ORIGINAL PAPER

Derelict fishing gears and other marine debris on coral communities on underwater pinnacles in Chumphon Province, Thailand

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Abstract. Underwater pinnacles are necessary marine resources because they have a complex structure, serving as a suitable habitat for various marine organisms. However, the underwater pinnacle has been experienced with heavy fishing pressure, resulting in the accumulation of derelict fishing gear (DFG). Almost all derelict fishing gear has been recognized as a source of marine debris pollution. In this regard, a reef cleanup program was initiated with collaborations of a volunteer group (Save Our Sea Foundation) and researchers from several institutions. The program was done in July 2019 at five underwater pinnacles in Chumphon Province. Derived from the cleanup program, all marine debris that was removed from the underwater pinnacles were derelict fishing gear (145 pieces) that covered a total area of 140.01 m^2, accounting for 19% of a total survey area (750 m^2). Four major categories of DFG found on live corals included fishing nets, ropes, monofilament lines, and fishing traps. Fishing traps had the most cover area (77.93 m^2), followed by fishing nets (77.93 m^2), ropes (59.86 m^2) and monofilament lines (4.91 m^2). Based on the total corals covered by DFG, 81.3% of which were impacted including pale tissue (35.8%), tissue loss (20.8%), diseases (10.4%), fragmentation (9.8%), and bleaching (6.4%.) on corals. The areas with higher live coral cover tend to have a higher diversity of marine organisms, becoming targeted by the fishing industries. However, in some areas, e.g., Hin Phum and Hin Thong Wo, where live coral covers are relatively low, had a high occurrence of the DFG. This study also shows that the accumulation of marine debris is likely to occur in the areas with high fishing activities than it the areas with high tourism activities. Therefore, the results of this study can serve as baseline information for managing marine debris in the Gulf of Thailand.

Keywords: impact, coral commpiecey, underwater pinnacle, marine debris, derelict fishing gear

1. Introduction

Underwater pinnacles are another structure of seamount but are small isolated pillar-like elevations rising off the seafloor and perhaps the most distinct submerged structures. These topographical characteristics have a limited area where a very high abundance of marine organisms is found, which makes them important as an oasis in the deep sea. Pinnacles and similarly structural features in the ocean are known to be associated with rich stocks of commercial reef fishes. Often, smaller reef fishes and other organisms only inhabiting in reefs live on the pinnacles. Underwater pinnacles are spotted among divers who want to see larger pelagic fishes as sharks, barracudas, tunas, groupers etc., that regularly linger around the coral community on a pinnacle. These pelagic fishes generally feed on the smaller reef fishes and marine invertebrates (Rogers, 2004; Richert et al., 2017).

The impacts of anthropologic activities, particularly tourism and fisheries, on coral reefs have been reported in several studies. Marine debris pollution caused by such activities has become a serious global environmental issue, particularly in the Southeast Asian countries and its impacts on marine biodiversity have also been recognized (Saphier & Hoffmann, 2005; Kershaw 2011; Ballesteros et al., 2018). The frequency of impacts varies according to the types of debris, which plastic debris holds the major proportion of over 80 %, while other debris such as paper, glass, and metal are accounted for less than 20 % (Dias and Lovejoy, 2012). Almost all marine debris found on coral reefs in Thai territorial waters is derelict fishing gears (DFG) (Chiappone et al., 2005; Ballesteros et al., 2018). Additionally, marine benthic organisms and ecosystems are vulnerable to the impacts of microplastic accumulating on the seafloor.

The understandings and information regarding marine debris in Thailand are still limited. This study aims to survey the types of marine debris accumulated on the coral reefs at several underwater pinnacles in the Western Gulf of Thailand. We focused on the occurrences of marine debris on coral communities in the underwater pinnacles dominating with two activities: tourism and fishery.

2. Materials and Methods

2.1 Study sites and field surveys

The field survey was a part of a reef cleanup program, which was initiated with the collaboration of a volunteer group (Save Our Sea Foundation) and researchers from several institutions. This program was implemented in July 2019 at five underwater pinnacles, including Hin Jen Ta Lay, Hin Kan Thuree, Hin Lak Ngam, Hin Pae, Hin Phum, and Hin Thong Wo. The underwater pinnacles are in Chumphon Province, located off the coast of approximately 12-20 kilometers.

