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Comparative Assessment of Fuel-Use and Carbon-Emission Intensities of the Fishing Systems at Chinnamuttom Fishing Harbour, India

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Comparative Assessment of Fuel-Use and Carbon-Emission Intensities of the Fishing Systems at *Chinnamuttom* Fishing Harbour, India

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Abstract

Fuel consumption and associated carbon dioxide (CO_2) emissions are important indicators of the operational energy performance of capture fisheries. This study compared fuel-use intensity (FUI) and carbon-emission intensity (CEI) among trawlers, gillnetters and longliners operating from *Chinnamuttom* Fishing Harbour, Kanyakumari, Tamil Nadu, during December 2025–May 2026. Operational data on fuel consumption and landed catch were used to estimate FUI, expressed as kilograms of fuel consumed per kilogram of fish landed, and CEI, expressed as kilograms of CO_2 emitted per kilogram of fish landed. Fuel-related CO_2 emissions were estimated using fuel-specific emission factors. The results showed clear differences in the two indicators among fishing systems. Trawlers recorded the highest mean FUI (0.533 kg fuel kg^{-1} fish) and CEI (1.673 kg CO_2 kg^{-1} fish), followed by gillnetters (0.337 kg fuel kg^{-1} fish and 0.947 kg CO_2 kg^{-1} fish). Longliners recorded the lowest mean values, with an FUI of 0.301 kg fuel kg^{-1} fish and a CEI of 0.844 kg CO_2 kg^{-1} fish. Monthly variation was also evident: trawlers exhibited their highest FUI and CEI in February, while gillnetters recorded their highest values in April. Longliner intensities showed a slight decline between March and May. These findings indicate that the fishing systems differed in fuel use and estimated operational CO_2 emissions relative to landed catch during the study period. The results provide a location-specific baseline for assessing energy use and operational emissions at *Chinnamuttom* Fishing Harbour. However, the six-month observation period and the shorter sampling window for longliners limit annual comparisons. Year-round monitoring with consistent fuel-conversion procedures and vessel- and trip-level data is needed to strengthen comparative assessments and identify opportunities for improving fuel efficiency.

Keywords: Carbon-emission intensity; fuel-use intensity; fishing systems comparison; *Chinnamuttom* Fishing Harbour; operational CO_2 emissions.

Introduction

Fisheries play an important role in global food supply, livelihoods and economic activity, particularly in coastal communities where fishing provides employment and income to large numbers of people. However, the increasing mechanization of marine fisheries has also increased dependence on fossil-fuel-based energy for vessel propulsion and fishing operations. Fishing is considered one of the more energy-intensive forms of food production, with direct fuel use representing a major component of the energy input associated with marine harvesting (Tyedmers, 2004; Tyedmers et al., 2005; Parker et al., 2018). The continued dependence of fishing operations on fossil fuels therefore links fisheries production not only with operational energy requirements, but

also with greenhouse gas emissions and the broader environmental implications of energy use in food production (Bastardie et al., 2022).

The quantity of fuel required to obtain a given quantity of fish provides a direct measure of the energy demand associated with harvesting and allows comparisons among fishing operations with different levels of fuel use. Fuel-use intensity (FUI), expressed in relation to the quantity of catch landed, is particularly useful because total fuel consumption alone does not account for differences in catch output. Fuel intensity is closely related to both operational efficiency and the carbon emissions associated with fishing, since combustion of fossil fuels in vessel engines generates carbon dioxide and other greenhouse gases (Parker et al., 2018; Vivekanandan et al., 2013; Asokan et al., 2023).

Vessel size, engine power, gear configuration, fishing duration, distance travelled, fishing method and the quantity of fish landed can all contribute to differences in fuel consumption (Tyedmers, 2004; Parker et al., 2018). Active gears such as trawls require continuous towing power during fishing, whereas passive gears such as gillnets and longlines generally have different energy requirements because the gear does not remain continuously under tow (Tyedmers, 2004; Parker et al., 2018). Differences in vessel and gear characteristics can therefore result in substantial variation in fuel use per unit of catch and, consequently, in operational carbon-emission intensity (Parker et al., 2018).

