Options for Innovation and Improvement of Currently Used Fishing Technologies and Operations in Thailand to Attain Sustainability

Sukchai Arnupapboon, Pirochana Saikliang, Thanyalak Suasi, Rattana Tiaye, Thaweesak Thimkrap, Khunthawat Manomayidthikarn, Nopporn Manajit, Nakaret Yasook, Santopong Putsa, and *Jitraporn Phaksopa*

Keywords: capture fisheries, initial capital investment, fisheries management plan, IUU fishing, vessel monitoring system, small-scale and commercial fishing fleets

Sustainability of fishing operations is a growing concern worldwide. To achieve this, transitions carried out by fishers regarding their fishing methods should be financially supported, particularly for small-scale fishing operations. Access to financial services would facilitate the fishing businesses to innovate and comply with improved fisheries management measures, and thus, generate social, economic, and environmental benefits. To address such concerns, FAO initiated in 2021 the Multi-Disciplinary Fund Project "Financing innovation for sustainable fisheries with the private sector," aimed at supporting fishing businesses in Thailand to access formal microfinance and credit sources.

This article summarizes the study report submitted to FAO by the SEAFDEC Training Department (SEAFDEC/TD) in 2022, on the Assessment of the Sustainability of Currently Used Fishing Technologies and Operations in Thailand and Options for Innovation and Improvements (FAO, 2022). The study features a literature review on the current situation of the marine capture fisheries sector, and an analysis of the currently used fishing technologies and operations to identify the options for innovation and improvements in fishing vessels, onboard equipment, and gear. Data gathering by literature review was done in 2021, followed by a field survey in Rayong Province, Thailand. The knowledge and experience of the researchers from SEAFDEC/TD were used to estimate the costs and benefits of introducing the most promising innovations. These were validated by discussing with stakeholders which included owners of fishing vessels, university lecturers, representatives from the Asia-Pacific Rural and Agricultural Credit Association (APRACA), representatives from the Bank for Agriculture and Agricultural Cooperatives (BAAC), officers from the Department of Fisheries of Thailand, technical consultants, and technical officers from SEAFDEC during the national workshop on 04 October 2021. The workshop was organized by SEAFDEC/TD and Rayong Marine Fisheries Research and Development Center of the Department of Fisheries, Rayong Province, Thailand. The monograph on the Assessment of the Sustainability of Currently Used Fishing Technologies and Operations in Thailand and Options for Innovation and Improvements was published by FAO for dissemination to the fisheries sector and to investors and financial service providers.

This article also reviews the main components of the aforesaid study report, namely: the trend of capture fisheries in Thailand; characteristics of the main fishing fleets operating in Thailand; innovations and technological upgrades; and national legislation, policies, and plans that affect fishing operations and technologies used.

Capture Fisheries Trends in Thailand, 1960-2018

Marine capture fisheries is socially and economically important for Thailand. However, several challenges have posed serious threats to its sustainability, including the degradation of fishery resources and critical habitats (mangroves, seagrasses, and coral reefs), as well as illegal, unreported, and unregulated (IUU) fishing. From 1960 to 1994, fishery production of Thailand from capture fisheries, marine and inland fisheries increased with a peak of 3,031,074 MT in 1995 (World Bank, 2020); however, the trend started to decline in the 2000s, with the lowest production points appearing around the year 2015 through 2017, as shown in **Figure 1**.

The slightly increasing trend of production from 2018 onwards could be attributed to the wide-ranging reforms in the marine capture fishery subsector, including the adoption of countermeasures to combat IUU fishing and the "IUU-free" strategy of Thailand by licensing the unregistered fishing vessels carried out by the Department of Fisheries (DOF) of Thailand (DOF, 2016; 2018b).

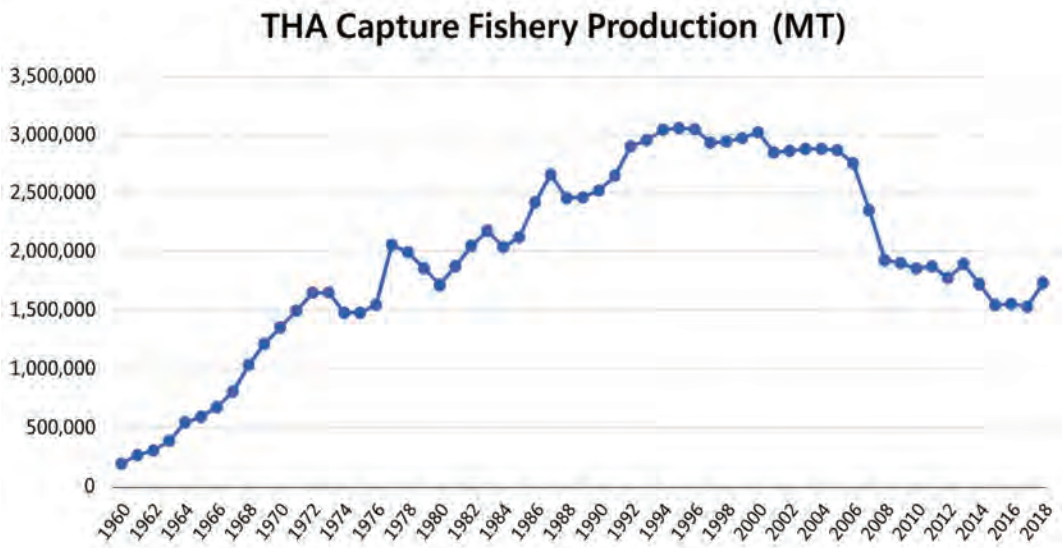

Figure 1. Capture fishery production of Thailand from 1960 to 2018 (World Bank, 2023)