Before the activities started, a brief meeting was organized to inform the participants about the environmental condition of the implementing areas. Researchers provided the participants with a brief information and methodology of data collection for scientific purposes, so the volunteers can help collect such data for this study. The presence of marine debris and coral coverage was estimated using the photo belt-transects method (English et al., 1997) to calculate the percentage cover of live corals (374 m^2), dead corals (166 m^2), rubbles (4 m^2), sand (62 m^2), rocky (129 m^2), and algal (16 m^2). The total surveyed area was 750 m^2. The marine debris found in the transects were noted. Size and impacts of marine debris on coral reefs were recorded. Other supporting data were also recorded such as types of anthropogenic activities (tourism and fishery activities), distance from the shore, geographical coordinates, depth, water transparency (Table 1).

Table 1. Study sites and information in Chumphon Province, Thailand

Study sites	Latitude (N), Longitude (E)	Distance from the Shore (km)	Depth range (m)	Count of dives	Water Transparency	Anthropogenic Activities
Hin Jen Ta Lay	9.802517 99.306217	16.99	7-11	3	Turbid	Fishery
Hin Kan Thuree	9.671950 99.237250	12.15	3-6	3	Turbid	Tourism
Hin Lak Ngam	10.449990 99.399986	21.14	5-15	3	Clear	Tourism
Hin Pae	10.533333 99.400833	17.14	0.2-12	1	Clear	Tourism
Hin Phum	9.738867 99.304233	20.60	5-10	3	Turbid	Fishery
Hin Thong Wo	10.020556 99.254722	18.28	9-12	2	Turbid	Fishery

