

# FUEL CONSUMPTION AND GREENHOUSE GAS EMISSIONS FROM GLOBAL TUNA FISHERIES: 2024 UPDATED REPORT



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# Fuel Consumption and Greenhouse Gas Emissions from Global Tuna Fisheries: 2024 Updated Report

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International Seafood  
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## Executive Summary

Global tuna fisheries are amongst the largest and most valuable marine capture fisheries in the world. As the climate continues to warm, it is critical to understand the scale of this industry's fuel use and related greenhouse gas (GHG) emissions, enhancing the sustainability of this fishery while contributing to global climate goals.

In 2010, Dr. Peter Tyedmers and Dr. Robert Parker undertook work for the International Seafood Sustainability Foundation (ISSF) to quantify direct fuel use and associated GHG emissions from tuna fishing vessels for the 2009 fishing year. The current study serves as an update to the original assessment, providing a snapshot of fuel use and related GHG emissions estimate of global tuna fisheries and supporting activities as of 2023. By comparing the current findings with the earlier project results and data published in the literature, this report also aims to provide a sense of the trajectory of fuel use and resulting GHG emissions within tuna fisheries, as well as to identify opportunities for further improvement.

Results are based on an analysis of industry surveys from ISSF's contact network, reporting catch and fuel use data from 78 fishing vessels and 18 transshipment vessels from 2023. Overall, these vessels accounted for 5.3% of global tuna landings and approximately 9.1% of all tuna transshipped in 2023. Results indicate that fishing operation specific fuel use intensity (FUI) averaged 508 L/t across all vessels reporting and was lowest amongst purse seiners (496 L/t), followed by handline (516 L/t), pole and line (750 L/t) and longline (1,523 L/t) vessels. Species-specific results indicate that skipjack tuna had the lowest average fishing related FUI (494 L/t), followed by yellowfin (503 L/t), bigeye (536 L/t), and albacore (1,522 L/t). Though fuel inputs to helicopters and spotter vessels used to target tuna schools only accounted for ~1% of fishing operation related fuel use, when fuel burned by transshipment vessels are included, the global average FUI increased by ~15% to 582 L/t of tuna caught and delivered to a port. Patterns of GHG emission intensities mirror vessel- and gear-specific FUI but depend on the fuel type that is combusted with life cycle emission intensities being greatest when using marine fuel oil and lowest when using diesel. Overall, fuel use related GHG emissions are estimated to fall between 1,574 and 1,808 kg CO<sub>2</sub>-eq/t of tuna caught and transshipped globally in 2023.

Compared to findings from 2009, FUI and resulting GHG emission intensities from fishing-related activities have increased ~27% per average tonne of tuna caught, though species-, gear- and basin-specific apparent changes vary considerably. Importantly, some of the apparent changes between 2009 and 2023 are likely a product of an overly small and hence biased sample size for 2023 fishing operations. The substantial overall apparent increase in FUI across tuna fisheries is concerning and efforts are warranted to work to reverse this trend.

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## Glossary

<b>CFP</b>	Carbon Footprint of a Product
<b>CO<sub>2</sub>-eq</b>	Carbon Dioxide Equivalent
<b>CPUE</b>	Catch Per Unit Effort
<b>FAD</b>	Fish Aggregating Device
<b>FAO</b>	Food and Agriculture Organization
<b>FEUD</b>	Fisheries Energy Use Database
<b>FSC</b>	Free-Swimming School
<b>FUI</b>	Fuel Use Intensity
<b>GHG</b>	Greenhouse Gas
<b>GRT</b>	Gross Register Tonnage
<b>HP</b>	Horsepower
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>ISSF</b>	International Seafood Sustainability Foundation
<b>L</b>	Litre
<b>m</b>	Metre
<b>MFO</b>	Marine Fuel Oil
<b>MGO</b>	Marine Gas Oil
<b>t</b>	Tonne (metric)
<b>UK</b>	United Kingdom
<b>US</b>	United States
<b>USD</b>	United States Dollar
<b>WCPO</b>	Western Central Pacific Ocean

## 1. Introduction

In 2016, the Paris Agreement was established to limit the global average temperature to 1.5°C above pre-industrial levels by the end of the century. Despite the commitment of 196 Parties, global temperatures have continued to rise with 2024 being the warmest year on record and exceeding the 1.5°C above pre-industrial levels global average threshold for the first time (World Meteorological Organization, 2025). The Intergovernmental Panel on Climate Change (IPCC) highlights essential pathways for enhancing human responses to climate change, emphasizing the need for individuals to reconsider lifestyle and dietary choices – particularly regarding the greenhouse gas (GHG)-intensity of food consumption (IPCC, 2018).

Global food systems, including production, processing, packaging, transport, and consumption, are responsible for approximately one-third of global anthropogenic GHG emissions (Crippa et al., 2021). Beyond emissions, these systems contribute to other environmental issues such as eutrophication, land use change, biodiversity loss, and soil degradation, which further exacerbate climate change (Poore & Nemecek, 2018). Notably, livestock production is a major contributor to GHG emissions and environmental impacts more generally within food systems, occupying approximately 70% of all agricultural land (directly or indirectly through feed production) and accounting for approximately half of all food-related GHG emissions (Sakadevan & Nguyen, 2017). While producers can take steps to reduce livestock-related emissions (Herrero et al., 2016; Pelletier, 2018; Poore & Nemecek, 2018), consumers have a significant opportunity to limit their impact through more environmentally conscious food choices (Poore & Nemecek, 2018).

In general, marine capture fisheries offer a lower-emission source of high quality animal protein compared to traditional livestock systems (Bianchi et al., 2022; Gephart et al., 2021; Parker & Tyedmers, 2015) while also supporting economies and providing critical sources of protein and micro-nutrients in less industrialized nations' diets (United Nations Conference on Trade and Development, 2024). Despite their lower carbon footprint, fisheries remain energy-intensive systems, with fishing fleets globally estimated to burn 30 to 40 million metric tonnes of fuel annually, resulting in significant CO<sub>2</sub> emissions (Parker et al., 2018; Tyedmers et al., 2005). Given the critical role that marine capture fisheries play in providing sustainable protein sources and supporting global economies, a comprehensive GHG assessment of these fisheries is essential. Global tuna fisheries, in particular, stand out not only for their total combined landings and their economic value, but also for their significant contribution to global high seas catches.

Global tuna fisheries are amongst the largest and most valuable marine capture fisheries in the world. When taken together, global fisheries for skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*T. obesus*), albacore (*T. alalunga*), and various

bluefin tuna species (*T. thynnus*, *T. orientalis*, *T. maccoyii*) had an estimated value of USD \$40.8 billion in 2018 (Pew Charitable Trusts & Poseidon Aquatic Resource Management Ltd., 2020). Together these species account for approximately 61% of total high seas catch by weight, emphasizing the scale of the tuna industry (Xie et al., 2023). Given the magnitude and importance of tuna fisheries globally, understanding the scale of its fuel use and related GHG emissions becomes increasingly vital – both as a basis upon which comparisons can be made with other sources of animal protein and to provide a benchmark against which future performance and fuel use/emissions reduction efforts can be judged. By identifying opportunities to reduce emissions, we can enhance the sustainability of this industry while contributing to global climate goals.

### *1.1. Fuel Use and Resulting GHG Emissions of the Global Tuna Fishery*

The modern global tuna fishing sector is composed of thousands of vessels that deploy one of five primary fishing gears (purse seine, longline, pole and line, gillnet, and troll). What they have in common is a dependence on the combustion of fossil fuels for a wide range of activities including principally fishing vessel propulsion and navigation, but in some instances, securing bait, identification of tuna schools, and the maintenance of cold storage of catch. Previous studies that have quantified the life cycle GHG emissions of tuna fishing activities up to the point at which tuna are landed have found that fuel combustion on tuna fishing vessels themselves typically accounts for the vast majority of GHG emissions in the fish supply chain (Avadí et al., 2015; Hospido & Tyedmers, 2005; Parker et al., 2018). In fact, Hospido and Tyedmers (2005) estimate that fuel combustion from tuna fishing vessels accounts for 60% to 90% of total emissions to the point of landing, surpassing the cumulative energy use and GHG emissions from processing, packaging, and transport of products (except when products are transported via air) (Hospido & Tyedmers, 2005; Ziegler et al., 2016). In addition to GHG emissions, vessel fuel consumption has also been identified as the primary driver of environmental toxicity, acidification, eutrophication, particulate matter, and abiotic resource depletion, further emphasizing the impact of vessel fuel consumption as a life cycle environmental hotspot within marine capture fisheries.

Given the list of environmental impacts associated with fishing vessel fuel consumption, increasing fuel efficiency must be a focal point when looking for opportunities to reduce the carbon footprint and related impacts of the global tuna fishery. Fuel use intensity (FUI) is often used to quantify fuel consumption of fishing vessels, or fisheries more generally, and is most frequently expressed as the litres of fuel required to catch one tonne of landings. Between fisheries, FUI has been found to vary over at least three orders of magnitude (Parker & Tyedmers, 2015). Many factors influence a fisheries FUI, including the relative abundance of a targeted stock both relative to other species, and from year to year (Bryne et al. 2021; Chassot et al., 2021), the fishing gear used (Driscoll & Tyedmers, 2010; Parker & Tyedmers, 2015), distance travelled to fishing grounds and duration of fishing trips (Basurko et al.,

2021), the relative skill of skippers and crews (Ruttan & Tyedmers, 2007), and the use of fish aggregating devices (FADs) (Basurko et al., 2022; Parker et al., 2015). Introducing more energy-efficient technologies, optimizing fishing routes, and ultimately transitioning to renewable energy sources for fishing vessels are potential strategies for reducing the FUI and GHG emissions associated with tuna fishing. Additionally, using more efficient gear and reducing bycatch can lead to shorter trips and lower fuel consumption, further decreasing emissions.

Ultimately, the tuna industry has an opportunity to address its fuel use and resulting GHG emissions through innovative practices and collaborative efforts among stakeholders. Measuring and improving the energy use and associated GHG emissions in the global tuna fishery can provide the industry a competitive advantage in the food industry, demonstrating interest on the part of fishermen and fishing companies in improving environmental performance, actively tracking and demonstrating improvements in performance, and communicating to consumers any relative environmental benefits in choosing certain products over others.

### *1.2. Fuel Use in the Global Tuna Industry: 2010 Study*

In 2010, Dr. Peter Tyedmers and Dr. Robert Parker were contracted by the International Seafood Sustainability Foundation (ISSF) to quantify direct fuel use and associated GHG emissions from tuna fisheries globally as of 2009. Using survey instruments, the researchers collected data on a range of vessel-specific attributes (e.g. vessel size, gear used, etc), fishing operations (e.g. days at sea, ocean basin of operation, etc), fuel use, and total tonnage and species composition of landings. From these data, FUI and associated GHG emissions of tuna fisheries were quantified for the 2009 fishing year (Tyedmers & Parker 2012). Results from this study showed that FUI varied according to fishing gear and target species. For example, fisheries that use purse seine fishing gear, primarily targeting skipjack and yellowfin tuna, had an average FUI of 390 litres (L) of fuel per tonne of tuna landed. In contrast, fisheries that use longline, and troll gears, that primarily target albacore and bluefin tuna, burned between 1070 L and 1490 L of fuel per tonne of tuna landed (Tyedmers & Parker, 2012). Results also revealed that FUI can increase substantially with the use of FADs, a phenomenon that had, to that point, not been previously described.

That study was the first global examination of direct fuel consumption by the world's tuna fishing fleets, providing a baseline for future assessments. Given that fifteen years have passed since the previous GHG assessment, ISSF has once again contracted Dr. Peter Tyedmers to complete a fuel use and related GHG emissions estimate of global tuna fisheries and supporting activities as of 2023. This report serves as an update to a fuel use study conducted over a decade ago, which established baseline data on fuel consumption patterns and emissions associated with the global tuna fishery. Since then, changes in the global tuna

industry fishing practices may have influenced fuel efficiency and environmental impact. In addition, potential sources of additional fuel consumption that support tuna fishing operations (e.g. fuel inputs to helicopters or spotter vessels used to identify tuna schools or vessels used for transshipping tuna) and not addressed in the first assessment by Tyedmers and Parker (2012), were to be included. By comparing the current findings with the earlier project results and data published in the literature, this report aims to provide a comprehensive assessment of progress made in reducing fuel use and emissions within the tuna fishery, as well as to identify opportunities for further improvement.

