Abandoned, Lost or Otherwise Discarded Fishing Gear in Coastal and Marine Areas of Selected Southeast Asian Countries: A Status Update and Recommendations

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Abstract

The issue of abandoned, lost, or otherwise discarded fishing gear (ALDFG) has been recognised for decades. This study aims to provide the current profile of marine capture fisheries of five selected Southeast Asian countries (Cambodia, Indonesia, Malaysia, Philippines, and Thailand), update the status of ALDFG in the coastal and marine areas of the five selected countries, and provide recommendations to address ALDFG and related issues. A desktop study was applied to obtain secondary data from various sources, and a questionnaire was used to obtain primary data from key informants. The five selected countries contributed significant fisheries production to the global markets through their multi-gear and multi-species fisheries. We also found that the common ALDFGs include gillnets, traps, and hooks and lines; with other potential sources of ALDFG as anchored fish aggregating devices, trawl nets, and fishing gear components. Our study categorised the impacts of ALDFGs into ecological, economic, and human well-being aspects. There have been various initiatives and projects carried out in the five selected countries to address ALDFG. For ALDFG management, we described the related legislation and national plan of action frameworks, the resolutions and management measures of regional fisheries management organizations, and the tools of inter-governmental bodies. The five selected countries had similar limitations/gaps in ALDFG including insufficient baseline information, weak ALDFG retrieval programs, and poor end-of-life fishing gear (EOLFG) management, while we found that the needs/recommendations of the five selected countries were similar. We provided recommendations to support fisheries stakeholders in the Southeast Asian region.

Keywords: small-scale fisheries, industrial fisheries, fisheries production, fisheries value, fishing gear marking, ghost fishing

Introduction

Southeast Asia comprises 11 countries, with a combined population exceeding 656 million (FAO, 2023a). The regional fisheries are vital for nutrition, livelihoods, and economy, contributing 46.2 million tonnes of production (SEAFDEC, 2023) or over 25 % of the global fisheries and aquaculture production of 177.8 million tonnes (FAO, 2022a). This highlights the significant role of the region in global seafood supply. For marine capture fisheries, this sub-sector produced 18.2 million t or around 40 % of the regional fisheries production valued at USD 24.5 billion (SEAFDEC, 2023). The regional production benefits from abundant marine resources due to its tropical location and surrounding seas. Its exclusive economic zone (EEZ) spans over 9.4 million km^2, of which Indonesia has the largest area, followed by the Philippines (Chokesanguan, 2011).

A variety of fishing gears used by fishers in the regional marine capture fisheries have been reported by SEAFDEC (2023). However, fishing gears can become abandoned, lost, or otherwise discarded fishing gear (ALDFG) due to various factors (Chumchuen et al., 2022; Daniel & Thomas, 2022; Dixon et al., 2018; Gilman

et al., 2016; Macfadyen et al., 2009; Richardson et al., 2018). ALDFG has been also defined by COFI (2018): "abandoned fishing gear" means fishing gear over which that operator/owner has control and that could be retrieved by operator/owner, but that is deliberately left at sea due to force majeure or other unforeseen reasons; "lost fishing gear" means fishing gear over which the owner/operator has accidentally lost control and that cannot be located and/or retrieved by the owner/operator; and "discarded fishing gear" means fishing gear that is released at sea without any attempt for further control or recovery by the owner/operator.

GESAMP (2021) identified various causes of ALDFG from global studies (1970–2019), including gear conflicts, bad weather, bottom obstructions, tides and currents, operational errors, intentional discards, gear design flaws, excessive fishing effort, excessively deep-water fishing, inadequate port facilities, gear deterioration, and illegal, unreported, and unregulated (IUU) fishing activities. These factors contribute to serious impacts on marine ecosystems such as marine pollution, ghost fishing, entanglement and ingestion by marine animals, food web contamination, and fish stocks decline (Arabi et al., 2023; Benson et al., 2022; Kruse et al., 2023; Thushari & Senevirathna, 2020; Wilcox et al., 2016; World Bank, 2023). ALDFG has become a broad concern in Southeast Asia (SEAFDEC, 2022a) and is identified under the UN Sustainable Development Goals (SDGs), particularly SDG 14 or "Life below water" (UN, 2024). Preventing, mitigating, and remediating ALDFG and its impacts is crucial for sustainable resource utilisation.

In order to effectively prevent and reduce the impacts of ALDFG, an understanding of the major causes and drivers behind fishing gear losses is imperative (Richardson et al., 2021). Globally, ALDFG was studied to obtain scientific evidence to support policymakers and fisheries managers (Gilman et al., 2016). In Asia, for example, Owiredu et al. (2022) carried out a bottom trawl survey in the South Sea of Korea (around Jeju Island) and found that more than 90 % (228.1 kg.km^{-2}) of marine debris on the seabed was ALDFG (mainly from gillnets and traps); moreover, they indicated that the significant level of marine pollution in the South Sea was caused by commercial fishing activities. In contrast, Kuroda et al. (2020) investigated marine debris on the seabed in offshore areas around Japan (i.e., Hidaka Bay, Off Joban, and East China Sea) using bottom trawls, and their results showed that around 16 % (13.9 kg.km^{-2}) of total marine debris was ALDFG, particularly fishing nets (e.g., gillnets and trawl nets) and fishing lines (from longline fishing). These results from Owiredu et al. (2022) and Kuroda et al. (2020) suggested that the source and magnitude of ALDFG could differ depending on areas; in addition, passive or unattended fishing gear (particularly gillnets) could be considered as a high potential risk to become ALDFG. In Southeast Asia, however, studies were limited in attempting to quantify ALDFG (Macfadyen et al., 2009). ALDFG and its impacts have been initially studied worldwide, whereas there are still research gaps in many countries, particularly in developing the knowledge for addressing ALDFG and its impacts on the coastal and marine ecosystems as well as on human well-being. Baseline information on marine capture fisheries and ALDFG of the Southeast Asian region, therefore, needs to be established. This study is the first collaborative desktop study among the countries in Southeast Asia on ALDFG and its impacts. This study aimed at providing the current marine capture fisheries profile, updating the status of ALDFG in the coastal and marine areas of Southeast Asia, and developing recommendations for addressing ALDFG and related issues. The results from this study are expected to serve as baseline information at both national and regional levels to support policymakers, fisheries managers, researchers, fishers, and related stakeholders to manage and/or mitigate ALDFG and its impacts.

Materials and Methods

Ethical approval

The questionnaire survey was conducted in accordance with ethical standards for research involving human subjects. The first author has been certified for Human Subject Protection (HSP) on 02 April 2024 by the National Research Council of Thailand. Participation in the survey was voluntary, and informed consent was obtained from all respondents. All information collected was kept confidential and used solely for research purposes.

Data sources

This desktop study applied a structured approach to investigate the status of ALDFG and its impacts on the Southeast Asian coastal and marine fisheries of five selected Southeast Asian countries: Cambodia, Indonesia, Malaysia, Philippines, and Thailand (Fig. 1). The approach included covering three topics, namely: 1) characterising of marine capture fisheries (i.e., fishing fleet size, fishing gear types, and landing (catch) information); 2) describing ALDFG and related impacts (i.e., ALDFG sources/causes, ALDFG impacts, and studies/projects to address ALDFG); and 3) identifying ALDFG management in the region (i.e., regulation and national plan of action, limitation/gap in ALDFG management, and need/recommendation to address ALDFG). Secondary data were derived from available articles, publications, technical reports, and other data formats obtained from various sources (e.g., Google Scholar, Web of Science, and media of government and non-government organisations).