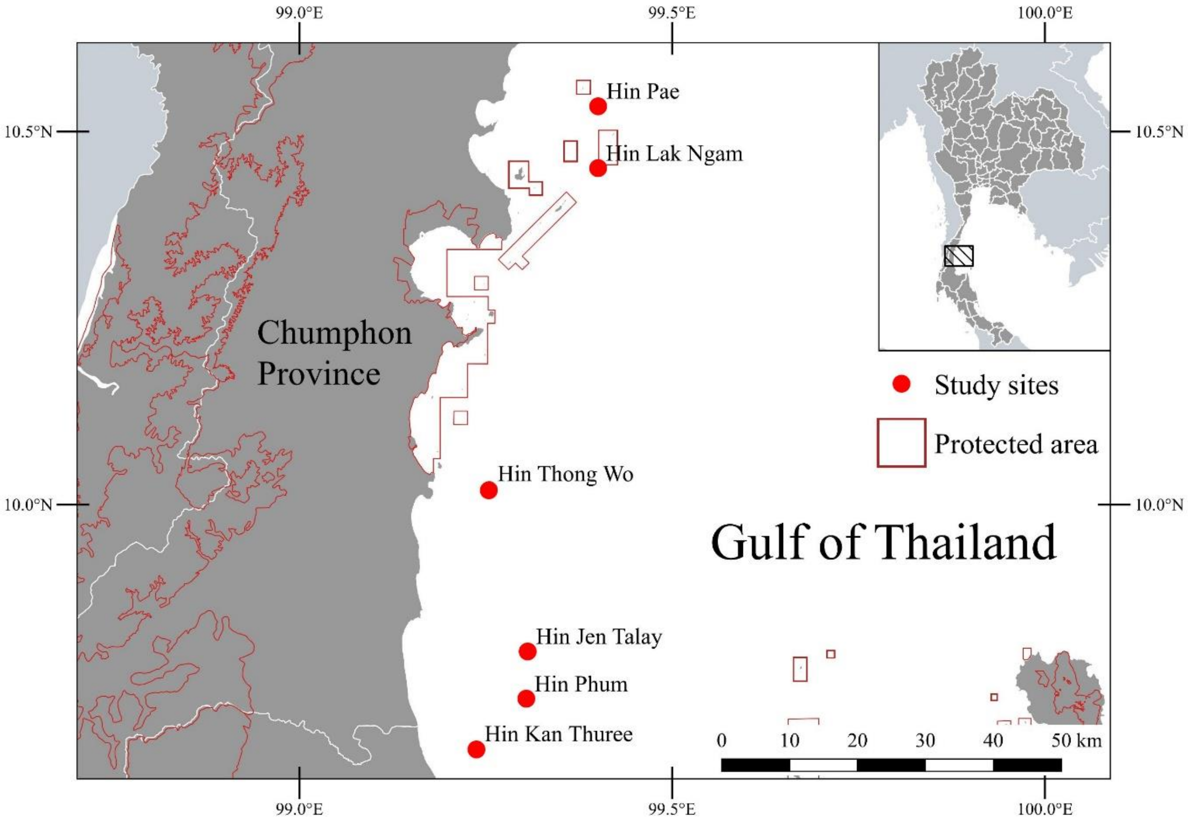

Figure 1. Location of the study sites at Chumphon Province in the Gulf of Thailand

Figure 2. The coral reefs cleaning project by volunteers

2.2 Data analyses

The coverage of marine debris was measured using ImageJ, a Java-based image processing program. One-way ANOVA was used to detect the variation of DFG coverage on coral reefs among study sites. Fisher's LSD test was selected for multiple comparisons when the ANOVA yields significant results. T-test was used to test the difference in DFG coverage between the study sites where high fishing activities or tourism activities are found, respectively. All analyses were performed using R version 4.1.1.

3. Results

3.1 Occurrence of marine debris by derelict fishing gears

Overall, the surveyed underwater pinnacles were mainly covered by live corals (49.91%), followed by dead corals (23.13%), rock (17.17%), sand (8.19%). The lowest proportion was rubbles. Almost all marine debris found in this study were derelict fishing gears (DFG), mostly distributing on live corals (145 pieces), followed by rock (15 pieces), sand (14 pieces), rubbles (7 pieces) and dead corals (1 piece) respectively. No marine debris was found on algae cover (Table 2, Figure 3).

The dominant corals were *Porites lutea*, *Goniopora columna*, and *Pavona decussata*. There are five types of derelict fishing gears found in this survey including fishing nets, fishing traps, ropes, monofilaments, and others. Fishing nets were mostly found (43 pieces), followed by ropes (36 pieces) and fishing traps (28 pieces). Considering the coverage of the DFG, fishing traps had the highest coverage (77.93 m^2), followed by fishing nets (59.86 m^2) and ropes (4.91 m^2) (Figure 4).