The landing trends of the main target fishery species from the Gulf of Thailand and Andaman Sea during 2014–2018 are shown in **Figure 2**. In the Gulf of Thailand, the main species commonly caught that generate the highest commercial value in Thai Baht (THB), based on total catch value from five fishery groups (otter board trawlers, squid cast netters, pair trawlers, gill netters, and purse seiners) in 2018, were squid (*Loligo* spp.) valued at THB 9,458,385,000; blue swimming crab (*Portunus pelagicus)* at THB 2,689,336,000; yellowtail scad (*Atule mate*) at THB 2,277,703,000; Indian mackerel (*Rastrelliger kanagurta)* at THB 1,602,408,000; and Spanish mackerel (*Scomberomorus* spp.) at THB 615,802,000. In the Andaman Sea, the main species landed were squid (*Loligo* spp.) valued at THB 1,588,066; round scad (*Decapterus* spp.) at THB 942,224,000; Indian mackerel (*Rastrelliger kanagurta)* at THB 693,264,000; snappers (*Lutjanus* spp.) at THB 118,112,000; and threadfin bream (*Nemipterus* spp.) at THB 98,969,000 (DOF, 2020).

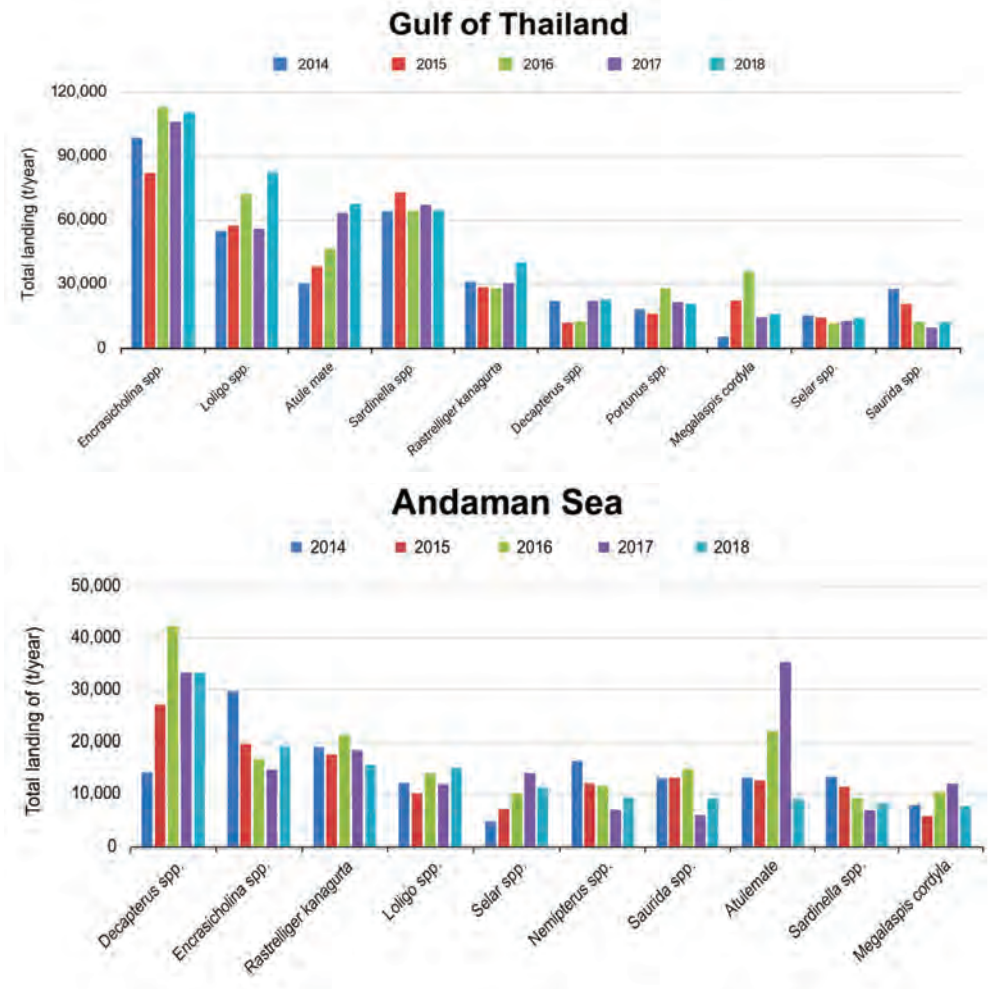

Figure 2. Total landing (t/year) of target fish species in the Gulf of Thailand and Andaman Sea in 2014–2018 (DOF, 2016; 2017; 2018a; 2019; 2020)

Since 2015, the Department of Fisheries of Thailand has adopted a quota system on fishing days to alleviate commercial fishing efforts, which also motivated commercial fishers to register for fishing operations in the waters of Thailand. As a result, the number of fishing vessels increased from 23,556 (7,596 commercial-scale and 15,960 small-scale) in 2014 to 37,018 (10,645 commercial-scale and 26,373 small-scale) in 2018.