## **2. Research Objectives**

Due to the widespread threat of climate change, it is critical to reduce GHG emissions associated with the global tuna fishery. As such, the objectives of the 2023 fuel use study are to 1) estimate average fuel use intensities and scope 1 GHG emissions of contemporary tuna fisheries, differentiating where possible on the basis of species targeted (excluding bluefin), gear deployed, and fishing location in terms of ocean basins; and 2) estimate the scale of global fuel consumption and resulting GHG emissions associated with total global tuna fisheries. This study provides a snapshot of the current state of fuel consumption in the global tuna fishery, highlighting how fuel consumption has changed since 2009.

Data collection was carried out between April and November 2024, by Dr. Peter Tyedmers and Sarah Donovan of the School for Resource and Environmental Studies at Dalhousie University, Canada. The project was supported and facilitated by the ISSF. In addition to the two primary research objectives outlined above, this research also set out to:

- Synthesize and report published data regarding fuel use in tuna fisheries.
- Identify trends, if any, in FUI in tuna fisheries through time.
- If possible, re-visit the relationship between FUI and the relative dependence on FAD fishing strategies.

## **3. Materials and Methods**

### *3.1. Primary Data Collection – Survey Distribution*

In this study, primary data on 2023 global tuna fishing operations were gathered through the distribution of two survey instruments. The surveys were developed by Dr. Peter Tyedmers and Sarah Donovan, with input from ISSF staff over the first quarter of 2024.

Potential survey respondents were identified through ISSF's contact network. Prior to survey distribution, Dr. Peter Tyedmers delivered an informative presentation to potential respondents on February 21<sup>st</sup>, 2024. The purpose of this presentation was to enhance transparency of the project by briefing ISSF contacts on the scope of the current study, highlighting the importance of this research, answering questions/concerns that may arise,

and building trust between the potential respondents and researchers. In addition to the presentation by Peter Tyedmers and in advance of survey distribution, a letter from Susan Jackson, President of ISSF, was emailed to ISSF's contact network in April 2024, announcing the upcoming project and encouraging all participating companies to share data (Appendix A).

Survey A, titled *Fuel Use and Greenhouse Gas Emissions from Tuna Fishing in 2023 – Study of Fishing Vessel Operations*, was designed to elicit several vessel- or fleet-specific characteristics and operational details for the 2023 fishing year. This survey was based, in part, on the survey employed by Tyedmers and Parker to characterize fuel use in tuna fisheries in 2009 but was refined in a number of ways. While the target year was 2023, respondents were encouraged to provide data for additional years, if possible. Survey A requested data on the following information:

- Vessel length, gross registered tonnage (GRT), and engine horsepower;
- Fishing basin (Indian, Atlantic, Western Pacific, Eastern Pacific);
- Primary and secondary fishing gears;
- Use of FADs;
- Number of days at sea and number of days actively fishing tuna;
- Total fuel consumption by fishing vessel;
- Total fuel consumption by scouting helicopters (if applicable);
- Proportion of tuna transferred to a transshipment vessel; and
- Landings of all tuna and non-tuna species.

Survey B, titled *Fuel Use and Greenhouse Gas Emissions from Tuna Fishing in 2023 – Transport Vessel Operations Survey*, was developed specifically to characterize fuel inputs to tuna transshipment vessel operations during the target fishing year. Survey B elicited the following information on tuna transport vessel operations:

- Vessel length, gross registered tonnage (GRT), and engine horsepower;
- Fishing basin (Indian, Atlantic, Western Pacific, Eastern Pacific);
- Total fuel consumption by transport vessel; and
- Mass and type of tuna transported.

A cover letter, signed by Susan Jackson (Appendix B), along with both surveys (Appendices C and D) were first distributed by ISSF via email on April 26<sup>th</sup>, 2024, to approximately 500 contacts. Respondents were asked to return completed surveys either directly to a designated email account set up for the purposes of this study, or to forward them through ISSF or other industry contact persons. Surveys and cover letters were distributed again in June 2024 and October 2024, to encourage more participation in the study.

The use of surveys to elicit data from industrial fisheries is associated with a number of challenges (Taherdoost, 2021). The most prominent obstacle is the potential of a low response rate resulting from reluctance on the part of vessel owners or operators to provide company-specific data, time constraints on vessel owners and operators, and/or effort required to access and gather requested information. Additional challenges include possible bias as a result of self-reporting, possible confusion as to what information is being requested, and sample bias as a result of how and to whom the survey is distributed.

## 3.2. Data Analysis

### 3.2.1. Fuel Use Intensity

#### 3.2.1.1. Tuna Fishing Operations

Primary data from Survey A was compiled in a Microsoft Excel spreadsheet for analysis. Where data provided were unclear, the data provider was contacted to clarify what was represented or intended. Fuel use and landings data were converted as necessary into standard metric units. Fuel use by fishing vessels, helicopters, and scouting boats (if applicable) were summed together for a total fuel use volume for each vessel, or set of vessels, represented in a single returned survey. Similarly, for each survey, landed fish species were aggregated into the following species/groups: skipjack tuna, yellowfin tuna, albacore tuna, bigeye tuna, and ‘other’ species. FUI (total fuel burned in litres divided by total live weight tonnes of fish landed) was calculated for each vessel or vessels represented in a survey and any obvious or potentially erroneous datasets (e.g. where apparent FUI appeared to be unrealistically high or low) were flagged for review and confirmation of the validity of the underlying data with the data provider. Once all data for each submitted dataset were standardized and checked, weighted average FUIs were calculated on the basis of gear type, ocean basin of operation, and species landed, by dividing the total fuel use by the mass of landings.

#### 3.2.1.2. Transshipment Vessels

Primary data from Survey B and alternate sources (i.e. spreadsheet of data provided as an e-mail attachment) were summarized in a Microsoft Excel spreadsheet. Where data provided were unclear, the data provider was contacted to clarify what was represented or intended. Fuel use and landings data were converted as necessary into standard metric units. If fuel quantity was provided on a mass basis, the density of fuel was assumed to be the same as marine fuel oil (MFO), with a density of 0.9 kg/L and fuel use was converted to litres. Fuel use intensity of transshipment activities was calculated by summing the total fuel quantity reported and dividing by the total mass of tuna transported during the reporting period. The average FUI for transshipment vessels was weighted by mass of tuna transported.

To quantify the amount of tuna transshipped for the reported fishing vessels in Survey A, secondary data was used to estimate the proportion of tuna transshipped across the world

(Poseidon Aquatic Resource Management Ltd., 2022). *Table 1* outlines the proportions of tuna transshipped according to ocean basin and gear type (Poseidon Aquatic Resource Management Ltd., 2022). It must be noted the secondary data only accounts for purse seine and longline vessels.

Using the relative proportions of tuna transshipped for each gear type, the calculated FUI for transshipment vessels was added to the FUI of fishing vessels in Survey A, to account for the additional fuel use from transshipments. Although only purse seine and longline gear types were represented by the secondary data, it is assumed that alternate gear types (i.e. pole and line and handline) have the same proportion of tuna transshipped as purse seine tuna. Since evidence suggests that purse seine caught tuna has the highest rate of transshipment (in port), this is a worst-case estimate of transshipment rates (Poseidon Aquatic Resource Management Ltd., 2022). In this study, a worst-case estimate is defined as an estimate that is likely to be larger than the actual value, to avoid underestimating FUI and associated GHG emissions.

**Table 1.** Proportion of tuna transshipped according to ocean basin and gear type as reported by Poseidon Aquatic Resource Management Ltd., 2022.

Ocean Basin	Gear Type	Proportion of Tuna Transshipped
Antarctic Ocean	PS	0%
	LL	38%
Atlantic Ocean	PS	49%
	LL	49%
East Pacific Ocean	PS	0%
	LL	41%
Indian Ocean	PS	41%
	LL	31%
Western Central Pacific Ocean	PS	45%
	LL	34%
<b>Total</b>	<b>PS and LL</b>	<b>39%</b>

### 3.2.2. Greenhouse Gas Emissions from Fishing Vessel Operations

In this study, there is uncertainty about the type of fuel used by reporting fishing vessels. To show the best-case and worst-case scenario for GHG emissions from fishing vessel operations, a sensitivity analysis was conducted on the type of fuel burned considering 100% diesel fuel or 100% MFO. GHG emissions per tonne of tuna landed were calculated using emissions factors from the *UK Government GHG Conversion Factors for Company Reporting* (Department of Energy Security and Net Zero, 2024). The emissions intensities reported by the UK Government consider the entire life cycle of the fuel, accounting for emissions from extraction, processing, right through to combustion. While alternative fuels,

such as marine gas oil (MGO), are also used by fishing vessels, MFO has the highest emissions intensity of fuels considered, and diesel has the lowest emissions intensity of fuels considered (*Table 2*).

GHG emissions are reported in kg carbon dioxide-equivalent emissions (CO<sub>2</sub>-eq) per live weight tonne of tuna landed and weighted by mass of landings.

**Table 2.** Emissions factors according to *UK Government GHG Conversion Factors for Company Reporting*.

Type of Fuel	Emissions Intensity (kg CO <sub>2</sub> -eq/L)
Combusted Marine Fuel Oil (MFO)	3.11
Combusted Marine Gas Oil (MGO)	2.77
Combusted Diesel Fuel	2.70

### 3.2.3. Fuel Use Intensity and Carbon Footprint of the Global Tuna Fleet

Resulting estimates of ocean basin-, gear-, and species-specific FUI and GHG emissions were used to estimate the fuel inputs and carbon footprint of the global tuna fishing fleet. The global 2023 species- and basin- specific reported landings of skipjack, yellowfin, albacore, and bigeye tuna were used to scale up the current study’s data to the global level (ISSF, 2025). Species-specific and basin-specific landings by gear were also assumed using data from ISSF (ISSF, 2025). *Table 3* outlines the fishing gear assumptions, as a proportion of total tuna landed globally, as provided by ISSF.

**Table 3.** Assumed percent of global tuna caught according to fishing gear employed (ISSF, 2025).

Gear Type	Percentage of Global Tuna Catch
Purse Seine	67.0%
Longline	9.5%
Pole and line	6.4%
Gillnets	3.5%
Trolling	1.2%
Other	12.3%

### 3.3. Secondary Data Compilation

In addition to collecting primary data from vessels engaged in tuna fishing operations, this study sought to gather and synthesize pre-existing data on tuna fisheries and fuel use. The previous study, conducted in 2010, synthesized then extant published fuel use data in tuna fisheries from 1980 to 2010. Here, we build on that effort and report FUI of tuna fishing activities taken from peer-reviewed articles, grey literature, and academic publications over the time period from 2010 to 2023.

To identify relevant studies for this review, a systematic search was conducted in Google Scholar and Scopus between March 2024 and April 2024. The databases were filtered to return English articles published after 2010. The search strategy used a combination of keywords and Boolean operators (AND, OR) to capture the most relevant articles. The following search strategies were employed in both Google Scholar and Scopus:

- “Fuel Use” OR “Greenhouse Gas Emissions” AND “Tuna” AND “Fishing”
- “Life Cycle Assessment” AND “Tuna” AND “Fishing”

Data on FUI, GHG emissions, total catch, and vessel characteristics were drawn from relevant articles. If studies only reported results in terms of GHG emissions, the UK emissions factor for MFO was used to estimate associated vessel fuel use. These data were compiled and recorded in the Fisheries and Energy Use Database (FEUD), maintained by Drs. Tyedmers and Parker. Following the literature review, all data regarding fuel inputs, landings by species, and vessel and gear characteristics of fisheries reporting tuna landings were extracted from the FEUD database and compiled in a Microsoft Excel spreadsheet, noting the year, gear, locale, primary target species, landings by species, and reported FUI.

