ผลกระทบของการประมงต่อประชาคมสัตว์ทะเลหน้าดินขนาดใหญ่บริเวณช่องเกาะช้าง จังหวัดตราด ประเทศไทย

Fishing impacts on macrobenthic communities in Chong Ko Chang, Trat Province, Thailand

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บทคัดย่อ

การศึกษานี้ประเมินผลกระทบของการประมงแบบเคลื่อนที่บริเวณพื้นทะเลต่อประชาคมสัตว์ทะเลหน้าดินขนาดใหญ่บริเวณช่องเกาะช้าง จังหวัดตราด ตั้งอยู่ในอ่าวไทยฝั่งตะวันออก พบสัตว์ทะเลหน้าดินขนาดใหญ่ทั้งหมด 72 กลุ่ม ใน 10 ไฟลัม ไส้เดือนทะเล หอยสองฝา และครัสเตเชียน เป็นสัตว์กลุ่มเด่นทั้งสองเขตและสองฤดูกาล ความชุกชุมของสัตว์ทะเลหน้าดินขนาดใหญ่ของจุดเก็บตัวอย่างแต่ละจุดแปรผันแตกต่างกันไป ความหนาแน่นรวมเฉลี่ยของสัตว์ทะเลหน้าดินขนาดใหญ่ในเขตห้ามทำประมงอวนลาก อวนรุน และคราดหอย ตลอดทั้งปี เท่ากับ 258.9 ± 135.6 ตัวต่อตารางเมตร ซึ่งมีค่ามากกว่าในเขตที่ห้ามทำประมงดังกล่าวเป็นเวลาหกเดือน (139.8 ± 67.2 ตัวต่อตารางเมตร) ($p < 0.01$) จำนวนกลุ่มสิ่งมีชีวิตและความมากชนิดในเขตห้ามทำประมงอวนลาก อวนรุน และคราดหอย ตลอดทั้งปีมีค่ามากกว่าเขตที่ห้ามทำประมงดังกล่าวเป็นเวลาหกเดือน องค์ประกอบชนิดสัตว์ทะเลหน้าดินขนาดใหญ่ระหว่างเขตและฤดูกาลแตกต่างกันอย่างมีนัยสำคัญ ($p < 0.01$) และไม่พบปฏิสัมพันธ์ระหว่างปัจจัย ($F = 0.44$, $p = 0.83$) ผลการศึกษายังแสดงให้เห็นว่าโครงสร้างประชาคมของสัตว์ทะเลหน้าดินขนาดใหญ่อาจได้รับอิทธิพลจากทั้งสภาพแวดล้อม (ความลึก ความเค็ม และ pH) และแรงกดดันจากการประมง ซึ่งพิจารณาได้จากความแตกต่างของความชุกชุมและความหลากหลายระหว่างเขตทั้งสอง ผลการศึกษานี้สามารถใช้เป็นข้อมูลพื้นฐานสำหรับการศึกษาวิจัยในอนาคตรวมถึงการจัดการประมงบนฐานระบบนิเวศ

Keywords: ความชุกชุม สัตว์ทะเลหน้าดินขนาดใหญ่ ผลกระทบ เครื่องมือประมง ช่องเกาะช้าง

Abstract

In this study, we assessed the impacts of mobile bottom fishing on macrobenthic communities in Chong Ko Chang, Trat Province, located in the eastern Gulf of Thailand. A total of 72 taxa in 10 phyla were found. Polychaetes, bivalves, and crustaceans were mainly found in both zones and seasons. The abundance of macrobenthos varied considerably among sampling sites. The average total density in the permanent closure zone was 258.9 ± 135.6 ind./m^2, which was higher than those in the six-month closure zone (139.8 ± 67.2 ind./m^2) ($p<0.01$). The number of taxa and species richness of the permanent closure zone were also greater than those of the six-month closure zone. The results revealed the significant differences of macrobenthic composition between zones ($p<0.01$) and seasons ($p< 0.01$) occurred while no interaction between factors was found ($F = 0.44$, $p=0.83$). Based on the results, the community structure of macrobenthos might be influenced by both environment (depth, salinity, and pH) and fishing pressure, illustrated by the differences on macrobenthic abundance and diversity between zones. These findings provide baseline information for future studies and ecosystem-based fisheries management.