In 2018, the six economically most important small-scale and commercial fishing fleets, in terms of the number of vessels operating in the Gulf of Thailand and the Andaman Sea, are: otter board trawl, squid cast net, pair trawl, purse seine, gillnets, and anchovy falling net (**Figure 3**). In the Gulf of Thailand, otter board trawl is the largest fleet in terms of the number of fishing vessels, followed by the squid cast net, pair trawl, gillnet, and purse seine; and in the Andaman Sea, the important fleets are the otter board trawl, purse seine, pair trawl, anchovy falling net, and squid cast net (DOF, 2020a). Most commercial-scale fishing vessels are made of wooden hulls and are powered by inboard diesel engines. As of 2020, only 15 steel-hulled commercial-scale fishing vessels were flying the Thai flag. All vessels are decked, except for a very small number of small purse seine and gillnet vessels. The basic and standard deck hauling system is a winch, while only some purse seine and gillnet vessels are equipped with a net hauler. All vessels have onboard ice and cool storage facilities for their catch. As most vessels are made of wood, regular maintenance is required at least once a year to ensure vessel stability and facilitate license renewal.

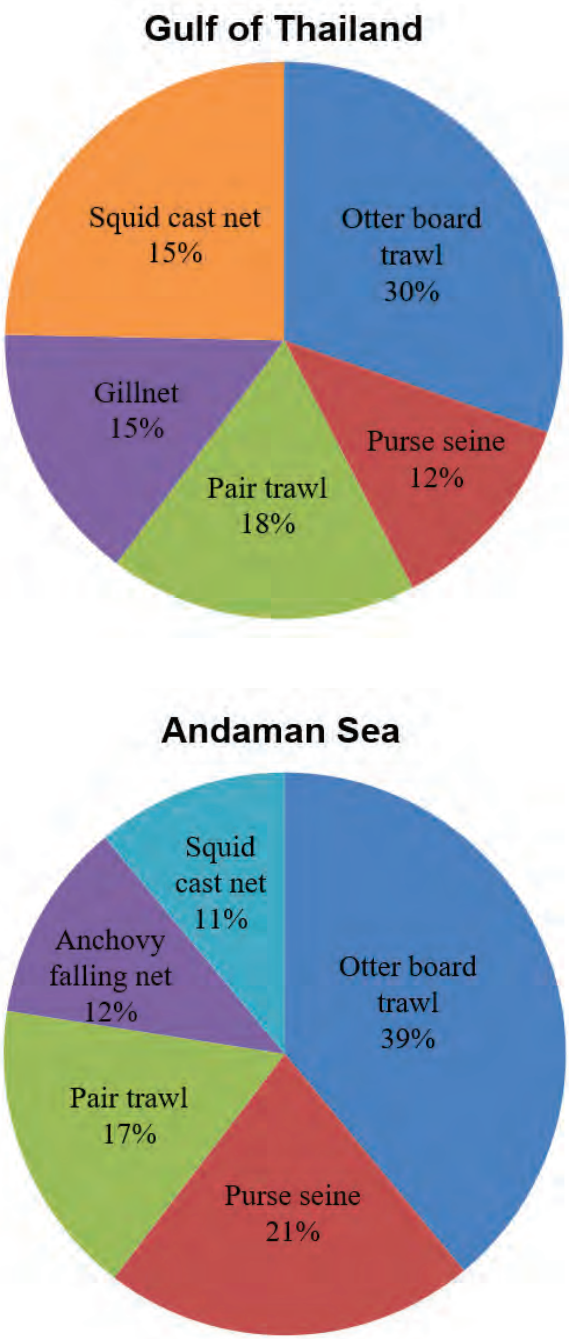

Figure 3. Percentage of the main commercial-scale fishing vessels in Thailand operating in the Gulf of Thailand and Andaman Sea in 2018 (DOF, 2020a)

Characteristics of the Thai Fishing Fleet: Economic Assessment

A field survey in 2021 was conducted by interviewing 27 fishermen who operate in the eastern provinces along the Gulf of Thailand (**Table 1**). **Figure 4** shows the annual revenue from the sale of catch at landing, with the gross value depending on fish species and price. In general, commercial-scale fishing vessels have higher revenues compared to small-scale fishing vessels. This has enabled the owners of commercial-scale vessels to more frequently and adequately maintain their vessels. On the other hand, small-scale fishing vessels can easily switch their fishery target because of the lower investment costs required by the vessels and the gear used.

