbooks and human observers are limited and tend to lead to large data gaps and inaccuracies in reporting. However, digital tools and processes such as eLogbooks and digitalised dockside monitoring are significantly improving these traditional systems.

eLogbooks

Electronic logbooks (eLogbooks) can be used by fishers to provide near real-time data on catches to fisheries managers and regulators. For example, Canadian ocean technology company Vericatch,[30] started developing an electronic logbook (ELOG) in 2020 to digitalise the reporting of catch data. It allows offline data entry, auto-fills repetitive data fields, and enables fishers to report catch details more efficiently. Although its application is largely in North America, the eLogbook has been used in numerous other countries such as Indonesia, Chile and Peru. In Indonesia, the Environmental Defence Fund, a US-based non-profit, partnered with Vericatch to develop an eLogbook app that dockside enumerators in the remote province of Lampung could use to record catches of the blue crab to inform the blue swimmer crab fishery policy. The ELOG app is accessible via mobile or tablet, and enables data entry on catch amounts, species and location, traditionally captured in paper logbooks.[31]

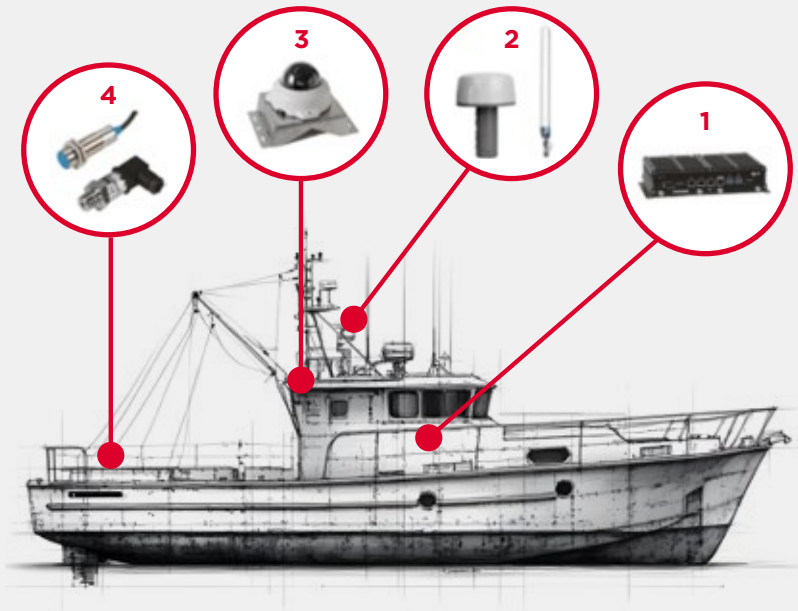
Remote electronic monitoring systems

In more advanced and comprehensive digitalisation initiatives, remote electronic monitoring systems (REM) can be used for data collection at sea, including onboard cameras to capture handling of the catch, sensors to monitor fishing gear and effort, and data storage and wireless communication for greater efficiency and accuracy of stock assessments (Figure 5).[32]

A pioneering implementation of an REM took place in Canada between 1990-2006 in the groundfish fishery. Since then, REM has been deployed in numerous fisheries in North America, Australia and New Zealand, with adoption growing elsewhere.[33] While effective in delivering monitoring goals, adoption has been challenging to scale, due to lack of regulatory frameworks to drive adoption, the cost of such systems, unwillingness by fishers to make these investments, privacy and data ownership concerns over video data by fishers, and fishers' resistance to change.[34]

Figure 5

Typical REM system[33]



1. **Black Box Video control unit** with built-in GPS & wireless communication modules, that captures & stores sensor and video data.
2. **Digital IP cameras** for capturing the handling and processing of the catch.
3. **Antenna** enabling the wireless communication of data from the vessel & remote connectivity to the vessel to monitor & manage the system.
4. **Sensors** (analog & digital) supported to capture fishing activity and effort.

Source: Environmental Defence Fund.

30 For more information see Vericatch: About us. (accessed 16 January 2025).
31 Ibid.
32 Fujita, R. et al. (2018). Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual. Environmental Defense Fund.
33 Environmental Defence Fund. (2018). Designing and Implementing Electronic Monitoring Systems for Fisheries.
34 Ibid.
35 Skirrow, R. (2021). Cefas and industry science collaborations: Fisheries monitoring, the electronic age. Marine Science.

Current use of digital technology for stock assessment in the Gulf of Thailand

Catch surveys, logbooks and dockside data collection remain primarily manual in Vietnam, Cambodia and Malaysia, and there is no electronic monitoring of catches at sea. However, Thailand's regulations demand the use of CCTV cameras to monitor fishing activities on large commercial vessels, and more recently, Thailand's Department of Fisheries has also launched an app to serve as an eLogbook for commercial fishers,[36] whereby a photograph of the paper logbook can be captured and shared with the DoF in digital format.

Digitalising catch data for small-scale fisheries

One of the key challenges in managing fisheries in the Gulf of Thailand, and in fisheries management more generally, is obtaining catch data from small-scale fishers. While the extent of fish caught, or of bycatch, by small-scale fisheries is unknown for the region, it is estimated that 50% of the world's fish is caught by small-scale fisheries, which account for 95% of total fishing.[37]

Typically, these fishers operate vessels below specific size thresholds, such as those less than 12 metres in Cambodia or under 10 gross tonnes in Thailand. These small vessels are generally unregulated in the Gulf of Thailand (though larger vessels are regulated). Research shows that small-scale vessels, particularly those using gill nets, can have significant environmental impacts, including high bycatch rates of marine megafauna like turtles, sharks and dugongs.[38] It has also been reported that some fishers may purposefully operate vessels just below the regulatory threshold to avoid scrutiny, complicating stock monitoring efforts. Moreover, commercial fishers may disguise themselves as small-scale operators to avoid reporting catches, while still overfishing and using harmful methods like bottom trawling near coastal waters, which damages ecosystems and depletes stocks.

There is therefore an increasing drive to understand and support the sustainability of fisheries by effective management of small-scale fisheries both globally and in the Gulf of Thailand. However, regulation should be carefully balanced to avoid disrupting the practices of traditional fishing communities who are reliant on traditional fishing methods for their livelihoods and nutrition.

36 e-Fishing Logbook System App.
37 CLS. (n.d.). Nemo: Connecting, Protecting & Empowering Small-Scale Fisheries.
38 Svarachorn, T., et al. (2023). Marine megafauna catch in Thai small-scale fisheries. Aquatic Conservation: Marine and Freshwater Ecosystems. John Wiley & Sons Ltd.

Mobile apps

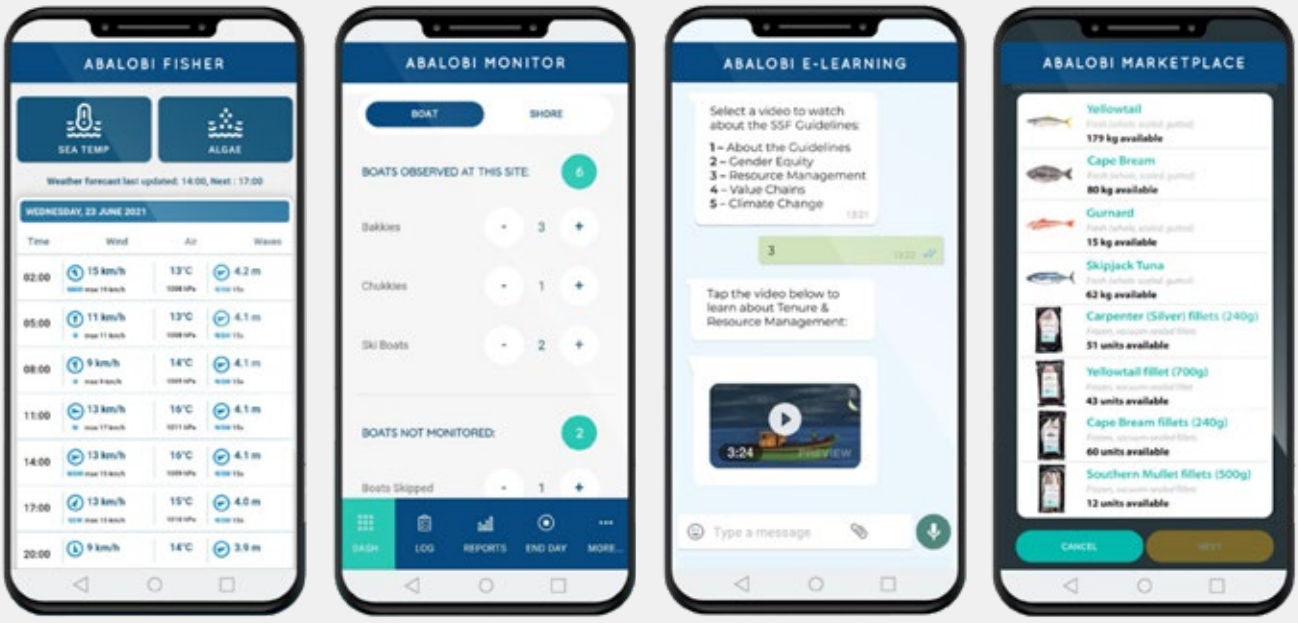
For small-scale and artisanal fishers, mobile data recording apps (effectively simplified eLogbooks) have proven to be the most practical and cost-effective method for gathering catch data. Many small-scale fishers operate nearshore and can connect to GSM networks, allowing them to use mobile apps to record catch data. Additionally, many mobile-based tools for small-scale fishers have been designed specifically to function offline as well as online, supporting remote data collection.

There are numerous examples of mobile apps for catch data collection, such as ABALOBI in South Africa (Box 2).

Box 2
ABALOBI,[39] a mobile-based solution for small-scale fishers

ABALOBI is a South Africa-based non-profit and social enterprise that supports small-scale fishing communities with social, economic and ecological sustainability and is deployed in numerous markets including South Africa, the Seychelles, Palau, Kenya, Madagascar, Ireland, Chile and Comoros. Offered to fishers via a mobile app, the company enables data collection via electronic catch documentation and traceability (eCDT), delivers skills building (edtech), and supports collective social entrepreneurship by providing access to an online marketplace platform, Fish With A Story, and linked digital financial services (Fintech) to artisanal fishers. The company works with NGOs and the government as well.

A key challenge ABALOBI solves is incentivisation. For both commercial fishing fleets and small-scale fishers, there is little incentive to report data on either their catch or vessel location, as there is a perception that it could lead to over-monitoring, misuse of data, taxation implications and a compromise of data privacy. By offering skills-building, relevant information and access to a marketplace and financial services, ABALOBI incentivises small fishers to share catch data, supporting sustainability.



39 For more information see the Abalobi website. (accessed 16 January 2025).

There are also a number of examples of the use of mobile apps in Indonesia, including mFish[40]. mFish is a mobile app that enables fishermen to log catch data and access vital information on weather, prices, and fishing practices. Designed to minimise data costs, it is free to use on Facebook Free Basics or through a mobile browser on both smartphones and feature phones. In Indonesia, mFish was piloted in 2016 in collaboration with the Indonesian Ministry of Marine Affairs & Fisheries (KKP), providing average price data to fishers at over 40 ports.[41] This information offered the potential to improve fishers' negotiating power, incentivising app adoption for catch reporting.[42] The app. registered over 14,000 fishers in the first month of launch.

Box 3
The Perahu app: Advancing traceability and financial inclusion for small-scale fishers in Indonesia

In Indonesia, small-scale fishers face growing challenges in meeting both local regulatory requirements and global market demands for digital catch documentation and traceability. Without proper records, these fishers struggle to comply with evolving catch documentation and traceability standards, limiting their access to premium markets. Additionally, a lack of financial track records prevents many fishers from securing bank loans or government grants, making it difficult to invest in more sustainable and profitable fishing practices.

To address these challenges, Indonesian seafood traceability software firm SLL Fisheries developed the Perahu App, a mobile application designed to help small-scale fishers log fishing data as well as their financial transactions. By integrating catch information—such as fishing grounds, gear type, and landing data—with economic records of fisher-to-buyer transactions, the app provides valuable insights to both fishers and stakeholders across the supply chain. The digital solution enables fishers to track their business operations, improve their market value, and establish a financial history, thereby increasing their eligibility for financial support. Moreover, the data collected supports fish stock assessments, aiding sustainable fisheries management.

The Perahu App also serves as a compliance tool, helping fishers and local suppliers meet government regulations and international traceability requirements. By ensuring that fish catches adhere to global sustainability standards, the app helps prevent IUU fishing products from entering the supply chain. Currently, SLL Fisheries, in collaboration with the MDPI Foundation, is piloting the Perahu App with 500 fishers across two communities, focusing on tuna, octopus, and shrimp fisheries. A key component of the project is community engagement, providing fishers with financial literacy training and hands-on guidance on how to log their fishing and financial transactions. With the support of the Ocean Resilience Innovation Challenge (ORIC)—financially backed by the Swiss Re Foundation, the UK's Blue Planet Fund, and the U.S. Department of State[43]—this initiative aims to scale adoption among more fishing communities to ultimately improve fisheries' sustainability across the country.

40 See mFish website. (accessed 16 January 2025).
41 Fujita, Rod et al. (2018). Technologies for improving fisheries monitoring. Environmental Defense Fund.
42 Ibid.
43 Information sourced from the SSL website.

Web-based data integration applications

Digital platforms that utilise application programming interfaces (APIs) to exchange data and communicate with each other can integrate fisheries data from multiple sources, enabling data aggregation, real-time monitoring and data analysis, and can support collaboration among stakeholders, such as fishers, regulators, fisheries scientists and policymakers, who can easily access the data online. One example is PeskAAS in Timor-Leste (Box 4).

