two groups: before the trawl net passed (stations 1B-9B) and after the trawl net passed (stations 1A-9A). The key finding as follow

1. **Surface Water TSS:**
   - **Before trawling:** 3.45–26.80 mg/L (9.38±8.46 mg/L)
   - **After trawling:** 3.65–8.96 mg/L (6.14±1.90 mg/L)
   - No statistically significant difference was observed (p-value = 0.29).
2. **Bottom Water TSS:**
   - **Before trawling:** 3.00–22.80 mg/L (11.38±5.93 mg/L)
   - **After trawling:** 4.45–17.79 mg/L (10.35±4.47 mg/L)
   - No statistically significant difference was observed (p-value = 0.69).

The similarity in TSS values before and after trawling was attributed to the high density of trawl fishing in the area, which causes continuous sediment disturbance and resuspension.

3. **Comparison with May 2023 Data:**
   A significant difference in TSS was observed between August and May 2023 (p-value = 0.00). TSS levels in August 2023 were higher at both the surface and bottom water levels compared to May 2023.
   - **Reason for Difference:**
     During May 2023, a seasonal fishing closure was in place, restricting trawl fishing activities. Only small trawlers (vessels ≤16 meters in length) were allowed to operate offshore at night, with all trawl fishing banned during the day. This reduced sediment disturbance, resulting in lower TSS levels. In contrast, August 2023 saw higher fishing activity, causing increased sediment resuspension and higher TSS levels.

The water transparency before trawl net operation ranged between 1.3–3.2 meters (2.1±0.7 meters), while after the trawl net passed, it ranged between 1.4–1.9 meters (1.6±0.2 meters). A statistically significant difference was observed at the 0.05 significance level (p-value = 0.044). The decrease in water transparency after the trawl net operation was attributed to sediment resuspension caused by the trawling process (Figures 2.2–4).