While a literature review reveals FUI trends for the broader tuna fishery, incorporating data from secondary sources can also present several challenges due to differences in methodologies. For instance, FUI estimates may be derived from actual fuel consumption reports, measured by on board fuel flow monitors, calculated from fuel expenditure data, or modeled using fishing effort or other data. Additionally, some studies focus on data from a single vessel, while others represent several vessels or even an entire national fleet. Similarly, some studies provide FUI measurements for specific tuna species (e.g., skipjack, yellowfin), while others report FUI for vessels or fleets targeting multiple species with landings composition undifferentiated. These limitations must be noted when analyzing FUI trends from 2010 to 2023.

## **4. Results**

### *4.1. Summary of Data Collection*

#### *4.1.1. Survey A*

Primary data collection yielded 26 Survey A submissions. After data quality checks, completed surveys successfully produced 26 data points, representing a total of 78 vessels whose 2023 fishing activities spanned three ocean basins (Atlantic, Indian, and Pacific) and employed four different gears (*Table 4*). Despite a concerted effort to secure data representative of diverse tuna fisheries from around the world, the data secured is heavily skewed to vessels fishing with purse seine gear (representing 99% of total landings of responding vessels) and vessels fishing in the Pacific Ocean (71% of total landings of responding vessels).

Overall, the reporting fishing vessels landed approximately 273,115 tonnes of tuna and burned approximately 139 million L of fuel in 2023 (*Table 4*). Reporting vessels varied by size, engine horsepower, and fishing effort, with purse seine vessels generally being larger, more powerful, and more continuously engaged in fishing than vessels deploying other gears (*Table 5*). Helicopters and scouting vessels accounted for approximately 1% of total fishing vessel-related fuel use.

**Table 4.** Summary of landings and fuel use by ocean, gear, and species in 2023 for reporting vessels (PS = purse seine, LL = longline, PL = pole and line, HL = handline).

Ocean	Gear	# of vessels	Skipjack Landings (t)	Yellowfin Landings (t)	Albacore Landings (t)	Bigeye Landings (t)	Other Landings (t)	Total Landings (t)	Total Fuel Use (L)
Pacific	PS	48	69,764	115,121	-	5,487	395	190,767	92,629,056
	LL	14	38	764	1,666	301	419	3,188	4,885,316
	PL	3	337	232	-	7	-	577	497,228
	HL	1	1	6	0	1	1	8	4,025
Atlantic	PS	-	-	-	-	-	-	-	-
	LL	-	-	-	-	-	-	-	-
	PL	3	-	74	112	6	-	192	79,100
	HL	-	-	-	-	-	-	-	-
Indian	PS	9	45,688	24,083	23	7,789	800	78,383	41,004,537
	LL	-	-	-	-	-	-	-	-
	PL	-	-	-	-	-	-	-	-
	HL	-	-	-	-	-	-	-	-
<b>Total</b>		<b>78</b>	<b>115,828</b>	<b>140,281</b>	<b>1,801</b>	<b>13,590</b>	<b>1,614</b>	<b>273,115</b>	<b>139,099,262</b>

**Table 5.** Characteristics of fishing vessels and tuna fishing activities in 2023 of vessels reporting (PS = purse seine, LL = longline, PL = pole and line, HL = handline). Averages are weighted based on the number of vessels represented in each survey.

Ocean	Gear	# of vessels	Average vessel length (m)	Average GRT (t)	Average main engine HP	Average auxiliary engine HP	Average days actively fishing tuna
Pacific	PS	48	63.20	1368.37	3096.72	1843.31	412.46
	LL	14	34.90	219.49	1073.51	247.71	1048.29
	PL	3	30.00	169.00	756.34	0.00	368.00
	HL	1	9.00	1.00	15.00	0.00	115.00
Atlantic	PS	-	-	-	-	-	-
	LL	-	-	-	-	-	-
	PL	3	16.57	34.50	346.88	-	-
	HL	-	-	-	-	-	-
Indian	PS	9	86.73	2459.33	5488.35	1948.95	477.78
	LL	-	-	-	-	-	-
	PL	-	-	-	-	-	-
	HL	-	-	-	-	-	-

#### 4.1.2. Survey B

Data collection efforts yielded five Survey B submissions. Three of these submissions were duplicates of the same fishing operation-related data provided in response to Survey A – the data provided did not reflect transshipment fuel use but fishing activity fuel use – and a fourth Survey B submission did not provide any data. Therefore, Survey B only yielded 1 data point. Fortunately, through contact with companies that either provided detailed data in support of Survey A, or that were interested in helping to leverage data in support of this work, additional data on transshipment vessel operations in 2023 were secured in the form of Excel spreadsheets. These additional datasets provided details on the number of vessels represented; individual or average vessel characteristics; mass of skipjack, yellowfin, bigeye, and albacore transported; and quantity and in some instances types of fuel burned.

After data quality checks, data from the operation of 18 transshipment vessels operating in the Western Central Pacific Ocean (WCPO) in 2023 were secured. These vessels together transported a total of 182,974 tonnes of tuna and burned just shy of 37 million L of fuel (*Table 6*).

**Table 6.** Summary of tuna transshipment vessel characteristic, tonnage shipped, and fuel use by vessels transporting tuna in the Western Central Pacific Ocean in 2023.

# of Vessels	Average Length (m)	Average GRT	Average Engine Power (HP)	Total Mass of Tuna Transported (t)	Fuel Use (L)
1	120.7	4,444	4,120	12,668	2,213,300
1	120.2	4,574	4,120	15,184	2,390,688
1	120.7	4,430	4,121	14,505	2,062,834
1	133.8	6,971	5,100	15,699	3,175,528
1	120.2	4,574	4,120	16,134	2,518,634
1	133.95	6,989	4,350	9,749	2,303,000
1	121.9	4,830	5,295	5,784	2,101,472
1	121.9	4,830	5,295	10,046	1,258,706
10	-	4,879	3,832	83,206	14,621,560
<b>Total</b>				<b>182,974</b>	<b>32,645,722</b>

## 4.2. Representation of Global Tuna Fishing Fleet

### 4.2.1. Total Landings

Data reported in this study represent approximately 5.3% of total global reported landings of major commercial tuna species in 2023, as reported by ISSF (*Table 7*). By percentage of total landings, yellowfin tuna fisheries were best represented, with primary data collected via Survey A accounting for approximately 8.9% of global landings, followed by skipjack and bigeye, with primary data accounting for 3.9% and 3.7% of global landings for these species, respectively. Geographically, landings reported in survey responses from the Indian Ocean are best represented, accounting for 6.3% of global reported catches within the Indian Ocean basin in 2023.

**Table 7.** Global reported tuna landings in 2023 and landings reported by respondents in this study.

Ocean	Tuna Species	Global landings in 2023 <sup>a</sup> (t)	Reported landings in this study (t)	Reported landings in this study (% of global landings)
Pacific Ocean	Skipjack	2,007,936	70,140	3.49%
	Yellowfin	1,043,400	116,124	11.13%
	Albacore	101,759	1,666	1.64%
	Bigeye	200,737	5,796	2.89%
	<b>Total</b>	<b>3,353,832</b>	<b>193,726</b>	<b>5.78%</b>
Atlantic Ocean	Skipjack	249,429	-	0.00%
	Yellowfin	139,529	74	0.05%
	Albacore	52,573	112	0.21%
	Bigeye	61,320	6	0.01%
	<b>Total</b>	<b>502,851</b>	<b>192</b>	<b>0.04%</b>
Indian Ocean	Skipjack	688,679	45,688	6.63%
	Yellowfin	401,364	24,083	6.00%
	Albacore	41,685	23	0.06%
	Bigeye	105,877	7,789	7.36%
	<b>Total</b>	<b>1,237,606</b>	<b>77,583</b>	<b>6.27%</b>
Global	Skipjack	2,946,045	115,828	3.93%
	Yellowfin	1,584,293	140,281	8.85%
	Albacore	196,017	1,801	0.92%
	Bigeye	367,935	13,590	3.69%
	<b>Total</b>	<b>5,094,289</b>	<b>271,501</b>	<b>5.33%</b>

a. Landings data from ISSF (ISSF, 2025).

Using data from ISSF that reports percent of global tuna catch by gear type in 2025 (ISSF, 2025), our data are most representative of purse seine tuna fishing operations in that year, accounting for just under 8% of global purse seine tuna catches (*Table 8*).

**Table 8.** Gear-specific landings and landings reported by gear type by survey respondents in 2023.

Gear Type	Percentage of Global Tuna Catch	Estimated Global Landings (t)	Reported Landings in this study (t)	Reported landings in this study (% of global landings)
Purse Seine	67.0%	3,466,864	269,150	7.8%
Longline	9.5%	490,442	3,188	0.65%
Pole and line	6.4%	333,108	769	0.23%
Gillnets	3.5%	179,763	-	-
Trolling	1.2%	64,092	-	-

#### 4.2.2. Tuna Transshipment

Assuming that 39% of all tuna landed is transshipped (see *Table 1*), it is estimated that 2,016,897 tonnes of tuna were transshipped globally in 2023. Transshipment data reported in this study therefore represents approximately 9.1% of global tuna transported via transshipment vessels (*Table 9*).

**Table 9.** Global tuna transshipments in 2023 and reported tuna transshipments by respondents in this study.

Global tuna landings in 2023 (t)	Estimated tuna transshipments in 2023 (t)	Reported tuna transshipped in this study (t)	Reported tuna transshipped in this study (% of global transshipments)
5,171,530.9	2,016,897.1	182,974.2	9.1%

#### 4.3. Fuel Use Intensity

##### 4.3.1. Tuna Fishing Operations

The weighted average FUI of vessels fishing tuna species in 2023 varied by type of gear deployed, species, and ocean basin (*Table 10*). The biggest differences in FUI are observed across fishing gear types, with purse seine being the most efficient gear (496 L/t), followed by handline (516 L/t), pole and line (750 L/t) and longline (1,523 L/t).

The results of this study indicate gear-specific FUI values that in some instances broadly align with, or deviate markedly from, other recent FUI values for tuna fishing reported in the literature. For example, previous research suggests that in some settings, pole and line fishing may be more fuel-efficient than purse seining. For example, a study of the Maldivian pole and line tuna fishery estimated a FUI between 197 L/t and 328 L/t (Miller et al., 2017), while data from Rahmadi et al. (2021) reported a FUI range of 122 L/t to 806 L/t for an Indonesian pole and line fishery. These values indicate that at least in the settings of these previous studies, pole and line fishing for tuna can at times result in much lower FUI than 750 L/t observed in the current study. This difference may be due to differences in fishing practices, relative tuna availability, vessel sizes, operational conditions, or data sources. Additionally, the limited sample size of six pole and line vessels for this study is an issue as the vessels for which we have data may be highly unrepresentative of typical pole and line fishing operations, highlighting the need for further data collection to improve the accuracy of FUI estimates for this gear type.

**Table 10.** Average 2023 fuel use intensities (weighted by landings) of vessels reporting aggregated by ocean, species and gear.

Parameter	Landings reported (t)	FUI (L/t)
Pacific	194,540.0	501.4
Atlantic	192.3	411.3
Indian	78,383.0	522.9
Purse Seine	269,150.3	496.3
Longline	3,188.4	1,523.3
Pole and Line	768.9	749.5
Handline	7.8	516.0
Skipjack	115,828.3	494.0
Yellowfin	140,280.9	502.9
Albacore	1,801.4	1,521.7
Bigeye	13,590.3	535.7
Other	1,614.4	810.0
<b>All tuna</b>	<b>273,115.4</b>	<b>507.5</b>

In contrast, the finding that purse seining for tuna results in a lower FUI compared to other gear types used to catch tunas aligns with many previous studies, including the prior project undertaken for ISSF in 2010 (Avadí & Fréon, 2013; Basurko et al., 2021; Iribarren et al., 2010; Kristofersson et al., 2021; Parker & Tyedmers, 2015; Tyedmers & Parker 2012). This is not overly surprising as purse seining is frequently found to be one of the most energy efficient fishing methods in settings where this gear can be used (e.g. where the target species readily forms schools and occurs within 100m of the surface), resulting in a high catch per unit effort (CPUE) (Basurko et al., 2021; Driscoll & Tyedmers, 2010; Muir, 2015, Parker and Tyedmers, 2015). Consequently, fuel use is allocated across larger quantities of fish, lowering the FUI and carbon footprint per tonne of fish landed. In contrast, passive fishing gears such as handline and longline encounter target fish by chance, often resulting in a lower CPUE and higher FUI per tonne of fish landed.