Box 4
PeskAAS in Timor-Leste[44]

Timor-Leste's fisheries are primarily small-scale, with most fishers using paddle canoes to fish in narrow fringing reefs. While the country's reefs currently support healthy fish stocks, there is a risk of overfishing vulnerable species.

PeskAAS is a digital data collection system designed for small-scale fisheries. This open-source, real-time dashboard was developed by Malaysia-based WorldFish,[45] an international research organisation working to improve food security, nutrition and livelihoods through aquatic food systems, with Timor-Leste's Ministry of Agriculture and Fisheries (MAF). Launched in 2019, it monitors fishing activities by artisanal fishers in Timor-Leste, capturing detailed information such as the number and type of fish caught by individual boats.

Since 2018, the CGIAR Research Program on Fish Agri-Food Systems (FISH), led by WorldFish, has partnered with US-based fisheries management technology company Pelagic Data Systems,[46] to equip 359 boats in Timor-Leste with solar-powered trackers. The devices record boat movements and transmit data via satellite to the dashboard. In 2019, MAF employed data collectors at 30 major landing sites across 11 coastal municipalities. These collectors meet fishers as they return from sea and use smartphones or tablets to document the quantity and type of species caught, uploading the data to the system, which is then updated on the dashboard within the same day.

PeskAAS automatically analyses data on catch collected on these digital devices from landing sites and solar-powered tracking devices installed on fishing boats. It equips fisheries officers, researchers and local stakeholders with data to enable them to better understand the role of fish and fisheries in supporting local livelihoods and food security.

A key element of the project's success has been the active involvement of fishing communities and municipal fisheries officers throughout its development. Responsibility for data collection management has now been transferred to MAF, with WorldFish continuing to provide technical support to ensure the system's sustainability and effectiveness. After demonstrated success in Timor-Leste, PeskAAS is expanding its product offerings and is now being trialled in five other countries, including Malaysia.

44 World Fish Center. (n.d.). PeskAAS - Automated analytics system for small scale fisheries in Timor-Leste.
45 For more information see the World Fish Centre: about us. (accessed 16 January 2025).
46 Pelagic Data Systems. (n.d.) Providing Data Solutions for Fisheries Around the World.

Box 5

Blue Ventures[47] and KoboToolbox – Globally deployed community-driven data collection tool for conservation

KoboToolbox is a data collection, management, and visualisation platform used globally for research for social good, developed and hosted by Kobo,[48] a global non-profit. Blue Ventures, a UK-based marine conservation social enterprise, is using KoboToolkbox to empower rural coastal communities to collect and manage their own fisheries data. Partnering with traditional fishers and community organisations, Blue Ventures believes that successful marine conservation must be community-led. By digitising data collection, fishers gain real-time insights, helping them make informed, data-driven decisions for sustainable marine area management.

With support from Blue Ventures, communities learn data collection best practices and how to develop digital forms to monitor critical conservation indicators, such as fish catch weights, species diversity, and mangrove restoration. KoboToolbox's offline functionality is especially valuable in remote areas, allowing mobile data collection without internet access. Fishing communities that have deployed KoboToolbox with the help of Blue Ventures, have observed rapid habitat recovery and fish population growth, showcasing the impact of accessible, community-centred conservation models.[49]

The potential for digital initiatives for small-scale fisheries in the Gulf of Thailand

Small-scale fisheries in the Gulf of Thailand are typically operated by local fishers using relatively low-tech, traditional methods and, in many cases, with non-powered boats. Small-scale fisheries play a key role in the livelihoods of coastal communities and contribute to the region's food security and cultural heritage. Yet currently, few digital initiatives support small-scale fisheries in the Gulf of Thailand. Catch data from small vessels is often unrecorded, meaning small-scale fishing efforts cannot be considered in fisheries management measures. Efforts to promote the sustainability of small-scale fisheries, address their challenges, and integrate them into broader regional and national fisheries management frameworks are essential to preserve the Gulf of Thailand's marine resources. Digital tools for catch data collection are not just management and enforcement mechanisms, they can also empower fishing communities. By adopting mobile-based catch data systems, small-scale fishers can demonstrate sustainable fishing methods to gain higher market value and better access to markets. Digital data also provides small-scale communities with leverage to advocate for their fishers and fishing.

A coordinated, mobile-based digital catch data collection initiative across Thailand, Malaysia, Cambodia and Vietnam could be instrumental in enabling improved community well-being and a clearer understanding of small-scale fishers' impact on fish stocks. Improved data could lead to better regulation, foster behavioural shifts toward sustainable fishing practices and support community-led monitoring and advocacy.

47 See Blueventures website. (accessed 16th January 2025).
48 See KoboToolbox: about us. (accessed 16 January 2025).
49 KoboToolbox. (2023). Building resilience in coastal communities: How Blue Ventures is using KoboToolbox to drive marine conservation and improve digital equality.

Emerging opportunities for improved stock assessments and data-informed fishing quotas

In addition to the digitalisation of catch data, emerging technology opportunities offer further possibilities for better stock assessments to inform more accurate fisheries management measures.

AI and ML

Scientists are exploring the potential of AI algorithms to predict fish stocks more easily, accurately, and affordably than current methods. In 2023, the Wildlife Conservation Society (WCS),[50] a U.S.-based global NGO, trialled an AI model in the Western Indian Ocean pilot region, achieving 85% accuracy in stock assessments.[51] The model combines years of fish abundance data with satellite measurements, using AI to generate rapid and cost-effective predictions. This approach is especially valuable in data-poor and resource-constrained regions. Developers aim to refine the model further, enabling it to generate accurate fish stock estimates from just seven simple data points—such as distance from shore, water temperature, and water depth—aiming to help governments, managers, and communities better understand the health of nearshore fisheries.

While still in development, the use of AI-trained algorithms to detect acoustic sounds that can identify different pelagic fish stocks is also showing some promise.[52] For example, researchers at the Spain-based AZTI research centre[53] have developed an automatic classification model to identify key pelagic fish species in the Bay of Biscay, such as anchovy, sardine, and Atlantic mackerel. The model uses acoustic echosounders to detect fish schools and has achieved somewhat promising results, achieving 63.5% accuracy in identifying labelled schools of fish and 80% accuracy when including both labelled and unlabelled schools. This AI-driven approach pairs acoustic data with machine learning and may offer an efficient way to enhance fisheries management in the future by improving species distribution assessments.[54]

50 See Wildlife Conservation Society website. (accessed January 2025).
51 Responsible Seafood Advocate. (2023). Artificial Intelligence algorithm from WCS is the first to accurately estimate fish stocks.
52 The Fishing Daily. (2024). AZTI Develops AI Model to Optimise Fish School Identification.
53 See: About AZTI. (accessed 16 January 2025).
54 The Fishing Daily. (2024). AZTI Develops AI Model to Optimise Fish School Identification.

Computer vision

AI-powered cameras onboard fishing vessels can use computer vision to identify species as they are brought onboard, classifying catches by size and type. If a protected or non-target species is detected, the system can alert the crew and even trigger automated sorting mechanisms. Tidal, an AI company focused on sustainable aquaculture, uses a network of AI-enabled cameras with computer vision to monitor fish stocks in aquaculture and wild fisheries. Tidal helps to prevent overfishing and improve fish stock management in Norway.[55]

In 2023, the Environmental Defense Fund (EDF),[56] collaborated with U.S. tech firms and local partners in Indonesia to trial SmartPass,[57] a digital tool aimed at fostering more productive and sustainable fisheries. SmartPass combines shore-based cameras with AI to accurately monitor the number of fishing vessels in a given area. EDF deployed these smart cameras at three crab landing sites to track total crab catch and fishing effort. This data was further enriched by catch information provided by fishers via mobile apps and collected by dockside enumerators. By integrating these data sources, EDF achieved a comprehensive assessment of total catch. The local fishing community embraced the technology as they recognised the long-term benefits of maintaining healthy fish stocks for sustainability. EDF plans to scale this model globally to promote sustainable fisheries and enhance food security.[58]

Similarly, AI-enabled video cameras have been developed by Shellcatch,[59] a Latin American company headquartered in Chile that provides a suite of digital fisheries management tools, including cloud-based vessel monitoring systems, to fishers in 14 countries. The cameras can be installed on fishing vessels to capture high-resolution images of fishing activities (technique, bycatch rate and more) to hold fishers accountable for how and what they are catching. Shellcatch uses an AI algorithm through its electronic monitoring sensor to detect bycatch of nontarget species. Its monitoring system caters to small-scale and artisanal fishers, and by 2020 was deployed in numerous markets, including Costa Rica, Ecuador, Thailand, Germany and Norway.[60]

AI also supports the development of robotic devices that reduce bycatch. For example, Smartrawl, developed by Heriot-Watt University scientists with support from the National Robotarium's Robotics and Autonomous Systems (RAS) laboratory, is an underwater robotic sorting device which helps fishing trawlers prevent bycatch by identifying and sizing fish and other marine life in real-time.[61] Funded by the UK Seafood Innovation Fund and delivered in partnership with Fisheries Innovation & Sustainability (FIS), a UK-based coalition of fisheries experts,[62] Smartrawl uses AI technology to determine the individual size and species of marine life captured inside a trawl net using images taken by an underwater stereo camera. It then releases or retains each marine animal, depending on whether it qualifies against a trawler's intended catch, using a computer-controlled robotic gate. Smartrawl was trialled in the Shetland Islands in the UK in 2023.

55 Fishfarmingexpert. (2024). Google-created company launches 'most advanced' cage camera and AI system.
56 See EDF website. (accessed 15 January 2026).
57 Environmental Defense Fund. (2021). SmartPass: Technology for more Sustainable and Productive Fisheries.
58 Environmental Defense Fund. (2023). SmartPass and Smartphones: An Innovative Approach to Small-Scale Fisheries Monitoring in Lampung Province, Indonesia.
59 See Shellcatch website. (accessed 16 January 2025).
60 Hook & Net. (2020). Latin American tech provides traceability for artisanal fisheries.
61 The National Robotarium. (2023). AI-empowered fishing net to help prevent marine bycatch.
62 See Fisheries and Sustainability website. (accessed 16 January 2025).

IoT sensors

IoT is a network of smart, connected devices that are embedded with sensors and software, allowing them to collect and share data.[63] On-board and in-water IoT cameras and motion sensors can be used to detect fish and categorise the detections by species, size and other programmed attributes. IoT-enabled devices can also monitor and record environmental data to improve knowledge related to environmental parameters influencing stock abundance and distribution.[64]

The Ocean Data Network,[65] a multi-organisational coalition conducting collaborative ocean observation efforts with fishing vessels, leverages IoT to fill data gaps in ocean data. The Ocean Data Network has piloted Bluetooth-enabled IoT sensors in Ghana. The sensors are connected to fishing nets on small boats to obtain oceanographic data for modelling.[66] The data is shared from vessels using a connected solar-powered device. The sensors can be deployed on either small or large boats and used to obtain a variety of data on ocean conditions to not only inform policymaking, but also help artisanal and small-scale fishers target their efforts better and more efficiently for more abundant, sustainably caught fish.

Blockchain

Blockchain has been extensively applied to supply chain traceability. By providing an immutable data store where there is virtually no possibility of modifying data, blockchain or other distributed ledger technologies offer potential to increase trust in fisheries supply chains, where there are significant risks of mislabelling or product substitution. Blockchain provides access to the digital ledger to directly verify information attached to a product, such as country of origin, fishers or fishing gear, certification, quality, or environmental credentials. Boat to plate schemes using blockchain technology have been trialled, for example to track tuna caught in the Pacific and sold in Australia, to confirm that individual fish sold are not derived from IUU fishing.[67]

Blockchains for fisheries follow the flow of seafood products from fishers, fish traders and processors, exporters, importers and brands or retailers. In principle, blockchain can provide transparency within the supply chain and identify whether fishers are complying with fisheries management regulations and global market requirements. However, it is reliant on data quality, accuracy and for each person in the supply chain to participate.[68] In addition, there is the possibility of mislabelling or substituting the physical product associated with a digital ledger. Blockchain is therefore not a standalone solution for traceability and transparency, and works best in combination with other processes and technologies such as effective control and enforcement, and catch certification schemes.[69]

Individual fish (in the case of high-value species such as bluefin tuna or Patagonian toothfish) or batches of fish are tagged with smart sensors such as radio frequency identification (RFID) or near-field communication (NFC) tags[70] to automatically track the product and send information about its movement through the blockchain. It is also given a unique identification number, usually via a QR code or barcode, which sets out its origin and fishing methods. Typically, the tag would then be scanned, usually through a mobile app to create the digital record. The tag follows the fish through the value chain and creates new records automatically as it is picked up by devices installed at all key points of the value chain—for example on the vessel, the port dock and the processing facility.

There is still limited evidence to prove the efficacy of blockchain technology in fisheries, but pilot projects have been implemented, primarily for small-scale fisheries, in Indonesia, the Pacific Island nations, the Philippines, Ecuador and Thailand.[71] High income countries that use blockchain in their fisheries on a large scale, and often industrial level, include Australia, Norway and the US.[72]

63 IBM. (2023). What is the Internet of Things (IoT)?

64 Additional emerging technologies that support stock assessment include Near Infrared Spectroscopy (NIRS), which automates the currently time-consuming process of analysing otoliths, and molecular tools such as e-DNA, which holds promise to deliver more wide-reaching monitoring of fish stock distribution through water sampling but are not at this time directly linked to mobile technologies.