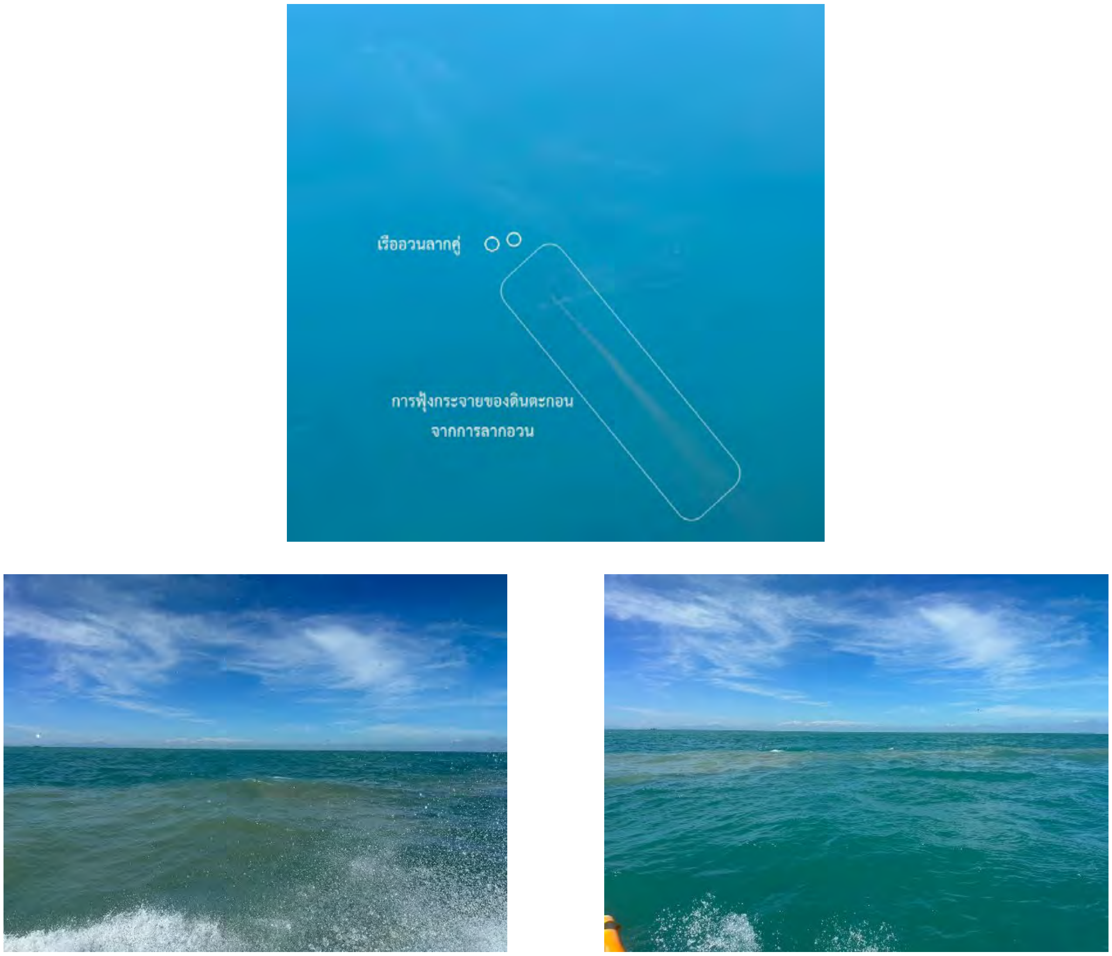


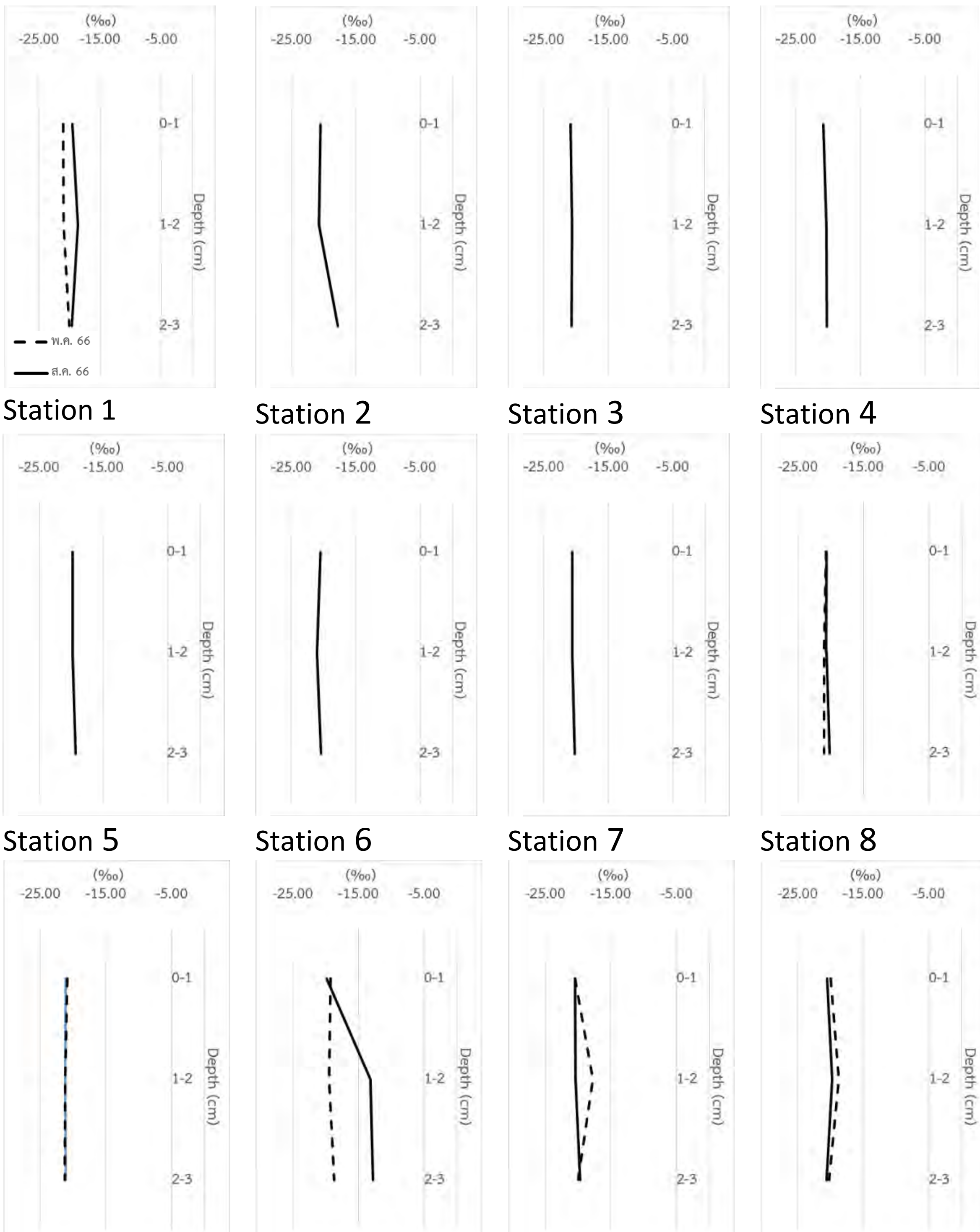
Figure 22-4 Sediment Resuspension from Pair Trawling in the Study Area in August 2023.When examining changes in **stable isotope δ13C values** across sediment depth (0-3 cm) in the western Gulf of Thailand, the δ13C values show an increasing trend with depth (as illustrated in **Figure 2.2-5**).

Group 1: Stations where stable isotope **δ13C** values increase with sediment depth include **Station 2** and **Station 10**

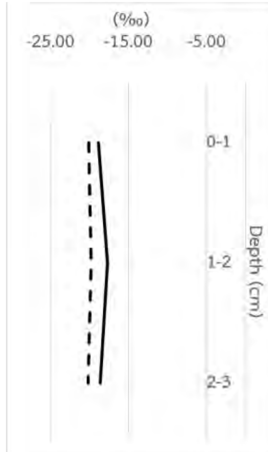
Group 2: Stations where stable isotope **δ13C** values remain relatively constant with increasing sediment depth include **Station 1 and Stations 3-9.**

Group 3: Stations where the stable isotope **δ13C** fluctuates without a clear trend as depth increases include **Stations 11-13.**

Typically, the natural stable isotope δ13C values in sediment increase with depth (Group 1) due to the decomposition of organic matter. However, when sediment is disturbed by human activities, δ13C values may decrease with depth, remain stable (Group 2), or show no clear directional change (Group 3). In the study area, intensive trawling activity has caused sediment turnover, bringing deeper layers to the surface and disrupting the natural stratification of δ13C values. Additionally, the relatively stable δ13C values observed in Group 2 may also result from high sedimentation rates, which prevent significant alteration of surface sediments through decomposition processes.



Station 9 Station 10 Station 11 Station 12



Station 13

Figure 2.2-5: Stable isotope **δ13C (‰)** in sediment in the western Gulf of Thailand at depths of **0-3 cm** in **May** (dashed line - Stations 1 and 8-13) and **August 2023** (solid line - Stations 1-13).

Furthermore, areas with high trawling activity tend to have lower water content in the sediment. The influence of trawling on sediment water content becomes more pronounced during the open season, as trawling disturbs the seabed, causing fine sediment to resuspend into the water column and be transported by currents. This effect is evident in the study area, where the sediment contains shell fragments and retains less water. Additionally, the seasonal closure of the fishing ground interacts with trawling intensity to influence the evenness of benthic organisms. During the open season, areas with high trawling density exhibit lower benthic species evenness, which plays a crucial role in maintaining ecosystem stability, resilience, and resource utilization efficiency.

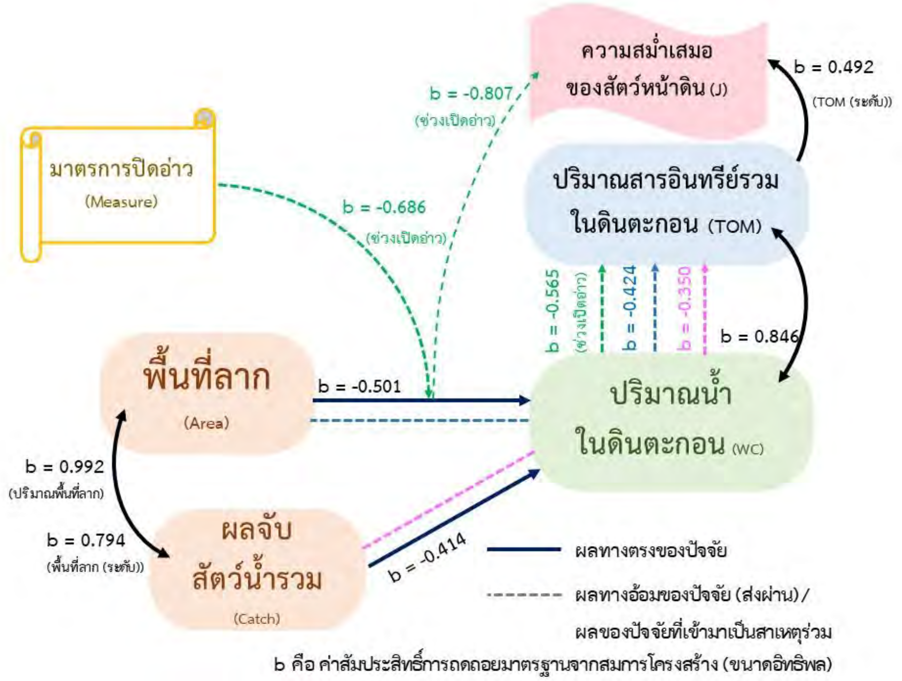


Figure 2.2-6 The Relationship Between Trawling Area, Total Fish Catch, and Seasonal Closure Measures on **Sediment Water Content, Total Organic Matter in Sediment, and Benthic Faunal Evenness.**

Conclusion

1. The general water quality parameters, dissolved nutrient concentrations, and sediment quality indicators (total sulfide content and total organic matter in sediments) in the study area mostly remain within normal ranges. The seawater quality observed in this study complies with the Marine Water Quality Standards for Aquaculture in Thai territorial waters, as specified by the National Environmental Board Notification, B.E. 2564 (2021).
2. The **source of organic matter in the sediments** in this study can be confirmed by the **stable isotope δ13C** values in the sediments. The findings indicate that the sediments in the study area are predominantly influenced by **marine-derived sources.**
3. For the **heavy metal concentrations in sediments** in the study area, the levels of **cadmium, lead, and copper** in surface sediments were found to comply with the **coastal sediment quality criteria** set by the **Pollution Control Department (Royal Gazette, 2021).** However, **zinc concentrations** in sediments slightly

exceeded the standard limit, with a recorded value of **119.760 ppm** compared to the standard limit of **≤102 ppm.**

4. Trawling fisheries have a significant impact on total suspended solids (TSS) in water, water transparency, and stable isotope δ13C values in sediments. The impact as follow.