In India, several studies have examined energy and fuel use in marine fisheries using different approaches. Earlier investigations evaluated fishing efficiency using measures such as energy intensity, energy efficiency and fuel consumption-based carbon assessments, while studies of mechanized fisheries have demonstrated the importance of fuel expenditure in overall fishing operations (Edwin and Hridayanathan, 1997; Boopendranath and Hameed, 2009, 2010, 2013; Vivekanandan et al., 2013). Devi et al. (2021) examined fuel-use intensity, energy intensity and carbon-emission intensity in trawlers operating along the northwest coast of India, demonstrating the relevance of fuel-based indicators for evaluating fishing performance. More recently, Asokan et al. (2023) conducted a comparative assessment of small-scale fishing vessels along the southeast coast of India using a bottom-up approach. Their study quantified fuel-use intensity and greenhouse gas emissions and demonstrated considerable variation in fuel consumption among fishing vessel categories.

The present study therefore aimed to comparatively evaluate the fuel-use and carbon-emission intensities of trawlers, gillnetters and longliners operating from *Chinnamuttom* Fishing Harbour, Kanyakumari, Tamil Nadu. The study quantified fuel consumption, estimated fuel-use intensity (FUI) and carbon-emission intensity (CEI) for the three fishing systems, examined their month-wise variation during the study period, and assessed the differences in fuel and emission performance associated with the respective fishing systems. The study provides location-specific evidence on the energy requirements and operational carbon emissions of contrasting marine fishing systems. It contributes to the broader assessment of fuel-efficient fishing practices in Indian marine fisheries.

Materials and Methods

Description of the study area

The study was conducted at *Chinnamuttom* Fishing Harbour, located in Kanyakumari district, Tamil Nadu, India (8.0959° N, 77.5634° E) (Fig. 1). The harbour is situated at the southern tip of the Indian peninsula and provides access to fishing grounds influenced by the Arabian Sea, Bay of Bengal and Indian Ocean.

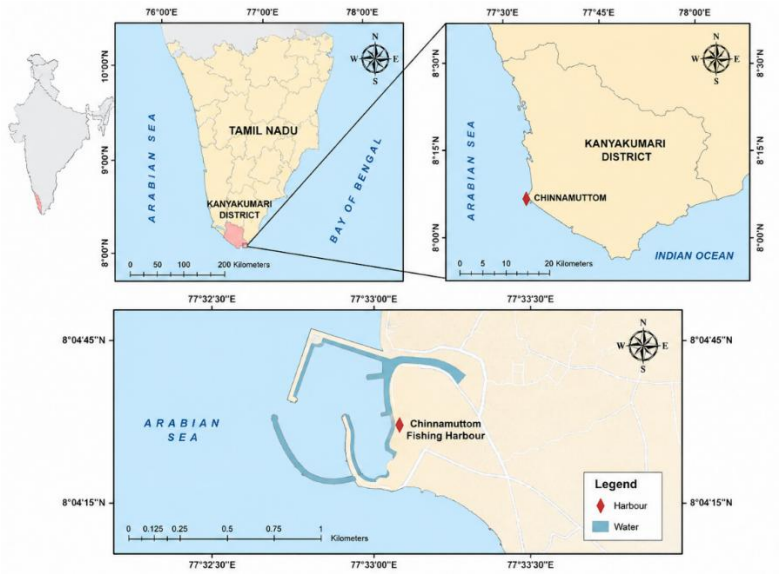


Fig. 1: Map showing *Chinnamuttom* Fishing Harbour, Kanyakumari District, Tamil Nadu

Methodological framework

The study was conducted for a period of six months, from December 2025 to May 2026, at *Chinnamuttom* Fishing Harbour. Three major fishing systems operating from the harbour were considered for the comparative assessment; they were trawlers, gillnetters and longliners. Primary field data were collected using a pre-tested questionnaire to obtain technical details of the fishing systems. Information was recorded for the three fishing systems on catch landed, fuel consumption and fishing effort. The collected information was organized on a monthly basis to facilitate comparison of fuel consumption, catch and derived fuel-use and carbon-emission intensities among the three fishing systems. The overall approach followed a field-based, bottom-up assessment in which fuel consumption and catch data were related at the fishing-system level as done by Asokan et al. (2023).