65 See OceanData Network website.

66 Ocean Data Network. (n.d.). Projects.

67 WWF. (n.d.). From Bait to Plate.

68 Cook. B. (2017). Blockchain: Transforming the Seafood Supply Chain. WWF.

69 Tolentino-Zondervan, F. et al. (2023). Use cases and future prospects of blockchain applications in global fishery and aquaculture value chains. Aquaculture, Volume 565.

70 Nomtek. (2023). What Are NFC Tags? A Beginner's Guide.

71 Tolentino-Zondervan, F. et al. (2023). Use cases and future prospects of blockchain applications in global fishery and aquaculture value chains. Aquaculture, Volume 565.

72 Ibid.

3.2.2 Digital tools for control and enforcement

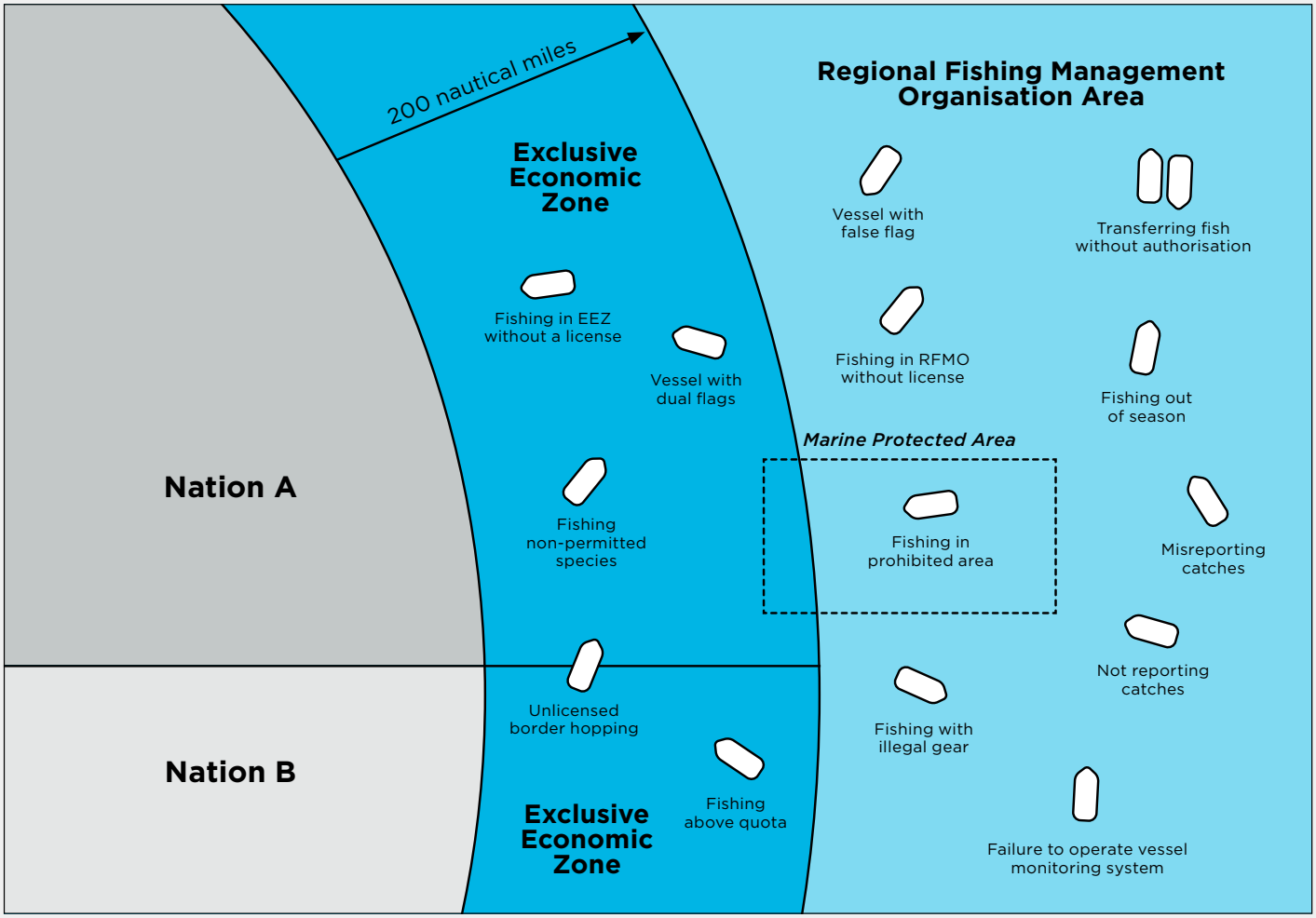
The threat of IUU fishing

IUU fishing is a global challenge, encompassing both small-scale coastal activities and large-scale industrial operations. This multifaceted problem undermines sustainable fisheries management by complicating accurate stock assessments, damaging marine ecosystems, and threatening livelihoods dependent on marine resources.[73]

Figure 6 captures the most common types of IUU fishing.

Figure 6

Common types of IUU fishing



$6bn
in economic losses

ASEAN countries experienced over $6 billion in economic losses in 2019 from IUU Fishing, with Indonesia and Vietnam experiencing the biggest losses.

IUU fishing has led to a **reduction in food supply, lost livelihoods and state revenues, diminishing fish stocks, and damaging ecosystems.**

Source: National Intelligence Council, US[74]

73 Young, L. et al. (2023). Future Illegal, Unreported and Unregulated Fishing Trends in a Warming World. A Global Horizon Scan. RUSI.
74 National Intelligence Council. (2016). Global Implications of Illegal, Unreported and Unregulated (IUU) Fishing.

The persistence of IUU fishing in the Gulf of Thailand

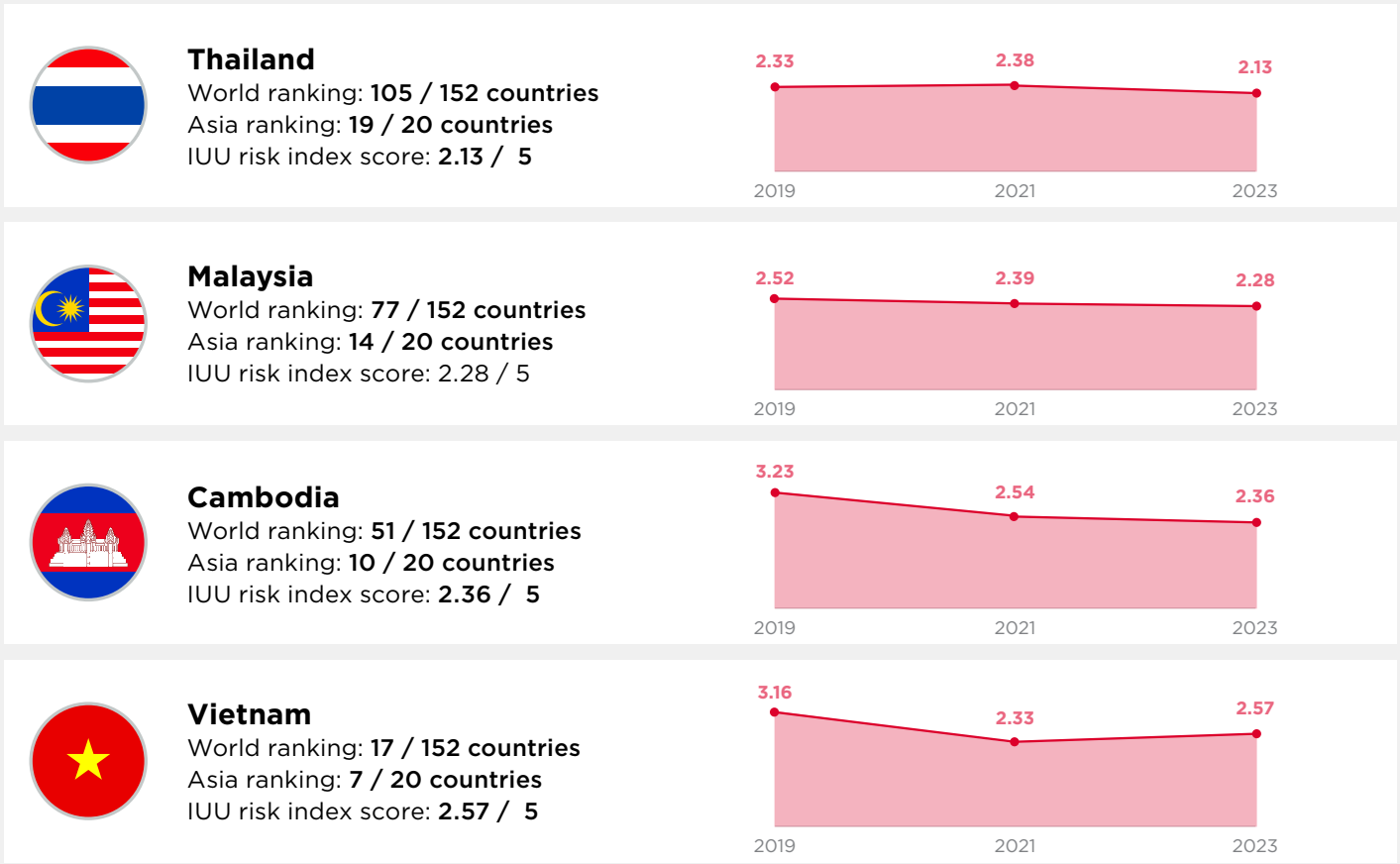
IUU fishing in the Gulf of Thailand is driven by several factors, including weak regional fisheries governance, limited law enforcement budgets, and insufficient cooperation among relevant authorities. Unregistered vessels, maritime boundary disputes (e.g. between Thailand and Cambodia),[75] and the use of illegal gear further exacerbate the problem.[76,77] Prohibited activities like bottom trawling in shallow waters and fishing within MPAs continue to persist, highlighting enforcement gaps.

Although three out of four states bordering the Gulf of Thailand (excluding Malaysia)[78] have ratified the Port State Measures Agreement (PSMA)[79] to prevent IUU vessels from landing their catches, implementation remains inconsistent. Many ports lack robust surveillance and fail to routinely inspect vessels, while informal coastal landing sites are exploited to offload illegal catches. Once landed, fish from IUU sources easily infiltrate markets due to inadequate cross-border trade regulations and limited traceability systems.[80]

Figure 7

Country rank and scores in the IUU fishing risk index[81]

Note: Higher scores, and ranks closer to 1, indicate worse/poor performance.



Source: IUU fishing risk index

75 Wilcox, C., et al. (2021). A review of illegal, unreported and unregulated fishing issues and progress in the Asia-Pacific Fishery Commission region. Bangkok and Hobart, FAO.

76 During the COVID-19 pandemic, there was a rise of IUU fishing within small-scale fisheries, due to unemployed people resorting to fishing to provide for their families, which created additional pressure on fisheries within the Gulf of Thailand. See FAO website (accessed 16 January 2025).

77 Wilcox, C., et al. (2021). A review of illegal, unreported and unregulated fishing issues and progress in the Asia-Pacific Fishery Commission region. Bangkok and Hobart, FAO.

78 FAO. (2009). Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal Unreported and Unregulated Fishing (PSMA).

79 FAO. (n.d.). Illegal, Unreported and Unregulated (IUU) fishing.

80 Wilcox, C., et al. (2021). A review of illegal, unreported and unregulated fishing issues and progress in the Asia-Pacific Fishery Commission region. Bangkok and Hobart, FAO.

81 The IUU Fishing Risk Index provides a measure of the likelihood that states are exposed to and effectively combat IUU fishing. The Index provides an IUU fishing risk score for all coastal states of between 1 and 5 (1 being the best, and 5 the worst). The Index allows countries to be benchmarked and ranked, and assessed for their vulnerability, prevalence and response to IUU fishing. The Index has been developed by Poseidon Aquatic Resource Management Ltd., a fisheries and aquaculture consultancy company working globally, and the Global Initiative Against Transnational Organized Crime, a Geneva-based NGO network of experts working on human rights, democracy, governance, and development issues where organized crime has become increasingly pertinent. See IUU Fishing Risk Index. Description taken verbatim from website.

High level assessment of the status of IUU fishing in countries bordering the Gulf of Thailand

Thailand

In 2019, Thailand set up a new division to handle IUU fishing under the Department of Fisheries,[82] and a respective office to coordinate actions,[83] with a dedicated Command Center for Combating Illegal Fishing (CCCIF), which works across both the public and private sector. The country has since increased port controls in alignment with the PSMA,[84] and restructured and enhanced vessel monitoring.[85]

However, by regulation, Thailand only monitors fishing vessels above a certain size (30 gross tonnes). Commercial companies can therefore use slightly smaller boats for commercial fishing without being tracked or regulated. Thailand also faces challenges with vessels entering Marine Protected Areas (MPAs) or crossing into neighbouring waters.