- Water transparency decreases immediately after a trawling vessel passes through an area.
- Total suspended solids (TSS) increase, particularly during the fishing season (August 2023), when trawling activities are at their peak.
- Stable isotope δ13C values in sediments show unnatural variations with depth, influenced by the physical disturbance caused by trawling. The trawl nets, designed to operate close to the seabed, stir up deeper sediments, disrupting the natural sedimentary structure and resuspending bottom sediments into the water column.

5. Trawling fisheries also impact the physical and chemical properties of sediments, as well as the uniformity of benthic fauna. In areas with intensive trawling activity the lower water content in sediments, reduced total organic matter (TOM) in sediments and decreased uniformity of benthic fauna have been found. These changes indicate that trawling disturbs the seafloor structure, affects the availability of organic matter, and alters the distribution and diversity of benthic organisms.

Recommendations

Trawling is an important economic activity that generates employment and revenue for the country. However, it also has significant environmental impacts, particularly on water quality, marine ecosystems, and benthic organisms. This study clearly demonstrates the short-term effects of trawling. To mitigate the impact on sensitive habitats such as coral reef areas, it is recommended that relevant authorities enforce stricter monitoring of trawling activities in designated zones (1.5–4.3 nautical miles from the shoreline adjacent to coastal islands, as per the Ministerial Regulation on Coastal Zone Designation in Surat Thani Province, 2022). For long-term impacts resulting from multiple contributing factors, this still require further investigation and data collection. Therefore, continued research on the environmental effects of trawling is essential for developing sustainable trawling practices that minimize damage to benthic ecosystems. This will help ensure the sustainable use of marine resources in the future.

- **(Research 2) Analysis of trawl fishing ground in the western Gulf of Thailand:**

Introduction: Trawling is considered the most important form of marine fishing in Thailand. According to data from 2022, 39.44% of marine species came from trawling activities. The majority of the catch was from the Gulf of Thailand rather than the Andaman Sea, accounting for 74% and 26%, respectively. There are three types of trawling gear used in Thailand: Beam trawl, Otter trawl and Pair trawl. The largest proportion of marine species was captured using pair trawling (61.3%), followed by otter trawling (36.3%) and beam trawling (2.4%). The catch is utilized for both consumption and the fishmeal industry as a raw material for the production of animal feed which extensively used in aquaculture industry (Department of Fisheries Policy and Planning, 2023).

The current management of trawl fisheries involves various measures, including the use of a Vessel Monitoring System (VMS). This system integrates Global Positioning System (GPS) technology and mobile network systems (Global Service Mobile; GSM) into a Vessel Positioning System (VPS) to track the locations of fishing vessels. Developed in Thailand through a collaboration between the Department of Fisheries and the National Electronics and Computer Technology Center (NECTEC) (Department of Fisheries, 2011), this system offers an effective way to monitor vessel activity. By combining data from the VMS with information from the Fishing Info system—managed by the Port In-Port Out Control Center—it is possible to analyze trawl fishing areas. This enables the creation of fishing ground maps and fishing activity maps, which are highly beneficial for further fisheries management.

Objectives

1. To study the patterns of trawl fishing in the Gulf of Thailand
2. To create maps of trawl fishing grounds and develop a trawl fishing database system for the Gulf of Thailand area.

Methodology

The data used in this study consists of two types: primary data and secondary data. The key secondary data used for calculating trawl areas and fish catch volumes was obtained from the Port In-Port Out database and the vessel monitoring system (VMS) of the Department of Fisheries, covering the period from January 1, 2021, to December 31, 2022. Additionally, data was collected through in-depth interviews with experienced vessel controllers or owners to gather information on the fishing practices of pair trawlers, otter board trawlers, and beam trawlers. These interviews aimed to study the factors affecting vessel speed during trawl fishing operations and to calculate trawl areas for mapping trawl fishing activities in the western Gulf of Thailand, from Prachuap Khiri Khan to Narathiwat provinces, as well as in the central Gulf of Thailand.

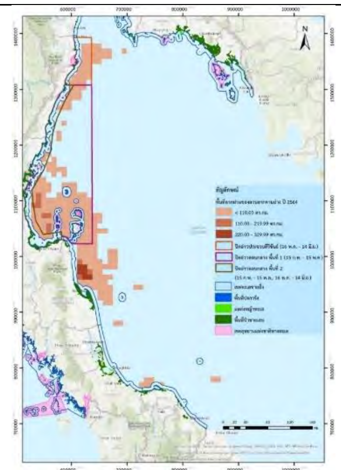
Study Results

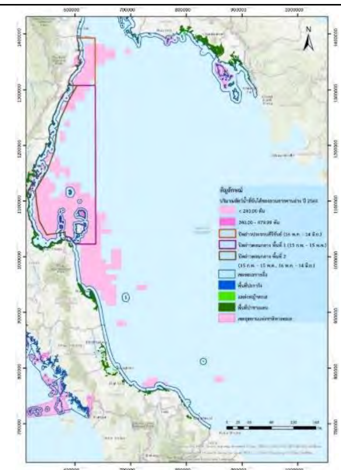
Trawl fishing in the western Gulf of Thailand can be categorized into three main types: single trawl (beam trawl and otter board trawl) and pair trawl, similar to other areas in the Gulf of Thailand. The primary factors influencing vessel speed during trawling operations are ocean currents (which are seasonal), engine horsepower, gear ratio, propeller size (related to engine size), and seabed characteristics (linked to fishing grounds). Additional factors affecting the number otter board and pair trawlers include fuel prices. From 2021 to 2022, there were 1,707–1,823 trawl fishing vessels (30 gross tons or larger) operating in the western Gulf of Thailand, from Prachuap Khiri Khan to Narathiwat. Among these, pair trawlers were the most common (859–900 vessels), followed by otter board trawlers (637–728 vessels) and beam trawlers (195–211 vessels). However, when considering fishing gear, otter board trawlers were the most prevalent, as pair trawlers require two vessels to operate. The highest trawled area and catch volume were attributed to pair trawlers (90,964–101,933 km² and 127,834–152,481 tons, respectively), followed by otter board trawlers (59,347–91,920 km² and 62,240–87,882 tons), and beam trawlers (6,378–7,049 km² and 5,746–8,331 tons). From 2021 to 2022, the total trawled area ranged between 156,690–200,902 km² per year, averaging 178,796.62 km² annually. The area accessible for trawling in the western Gulf of Thailand was 158,407.41 km², representing 1.13 times the total fishable area. The annual fish catch volume ranged from 198,405 to 246,109 tons. While the trawled area and fish catch volume were higher in 2021 than in 2022, the catch per unit area increased from 1.23 tons/km² in 2021 to 1.27 tons/km² in 2022 (see Table 1 and Figure 1).