Keywords: Abundance, Macrobenthos, Impacts, bottom fishing gear, Chong Ko Chang

Introduction

Although fisheries are a great part of economic development and coastal livelihoods of many countries, overfishing and destructive fishing practices have threatened marine ecosystems worldwide. Recent studies reveal the scientific evidence of the impacts of mobile bottom fishing on biogenic structures and benthic communities (Hiddink *et al.*, 2017). Mobile bottom fishing gears, especially dredges, otter-board trawls, and beam trawlers, had been mostly studied in terms of their impacts on the marine environment (Harris, 2012; Jackson, 2008; Kaiser *et al.*, 2002; Martín *et al.*, 2014). Some reports illustrated that bottom trawling activity has impacts on the abundance of coral reefs, deep-sea corals, sea anemones, sponges, and hydroids in the Western Mediterranean and Alaska (Pierdomenico *et al.*, 2018; Rooper *et al.*, 2011). The impacts of mobile fishing gear, particularly bottom-trawling and dredging, on seagrass beds and seabed destruction have been also documented (Griffiths *et al.*, 2020; National Research Council, 2002). In addition, marine debris has become a significant concern as lost or derelict fishing gears may entangle with the seafloor and threaten biological habitats and marine species (Du Preez *et al.*, 2020).

Additionally, some fishing gears that come in contact with the seafloor also destroy macrobenthic communities and seabed structure. Bottom trawling greatly reduces the abundance of epibenthos as much as 70% compared to untrawled areas, while less impact is found on deep burrowers (Tiano *et al.*, 2020). Similarly, the abundance of some polychaetes in a soft-bottom substrate in trawled areas was less than what has been observed in untrawled areas (Romano *et al.*, 2016). Dredging, which has been used to catch mollusks worldwide, shows its potential to cause disturbances on macrobenthic communities and the seafloor. The impact of bivalve dredge fishing on macrobenthic community structure revealed less abundance and diversity in dredged areas. Crustaceans are considered to be the most vulnerable species to dredging (Gaspar *et al.*, 2009). Hydraulic dredges showed more impacts on biogenic structures compared with trawlers. It was reported that hydraulic dredges and bottom trawlers destroyed 6% and 41% of biota in the disturbed areas, respectively (Hiddink *et al.*, 2017). According to Turner *et al.* (1999), the loss of large epibenthic organisms from the fishing activities may have some effects on fish species. Some studies (Fisher *et al.*, 2015; Shephard *et al.*, 2014; Tiano *et al.*, 2019) illustrated the possibility of such fishing impacts on seafloor environment; e.g. sediment composition, water quality, nutrient cycling etc., that may have adverse effects on other marine organisms and the marine food web.

Macrobenthos has been applied as a bioindicator to monitor adverse impacts on the marine environment. Impacts of trawling and dredging have been generally assessed by looking at the changes of epi- and infauna to such fishing pressure such as abundance and distribution, biomass, species composition, species diversity, species richness, evenness etc. (Sciberras *et al.*, 2013). Hiddink *et al.* (2020) suggested that considering whole-community numbers and biomass is suitable rather than individual taxa. To monitor the impacts of trawling, species richness, abundance and biomass show a higher sensitivity than other indices.

In Thailand, bottom trawling, dredging and push net fisheries are operated throughout Thai coastal waters. Bottom trawling and push net target demersal fish and shrimp, while dredging catch mostly clams. Currently, bottom trawling and dredging are considered as a commercial fishery and they are not allowed to operate in Thai coastal seas. Push net, excluding krill push net, has been banned, according to the Royal Ordinance on Fisheries B.E. 2558 announced in the Government Gazette on 13 November 2015. In Thailand, the research on the fishing impacts of bottom trawling and dredging on the marine benthic environment has been limited (Suebpala *et al.*, 2017). Almost of the studies of marine macrobenthic community in Thailand were conducted in biodiversity and ecological aspects, and some of them used macrobenthos to detect water quality and pollution. Only one study regarding the environmental impact of surf calm (*Phapia* spp.) fishing was found describing the change of the seafloor and the loss of parental surf clam stock. Increases in total suspended solids and some nutrients were detected during the fishing (Chanrachkij, 2012). Due to the knowledge gap, this study aimed to investigate the impacts of trawling, dredging, and push net fisheries on macrobenthic communities in Chong Ko Chang, Trat Province, Thailand.