In this study, the most to least fuel-efficient species caught were skipjack (494 L/t), followed by yellowfin (503 L/t), bigeye (536 L/t), and albacore (1,522 L/t) (*Table 10*). According to Parker et al. (2015), skipjack and yellowfin tuna account for the vast majority of fish landed within the purse seine tuna fishery, with skipjack accounting for 2/3 of all purse seine tuna landings. Given the efficiency of purse seine fishing gear, it is logical that skipjack and yellowfin have the lowest FUI of all tuna species evaluated in this study. In contrast, longline is one of the main fishing methods for albacore, explaining the higher FUI associated with this tuna species in the current study (Pew Charitable Trusts & Poseidon Aquatic Resource Management Ltd., 2020). Bigeye tuna is caught using a combination of both purse seine and longline fishing methods, with these two gear types accounting for 85%-90% of the Western and Central Pacific bigeye catch each year (Post & Squires, 2020). In the current study, the

majority of bigeye tuna is caught via purse seine, influencing the low FUI observed for this tuna species.

#### 4.3.2. Transshipment Vessels

In this study, the weighted average FUI of transshipment vessels operating in the WCPO was calculated to be approximately 190.7 L/t of tuna transshipped. According to transshipment statistics summarized in *Table 1*, approximately 45% of purse seine caught tuna are transshipped within the WCPO. For the purpose of this study, it is assumed that 45% of all tuna is transshipped in the Pacific Ocean, regardless of fishing gear employed, given that purse seine is the dominant gear type used to fish tuna globally and in the data collected here. When applying the weighted average transshipment FUI to 45% of tuna caught in the Pacific Ocean, the FUI of tuna fishing operations increases from 501 L/t to 587 L/t of tuna caught and transshipped (*Table 11*). This represents a 17.1% increase in FUI per tonne of tuna landed when accounting for the fuel use contributions of transshipment vessels.

Although this study did not obtain fuel use data for transshipment vessels operating in the Atlantic and Indian Ocean, we used the calculated FUI of transshipment vessels in the WCPO to estimate the fuel use contributions of transshipment vessels in other ocean basins. It must be noted that there is a large uncertainty associated with this assumption as there are differences in distances typically travelled in the WCPO when compared to other ocean basins. The use of the WCPO transshipment vessel FUI likely results in an overestimate of global transshipment vessel contributions, given the Pacific is the largest ocean basin and transshipment vessels are likely to travel great distances, and consequently burn more fuel.

According to transshipment statistics summarized in *Table 1*, approximately 39% of purse seine caught tuna are transshipped between ports globally. If we assume the calculated transshipment vessel FUI (190.7 L/t) is representative across all ocean basins, and apply the FUI to 39% of tuna landings reported in this study, the overall average FUI increases from 508 L/t to 582 L/t (*Table 11*). This represents a 14.5% increase in FUI per tonne of tuna landed across ocean basins when accounting for the fuel use contributions of transshipment vessels.

**Table 11.** Contributions of transshipment vessels to FUI of tuna landed in Pacific Ocean and across all ocean basins. The FUI for transshipment vessels was calculated to be 190.7 L/t of tuna transshipped.

Ocean Basin	Assumed Proportion of Tuna Transshipped	Average FUI of Tuna Fishing Vessels (L/t)	Average FUI of Tuna Fishing & Transshipment Vessels (L/t)	% Increase
Pacific Ocean	45%	501.4	587.3	17.1 %
All Ocean Basins	39%	507.5	581.9	14.5%

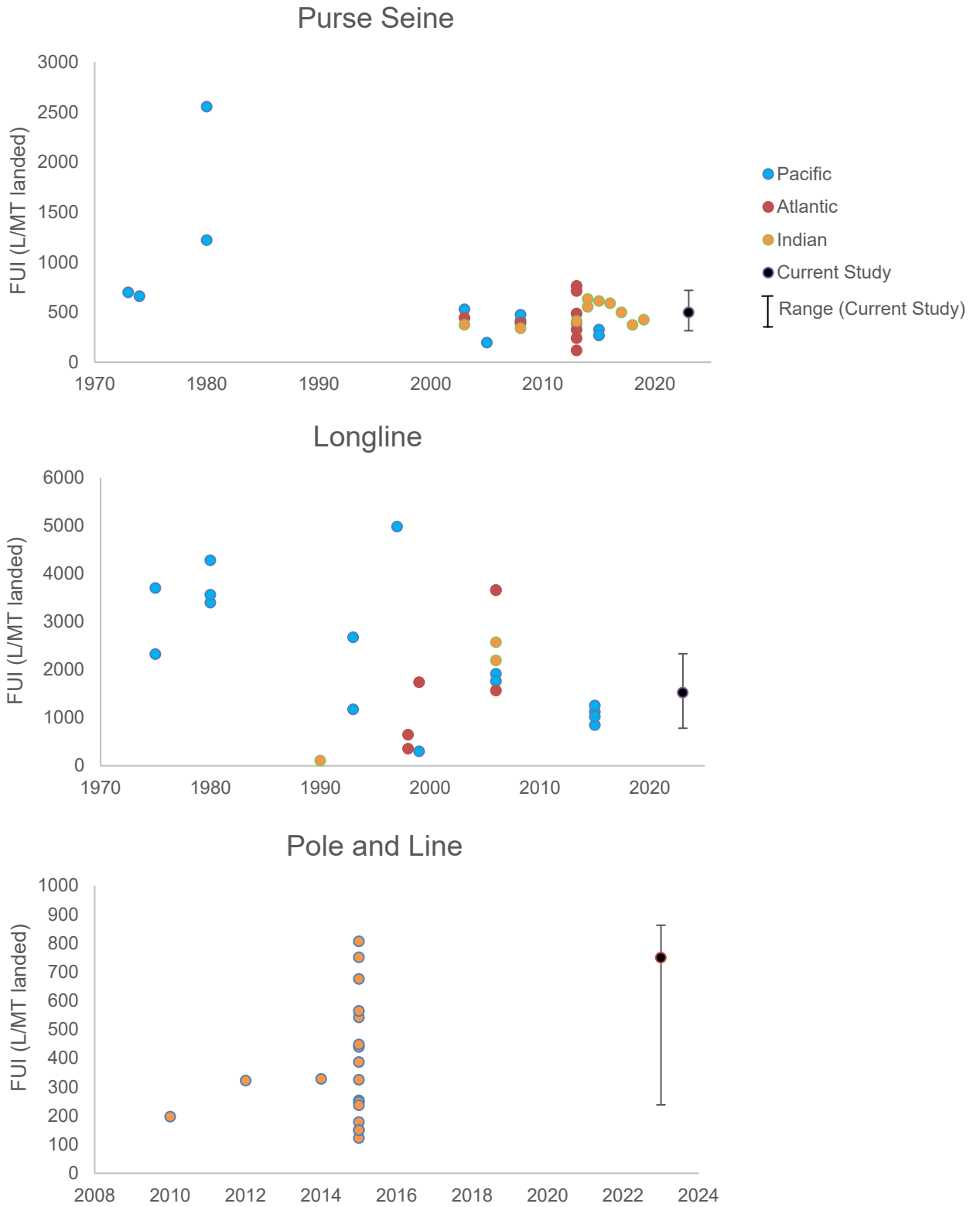
Due to the high proportion of tuna transshipped across the world, the exclusion of transshipment vessel fuel use in prior efforts to characterize the fuel use and GHG emissions of tuna fishing (e.g. Hospido & Tyedmers, 2005; Parker et al., 2015) represents a major oversight in fuel use estimations. When scaling the FUI up to the global fishing fleet, this exclusion can severely underestimate fuel use and associated GHG emissions. Despite the scale of transshipment fuel use, no fuel use studies have accounted for the fuel use contributions of transshipment vessels within the tuna fishing industry, to our knowledge. Future studies should ideally consider the additional fuel use from transshipment vessels, particularly when a relatively large fraction of landings are transshipped, to ensure the efforts to characterize both fuel use and GHG emissions of marine-capture fisheries are representative.

#### *4.4. Fuel Use Intensity of Tuna Fishing Trends over Time*

From the literature review conducted to supplement FUI data synthesized in the 2010 study, data on tuna fisheries and fuel use of fishing vessels between 2010 and 2023 were compiled. Ten additional studies were identified during secondary data compilation, with studies ranging in terms of number of vessels represented, average size of vessels, gear types, and methods used to characterize fuel use. *Table 16* in Appendix F summarizes the studies analyzed.

When zooming in on average FUI across gear types in these compiled studies, pole and line fishing for tuna appears to be the most fuel-efficient fishing gear at 375 L/t. Purse seine has the next lowest FUI (549 L/t), followed by handline (1,189 L/t), trolling (2,038 L/t), and longline (2,119 L/t). There was one study that reported the fuel use for gillnet-based tuna fishing (328 L/t); however, no conclusions can be made on this gear type given the very small sample size that it represents. Primary data collected on purse seine, long line, and pole and line fishing vessels reported in the current study generally falls within the range of FUI values reported in recent publications and datasets, as evidenced by *Figure 1*.

No clear trends emerge for the FUI of purse seine, long line, and pole and line vessels over time. Although there appears to be a slight decrease in FUI over time for purse seine and long line vessels, there is a weak negative relationship; therefore, no conclusions can be drawn. *Figure 1* presents the FUI over time for purse seine, long line, and pole and line fishing gears.



**Figure 1.** FUI from secondary literature for purse seine, long line, and pole and line fishing gears. Bars around the current study data point represent the range of FUI recorded in the current study.

#### 4.5. Carbon Emissions from Fuel Use

Life cycle GHG emissions from tuna fishing vessel fuel use were calculated using emissions intensities of both diesel (2.7 kg CO<sub>2</sub>-eq/L) and MFO (3.1 kg CO<sub>2</sub>-eq/L) to provide a range of potential emissions (see *Table 2* for a summary of emissions intensities of diesel and MFO).

##### 4.5.1. Tuna Fishing Vessels in this Study

GHG emission intensities (in kg CO<sub>2</sub>-eq/tonne tuna) follow the same patterns as FUI, as outlined in Section 4.3.1. Across all tuna landed, the average GHG emissions from combustion of fuel on tuna fishing vessels were calculated to range from 1,373 to 1,577 kg CO<sub>2</sub>-eq/t of tuna landed (*Table 12*).

**Table 12.** GHG emissions associated with the combustion of diesel or MFO on tuna fishing vessels, represented in kg CO<sub>2</sub>-eq per tonne of tuna landed.

Parameter	FUI (L/t)	GHG Emissions using Diesel (kg CO <sub>2</sub> -eq /t)	GHG Emissions using MFO (kg CO <sub>2</sub> -eq/t)
Pacific	501.4	1,356.6	1,557.7
Atlantic	411.3	1,112.8	1,277.8
Indian	522.9	1,414.7	1,624.5
Purse Seine	496.3	1,342.8	1,541.9
Longline	1,523.3	4,121.3	4,732.4
Pole and Line	749.5	2,027.8	2,328.5
Handline	516.0	1,396.1	1,603.1
Skipjack	494.0	1,336.5	1,534.7
Yellowfin	502.9	1,360.6	1,562.4
Albacore	1,521.7	4,117.0	4,727.5
Bigeeye	535.7	1,449.4	1,664.3
Other	810.0	2,191.5	2,516.4
<b>All tuna</b>	<b>507.5</b>	<b>1,373.1</b>	<b>1,576.6</b>

##### 4.5.2. Transshipment Vessels in this Study

Cumulative GHG emissions from combustion of fuel on tuna fishing vessels and transshipment vessels in the Pacific Ocean were calculated to range from 1,589 to 1,825 kg CO<sub>2</sub>-eq/t of tuna landed, depending on the fuel type (*Table 13*).