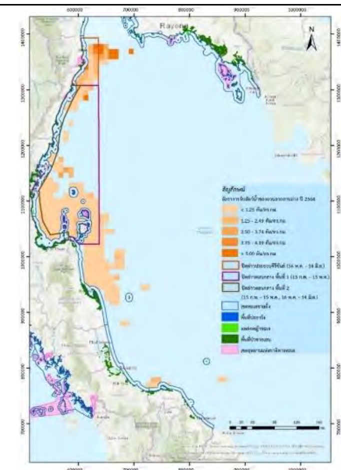
Table 1: Trawled Area, Fish Catch Volume, and Efficiency Catch Rates of Trawl Fishing

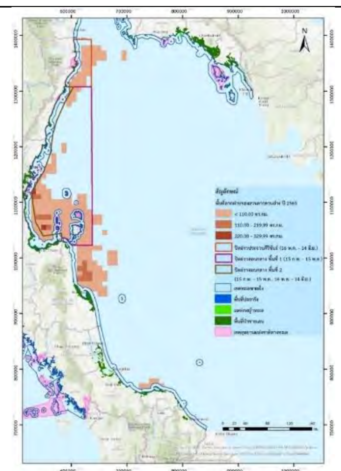
Type of Gear	Trawled Area (sq. km)		Fish Catch Volume (tons)		Fish Catch Volume (%)		Change Rate	Catch Rate (tons/sq. km)	
	2564	2565	2564	2565	2564	2565	+/-	2564	2565

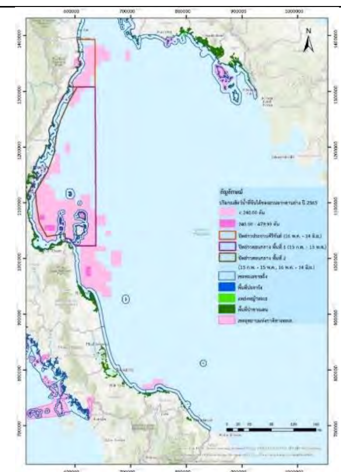
Beam Trawl	7,049.17	6,378.34	5,746.39	8,331.22	2.33%	4.20%	2,584.83	0.82	1.31
Otter Board Trawl	91,920.44	59,347.53	87,882.11	62,240.23	35.71%	31.37%	(25,641.89)	0.96	1.05
Pair Trawl	101,933.31	90,964.45	152,481.26	127,834.14	61.96%	64.43%	(24,647.12)	1.50	1.41
Total	**200,902.92**	**156,690.32**	**246,109.77**	**198,405.59**	**100.00%**	**100.00%**	**(47,704.18)**	**1.23**	**1.27**

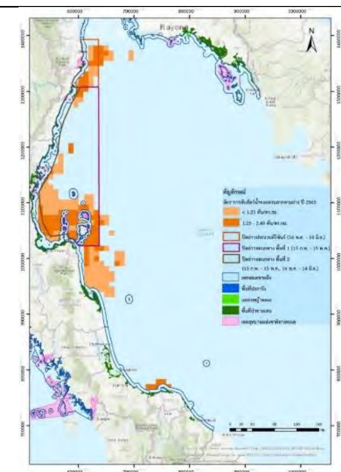

Trawled Area in 2021


Fish Catch Volume in 2021

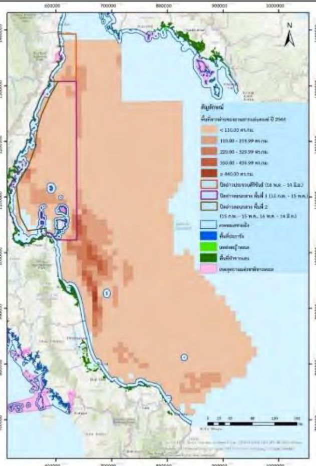
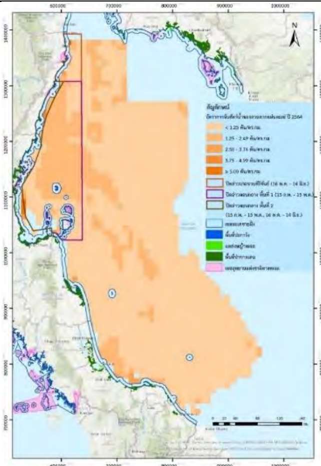
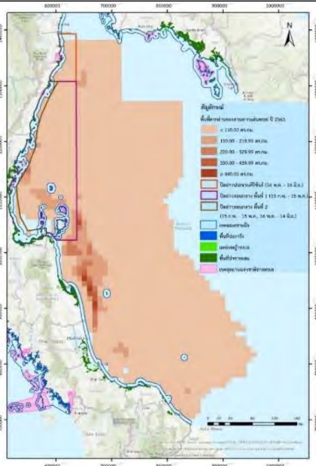
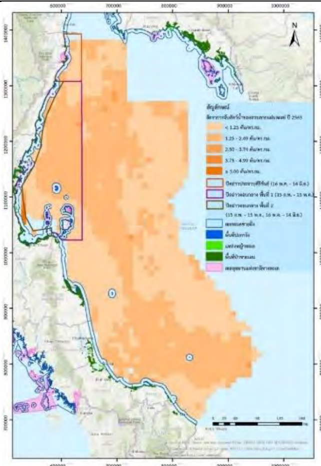
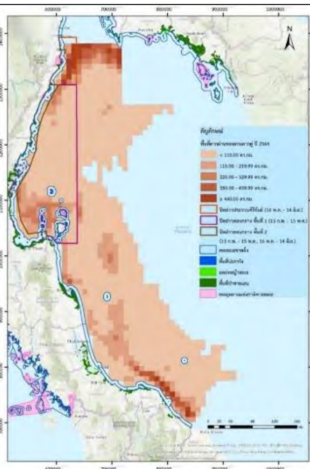

Catch Rate in 2021

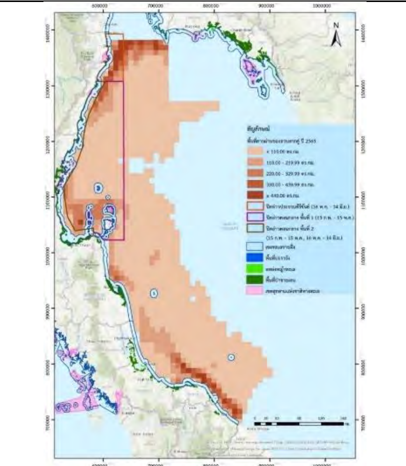
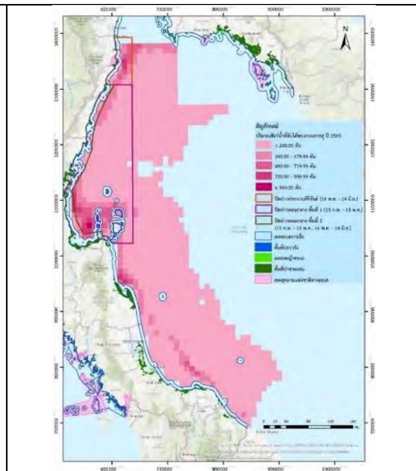
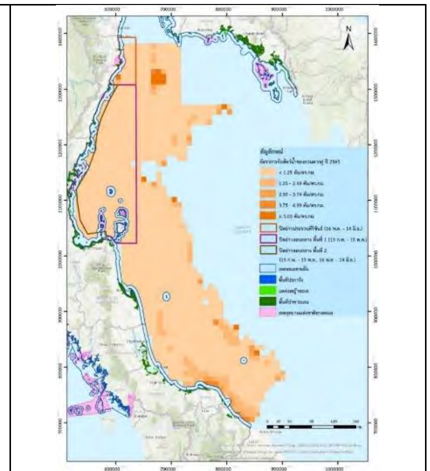