Materials and methods

Study site

Chong Ko Chang is located in the eastern Gulf of Thailand between the mainland and Ko Chang in Trat Province (Figure 1). Before the Royal Ordinance on Fisheries B.E. 2558 (2015) and Ministerial Regulation on Coastal Seas in Thailand B.E. 2560 (2017) became effective, two different zones in Chong Ko Chang where different fishing regulations were posed are as follows: 1) the green zone where trawling, dredging, and push net fisheries with motorized vessel are completely prohibited all year round, in which a total of six study sites including station A, B, C, D, E, and F were investigated, 'permanent closure zone' is called hereafter; 2) the red zone where such fisheries with motorized vessels were prohibited during June – November each year according to the Notification of Trat Province on the prohibition of trawling, dredging, and push net fisheries in Chong Ko Chang, within which four study sites including station G, H, I, and J were investigated, 'six-month closure zone' is called hereafter.

Sampling and sample processing

At each study site, six replications were collected using Van Veen grab with its surface area of 900 cm^2. Samplings were done in August 2015 and March 2016 representing a wet and dry season, respectively. The samples were washed over a 0.5-mm mesh-sized sieve. Macrobenthic species retained on the sieve were fixed in 10% buffered formalin for further identification. Sediment samples were also collected and fixed in 10% buffered formalin to analyze organic matter content and particle size analysis. At each sampling station, some environmental parameters such as depth, temperature, salinity, dissolved oxygen, pH, salinity, total dissolved solids (TDS) and conductivity, were measured using a YSI 556 MPS water quality monitoring device.

In a laboratory, the samples were stained with Rose Bengal before sorting and identification. The individuals of each taxon were counted and recorded under a microscope. Content of organic matter in the sediment samples was analyzed using loss on ignition method (Heiri *et al.*, 2001). The dry-sieve method was used to find sand fraction in the sediment samples while particle-size fractionation was further used for determining silt and clay fraction (English *et al.*, 1997).