To supplement this information, primary data was collected from key informants, including seven fisheries officers, as representatives from their respective fisheries agencies. The key informants were selected by considering their insight and experience on marine capture fisheries and ALDFG in their own country. This study used a questionnaire to

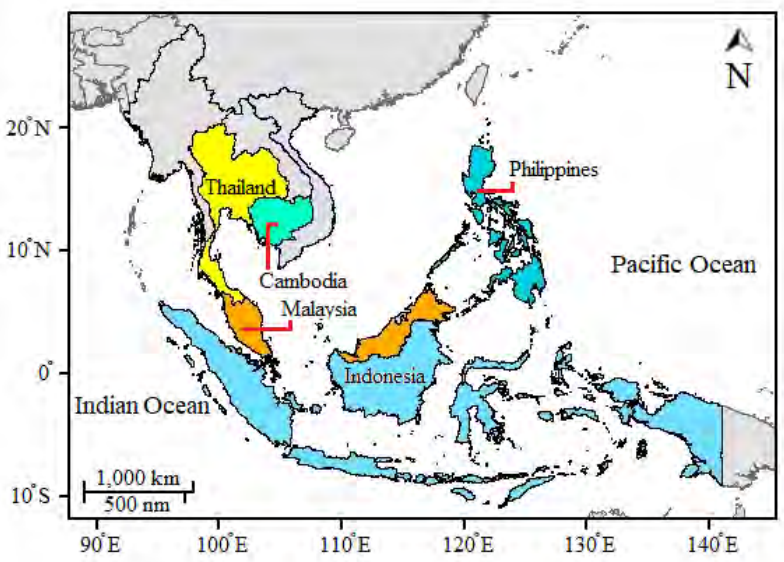

Fig. 1. Location of the five selected Southeast Asian countries, including Cambodia, Indonesia, Malaysia, Philippines, and Thailand for the study of abandoned, lost and discarded fishing gears (ALDFG) (modified from SEAFDEC, 2007a).

collect information on ALDFG and related issues in their country, including limitation/gap in ALDFG management as well as need/recommendation to address ALDFG (Supplementary Table 1).

Marine capture fisheries profile

The artisanal or small-scale fisheries (SSF) as well as industrial or commercial-scale fisheries (IDF) in each country were described for the mode of marine capture fisheries as well as annual catch landing information including volume (t), value (United States Dollar, USD), and major fish species. For the characteristics of marine capture fisheries, the data consisted of the number of fishing vessels for both SSF and IDF based on the fishing gear types. The fishing gear classification in this study followed the International Standard Statistical Classification of Fishing Gear endorsed in 2016 (CWP, 2023). For the annual catch landing statistics, the volume of marine capture production of the respective countries was obtained from the Food and Agriculture Organization of the United Nations (FAO, 2021); the value of marine capture fisheries production was adopted from SEAFDEC (2023); and the major fish species landed in the five Southeast Asian countries were selected from the top 10 species/groups from the total landings of the five Southeast Asian countries using DOF Malaysia (2021a), DOF Thailand (2022a; 2022b), FiA (2023), MMAF (2021a), and PSA (2022). Due to the different currencies among the five Southeast Asian countries for their landed fish species, the USD currency conversion was applied using the currency calculator at https://www.xe.com which was recommended in the ALDFG Global Survey (Einarsson, 2021).

ALDFG and related impacts

The data on sources of ALDFG were categorised into fishing gear types, and the causes and impacts of ALDFG were described. The initiatives/studies and projects to address ALDFG in the region were documented and synthesised. The ALDFG management measures of each country, such as regulations and national plans of action were also described.

The data on ALDFG obtained from the available sources and key informants were used to calculate the percentage frequency of occurrence (%F) of each cause of ALDFG, limitation/gap in ALDFG management, and need/recommendation to address ALDFG. The %F was calculated as:

$$\%F_i = C_i/S \quad (1)$$

where $\%F_i$ is the percentage frequency of occurrence of the i-th cause of ALDFG; C_i is the number of countries occurred for the i-th cause of ALDFG; and S is the total number of countries (S-value is five in this study). Equation (1) was also used to calculate the %F for limitations/gaps in ALDFG management and the needs/recommendations to address ALDFG.

We tested the goodness of fit among the total number of fishing vessels of the five Southeast Asian countries using the Chi-square (χ^2) test. The relationship between the total number of fishing vessels and the EEZ area of the five Southeast Asian countries was also tested using simple linear regression analysis. The significance level (α) of 0.05 was applied for all statistical analyses in this study.

Results

Our findings revealed that marine capture fisheries in Southeast Asia are diverse and complex due to the two major categories of fisheries (i.e., SSF and IDF) with numerous fishing vessels and gear types. The nature of marine capture fisheries of the region is multi-gear

and multi-species supporting the regional economy. However, the large scale of marine capture fisheries represented by fishing fleets may raise significant issues, particularly related to ALDFG. Thus, the understanding of SSF and IDF characteristics and fisheries-related baseline information is a key factor in developing effective management measures and policies to address ALDFG and related issues.

The total population of the five Southeast Asian countries was more than 497 million people in 2020 (Table 1). The total coastline length was 148,158 km, with EEZs of more than 8.85 million km^2 and a total fishery production for the region of more than 20 million t.year^{-1} (Table 1). The overall fish consumption per capita calculated based on the population and fish consumption of the five Southeast Asian countries was 39.3 kg.year^{-1}. Furthermore, the five Southeast Asian countries played an important role in international trade with the total value of imported and exported fishery commodities of 7,069 million USD.year^{-1} and 19,770 million USD.year^{-1}, respectively (Table 1). The significance of the fisheries sector was represented by its contribution to the total GDP of the five Southeast Asian countries, which ranged from 0.7 % to 5.0 %.

Marine capture fisheries

Mode of marine capture fisheries

There have been various terms for the mode of marine capture fisheries used in the five Southeast Asian countries; nevertheless, we identified and categorised them into two main modes (scales), i.e., SSF and IDF. The SSF included artisanal, coastal, and municipal fisheries that intended to harvest fishery resources for household consumption and source of income. On the other hand, the IDF (also known as commercial-scale fisheries) included medium- and large-scale fisheries that harvested fishery resources for commercial purposes. The modes of marine capture fisheries were classified according to the size of the fishing vessel and type of fishing gear (i.e., trawl and dredge) (Table 2). The SSF fishing grounds were mainly designated in nearshore or inshore, while offshore areas were designated for fishing vessels in IDF (Table 2). Our findings indicated that the fishing grounds for fishing vessels between SSF and IDF overlapped for Cambodia, Malaysia, Indonesia, and Thailand. These multiple criteria showed the contrast between the SSF and IDF of the five Southeast Asian countries.

Number of fishing vessels by fishing gear type

There were more than 1.3 million fishing vessels recorded from censuses, registrations, and estimations in the five Southeast Asian countries (Table 3). The total number of fishing vessels differed significantly among the five Southeast Asian countries (χ^2_4 = 2,559,292; P < 0.001). The number of fishing vessels in Indonesia accounted for more than 70 % of the total number of fishing vessels in the five Southeast Asian countries. In addition, the relationship between the total number of fishing vessels (Y) and EEZ area in km^2 (X) of the five Southeast Asian countries showed a positive correlation using the equation $Y = 0.16776X$ (df = 4; P < 0.001; R^2 = 0.994). For the fishing gear type, hooks and lines, gillnets and entangling nets, traps, and trawls were considered as common fishing gear (Table 3). It is also important to note that a fishing vessel was able to operate more than one type of fishing gear, particularly in SSF, depending on the fishing season. No fishing vessel was equipped with a seine net in Cambodia and Thailand, a dredge in the Philippines, a lift net in Cambodia, and a falling gear in Cambodia and Malaysia as the main fishing gear.

Landing from marine capture fisheries

Between 2010 and 2019, Indonesia accounted for the highest production volume from marine capture fisheries, followed by the Philippines (Fig. 2). It should be noted that the increasing trend of production volume of Indonesia started in 2010, while other Southeast Asian countries were relatively stable during this time. However, no production data were available during 2010–2019 for Cambodia (SEAFDEC, 2023). Among the remaining four Southeast Asian countries, Indonesia also had the highest production value which could be attributed to its

Table 1. General and fisheries-related information on five selected Southeast Asian countries for the study of abandoned, discarded, and lost fishing gears (ADDLFG).