Table 1. Fishers/owners of vessels interviewed for the financial and economic characteristics of fleets in August 2021

Fleet/Gear	Province	Size (GT)	Length (m)	No. of crew
Otter board trawl				
Vessel no.1	Rayong	26.84	15	6
Vessel no.2	Rayong	44.71	17	7
Vessel no.3	Rayong	28.5	14	5
Vessel no.4	Rayong	58.89	19.29	6
Squid cast net				
Vessel no.1	Rayong	40	18	5
Vessel no.2	Rayong	28.82	17.6	5
Vessel no.3	Rayong	56	21	7
Vessel no.4	Rayong	28	14	6
Vessel no.5	Rayong	47.88	18.97	6
Pair trawl				
Vessel no.1	Chanthaburi	78.65	21.54	15
Vessel no.2	Trat	92.34	21.62	15
Vessel no.3	Trat	61.81	18.79	13
Gillnet				
Vessel no.1	Rayong	80	20	17
Vessel no.2	Rayong	90	20	16
Vessel no.3	Rayong	57.39	18	14
Vessel no.4	Rayong	59.34	20.72	15
Vessel no.5	Rayong	36.26	16.7	16
Purse seine				
Vessel no.1. Group 1	Rayong	21.3	14.4	14
Vessel no.2. Group 1	Rayong	22.4	15.5	13
Vessel no.3. Group 2	Rayong	139.22	24.97	38
Vessel no.4. Group 2	Rayong	172.83	27.7	40
Vessel no.5. Group 2	Rayong	180.41	26.9	38
Anchovy falling net				
Vessel no.1. Group 1	Chanthaburi	20	15.45	10
Vessel no.2. Group1	Chanthaburi	35.02	15.86	16
Vessel no.3. Group 1	Chanthaburi	46.71	16.39	11
Vessel no.4. Group 2	Chanthaburi	52.47	18.79	11
Vessel no.5. Group 2	Chanthaburi	65.03	21	12

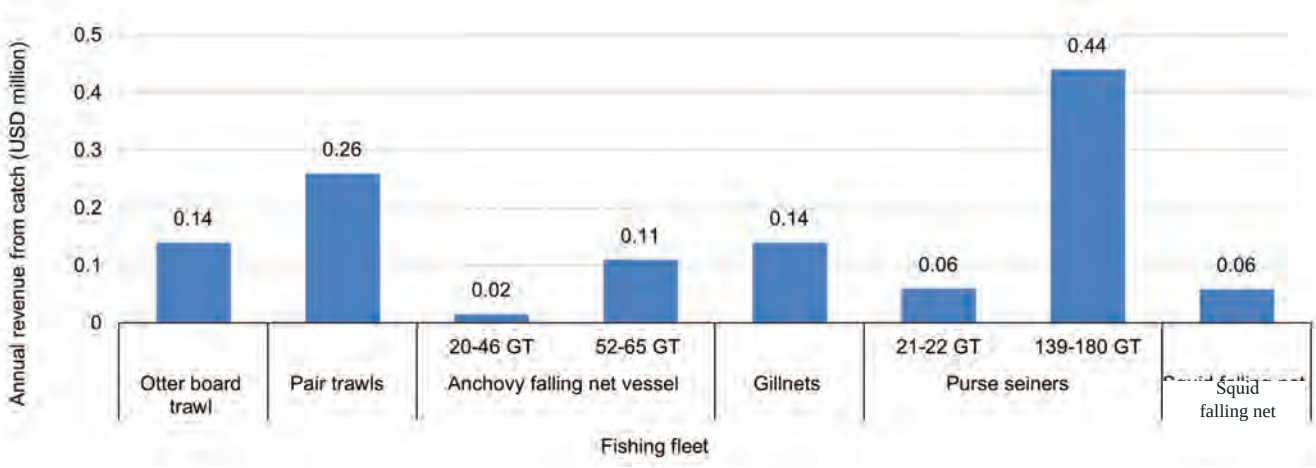

Figure 4. Revenue (million USD) from the catch of fishing fleets operating in the Gulf of Thailand

The initial capital investment for each type of commercial fishing vessel, which includes hull, engine, winch, ice storage, fishing gear, echo sounder, sonar, radar, vessel monitoring system, MS, GPS, Radio and other communication equipment, is shown in **Table 2.**

The average cost of operating a fishing fleet by type of gear **(Table 3)** includes operational costs consisting of fuel, labor, and others (lubricant, harbor dues, ice, and food), and owner costs that include vessel and gear repair and maintenance, gear replacement, and others.