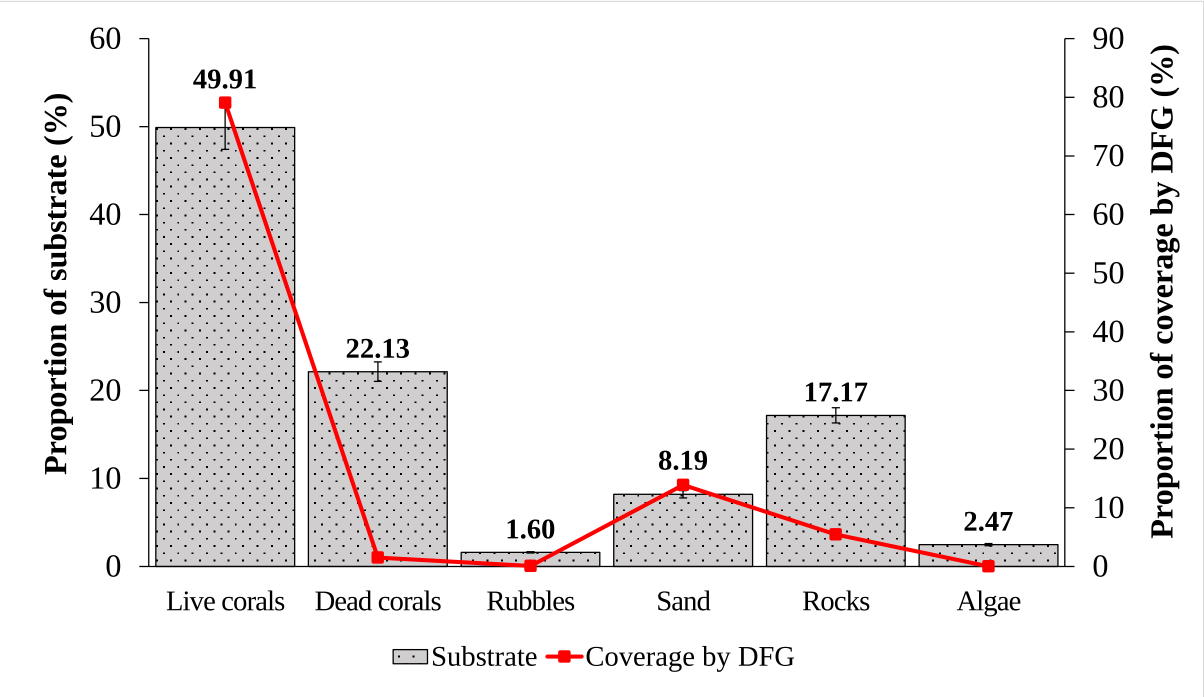

Figure 3. The proportion of substrates and coverage by DFG on the underwater pinnacles

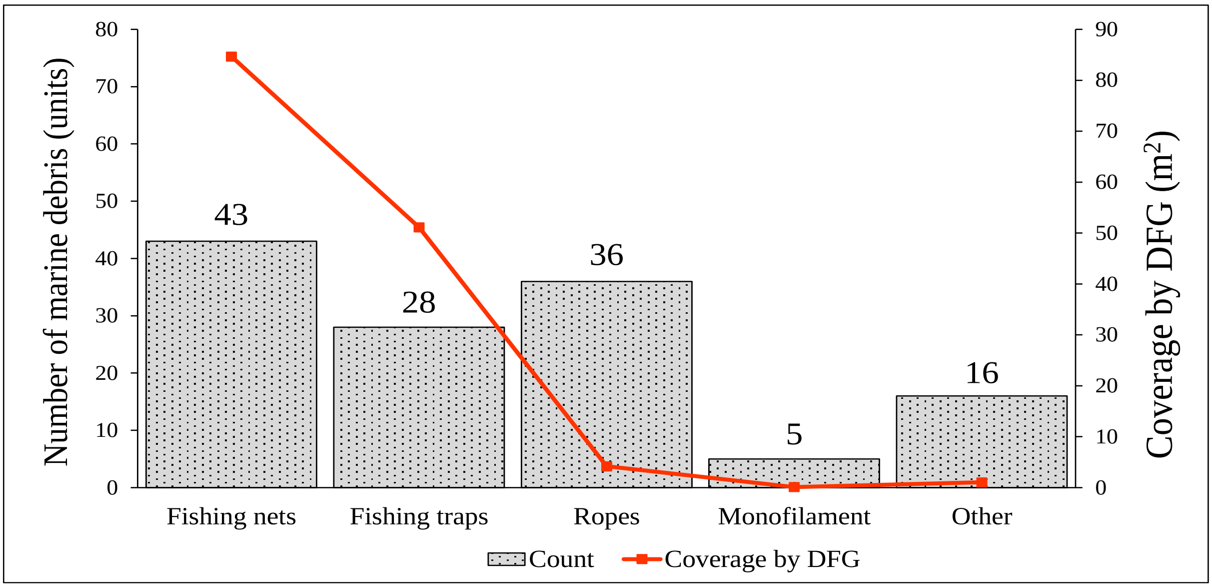

Figure 4. Total number of derelict fishing gear in each category (bar graph) and total coverage of derelict fishing gear on coral reefs (line graph)

Table 2. Coverage area by derelict fishing gear on each substrate

Substrate	**Substrate (%)**	**Coverage area of derelict fishing gear on each substrate in the study (m^2)**					
		Fishing nets	**Fishing traps**	**Mono-filament lines**	**Ropes**	**Other**	**Total**
Hin Jen Ta-Lay							
Live corals	71.64	44.16	19.34	0.01	0.87	0.03	64.38
Dead corals	18.96	1.07	0.77	-	-	-	1.84
Rubble	-	-	-	-	-	-	-
Sand	5.02	-	-	-	-	-	-
Rock	1.14	2.44	-	-	-	-	2.44
Algae	3.24	-	-	-	-	-	-
	Total	44.929	22.850	0.001	0.869	0.030	68.66
Hin Kan Thuree							
Live corals	68.24	-	-	-	-	-	-
Dead corals	18.96	-	-	-	-	-	-
Rubble	-	-	-	-	-	-	-
Sand	3.31	-	0.21	-	-	-	0.21
Rock	6.6	-	-	-	0.20	-	0.20
Algae	2.89	-	-	-	-	-	-
	Total	-	0.212	-	0.201	-	0.41
Hin Lak Ngam							
Live corals	63.88	0.63	-	-	0.10	0.07	0.73
Dead corals	24.00	0.27	-	-	-	-	0.27
Rubble	-	-	-	-	-	-	-
Sand	8.14	-	-	-	0.60	-	0.60
Rock	1.89	-	-	-	-	0.02	-
Algae	2.09	-	-	-	-	-	-
	Total	0.900	-	-	0.700	0.092	1.6
Hin Pae							
Live corals	66.60	-	-	-	0.48	-	0.48
Dead corals	22.79	-	-	-	-	-	-
Rubble	-	-	-	-	-	-	-
Sand	3.64	-	-	-	-	-	-
Rock	5.86	-	-	-	1.22	-	1.22
Algae	1.11	-	-	-	-	-	-
	Total	-	-	-	1.691	-	1.7