Trawled Area in 2022


Fish Catch Volume in 2022


Catch Rate in 2022

A. Beam Trawl

		
Trawled Area in 2021	**Fish Catch Volume in 2021**	**Catch Rate in 2021**
		
Trawled Area in 2022	**Fish Catch Volume in 2022**	**Catch Rate in 2022**
A. Otter Trawl		
		
Trawled Area in 2021	**Fish Catch Volume in 2021**	**Catch Rate in 2021**

		
Trawled Area in 2022	**Fish Catch Volume in 2022**	**Catch Rate in 2022**
A. Pair Trawl		
Figure 1: trawl Area, Fish Catch Volume, and Catch Rate by Trawl Type		

In this study, the survey area was divided based on the marine survey zones of the Department of Fisheries, which continuously monitors aquatic resources. The Department of Fisheries divides the survey area into nine zones. This study focused on Zones 4–9 and added a central Gulf area as Fisheries Zone 10. Additionally, the study area was classified into four distance zones from the shore. Distance Zone 1: Extends 10 nautical miles from the coastal baseline. Distance Zone 2: Extends an additional 15 nautical miles beyond Distance Zone 1. Distance Zone 3: Extends another 30 nautical miles beyond Distance Zone 2. Distance Zone 4: Covers all remaining areas. According to Figure 2, Fisheries Zone 6 recorded the highest catch per unit area (1.792–1.820 tons per square kilometer). Similarly, the highest catch per fishing ground unit was also found in Fisheries Zone 6 (3.834–4.065 tons per square kilometer). Fisheries Zone 6, which spans from Mueang Chumphon District to Ban Don Bay in Surat Thani Province, was identified as the most abundant fishing area in the western Gulf of Thailand (Table 2). Furthermore, considering the distance zones, Distance Zones 2 and 3 had the highest fishing intensity in 2021. However, in 2022, fishing activity was most concentrated in Distance Zones 2 and 1. This suggests that fishing in 2022 occurred closer to shore, likely due to rising fuel costs, prompting vessel operators or owners to reduce fuel expenses by avoiding distant fishing grounds. The most abundant distance zone was Distance Zone 1, which extends 10 nautical miles from the shoreline. This zone had the highest fish catch volume (an average of 69,707.94 tons per year or 31.36% of the total) and the highest catch per unit area (an average of 1.518 tons per year) (Table 3)

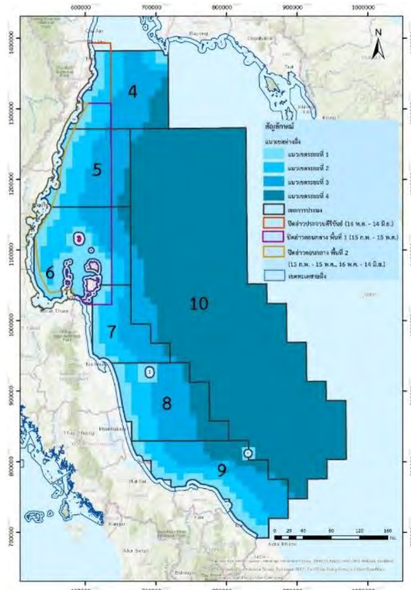


Figure 2: Study Area Classification Based on the Department of Fisheries Survey

Table 2: Fish Catch Volume by Trawl Type Classified by Fisheries Zone

Fisheries Zone	Trawling Area (sq. km)		Fish Catch Volume (tons)		Fish Catch Volume (%)		Catch Rate per Swept Area (tons/sq. km)		
	2021	2022	2021	2022	2021	2022	2021	2022	+/-
4	39,700.51	32,450.60	49,778.17	35,494.93	20.23%	17.89%	1.254	1.094	(0.160)
5	14,551.45	10,393.04	21,430.72	14,644.28	8.71%	7.38%	1.473	1.409	(0.064)
6	31,767.17	29,513.13	56,936.61	53,702.76	23.13%	27.07%	1.792	1.820	0.027
7	26,962.26	23,740.74	26,373.73	24,738.38	10.72%	12.47%	0.978	1.042	0.064
8	23,932.03	19,773.94	27,607.73	24,323.09	11.22%	12.26%	1.154	1.230	0.076
9	29,017.47	24,098.18	25,837.38	22,481.26	10.50%	11.33%	0.890	0.933	0.042
10	34,972.04	16,720.69	38,145.43	23,020.90	15.50%	11.60%	1.091	1.377	0.286

Table 3: Fish Catch Volume from Trawls Classified by Distance Zones from Shore

Distance Zone	Trawling Area (sq. km)		Fish Catch Volume (tons)		Fish Catch Volume (%)		Catch Rate (tons/sq. km)		
	2564	2565	2564	2565	2564	2565	2564	2565	+/-
1	44,411.62	47,433.92	69,575.06	69,840.82	28.27%	35.20%	1.567	1.472	(0.094)
2	61,442.64	53,898.36	71,756.95	57,843.40	29.16%	29.15%	1.168	1.073	(0.095)
3	60,693.52	37,989.82	67,108.04	46,102.83	27.27%	23.24%	1.106	1.214	0.108
4	34,355.14	17,368.23	37,669.72	24,618.54	15.31%	12.41%	1.096	1.417	0.321

The fish caught by trawl nets can be classified into two main groups: fish for consumption and fish used as raw material for fishmeal. During 2021–2022, these two groups accounted for 48.79% and 51.21%, respectively. Within the fish for consumption category, the largest proportion consisted of demersal fish (61.11%), followed by squid (15.89%), pelagic fish (15.88%), shrimp (5.61%), crab (1.27%), shellfish (0.52%), mantis shrimp (0.12%), and other aquatic species (0.05%). The composition of the catch may vary depending on the fishing gear used. The highest proportion of trash fish was caught using pair trawls (56.45%), followed by otter trawls (45.64%) and beam trawls (6.17%). By fisheries zone, Fisheries Zone 6—which covers the sea from Chumphon District to Ban Don Bay in Surat Thani Province—was the most abundant area, yielding economically significant species such as short-bodied mackerel, Indo-Pacific mackerel, Indian scad, Spanish mackerel, black pomfret, red snappers, cuttlefish, Metapenaeus shrimp, banana shrimp, tiger shrimp, blue swimming crab, and trash fish. In Fisheries Zone 4, which covers the coastal area from Hua Hin to Thap Sakae in Prachuap Khiri Khan Province, the main commercial species included goatfish, razorbelly scad, bigfin reef squid, oval squid, mantis shrimp, mud shrimp, and scallops.Meanwhile, Fisheries Zone 10, located in the central Gulf of Thailand, was identified as the primary fishing ground for bigeye fish (Priacanthus tayenus).

The analysis of key economically significant fish populations focused on threadfin bream (Nemipterus hexodon), bigeye (Priacanthus tayenus), and brushtooth lizardfish (Saurida elongata).

Threadfin Bream (Nemipterus hexodon)

- Total catch over two years: 7,453.75 tons
- Estimated population: 165,873,327 individuals
- Percentage of fish caught below the size at first maturity (18.77 cm): 89.31%
- Most critical area: Fisheries Zone 10 (Central Gulf), where 94.88–96.28% of the caught threadfin bream were below the size at first maturity.