Table 2. Initial capital investment of the fishing fleet in Thailand

Fishing fleet	Initial capital investment (THB)	Percentage (%) of investment				
		Hull	Engine	Equipment	Fishing gear	Electronic devices
Otter trawl	1,826,083	64.3	15.3	5.1	5.0	10.3
Squid cast net	1,563,553	74.2	12.6	4.3	3.5	5.4
Pair trawl	11,235,334	83.1	11.6	0.6	1.1	3.6
Gillnet	3,668,800	49.1	26.4	0.5	20.1	3.9
Purse seine						
21–22 GT	2,177,500	39.0	9.0	4.6	32.1	15.3
139–180 GT	13,988,167	66.7	8.1	2.3	16.2	6.7
Anchovy falling net						
20–46 GT	2,641,167	47.3	7.6	8.9	19.4	16.8
52–65 GT	3,083,500	56.8	22.0	1.6	14.6	5.0

Table 3. Average cost for operating a fishing fleet by type of gear

Fishing fleet	Operational costs (%)				Owner costs (%)			
	Fuel	Labor	Others	Total	Repair and maintenance	Depreciation Cost[1]	Others	Total
Otter board trawl	54.15	17.90	19.69	**91.74**	5.70	1.93	0.62	**8.26**
Squid falling net	32.38	33.97	10.16	**86.51**	9.90	2.94	0.65	**13.49**
Pair trawls	40.67	31.74	8.44	**80.85**	12.55	6.25	0.35	**19.15**
Gillnets	12.34	57.64	19.85	**89.83**	6.34	3.25	0.58	**10.17**
Purse seiner								
21–22 GT	12.72	64.33	17.2	**94.25**	1.89	3.39	0.47	**5.75**
139–180 GT	18.33	50.10	17.45	**85.88**	8.84	5.05	0.23	**14.12**
Anchovy falling net								
20–46 GT	13.07	49.96	17.75	**80.78**	13.94	4.74	0.54	**19.22**
52–65 GT	12.01	30.00	32.09	**74.10**	22.69	2.61	0.60	**25.90**

[1]*Depreciation cost includes the cost of the vessel, engine, equipment, and gear that last more than 3 years*

Fishery Workers

Based on the same survey, results showed that fishery workers are generally on full-time employment and are mostly foreign nationals. Operators of the fishing fleet employ Thai workers to serve as the vessel captain and engineer. There are no female workers on board the fishing vessels. Purse seine fishery vessels usually have the highest number of workers (29 persons) on average, followed by vessels using gillnet (16), pair trawl (14), anchovy falling net (12), otter board trawl (6), and squid cast net (6). Most fishing vessel crew members have participated in general fisheries education/ training and basic safety training and have access to health insurance and banking services. However, they do not take part in the national social security scheme and therefore do not contribute to any pension fund. They also have little or no participation in fishers' organizations, cooperatives, or unions.

The average monthly wages of the captains/skippers in each fishing vessel range from THB 11,367 to 37,500. The captain of the gillnetter vessel gets the highest monthly wage, while the captain of a squid falling net vessel earns the lowest wage. Crew members of each fishing fleet receive an average monthly wage on board of around THB 11,347 **(Table 4)**.

Table 4. Monthly income of fishery workers by fishing gear

Fishing gear	Monthly income (Thai Baht)					
	Skipper/Master			Crew		
	Min	Max	Ave	Min	Max	Ave
Otter board trawl	10,000	20,000	17,500	10,000	10,100	10,275
Squid falling net	10,100	12,000	11,367	10,100	10,100	10,100
Pair trawls	20,000	30,000	23,333	12,000	12,000	12,000
Purse seine	12,000	30,000	20,667	10,100	15,000	12,525
Anchovy falling net	15,000	20,000	16,667	9,700	12,000	10,350
Gillnets	30,000	40,000	37,500	12,000	15,000	12,833

Technological Innovations in Vessels, Equipment, and Gear

The study report provides some recommendations for a loan guarantee program that supports the commercial lending scheme of Thailand offered to fishing vessel owners. A case study of the improvement of a 91-GT Thai purse seiner in Pattani Province in Thailand was conducted by reconfiguring the said vessel (**Figure 9**). The technology upgrade had increased efficiency by making it easier and faster to haul in and handle the catch, reduced labor requirements, improved refrigeration and preservation of the catch (thus increasing the catch's market value) and enhanced the working conditions and livability of the crew onboard. After the reconfiguration, revenues increased to THB 1,425,000 and the cost of labor had decreased to THB 874,146 per year.

Findings from the case study were used as a basis for the recommendations for a loan guarantee program. A soft loan program for purse seiner reconfigurations and modified old fishing net of THB 2.0–2.5 million (with a new fishing net, THB 3–4 million or more is required) would allow fishing operators, with support from public and private lending institutions, to make these improvements and comfortably repay loans in about two years (3–5 years in case of a new fishing net). A loan guarantee program that supports THB 160 million in lending, for example, can help reconfigure 80–100 vessels (specifically purse seiners) in a two-year cycle.