Country	Population (million)[1]	Coastline length (km)[2]	EEZ area (km^2)[3]	Fishery production (million t.year^{-1})*,[1]	Fish consumption (kg.capita^{-1}.year^{-1})[1]	International trade of fishery commodities (million USD.year^{-1})[1]		% GDP from fisheries*,[1]
						Imported	Exported	
Cambodia	15.68	435	48,697	0.93	42.7	22.6	75.9	5.0
Indonesia	270.20	104,000	6,020,917	12.15	44.7	380.9	4832.4	2.7
Malaysia	32.58	4,810	510,804	1.61	57.8	1101.8	858.4	0.9
Philippines	108.77	36,289	1,971,033	2.77	26.2	466.3	804.3	1.2
Thailand	69.80	2,624	298,683	2.62	29.5	3646.6	5612.4	0.7

*Including capture fisheries and aquaculture from both inland and marine areas.
[1]FAO (2023a); [2]FAO (2023b); [3]Flanders Marine Institute (2019)

Table 2. Characteristics of small-scale and industrial (medium- to large-scale) fisheries in five selected Southeast Asian countries.

Country	Small-scale fishery		Industrial fishery		Source
	Size of fishing vessel	Fishing ground	Size of fishing vessel	Fishing ground	
Cambodia	<12 m LOA	NS	≥12 m LOA or <12 m if equipped trawl or mechanised clam dredge	1) NS for fishing vessel 12-24 m LOA 2) Beyond 20 m depth for trawler, mechanised clam dredger, or fishing vessel >24 m LOA	FiA (2006, 2021); Em (2007)
Indonesia	<5 GT	Within 12 nm from shoreline or island	>5 GT	Beyond 4 nm from shoreline	MMAF (2021b, 2023)
Malaysia	<40 GRT	NS	≥40 GRT	Beyond 12 nm from shoreline	DOF Malaysia (2008)
Philippines	≤3 GT	Within 15 km from shoreline or island	>3 GT	Beyond 15 km from shoreline or island	DA (1988)
Thailand	<10 GT	Within 12 nm from shoreline or island	≥10 GT	Beyond 3 nm from shoreline	DOF Thailand (2015); MD (2018)

LOA = length overall; NS = not specified.

Table 3. Number of fishing vessels in the small-scale fishery (SSF) and industrial fishery (IDF) by main fishing gear.

Fishing gear types	Cambodia		Indonesia		Malaysia		Philippines		Thailand	
	SSF[1] (C)	IDF[1] (C)	SSF[2] (C)	IDF[2] (R)	SSF[3] (R)	IDF[3] (R)	SSF[4] (R)	IDF[4] (R)	SSF[5-8] (E, R)	IDF[6] (R)
Surrounding nets	0	48	14,679	16,170	465	663	9,774	1,271	27	915
Seine nets	0	0	29,647	27,565	456	0	2,373	27	0	0
Trawls	0	1,569	23,477	2,488	3,304	1,811	0	485	90	3,127
Dredges	0	101	7,831	576	163	0	0	0	33	174
Lift nets	0	0	22,719	7,461	427	2	752	0	3	56
Falling gear	0	0	11,993	1,556	0	0	2,448	0	8,352	1,729
Gillnets and entangling nets	1,689	831	286,467	36,068	30,562	63	142,898	229	23,768	662
Traps	1,369	787	76,400	12,640	2,640	91	1,695	128	8,842	782
Hooks and lines	407	55	378,767	20,461	6,291	177	67,210	1,112	593	56
Miscellaneous gear	279[a]	28[b]	13,871[c]	13,224[d]	413[e]	86[f]	27,411[g]	167[h]	5,383[i]	1,998[j]
All fishing gear types	3,744	3,419	865,851	138,209	44,721	2,893	254,561	3,419	47,091	9,499

C = census; E = estimation; R = registration.

[a]Including 100 hand-collecting and 179 push net vessels; [b]Including 28 push net vessels; [c]Including 2,260 scoop net, 9,238 spear and harpoon, 2,305 push net, and 68 set net vessels; [d]Including 156 scoop net, 362 spear and harpoon, 11,040 push net, and 1,666 set net vessels; [e]Including 395 fish aggregating device supply and 18 push/scoop net vessels; [f]Including 86 fish aggregating device supply vessels; [g]Including 43 fish aggregating device supply, 13,358 scoop net, and 14,010 other vessels; [h]Including 150 push net and 17 other vessels; [i]Not identified; [j]Including 1,898 luring light (operating for purse seine fishing), 3 red frog crab dillies, and 97 push net vessels.

[1]FiA (2021); [2]MMAF (2021a); [3]DOF Malaysia (2021a); [4]BFAR (unpublished data); [5]DOF & CCCIF (2017); [6]DOF Thailand (2023); [7]MD (2023a); [8]DOF Thailand (unpublished data).

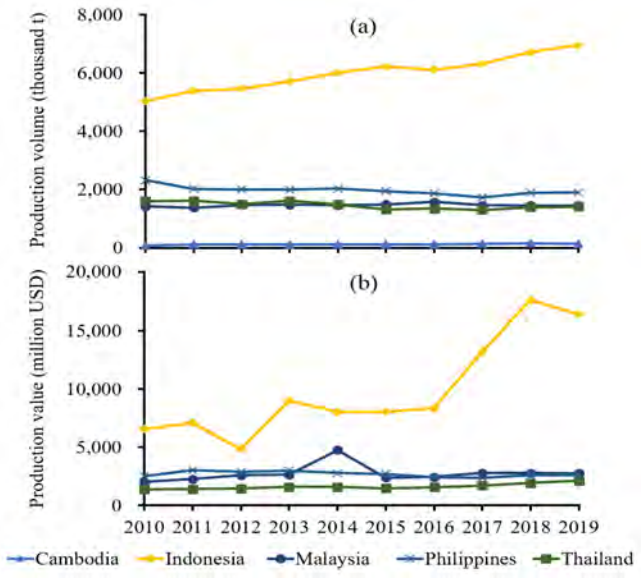

Fig. 2. Annual capture fisheries production of five selected Southeast Asian countries (except production value for Cambodia) between 2010 and 2019 by volume (a) and value (b). Data for production volume from FAO (2021) and value from SEAFDEC (2023).

production volume (Fig. 2). It should be also noted that the production value of Indonesia started to increase significantly from 2016, while it remained stable for the three other Southeast Asian countries.

The volume of the top 10 species/groups accounted for between 36 % and 65 % of the total production among the five Southeast Asian countries (Fig. 3). Meanwhile, the total value of the top 10 species/groups amounted to more than half of the total values of the marine capture fisheries production in Cambodia, Indonesia, Philippines, and Thailand, except for Malaysia (Fig. 3). The common species/groups from marine capture fisheries in the five Southeast Asian countries were mackerels, scads, anchovies, and squids.

ALDFG and related issues

Sources and causes of ALDFG

The sources and causes of ALDFG were synthesised from the secondary data. The results from the desktop study revealed that the common sources of ALDFG in the five Southeast Asian countries were gillnets, traps, and hook and lines which were reported by previous studies (Table 4). Nevertheless, other potential sources reported in four of the five countries were trawl nets, anchored fish aggregating devices (AFADs), and fishing gear components (ropes, floats, and net webbings). The results indicated that it is sometimes difficult to identify the original fishing gear type when only the detached fishing gear components or fragments are examined.