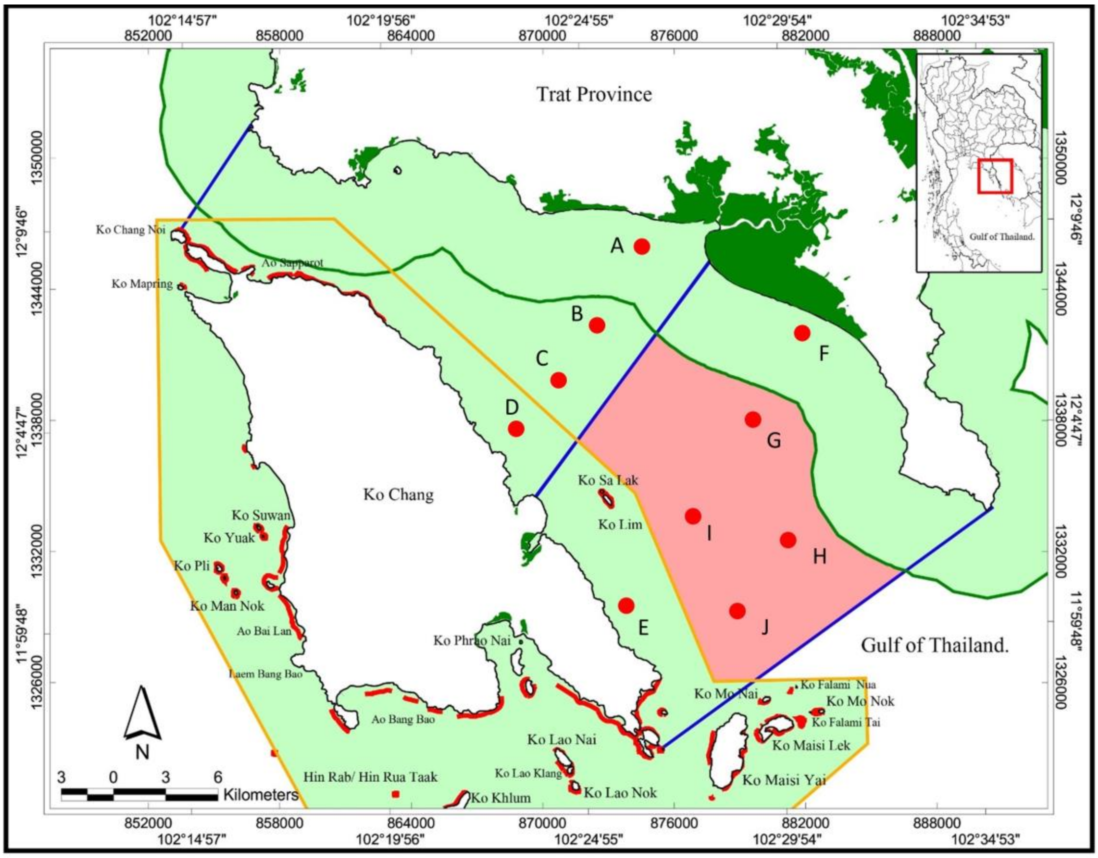


Figure 1 Sampling sites (red dots) investigated for the macrobenthic community in different fishing regulations: 1) the green line represents the boundary of coastal waters prohibiting the operation of commercial fisheries; 2) the yellow line represents the boundary of Mu Ko Chang National Park; and 3) blue lines represent a permanent closure (upper part) and a 6-month closure (lower part) boundary according to the Notification of Trat Province on the Prohibition of Trawling, Dredging, and Push Net Fisheries in the Staite of Ko Chang B.E. 2543 (2000).

Data treatment and analyses

Densities of each taxon were totalled to give total densities in each replicate and sampling station. Since raw data were not normally distributed, all of the data were treated with square root transformation before testing the differences of the mean total densities between six-month closure zone and the permanent closure zone with t-test. Two-way ANOVA was performed to test whether the macrobenthic abundance is influenced by zone or season as well as the interaction between two factors. Spatial variation among sites was tested by one-way ANOVA with Tukey's HSD (honestly significant difference) test. All univariate data analyses were performed using SPSS version 22.

In addition to these individual species, the number of taxa (family level) and density data for all macrobenthic species were used to calculate diversity indices as follows (Clarke *et al.*, 2014):

Shannon–Wiener diversity index [$H' = -\sum(p_i \cdot \log(p_i))$]; Margalef's species richness [$d=(S-1)/\log(N)$]; Pielou's evenness [$J' = H'/\log(S)$]. The difference in the total number of taxa between the six-month closure zone and the permanent closure zone was tested with the Mann-Whitney U test.

The similarity of species composition based on Bray-Curtis Similarity between zones and seasons was conducted with Permutational multivariate analysis of variance (PERMANOVA) (Anderson *et al.*, 2018). The Similarity Percentage (SIMPER) was performed to identify which taxa are responsible for a major contribution to similarity and help identify the taxa that are generally found in a certain group. A distance-based linear model (DistLM) and distance-based redundancy analysis with ordination (dbRDA) were performed to observe the relationship of environmental gradients and similarities of sampling station. Diversity Indices, PERMANOVA, SIMPER, DistLM and dbRDA were done using PRIMER version 7.0. The fourth-root transformation was performed prior to conducting the multivariate data analyses (Clarke *et al.*, 2014).

Results and Discussion

Abundance of macrobenthos

Macrobenthic communities are used as an ecological indicator to assess fishing impacts in two different zones (permanent closure zone and six-month closure zone) in Chong Ko Chang. The results showed that the dominant groups of macrobenthos found in every sampling station included polychaetes, bivalves, decapods, amphipods, ophiuroids etc. In an overall picture, the mean total density in the permanent closure zone (258.9 ± 135.6 ind./m^2) was higher than that in the six-month closure zone (139.8 ± 67.2 ind./m^2) ($t=6.08$, $p<0.01$). The mean total density of macrobenthos in the permanent closure zone (265.0 ± 84.6 ind./m^2) was significantly higher than those observed in the six-month closure zone (153.7 ± 71.3 ind./m^2) in the wet season ($t=5.53$, $p<0.05$). The surveys in dry season exhibited a significantly lower abundance in the six-month closure zone (125.9 ± 60.8 ind./m^2) compared to the permanent closure zone (252.1 ± 174.8 ind./m^2) ($t=3.72$, $p<0.05$). However, the spatial variation among stations was also detected (One-way ANOVA). The two-way ANOVA testing on the effect of the zone and season on the abundance revealed only an effect of the zone on their abundance ($F=43.31$, $p<0.01$) and no interaction between the two factors was found ($F = 0.44$, $p=0.83$) illustrating that the abundance is influenced by zone (Figure 2).