Regulations and Technology Adoption

A study on the effects of some policies and regulations on vessel owners' willingness to make capital investments in upgrades, new vessels, or new technology, as well as the economic viability of their business, has identified several innovations, technologies, onboard facilities, and devices that owners can invest in, benefit from, and contribute to social and environmental objectives. These range from small items like hooks and Juvenile and Trash Excluder

Figure 9. Reconfiguration of a 91-GT Thai purse seiner: Hydraulic crane and power block for hauling purse seine net (left) and refrigeration system for chilling the catch (right)

Devices to the replacement of engines or vessels with hulls of materials other than wood (which would allow several features to be installed, such as a bulbous bow). Costs of some innovations are provided, but most are indicative. In most cases, the assessment showed a mix of quantitative data and qualitative statements. Identifying barriers to innovation and sustainability helps inform policies and financial measures that encourage vessel owners to invest in technological upgrades and access to capital.

Innovations and Technological Upgrades

Thai fishing vessels, onboard equipment, and gear currently used in fishing fleets could benefit from improvements that would reduce fuel consumption, raise the efficiency of energy use, and bring down operational costs, with a positive contribution to climate change mitigation. Other improvements can be made to increase fishing efficiency, reduce the environmental (habitat, biodiversity, and ecosystem) impact of fishing, and improve fish handling and product quality, as well as safety at sea and on-board working conditions.

Vessel Upgrade

Vessel hulls made of materials other than wood, preferably aluminium, steel, or fiberglass could lower maintenance costs and provide better maneuverability and faster movement. Refinement in the shape of the appendages of the hull (in large vessels) could result in improved stability and safety. A vessel should have a buoyancy compartment and should be installed with bulwarks and guardrails. The installation of a bulbous bow reduces water resistance at the bow and saves fuel consumption by about 5% during steaming and reduces fuel consumption and exhaust gas emissions. Therefore, fishing vessel operators need to retrofit their existing wooden-hulled vessels with steel-hulled vessels. The construction cost of a steel-hulled 75.87 GT vessel, LOA 23.95 m, is about THB 30,000,000 (not including gear).

Equipment Upgrade

Replacement of engines, *i.e.* by a modified diesel-electric generator diesel, could increase fuel and fishing efficiency and reduce exhaust gas emissions. Fishing vessel operators need to use a suitable new diesel engine and propeller to improve fuel efficiency. For a trawl fishing boat made of steel, its inboard diesel engine should be 5 to 6 HP per ton of displacement. Typically, the optimal fuel efficiency of a diesel engine is at 85 % maximum continuous rating. Two owners of trawlers were interviewed; the first trawler (LOA 18 m) uses a modified second-hand diesel-electric generator engine with 275 HP as the main propulsion engine and costs between THB 100,000–150,000, plus another THB 50,000 for installation services. The second trawler owner uses a 180 HP Hino truck diesel engine with modification and installation costs of THB 20,000 and THB 50,000, respectively.

An electric propulsion system is a new propulsion technology for local Thai fishing boats and helps in reducing fossil fuel costs and non-renewable greenhouse gas emissions. However, it has a high initial capital investment and installation costs. Retrofitting of an electric driving system of a personal car performed by a local mechanic shop included a permanent magnet synchronous motor (PMSM) with a Rated Power of 30 kW and Peak Power of 60 kW, a 384 VDC for a 3-ton maximum load, 120 Ah 64 kWh lithium-manganese-cobalt-oxide batteries (MNC), that allow 250–280 km per charge, and available speed range of 140–150 km/hr. The system costs about THB 600,000. Total installation and operating costs for the retrofitted electric car amount to THB 1,182,400 (582,400 + 600,000). The cost ratio between an electric and diesel-powered engine is 0.598. Matching a suitable new diesel engine and propeller is key to fuel efficiency, about which most fishers do not have the knowledge before having their trawl fishing boat modified.

Reconfiguration of the vessel also requires the installation of such systems as a crane, hydraulic system, power block, and a central cooling and refrigeration system. The installation of a fuel flow monitor/electronic data logger can help the skipper know the real-time condition of the engine and fishing vessel for better planning and management of the fishing route, saving on time and fuel. Moreover, replacement of sustainable energy engine (solar and/or wind power), and installation of emergency stop devices for winches and hauling equipment, lightning conductors, distress signal devices, lifesaving equipment and survival crafts, radio communications, firefighting equipment, and provision of first aid kit, medical equipment and medicines, and cooking, eating, sanitary and water facilities are also necessary for the efficient operation of a fishing vessel.

Fishing Gear

Fishing gear could be improved through some innovations, *i.e.* the use of low-resistance fishing gear (suitable for offshore trawls) and circle hook for long line fishing (reduces mortality rate of non-target species, specifically sea turtles), which cost from THB 450–850 per 100 hooks; installation of Turtle Excluder Devices (TEDs) to avoid catching sea turtles and other non-target species (Size 0.5 x 0.8 m), and installation of Juvenile and Turtle Excluder Device (JTED) to avoid catching juveniles and "trash fish" as they compose the undersized economically important species.