Malaysia

Malaysia has several maritime agencies with oversight of fisheries. These include the Malaysian Maritime Enforcement Agency (MMEA), the Department of Fisheries, the Marine Police, the Malaysian Navy (TLDM), and Lembaga Kemajuan Ikan Malaysia (The Fisheries Development Board). Overlapping responsibilities and jurisdictional powers have, however, led to a fragmented approach of implementing such controls.[86] In 2019, Malaysia established a National Committee on IUU Fishing and National Plan of Control and Inspection (NPCI), as well as a special task force to address illegal fishing activities by foreign vessels.[87] According to a report published by MMEA in 2021, numerous seizures were reported for foreign vessels originating from Vietnam, Indonesia and Thailand.[88]

82 Department of Fisheries. (2016). Orders of the Department of Fisheries No. / 2559. Re: The Setting Up of the Prevention and Combating IUU Fishery Division

83 FAO. (2019). Order of the Department of Fisheries No. 585/2019. Re: Establishment of the Office of Coordination on Prevention and Combating Illegal Unregulated and Unreported Fishing

84 Pew. (2022). Thailand's Fisheries Management Transformation Is a Model for Fighting Illegal Fishing.

85 Saraphaivanich, K., et al. (2024). Reinforcing the ASEAN Member States to Combat IUU Fishing in Southeast Asia through Monitoring, Control, and Surveillance. Fish for the People Vol. 22 No. 1 (pp. 18-25).

86 Yusof, N. A., et al. (2024). IUU Fishing in Malaysia: A Gateway to Transnational Crime? Proceedings of the International Seminar on Border Region (INTSOB 2023) (pp. 208-217). Advances in Social Science, Education and Humanities Research.

87 Saraphaivanich, K., et al. (2024). Reinforcing the ASEAN Member States to Combat IUU Fishing in Southeast Asia through Monitoring, Control, and Surveillance. Fish for the People Vol. 22 No. 1 (pp. 18-25).

88 Yusof, N. A., et al. (2024). IUU Fishing in Malaysia: A Gateway to Transnational Crime? Proceedings of the International Seminar on Border Region (INTSOB 2023) (pp. 208-217). Advances in Social Science, Education and Humanities Research.

Cambodia

The National Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Marine Fishing 2020-2024 (IUU Plan of Action) highlights that approximately one-third of catches in Cambodia's waters are a result of IUU fishing, with annual losses estimated between 26,500 to 37,500 tonnes, equal to a financial loss of $27-56 million.[89] Illegal fishing activities are conducted by both foreign and national vessels, and include violations of fisheries restrictions, the use of illegal fishing gear, fishing in closed seasons, and illegal transshipments (transfer of cargo from one vessel to another). A global assessment on monitoring, control and surveillance systems (MCS) across countries demonstrated that the threat of IUU fishing in Cambodia originates from foreign vessels, mainly Vietnamese and Thai trawlers.[90] Barring a recent pilot aiming to monitor large fishing vessels in Cambodia, there has been little vessel monitoring to date, conducted by community-based fishermen and observers, and some scrutiny at landing sites.

Vietnam

Vietnam has scaled its efforts in implementing IUU fishing counter-measures over the past few years, from increased and improved data collection to national patrols and better licensing processes.[91] For example, fishing vessels between 15-24 metres long are now required to have monitoring equipment running 24 hours[92] and a recent regulation (2022) further aims to upgrade technical systems and install another 300 VMS devices to deter IUU fishing.

While the number of violations have therefore declined significantly, there are still challenges to preventing illegal fishing. Between January and August 2023, 36 Vietnamese vessels were detained by neighbouring countries, namely Malaysia, Indonesia, Thailand and Cambodia.[93] Regional collaboration is therefore essential for countries in the Gulf of Thailand to combat IUU fishing effectively.

Vietnam has signed up to the PSMA and takes part in various regional initiatives to combat IUU fishing, but it remains a pressing issue. Government oversight is complicated by fragmented responsibilities among different agencies and regional authorities and enforcement gaps persist. Joint efforts with neighbouring countries through platforms like SEAFDEC focus on data-sharing and regional cooperation, although practical data exchange is limited.

89 Royal Government of Cambodia. (2020). National Plan of Action to prevent, deter, and eliminate Illegal, Unreported, and Unregulated Marine Fishing 2020-2024.

90 Ganapathiraju, P. (2018). Policing the Open Seas: Global Assessment of Fisheries Monitoring Control and Surveillance: Assessing Risk-Based Solutions A baseline analysis of maritime enforcement in 84 countries. IUU Risk Intelligence.

91 Saraphaivanich, K., et al. (2024). Reinforcing the ASEAN Member States to Combat IUU Fishing in Southeast Asia through Monitoring, Control, and Surveillance. Fish for the People Vol. 22 No. 1 (pp. 18-25).

92 FAO. (2019). The Government Decree No.26/2019/ND-CP of the Government Regulating a number of articles and measures to implement the Fisheries Law.

93 Giang, N.K., (2024). Assessing Vietnam's Challenges in Fighting IUU Fishing. ISEAS Yusof Ishak Institute. No. 18.

Role of digital technologies in combatting IUU fishing

There are many ways in which digitalisation can play—and is already playing—a role in combatting IUU fishing via monitoring, control and surveillance (MCS) measures, which are generally mandated via a regulatory framework to map the location and speed of vessels to track illegal activity.[94] Key technologies include Automatic Identification Systems (AIS) and vessel monitoring systems (VMS), which are used as the two primary tools for vessel monitoring. AIS and VMS assist fisheries managers and enforcement authorities to track the activities of their licensed vessels,[95] and are being increasingly mandated by countries and RFMOs to ensure reliable surveillance of licensed fishing vessels.

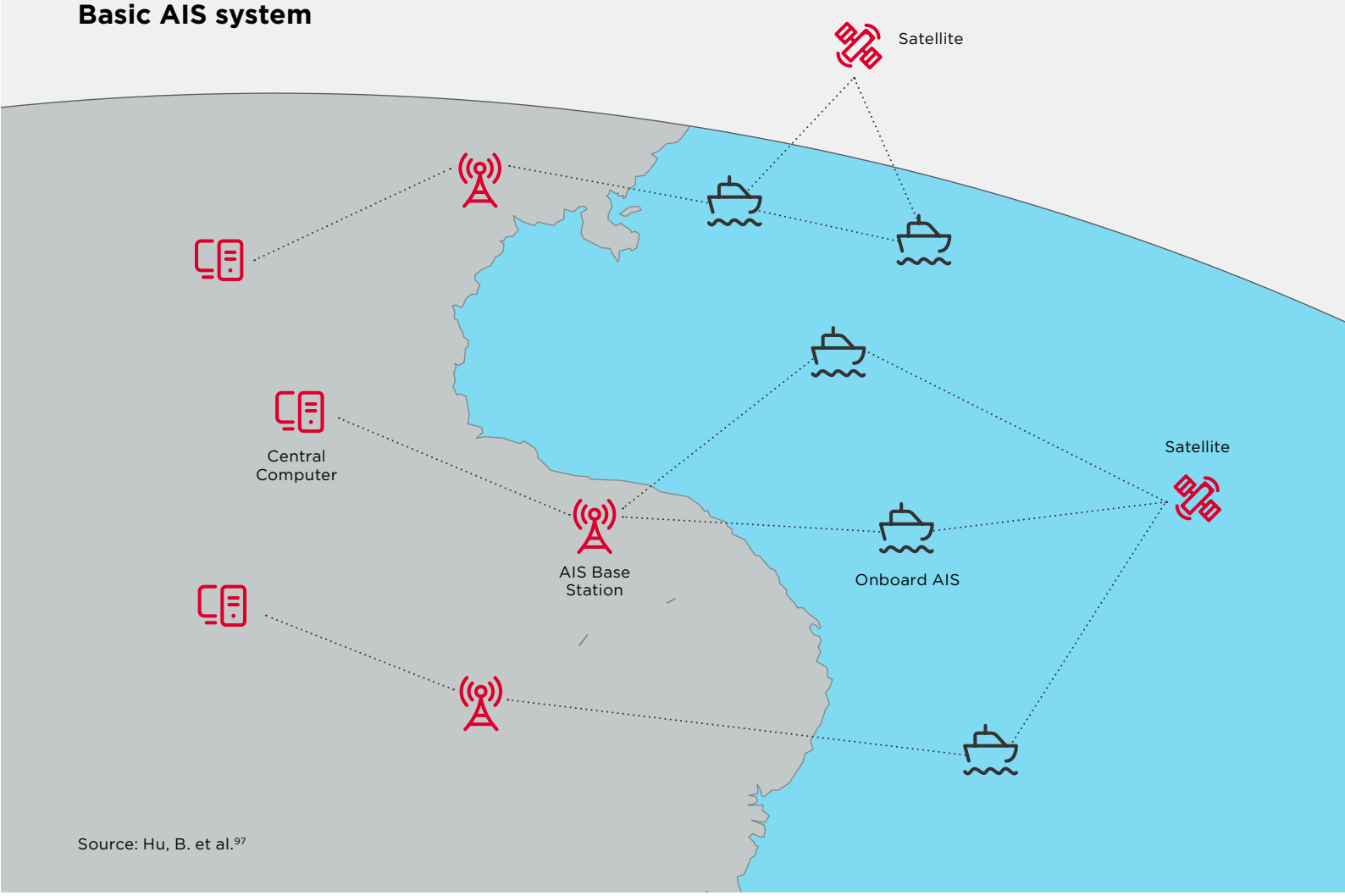
94 Marine Management Organisation. (n.d.). Risk-based enforcement process: Risk monitoring of non-compliant behaviours.
95 FAO. (2025). Fishing Technology Equipments. Vessel Monitoring System. Technology Factsheets.

Automatic Identification Systems

AIS, originally a safety and security tool under the International Maritime Organisation's Safety of Life at Sea (SOLAS) regulations,[96] allows vessels to share identity, position, course, and speed data with nearby vessels and authorities. Mandated for larger vessels, AIS is increasingly required for smaller fishing vessels by some States and RFMOs for fleet tracking and safety. AIS transmits positional data and vessel details, such as name and license, to data centres at regular intervals while receiving information from other vessels using satellite connectivity (Figure 8). However, AIS can be compromised, as skippers can disable or tamper with the transponder, limiting its reliability for fisheries management.

Figure 8

Basic AIS system



Source: Hu, B. et al.[97]

96 IMO. (n.d.). International Convention for the Safety of Life at Sea (SOLAS) 1974.

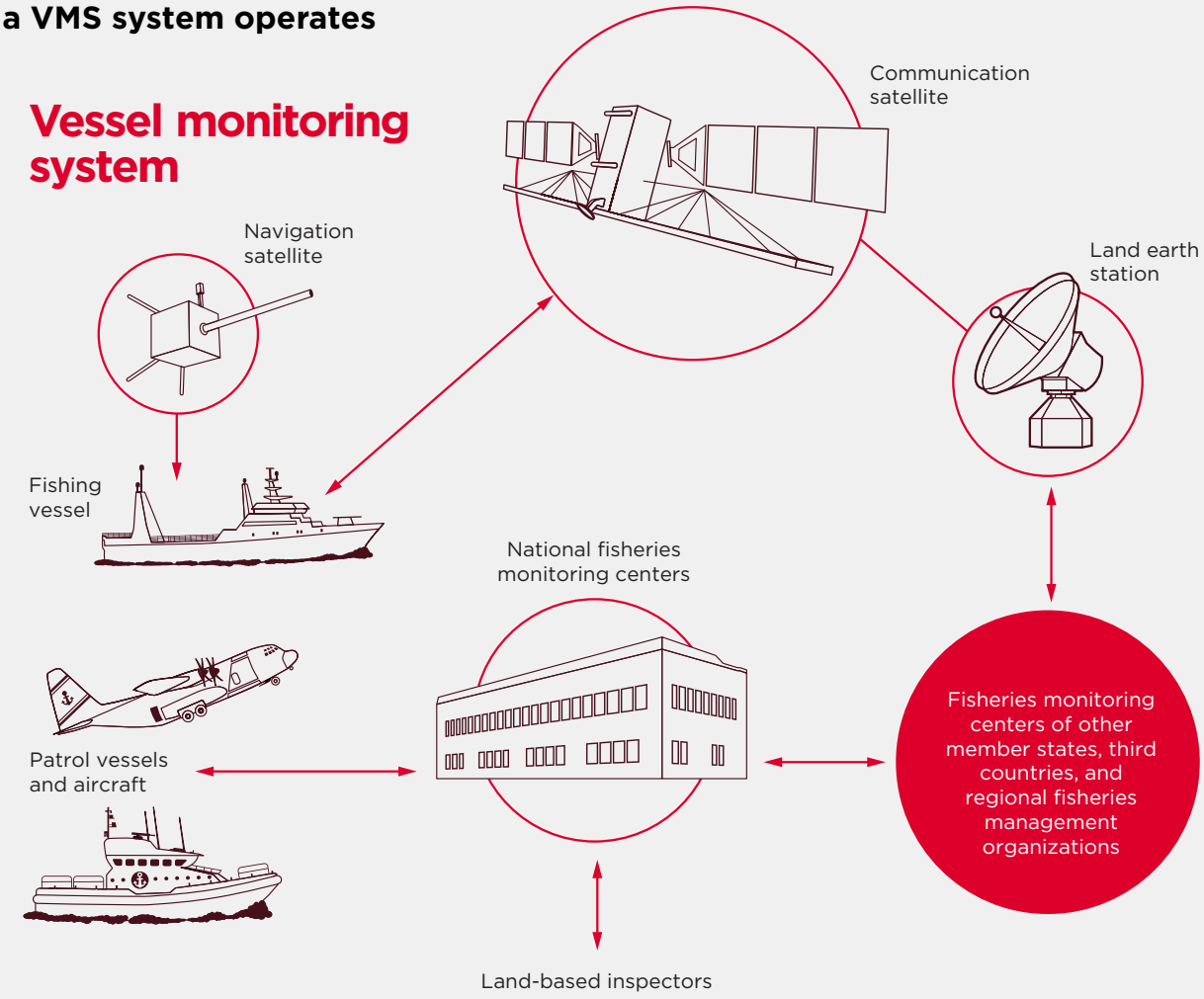
97 Hu, B. et al. (2017). Statistical Analysis of Massive AIS Trajectories Using Gaussian Mixture Models. 2017 2nd International Conference on Multimedia and Image Processing (ICMIP) Wuhan, China pp.113-117.