GHG emissions from combustion of fuel on tuna fishing vessels and transshipment vessels across all ocean basins were estimated to range from 1,574 to 1,808 kg CO<sub>2</sub>-eq/t of tuna landed (*Table 13*).

**Table 13.** GHG emissions associated with the combustion of diesel or MFO on tuna fishing vessels, represented in kg CO<sub>2</sub>-eq per tonne of tuna landed.

Ocean Basin	Average FUI of Tuna Fishing & Transshipment Activities (L/t)	GHG Emissions using Diesel (kg CO <sub>2</sub> -eq/t)	GHG Emissions using MFO (kg CO <sub>2</sub> -eq/t)
Pacific Ocean	587.3	1,589	1,824
All Ocean Basins	581.9	1,574	1,807

#### 4.6. Fuel Consumption and Carbon Emissions by the Global Tuna Fishing Fleet

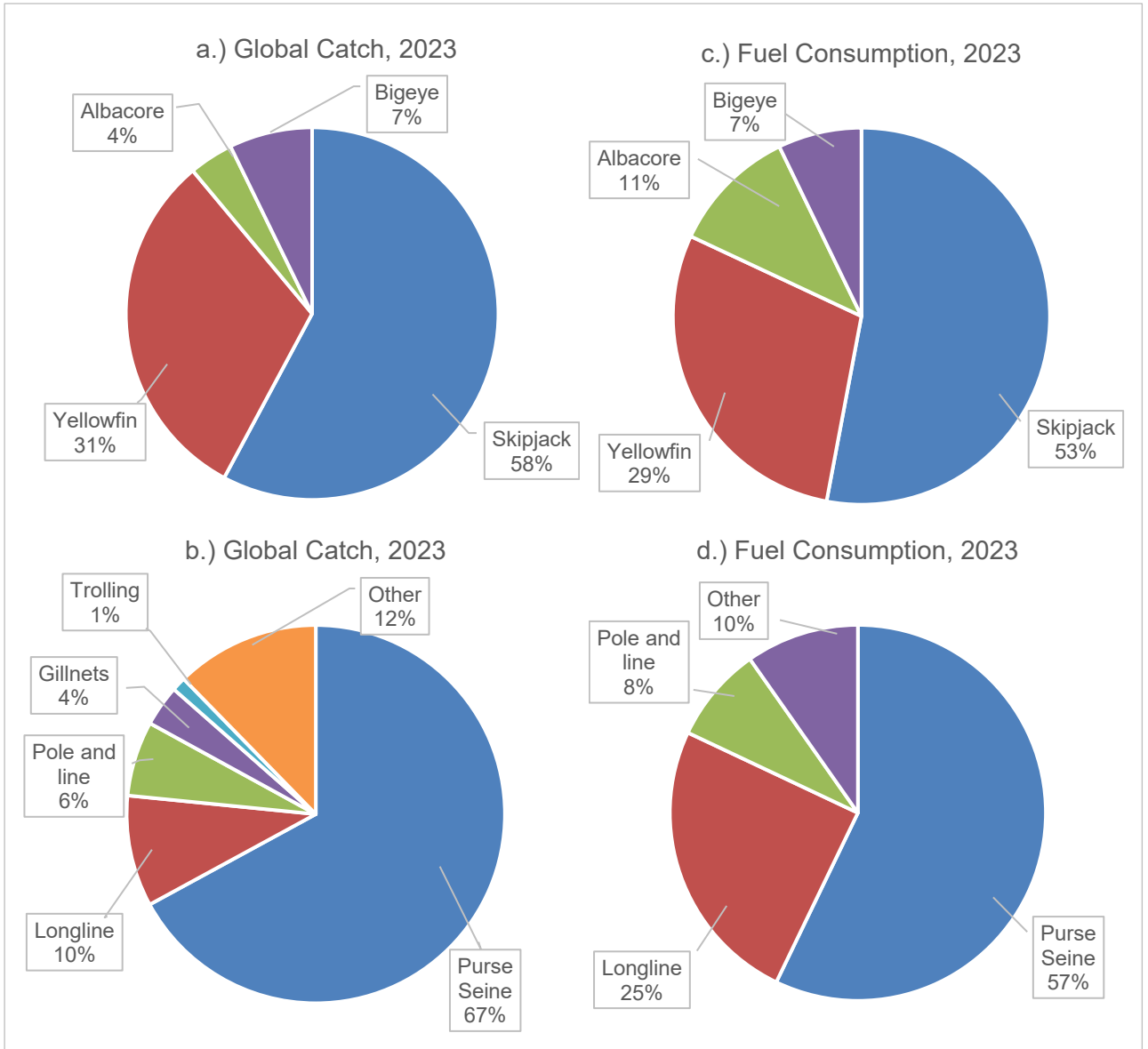
Using the global landings data in *Table 7*, the FUI and associated GHG emissions from fishing vessel and transshipment vessel operations were scaled up to the global tuna fishery. It is estimated that in 2023, the global tuna industry burned approximately 3 billion L of fuel and emitted between 8.0 to 9.2 million tonnes of CO<sub>2</sub>-eq greenhouse gases into the atmosphere (dependent on fuel type).

When examining the principal tuna species landed at a global scale, skipjack accounts for the majority of landings (58% of global catch) and vessel fuel consumption (53% of total fuel use). Yellowfin represents the second-largest share, making up 31% of global landings and 29% of total vessel fuel consumption. Interestingly, while albacore has the lowest landings (4% of global catch), it accounts for 11% of global tuna fishing vessel fuel consumption—surpassing that of bigeye tuna, despite bigeye having a higher catch volume. This is likely due to the fact that albacore is predominantly harvested using longline gear, which has a higher FUI compared to other fishing methods (NOAA Fisheries, 2024). Figure 2 a.) and 2 c.) break down global tuna landed and fuel consumption according to tuna species.

Examining fuel use by fishing gear type further highlights these differences in efficiency. Purse seine gear, which has a relatively low FUI (*Table 10*), accounts for approximately 67% of global tuna landed and 57% of fuel consumed by tuna fishing vessels. In contrast, longline fishing gear contributes just 10% of global tuna catch but consumes 25% of total fuel used in the tuna fishery, emphasizing its low inefficiency. Figure 2 b.) and 2 d.) break down global tuna landed and fuel consumption according to gear type employed.

Overall, the estimates from this study suggest that global tuna fisheries could account for approximately 8% of Parker and colleagues' (2018) estimate of global fuel use by fisheries (40 billion litres in 2011). However, this fraction could be overestimated given the 12-year interval between these fuel use estimates, and the historic upward trajectory of global fisheries fuel use also described by Parker and colleagues (2018). More generally, the fuel inputs to global tuna fishing estimated here appear to represent 0.05% of total global oil consumption (37.6 billion barrels in 2023) (U.S. Energy Information Administration, 2025),

and 0.02% of total global anthropogenic GHG emissions (53.0 Gt CO<sub>2</sub>-eq emissions in 2023) (Crippa et al., 2024).



**Figure 2.** Global landings of major commercial tunas in 2023 broken down by species (a) and gear (b), with corresponding modeled fuel consumption by tuna fishing vessels by species (c) and gear (g). Both global catch values by species and the relative proportion of fishing gears used are sourced from ISSF (ISSF, 2025).

#### 4.7. Estimating Life Cycle Greenhouse Gas Emissions

The scope of this project focused on quantifying fuel inputs to tuna fishing operations and transshipment activities in 2023. From those data it is possible to make robust estimates of the life cycle GHG emissions associated with fuel production (from extraction, through refining and transportation) and fuel combustion on tuna fishing and transshipment vessels (*Table 13*). However, a more complete understanding of the life cycle GHG emissions of tuna fishing activities would encompass a much wider range of material and energy inputs to tuna fishing activities (e.g. to vessel construction and maintenance, gear manufacturing, bait provision, use of refrigerants, etc.), and employ a more structured method for analyzing data like life cycle assessment (LCA) (see for example Avadí et al., 2015; Hospido & Tyedmers, 2005). Similarly, if a robust understanding of the life cycle GHG emissions of tuna *products* is sought, additional downstream activities such as processing, packaging, storage, retail, consumer use, and various transport activities would also ideally be assessed using an LCA framework. Consequently, while emissions from fuel use in fishing operations typically accounts for the vast majority of GHG emissions within fish supply chains, at least to the point at which fish are landed (Avadí et al., 2015; Hospido & Tyedmers, 2005; Parker et al., 2018), one cannot draw firm conclusions about the life cycle carbon footprint of the tuna industry without considering all sources of emissions.

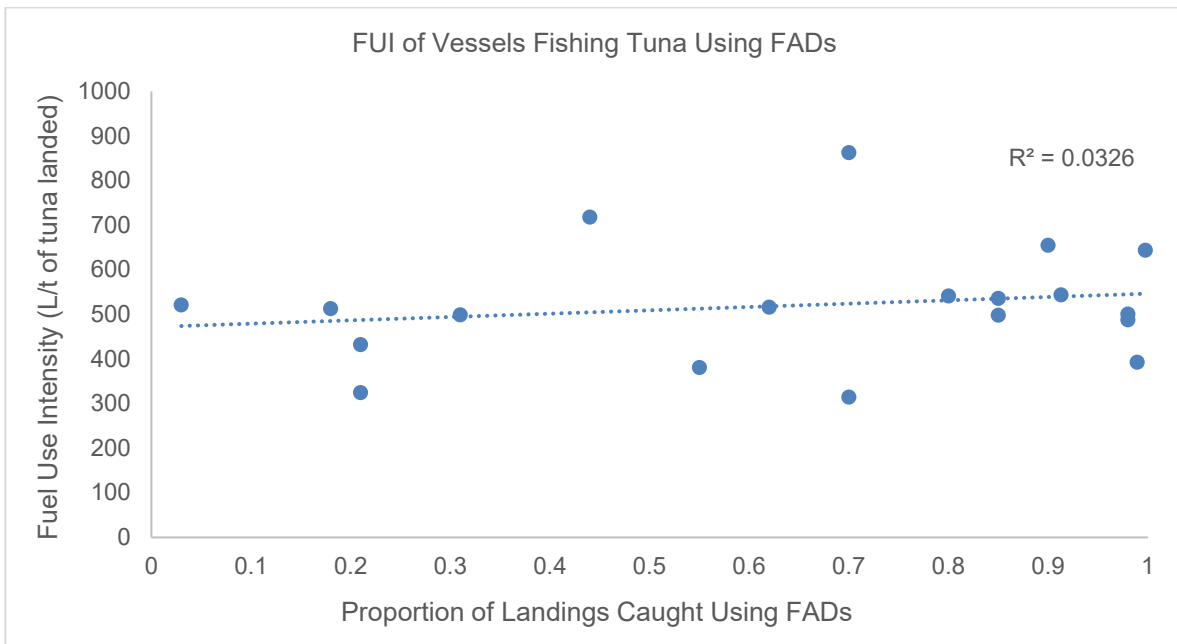
It is possible to coarsely estimate non-fuel sources of emissions within the fishing phase for marine capture fisheries by scaling up fuel-related life cycle emissions by 25% (for published work that has used this same approach to approximate life cycle GHG emissions from fisheries, see Bianchi et al., 2022; Gephart et al., 2021; Parker et al., 2018). If we assume a similar proportional relationship between fuel and non-fuel sources of GHG emissions, we can estimate that the life cycle GHG emissions associated with catching and delivering a tonne of tuna in 2023 ranged from 1,970 kg CO<sub>2</sub>-eq per tonne of tuna landed, if diesel was the primary fuel burned, to 2,260 kg CO<sub>2</sub>-eq per tonne of tuna landed, if MFO was the main fuel burned.

While several recent prominent studies have used this scaling factor approach to estimate non-fuel sources of GHG emissions within the fishing phase of marine capture fisheries, it should be noted that there are substantial limitations associated with this approach and the results should not be considered equivalent to results of a detailed life cycle assessment of tuna fishing operations. Emissions can vary depending on type of gear used and rates of gear renewal, size and composition of vessels, type and source of bait used, etc. Therefore, there is a lot of uncertainty associated with scaling the fuel-related emissions by 25%. Future studies should focus on collecting primary data on vessel and gear manufacturing, provision of bait, and refrigeration losses, and model these inputs alongside fuel inputs using LCA methods if a more robust understanding of the GHG emissions of tuna fishing activities is sought.