Improved Operations

The operation of the hydraulic pump and hydraulic system could slow down speed, and the use of a fish finder can reduce fuel consumption and increase fishing efficiency by reducing steaming time and distance to the location of the fish. Installation of a Vessel Monitoring System (VMS) enables the monitoring and surveillance of the vessels by authorities to, among others, prevent IUU fishing, provide quick alerts and warnings of storms, and easily monitor the location of the vessels in case of emergency. Adoption of Fish Aggregating Devices (FADs) can raise fishing efficiency by attracting more fish into the FAD area and reduce steaming time spent on locating target fish species.

National Legislation, Policies, and Plans that Affect Fishing Operations and Technology Use

The new Fisheries Law of Thailand, the Royal Ordinance on Fisheries B.E. 2558 (2015), was enacted on 14 November 2015, seven months after the EU issued an IUU yellow card to Thailand. The law provides for a comprehensive reform of the legal framework governing Thai fisheries. The law changed the conservation and management of Thailand's aquatic living resources from an "open access" system to a controlled system under a licensing regime. This was based on scientific evidence, *i.e.* the maximum sustainable yield (MSY), and a prescribed total allowable catch to prevent overexploitation. A key aspect of the law provides that IUU fishing is an international crime and, commensurately, imposes serious sanctions to ensure effective compliance.

In addition, the Royal Ordinance on Thai Vessels B.E. 2561 (2018) was brought into law in March 2018 to enforce the regulations contained in the Navigation in Thai Waters Act, and is also aimed at combating IUU fishing. Thailand is a party to key international treaties that promote sustainable fisheries, such as the United Nations Fish Stock Agreement (UNFSA), Agreement on Port State Measures to Prevent, Deter and Eliminate IUU fishing (PSMA), and other Regional Fisheries Management Organization (RFMO) agreements. A buy-back scheme was launched to help fishers affected by the government's program of reducing the number of fishing vessels and bringing the fishery resources back to balance. For some 305 fishing vessels with less than 90 GT (bought back as of 2019), the compensation amount was estimated at THB 764.45 million.

National Plan of Action to Prevent, Deter, and Eliminate IUU Fishing

The National Plan of Action to Prevent, Deter and Eliminate IUU Fishing (NPOA-IUU), which was approved on 03 November 2015, reflected the Thai Government's recognition that IUU fishing is a serious threat to marine fishery resources, and that concerted global, regional and national actions are required to address the challenge. It specifies actions and measures needed to prevent, deter, and eliminate IUU fishing both inside and outside Thai waters, drawing on the FAO IPOA-IUU and Thailand's international obligations. The measures stipulated in the NPOA-IUU aim to fulfil Thailand's responsibilities as a flag state, coastal state, port state, and market state.

Marine Fisheries Management Plan (FMP)

The Marine Fisheries Management Plan (FMP, 2015–19) of Thailand is closely linked to the NPOA-IUU and the National Control Plan (NCP) 2015. Based on a risk assessment, two high-priority issues were identified: (i) overfishing and overcapacity, especially by commercial fleet, and (ii) IUU fishing (DOF, 2021). The FMP, which aims to reduce fishing capacity and fishing effort over three years, was designed to reduce IUU fishing to a level that can be controlled through regular MCS arrangements. Specific management measures to achieve this include: (a) strengthening Monitoring, Control, and Surveillance measures, and (b) improving the licensing and registration system so that all vessels are registered and licensed (DOF, 2022). Any vessel with a history of IUU fishing would not be registered.

Regulations and Technology Adoption

Highly relevant to the issue of technology adoption by the fishery sector are the findings of the International Labour Organization (ILO) on the effect of some policies and regulations on vessel owners' making capital investments on upgrades, new vessels, or new technology, as well as the economic viability of their business. The ILO findings (ILO, 2019) are noteworthy:

- Concern of vessel owners about changes in vessel monitoring system (VMS) regulations that require additional cost for a secondary system to supplement and replace the system already in place
- Report of many vessel owners on the rapid policy change, which is difficult for the industry to adapt to; thus, any new changes should be properly researched to support the industry, and that the industry should be consulted when the rules are to be changed, and should be given time for implementation after a law is passed so that the industry can make the necessary adjustments
- Concern of some Thai vessel owners that although a tight labor market would drive investment in new technologies, this would lead to increased mechanization of the fishing fleet and a consequent reduction in the level of labor required. However, to take up labor-reducing technologies, new vessels would need to be purchased, which is not easy as in the case of purse seine vessels which make up 909 (or 17 percent) of the approximately 5,500 vessels in the Thai commercial fishing fleet over 30 GT in size
- Reluctance of owners to invest in vessel upgrades likely reflects the lack of informed debate among vessel owners about available technologies, costs, and means of accessing financing capital investments
- Vessel owners contemplating on making capital investments require predictability and evidence of prospects for profitability, while commercial lenders, likewise, look for predictability
- The long-term plan of the Department of Fisheries (DOF) to decrease the size of its commercial fishing fleet by adopting a buy-back scheme (as of 2019, 305 vessels had been bought by the Thai Government), and the plan of DOF to adopt measures for increasing the use of labor-saving technologies to reduce the requirements for fishery workers

Conclusion

Thailand's fishing fleet, onboard equipment, and gear currently used in fishery vessels could benefit from improvements to reduce fuel consumption, raise the efficiency of energy use, and bring down operational costs, with a positive contribution to climate change mitigation. Likewise, other innovations would also increase fishing efficiency, reduce the negative environmental impacts of fishing, improve fish handling and product quality, and improve safety at sea and on board working and living conditions.