In the overall picture, the average abundance of macrobenthos in the permanent closure zone was significantly higher than those observed in the six-month closure zone and the average abundance of macrobenthos varied considerably among study sites. Comparing the previous studies, Jualaong (2007) reported that the average abundance of macrobenthos in Mu Ko Chang and Ko Kut was 144.8 ind./m^2 dominated by polychaetes. In Trat Bay, the abundance of benthos ranged from 19 – 964 ind./m^2 dominated by molluscs (Poonapa-amporn *et al.*, 2019). According to the study of Putchakarn (2005), the average abundance of macrobenthos along the eastern Gulf of Thailand (from Chonburi to Trat) was 554.5 ind./m^2 dominated by polychaetes, crustaceans, bivalves, gastropods, and echinoderms. In terms of fisheries importance, some studies focused on the abundance and distribution of short neck clam (*P. undulates*); for example, Chatananthawej and Thubthimsang (1989) reported that catch rate of the short neck clam in Trat Province 0.4-17.5 kg/hr, which had drastically declined compared with the past. Kanmarangkool *et al.* (2019) reported that the short neck clam was randomly distributed and it was influenced by particle size which was silty sand or sandy silt. Fortunately, the great efforts of fisheries resources management in Chong Ko Chang; i.e. designation of untrawed area, temporal closure, breeding research as well as broodstock enhancement of short-necked clam, have revitalized the abundance of short-necked clam in this area (Tunvilai *et al.*, 2017).