In relation to the magnitude of ALDFG, there were only a few studies carried out in the five Southeast Asian countries for the quantity or abundance of ALDFG in the coastal and marine areas. For example, the ALDFG of 3,286–4,930 fishing nets.year^{-1} was estimated for Cambodia (UNEP, 2022). The coral reef surveys revealed that ALDFG (i.e., fishing nets and lines) were the dominant marine debris in Koh Kong and Sihanoukville Provinces in Cambodia, with a proportion of 78 % and 66 % of the total marine debris,

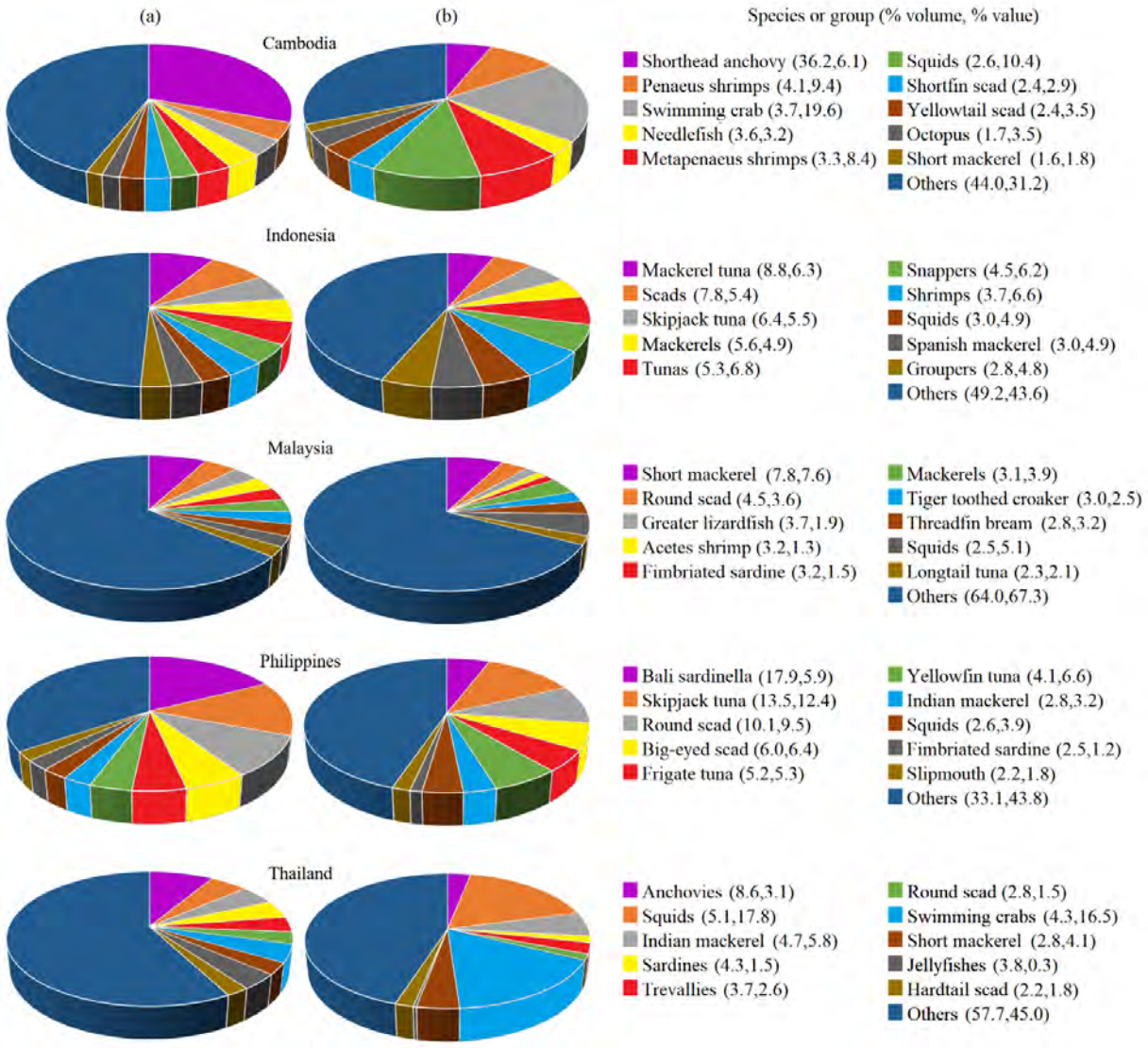

Fig. 3. Top 10 species or groups in annual landing in five selected Southeast Asian countries by volume (a) and value (b).

Table 4. Sources of ALDFG reported in five selected Southeast Asian countries.

Reported ALDFG	Cambodia[1-4]	Indonesia[5-9]	Malaysia[10-15]	Philippines[6,14,16-20]	Thailand[6,21-29]
Gillnets	+	+	+	+	+
Traps	+	+	+	+	+
Trawl nets		+	+	+	+
Purse seine nets			+		+
Dredges		+			+
Falling nets		+			
Lift nets		+			
Hooks and lines	+	+	+	+	+
Anchored fish aggregating devices		+	+	+	+
Ropes	+		+	+	+
Floats	+				+
Unknown net webbings or fishing nets	+		+	+	+
Unknown plastic-based fishing gear components	+		+	+	+

[1]Leng & Than (unpublished data); [2]FFI (2020); [3]SEAFDEC (2020); [4]UNEP (2022); [5]Duta (unpublished data); [6]Kiessling (2003); [7]Richardson et al. (2019); [8]Susanto et al. (2022); [9]Gilman et al. (2022); [10]Khairudin (unpublished data); [11]Miswan & Abdullah (unpublished data); [12]Najihah et al. (2020); [13]Hamizah et al. (2022); [14]SEAFDEC (2022b); [15]Chelliah et al. (2024); [16]Yleaña (personal communication); [17]Macusi et al. (2015); [18]CBD (2016); [19]Bucol et al. (2020); [20]Sajorne et al. (2021); [21]DOF Thailand (unpublished data); [22]Yasook et al. (2015); [23]Ballesteros et al. (2018); [24]Sukhsangchan et al. (2020); [25]Prasatkaew (2021); [26]Russell (2021); [27]Wongnutpranont et al. (2021); [28]Chumchuen et al. (2022); [29]Chumchuen et al. (2023).

respectively (FFI, 2020). The density of ALDFG retrieved by bottom trawl operation in the Gulf of Thailand was 2.2 kg.km^{-2} (3 % of all litter by weight) in Chon Buri Province, Thailand (Yasook et al., 2015) and 8.6 kg.km^{-2} (6 % of all marine debris by weight) in Pahang State, Malaysia (Hamizah et al., 2022). The reef clean-up program in Chumphon Province, Thailand also revealed that the total covered area of ALDFG on reefs composed of fishing nets (60.0 %), followed by fishing traps (36.1 %), fishing ropes (3.1 %), and nylon monofilament lines (< 0.1 %), and other fishing gears (0.7 %)(Wongnutpranont et al., 2021).

The major causes of ALDFG in the five countries, with 100 %*F*, were adverse weather conditions, fishing gear conflicts, and discarded fishing gear into the sea (Fig. 4). The adverse weather conditions such as storms or typhoons, strong winds, and high waves resulted in the abandonment of fishing gear in the sea by fishers as well as the damage or displacement of fishing gear by environmental forces (Chumchuen et al., 2022; GGGI, 2019; Russell, 2021; Susanto et al., 2022; UNEP, 2022). Fishing gear conflicts occurred when more than one type or unit of fishing gear operated in the same fishing ground; consequently, the fishing gears were damaged or displaced from the deployed location (Richardson et al., 2021; Russell, 2021; SEAFDEC, 2020; Sukhsangchan et al., 2020; Susanto et al., 2022). Meanwhile, discarded fishing gears were found in the five Southeast Asian countries when fishers disposed of their end-of-life fishing gear (EOLFG) or worn/damaged fishing gear components into the sea (Chelliah et al., 2024; FFI, 2020; Richardson et al., 2018; UNEP, 2022). Common causes of ALDFG, with 80 %*F*, were strong currents and tides, bottom obstructions, and illegal fishing activities. Strong currents and tides damaged or displaced

