Fishing Vessels Energy Audit: Operational Benchmarking of Fuel Consumption in Southeast Asian Trawl Fisheries – Pilot Project in Thailand

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Despite the increasing demand for fish and fishery products in view of their importance to human well-being, global fisheries production is at risk of falling off due to escalating and volatile fuel prices. Since the turn of the 21st century, the real global price of fuel has more than doubled and is characterized by unparalleled volatility. Rising fuel prices have also generally outpaced increases in fish prices (Gulbrandsen, 2012), making it difficult to offset this differential without landing more fish per unit of fuel consumed or reducing other fishing costs. Subsequently, the profitability of many fishers in Southeast Asia is under threat, jeopardizing the livelihoods of fishing families, communities, and others that directly rely on wild-caught seafood. The high consumption of fuel by the commercial fishing industry is also a concern because of its link to greenhouse gas emissions and climate change. According to Tyedmers *et al*. (2005), the global commercial fishing industry produces approximately 1.7 tons of greenhouse gas emissions for every 1.0 ton of live-weight seafood, and is responsible for over 1% of the greenhouse gas emissions from all sources combined. Starting in late 2013, FAO and SEAFDEC launched a Fishing Vessel Energy Audit Pilot Project in response to concerns on high and variable fuel costs, and associated greenhouse gas emissions from Thai commercial fishing industry. The project was aimed at evaluating fuel consumption in single-boat trawl fleet and identifying potential fuel savings through energy efficient fishing operations and practices. This Project also applied energy audits to trawlers in single-boat trawl fleet. It is envisioned that results of this pilot project could also be adapted in other countries of Southeast Asia to ensure that trawl fisheries is not only cost-effective but also environmentally efficient.

Fishing Vessel Energy Audit Pilot Project

The Training Department (TD) of the Southeast Asian Fisheries Development Center (SEAFDEC) in collaboration with the Food and Agriculture Organization of the United Nations (FAO) launched a Fishing Vessel Energy Audit Pilot Project in Thailand starting in November 2013. The Project surveyed the trawl fisheries in the Provinces of Chon Buri, Rayong, and Trat in the eastern Gulf of Thailand, and Prachaup Khiri Khan and Chumphon in the central Gulf of Thailand, to identify fuel-saving potentials through energy efficiency practices. Based on other experiences on fishing vessels energy audit and management plans, fishing vessels have the potential to reduce their energy use by 15-40% through improved efficiency. As envisioned, this pilot project on fishing vessel energy audit could provide a description of the energy usage patterns of fishing vessels for different operational phases and/or through a fishing season; potential energy saving measures together with expected payback periods; and measures of performance against recognized energy audit parameters, such as catch quantity per liter of diesel-fuel and fuel expense against catch revenue. Such information is necessary in order that fishing companies could undertake rational change towards energy saving practices and technologies. Furthermore, results of the fishing vessel energy audit could also address the concerns of the government sector as well as non-government organizations on the performance of the fishery sector as a primary industry, not only in terms of energy efficiency and viability but also its possible contributions to the increasing greenhouse gas emissions and carbon footprint.

The pilot project made use of the energy audit protocol based on a three-level audit process developed for Australian fishing vessels (**Box 1**). This process was designed to systematically collect data on fishing vessel design and operation, machinery specifications, and fuel consumption, in order that a prioritized, focused, and cost-

Map of Thailand

Box 1. Energy audit protocol used in the FAO-SEAFDEC Pilot Project on Fishing Vessel Energy Audit

Level 1: This audit process involves conducting consultations with fishers or trawler owners to estimate energy consumption, including annual and seasonal rates of consumption and associated costs. The required data are usually obtained through examination of their historical records or receipts, ideally during the past 24 months. Catch landings and value data is also compiled for the same corresponding period. These data can then be used to provide an initial assessment of peaks, troughs, and trends in energy consumed per unit of output, such as liters per hour or per kilogram of fish. This assessment provides a benchmark from which future energy consumption could be monitored, especially after the application of fuel saving technology or changes in operational behavior. Potential options to reduce fuel consumption may be identified at this time along with first order estimates of fuel savings; the accuracy of these estimates is likely to be ±40% of actual savings (Wakeford, 2010).

Level 2: This audit process usually involves a site visit to identify and view the sources of energy consumption. During this visit information on important vessel dimensions and specifications are collected. All sources of energy consumption are identified (*e.g.* diesel, lubricating oil, among others.) and machinery specifications, including rates of energy consumption, and usage patterns which also should be documented. At this time a list of applicable fuel saving options should be developed with estimated cost of installation, expected fuel-saving targets and annual savings, and payback periods based on knowledge of the vessel's operation. The accuracy of fuel saving estimates after completion of Level 2 should be ±20% of actual savings (Wakeford, 2010).