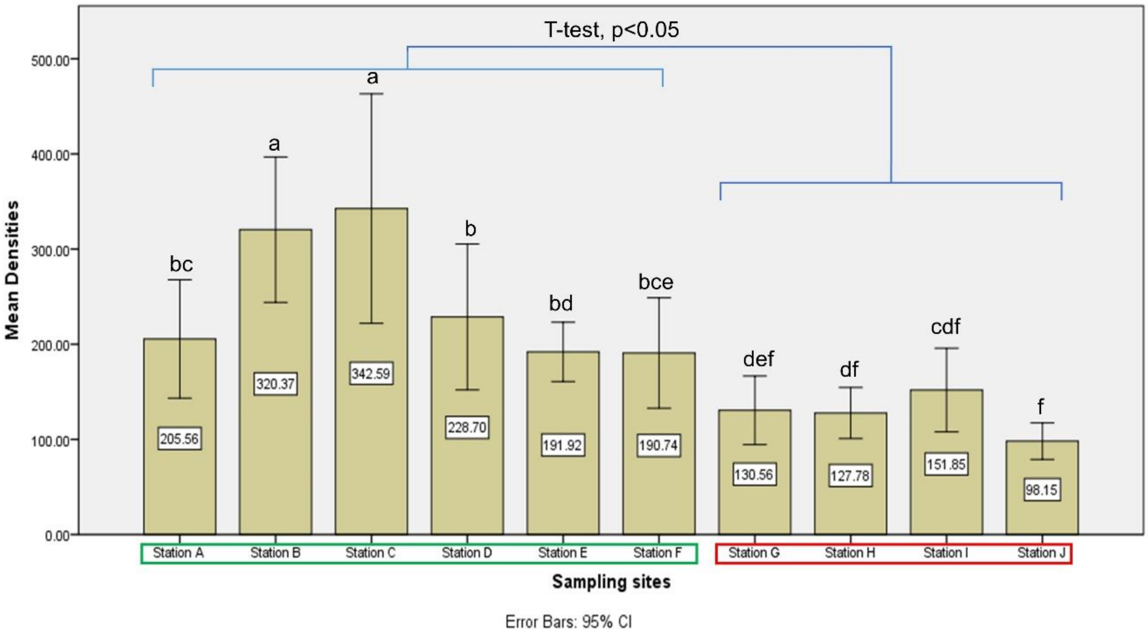


Figure 2 Mean (±SD) total density of macrobenthos (ind./m^2) at each study site

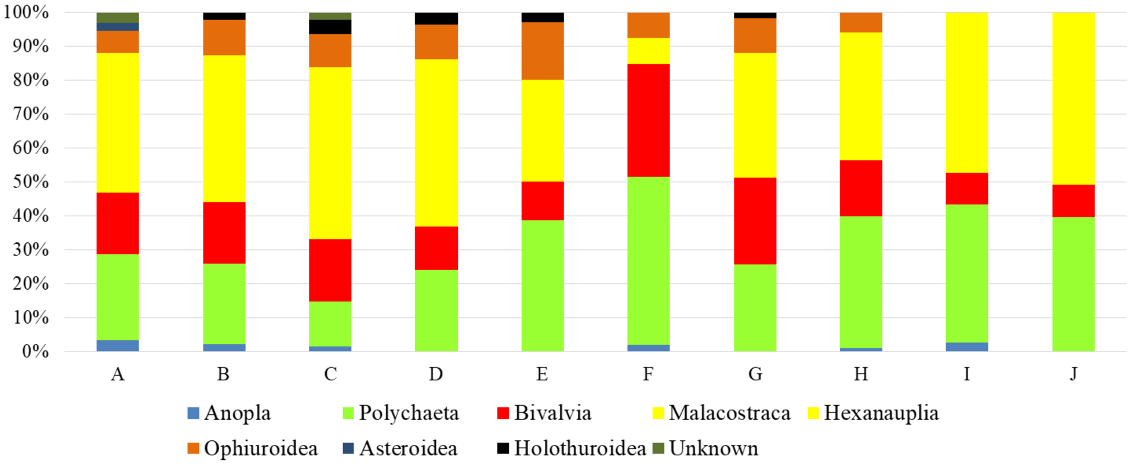
Remark: Means sharing the same letter are not significantly statistically different (Tukey's HSD test, p<0.05). The t-test was used to compare the means between two zones.

Diversity of macrobenthos

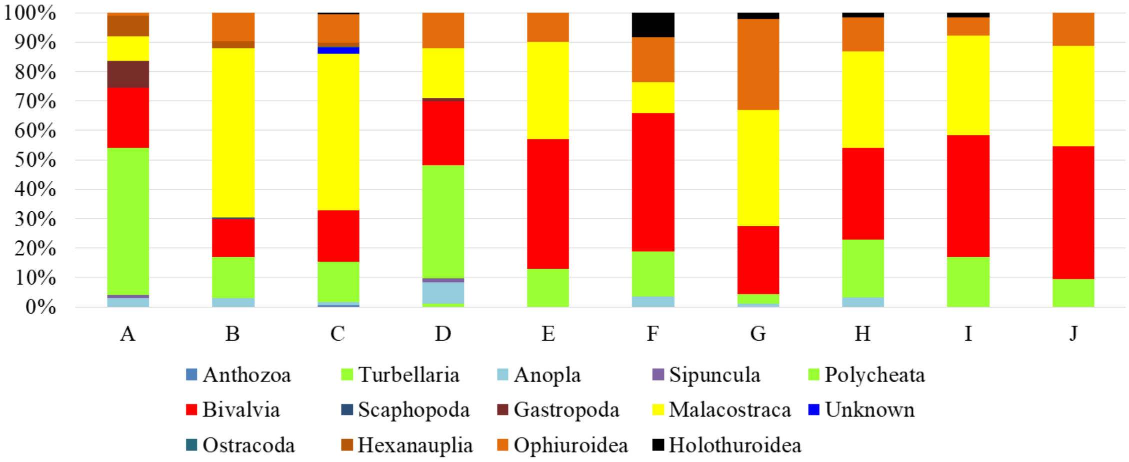
In this study, a total of 72 taxa in 10 phyla was observed. Crustaceans, polychaetes and bivalves were mainly found in both zones and seasons. Overall, the permanent closure zone (35 taxa) had higher taxa (35) than the six-month closure zone (19 taxa). The Pielou's evenness and Shannon diversity index were 0.83 and 1.08, for the permanent closure zone and 0.85 and 1.02 for the six-month closure zone, respectively. The highest diversity was found at station D, which is close to Ko Chang, exhibiting the Margalef's species richness, Pielou's evenness and Shannon diversity indices of 4.25, 0.91 and 1.03 in the dry season (Table 1). The statistical tests showed statistical differences in terms of the number of taxa (Mann-Whitney U = 7.500; p=0.005) and species richness (Mann-Whitney U = 13.000; p=0.007) between the permanent closure zone and the six-month closure zone (Figure 3 and Table 1).