Fuel-use intensity

Fuel-use intensity (FUI) was used to quantify the amount of fuel required to produce a unit quantity of landed catch. Following the approach of Tyedmers (2004) and Asokan et al. (2023), fuel consumption was expressed in kilograms and related to the corresponding catch landed in kilograms. FUI was calculated as:

$$\text{FUI} = \frac{\text{Fuel consumed (kg)}}{\text{Catch landed (kg)}}$$

Lower FUI values indicate a lower quantity of fuel required per unit of landed catch. For conversion of liquid fuel consumption to mass, the conversion factor applied in the study was 0.86 kg L^{-1} for diesel. For the petrol–kerosene mixture, a conversion value of 0.75 kg L^{-1} was used.

Carbon-emission intensity

Carbon-emission intensity (CEI) was estimated to express the quantity of carbon dioxide emitted through fuel combustion per unit quantity of fish landed (Parker et al., 2018). CEI was calculated as:

$$\text{CEI} = \frac{\text{CO}_2 \text{ emissions (kg)}}{\text{Catch landed (kg)}}$$

The calculation considered carbon dioxide emissions associated with the combustion of the fuel consumed during fishing operations. Thus, CEI represents the operational, fuel combustion related CO_2 intensity of the fishing systems.

Fuel-specific emission factors

Carbon dioxide emissions were estimated using fuel-specific emission factors reported in the study methodology. The factors applied were 2.70 kg CO_2 L^{-1} for diesel, 2.30 kg CO_2 L^{-1} for petrol and 2.53 kg CO_2 L^{-1} for kerosene Eggleston (2006). For diesel-powered operations, emissions were calculated as:

$$\text{CO}_2 \text{ emissions (kg)} = \text{Diesel consumed (L)} \times 2.70$$

For operations using petrol and kerosene, an emission factor of 2.415 kg CO_2 L^{-1} is applied to the combined fuel volume:

$$\text{CO}_2 \text{ emissions (kg)} = \text{Petrol + kerosene consumed (L)} \times 2.415$$

The value of 2.415 kg CO_2 L^{-1} corresponds to the arithmetic mean of the petrol and kerosene factors (2.30 and 2.53 kg CO_2 L^{-1}, respectively).

Data analysis

The recorded data were compiled on a monthly basis for each fishing system. Fuel consumption, catch landed and fishing effort were summarized to examine temporal and system wise differences in fishing operations. FUI and CEI were calculated for each month in which data were available and subsequently summarized for each fishing system.

The analysis included (i) monthly FUI, (ii) monthly CEI, (iii) system-wise mean FUI, (iv) system-wise mean CEI, and (v) month-to-month variation in fuel-use and carbon-emission intensities. The correspondence between FUI and CEI was also examined to describe how differences in fuel use per unit of catch translated into differences in operational CO_2 emissions. Because CEI is derived directly from fuel consumption and the applicable emission factor, the relationship between the two indicators was interpreted primarily in terms of their mathematical and fuel-specific relationship rather than as an independent ecological association.

For comparison among fishing systems, arithmetic means of the available monthly FUI and CEI values were calculated.

Results

Fuel consumption of the fishing systems

Fuel consumption varied substantially among the three fishing systems during the study period. Trawlers recorded the highest fuel consumption, whereas gillnetters and longliners required considerably lower quantities of fuel per fishing operation. The monthly fuel-use pattern also varied within each fishing system during the study period.

On average, gillnetters consumed 46, 41, 32, 36, 49 and 47 L of fuel during December, January, February, March, April and May, respectively. Fuel consumption was lowest in February (32 L) and highest in April (49 L). The relatively moderate variation across months indicates that fuel requirements of gillnetters remained comparatively stable throughout the study period.

Trawlers showed substantially higher fuel requirements than the other fishing systems. Monthly fuel consumption increased from 758.14 L in December to 801.50 L in January and 835.95 L in February, reaching 895.65 L in March, the highest value recorded during the study period. Consumption subsequently declined slightly to 870.93 L in April. No trawler observations were recorded in May because of the seasonal fishing restriction applicable to trawling operations.