Substrate	Substrate (%)	Coverage area of derelict fishing gear on each substrate in the study (m^2)					
		Fishing nets	Fishing traps	Mono-filament lines	Ropes	Other	Total
Hin Phum							
Live corals	15.52	25.21	9.47	-	0.32	0.11	35.00
Dead corals	46.02	0.03	-	-	-	-	0.03
Rubble	1.71	-	-	-	0.01	-	0.01
Sand	12.93	-	2.57	0.06	-	0.40	2.62
Rock	23.82	0.28	0.48	-	0.25	0.10	1.01
Algae	-	-	-	-	-	-	-
	Total	25.518	12.516	0.058	0.582	0.605	38.67
Hin Thong Wo							
Live corals	13.57	7.79	2.52	0.05	0.15	0.32	10.51
Dead corals	2.07	-	-	-	-	-	-
Rubble	1.48	0.09	-	-	-	-	0.09
Sand	16.12	-	15.75	-	-	-	15.75
Rock	63.72	2.71	-	-	-	-	2.71
Algae	3.04	-	-	-	-	-	-
	Total	10.589	20.277	0.050	0.150	0.316	29.06
	Total all surveys	**81.93**	**55.86**	**0.11**	**4.19**	**1.04**	**140.10**

Table 3. Results of one-way ANOVA and Fisher's LSD test examining the variation of DFG coverage among substrates.

Source of Variance	df	Mean square	F	*p*-value
Between groups	5	2.349	5.145	< 0.001*
Within groups	174	0.457		
Lc vs. Dc				< 0.001*
Lc vs. Ru				< 0.001*
Lc vs. Ro				< 0.001*
Lc vs. Sa				0.002*
Lc vs. Al				< 0.001*
Dc vs. Ru				0.835
Dc vs. Ro				0.651
Dc vs. Sa				0.449
Dc vs. Al				0.825
Ru vs. Ro				0.510
Ru vs. Sa				0.335
Ru vs. Al				0.990
Ro vs. Sa				0.760
Ro vs. Al				0.501
Sa vs. Al				0.328

* Significant difference ($p < 0.05$)
** Lc = Live corals, Dc = Dead corals, Ru = Rubble, Sa = Sand, Ro = Rock, Al = Algae

One-way ANOVA revealed the variation of DFG coverage among substrates (*p*-value < 0.001). Fisher's LSD test illustrated that the DFG coverage on live corals was significant different that those on dead corals (*p*-value < 0.001), rubble (*p*-value < 0.001), rock (*p*-value < 0.001), sand (*p*-value < 0.01), algae (*p*-value < 0.001). The DFG coverage between other substrates were not significant (Table 3).

3.2 Impacts of derelict fishing gear on coral reefs

About 18.7% of the total surveyed coral cover was covered by derelict fishing gears. Of which, approximately 11.3% was covered by fishing nets, followed by fishing traps (6.81%), ropes (0.58%), other gears (0.14%) and monofilament lines (0.01%) (Figure 5).

Most of the fishing gears found in coral reefs were fishing nets, fishing traps, and ropes, contributing the most severe severity to coral reefs, whereas the impacts of monofilament lines and other types of gears on coral reefs remained low. Five types of impacts were observed, including pale tissue, tissue loss, bleaching, fragmentation, and diseases. The most common consequences of the fishing nets on coral reefs were pale tissue (35.8 %), tissue loss (20.8 %), diseases (10.4 %), fragmentation (9.8 %), and bleaching (6.4 %). The impacts caused by ropes and fishing traps were somewhat similar, dominating by tissue loss and diseases. No pale tissues were found on the corals covered by monofilament lines (Figure 6).