Furthermore, all diversity indices were not significantly different between wet and dry seasons except the Shannon-Wiener Index. However, when the observed data from every sampling were pooled, more taxa tended to be found in the dry season (12 - 35 taxa) than the wet season (15 - 22 taxa). The diversity of macrobenthos observed in this study was relatively low compared to the study of Putchakarn (2005) showing the higher diversity of macrobenthos (H'=1.76) along the eastern Gulf of Thailand and the study of Jualaong (2007) reporting the diversity index of macrobenthos in Mu Ko Chang (H' = 1.30). Poonapa-amporn *et al.*, (2019) reported that the species richness and diversity in Trat Bay were similar, ranging from 0.0 - 2.7. They also found that the diversity in the dry season was higher than that in the wet season. This is because of the freshwater discharged from the Trat River making the conditions in this area dynamic; i.e. salinity change, amount of organic matter, particle characteristics.

Although no seasonal change in the mean total densities was detected, the composition of macrobenthos varied greatly between wet and dry seasons. Generally, macrobenthic communities are dynamic and seasonally changed within a year (Shou *et al.*, 2009). The unclear difference in the mean total densities observed between seasons was due to a great variation of the densities among samples. Seasonal variation in species composition of macrobenthos can be influenced by various factors, particularly environmental conditions and the recruitment process and predator-prey relationship (Lamptey and Armah, 2008; Shou *et al.*, 2009).



Wet season



Dry season

Figure 3 Species composition of macrobenthos at each zone during wet and dry seasons

Table 1 Total number of taxa, richness, evenness, and diversity of macrobenthos at each site and season

Zone	Study site	Dry season				Wet season			
		S	d	J'	H'	S	d	J'	H'
Permanent closure zone	A	17	2.29	0.86	1.06	20	2.64	0.91	1.19
	B	20	2.53	0.68	0.89	22	2.76	0.86	1.16
	C	35	4.34	0.66	1.02	16	2.04	0.80	0.97
	D	30	4.25	0.91	1.35	20	2.53	0.87	1.13
	E	20	2.77	0.79	1.03	19	2.55	0.85	1.09
	F	16	2.17	0.76	0.92	22	2.94	0.88	1.18
	Average	**23.00**	**3.06**	**0.78**	**1.05**	**19.83**	**2.58**	**0.86**	**1.12**
Six-month closure zone (June – November)	G	14	1.98	0.82	0.94	18	2.52	0.87	1.09
	H	14	1.95	0.90	1.03	15	2.11	0.92	1.09
	I	13	1.84	0.89	0.99	19	2.56	0.89	1.14
	J	12	1.73	0.82	0.88	16	2.35	0.87	1.05
	Average	**13.25**	**1.88**	**0.86**	**0.96**	**17.00**	**2.39**	**0.89**	**1.09**

Remarks: *Permanent closure zone, **six-month closure zone; S, d, J', and H' denote total taxa, Margalef's species richness, Pielou's evenness, and Shannon-Wiener Index, respectively.

Regarding the species composition, a Bray-Curtis Similarity and Permutational Multivariate Analysis of Variance (PERMANOVA) revealed significant differences of macrobenthic composition between zones (Pseudo-F = 8.9813, p(perm)= 0.001) and seasons (Pseudo-F = 10.267, p(perm)= 0.001). The Similarity Percentage (SIMPER) was performed to identify which taxa are responsible for a major contribution to similarity and helps identify the taxa that are generally found in a certain group. In the permanent closure zone, polychaetes, bivalves, ophiuroids, and amphipods contribute 73% of a total similarity, while most similarity found in the six-month closure zone were contributed mostly (80%) by bivalves, polychaetes, amphipods and decapods (Figure 4, Table 2).