Vessel monitoring systems

VMS hardware, or automatic location communicators, are installed on fishing vessels to transmit GPS-based position data via satellite to authorities at regular intervals.[98] These tamper-proof systems cannot be disabled by skippers. Data is relayed to land-based stations and shared with State fisheries monitoring centres (FMCs) or relevant RFMO secretariats, managed at national, regional or sub-regional levels. (Figure 9).

Figure 9

How a VMS system operates



Source: Pew Trust[99]

Inshore vessel monitoring systems

Inshore vessel monitoring systems (IVMS) use cost-effective mobile connectivity instead of satellite connectivity to report vessel position, including latitude, longitude, course, speed and timestamps, to authorities. Suitable for small-scale fisheries, IVMS provides high-resolution data, which can help maximise fishing opportunities because location data can be used to enable zoned management within MPAs.[100] A current weakness is that vessels may be operating in areas where there is weak or no signal. In this instance, the IVMS continues to store the positional information and submits the data once mobile coverage becomes available.[101]

98 Pew. (2017). Tracking Fishing Vessels Around the Globe.
99 Ibid.
100 Succorfish. (2018). IVMS Consultation Begins with British Fishing Vessels.
101 Marine Management Organisation. (2022). Inshore Vessel Monitoring (I-VMS) for under-12 metre fishing vessels registered in England.

Comprehensive digital systems supporting stock assessments and control and enforcement

The integration of AIS/VMS technology with electronic monitoring systems to enhance fish catch assessments tied to vessel tracking can provide a comprehensive overview of fishing activity for data-informed fisheries management. Such multi-technology systems combine cameras and sensors on equipment such as winches, conveyors and freezers to provide a more accurate picture of species captured, including bycatch.

While many countries have mandated landing obligations for bycatch, monitoring compliance dockside remains difficult. The use of multiple integrated technologies offers a robust alternative by providing real-time data on commercial fleets at sea, reducing reliance on human observers.[102] Collectively, these technologies generate critical insights for informed fisheries management. For instance, Ghana is employing multiple technologies in its Exclusive Economic Zone (EEZ) to enhance transparency and sustainability in its fisheries operations (Box 6).

Box 6
Development of a comprehensive digitalised fisheries management system in Ghana

Ghana was given its second yellow card warning by the European Union for failing to clamp down on IUU fishing in 2021. Since then, it has been working to improve its monitoring and control processes. Ghana's Fisheries Information System (FIA), which was built in partnership between the Ghana Fisheries Administration, the Environmental Justice Foundation and other organisations, uses multiple technologies and sources of data for stock assessments, with digital tools directed specifically for small-scale fishers. The government has recently committed to complete industrial fishing transparency by using a system enabled by multiple technologies[103] that includes the following elements:

- Fishers and vessel operators use mobile devices to record their catch data, including species, quantities, fishing locations, and time spent at sea. This data is transmitted electronically to a centralised database in real-time, allowing fisheries managers to have a clear picture of the catch and fishing effort.
- All licensed fishing vessels are equipped with a VMS that uses GPS technology to track vessel movements. This system helps authorities detect and respond to illegal fishing activities, such as fishing in prohibited areas or crossing into neighbouring countries' waters. The VMS data is transmitted to monitoring centres, where real-time alerts are generated if any vessel deviates from its authorised fishing zone.

The multi-technology system in Ghana also includes a digital system for registering and licensing fishing vessels. Each vessel is assigned a unique identifier, making it easier to manage and regulate the fishing fleet. In addition, the system leverages a network of local fishing communities and monitors that use smartphones to document illegal fishing activities. Community buy-in strengthens the monitoring system.

102 Wilette, D.A., et al. (2023). Emerging monitoring technologies to reduce illegal fishing activities at sea and prevent entry of fraudulent fish into markets. Front. Sustain. Food Syst., Sec. Aquatic Foods. Vol 7.

103 Nature. (2023). All Eyes on Deck: The Republic of Ghana Commits to 100% Transparency on Industrial Fishing Vessels.

Cloud-based data analytics

VMS and AIS data is also being combined with satellite data to provide a more comprehensive global picture of fishing activity and to identify IUU fishing. For example, Global Fishing Watch was founded in 2015 through a collaboration between three partners: Oceana, an NGO registered in the US that focuses on influencing specific policy decisions at the national level to preserve and restore the world's oceans, SkyTruth, a US-based tech. startup using satellite imagery to help identify practices destructive to the planet, and the big tech. company Google. In June 2017, it was established as an independent, international nonprofit organisation. Global Fishing Watch is an open-access online platform which uses satellite technology and ML to identify fishing activity, encounters between vessels, night light vessel detection and vessel presence of up to 65,000 industrial fishing vessels.

Global Fishing Watch emphasises the need for transparency to tackle IUU fishing and works with flag and coastal States to encourage them to make their VMS data publicly available on the Global Fishing Watch platform. To date, 10 countries have done so.

An example of a comprehensive stock assessment and monitoring and control system, which combines IVMS as well as VMS to ensure efficient and cost-effective connectivity based on a vessel's location, incorporates AI for data analytics to inform fisheries management, and offers solutions for seafood traceability, is the NEMO device, developed for small-scale, inshore fisheries (Box 7).

Box 7

NEMO - A globally deployed combined mobile-satellite VMS system bolstered by big data analysis for small-scale fisheries

CLS,[104] a fisheries management technology provider headquartered in France, offers a VMS designed to meet the unique needs of small-scale fisheries. Its solutions have been deployed in over 90 countries, including Ireland, Vietnam, Indonesia, the Congo and Myanmar.

The system seamlessly transitions between mobile connectivity for cost-effective inshore operations and satellite connectivity for vessels operating further at sea. Tailored to small-scale fishers, the VMS provides a range of services to enhance its appeal, including safety-at-sea alerts, weather forecasts and warnings, and a seafood traceability tool. This traceability feature empowers fishers to access export markets directly or secure better prices for sustainably caught fish, increasing their economic resilience.

Beyond the capabilities of its mobile apps and VMS, NEMO leverages data sourced from over 130 satellites. This data is processed through a Fisheries Management Centre (FMC) software platform, enabling fisheries managers to access high-quality insights for policy formulation and resource management. Fishers are further incentivised to share data, as it provides valuable information on where they should direct their fishing efforts, optimising yields and sustainability.

The system is also engineered to endure challenging oceanic environmental conditions, ensuring reliability in demanding settings.

Thailand and Malaysia have already moved towards a more integrated fisheries management approach, adopting elements of remote electronic monitoring for large-scale vessels, though data on vessel tracking and catch remain unlinked. While there is improving surveillance of vessels in Vietnam, there is negligible vessel monitoring of encroaching ships in Cambodia's waters, and VMS systems are currently in the pilot stage on a limited number of large vessels.

104 See CLS website (accessed 16 January 2025).

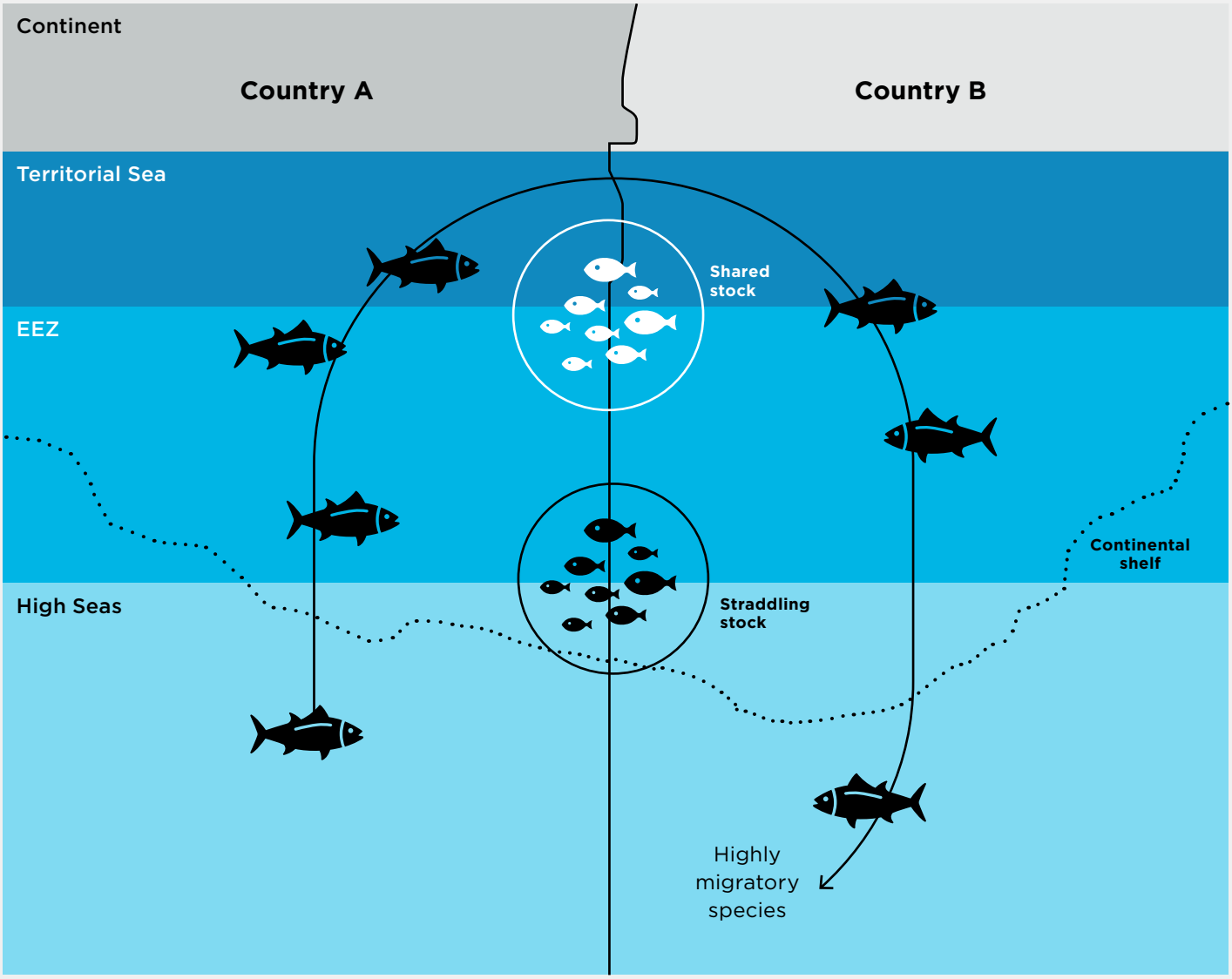
4. Regional cooperation for sustainable fisheries management

Regional cooperation is critical for effective fisheries management in the Gulf of Thailand, particularly for stock assessment, monitoring fishing efforts, and addressing IUU fishing. The migratory nature of many fish species (Figure 9) complicates management efforts, as fishing vessels often cross into nonterritorial waters to increase their catches.[105] To manage these fish stocks effectively, collaboration is needed across borders for:

- **Shared stocks:** These require bilateral agreements between neighbouring countries.
- **Straddling stocks:** These involve multilateral agreements among countries that fish these stocks, particularly in international waters.
- **Highly migratory species:** These require cooperative management among countries to ensure conservation and optimal harvest.

Figure 10

Schematic of different fish stock classification according to international law



Source: United Nations Convention on the Law of the SEA: Schematic of fish stocks according to international law.

105 Transboundary cooperation is a fundamental principle of international law. Legal frameworks applicable to marine resource management and transboundary crimes, such as IUU fishing, are no exception. The United Nations Convention on the Law of the Sea (UNCLOS) sets out the fundamental legal framework for the regulation of marine space.

Current status of collaboration in the Gulf of Thailand

Despite the need for cooperation, regional collaboration faces significant challenges. Fisheries data, which could form the basis for sustainable management, is often considered sensitive, and countries typically take a national rather than regional approach to data collection and analysis. This lack of data sharing limits transparency and the implementation of cohesive strategies across the Gulf of Thailand. Although there are three regional organisations—the Seafood Taskforce, the ASEAN Network for Combating IUU Fishing, and SEAFDEC—focused on control and enforcement measures and capacity building, their effectiveness is hindered by limited transparency and multilateral cooperation.

There are some bilateral agreements, such as the memoranda of understanding between Cambodia and Thailand on cooperation in fisheries, and between Cambodia and Vietnam to combat IUU fishing.[106] Similarly, the joint development area established by Thailand and Malaysia provides a solution to overlapping maritime claims while sharing resources.[107]

For some species, including highly migratory species such as tuna and short mackerel, regional approaches to management are taken; for example, the development and implementation of a Common Fisheries Resource Analysis (CFRA) of skipjack tuna in the South China Sea. This initiative between scientists from China, Indonesia, Malaysia, the Philippines and Vietnam represents a significant development in regional cooperation.[108] Such initiatives are vital if highly migratory species are to be sustainably managed in the future.

Nevertheless, several barriers persist. Concerns about data privacy prevent the widespread adoption of cross-border technology solutions. Financial constraints also pose a challenge, as much of the work carried out by organisations like ASEAN and SEAFDEC depends on international funding sources, including the Global Environment Facility and the FAO. Furthermore, countries often lack incentives to prioritise regional data collection, as the immediate benefits to national fisheries are not always apparent.