Longliners were recorded only from March to May and consumed 51.2, 44.9 and 54.8 L of fuel during these months, respectively. Fuel consumption was lowest in April and highest in May. However, direct comparison of absolute fuel consumption alone does not account for differences in the quantity of fish landed; therefore, fuel-use intensity was subsequently used to evaluate fuel requirements relative to catch.

Fuel-use intensity of the fishing systems

Fuel-use intensity (FUI), expressed as kilograms of fuel consumed per kilogram of fish landed, differed among the three fishing systems during the study period (Table 1). The mean FUI was highest for trawlers (0.533 kg fuel kg^{-1} fish), followed by gillnetters (0.337 kg fuel kg^{-1} fish) and longliners (0.301 kg fuel kg^{-1} fish). These results indicate that, on the basis of the reported system-wise means, trawlers required a greater quantity of fuel per unit of landed catch than either of the other two fishing systems.

Monthly FUI among gillnetters ranged from 0.236 to 0.441 kg fuel kg^{-1} fish. The lowest value was recorded in February (0.236 kg fuel kg^{-1} fish), whereas the highest occurred in April (0.441 kg fuel kg^{-1} fish). Trawlers recorded monthly FUI values ranging from 0.451 to 0.679 kg fuel kg^{-1} fish. The lowest value occurred in December (0.451 kg fuel kg^{-1} fish), while the highest was observed in February (0.679 kg fuel kg^{-1} fish). Longliner FUI was recorded only from March to May, with values of 0.313, 0.296 and 0.293 kg fuel kg^{-1} fish, respectively. The monthly values showed a slight decline over the three observed months, and the mean FUI was 0.301 kg fuel kg^{-1} fish. Although this was the lowest system-wise mean among the three fishing systems, the comparison should be interpreted in the context of the shorter observation period for longliners.

Overall, the FUI results distinguish the three systems more clearly than absolute fuel consumption alone (Fig. 2). Trawlers exhibited the highest mean fuel requirement per unit of landed catch, whereas longliners and gillnetters recorded lower means.

Table 1. Monthly fuel-use intensity (FUI) of trawlers, gillnetters and longliners at *Chinnamuttom* Fishing Harbour, December 2025–May 2026.

	Fuel use intensity (kg fuel/kg fish)		
Month	**Gillnetters**	**Trawlers**	**Longliners**
December	0.372	0.451	—
January	0.311	0.511	—
February	0.236	0.679	—
March	0.297	0.484	0.313
April	0.441	0.540	0.296
May	0.365	—	0.293
Mean	**0.337**	**0.533**	**0.301**