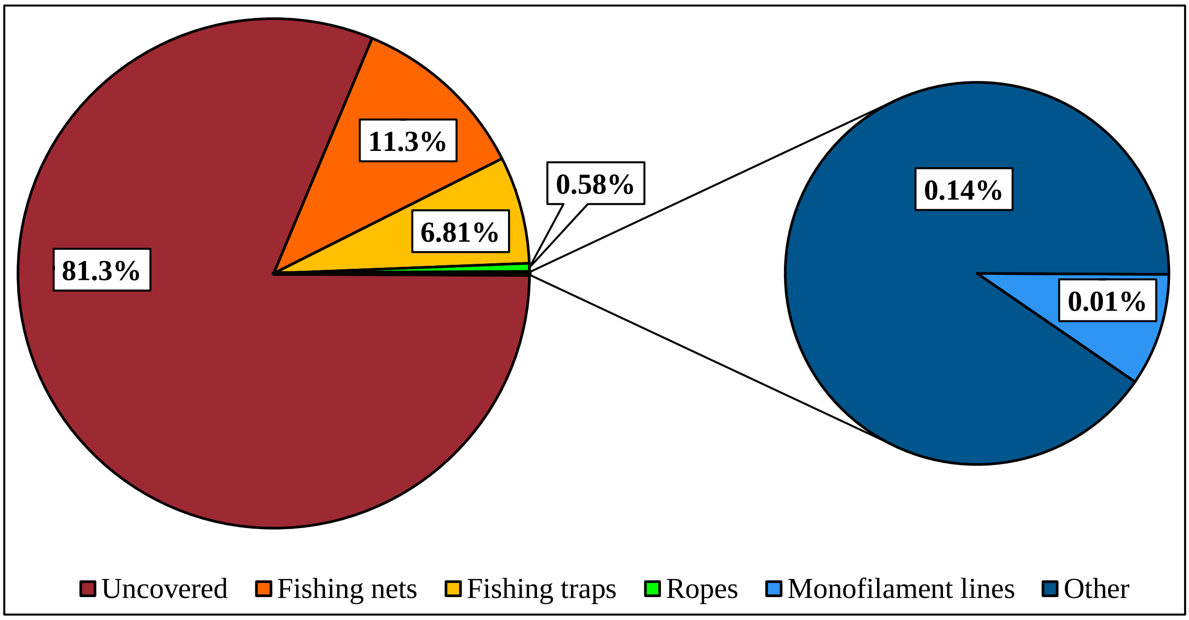

Figure 5. The proportion of coral reef covered by each derelict fishing gear

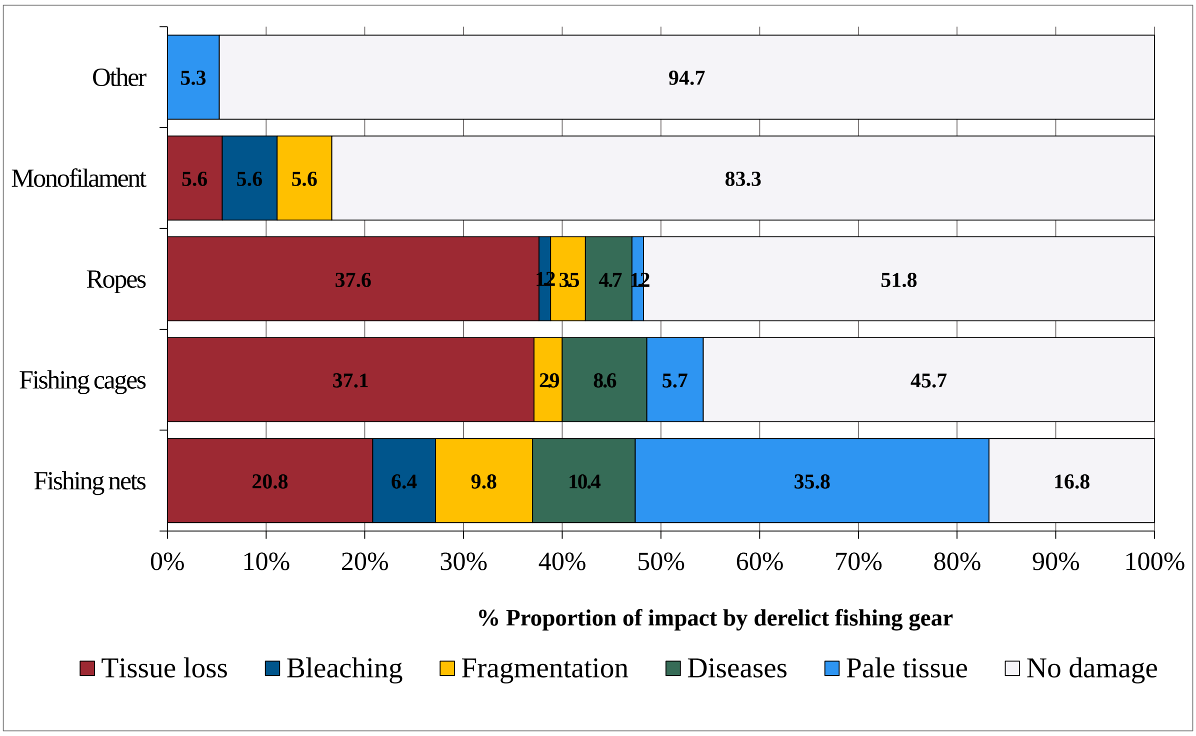

Figure 6. The proportion of