Opportunities for cooperation

Opportunities for improved cooperation lie in aligning national initiatives with regional policies and standards to facilitate future collaboration. For instance, developing standardised catch certification systems that are interoperable across borders could enhance data sharing and streamline management. Additionally, expanding regional initiatives for migratory species, such as those exemplified by the CFRA, would strengthen both scientific understanding and cooperative governance.

Electronic catch documentation schemes are examples of mechanisms that can be used to improve compliance and share information. For example, eACDS is a mobile app for catch reporting at sea, developed under the ASEAN catch documentation scheme by SEAFDEC. Launched in 2013 and first piloted in Brunei Darussalam, it has since been implemented or piloted in five countries—Brunei Darussalam, Malaysia, Myanmar, Cambodia, and Vietnam—with varying levels of success. While the pilot in Brunei demonstrated the potential of the eACDS to streamline catch documentation and improve traceability across the fisheries supply chains, challenges emerged during implementation, including limited technical capacity and digital literacy among fisheries stakeholders, difficulties integrating the system with national fisheries management and legislation, and the need to secure buy-in from small-scale fishers. Financial constraints also posed a significant barrier to implementation and scaling efforts.

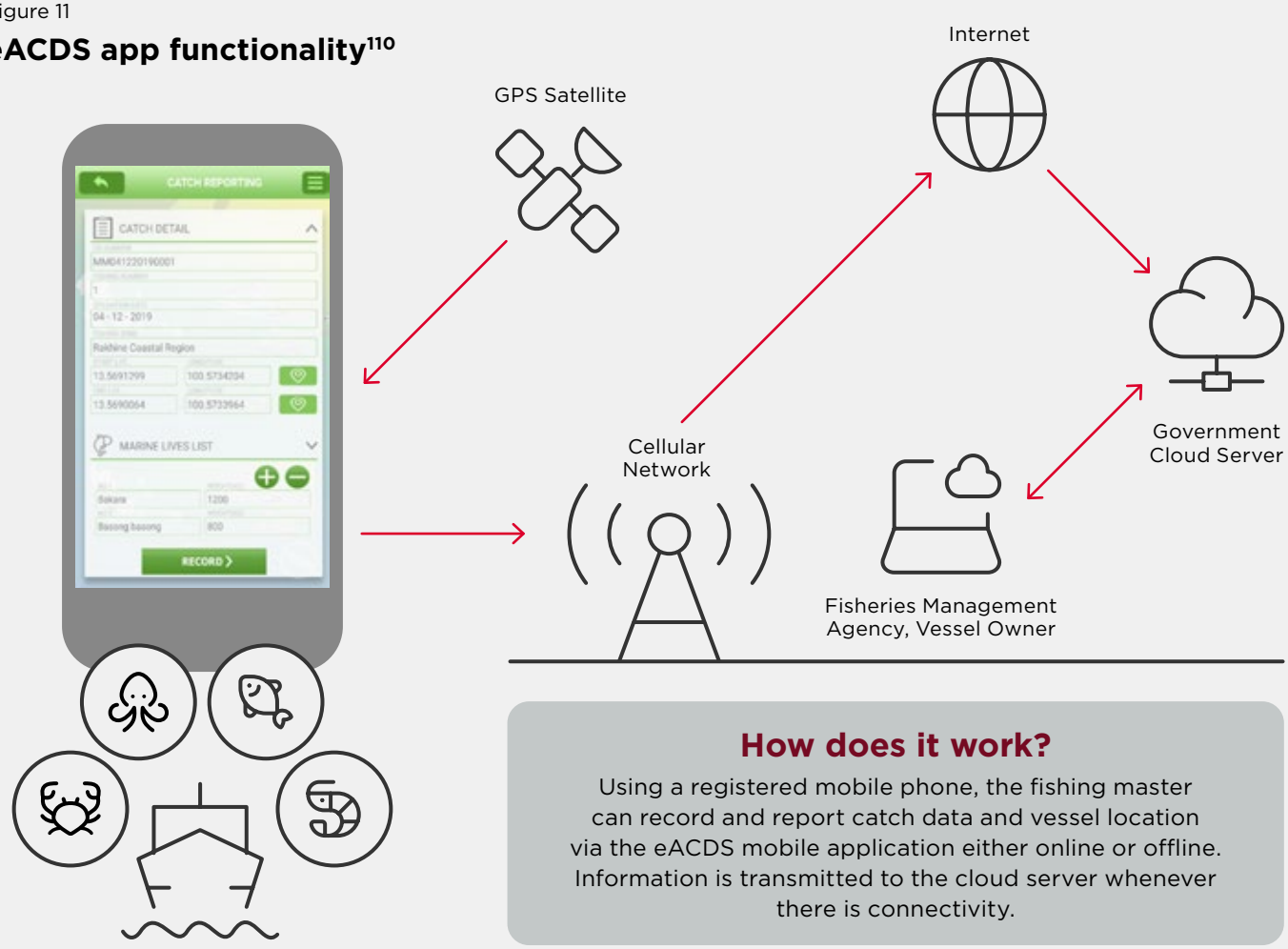
Therefore, adoption of the eACDS has varied by country. While Brunei Darussalam has maintained consistent use, other countries are progressing at different speeds, influenced by their national infrastructure, regulatory frameworks, and institutional readiness. The success of implementation has also largely depended on ASEAN's endorsement, government commitment, and capacity-building efforts aimed at equipping fisheries stakeholders with the necessary skills. Vietnam, for example, used lessons from its eACDS implementation to develop a national traceability system tailored to its specific fisheries sector.

106 Sok, S. (2022). Addressing Illegal, Unreported, Unregulated (IUU) Fishing in Cambodia: The Impact of the EU's IUU Regulation. World Maritime University.
107 Nguyen, H. T., (1999). Joint Development in the Gulf of Thailand. Boundary and Security Bulletin 7-3.
108 Prince, J., et al. (2022). A Joint Assessment of South China Sea Skipjack Tuna Stocks. CFRA.

Moving forward, there are plans to expand eACDS implementation to additional ASEAN countries, with a focus on making the system more accessible and user-friendly for small-scale fisheries and providing technical assistance tailored to each country's fisheries context. Strengthening regional and international collaboration could help standardise traceability protocols, and public-private partnerships to better spread both costs and benefits could help accelerate implementation across countries.

Figure 11

eACDS app functionality[110]



Another example of successful regional collaboration is the Pacific Islands Forum Fisheries Agency (FFA), which helps its 17 member countries sustainably manage their tuna fisheries within their EEZs. The FFA offers expertise and technical assistance, and supports regional decision-making on tuna management.

Regional digital fisheries management systems, such as TUFMAN2 (Tuna Fisheries Data Management System), could also enable countries to share stock data collaboratively. TUFMAN2 is a cloud-hosted database developed for Pacific Island countries by the SPC, the Pacific Islands Community, to collectively manage their tuna fishery data (Box 8), and relies on standardised data collection as implemented by its members. Since 1947, the SPC has been the principle scientific and technical organisation in the Pacific region and is an international development organisation owned and governed by its 27 country and territory members.[110]

109 SEAFDEC. (n.d.). eACDS Application: Offline technology for catch report at sea.
110 See The Pacific Community website. (accessed 16 January 2025).

Box 8
Integrated regional tuna stock data sharing via TUFMAN2 in the Pacific Islands

TUFMAN2 is a comprehensive integrated web-based tuna data management tool. It integrates data from vessels using major gears as well as artisanal vessels:

- Logsheets (captain reported data)
- Port sampling (measurement of fish at the port)
- Unloadings (record of the catch unloaded from the boat)
- Observer trips (collected by an independent observer on the boat)
- Packing lists (data on fish being shipped to another location)
- Vessel Activity Reports (counts of vessels leaving and entering the port)
- Vessel Position Reports (reports from boats at sea)
- VMS (regular automated vessel position reporting from a black box onboard)

TUFMAN2 also integrates data from mobile apps. It provides secure data entry, data management, data quality control, data visualisation and administration through a comprehensive interface accessible with authentication.

The system relies on standardised data collection throughout the region, but there is some level of customisation to accommodate for the needs of each individual country. Regional data sharing business rules have been incorporated to ensure authorised and efficient management of fisheries data among member countries. TUFMAN2 also receives data (automatically) from other sub-regional and regional VMS.

Another online tool developed by the SPC is the DORADO reporting system,[111] a secure online reporting tool which allows registered users to browse through and query two sources of data, namely logbook data and observer data, for specific fishing gear types. DORADO interfaces with TUFMAN2 to produce a wide range of integrated reports to facilitate access to tuna fisheries data by member countries. This web-based reporting system currently features over 200 reports.[112]

It is important to note that TUFMAN2 applies to tuna fisheries only and the level of collaboration achieved has taken decades of cooperation under the SPC. The Pacific Community manages the tuna fisheries collaboration under the Oceanic Fisheries Program as a scientific provider to the Western and Central Pacific Fisheries Commission, an RFMO that has a mandate to implement harvest strategies for four target tuna species. TUFMAN2 works because there is a formal regional management body for Pacific tuna fisheries that stipulates that members must provide the necessary data.

TUFMAN2 also works because it is attached to high-value tuna fisheries where the product is destined for export markets that demand sustainable practices and the adoption of transboundary management approaches.

While it is therefore an exceptional case of regional collaboration, TUFMAN2 provides a roadmap to successful future collaboration in other contexts, such as the Gulf of Thailand, starting with setting shared policy, data standards and data collection methods.

111 SPC Oceanic Fisheries Programme. (2019). DORADO online reporting system.
112 SPC Oceanic Fisheries Programme. (2019). Tuna Fisheries Data Management system (TUFMAN2).

Another example of regional cooperation in adopting digital solutions to combat IUU fishing comes from the Gulf of Guinea Regional Fisheries Commission (COREP).[113,114] In 2024, COREP established a partnership with Global Fishing Watch to address maritime challenges in the Gulf of Guinea, including IUU fishing.[115]

The Gulf of Guinea, which extends over 5,700 kilometres of coastline, has long been considered one of the most biodiverse marine environments in the world. Its waters are an important economic engine for the region, supporting livelihoods and providing a key source of food for its coastal States. However, Gulf of Guinea has also long been subject to IUU fishing, with damages estimated at an annual economic loss of over $2 billion. The region relies on cooperation and collaboration between States to effectively manage marine resources and combat IUU fishing.

The partnership between COREP and Global Fishing Watch will enable information sharing, tactical coordination and vessel transparency in fisheries management approaches.[116] Global Fishing Watch will assist with developing collaborative policies and regulations relating to the fight against IUU fishing and sustainable fisheries management and also provide COREP with analytical support for vessel monitoring efforts, training on the use of Global Fishing Watch tools to enable more robust marine management, and technical assistance in reviewing and revising IUU fishing policies and regulations.

Global Fishing Watch is also planning to work with the West African Sub-Regional Fisheries Commission (SRFC). The two organisations have committed to data sharing to leverage open data to combat IUU fishing, and advancing key regional policy reforms around vessel tracking methods and data sharing practices in the region.[117]

In Asia-Pacific, the Western and Central Pacific Fisheries Commission is an RFMO which entered into force in June 2004 and has the legal remit to manage highly migratory fish species in the Gulf of Thailand and wider Pacific. Both Thailand and Vietnam are cooperating non-members, meaning that they are not legally bound by the decisions made by the RFMO, but adhere to their provisions.

113 COREP is an intergovernmental body comprising 11 African nations that work together for sustainable fisheries.
114 See COREP website (accessed 16 January 2025).
115 Global Fishing Watch. (2024). Global Fishing Watch and Gulf of Guinea Regional Fisheries Commission forge partnership in fight against illegal fishing.
116 Ibid.
117 Ibid.

5. Digitalisation for sustainability

5.1 Current status of digital adoption

The current uptake of digital technologies in the Gulf of Thailand reflects the complexity captured in Figure 4. Simpler technologies, including mobile phones, eLogbooks and VMS, have greater uptake in both industrial and small-scale fisheries, and across all four countries in the case of mobile-based apps. Those that are more challenging to implement, such as cloud-based data analytics, AI and ML, have been applied only in industrial fisheries or countries with more advanced and better resourced fisheries management systems (Table 3).

It is important to note that fisheries technology uptake in many LMICs, including those in the Gulf of Thailand, is often driven by multilateral agencies and environmental NGOs through short-term Official Development Assistance and philanthropic-funded projects. This can result in a peak and then decline in use of the introduced technology, especially in small-scale fisheries, unless enabling conditions are in place.