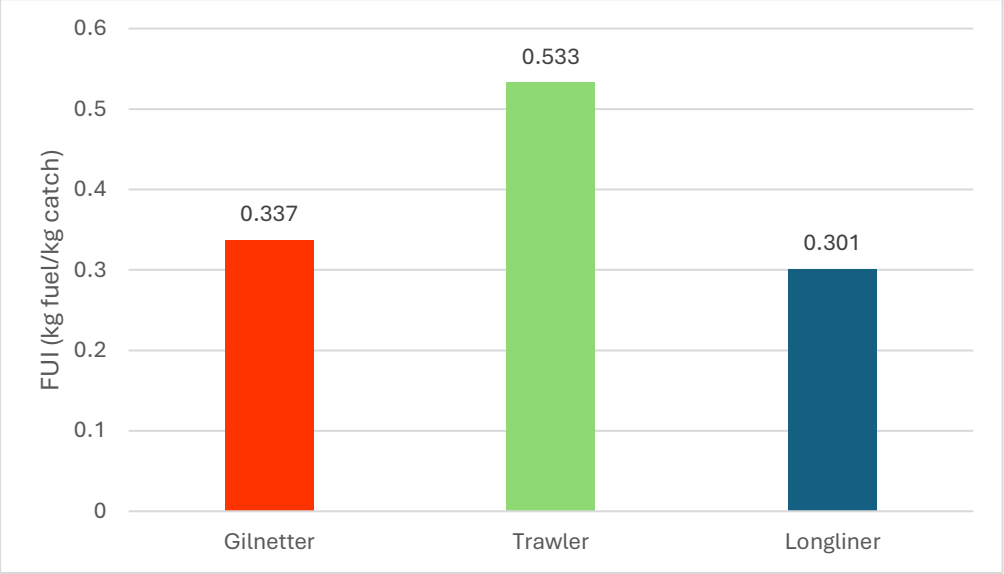


Fig. 2: Comparison of Fuel Use Intensity

Carbon dioxide emissions from the fishing systems

Estimated carbon dioxide (CO_2) emissions associated with fuel combustion differed considerably among the three fishing systems. For gillnetters, the highest monthly value occurred in April (118.335 kg), and the lowest monthly value occurred in February (77.280 kg). The mean of the six monthly estimates was approximately 101.696 kg CO_2.

Trawlers exhibited substantially higher estimated emissions. The highest monthly value occurred in March (2,418.260 kg CO_2), and the lowest monthly value occurred in December (2,046.980 kg CO_2). The mean of the five monthly estimates was approximately 2,247.574 kg CO_2.

For longliners, estimated CO_2 emissions were 123.648 kg in March, 108.434 kg in April and 132.342 kg in May. Emissions were lowest in April and highest in May, with a three-month mean of approximately 121.475 kg CO_2. These estimates represent only the months for which longline observations were available.

Carbon-emission intensity of the fishing systems

Carbon-emission intensity (CEI), expressed as kilograms of CO_2 emitted per kilogram of fish landed, varied among fishing systems and across months (Table 2). The mean CEI was highest for trawlers at 1.673 kg CO_2 kg^{-1} fish, followed by gillnetters at 0.947 kg CO_2 kg^{-1} fish and longliners at 0.844 kg CO_2 kg^{-1} fish. Thus, trawlers exhibited the highest estimated operational CO_2 emissions per unit of landed catch among the three systems.

For gillnetters, monthly CEI ranged from 0.662 to 1.239 kg CO_2 kg^{-1} fish. The lowest value was recorded in February (0.662 kg CO_2 kg^{-1} fish), while the highest occurred in April (1.239 kg CO_2 kg^{-1} fish). The mean across the six monthly observations were 0.947 kg CO_2 kg^{-1} fish.

For trawlers, monthly CEI ranged from 1.417 to 2.132 kg CO_2 kg^{-1} fish. The minimum was recorded in December (1.417 kg CO_2 kg^{-1} fish), whereas the maximum occurred in February (2.132 kg CO_2 kg^{-1} fish). The mean across the five observed months was 1.673 kg CO_2 kg^{-1} fish.

Longliner CEI values were comparatively consistent over the three observed months, declining from 0.883 kg CO_2 kg^{-1} fish in March to 0.828 in April and 0.821 in May. The mean CEI was 0.844 kg CO_2 kg^{-1} fish. Although this was the lowest system-wise mean, the result is limited to March–May and should not be interpreted as representative of the entire annual fishing cycle. Overall, the system-wise mean CEI values followed the order trawlers > gillnetters > longliners (Fig. 3).

Table 2. Monthly estimated CO_2 emissions and carbon-emission intensity of the three fishing systems at *Chinnamuttom* Fishing Harbour, December 2025–May 2026.

Month	**Gillnetter CO_2 (kg)**	**Gillnetter CEI**	**Trawler CO_2 (kg)**	**Trawler CEI**	**Longliner CO_2 (kg)**	**Longliner CEI**
December	111.090	1.045	2,046.980	1.417	—	—
January	99.015	0.873	2,164.050	1.603	—	—
February	77.280	0.662	2,257.070	2.132	—	—
March	86.940	0.834	2,418.260	1.519	123.648	0.883
April	118.335	1.239	2,351.510	1.694	108.434	0.828
May	113.505	1.026	—	—	132.342	0.821
Mean CEI	**—**	**0.947**	**—**	**1.673**	**—**	**0.844**