impacts on coral reefs by each derelict fishing gear

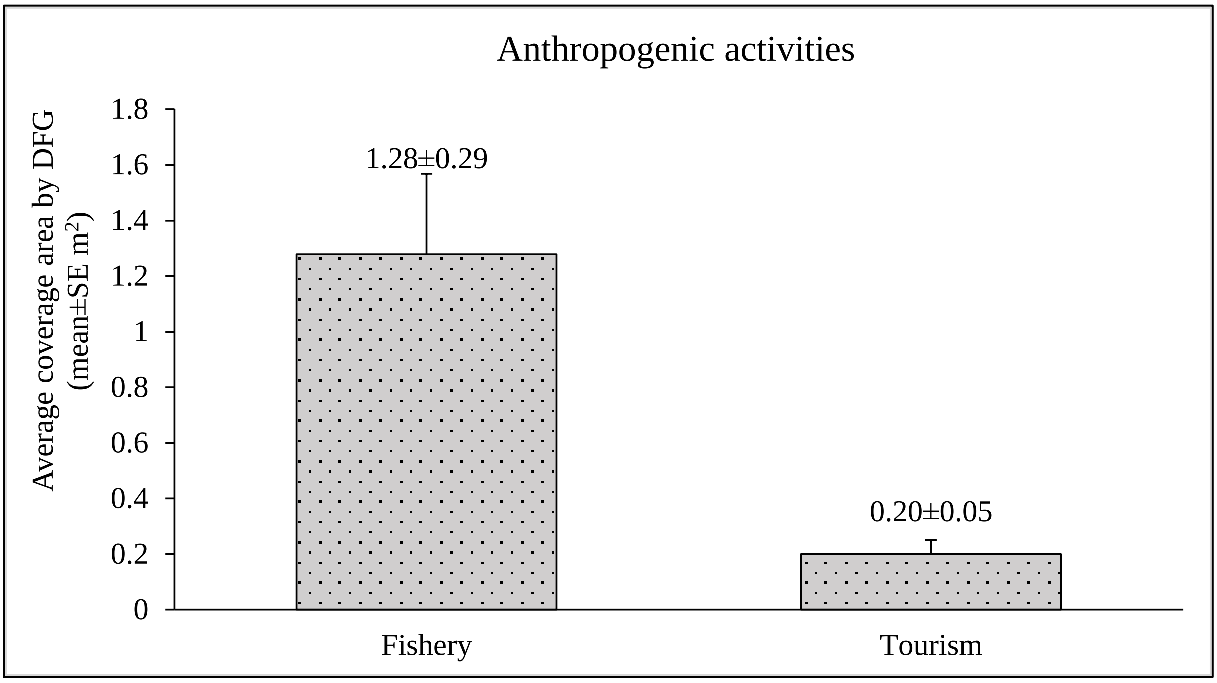

Figure 7. The average of DFG coverage between the study sites with fishing and tourism activities