Table 3: Overview of technologies currently applied to fisheries across the Gulf of Thailand[118]

	Commercial Fisheries				Small-scale Fisheries			
Type of tech	Cambodia	Malaysia	Thailand	Vietnam	Cambodia	Malaysia	Thailand	Vietnam
Mobile-based apps	✓	✓	✓	✓	✓	✓	✓	✓
eLogbook	✗	✓	✓	✓	✗	✗	✗	✗
VMS	✓	✓	✓	✓	✗	✗	✗	✗
IVMS	✗	✗	✗	✗	✓	✗	✓	✗
Web-based data integration	✗	✓	✓	✓	✗	✓	✗	✗
Cloud-based data analytics	✗	✗	✓	✗	✗	✗	✗	✗
AI and ML	✗	✗	✓	✗	✗	✗	✗	✗
REM	✗	✗	✓	✗	✗	✗	✗	✗
IoT	✗	✗	✗	✗	✗	✗	✗	✗
Blockchain	✗	✗	✓	✗	✗	✗	✗	✗

✓ Deployed ✓ Piloted ✓ Trialled ✗ Not in use

118 Derived largely from stakeholder interviews and some desk-based research where gaps in knowledge were identified.

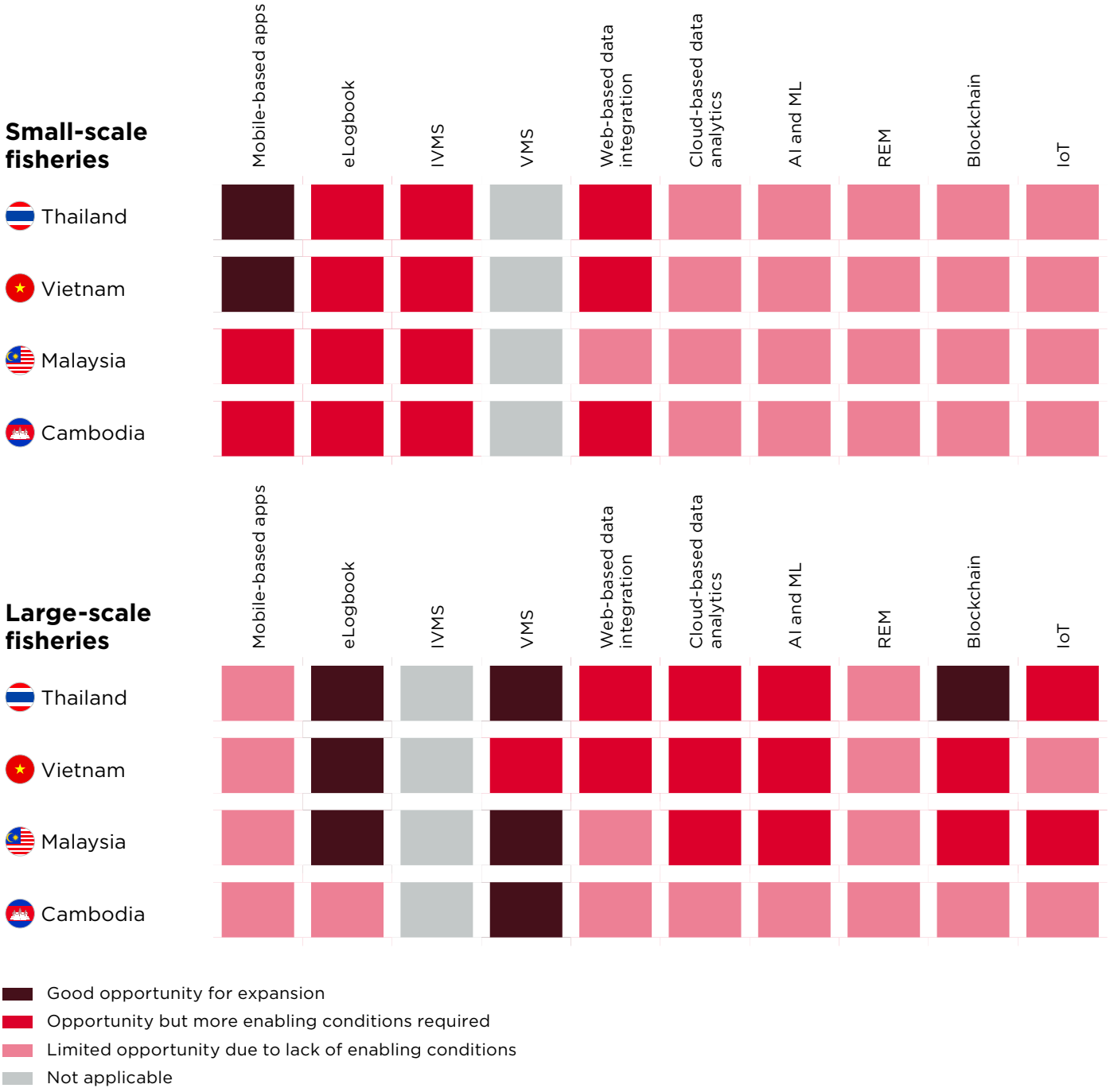
5.2 Opportunity analysis

Informed by the challenges and enablers identified, we conducted a SWOT analysis to identify which of the 10 technologies are most suited to each country across both small-scale and industrial fisheries. A combination of qualitative and quantitative criteria was used to cover function, scale, cost, readiness and application (Table 4).

Table 4: Criteria applied in SWOT analysis of fisheries technology

Criteria	Description
Stock assessment/control and enforcement of IUU	Does the technology apply to one or both aims?
Need for user input	A cooperative technology e.g. VMS, requires user (e.g. fishers) input, while a non-cooperative technology e.g. autonomous in-water drones, can be applied without the need for user input
Capability	Qualitative assessment of the impact of the technology
Operational scale	The scale at which the technology can be used: regional, national or community level
Ease of use	How easy is the technology to adopt?
Operational requirements	Data, infrastructure and administrative capacity needed to operate and utilise the technology
Cost	Associated cost of deploying and using the technology
Challenges in deployment	Limitations in deployment, and challenges to overcome for the technology to work as intended
Evidence from existing use	Which technologies have scaled and why?
Readiness for adoption	Stage of development and application potential of the technology. The scale is based on McKinsey's Digital Technology Trends 2024 report. 1= New concept 2=Experimental 3=Piloting 4=Scaling and 5=Fully scaled
Impact	What impact will the technology have?

Table 5: Summary of opportunities to implement or expand fisheries technology in the Gulf of Thailand



The opportunity analysis reflects the current application of technology within the Gulf of Thailand and highlights that the main opportunities lie with scaling of simpler mobile-based technologies such as catch apps, eLogbooks and IVMS within small-scale fisheries, providing that enabling conditions exist, or measures are put in place to create them.

There are some opportunities to supply VMS and associated advanced technologies—for example data integration and AL and ML—for industrial fisheries, but this would require significant engagement and buy-in with central governments. Investing in the industrial fisheries sector would also be highly dependent on enabling conditions, especially policy and legislation. Small-scale fisheries are generally governed at a provincial level in the Gulf of Thailand and there may be more opportunity to work with, and gain buy-in from, provincial administrators, though capacity constraints may be significantly larger at the provincial level.

Challenges, enablers and opportunities

Challenges

The Gulf of Thailand presents a highly complex landscape for the implementation of fisheries technology, with significant challenges at both regional and national scales. Regionally, cooperation between the four bordering countries on fisheries management is minimal. Policy and regulatory gaps further hinder the potential for cross-border data integration and the adoption of emerging technologies like cloud-based analytics, which would require extensive government engagement to establish an enabling framework.

At the national level, the situation varies but common issues persist. Several countries in the region are engaged with international organisations to improve fisheries management, but industrial fisheries remain challenging to regulate effectively. Lack of coordination across government departments further complicates efforts to introduce technology. Emerging technologies such as blockchain and REM face significant barriers due to the high investment required, as well as the need for associated data policies and legislative frameworks.

There is also a cost associated with technology adoption, from the acquisition of VMS and satellite connectivity for large-scale fisheries, to the use of mobile devices and mobile services for small-scale fisheries. The cost of VMS can be particularly prohibitive for small-scale fisheries.

In the case of small-scale fisheries, in addition to limited resources, low digital literacy and a lack of trust in technology also hampers tech adoption. Many fishers lack the education and technical skills needed to use vessel monitoring systems, digital catch reporting, and data analytics tools effectively.

There is also apprehension about being monitored and concerns over data privacy that deter small-scale fishers from sharing their location and catch data.

Opportunities

Despite these challenges, there are opportunities to leverage existing initiatives and partnerships to introduce fisheries technology. These include regional organisations and programmes, such as SEAFDEC, ASEAN's Regional Plan of Action on IUU Fishing, and fisheries improvement plans. Discussions on value chain measures, like the development of a standard catch certificate for the region, could enable the adoption of eLogbooks and integrated databases.

On a national level, opportunities are emerging. In Cambodia, the private sector and multilateral initiatives are creating an environment conducive to technology adoption, with initiatives like catch apps to support local markets being considered by the government.

Malaysia is advancing rapidly in digital infrastructure, with extensive mobile phone use and nationwide 5G coverage under development. These advancements, coupled with strong political will, create a promising environment for integrating fisheries management tools, including GPS and spatial resource planning systems.

Thailand's increasing capacity for fisheries management, supported by dedicated departments and training programmes, offers a pathway to implement technologies such as blockchain and AI, and scale market-linked mobile apps for stock assessment. However, Thailand is experiencing mounting pressure from industrial fisheries to ease regulatory burdens. In February 2024, the Thai parliament unanimously voted to loosen fishing regulations in response to industry demands, reflecting efforts to alleviate economic pressures on fishers. These recent and proposed regulatory rollbacks, while addressing short-term industry concerns, could negatively impact to the long-term sustainability of Thailand's fisheries.

In Vietnam, co-management of fisheries is embedded in provincial legislation, with several provinces demonstrating strong governance and readiness to collaborate on technological solutions. The country's robust mobile network and tech-savvy population also create favourable conditions for introducing tools like electronic logbooks and apps that connect fishers directly with markets.

For long-term success, several fundamental needs must be addressed across the region. A strong political commitment, consistent funding, capacity building, and agreements on data sharing are essential. Policies and legislation that support the use of technology in fisheries must also be developed and harmonised. If these foundational elements are addressed, there is great potential to transform fisheries management in the Gulf of Thailand via digitalisation.

5.3 Incentivising adoption of digital technologies

A key challenge to the adoption of digital technologies for better stock monitoring and control and enforcement is the lack of incentives for fishers to adopt these technologies. To overcome these barriers and incentivise both small-scale and industrial fishers to adopt these solutions, the following actions can be taken by donor and development partners supporting the Blue Economy, fisheries technology providers, and regulators aiming to roll out digital solutions for more sustainable fisheries:

Obtain community buy-in from small-scale fisheries for sustainability

- Empower and train local communities to participate in co-management initiatives using digital technologies, especially in MPAs, to demonstrate the benefits of protected areas to stocks.
- Co-develop and run data collection and analysis with communities to demonstrate the benefits of technology adoption to understand fish stocks and better target fishing efforts.
- Offer incentives such as preferential access to fishing grounds for using monitoring technology, and encourage community reporting of large-scale fisheries incursions into nearshore areas.

Make solutions more affordable for small-scale fisheries

- Create tech solutions at low price points and offer rental as well as pay-as-you-go schemes to improve affordability.
- Introduce subsidies for fishers to adopt sustainable practices and technologies.

Solve problems faced by small-scale fishers

- Use technologies to increase safety at sea, such as advanced weather warning SMS systems.
- Create feedback loops where fishers receive valuable information to improve their fishing practices and catches while engaging in sustainable fishing practices.
- Develop catch apps that enable small-scale fishers to secure better market prices and better entry to markets, especially by demonstrating that their fish is sustainably caught.

Build confidence in protocols

- Develop and implement secure data privacy and protection policies to build fishers' trust and confidence.

Offer rewards to industrial fishers for compliance

- Link the uptake of VMS in industrial vessels to benefits such as licence conditions permitting access to specific fishing grounds.

6. Conclusion and recommendations

Sustainable fishing is crucial for preserving marine ecosystems and ensuring long-term food security. However, fisheries worldwide—including those in the Gulf of Thailand—face persistent challenges related to stock assessment, and control and enforcement, which are fundamental to effective fisheries management.

The Gulf of Thailand, a vital marine ecosystem supporting coastal livelihoods and regional food security, has witnessed significant progress in fisheries management across its four bordering countries. These advancements have been driven by national policies and actions, regional initiatives, and international support.

Despite these efforts, concerns remain about the effectiveness of existing stock assessment and control and enforcement mechanisms. Strengthening these areas is essential to enhance sustainability and protect marine resources.

Digital technologies present a powerful opportunity to bridge knowledge gaps, improve data collection, and support more informed decision-making. However, their success depends on identifying current deficiencies, strengthening governance capacity, and ensuring that data generated is both reliable and effectively utilised within the wider fisheries management system.

6.1 Key findings

The four countries bordering the Gulf of Thailand all face the challenge of limited data on stocks to set sustainable fisheries policy: digitalisation could significantly improve stock assessments across the region.

Thailand and Malaysia have more robust assessments of primary stocks in comparison to Vietnam and Cambodia's very limited stock monitoring. Without improved assessments, sustainable fisheries management will remain challenging.

Recommendations

Establish secure data privacy and protection policies

Fisheries regulators must develop and implement policies that ensure secure data usage, address privacy concerns, and promote transparency, fostering trust among stakeholders in the fisheries sector.

Promote public-private partnerships to support viable digital innovations for small-scale fisheries

Government agencies can work with **fisheries technology developers** to develop and scale user-friendly mobile apps for catch reporting for small-scale fishers, with offline functionality to address connectivity challenges in remote regions. While some initiatives exist, they often fail due to unsuitable mobile devices for harsh environmental conditions on boats, limited connectivity, and continued reliance on traditional paper-based methods. Adoption by small-scale fisheries can be encouraged by incorporating features like safety-at-sea alerts, advisory services on fishing activities, and market linkages.

Provide tailored training programmes for small-scale fishers

A wide range of stakeholders can play a crucial role, independently or in partnership with each other, in equipping small-scale fishers with the skills needed to effectively use mobile applications for sustainable fisheries management. **Fisheries departments, international donors and development partners supporting marine conservation and the Blue Economy, multilateral institutions such as UN organisations, and international, regional, and local NGOs** advocating for and developing solutions to protect the oceans, can all provide training programs that enhance digital literacy and maximise the impact of these tools. To ensure accessibility and ongoing support, training modules could be embedded directly within apps, allowing fishers to learn at their own pace.