Level 3: This audit provides a detailed analysis of energy consumption, savings, and associated costs. Based on the outcomes of Level 2, this level focuses on critical areas that affect the energy efficiency of the fishing operation. At this level, a specialist may be required to carry out specific parts of the audit or to install metering or logging equipment to measure energy consumption over a variety of operating conditions. Identified fuel saving options may also be installed and their performance measured at this time. The outcome is a thorough evaluation of energy consumption and precise cost estimates for the implementation of energy saving options and their associated savings. Result of this analysis should be ±10% of actual savings (Wakeford, 2010).

effective effort could be made to reduce fuel consumption and greenhouse gas emissions. More specifically, the Project applied the Level 1 process as well as combined Levels 2 and 3 for convenience. While taking up the Level 1 process, 94 trawl fishers based in Chon Buri, Rayong, Trat, Prachaup Khiri Khan, and Chumphon Provinces were asked to accomplish a questionnaire that sought to obtain detailed information on five major aspects, *i.e.* trawler design, construction, condition, age, and maintenance schedule; design and specification of engine, transmission, propeller, and rudder; fishing gear design, specification, rigging, and operation; fishing trip characteristics, including duration, steaming and fishing times, impacts due to weather or damaged gear; and operating costs such as fuel, crew, food, lubricant, and ice.

Results of the Questionnaire Survey

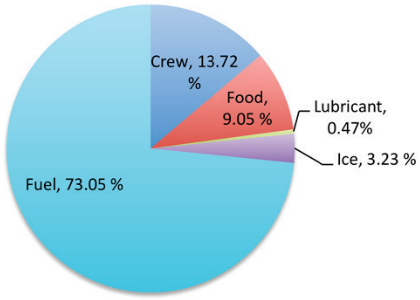
In order to be consistent with the classifications used by the Department of Fisheries of Thailand, the responses of the trawl fishers were categorized into two aspects, namely: for trawlers less than 14 m in length, and trawlers that were larger. Analysis of the responses indicated that 65 fishers have been operating trawlers with overall length of less than 14 m, the volume of such trawlers ranged from 1 to 40 GT while engine propulsion ranged from 16 and 500 Hp, and no trawlers were equipped with auxiliary engine. The age of trawlers ranged from 6 months to 40 years, although trawlers between 5 to 10 years old were more common.

All trawlers were made of timber with service speed that ranged from 2 to 10 knots, propeller size ranging from 7 to 102 inches, and 90% of the fishers had been using four-blade propellers. The results also showed that over

80% of the fishers operate small trawlers and just less than 60% operate larger trawlers, while the fishers cited that fuel accounted for 50% or more of their total annual expenditures.

Results based on Level 1 audit

Although a small number of fishers did not or were unable to provide an estimate of the proportion of total expenditures that comprised fuel, the results suggested that the range of fuel expenditures for larger trawlers was 3,476,295 to 3,936,205 THB/year/trawler accounting for 36% to 86% of total expenditures. For small trawlers, the expenditures ranged from 1,452,211 to 1,647,257 THB/year/trawler which accounted for 34% to 73% of total expenditures. The average fuel cost for all trawlers accounted for just over 70% of the total expenditures (**Fig. 1**). On their fuel consumption per day or fishing trip, in an assumed 24-hr operation, the fishers also reported daily fuel consumption rate for all trawlers combined at 10.4 to 22.0 liters per hour.



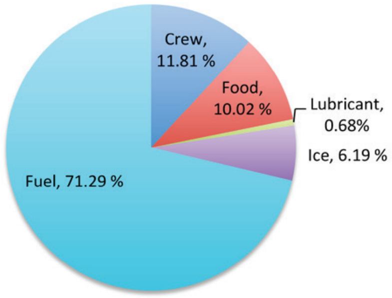


Fig. 1. Average expenditure of trawlers less than 14 m in length *(left)*, and trawlers 14 m or greater in length *(right)* based on responses of fishers using the Level 1 audit

Results based on Level 2 audit

Adoption of the next level of the audit process involved installing and using at-sea data collection equipment during the sea trials. Six trawlers were selected for this audit (**Table 1**), four of which were less than 14 m in length and the other two were 14 m in length or longer. Equipment were installed in the trawlers such as a fuel flow meter system, engine RPM tachometer, portable GPS to indicate trawler's location, heading, and speed, as well as a wind speed and direction indicator, and a vessel speed log. Small CCTV cameras were used to film the fuel meter, engine RPM, GPS, and activity on the back deck, the information of which was recorded on a 4 channel video recorded for subsequent review and analysis. The vessel specifications and machinery were also recorded.