Bigeye (Priacanthus tayenus)

- Total catch over two years: 4,174.35 tons
- Estimated population: 49,286,057 individuals

- Percentage of fish caught below the size at first maturity (17.38 cm for males): 86.24%
- Most critical areas: Fisheries Zones 5, 6, and 7, where more than 90.00% of the caught bigeye were below the size at first maturity.

Brushtooth Lizardfish (Saurida elongata)

- Total catch over two years: 3,370.22 tons
- Estimated population: 66,326,104 individuals
- Percentage of fish caught below the size at first maturity (31.62 cm for females): 98.45%
- Critical concern: In all surveyed zones, more than 90% of the caught brushtooth lizardfish were below the size at first maturity.

Recommendations

The recommendations derived from this study are as follows:

1. The catch rate per trawling area for many aquatic species is higher in coastal areas and near island clusters. This highlights the importance of conserving these areas to protect nursery and habitat zones, ensuring higher survival rates before these species enter fishing grounds.

2. The towing speed during trawling operations affects the trawling area, fish catch volume, and catch rate per unit area. In addition to factors such as engine and machinery specifications and seasonal variations, which are crucial for all trawl types, fuel prices also play a significant role in decision-making regarding trawling operations (whether to halt, reduce, or increase fishing efforts). This is particularly evident in otter trawls and pair trawls. Continuous monitoring of trawl fishing operations using swept area and fish catch volume as key indicators is essential. These indicators can serve as predictive tools to track resource utilization trends and assess the impact of trawl fishing on marine resources. Moreover, such data will help in developing spatial management measures, especially under special circumstances such as rising fuel prices, to ensure more effective fisheries management.

3. High-Risk Fish Groups: Brushtooth Lizardfish (Saurida elongata) High-risk fish species, such as brushtooth lizardfish (Saurida elongata), are heavily impacted by trawl fishing, which accounts for over 80% of the total catch. Approximately 32–40% of the catch comes from trawling operations in the Central Gulf of Thailand, Lower Gulf of Thailand, and the Central Offshore Gulf. The study highlights a critical concern: over 90% of brushtooth lizardfish caught by trawls are below the size at first maturity.

Key Fishing Grounds: The most significant fishing areas for brushtooth lizardfish are in Fisheries Zones 4 and 5, covering marine waters from Hua Hin District, Prachuap Khiri Khan Province, to Mueang Chumphon District, Chumphon Province. According to the Department of Fisheries' statistical zoning, these areas fall under Fisheries Zone 3.

Population Distribution Patterns

- Smaller-sized brushtooth lizardfish (<10 cm):
    - Found in coastal areas, particularly in grid cells 15, 23, 47, 59, and 73, where they constitute at least 10% of the local population.
- Mature brushtooth lizardfish (≥31.62 cm, first maturity size):
    - Found in grid cells 17, 25, 26, 49, 59, 73, 74, and 75, where they make up at least 10% of the local population.
    - Grid cells 59 and 73 contain high densities of both juvenile and mature individuals.

Conservation and Management Considerations. This to ensure the sustainability of brushtooth lizardfish populations, in-depth spatial studies are recommended to identify nursery and spawning grounds. This research will support conservation, restoration, and sustainable management efforts for this species.

Section D-Ecosystems

- **Summary: The ECOPATH model for the Gulf of Thailand**

The ecosystem of the Gulf of Thailand (GoT) was analyzed by using Ecopath model under the mass-balanced assumption, by using the 2020 landings data of the whole GoT's area. A total of 46 functional groups, and a group of detritus, were employed to representatives in the model. All input parameters were taken from scientific reports of the GoT *per se* and the neighbored ecosystems, which made the overall pedigree of the model is closed to 1. The basic results are shown in **Table 1**. The trophic level of the studied components ranged from 1 (phytoplankton, seaweed and detritus) to 4.232 (sharks), which the mean trophic level of the catches was 2.96. The values of ecotrophic efficiency of most components in the ecosystem were over 0.9, implying the high utilization by predation in the system as well as exploitation by fishing fleets. Energy transfer in the GoT's ecosystem was run through both grazing- and detrital- food chains, which the transfer efficiencies were 42 % and 33 %, respectively as described by Lindeman spine analysis (**Figure 1**). The estimated system statistics, from Ecopath, are presented in **Table 2**. Three (3) system statistics of the GoT's ecosystem as gross efficiency (0.0003), transfer efficiency (5.90 %) and Total primary production/total respiration (2.913) indicated that the system is far from mature stage due to the external stressors, in particular the fisheries.

The network flow diagram shows a complex energy transfer in the GoT system and depict the size of biomass flows between groups and trophic level (**Figure 2**). The mixed trophic impact analysis showed that trawl fisheries made negative impacts to various components in the GoT's ecosystem (**Figure 3**). Two (2) species, i.e. mammals and zooplankton, were identified as keystone species, which have considerable impact and play an important role in the GoT's ecosystem. The Ecosim was analyzed under the scenarios of reduction the fishing effort of trawler's fleets to 85 %, 95 % and 80 % of the current situation of the otter-board-, paired and beam- trawlers, respectively. The results showed that there were both positive and negative impacts to the relative biomass of each individual component in the GoT ecosystem (**Table 3**).

Table 1 Final parameters for the ECOPATH model of the Gulf of Thailand.

No	Component	TL	Biomass	P/B	Q/B	EE	P/Q
1	Indian Mackerel	2.851	0.095	3.00	12.00	0.742	0.25
2	Indo-Pacific Mackerel	2.862	0.048	3.00	12.00	0.953	0.25
3	Scomberomorus	3.889	0.025	0.66	3.29	0.950	0.20
4	Adult Caranx	3.444	0.274	1.32	5.92	0.887	0.22
5	Juvenile Caranx	3.000	0.041	3.00	15.00	0.870	0.20
6	Pomfret	3.492	0.024	1.39	6.97	0.950	0.20
7	Adult anchovies	2.900	0.333	3.00	4.28	0.241	0.70
8	Juvenile anchovies	2.900	0.005	4.00	16.00	0.977	0.25
9	Other small pelagics	2.900	0.204	4.00	12.50	0.996	0.32
10	Bream	3.502	0.024	2.00	10.00	0.871	0.20
11	Large piscivores	3.914	0.055	1.00	5.00	0.866	0.20
12	Scianidae	3.403	0.018	1.50	7.50	0.613	0.20
13	Adult Saurida	3.652	0.060	0.80	4.49	0.870	0.18
14	Juvenile saurida	3.000	0.003	3.00	16.00	0.928	0.19
15	Lutianidae	3.718	0.018	1.50	7.50	0.536	0.20
16	Mugiilidae	3.180	0.008	1.40	7.00	0.885	0.20
17	Priacanthus spp.	3.334	0.032	1.80	9.00	0.485	0.20
18	Sillago	3.255	0.004	1.00	5.00	0.893	0.20
19	Adult Nemipterus	3.042	0.106	0.9	4.41	0.992	0.20
20	Juvenile Nemipterus	3.000	0.007	3.00	16.00	0.801	0.19
21	Ariidae	3.247	0.002	1.20	6.00	0.277	0.20
22	Rays	3.115	0.010	0.30	1.50	0.817	0.20
23	Sharks	4.232	0.005	0.50	2.50	0.408	0.20
24	Squid	3.204	0.165	2.00	8.00	0.798	0.25
25	Cuttlefish	3.210	0.043	2.00	8.00	0.988	0.25
26	Octopods	3.233	0.019	1.80	7.20	0.972	0.25
27	Metapenaeids	2.346	0.018	5.00	20.00	0.993	0.25
28	Penaeids	2.346	0.025	5.00	20.00	0.620	0.25
29	Other shrimp	2.346	0.030	5.00	20.00	0.890	0.25
30	Blue swimming crab	2.616	0.089	2.50	10.00	0.433	0.25