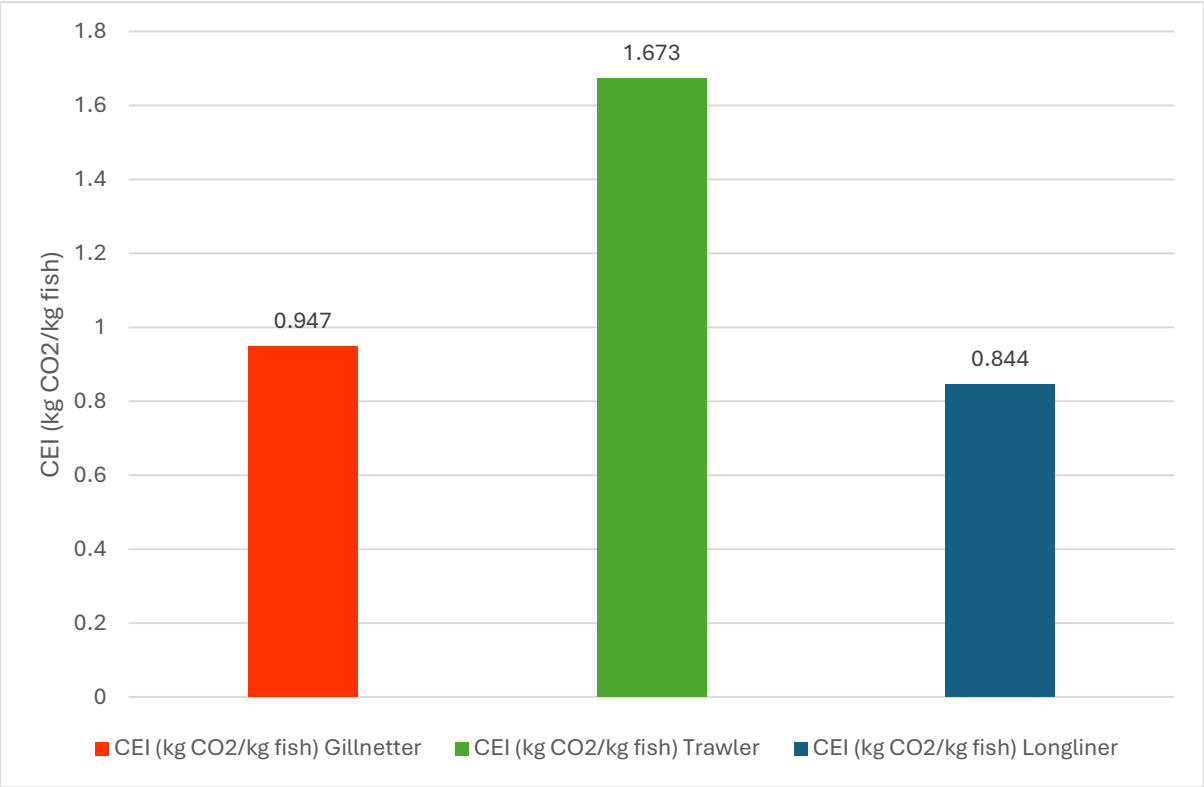


Fig. 3: Comparison of Carbon Emission Intensity

Monthly variation in fuel-use and carbon-emission intensities

Monthly variation in FUI and CEI showed broadly similar patterns within each fishing system. For gillnetters, both indicators reached their lowest values in February and their highest values in April. FUI ranged from 0.236 to 0.441 kg fuel kg^{-1} fish, while CEI ranged from 0.662 to 1.239 kg CO_2 kg^{-1} fish. This parallel variation indicates that changes in fuel consumed relative to landed catch were reflected in the estimated CO_2 emissions per unit of catch.

For trawlers, both indicators reached their highest values in February, when FUI was 0.679 kg fuel kg^{-1} fish and CEI was 2.132 kg CO_2 kg^{-1} fish. Their lowest observed values occurred in December, at 0.451 kg fuel kg^{-1} fish and 1.417 kg CO_2 kg^{-1} fish, respectively. The subsequent monthly fluctuations in both indicators followed the same general direction, consistent with their shared dependence on fuel consumption relative to catch.