For each trawler the relationship between fuel consumption and trawler speed was measured over a range of speed ranges and engine revolutions (rpms) during a 10-day period at sea. The result indicated that fuel costs were the dominant expenditures during the 10-day period for each trawler, accounting for 52-81% of total expenditures (**Fig. 2**). For five of the trawlers, labor costs were the second most dominant expenditure, although for one trawler the expenditure on ice was greater than that of labor. Income for the W. Yingcharoen was much greater than that of the

Table 1. General information of the six trawlers used for the Level 2 audit

Specifications	Name of Trawler					
	W. Yingcharoen	Chokepanthawee	Supsaitong	Chokenimitr	Chokchanapol	S. Charoenchai 1
Trawl type	Shrimp	Shrimp	Shrimp/fish	Shrimp/fish	Shrimp/squid	Shrimp/squid
Engine manufacturer	Gardner	Hino	Hino	Hino	Hino	Hino
Engine model	6LXB	EH700	EH700	H07D	H07D	EK100
Horsepower	180	130	168	180	190	275
RPM (steaming)	1000-1100	1200-1300	1400-1550	1700-1900	1400-1500	1300-1400
RPM (trawling)	1100-1200	1100-1200	1100-1200	1400-1500	1000-1100	1000-1100
RPM (idle/laying to)	700-800	700-800	700-800	700-800	700-800	700-800
Gearbox ratio	6:1	6:1	4:1	4:1	5:1	5:1
Length overall (m)	17	11.2	11	12	14.0	13.2
Length waterline (m)	16	10.4	10	11	13.0	12.2
Breadth (m)	4.6	3.7	3.7	3.7	3.6	3.1
Draft (m)	1.5~1.8	1.38	1.5	1.5	1.3	1.5
Fuel price (THB/l)*	25.52	29.96	29.96	29.96	23.00	23.00
Propeller dia.(inches)	50	44	38	39	42	52
Test period	14-24/10/13	6-16/11/13	14-24/10/13	6-16/11/13	23-31/11/13	23 - 31/11/13

*Price per liter of fuel paid by trawl fishers during the implementation of the project

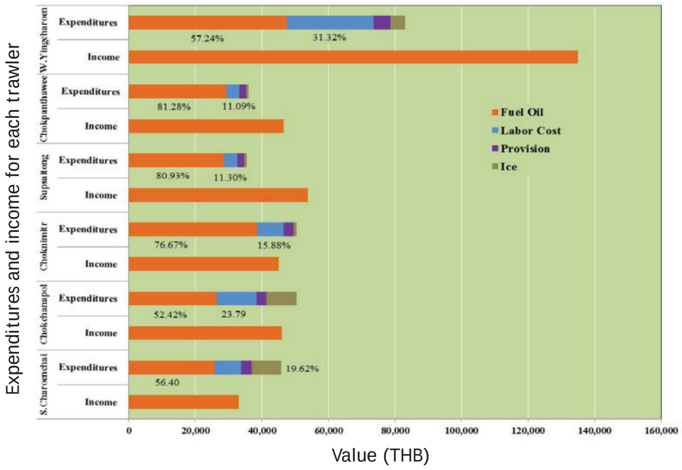


Fig. 2. Income and expenditures of trawlers in 10-day fishing trip, indicating the two most dominant expenditures proportionate to the total expenditures for each trawler

other trawlers due to its substantially higher landing volume and higher proportion of high-value species in the catch, such as blue crabs.

The fuel consumption data at free running speed from all 6 trawlers was collected over a range of rpm and speed in free running or steaming condition (with all fishing gear stowed onboard). In such a condition, there was substantial diversity between trawlers for a given engine revolution (**Fig. 3**). For example, at 1150 rpm the steaming speed