31	Other crustaceans	2.616	0.019	2.50	10.00	0.724	0.25
32	Trashfish	2.558	0.758	4.00	16.00	0.738	0.25
33	Small demersal fish	3.151	0.165	3.50	14.00	0.939	0.25
34	Medium demersal piscivore	3.639	0.016	2.20	11.00	0.930	0.2
35	Medium demersal benthivore	3.224	0.015	3.00	15.00	0.938	0.2

Note: TL is trophic level; Biomass is reported in t/km2, P/B is the production to biomass ratio; Q/B is the consumption to biomass ratio; EE is the ecotrophic efficiency and P/Q is the production to consumption ratio.

Table 1 Final parameters for the ECOPATH model of the Gulf of Thailand.

No	Component	TL	Biomass	P/B	Q/B	EE	GE
36	Shellfish	2.200	0.890	3.00	15.00	0.225	0.2
37	Jellyfish	3.000	0.102	5.00	20.00	0.069	0.25
38	Sea cucumber	2.000	1.000	4.50	22.50	0.000	0.2
39	Seaweeds	1.000	0.100	15.00		0.100	
40	Coastal tuna	4.002	0.080	1.20	6.00	0.938	0.2
41	Sergestid shrimp	2.346	0.057	10.00	40.00	0.938	0.25
42	Mammals	3.383	0.100	0.10	30.00	0.000	0.00
43	Pony fishes	2.669	0.101	3.50	14.00	0.990	0.25
44	Benthos	2.232	33	5.00	25.00	0.579	0.2
45	Zooplankton	2.000	17.3	40	160.00	0.145	0.25
46	Phytoplankton	1.000	30	200		0.446	
47	Detritus	1.000	10000			0.168	

Note: TL is trophic level; Biomass is reported in t/km2, P/B is the production to biomass ratio; Q/B is the consumption to biomass ratio; EE is the ecotrophic efficiency and P/Q is the production to consumption ratio.

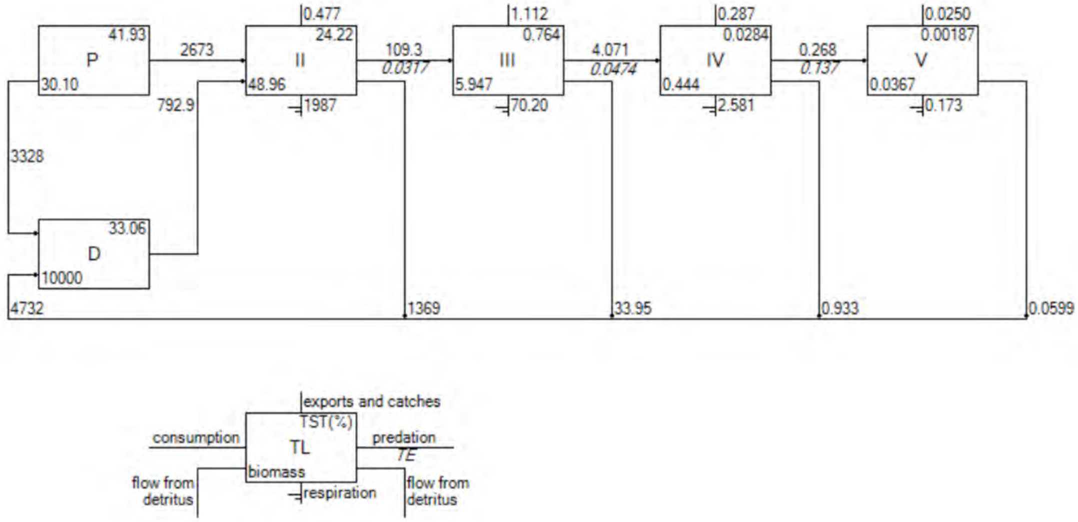


Figure 1. Lindeman spine representation of trophic flows of Gulf of Thailand model. Primary producers (P) and detritus (D) are separated to clarify the representation. TST is the total system throughput.

Table 2 Summary statistics for the Gulf of Thailand's Ecopath model,

Statistics	Estimates	Units
Sum of all consumption	3,667.592	t km^{-1} yr^{-1}
Sum of all exports	3,941.261	t km^{-1} yr^{-1}
Sum of all respiratory flows	2,060.378	t km^{-1} yr^{-1}
Sum of all flows into detritus	4,732.257	t km^{-1} yr^{-1}
Total system throughput	14,401.49	t km^{-1} yr^{-1}
Sum of all production	6,875.195	t km^{-1} yr^{-1}
Mean trophic level of the catch	2.956	
Gross efficiency (catch/net p.p.)	0.00032	
Calculated total net primary production	6,001.5	t km^{-1} yr^{-1}
Total primary production/total respiration	2.913	
Net system production	3,941.122	t km^{-1} yr^{-1}
Total primary production/total biomass	70.20	
Total biomass/total throughput	0.0059	yr^{-1}
Total biomass (excluding detritus)	85.49	t km^{-1}
Total catch	1.90322	t km^{-1} yr^{-1}
Shannon diversity index	1.398	
Connectance index	0.166	
System omnivory index	0.155	

Table 3 Changes in relative biomass under the scenario, using ECOSIM, of the buy-back program by DoF in the Gulf of Thailand

Scenario	Changes in relative biomass under the scenario	
	Positive change	**Negative change**
Otter board trawlers (decrease fishing effort for 15%)	Rays, Large piscivores, Adult Saurida, Priacanthus spp.	Medium demersal piscivore, Scianidae, Pony fishes
Pair trawlers (decrease fishing effort for 5%)	Scomberomorus, Lutianidae, Large piscivores, Saurida, Priacanthus spp.	Sillago, Medium demersal piscivore, Octopods Adult Nemipterus
Beam trawlers (decrease fishing effort for 20%)	Rays, Metapenaeids, Penaeids, Squid	Benthos, Sergestid shrimp, Juvenile fishes
Combined all scenarios	Rays, Large piscivores, Adult Saurida, Priacanthus spp., Sharks, Metapenaeids, Penaeids	Sillago, Medium demersal piscivore, Octopods Adult, Nemipterus, Benthos, Sergestid shrimp, Juvenile fishes