A few innovations, several technological upgrades, and a range of technical, operational, and material features have been identified through this study, contributing to the general objective of attaining sustainability in the fishing industry. Some innovations require a small investment, such as the use of hooks and installation of JTED to avoid catching non-target species and juveniles. Moreover, significant investments would be necessary for the replacement of vessel engines; even more sizeable investments need to be made for the replacement of ageing wooden-hulled vessels with hulls made of steel, aluminum, or fiberglass. The refurbished vessels would allow the installation of innovative and efficiency-enhancing features like a bulbous bow, fins fitted forward, a duct on the propeller, as well as a safety feature like a buoyancy compartment. The costs of investing in some of these features have been determined, although some of the amounts are only indicative. In most cases, the assessments are a blend of quantitative information and qualitative statements derived from interviews with vessel owners, published studies, as well as from the experiences and expertise of the fishers and experts that took part in the stakeholders meeting, and the members of the team from SEAFDEC/TD who worked on this study. Indications of the economic benefits from investing in certain technological upgrades are also provided, as these could contribute to addressing the interlinked issues of what modes of assistance and what forms of incentive can be provided to vessel owners to persuade and enable them to invest in innovations and technological upgrades.

References

DOF. (2016). *Fisheries Statistics of Thailand 2014. No. 11/2016*. Information and Communication Technology Center, Department of Fisheries, Ministry of Agriculture and Cooperatives. 87 pp.

DOF. (2017). *Fisheries Statistics of Thailand 2015. No. 5/2017*. Fisheries Development Policy and Strategy Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 92 pp.

DOF. (2018a). *Fisheries Statistics of Thailand 2016. No. 12/2018*. Fisheries Development Policy and Strategy Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 92 pp.

DOF. (2018b). *Thai Fishing Vessels Statistics 2018. No. 11/2018*. Fisheries Development Policy and Strategy, Department of Fisheries, Ministry of Agriculture and Cooperatives. 227 pp.

DOF. (2019). *Fisheries Statistics of Thailand 2017. No. 9/2019*. Fisheries Development Policy and Strategy Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 92 pp.

DOF. (2020). *Fisheries Statistics of Thailand 2018. No. 10/2020*. Fisheries Development Policy and Planning Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 81 pp.

DOF. (2020a). *Thai Fishing Vessels Statistics in 2020. No. 11/2020*. Fisheries Development Policy and Planning Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 214 pp.

DOF. (2021). *Assessment Report for the Marine Fisheries Management Plan of Thailand (2015–2019)*. Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand. 25 pp.

DOF. (2022). *Marine Fisheries Management Plan of Thailand2020-2022*. Retrieved February 5, 2022, from https://www4.fisheries.go.th/local/file_document/20220912132213_1_file.pdf

FAO. (2022). *Assessment of the Sustainability of Currently Used Fishing Technologies and Operations in Thailand and Options for Innovation and Improvements*. FAO Fisheries and Aquaculture Circular No. 1246. 74 pp.

ILO. (2019). *Less is more: How policy and technology can impact the Thai labor market for work in fishing*. ILO, Bangkok. https://www.ilo.org/asia/publications/WCMS_733899/lang--en/index.htm

World Bank. (2023). *Capture Fisheries Production (metric tons)–Thailand*. Retrieved June 23, 2023, from https://data.worldbank.org/indicator/ER.FSH.CAPT.MT?locations=TH

About the Authors

Mr. Sukchai Arnupapboon is the Head of Fishing Ground and Oceanography, SEAFDEC Training Department, Samut Prakan, Thailand.

Mr. Pirochana Saikliang is a Consultant for DOF Thailand based at the Department of Fisheries, Thailand.

Ms. Thanyalak Suasi is the Head of the Fisheries Management Section, Research and Development Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Ms. Rattana Tiaye is a Fisheries Management Scientist of the Fisheries Management Section, Research and Development Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Mr. Thaweesak Thimkrap is Head of Marine Engineering Section, Training and Research Supporting Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Mr. Khunthawat Manomayidthikarn is a Marine Engineer of the Marine Engineering Section, Training and Research Supporting Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Dr. Nopporn Manajit is a Marine Fisheries Senior Researcher of the Research and Development Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Dr. Nakaret Yasook is Head of the Fishing Technology Section, Research and Development Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Mr. Santipong Putsa is a Fishing Gear Technologist of the Fishing Technology Section, Research and Development Division, SEAFDEC Training Department, Samut Prakan, Thailand.

Dr. Jitraporn Phaksopa is a lecturer at the Faculty of Fisheries, Kasetsart University, Thailand.