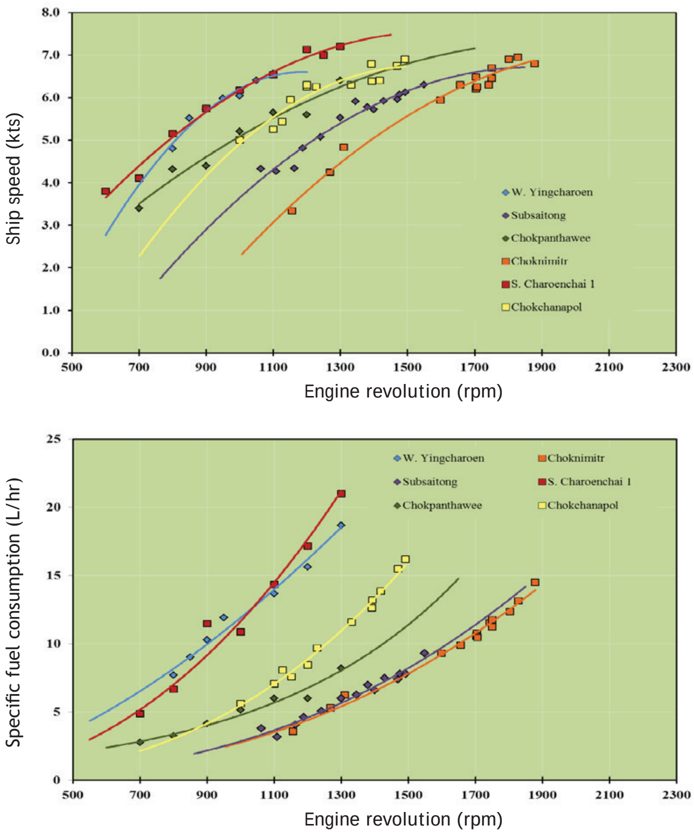


Fig. 3. Relationship between ship speed, fuel consumption and engine revolutions of vessels at free running (steaming)

of the **Choknimitr** was around 3.5 knots (kts) while the steaming speed of the **Chokchanapol** was around 6 kts. This may have been due to the differences in hull design and propulsion systems, although the influence of tide may also have been a contributing factor.

Meanwhile, the **W. Yingcharoen** and the **S. Charoenchai 1** were consistently the fastest trawlers based on the tested range of engine revolutions, while the **Choknimitr** was the slowest. At higher revolutions, the impact of reducing the rpms on steaming speed was relatively modest for all trawlers, compared to the same reduction at lower revolutions.

More importantly, the collection of this data also permits an evaluation of the impact of trawler speed and rpm on fuel consumption. For example, a reduction in steaming speed from 7.0 kts to 6.0 kts resulted in an estimated fuel saving of approximately 40% while increasing the steaming time by a modest 14%.

Primarily in view of the concerns of fishers on the impact of data collection activities on their catch while trawling, fuel consumption data over a relatively narrow range of trawling speeds was collected from two trawlers only. Subsequently, the results only confirmed increased fuel consumption with speed but no further analysis could be made.

Discussion and Conclusion

This project represents the first known attempt to formally complete energy audits of Thai fishing trawlers. As a pilot project, testing new equipment and data collection and analysis protocols, and the results provide a benchmark to guide future efforts in this or other fisheries in Thailand or elsewhere in Southeast Asia. As part of the Level 1 audit process, it was observed that fishers do not keep accurate records of their expenditures. Many interviewed fishers only had a vague idea of the volume and cost of fuel

consumed each year, or the relative costs of other expenses such as food and ice.

This challenges the ability to review past fishing behavior, identify periods when fuel costs are highest, and hone in on remedial solutions. In Australia, the energy audit process ideally requires expense and catch reports over a 24-month period for this very reason. Site visits had enabled the compilation of important details and specifications of all 6 trawlers used in the audit based on Level 2, and the installation of metering and logging equipment. This was followed by at-sea data collection of energy and catch information on each trawler and an evaluation of the expenses and profitability of each trawler over a 10-day period. This period was an excellent opportunity to test sampling equipment under commercial conditions and develop the data collection protocol.

Initial assessment based on at-sea data collection indicated that judicious use of engine rpms is a key means for fishers to reduce fuel consumption. It also provides immediate fuel savings and requires no installation cost as many trawlers are already equipped with a tachometer. Another relatively inexpensive option is the installation of a fuel flow meter. In fisheries elsewhere, this meter is invaluable because it makes fishers acutely aware of the relationship between rpms and fuel consumption, and on how much fuel could be saved through modest throttle adjustments.

Way Forward

Analysis of the data compiled from this project would be continued with the objective of identifying, establishing and thoroughly evaluating the potential fuel saving options and protocols. The results would also include the time needed for fishers to pay back the acquisition and installation costs of fuel saving options (payback period) based on the collected data and the fuel saving potential of each option. Such an approach has been effectively used by Eayrs *et al*. (2012) to help prioritize a variety of fuel saving options by accounting for their relative contribution to fuel conservation and their purchase and installation costs.

A more extensive energy audit project with Thai fishing vessels has just been started using the knowledge and skills gained from this project. A follow-up project would therefore be carried out by SEAFDEC, making use of improved equipment and data collection protocols, and data collection to be conducted over a 6-month period. In this way, the data is expected to be more accurate and reflective of the fishing year and exhibit a better account of the impacts of the vagaries of tide and other severe environmental conditions.

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