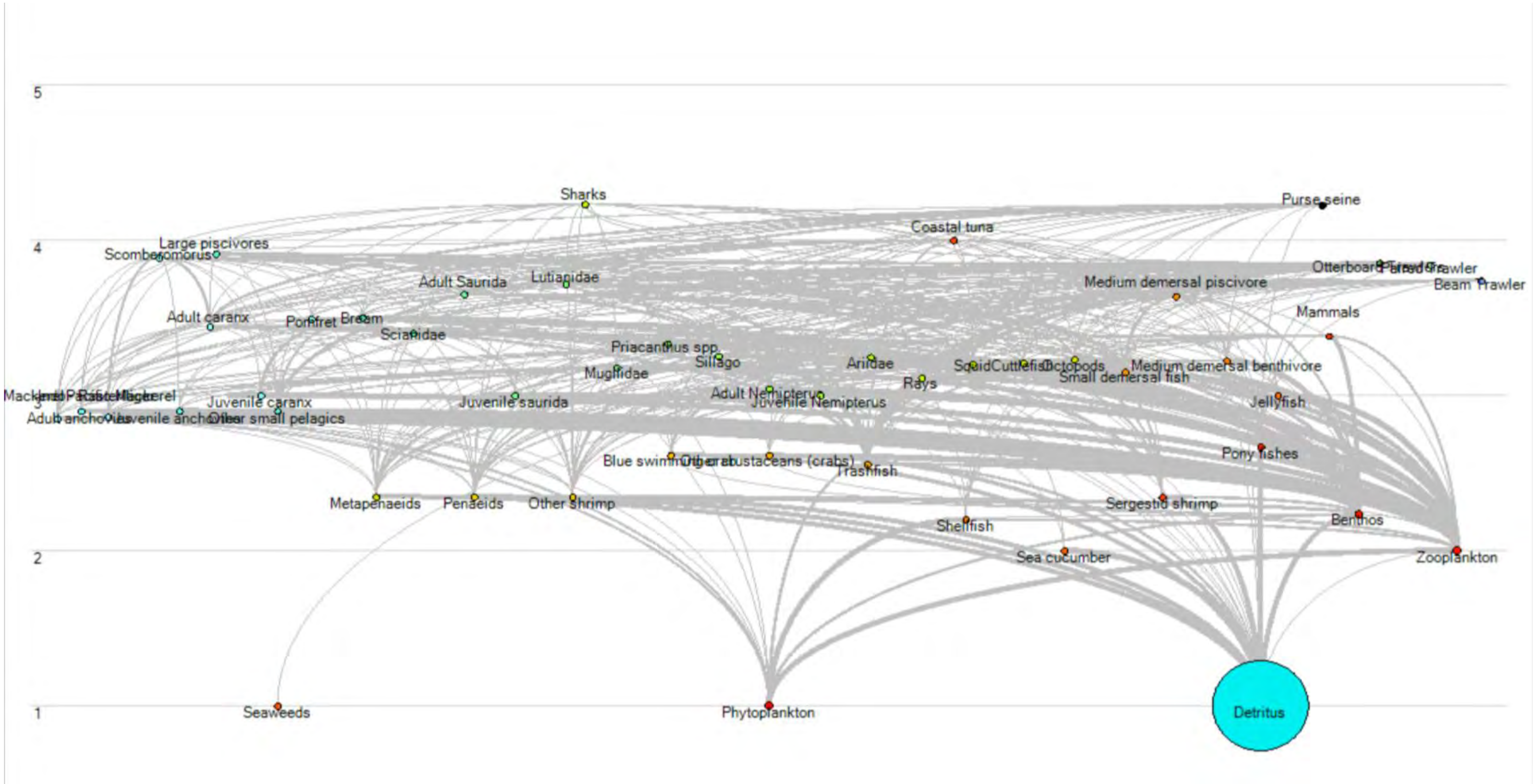


Figure 2. Flow diagrams of the Gulf of Thailand, where the node size indicates biomass, curved lines show food web connectivity and vertical lines show trophic levels.

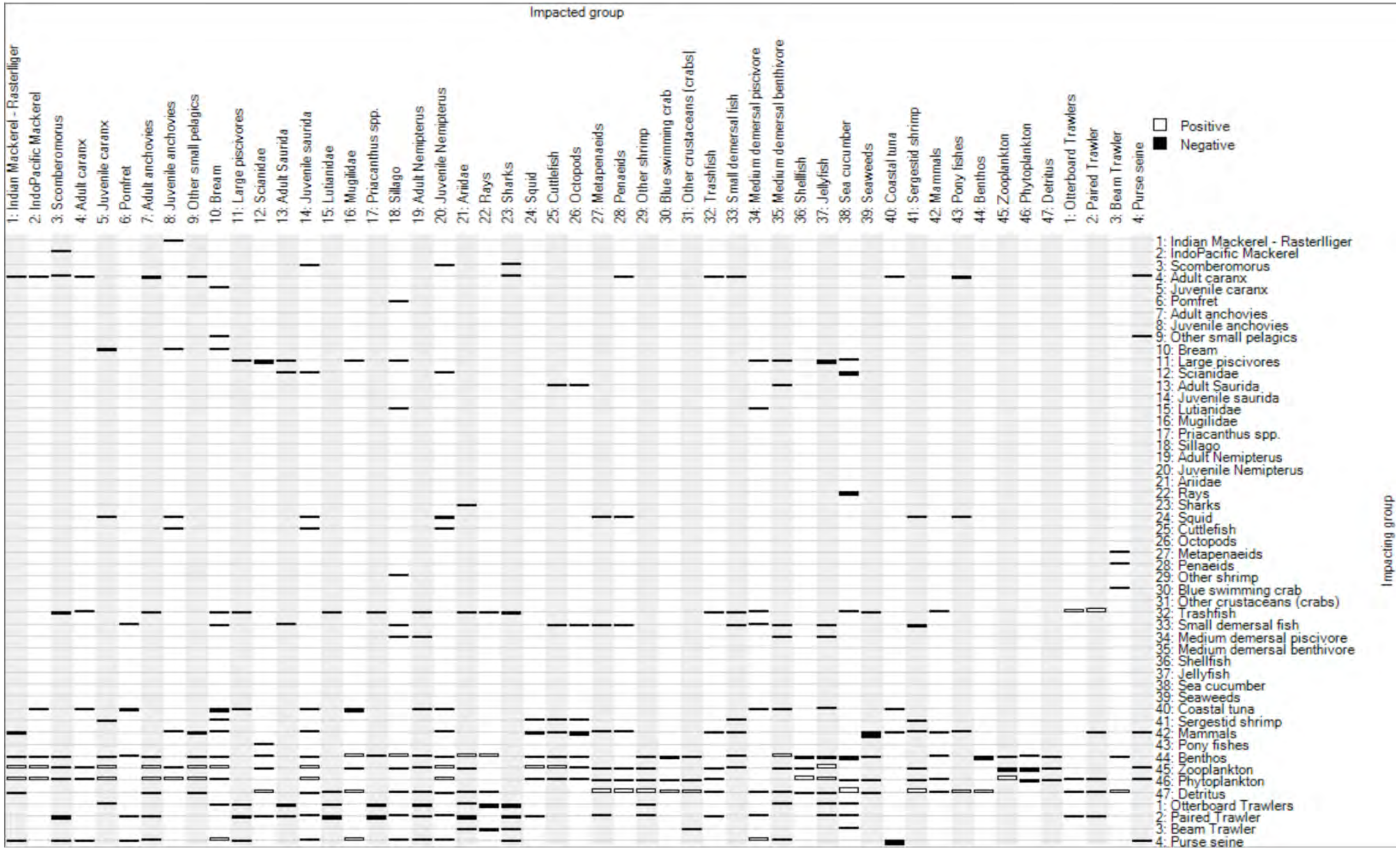


Figure 3. Mixed Trophic Impact analysis of the Gulf of Thailand food web. The size of a bar represents the size of the trophic impact of the functional groups (“above line” white bars indicate positive impact, while “below line” black bars show negative impact)