3.3 Influence of anthropogenic activities on derelict fishing gear coverage.

The result of t-test showed the significant difference in the DFG coverage between the areas that have fishing and tourism activities, reflecting that anthropogenic activity may influence the occurrence of the DFG (Figure 7). The average of DFG coverage at the study sites with fishing activity (1.28 ±0.29 m^2) was significantly greatly higher than that observed in the study sites with tourism activity (0.02 ±0.05 m^2) (t-test, *p*-value = 0.014). The study site with fishing activity i.e., Hin Jen Ta-Lay, Hin Phum, and Hin Thong Wo had relatively high DFG coverage, accounting for 22.88, 12.89, and 14.53 m^2, respectively, but the live coral covers remained low.

4. Discussion

4.1 Concerning impacts on live coral cover

Based on our findings, most marine debris were found on live coral cover (49.91%). Because habitats with high proportion of live coral cover serve suitable for a wide variety of marine organisms, making these areas a high potential for fisheries. In some areas such as Hin Phum and Hin Thong Wo, live coral covers were low but derelict fishing gears were found still more than that on other substrates. When considered spatially, the complex structure of live coral areas on the underwater pinnacle may induce marine debris to be easily attached. Fishing in this area are more likely to damage fishing gears than in other areas (Clark & Koslow, 2007). However, the prevention of fisheries issues can achieve by using a spatial management policy such as marine spatial planning or marine protected areas (Yates et al., 2015). The result showed that the areas with heavy fishing activities tend to have more marine debris than the areas with only tourism activities. Thus, controlling certain activities that are potential to generate impacts on live corals is important to protect coral reef ecosystems.

4.2 Fishing activities inducing the occurrence of marine plastic debris

Fishing is a considerable activity, tending to increase the occurrence of marine plastic debris. The study found that large-scale or commercial fisheries cause a direct impact on marine ecosystems by generating derelict fishing gears, such as surrounding nets and trawl nets, which are the common fishing gears used in commercial fishing vessels (DOF, 1997; Adamidou, 2007). All stations are located more than 11 kilometers (6 miles) from the shore and these areas are not protected from commercial fisheries. Such long distance from the shoreline automatedly limits small-scale or artisanal fisheries, whose fishing vessels are relatively small, to fish there. Some fishers prefer to use monofilament lines to ropes (or fishing nets) while some use fishing traps for fish around the pinnacles.

Fishing nets can be found on live corals, dead corals, and rock because fishing nets are commonly used for fishing. The different types of derelict fishing traps (fish, shrimp, and crab traps) also have different gear sizes and different areas to be deployed such as coral reefs, sand, rock etc. Thus, the level of impact severity of each gear is also different. The size of derelict fishing gears is also linked to the impact severity. The larger size of DFG generates more impacts. This result is consistent with another research conducted in the Mu Ko Chumphon and nearby Koh Tao, the Gulf of Thailand, reporting that fishing nets were the most common fishing gear in the areas (Suebpala et al., 2017; Ballesteros et al., 2018). Conversely, derelict fishing nets with small coverage such as ropes, monofilament lines, and others (buoy, weight, pipe, and plastic pieces) may generate a higher impact. The fishing gears that directly touch the coral reef can cause physical damages to coral reefs. For instance, fish traps with its size of 10 square meters are generally placed directly on coral reefs, for example, at Hin Jen Ta-lay, leading to serious damage on coral reefs. This study has shown the interaction between DFG and the coral reef ecosystem in terms of the physical damage to corals.

4.3 Marine spatial planning as a tool for reducing DFG impacts

Marine spatial planning and managing fisheries displacement could be a good choice for a very delicate problem. However, even potentially negative economic and social impact on the locality but the understanding fisheries behaviors in the local spatial could lead to successful management of fisheries displacement. According to Van Putten et al. (2012), management of maritime activities by policy or administrative intervention and introduced new maritime activities to the change in the dynamics of impacts. Controlling fishing activities through marine spatial planning could be implemented through proactive and passive management strategies. Proactive management involves defensive measures, such as avoiding spatial conflicts before taking the process. However, passive management has expressed to resolve the contradictions after the end process and relates to mitigation measures for reducing the extent and impact of fisheries displacement (Yates et al., 2015).

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