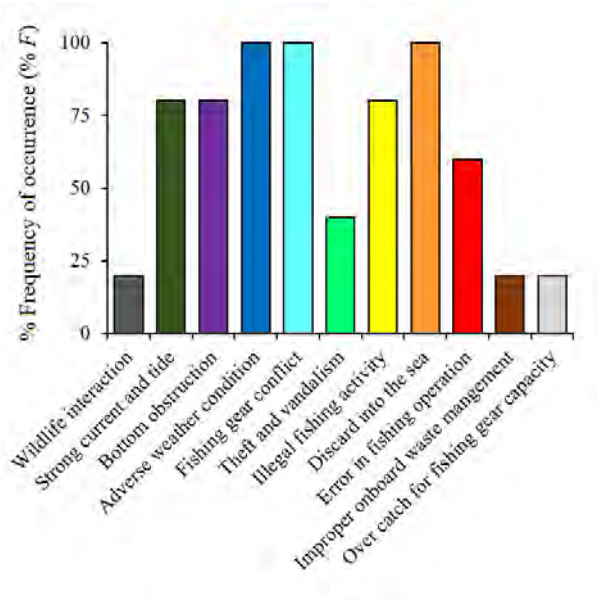

Fig. 4. Percentage frequency of occurrence of causes of abandoned, lost, and discarded fishing gears (ALDFG) in five selected Southeast Asian countries.

fishing gear and equipment (Russell, 2021; Sukhsangchan et al., 2020); besides, bottom obstructions (e.g., reefs, rocks, and wrecks) snagged or damaged fishing gear (Richardson et al., 2018; UNEP, 2022). In addition, fishers who engaged with IUU fishing activities usually abandoned or discarded their fishing gear to avoid the penalty or punishment for their illegal fishing operations (DOF Thailand, unpublished data; FFI, 2020).

ALDFG impacts

The negative impacts of ALDFG were identified and

categorised into three aspects, i.e., ecological, economic, and human well-being, based on the available data from the five Southeast Asian countries. Referring to the ecological aspect, ALDFG resulted in solid wastes and caused adverse impacts on the biodiversity and ecosystem (MAFF, 2022), such as alterations in marine habitats and mortality of marine life (e.g., dolphins, turtles, fishes, and other species) (Leng & Than, unpublished data) through ghost fishing, entangling, and ingestion (DENR, 2021; FFI, 2020). Besides, ALDFG also made impacts on sea bottoms and corals including pale tissue, tissue loss, diseases, fragmentation, and bleaching (Ballesteros et al., 2018; Wongnutpranont et al., 2021). With regard to the economic aspect, disentangling and clearing ALDFG from vessels, engines, propellers, shafts, or rudders were costly (Guzman, 2021); besides, the ghost fishing led to the deterioration fish stock resulting in the decline of fishers' income (Guzman, 2021; Leng & Than, unpublished data). ALDFG as marine litter also caused negative impacts on other livelihoods, such as in the tourism sector (FFI, 2020; Guzman, 2021). For the human well-being aspect, ALDFG caused navigational hazards and safety-at-sea problems (FAO, 2019; Leng & Than, unpublished data;). Moreover, beached ALDFG and other marine debris were considered coastal pollution, deteriorating recreational places (Fig. 5).

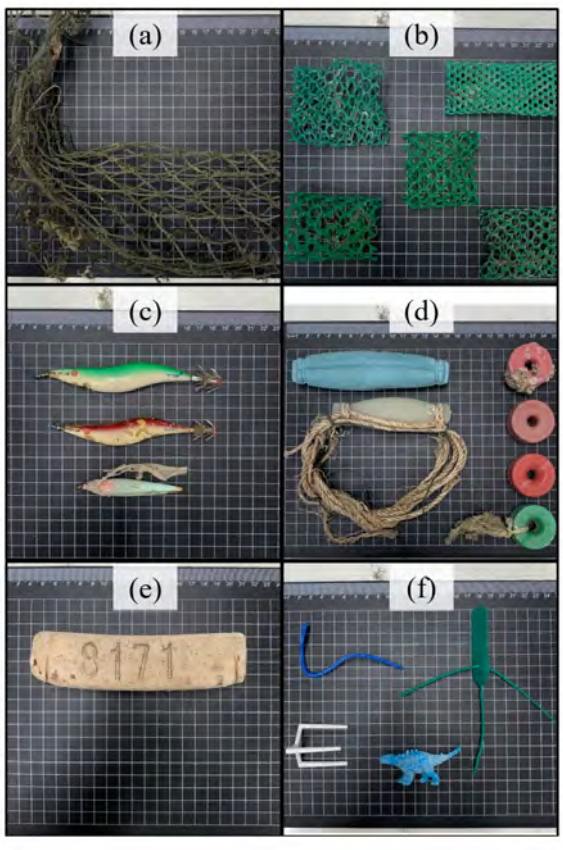

Fig. 5. Beached ALDFG and marine debris in the coastal area of Surat Thani Province, Thailand including a part of trawl net (a), plastic bait bags of crab trap (b), squid jigs (c), floats with headrope of gillnets (d), coded float of unknown fishing gear (e), and other marine plastic debris including tags, pizza saver, and toy (f).

Previous efforts to address ALDFG

The five Southeast Asian countries have launched various approaches and initiatives to facilitate the studies/projects to address ALDFG and related issues (Macfadyen et al., 2009; SEAFDEC, 2022b), for example, clean-up campaign, ALDFG recycling, fishing gear modification, and fishing gear marking (FGM) practice. The ALDFG mitigations in the five Southeast Asian countries were mostly removal programs through coastal or reef clean-up campaigns in Cambodia (Leng & Than, unpublished data), Indonesia (The SeaCleaners,2023), Malaysia (DOF Malaysia, 2022; Khairudin, unpublished data; SEAFDEC, 2022b), Philippines (BFAR, 2021), and Thailand (Ballesteros et al., 2018; DOF Thailand, 2022c; Wongnutpranont et al., 2021). As an application of the circular economy, ALDFG recycling or upcycling was implemented for making new fishing gears or other products in Indonesia (FTC, 2023), Philippines (BFAR, 2021; CBD, 2016; Huntington & Drinkwin 2023), and Thailand (Guzman, 2021; Huntington & Drinkwin 2023). The fishing gear modification to reduce the impact of ghost fishing on the marine ecosystem was also studied, for example, the use of escape gaps or escape vents in crab trap fishery in Indonesia (Rahman et al., 2021; Sara et al., 2016), Philippines (Picoy-Gonzales et al., 2025), and Thailand (Putsa et al., 2016). For FGM practice, there were also efforts to apply and develop suitable FGM technology for fishers in Cambodia (Chap et al., 2016; Chin et al., 2021), Indonesia (Dixon et al., 2018; GGGI, 2019, 2022; Guzman, 2021; SEAFDEC, 2022b; TCMFG, 2018), Malaysia (DOF Malaysia, unpublished data; Khairudin, unpublished data; SEAFDEC, 2022a, 2022b), Philippines (SEAFDEC, 2022b), and Thailand (Chumchuen & Krueajun, 2021; Chumchuen et al., 2022, 2023; FAO, 2022b; SEAFDEC, 2022b). Meanwhile, the outputs of research and development in the five Southeast Asian countries to prevent or reduce ALDFG and its impacts were deemed to be inadequate, considering the variety of fishing gear types used in the region.

ALDFG management

Regulation and national plan of action

The regulations and national plan of action of the five Southeast Asian countries obtained from the desktop study were summarised into six categories, and each category was classified as prevention, mitigation, and/or remediation of ALDFG (Table 5). The six categories consisted of two regulations and four national plans of action frameworks. Some of the Southeast Asian countries have established regulations and/or national plans of action related to ALDFG management at the national level, while other countries have set protocols or measures to indirectly address ALDFG (Table 5).

The regulations or legal frameworks were categorised into (1) prohibition to discard fishing gear or its

Table 5. Regulations and national plan of action frameworks addressing abandoned, lost, and discarded fishing gears (ALDFG) and related issues in the five Southeast Asian countries.