## 5. The Role of Fish Aggregating Devices

In addition to FUI and GHG emissions, this study also examined the use of fish aggregating devices (FADs) in the global tuna industry. In the 2009 study of fuel inputs and GHG emissions from tuna fishing activities under for ISSF, Tyedmers and Parker (2012) identified a statistically significant positive correlation between the FUI of tuna fishing and dependence on FAD usage. The results indicated that vessels heavily reliant on FADs tend to have higher fuel consumption per tonne of tuna landed—an insight not previously recognized in earlier fuel use studies. However, as FUI also showed a positive correlation with vessel size, it was difficult for Tyedmers and Parker to determine whether FAD use or vessel size was the primary driver of increased FUI (Tyedmers & Parker, 2012).

In the current study, 19 survey responses representing 38 purse seine vessels reported relying on FADs for a portion of their catch, accounting for approximately 134,960 tonnes of tuna landed. Plotting the proportion of tuna fishing operations in 2023 undertaken on FADs vs associated FUI for these vessels (Figure 3) we find a very weak positive correlation (coefficient of determination=0.0326). Given the weak relationship between these two variables, we cannot say that one variable influences the other.



**Figure 3.** FUI and the proportion of tuna caught using FADs.

Since the first project undertaken for ISSF based on tuna fishing activities in 2009, recent publications have examined the relationship between FUI and the use of FADs. Basurko and colleagues (2022) investigated the fuel consumption of purse seiners employing strategies targeting free-swimming school (FSC) versus vessels targeting FAD associated tuna in the Indian Ocean. The researchers observed that FAD fishing resulted in substantially higher FUI (543.6 L/t) than did vessels targeting FSC (439.4 L/t) (Basurko et al., 2022), supporting

the findings from the first study undertaken for the ISSF (Tyedmers and Parker, 2012). From the analysis by Basurko and colleagues (2022), it would seem that purse seiners that rely heavily on FAD-associated tuna navigate to and from FADs over long distances, whereas vessels targeting free-swimming schools of tuna generally hunt in smaller geographic regions where naturally occurring schools are likely to appear, thus travelling shorter distances. Therefore, Basurko et al. (2022) attribute the difference in FUI between these strategies to the total distance travelled during a fishing trip.

Chassot and colleagues (2021) also investigated factors that influence FUI, specifically focusing on purse seine vessels in the western Indian Ocean. The researchers observed a positive relationship between FUI and the use of FADs; however, vessel length, fishing effort, and the period of vessel construction also influenced FUI, making it difficult to discern which factors are the leading driver behind increased FUI. Ultimately, there are several factors beyond fishing strategy that may influence FUI, so further work is required to better understand their relative impacts and identify the primary drivers of FUI in the global tuna fishery.

## **6. Comparison of Results to Prior Study Undertaken for ISSF**

The current study serves as an update to the work undertaken by Dr. Peter Tyedmers and Dr. Robert Parker to quantify FUI and associated GHG emissions from tuna fishing activities in 2009 on behalf of ISSF (Tyedmers & Parker, 2012). Both studies evaluate vessel fuel use and the associated carbon emissions within the global tuna industry; however, notable differences emerge between the results of the two assessments, as already indicated in the role of FADs on FUI.

Results show that the weighted average fishing vessel FUI is 26.6% higher for the current study (508 L/t) when compared to weighted average FUI of tuna fisheries in 2009 (401 L/t). In general, this trend of increasing FUI over time is consistent across ocean basins, gear types and tuna species analyzed (*Table 14*). The only exceptions appear for vessels operating in the Atlantic Ocean and tuna caught using pole and line. In these cases, the FUI is 19.8% and 49.5% lower, respectively, in the current study.

Importantly, the data underpinning the analysis of tuna fisheries from 2009 was more representative of the global tuna industry, accounting for approximately 12.6% of total global tuna landings in 2009. In contrast, the current study only represents approximately 5.3% of global tuna landings in 2023 (*Table 7*). This difference is primarily due to a lower response rate in the current study, resulting in a vessel sample size that is approximately 52% smaller (n=78 vessels) when compared to the baseline assessment (n=164). As a result of this reduced sample size, the current study's findings are more sensitive to outliers, which may explain some of the variance in FUI that we see in *Table 14*. For example, in the current study we have data for only three vessels reported fishing in the Atlantic Ocean in 2023 and

six vessels reported using pole and line gear. These small sample sizes may lead to unrepresentative results for the broader tuna industry.

The current analysis broadens the scope of study to include helicopter and scouting boat fuel use, while the earlier study does not consider these additional sources of fuel combustion during fishing operations. It is important to highlight that helicopter and scouting boat fuel use only accounts for ~1% of all fishing related fuel use reported; therefore, the inclusion of this supplementary fuel is not expected to drive the differences in FUI between the two studies.

In addition, the current analysis also extends the scope of analysis to include transshipment vessel fuel use. The results show a 14.5% increase in FUI per tonne of tuna landed across ocean basins when accounting for the fuel use contributions of transshipment vessels. It must be noted that the values in *Table 14* only include fuel use from fishing vessels, helicopters, and scouting boats, excluding additional fuel consumptions from transshipment vessels.

**Table 14.** Comparison of fishing vessel FUI (excluding transshipment vessels) according to ocean basin, fishing gear employed, and tuna species landed, for the 2010 study and the current study.

Parameter	2010 Study FUI (L/t)	Current Study FUI (L/t)	% Difference
Pacific	374	501	34.1%
Atlantic	513	411	-19.8%
Indian	454	523	15.2%
Purse Seine	390	496	27.3%
Longline	1,069	1,523	42.5%
Troll	1,464	N/A	N/A
Pole and Line	1,485	750	-49.5%
Handline	N/A	516	N/A
Skipjack	386	494	28.0%
Yellowfin	410	503	22.7%
Albacore	1,303	1,522	16.8%
Bigeye	472	536	13.5%
Bluefin	1,478	N/A	N/A
Other	N/A	810	N/A
<b>All tuna</b>	<b>401</b>	<b>508</b>	<b>26.6%</b>

Interestingly, the increase in the FUI of tuna fisheries between 2009 and 2023 (*Table 14*) is in accordance with results of a study on global trends in CO<sub>2</sub> emissions from fuel combustion in marine fisheries between 1990 and 2011 (Parker et al. 2018). Over the 21-year period considered by Parker and colleagues, they estimated that total GHG emissions from capture fisheries globally grew 28% despite overall landings remaining largely unchanged over the same period (Parker et al. 2018). Though much of this increase in total fisheries-related GHG emissions resulted from a ~60% increase in landings from high fuel input crustacean

fisheries between 1990 and 2011, a secondary source of increase was attributed to a statistically significant increase in the FUI of fisheries for demersal and large pelagic finfish (Parker et al. 2018).

While evolving industry practices were expected to reduce fuel consumption and emissions over the last decade, the results of this study suggest that with a few exceptions, the FUI of tuna fishing has increased since 2009 (*Table 14*). The findings also highlight the importance of sample size and data representation in shaping results, as the reduced sample size in the current study may not fully capture the diversity of the global tuna fleet, leading to potential inconsistencies in the data. These findings suggest that while the industry has made some progress, significant challenges remain in reducing the overall environmental impact of tuna fishing, pointing to the need for more comprehensive data collection and continued innovation to address these sustainability issues.

## **7. Study Limitations**

While surveys are a widely used and effective tool for collecting data from specific target populations, the limitations inherent in the survey design and data collection process may have influenced the accuracy and reliability of the results. These challenges include sampling bias, coverage and representativeness, data quality concerns, and study exclusions, which must be considered when interpreting the application of the study results.

### *7.1. Sampling Bias*

In this study, survey instruments were only distributed to contacts within ISSF's network. Contacts were encouraged to forward the surveys to other fishing vessel operators; however, this did not garner any additional data points. As a result, data was primarily comprised of participating companies of ISSF, introducing potential sampling bias. Although ISSF has contacts across the globe, representing different fishing gears, target species, vessel type, and ocean basin, caution should be exercised when inferring broader representativity of the global tuna industry.

### *7.2. Coverage and Representativeness*

As previously stated, the sample size for this study was relatively small ( $n=78$  vessels), with primary data representing about 5.3% of global tuna landings in 2023 (*Table 7*). As a result of the small sample size, the data was heavily influenced by purse seine fishing vessels ( $n=57$ ). Of the species landed, yellowfin (51.4% of landings) and skipjack (42.4% of landings) represented the vast majority of tuna represented in this study. The majority of survey respondents were also located in the Pacific Ocean ( $n=66$ ), with few vessels represented in the Indian ( $n=9$ ), and Atlantic Oceans ( $n=3$ ). Given the small sample size of this study, FUI and GHG emissions were heavily skewed by yellowfin and skipjack tuna caught via purse seine vessels in the Pacific Ocean. Results relating to other gears, tuna

species, and ocean basins should be considered less reliable as a result of the more limited sample sizes involved.

Several reasons may have influenced the poor coverage and representativeness observed in this study. This is potentially a partial result of a sampling bias that results from targeting primarily ISSF-associated companies, as skipjack and yellowfin are targeted for production of canned tuna. Additionally, the low response rate may have been caused by a lack of trust between the participants and researchers. For example, revealing data on high fuel use, a major cost in many fisheries, may be considered damaging for sales purposes as it reveals a key detail of a firm's cost of production. Thus, participants may be reluctant to share this information because they do not trust how the data may be used (Kalkman et al., 2022; van der Burg et al., 2021). Other factors which may have influenced the low survey response rate are potential language barriers or those who were willing to respond might lack the time or resources needed to gather the required information (Reid & Squires, 2007).

Efforts were made to reduce nonresponse bias and increase the study's sample size through several follow-up emails, as reminders have been shown to increase survey response rate (Holtom et al., 2022). Several information sessions were also held to increase the trust between researchers and participants and enhance the transparency of the study, but despite these efforts, participant response rate remained low.

### *7.3. Data Quality Issues*

Additional errors may have occurred from respondents misreporting data due to a misunderstanding of the information being requested, mistakes made while completing the survey, or intentionally underreporting fuel use to reduce the apparent resulting GHG emissions of tuna fishing activities and gain competitive advantage in an increasingly climate concerned marketplace. Issues were occasionally detected in the quantity of fuel consumed, units provided, and quantity of tuna landed. To address these discrepancies, we followed up with participating companies to confirm data points or exclude data that did not meet data quality standards. Due to the nature of survey instruments, the data remains self-reported, and we must rely on the good-faith efforts and honesty of respondents.

As previously stated in Section 4.7, there are also data quality concerns associated with the scaling factor used to estimate the GHG emissions associated with the entire fishing phase of the tuna industry. Although previous studies have used this approach to estimate non-fuel sources of GHG emissions within the fishing phase of marine capture fisheries, emissions vary according to gear type manufactured, size of boat, and type of bait, therefore there is uncertainty associated with these results.

#### *7.4. Study Exclusions*

This study sought to quantify the fuel use and GHG emissions associated with vessel fuel use in the fishing phase of the tuna product life cycle. Although this analysis highlights important insights into the most impactful phase of the tuna product life cycle, it excludes other sources of emissions including transport from dock, processing, packaging, storage, distribution, consumption, and end of life activities. In some cases, the exclusion of these life cycle phases ignores important sources of emissions, such as when products are transported via air freight (Ziegler et al., 2016) as occurs in some tuna supply chains.

Furthermore, due to the nature of GHG emission assessments, other environmental indicators were not addressed in the scope of this study. For instance, the depletion of tuna stocks – an important concern given the status of some tuna stocks, was not included. Other environmental concerns such as bycatch, ghost gear, impact on sources of bait used in some tuna fisheries, and ocean pollution resulting from tuna fishing operations were excluded from the scope of this analysis. Since this study only investigates GHG emissions, no conclusions can be drawn about the overall environmental impact of the tuna fishing industry.