Longliner FUI and CEI both declined slightly from March to May. FUI decreased from 0.313 to 0.293 kg fuel kg^{-1} fish, while CEI declined from 0.883 to 0.821 kg CO_2 kg^{-1} fish. The close correspondence between the two indicators is consistent with the calculation method used in the study, in which CO_2 emissions were estimated from fuel consumption using specified fuel-related emission factors.

Comparative assessment of fuel-use and carbon-emission intensity

Comparison of system-wise mean FUI and CEI provides a standardized assessment of fuel requirements and associated operational CO_2 emissions relative to landed catch. Trawlers recorded a mean FUI of 0.533 kg fuel kg^{-1} fish and a mean CEI of 1.673 kg CO_2 kg^{-1} fish, both higher than the corresponding values for gillnetters and

longliners. Gillnetters recorded mean values of 0.337 kg fuel kg^{-1} fish and 0.947 kg CO_2 kg^{-1} fish, while longliners recorded 0.301 kg fuel kg^{-1} fish and 0.844 kg CO_2 kg^{-1} fish.

The FUI and CEI indicators showed broadly consistent rankings across the three systems (Table 3). This correspondence is expected because CEI was derived from fuel consumption and the applicable emission factors, with both indicators expressed relative to landed catch.

Table 3. System-wise mean fuel-use intensity and carbon-emission intensity.

Fishing system	Mean FUI (kg fuel/kg fish)	Mean CEI (kg CO_2/kg fish)
Gillnetter	0.337	0.947
Trawler	0.533	1.673
Longliner	0.301	0.844

Discussion

Differences in fuel-use intensity among fishing systems

The present study demonstrated clear differences in fuel-use intensity (FUI) among trawlers, gillnetters and longliners operating from *Chinnamuttom* Fishing Harbour. Trawlers recorded the highest mean FUI (0.533 kg fuel kg^{-1} fish), followed by gillnetters (0.337 kg fuel kg^{-1} fish) and longliners (0.301 kg fuel kg^{-1} fish).

The comparatively high FUI of trawlers may be associated with their larger vessel dimensions, higher engine power and the energy requirements of towing fishing gear through the water. This interpretation is consistent with Devi et al. (2021), who found differences in fuel efficiency and emission performance among trawler categories operating along the northwest coast of India. Their findings demonstrated that operational characteristics, including vessel category and fishing duration, are important when assessing fuel use. Similarly, Boopendranath and Hameed (2013) reported a gross energy requirement of 20.2 GJ per tonne of fish produced by mini-trawl operations off Cochin, highlighting the substantial energy demand associated with this fishing method.

The FUI values observed at *Chinnamuttom* are also consistent with the broad range reported by Asokan et al. (2023), who investigated 24 small-scale fishing vessels along the southeast coast of India and reported FUI values ranging from 0.08 to 0.80 kg fuel kg^{-1} catch across seven fishing-method categories. All three mean values obtained in the present study fall within this range.

Carbon-emission intensity and its relationship with fuel use

Carbon-emission intensity (CEI) followed the same system-wise ranking as FUI, with the highest mean recorded for trawlers (1.673 kg CO_2 kg^{-1} fish), followed by gillnetters (0.947 kg CO_2 kg^{-1} fish) and longliners (0.844 kg CO_2 kg^{-1} fish). These findings indicate that, under the fuel-specific emission factors applied in this study, trawlers had the highest estimated operational CO_2 emissions per unit of landed catch.

A comparable pattern was reported by Vivekanandan et al. (2013), who estimated that Indian marine trawlers emitted approximately 1.43 tonnes CO_2 per tonne of fish caught, whereas the corresponding values for several other mechanized fishing craft categories ranged from 0.56 to 1.07 tonnes CO_2 per tonne of fish. The trawler CEI observed in the present study (1.673 kg CO_2 kg^{-1} fish, numerically equivalent to 1.673 tonnes CO_2 per tonne of fish) is higher than the national trawler estimate reported by Vivekanandan et al. (2013). This difference may reflect variation in vessel characteristics, fishing operations, fuel use, catch composition, study periods and emission-estimation procedures.

The higher CEI of trawlers is also consistent with the broader findings of Devi et al. (2021), who demonstrated differences in carbon-emission performance among trawler categories on the northwest coast of India. At the global scale, Parker et al. (2018) documented the importance of fuel consumption as a driver of greenhouse-gas emissions from marine fisheries, reinforcing the value of evaluating emissions relative to fish production rather than considering total fuel use alone.