Category	Management strategy	Country
Regulations		
Prohibition on discarding fishing gear or its components	P	KHM, IDN, MYS, PHL, THA
Fishing gear marking practice-related regulation for inside and/or outside EEZ	P, M	IDN, MYS, PHL, THA
National plan of action frameworks		
Reduce, reuse, or recycle fishing gear and its components	P, M, R	KHM, IDN, MYS, PHL, THA
Marine debris or waste management	M	KHM, IDN, MYS, PHL, THA
Awareness raising	P, M	KHM, IDN, MYS, PHL, THA
Environment-friendly fishing gear material and/or practice	P, M	KHM, IDN, PHL

P = Prevention; M = Mitigation; R = Remediation; KHM = Cambodia; IDN = Indonesia; MYS = Malaysia; PHL = Philippines; THA = Thailand.

components into the fishing grounds or marine environments, and (2) implementation of the fishing gear marking (FGM) practice. For the related regulations on the prohibition to discard fishing gear or its components, our results highlighted that there is no specific legal framework on ALDFG in the five Southeast Asian countries. However, some existing laws/instruments cover aspects of ALDFG, e.g., marine litter or solid waste management, prevention of pollution made by garbage from vessels, and licensing, monitoring, control, and surveillance of fishing gear. These laws/instruments prohibit the discard of fishing gear or its components in Cambodia (FAO, 2023c; FiA, 2006), Indonesia (JDIH, 2021), Malaysia (DOF Malaysia, 2021b), Philippines (GOVPH, 2001), and Thailand (DOF Thailand, 2015; MD, 2023b). Besides, the regulations on FGM practice for inside and/or outside EEZ of the countries have been enforced by Indonesia (MMAF, 2021c, 2021d), Malaysia (Sallehudin et al., 2019), Philippines (DA, 2012, 2018), and Thailand (DOF Thailand, 2019). It should be noted that the FGM-related regulation has been enforced by countries for the overseas fisheries to comply with the resolutions and/or management measures of regional fisheries management organisations (RFMOs), including the Western and Central Pacific Fisheries Commission (WCPFC), Indian Ocean Tuna Commission (IOTC), and the Southern Indian Ocean Fisheries Agreement (SIOFA). Furthermore, some fishers in the five Southeast Asian countries have been practicing FGM for their own purposes, such as locating, maintaining fishing gear, and displaying and distinguishing ownership of their fishing gear among local fishers (Chumchuen & Krueajun, 2021; DOF Thailand, 2022d; DOF Thailand, unpublished data; Miswan & Abdullah, unpublished data; SEAFDEC, 2020).

The national plan of action frameworks established by the five Southeast Asian countries were categorised into (1) reduce, reuse, or recycle fishing gear and its components, (2) marine debris or waste management, (3) awareness raising, and (4) environment-friendly fishing gear material and/or practice (Table 5). The first three categories (1-3) have been directly or indirectly implemented by the five Southeast Asian countries, including Cambodia (FiA, 2006, 2011, 2015, 2019, 2020a, 2020b), Indonesia (Arifin et al., 2023; IMO, 2023; Wang & Karasik, 2022), Malaysia (KASA, 2021), the Philippines (DENR, 2021), and Thailand (DOF Thailand, 2022c; PCD, 2023) (Table 5). Lastly, the environment-friendly fishing gear material and/or practice has been imposed in Cambodia (FiA, 2011, 2020b), Indonesia (Arifin et al., 2023; Wang & Karasik, 2022), and the Philippines (DENR, 2021; Yleaña, unpublished data).

Limitations/gaps in ALDFG management

All five Southeast Asian countries (100 %*F*) responded that the limitations/gaps include a lack of systematic ALDFG data collection, inadequate budget and expertise in ALDFG retrieval, and insufficient funding to perform large-scale ALDFG retrieval (Table 6). Four Southeast Asian countries (80 %*F*) indicated the lack of attention to preparing and selling their EOLFGs to the collectors or recyclers. Besides, three Southeast Asian countries (60 %*F*) revealed the limitation/gap in the regulation of the FGM system, awareness of fishers (e.g., impacts of ALDFG and benefits of FGM practices), and participation of fishers and seafarers in reporting any sighting of ALDFG. Our results indicated that there are different limitations/gaps among the five Southeast Asian countries in ALDFG management.

Needs and recommendations to address ALDFG

A total of 11 out of the 14 needs/recommendations to address ALDFG were similar among the five Southeast Asian countries (Table 7). All five Southeast Asian countries indicated the need to increase public awareness of ALDFG and its impacts, promote capacity building for officers and related stakeholders on ALDFG management, implement baseline surveys and pilot projects on ALDFG, improve traditional FGM practices (i.e., labelled or embedded with alphanumeric codes on high-flyer/flag/buoy attached on fishing gear), implement FGM system or related mechanisms (e.g., regulation and legal framework), mitigate ALDFG and its impacts (e.g., expand seabed cleaning areas to retrieve ALDFG), develop responsible fisheries practices to prevent ghost fishing of ALDFG (e.g., use biodegradable materials, develop escape vents, and apply ropeless technique), encourage collaboration between fishers and recycling facilities, develop fishing gear disposal facility and impose

Table 6. Percentage frequency of occurrence (%*F*) of limitation/gap in abandoned, lost and discarded fishing gear (ALDFG) management in the Southeast Asian countries, as specified by key informants (n = 5).

Limitation/gap in ALDFG management	%*F*
Lack of systematic ALDFG data collection	100
Requirement on budget and expertise for ALDFG retrieval	100
Insufficient funding to perform ALDFG large-scale retrieval	100
Lack of attention to preparing and selling end-of-life fishing gear to the collectors or recyclers	80
Regulation for fishing gear marking (FGM) system	60
Awareness of fishers (e.g., impacts of ALDFG and benefits of FGM practice)	60
Participation of fishers and seafarers in reporting any sighting of ALDFG	60
Laws/regulations to register for lost fishing gear	20
Insufficient traditional FGM practice for local fishers	20

Table 7. Percentage frequency of occurrence (%*F*) of needs/recommendations responded by key informants to address abandoned, lost and discarded fishing gears (ALDFG) and related issues in the five Southeast Asian countries (n = 5).

Needs/recommendations to address ALDFG	%*F*
Increase public awareness of ALDFG and its impacts	100
Promote capacity building for officers and related stakeholders on ALDFG management	100
Implement baseline surveys and pilot projects on ALDFG	100
Improvement of traditional fishing gear marking (FGM) (i.e., add alphanumeric codes on high-flyer/flag/buoy)	100
Implement FGM system or related mechanisms (e.g., regulations and legal frameworks)	100
Mitigation of ALDFG and its impacts (e.g., expand seabed cleaning areas to retrieve ALDFG)	100
Development of responsible fisheries practices to prevent ghost fishing from ALDFG (e.g., biodegradable materials, escape vents, and ropeless technique)	100
Collaboration between fishers and recycling facility	100
Development of fishing gear recycling facility and capacity	100
Improvement of fishing gear disposal facility	100
Satisfactory incentive or payment for selling end-of-life fishing gear	100
Development of FGM practice (e.g., suitable materials, appropriate installation methods, and effective cost)	80
Enhance strategic collaboration among stakeholders on ALDFG monitoring and retrieval	80
Use of high-quality fishing gear with longer lifespan	80

satisfactory incentive or payment for selling the damaged or used fishing gear (Table 7). Meanwhile, four Southeast Asian countries recommended the development of FGM practice (e.g., suitable materials, appropriate installation methods, and effective cost), enhancement of strategic collaboration among stakeholders on ALDFG monitoring and retrieval, and use of high-quality fishing gear with a longer lifespan.

Discussion

Marine capture fisheries profile

The fisheries sector is essential for the five Southeast Asian countries and the whole region, considering its important role in the regional and global seafood supplies. FiA (2022) reported that four of the countries in our study (excluding Cambodia) had an estimated annual production value of USD 200-300 million from the total landings, of which approximately 50 % of the total landing was made by small-scale fishers operating in the inshore area. For the mode of marine capture fisheries, it should be noted that each country may revise the criteria between SSF and IDF from time to time, corresponding to their respective fisheries policy and management. For example, the criteria for SSF and IDF of Cambodia, Malaysia, and Thailand reported by Teh & Pauly (2018) were different from this study due to the revision of fisheries laws and regulations. Furthermore, the new fisheries law of Cambodia is being developed, and the modes of marine capture fisheries are being defined based on the type, size, length, and number of fishing gear or type of vessels (Bann & Lieng, 2020).