### **8. Direction for Future Research**

This study provides a snapshot of fuel use in the global tuna industry for 2023, highlighting how FUI may vary according to target species, fishing gear employed, ocean basin, and use of transshipment vessels. While this study revealed important insight into fuel use between tuna fisheries and in comparison with earlier work, there are future research opportunities that should be undertaken to improve the study design and reliability of the findings.

Future research efforts should focus on improving data collection efforts to increase the industry's understanding of factors that influence GHG emissions within the tuna fishing phase. While several attempts were made to increase the number of participants in the current study, the sample size remained quite low, resulting in highly skewed data towards yellowfin and skipjack tuna, purse seine fishing gear, and vessels operating in the Pacific Ocean. Studies show that providing incentives is often associated with higher response rates when using survey instruments as the primary form of data collection (Holtom et al., 2022), presenting a possible strategy to improve response rates in the future. Another strategy to increase the number of participants could be to translate surveys into different languages. Not only could translated survey instruments increase the number of respondents, but translations can also improve data quality by reducing the number of misunderstandings driven by language barriers.

Furthermore, it is important to diversify respondents to reduce sampling bias. The current study hinged on responses from contacts within ISSF's network, presenting potential sampling bias among participants. Future research efforts could expand to other stakeholders

within the tuna industry, including government stakeholders, regional fisheries management organizations, other organizations like the ISSF, and transshipment vessel companies. Results showed the transshipment vessels increase the overall FUI of tuna fishing operations in the WCPO by approximately 17%. Additional data on these vessels and their operations, particularly those operating in the Atlantic and Indian Oceans basins could substantially improve FUI estimates at a global scale.

Increased participation and diversification of participants can enhance the representativeness of the data. This will normalize the data and reduce the influence of outliers associated with the current study. Furthermore, more fishing gear types will be represented with more respondents. The current study was only represented by purse seine, long line, pole and line, and handline fishing gear; however, *Table 3* indicates that gillnets account for 3.5% of global tuna landings and trolling accounts for 1.2% of all tuna landed. Increasing the representation of data will provide a more holistic snapshot of the global tuna industry.

The current study only evaluates fuel use within the fishing phase of the global tuna industry. Future research efforts should seek to expand on the work done here by collecting primary data on vessel and gear manufacturing, provision of bait, and refrigeration losses, to improve the credibility of the findings for the fishing life cycle phase. A full LCA of the tuna industry would further enhance the findings of this study, extending beyond a focus on fuel use and directly associated GHG emissions through the quantification of additional environmental impacts such as ecosystem degradation, resource use, and human health impacts.

## **9. Conclusion**

While tuna fisheries and marine capture fisheries more generally present a lower-emission source of animal protein compared to conventional livestock systems (Bianchi et al., 2022; Gephart et al., 2021), it is evident that the global tuna fishery is still energy-intensive and seemingly increasingly so. Although the representativeness of this research is limited on a global scale, the findings from this study provide additional insights into fuel consumption and GHG emissions of the tuna fishery. Importantly, the results show how transshipment vessels increase FUI associated with the fishing phase of the tuna industry. Few studies have investigated the influence of transshipment vessels, so this highlights an important area for further research.

The tuna industry must address its GHG emissions through innovative practices and collaborative efforts among stakeholders. Increased industry participation in primary data collection on fuel use and tuna landings will enhance the findings from this study, enabling stakeholders to make informed choices on fishing practices and reduce their carbon footprint. Ultimately, reducing the industry's environmental impact requires a unified approach from fishing companies, fishermen, policymakers, and other key players. As global seafood

demand continues to rise, a strong commitment to sustainable fishing practices will be critical in mitigating the effects of climate change.

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All errors and omissions are, of course, the responsibility of the authors.

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## APPENDIX A – Introductory letter sent to potential respondents

Re: Important new ISSF research project – carbon footprint of tuna fisheries

The International Seafood Sustainability Foundation has commissioned a research project to quantify and update fuel inputs and associated global warming contributions (carbon footprint) of various tuna fishing methods currently in use around the world. This research is being undertaken by scientists based at the School for Resource and Environmental Studies at Dalhousie University, Canada under the direction of Dr. Peter Tyedmers. This study will update and complement an earlier study by the same researcher ([ISSF-2012-03](#)). Results of this project will help us better understand the holistic environmental impact associated with these fisheries, the relative impact of the different tuna fishing gear types and provide a basis upon which the carbon footprint of tuna products could be then estimated and compared to other proteins. Research to date suggests that in many cases, fisheries products compare very favorably with beef and other animal proteins in terms of their carbon footprint.

To succeed, this project will require the assistance of industry. Specifically, the researchers will survey tuna vessel owners and operators over the coming months to secure data related to their operations. ISSF will be sending this survey out to your contact for the Proactive Vessel Record (PVR) in April.

All company-specific information provided to the researchers will be kept confidential. Contact lists will not be shared and only aggregated data representing multiple vessels fishing in any given region, utilizing a particular fishing gear type, will be reported in the final study.

Please note that the study will aim to cover all of the main tuna fishing methods. **Therefore, we would also like you to help us identify other fishing companies who are not engaged on the PVR, who might be willing to participate in the survey.** Specifically, please send a list of company names and addresses along with individual contact names, phone numbers and e-mail addresses to the email we have dedicated for the study ([2024tunaenergysurvey@gmail.com](mailto:2024tunaenergysurvey@gmail.com)), or to Victor Restrepo ([VRestrepo@iss-foundation.org](mailto:VRestrepo@iss-foundation.org)) as soon as possible.

Thank you in advance for your assistance with this important project and please contact us or Dr. Peter Tyedmers ([peter.tyedmers@dal.ca](mailto:peter.tyedmers@dal.ca)) if you have any questions.

Sincerely,

Susan Jackson  
President

## **APPENDIX B – Secondary letter sent to potential respondents**

Re: Reminder – Fuel use and greenhouse gas emissions of tuna fisheries survey data

In April, we announced the start of a new research project to quantify fuel inputs and the associated carbon footprint of various tuna fishing methods currently in use around the world. Thank you to all participants who have contributed data thus far; however, to achieve a comprehensive study, we require more fishing vessel and transport vessel operations data from ISSF members.

We encourage all of our partners who have direct access to tuna fishing data to provide this information to the project and to also urge their contacts in the tuna fishing industry to do the same. The research team has prepared two short surveys to gather the required data. One survey is for tuna fishing related activities and the second is for tuna transport (carrier) related activities. Please see the guidance at the top of each survey. Note: you only need to fill out the tuna transport (carrier) survey if you operated carrier vessels in 2023.

Once you have completed one or more data forms (as appropriate), please forward them directly to the research team via the dedicated e-mail address established for this study (2024tunaenergysurvey@gmail.com) or to Victor Restrepo at ISSF ([VRestrepo@issf-foundation.org](mailto:VRestrepo@issf-foundation.org)).

All company-specific information provided to the researchers will be kept confidential. Contact lists will not be shared and only aggregated data representing multiple vessels fishing in a given region, utilizing a particular fishing gear, will be reported in the final study.

Thank you for your continued assistance with this important project and please contact Victor Restrepo, at the email address noted above, or Dr. Peter Tyedmers (peter.tyedmers@dal.ca), the project lead, if you have any questions.

Sincerely,

Susan Jackson

President

## APPENDIX C – Survey A

### Fuel Use and Greenhouse Gas Emissions from Tuna Fisheries in 2023 Survey of Fishing Vessel Operations

On behalf of our team and the International Seafood Sustainability Foundation, thank you for participating in this survey.

Ideally **provide data for individual vessels on separate forms whenever possible**. If this is impossible, data representing multiple vessels can be reported on one form if vessels fished in the same region, used the same gear, and targeted similar species (e.g. one form can be used to report cumulative data for 3 vessels fishing Skipjack Tuna with purse seine in the Indian Ocean). If using one form for multiple vessels, please confirm the number of vessels in *Section 1* below and provide TOTAL fuel purchases, TOTAL landings, TOTAL days at sea, TOTAL fishing days for all vessels represented and AVERAGE values for all other aspects as appropriate.

Please report data below **for fishing operations in calendar year 2023**. If you can share data for other years, please e-mail us at [2024tunaenergysurvey@gmail.com](mailto:2024tunaenergysurvey@gmail.com) and we will work with you to determine what will be the easiest way of transferring key data.

Finally, **please circle, highlight or otherwise indicate correct units where applicable**.

Company: \_\_\_\_\_

Contact (name and email): \_\_\_\_\_

<p><b>1. VESSEL(S) REPRESENTED:</b> <input style="width: 50px;" type="text"/> #</p> <p>Vessel length (or average): <input style="width: 100px;" type="text"/> m/ft</p> <p>Vessel GRT (or average): <input style="width: 100px;" type="text"/> t</p> <p>Main engine power (or ave): <input style="width: 100px;" type="text"/> HP/kW</p> <p>Auxiliary engine power: <input style="width: 100px;" type="text"/> HP/kW</p>	<p><b>2. WATERS FISHED IN 2023</b></p> <p>% of 2023 effort spent in RFMO: <input style="width: 50px;" type="text"/> % Indian</p> <p><input style="width: 50px;" type="text"/> % Atlantic</p> <p><input style="width: 50px;" type="text"/> % Western Pacific</p> <p><input style="width: 50px;" type="text"/> % Eastern Pacific</p>																
<p><b>3. GEAR USED IN 2023</b></p> <p>Primary tuna fishing gear (purse seine, long-line, troll, pole and line, etc): <input style="width: 150px;" type="text"/></p> <p>Secondary fishing gear: <input style="width: 150px;" type="text"/></p> <p>What % of catch with secondary gear? <input style="width: 50px;" type="text"/> %</p> <p>Did you fish on FADs in 2023? <input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>% of 2023 catch caught using FADs? <input style="width: 50px;" type="text"/> %</p>	<p><b>4. EFFORT IN 2023</b></p> <p>Total days at sea on tuna trips: <input style="width: 50px;" type="text"/> days</p> <p>Total days actively fishing tuna: <input style="width: 50px;" type="text"/> days</p> <p>Total fuel burned in 2023 by vessel(s): <input style="width: 100px;" type="text"/> Gal/L</p> <p>Did you fish using helicopters in 2023?: <input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>Total fuel burned by helicopters in 2023: <input style="width: 100px;" type="text"/> Gal/L</p> <p>% of catch transferred to a carrier vessel: <input style="width: 50px;" type="text"/> %</p>																
<p><b>5. CATCH IN 2023</b>      <b>Please indicate the total live weight mass of <i>all</i> tuna and non-tuna species landed by all vessels.</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%;">Skipjack tuna</td> <td style="width: 20%;"><input style="width: 100px;" type="text"/> t</td> <td style="width: 20%; border-bottom: 1px solid black;"></td> <td style="width: 20%;"><input style="width: 100px;" type="text"/> t</td> </tr> <tr> <td>Yellowfin tuna</td> <td><input style="width: 100px;" type="text"/> t</td> <td style="border-bottom: 1px solid black;"></td> <td><input style="width: 100px;" type="text"/> t</td> </tr> <tr> <td>Albacore tuna</td> <td><input style="width: 100px;" type="text"/> t</td> <td style="border-bottom: 1px solid black;"></td> <td><input style="width: 100px;" type="text"/> t</td> </tr> <tr> <td>Bigeye tuna</td> <td><input style="width: 100px;" type="text"/> t</td> <td style="border-bottom: 1px solid black;"></td> <td><input style="width: 100px;" type="text"/> t</td> </tr> </table>		Skipjack tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t	Yellowfin tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t	Albacore tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t	Bigeye tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t
Skipjack tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t														
Yellowfin tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t														
Albacore tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t														
Bigeye tuna	<input style="width: 100px;" type="text"/> t		<input style="width: 100px;" type="text"/> t														

Can we contact you to clarify data?  Y  N

Additional comments (please extend onto a second page if necessary):

# APPENDIX D – Survey B

## Fuel Use and Greenhouse Gas Emissions from Tuna Fisheries in 2023 Survey of Transport Vessel Operations

On behalf of our team and the International Seafood Sustainability Foundation, thank you for participating in this survey.