Relative to gillnetters, the mean FUI of trawlers was approximately 58% higher and their mean CEI was approximately 77% higher. Compared with longliners, the corresponding differences were approximately 77% for FUI and 98% for CEI.

The close correspondence between FUI and CEI is expected because the latter was calculated from fuel consumption and fuel-specific emission factors. Therefore, the two indicators are related measures of operational fuel use rather than independent evidence of environmental performance. The principal contribution of the present study is its comparison of three fishing systems operating from a common harbour, providing location-specific information on their observed fuel-use and associated CO_2-emission intensities.

Monthly variability in fuel and emission intensity

The monthly results showed that FUI and CEI varied within individual fishing systems during the study period. Among gillnetters, both indicators reached their lowest values in February and their highest values in April. For trawlers, the highest values occurred in February and the lowest in December, while longliners showed a slight decline in both indicators from March to May.

These findings are consistent with the general interpretation of fuel-use intensity presented by Asokan et al. (2023), who examined differences in fuel consumption among small-scale fishing vessel categories and discussed the operational factors contributing to these differences. At the global scale, Greer et al. (2019) demonstrated that fuel-use and CO_2-emission intensities vary across fishing sectors and regions, cautioning against transferring intensity estimates between fisheries without considering regional differences in fishing activity and catch.

The monthly fluctuations observed at *Chinnamuttom* suggest that FUI and CEI should not be regarded as fixed characteristics of a fishing method. Instead, both indicators reflect the relationship between fuel consumed and catch obtained during a particular observation period. A higher intensity may occur when fuel consumption increases relative to catch or when lower catches are obtained despite continued fuel use. Conversely, a higher catch relative to fuel consumption can reduce the intensity value. Consequently, the three systems do not provide

a balanced month-by-month comparison across the entire study period. As Greer et al. (2019) also demonstrated, differences in data coverage and regional fishing characteristics can affect comparisons of fuel use and emissions.

Implications for fuel management in fishing operations

This interpretation is supported by Devi et al. (2021), who recommended measures to improve the fuel and emission performance of trawler fleets, including attention to fishing capacity and engine power. Vivekanandan et al. (2013) likewise highlighted the potential for improving fuel efficiency and reducing CO_2 emissions from Indian marine fishing boats. Together, these studies indicate that vessel-level fuel monitoring and operational improvements are relevant areas for fisheries-management research.

At the broader scale, Parker et al. (2018) demonstrated that fuel consumption contributes substantially to the greenhouse-gas emissions associated with marine fisheries. Greer et al. (2019) further showed that fuel use and emission intensity vary between fishing sectors and regions, highlighting the importance of context-specific assessments. The present study contributes to this evidence by providing a local comparison of trawlers, gillnetters and longliners at *Chinnamuttom*.

Conclusion

The present study compared the fuel-use intensity (FUI) and carbon-emission intensity (CEI) of trawlers, gillnetters and longliners operating from *Chinnamuttom* Fishing Harbour, Tamil Nadu, during December 2025–May 2026. The results revealed differences in fuel requirements and estimated operational CO_2 emissions relative to landed catch among the three fishing systems. Trawlers recorded the highest mean FUI (0.533 kg fuel kg^{-1} fish) and CEI (1.673 kg CO_2 kg^{-1} fish), whereas longliners recorded the lowest mean values (0.301 kg fuel kg^{-1} fish and 0.844 kg CO_2 kg^{-1} fish, respectively). Gillnetters showed intermediate mean values, with an FUI of 0.337 kg fuel kg^{-1} fish and a CEI of 0.947 kg CO_2 kg^{-1} fish.

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Author contribution

Denorish D: conceptualization, methodology, validation, formal analysis, investigation, data curation, writing-original draft, visualization. Amrutha R Krishnan: conceptualization, methodology, validation, formal analysis, writing-original draft, project administration.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval

This article does not content any experimental studies with animals performed by any of the authors.

Declarations

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

Conflict of interest

The author declares no competing interests.

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