The over a million fishing vessels operating in the five Southeast Asian countries reflect the fact that intensive fishing activities are apparent in the region. The number of fishing vessels in our study was based on the censuses, registrations, and estimations, while the actual number of fishing vessels could be higher than our results due to unregistered fishing vessels, particularly in SSF. Tavarutmaneegul (2002) also reported that more than four million fishers are using various types of fishing gear in the marine capture fisheries in the region. In the five Southeast Asian countries, it was revealed that some fishing gear types (i.e., seine nets, dredges, lift nets, and falling gear) were not the main fishing gear of fishing vessels in both IDF and SSF in some countries. Nevertheless,

these fishing gear types were observed in Southeast Asian countries as minor fishing gear using a fishing vessel or hand-operated fishing gear without a fishing vessel, such as beach seines, hand dredges, stationary and portable lift nets, and cast nets (Bann and Sopha, 2020; SEAFDEC, 2002, 2004a, 2004b, 2007b).

ALDFG and related issues

Although there were several studies related to ALDFG in the five Southeast Asian countries, most of them were qualitative studies. Macfadyen et al. (2009) stated that only a few studies attempted to quantify ALDFG in Southeast Asia. This may be due to sampling difficulties, inaccessibility, and substantial cost for quantitative studies to be undertaken through field surveys (Hamizah et al., 2022). Moreover, countries still need to improve their knowledge of the causes of ALDFG as a research gap due to insufficient available information. Identifying the causes of ALDFGs is necessary for establishing baseline information for preventing and reducing ALDFG. The gaps in ALDFG studies in the Southeast Asian countries are reflected in our results; therefore, the baseline information on ALDFG of the region needs to be established. GESAMP (2021) reviewed global ALDFG and reported that the causes of ALDFG include fishing gear conflicts, poor weather conditions, and snagging on bottom obstructions. Huntington & Drinkwin (2023) also reported that theft and sabotage sometimes occur, but it is not a major cause of ALDFG. These causes are similar to our results and demonstrate that ALDFG could be caused by similar factors worldwide.

In the five Southeast Asian countries, Yasook et al. (2015) reported that some fishers intended to discard unwanted things, including marine litter, from the trawl cod-end back to the sea. This indicates that ALDFG could be circulated within the marine environment and cause more adverse impacts on the marine ecosystem for a long time until it is either decomposed or brought back to the shore. Therefore, the management of retrieved ALDFG should be considered by policymakers and/or fisheries managers; besides, building awareness among fishers to support appropriate ALDFG retrieval and disposal is also necessary. For fisheries management and policy development, He & Lansley (2023) suggested a risk assessment framework to evaluate the risks associated with different gear types into potentially becoming ALDFG and its impacts on the ecosystem and economy. Risk assessments could provide essential information in prioritising fishing gear types for FGM implementation toward preventing and reducing ALDFG.

Among the impacts of ALDFG on ecological, economic, and human well-being aspects, the ecological impacts are wide-ranging. For example, marine plastics impact marine organisms through ingestion and entanglement, while the economic impacts are focused on the value of the abandoned or lost fishing gear, degradation of fishery resources (ghost fishing), and cost of disentanglement of ALDFG from propellers (NUS, 2022). The impacts found in this study were also similar to the impacts of ALDFG on marine wildlife, the marine environment, and socio-economics in South Asian countries reported by the World Bank (2023). For decades, ALDFG and its impacts have been recognised in Southeast Asia. The Regional Guidelines for Responsible Fishing Operations in Southeast Asia were developed as an output of a core experts meeting in 1998 for regional cooperation in developing and applying technologies, materials, and operational methods that minimise ALDFG and ghost fishing (SEAFDEC, 2000). However, the current situation of addressing ALDFG and related issues in the region seems to be slowly progressing and needs improvement. It is recommended that countries should take into consideration addressing ALDFG and related issues through policy, action plan, and implementation by involving related stakeholders, particularly those in the fisheries sector.

ALDFG management

Aside from the ALDFG retrieval exercise mentioned in our results, volunteers from the five Southeast Asian countries participated in the International Coastal Clean-up in 2018 and collected about 405 t of beached marine debris (Ocean Conservancy, 2019). FGM system has also received global attention, whereby FAO developed the Voluntary Guidelines on the Marking of Fishing Gear – Manual for the Marking of Fishing Gear (Einarsson et al., 2023) as a tool to develop an FGM system at the national, regional, and global levels. In this regard, it is recommended that the five Southeast Asian countries enhance their capacity in both public and private sectors relating to the FGM system.

For fishing gear modification, one of the key informants suggested considering and developing fishing gear technology to reduce the ghost fishing phenomenon, such as replacing the synthetic ropes/yarns in certain parts of the fishing gear with biodegradable materials (e.g., natural ropes) to facilitate the release of fish once the fishing gear becomes ALDFG for a while. Gear modifications have been introduced worldwide to mitigate or reduce the impacts of ghost gears on aquatic animals. Considering traps and gillnets were the major players causing ghost fishing in coastal and marine areas (He, 1997), therefore, prevention and/or mitigation measures are needed to reduce the impacts of ALDFG and ghost fishing. In trap fisheries, ropeless techniques (Hamilton and Baker, 2019) and escape vents (Zhang et al., 2021) were applied to reduce the bycatch of marine mammals and small-sized animals, respectively. In the gillnet fishery, Kim et al. (2016) reported that biodegradable and nylon monofilament bottom gillnets had similar catch rates for yellow croaker (*Larimichthys polyactis* (Bleeker, 1877)), and biodegradable monofilament started to degrade after 24 months in seawater. Biodegradable monofilament

netting has potential and can be further considered in improving gillnet material to mitigate the impact of ALDFG and ghost fishing in the Southeast Asian region. Recently, several types of biodegradable monofilaments, e.g., polylactic acid (PLA), polyhydroxyalkanoates (PHAs), and polybutylene succinate (PBS) have been supplied in various countries. Its application to fishing gear improvement, particularly ghost fishing prevention, has also been studied, for example, the use of PBS in comparison to nylon monofilaments in fishing nets carried out by Kim et al. (2023). PBS was considered to have a great biodegradable property with a high degradation rate in the marine environment (Liu et al., 2022). However, more investigations are needed to develop fishing gear materials and designs using biodegradable materials by taking into consideration ghost fishing prevention, and also not forgetting the need for high-quality fishing gear with a longer lifespan.

For the legislation regarding ALDFG in the five Southeast Asian countries, this study found that certain levels of direct and indirect prevention measures are imposed at the national level to address ALDFG and related issues. In addition, international instruments are also implemented to address ALDFG and support FGM practice, for example, the MARPOL Annex V (IMO, 2018), FAO Code of Conduct for Responsible Fisheries (FAO, 1996), Voluntary Guidelines on the Marking of Fishing Gear: Manual for the Marking of Fishing Gear (Einarsson et al., 2023), Agreement of Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (FAO, 2016) as well as Sustainable Development Goals (UN, 2024). These instruments support the prevention and reduction of ALDFG at the national, regional, and global levels.