Additionally, **fisheries technology developers** must design apps to accommodate diverse user needs by offering local language options and features tailored to fishers with lower literacy levels, ensuring broader adoption and usability.

Explore the potential of relatively more easily implementable and more cost-effective technologies, such as IoT, in bolstering data collection

A wide range of stakeholders, including **fisheries departments, science and technology departments at universities, NGOs working in marine conservation, donor and development partners investing in marine biodiversity protection, fisheries technology developers,** and **commercial fisheries** could pilot IoT-enabled sensors for real-time marine environment monitoring, detection of illegal fishing, and the deployment of smart nets to reduce bycatch.

These innovations can enhance fisheries management and sustainability efforts, but their effectiveness depends on how well the collected data is integrated into broader fisheries management systems.

A key challenge lies in scaling and effectively utilising data from these IoT pilots. Initial data sets may be limited in scope, making it essential to establish clear pathways for data integration to inform policy decisions and enforcement strategies. Achieving this requires collaboration among stakeholders and investment in data analytics to ensure the data translates into actionable insights.

While small-scale or localised IoT deployments may be cost-effective, scaling these systems presents significant financial challenges as well, underscoring the need for sustained investment and innovative funding models to maximise their utility.

Develop adaptable, interoperable, and marine-specific technologies

Software developers should design tools that are both adaptable and capable of integrating diverse data formats and sources, ensuring compatibility with existing fisheries management systems. **Hardware developers** must also address the unique challenges of the marine environment, ensuring devices are energy-efficient, operable offline in areas with limited connectivity, and easily powered on board vessels. To encourage adoption, tools should be user-friendly, offer clear benefits such as improved safety, efficiency or profitability, and be affordable, particularly for small-scale fisheries.

The countries bordering the Gulf of Thailand vary in their capacity to combat IUU fishing, but all four countries can strengthen control and enforcement mechanisms by digitalising vessel monitoring of both large and small-scale fisheries.

Thailand and Malaysia have relatively effective systems for monitoring large-scale fisheries, but small-scale fisheries remain largely unmonitored. Vietnam has made progress in addressing encroachment within its Exclusive Economic Zone, though its measures are only partially effective. Cambodia faces severe limitations in its enforcement capacity and enforcement against encroachment relies primarily on informal mechanisms.

Recommendations

Subsidise VMS units for small-scale fisheries to make them more accessible

Government agencies could provide subsidies to make VMS units more affordable for small-scale fishers. For example, subsidies have been provided by the US NOAA fisheries for VMS installation in the Gulf of Mexico and the European Maritime and Fisheries Fund for I-VMS installation. Financial assistance would increase adoption and ensure more comprehensive monitoring coverage.

Promote hybrid VMS solutions

Fisheries technology companies need to innovate to develop increasingly cost-effective, hybrid VMS solutions that combine satellite and cellular connectivity to reduce costs, the latter being the more affordable option. Durable VMS systems able to operate in and withstand the marine environment and requiring low maintenance, currently remain prohibitively expensive for small-scale fishers.

Leverage digital tools for community reporting

Multiple stakeholders, **including fisheries departments, international donor and development partners investing in Blue Economy sustainability, NGOs advocating for and supporting marine conservation,** and **fisheries technology developers** can collaborate to create and launch user-friendly digital tools, such as mobile apps, that enable fishing communities to report illegal, unreported, and unregulated (IUU) fishing incidents in real time. By empowering local fishers to actively participate in enforcement efforts, these tools can help protect their livelihoods, fill monitoring gaps in areas where fisheries departments have limited resources, and deter harmful fishing practices through community-driven oversight.

Since fisherfolk are already engaged in daily activities at sea, they represent a readily available resource for enforcement efforts. By equipping them with digital reporting tools, authorities can leverage their firsthand observations to strengthen nearshore IUU detection and response.

The countries bordering the Gulf of Thailand are improving their capacity in the use of digital tools for sustainable fisheries management but further investments in capacity and skills development for fisheries departments would significantly enhance their ability to manage fisheries more effectively.

All four countries in the Gulf of Thailand would benefit from initiatives focused on knowledge exchange and capacity building, particularly through the adoption of digital tools, demonstration projects and pilot programmes that facilitate the rollout of technological solutions.

Recommendations

Strengthen the capacity of fisheries departments through upskilling and targeted use of digital tools

Government agencies should invest in upskilling fisheries departments, fostering cross-national and regional peer-to-peer knowledge exchange to leverage emerging technologies for sustainable fisheries management and more digitally enabled systems. Simultaneously, they must focus on addressing critical data gaps by building capacity to adopt and effectively use digital tools, enabling evidence-based policy development and improved management practices.

Collaborate for knowledge sharing and skills development

International NGOs focused on marine conservation, food security and seafood sustainability, **development partners** implementing marine protection programs, **multilateral agencies** with expertise in fisheries management, and **marine biologists** and **fisheries scientists** should actively collaborate to share knowledge and train fisheries managers in the Gulf of Thailand on emerging technologies and digitalised fisheries management practices.

Regional organisations such as ASEAN and SEAFDEC can play a pivotal role by facilitating regular regional knowledge exchange sessions, and inviting global experts to contribute to capacity-building initiatives.

The cross-boundary nature of fish stocks and the persistent issue of illegal fishing, including vessel encroachment into exclusive economic zones, highlights the need for stronger regional collaboration among the four countries bordering the Gulf of Thailand. Digitalisation can play a key role in facilitating such cooperation to develop a comprehensive understanding of stocks and fishing activity across the region.

Enhanced regional partnerships would provide a clearer picture of the Gulf of Thailand's productivity, encompassing both large-scale and small-scale fisheries. This shared understanding is critical for effective management and control and enforcement.

Recommendations

Strengthen cross-border collaboration through partnerships, joint enforcement, and data-sharing

Fisheries regulators should leverage existing bilateral and regional partnerships, such as those facilitated by SEAFDEC, to promote harmonised fisheries regulations and foster data-sharing agreements. Regular dialogue among the four countries is essential to build trust, develop shared policies, and establish standards for data collection, supporting joint enforcement initiatives and a unified approach to managing shared marine resources.

Develop a centralised data-sharing platform

Ideally, the four **governments** could collaborate to create a centralised platform for data sharing. This platform could integrate tools for vessel tracking and stock monitoring while ensuring systems are interoperable to support long-term regional cooperation. Such a platform would enable more effective management and enforcement while fostering transparency and trust among stakeholders.

6.2 Key lessons to leverage digital tools for sustainable fisheries management in LMICs

Advancing digital tools for data collection for stock assessment and control and enforcement offers a transformative opportunity for sustainable fisheries management. Data collection and control and enforcement via mobile apps, IoT technologies, and hybrid VMS systems, and data integration using digital tools and platforms, can help improve fisheries management in the short to medium term, while AI and satellite data hold promise for much improved fisheries management in the longer term.

The following principles and actions can help ensure that LMICs can effectively leverage the opportunity digitalisation offers to improve the sustainability of fisheries.

Capacity building and training

Empowering fisheries departments and fishers through skills development, training, and knowledge sharing ensures effective technology adoption and sustainable practices. Digital tools must cater to local languages and levels of literacy.

Affordability and practicality

Technologies should be cost-effective, adaptable to harsh marine environments, and functional in areas with limited connectivity. Governments and tech. developers must ensure these tools are affordable and incentivise their use.

Collaborative partnerships

Public-private partnerships and regional cooperation are essential for harmonising regulations, sharing data, and leveraging collective resources, to ensure more cohesive management of shared fish stocks and control and enforcement mechanisms.

Evidence-based policy-making

Filling data gaps taking a targeted approach, with the help of digital tools, can enable evidence-based policies for setting quotas and addressing IUU fishing.

Trust and data security

Developing transparent data policies and secure platforms fosters trust among stakeholders, including fishers, government agencies, and technology providers, essential for widespread adoption.

Cross-boundary coordination

Regional collaboration on stock assessments and control and enforcement is vital for addressing cross-border management challenges such as the assessment of shared, straddling and migratory stocks, EEZ encroachment and illegal fishing.

Annexes

Annex 1:
Marine environment in the Gulf of Thailand

The Gulf of Thailand is home to diverse and interconnected coastal and marine ecosystems, including coral reefs, mangrove forests, and seagrass meadows, which are essential for maintaining biodiversity and supporting coastal livelihoods. The Gulf encompasses approximately 75,590 rai (12,094 hectares) of coral reefs, primarily fringing types dominated by species like Porites and Favid corals. These reefs provide critical habitats for marine species and contribute to fisheries and tourism. Mangrove forests, lining much of the coastline, serve as nurseries for fish and crustaceans, protect against erosion, and supply resources like firewood and charcoal. Seagrass meadows are key feeding and breeding areas for endangered species, including dugongs and sea turtles, while also playing roles in carbon sequestration and water quality maintenance.

Despite their importance, these ecosystems are facing significant decline. Coral reefs have experienced severe bleaching, with events like the 2010 mass bleaching and continued damage in 2016. Only about 5% of the reefs remain in fertile condition. Mangrove forests have been heavily impacted by coastal development, aquaculture, and logging, leading to erosion and biodiversity loss. Seagrass meadows are deteriorating due to pollution, sedimentation, and harmful fishing practices, endangering the species that rely on them.

Four primary factors drive this environmental degradation:

- Climate change, with rising sea temperatures causing bleaching and storm surges threatening coastal habitats;
- Pollution, stemming from untreated sewage, agricultural runoff, and industrial discharge, degrading water quality and creating hypoxic conditions;
- Overfishing, which depletes stocks, damages habitats, and disrupts ecosystems, particularly through trawling; and
- Coastal development, which accelerates habitat loss and sedimentation.

The diverse mix of coral reefs, mangroves, and seagrass meadows forms a highly productive system that supports fish populations vital for the region's fisheries. This ecosystem underpins food security, employment, and economic stability for the countries that border the Gulf of Thailand and its ongoing degradation poses a critical threat to sustainable fisheries and the livelihoods of millions dependent on them.

Annex 2:
Note on stock assessment

Stock assessment models are mathematical tools designed to provide simplified representations of population and fishery dynamics. These models rely on data categorised into three primary areas—catch, abundance, and biology—and increasingly incorporate ecological information to support ecosystem-based fisheries management (EBFM). EBFM recognises the interconnectedness of fished species within their ecosystems, considering food web dynamics and habitat interactions in determining fishing opportunities. This approach has gained prominence as a legal and policy objective in international fisheries management.

The central purpose of stock assessments is to estimate fishing mortality and stock abundance accurately. Approaches range from data-rich, complex models that integrate ecological and environmental factors to simplified methods for data-limited scenarios. High-quality assessments are typically the result of long-term collaborations, rigorous benchmarking, and iterative refinements to ensure accuracy and reliability. Notable examples include the International Council for the Exploration of the Seas (ICES) assessments of North Sea herring and the NOAA assessments of Alaskan walleye pollock, both representing data-intensive and socially, economically, and ecologically critical fisheries.

In contrast, fisheries in regions like the Gulf of Thailand are often constrained by limited data, which poses significant challenges to achieving sustainable management goals such as maximum sustainable yield. The quality of fisheries management depends heavily on the availability, accuracy, and timeliness of stock assessments. Consequently, improving methodologies for data-deficient fisheries is a critical priority.

Several techniques have been developed to address data limitations, including length-based methods, stock depletion techniques, and surplus production models. While these approaches are less resource-intensive, concerns about their effectiveness persist, highlighting the need for validation and expertise within fisheries administrations to ensure the robustness and utility of the resulting assessments.

Three core requirements underpin effective stock assessments: the availability of stock data, the accuracy of these data over time, and their timeliness for analysis. Consistent and reliable time-series data are essential for identifying trends and deviations, forming the foundation of evidence-based fisheries management.

Multispecies fisheries

Multispecies fisheries, such as those prevalent in the Gulf of Thailand's demersal trawling sector, present additional complexities. Multispecies stock assessment methods, which account for predator-prey interactions and ecosystem dynamics, offer a more holistic perspective but remain underutilised globally. These methods typically supplement single-species assessments and require substantial data, collaboration, and expertise. Barriers to their operationalisation include technical challenges and institutional constraints, emphasising the importance of integrating advanced models within effective governance frameworks.

In summary, while data-rich assessments represent the "gold standard," advancing approaches suitable for data-limited fisheries, particularly multispecies fisheries, is vital. This progress needs to be supported by investments in capacity building, governance, and long-term monitoring initiatives, ensuring fisheries management adapts to ecological complexities and remains grounded in sound scientific principles.

Annex 3:
List of organisations and experts consulted

We would like to thank the following organisations and individuals who have helped advance this research, as well as those that took part anonymously.

International / Regional

ABALOBI

CLS Fisheries

FCDO Indonesia

FUTUREFISH

Kumbatia

Marin Trust

Ocean Data Network

OceanMind

Pinpoint Earth

Teem Fish

Cambodia

Eric Baran

FAO Cambodia

FCDO Cambodia

Fisheries Administration

Fisheries Action Coalition Team

Greenovator

Marianne Teoh

Paul Ferber

Thailand

Algaeba

Department of Fisheries

Environmental Justice Foundation

ETNECA

FCDO Thailand

Geo-informatics and Space Tech Development Agency (GISTDA)

Hydroneo

Mast Human

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