Data representing multiple transport vessels can be reported on one form if vessels operated in the same ocean basin (e.g. Atlantic ocean).

Please report data below for fishing operations in calendar year 2023. If you can share data for other years, please e-mail us at [2024tunaenergysurvey@gmail.com](mailto:2024tunaenergysurvey@gmail.com) and we will work with you to determine what will be the easiest way of transferring key data.

Finally, please circle or otherwise indicate correct units where applicable.

Company: \_\_\_\_\_

Contact (name and email): \_\_\_\_\_

<b>1. VESSEL(S) REPRESENTED:</b>	<input type="text"/>	#
Vessel length (or average):	<input type="text"/>	m/ft
Vessel GRT (or average):	<input type="text"/>	t
Main engine power (or ave):	<input type="text"/>	HP/kW

<b>2. TUNA TRANSPORT OPERATIONS IN 2023</b>	
In which Ocean did vessel(s) operate:	<input type="text"/>
Total fuel burned in 2023 by vessel(s):	<input type="text"/> Gal/L
Total mass of tuna transported in 2023:	<input type="text"/> t
Approx. % of tuna transported that were:	
Skipjack:	<input type="text"/> %
Yellowfin:	<input type="text"/> %
Albacore:	<input type="text"/> %
Other:	<input type="text"/> %

Can we contact you to clarify data?  Y  N

Additional comments (please extend onto a second page if necessary):

## APPENDIX E – Supplementary Tables

**Table 15.** Fishery-specific landings and average fuel use intensities (weighted by landings) of vessels reporting by ocean, species, and gear.

Ocean	Species	Gear	Landings (tonnes)	FUI (L/t)
Pacific	Skipjack	Purse seine	69,764.3	473.39
		Longline	38.3	1,226.35
		Pole and Line	337.3	862.34
		Handline	0.5	516.03
	Yellowfin	Purse seine	115,120.8	492.12
		Longline	764.5	1,305.41
		Pole and Line	232.4	862.34
		Handline	5.8	516.03
	Albacore	Purse seine	-	-
		Longline	1,666.0	1,605.60
		Pole and Line	-	-
		Handline	0.1	516.03
	Bigeye	Purse seine	5,487.5	499.46
		Longline	300.7	1,661.68
		Pole and Line	6.9	862.34
		Handline	0.5	516.03
Atlantic	Skipjack	Purse seine	-	-
		Longline	-	-
		Pole and Line	-	-
		Handline	-	-
	Yellowfin	Purse seine	-	-
		Longline	-	-
		Pole and Line	74.4	306.65
		Handline	-	-
	Albacore	Purse seine	-	-
		Longline	-	-
		Pole and Line	112.3	483.04
		Handline	-	-
	Bigeye	Purse seine	-	-
		Longline	-	-
		Pole and Line	5.6	363.99
		Handline	-	-
Indian	Skipjack	Purse seine	45,688.0	522.07
		Longline	-	-
		Pole and Line	-	-
		Handline	-	-
	Yellowfin	Purse seine	24,083.0	526.35
		Longline	-	-
		Pole and Line	-	-
		Handline	-	-
	Albacore	Purse seine	23.0	517.77
		Longline	-	-
		Pole and Line	-	-
		Handline	-	-
	Bigeye	Purse seine	7,789.0	517.59
		Longline	-	-
		Pole and Line	-	-
		Handline	-	-

## APPENDIX F – Secondary Data Compilation

**Table 16.** Summary of FUI studies within the tuna fishery from 1975 to 2023. PS = purse seine, T = trolling, DN = drift nets, HL= handline, PL = pole and line, LL = long line.

Ocean	Gear	Year	Catch (tonnes)	Primary Target	FUI (L/t)	Reference
Pacific	PS	1973	N.R.*	Tuna	697	Rawitscher, 1978
Pacific	PS	1974	N.R.*	Tuna	659	Rawitscher, 1978
Pacific	PS	1980	N.R.*	Yellowfin	2,554	Watanabe & Okubo, 1989
Pacific	PS	1980	N.R.*	Tuna	1,219	Watanabe & Okubo, 1989
Atlantic	PS	2003	23,452	Skipjack / Yellowfin	442	Hospido & Tyedmers, 2005
Indian	PS	2003	29,554	Skipjack / Yellowfin	373	Hospido & Tyedmers, 2005
Pacific	PS	2003	24,994	Skipjack / Yellowfin	527	Hospido & Tyedmers, 2005
Pacific	PS	2005	14,207	Skipjack	195	Tyedmers ( <i>unpublished</i> )
Pacific	PS	2008	N.R.*	Tuna	412	Wilson & McCoy, 2009
Indian	PS	2008	70,800.1	Skipjack/yellowfin	336.4	Iribarren, 2010
Atlantic	PS	2008	38,037.8	Skipjack/yellowfin	392.0	Iribarren, 2010
Pacific	PS	2008	26,067.8	Skipjack/yellowfin	472.6	Iribarren, 2010
Atlantic	PS	2013-2015	355.8	Unspecified tuna	761.9	Basurko, 2022
Atlantic	PS	2013-2015	2,333.5	Unspecified tuna	485.5	Basurko, 2022
Atlantic	PS	2013-2015	1,765.4	Unspecified tuna	710.9	Basurko, 2022
Atlantic	PS	2013-2015	2,579.7	Unspecified tuna	116.8	Basurko, 2022
Atlantic	PS	2013-2015	500.0	Unspecified tuna	393.0	Basurko, 2022
Atlantic	PS	2013-2015	1,149.0	Unspecified tuna	239.3	Basurko, 2022
Atlantic	PS	2013-2015	336.0	Unspecified tuna	324.4	Basurko, 2022
Indian	PS	2013	11,463.0	Unspecified tuna	409.4	Chassot, 2021
Indian	PS	2014	7,593.0	Unspecified tuna	552.8	Chassot, 2021
Indian	PS	2014-2015	7,859.4	Unspecified tuna	629.8	Basurko, 2022
Pacific	PS	2015	N.R.*	Bigeye, skipjack, yellowfin	325	McKuin, 2021
Pacific	PS	2015	N.R.*	Skipjack	266	McKuin, 2021
Indian	PS	2015	6,672.0	Unspecified tuna	611.0	Chassot, 2021
Indian	PS	2016	7,207.0	Unspecified tuna	588.5	Chassot, 2021
Indian	PS	2017	8,283.0	Unspecified tuna	497.0	Chassot, 2021
Indian	PS	2018	11,064.0	Unspecified tuna	371.5	Chassot, 2021

Indian	PS	2019	8,384.0	Unspecified tuna	422.9	Chassot, 2021
Pacific	T	2005	12	Albacore	1,647	Tyedmers ( <i>unpublished</i> )
Pacific	T	2015	N.R.*	Skipjack, yellowfin	3896	McKuin, 2021
Pacific	T	2015	N.R.*	Skipjack	2354	McKuin, 2021
Pacific	T	2015	N.R.*	Albacore, bigeye, yellowfin, skipjack	2246	McKuin, 2021
Pacific	T	2015	N.R.*	Yellowfin	1512	McKuin, 2021
Pacific	T	2015	N.R.*	Albacore	573	McKuin, 2021
Indian	DN	1988	2	Tunas, bonitos, billfishes	328	Gallene, 1993
Pacific	HL	1975	1,290	Skipjack	1,163	Nomura, 1980
Pacific	HL	1980	N.R.*	Skipjack	1,486	Watanabe & Okubo, 1989
Pacific	HL	1980	N.R.*	Albacore	1,753	Watanabe & Okubo, 1989
Pacific	HL	1980-1984	15,944	Skipjack	1,007	Monintja & Mathews, 2000
Pacific	HL	1985-1989	34,353	Skipjack	535	Monintja & Mathews, 2000
Indian	PL	2010-2014	28,202.0	Skipjack	197	Miller, 2017
Indian	PL	2012	2,515.0	Skipjack	322	Miller, 2017
Indian	PL	2014	147.0	Skipjack	328	Miller, 2017
Indian	PL	2015	25.3	Skipjack, mackerel tuna	253.0	Rahmadi, 2020
Indian	PL	2015	26.1	Skipjack, mackerel tuna	247.4	Rahmadi, 2020
Indian	PL	2015	22.7	Skipjack, mackerel tuna	177.9	Rahmadi, 2020
Indian	PL	2015	13.2	Skipjack, mackerel tuna	122.3	Rahmadi, 2020
Indian	PL	2015	5.3	Skipjack, mackerel tuna	750.6	Rahmadi, 2020
Indian	PL	2015	16.0	Skipjack, mackerel tuna	325.2	Rahmadi, 2020
Indian	PL	2015	3.6	Skipjack, mackerel tuna	439.2	Rahmadi, 2020
Indian	PL	2015	16.4	Skipjack, mackerel tuna	386.4	Rahmadi, 2020
Indian	PL	2015	27.8	Skipjack, mackerel tuna	150.1	Rahmadi, 2020
Indian	PL	2015	24.8	Skipjack, mackerel tuna	150.1	Rahmadi, 2020
Indian	PL	2015	24.2	Skipjack, mackerel tuna	236.3	Rahmadi, 2020
Indian	PL	2015	21.4	Skipjack, mackerel tuna	542.1	Rahmadi, 2020

Indian	PL	2015	8.3	Skipjack, mackerel tuna	675.5	Rahmadi, 2020
Indian	PL	2015	8.5	Skipjack, mackerel tuna	564.3	Rahmadi, 2020
Indian	PL	2015	6.0	Skipjack, mackerel tuna	806.2	Rahmadi, 2020
Indian	PL	2015	11.0	Skipjack, mackerel tuna	447.6	Rahmadi, 2020
Pacific	LL	1975	259	Tuna	3,704	Nomura, 1980
Pacific	LL	1975	168	Tuna	2,326	Nomura, 1980
Pacific	LL	1980	269	Tuna	4,282	Watanabe & Okubo, 1989
Pacific	LL	1980	N.R.*	Bluefin	3,400	Watanabe & Okubo, 1989
Pacific	LL	1980	N.R.*	Bigeye	3,565	Watanabe & Okubo, 1989
Indian	LL	1990	146	Tunas, bonitos, billfishes	106	Iyer, 1993
Pacific	LL	1993	7,628	Primarily swordfish	2,678	Tyedmers (unpublished)
Pacific	LL	1993	3,627	Primarily Bigeye tuna	1,176	Tyedmers (unpublished)
Pacific	LL	1997	203	Tunas, bonitos, billfishes	4,985	Qu, 1998
Atlantic	LL	1998	115	Primarily swordfish	646	Hazin <i>et al.</i> , 2000
Atlantic	LL	1998	28	Primarily swordfish	356	Hazin <i>et al.</i> , 2000
Pacific	LL	1999	18	Primarily Albacore	302	Sokimi & Chapman, 2000
Atlantic	LL	1999	1,204	Primarily swordfish	1,740	Tyedmers, 2001
Pacific	LL	2006	390,000	Albacore	1,915	Krampe, 2006
Indian	LL	2006	290,000	Albacore	2,574	Krampe, 2006
Atlantic	LL	2006	476,000	Albacore	1,569	Krampe, 2006
Pacific	LL	2006	408,000	Bluefin / Bigeye	3,660	Krampe, 2006
Indian	LL	2006	680,000	Bluefin / Bigeye	2,196	Krampe, 2006
Atlantic	LL	2006	408,000	Bluefin / Bigeye	3,660	Krampe, 2006
Pacific	LL	2006-2008	N.R.*	Tuna	1,765	Wilson & McCoy, 2009
Pacific	LL	2015	N.R.*	Albacore, bigeye, yellowfin, skipjack	1124	McKuIn, 2021
Pacific	LL	2015	N.R.*	Albacore	849	McKuIn, 2021
Pacific	LL	2015	N.R.*	Albacore, bigeye, yellowfin, skipjack	1256	McKuIn, 2021
Pacific	LL	2015	N.R.*	Bigeye	1023	McKuIn, 2021

\* N.R. indicates not reported.



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