Insufficient ALDFG systematic data collection, as well as limited budgets and expertise to perform ALDFG large-scale retrieval, were the limitations/gaps faced by the five Southeast Asian countries in managing ALDFG as reported in Cambodia (Leng & Than, unpublished data), Malaysia (Khairudin, unpublished data), Philippines (Yleaña, unpublished data), and Thailand (Russell, 2021). Recently, NGOs and global networks in the Asia-Pacific have played important roles in supporting studies and research on ALDFG, particularly in developing countries (Sulistiawati & Eisma-Osorio, 2021). This could enhance the regional ALDFG baseline information as well as mitigate its impacts. It should also be noted that the lack of effort to prepare and sell EOLFG to collectors or recyclers is also a limitation/gap as reported by Russell (2021). EOLFG can be recycled or upcycled as a way to prevent ALDFG occurrence and to support the circular economy; however, pre-processing, e.g., sorting, disassembling, and cleaning, is necessary. Each type of material in the ALDFG and EOLFG requires a particular procedure to recycle. More complex and costly processes such as incineration, chemical recovery, and thermal conversion may take place, especially when a component of fishing gear is made of different types of material or polymer mixtures (Sala & Richardson, 2023).

Noting the results of the previous studies and reports, it is recommended that the five Southeast Asian countries should develop and implement FGM systems or related mechanisms, mitigate ALDFG and its impacts, and develop fishing gear recycling facilities and capacity (Chumchuen & Krueajun, 2021; Chumchuen et al., 2022, 2023; FFI, 2020; IMO, 2023; Khairudin, unpublished data; Russell, 2021; Yleaña, unpublished data). Sala & Richardson (2023) mentioned that there are four levels or processes involved in fishing gear recycling. The primary and secondary recycling processes (mechanical recycling process) are the most economical and available worldwide, but these processes are only applicable to fishing gears containing less contamination, less mixed materials, and a single polymer. The tertiary recycling process (chemical recycling, thermal conversion, or physical dissolution/solvent-based purification process) can be complemented when fishing gear and components are not recyclable under the primary and secondary processes. Quaternary recycling process is the last option, using incineration or energy recovery as an alternative processing for ALDFG and EOLFG.

In order to sustain fishing gear recycling activity, one of the key informants suggested that economic incentives should be considered for both suppliers (fishers/collectors) and consumers (recyclers/end-product users). Russell (2021) also supported that a satisfactory incentive or payment from selling the EOLFG is necessary for fishers to maintain recycling activity. Hence, it is recommended that the provision of economic incentives be considered to encourage fishers to prepare and sell their EOLFGs to collectors or recyclers. In addition, the development of responsible fishing practices to mitigate ghost fishing by using fishing gear made from biodegradable materials as well as fishing gear and fishing method improvement were recommended by the key informants, with emphasis given on cost-effective and environmentally friendly materials. Apart from that, Yleaña (unpublished data) suggested that the fishing gear swap was initiated as a livelihood support intervention by using natural-based fishing gear (i.e., bamboo traps) rather than synthetic fishing gear to reduce the impacts of ALDFG and ghost fishing.

For the way forward, we firstly recommend that the knowledge of ALDFG, ghost fishing, and FGM system in Southeast Asian countries needs to be strengthened, considering the multi-gear and multi-species characteristics of marine capture fisheries in this region. This knowledge could serve as baseline information for further research and formulation of management plans in addressing ALDFG and related issues. Further quantitative systematic studies or surveys in Southeast Asian countries for ALDFG are

also needed as scientific evidence or baseline information. For example, fishing gear or fishing gear components were found in bays, coasts, and rivers, which were left behind by fishers because of damage, bad weather, or closed fishing season. Secondly, although the region was supported by inter-governmental organizations and NGOs (including capacity-building programs, projects, and information dissemination), we recommend that high priority should be given at the national level for raising the awareness of stakeholders (specifically fishers) to impel ALDFG management. Lastly, cooperation and information sharing at the regional and global levels, particularly among Southeast Asian countries, are recommended as an essential action to deal with ALDFG and related issues.

Conclusion

The five Southeast Asian countries contributed significant fisheries production through multi-gear and multi-species fisheries to support regional and global demand. This study highlighted that the common ALDFGs in the five Southeast Asian countries were gillnets, traps, and hook and lines; besides, other potential sources were AFADs, trawl nets, and fishing gear components (ropes, floats, and net webbings). The impacts of ALDFG reported in this study were categorised into three aspects (ecological, economic, and human well-being), of which the ecological impacts caused wide-ranging effects on marine habitats, animals, food web, and contamination in the environment. Some legislation and action plans related to ALDFG have been developed and put in place at the national level, for example, EOLFG management, ALDFG retrieval, FGM system, and ghost fishing reduction. Besides, the resolutions and management measures of RFMOs to prevent ALDFG were introduced to the member countries at the regional level, as well as the implementation tools of the inter-governmental bodies at the global level were also available to address ALDFG and related issues. The limitations/gaps identified in the five Southeast Asian countries were mainly related to insufficient ALDFG baseline information, lack of ALDFG retrieval programs, and weak EOLFG management. The needs/recommendations of the five Southeast Asian countries to address ALDFG were similar, whereby all of the countries emphasised increasing public awareness, promoting capacity building, enhancing baseline information, improving FGM practice and system, mitigating impacts of ALDFG, preventing ghost fishing, improving disposal and recycling facilities, and promoting economic incentives for EOLFG. This study recommends that the knowledge of ALDFG, ghost fishing, and FGM system in Southeast Asian countries should be further strengthened. Higher priority should be given to addressing ALDFG and related issues at the national level; besides, cooperation and information sharing at the regional and global levels should be continued. These recommendations could support the policymakers, fisheries managers, researchers, fishers, and other relevant stakeholders in managing ALDFG and its impacts in the Southeast Asian region.

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Supplementary Table 1. Questionnaire for a study on Abandoned, Lost or Otherwise Discarded Fishing Gear in Coastal and Marine Areas of Selected Southeast Asian Countries: A Status Update and Recommendations

Part 1: Please answer Y (Yes) or N (No) for the limitation/gap to manage abandoned, lost, discarded fishing gear (ALDFG) in coastal and marine areas in your country.

Item	Limitation/gap	Y/N
1	Laws/regulations to register for lost fishing gear	
2	Regulation for fishing gear marking (FGM) system	
3	Insufficient traditional FGM practice for local fishers	
4	Awareness of fishers (e.g., impacts of ALDFG and benefit of FGM practices)	
5	Participation of fishers and seafarers in reporting any sighting of ALDFG	
6	Lack of systematic ALDFG data collection	
7	Requirement on budget and expertise for ALDFG retrieval	
8	Insufficient funding to perform ALDFG large-scale retrieval	
9	Lack of attention to preparing and selling end-of-life fishing gears to collectors or recyclers	
10	Other (specify).....	
11	Other (specify).....	
12	Other (specify).....	

Please provide your comment for the limitations/gaps (if need)

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Part 2: Please answer Y (Yes) or N (No) for the need and recommendations to support or fulfill the limitations/gaps (corresponding to 2).

Item	Need/recommendation	Y/N
1	Increase public awareness of ALDFG and its impacts	
2	Promote capacity building for officers and related stakeholders on ALDFG management	
3	Implement baseline surveys and pilot projects on ALDFG	
4	Improvement of traditional fishing gear marking (FGM) (i.e., add alphanumeric codes on high-flyer/flag/buoy)	
5	Development of FGM practice (e.g., suitable materials, appropriate installation methods, and effective cost)	
6	Implement FGM system or related mechanisms (e.g., regulations and legal frameworks)	
7	Mitigation of ALDFG and its impacts (e.g., expand seabed cleaning areas to retrieve ALDFG)	
8	Enhance strategic collaboration among stakeholders on ALDFG monitoring and retrieval	
9	Development of responsible fisheries practices to prevent ghost fishing from ALDFG (e.g., biodegradable materials, escape vents, and ropeless technique)	
10	Use of high-quality fishing gear with longer lifespan	
11	Collaboration between fishers and recycling facility	
12	Development of fishing gear recycling facility and capacity	
13	Improvement of fishing gear disposal facility	
14	Satisfactory incentive or payment for selling end-of-life fishing gear	
15	Other (specify).....	
16	Other (specify).....	
17	Other (specify).....	

Please provide your comment for the needs and recommendations (if need)
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Thank you very much for your valuable time and responses to support our study

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