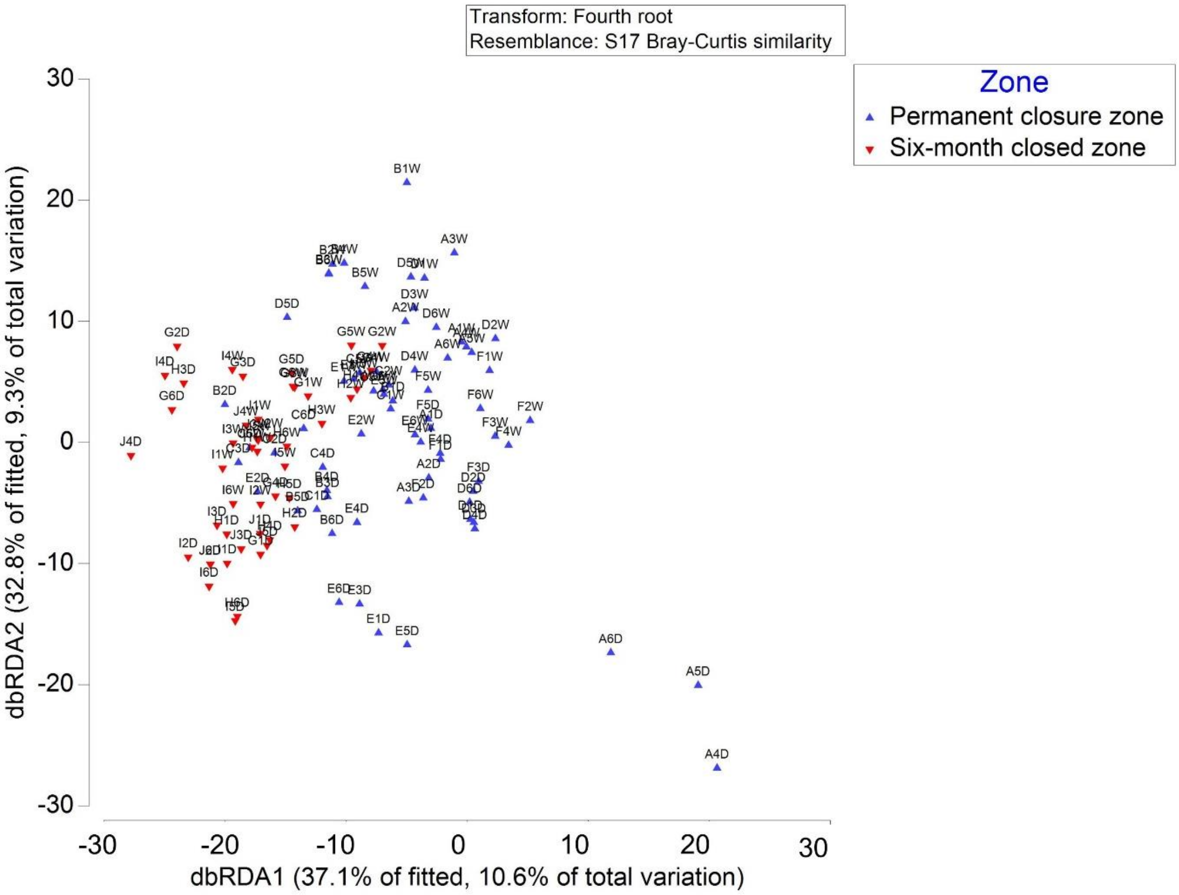


Figure 4 A dbRAD plot based on the fourth-root transformed data (number of individuals) showing the similarity of specie composition of each sample. The abbreviation code of each point consists of a sampling site (A-J), a replicate number (1 – 6) and a season (Dry or Wet), respectively.

Table 2 The Similarity Percentage (SIMPER) showing the contribution of major macrobenthos to dissimilarities among factors (zone and season).

Examining between zones			
Group: Permanent closure zone (Average similarity: 66.13)		Group: Six-month closure zone (Average similarity: 70.93)	
Taxon	% Contribution	Taxon	% Contribution
Polychaeta	26.58	Bivalvia	21.43
Bivalvia	21.94	Polychaeta	21.41
Ophiuroidea	13.39	Amphipoda	20.70
Amphipoda	12.01	Decapoda	16.97

Table 2 (Cont.) The Similarity Percentage (SIMPER) showing the contribution of major macrobenthos to dissimilarities among factors (zone and season).

Examining between seasons			
Group: Dry (Average similarity: 63.26)		Group: Wet (Average similarity: 71.80)	
Taxon	% Contribution	Taxon	% Contribution
Bivalvia	26.62	Polychaeta	27.61
Polychaeta	21.69	Bivalvia	17.67
Amphipoda	17.67	Decapoda	17.36
Ophiuroidea	11.01	Amphipoda	12.44

Environmental factors

Environmental parameters played an important role in shaping community structure and abundance. Our results showed the significant differences in the five parameters of depth, sand, silt, organic matter and salinity between the two zones (Student's t-test, $p<0.05$). Some parameters; i.e. organic matter, temperature, dissolved oxygen, salinity, TDS, conductivity, were significantly changed between wet and dry seasons.

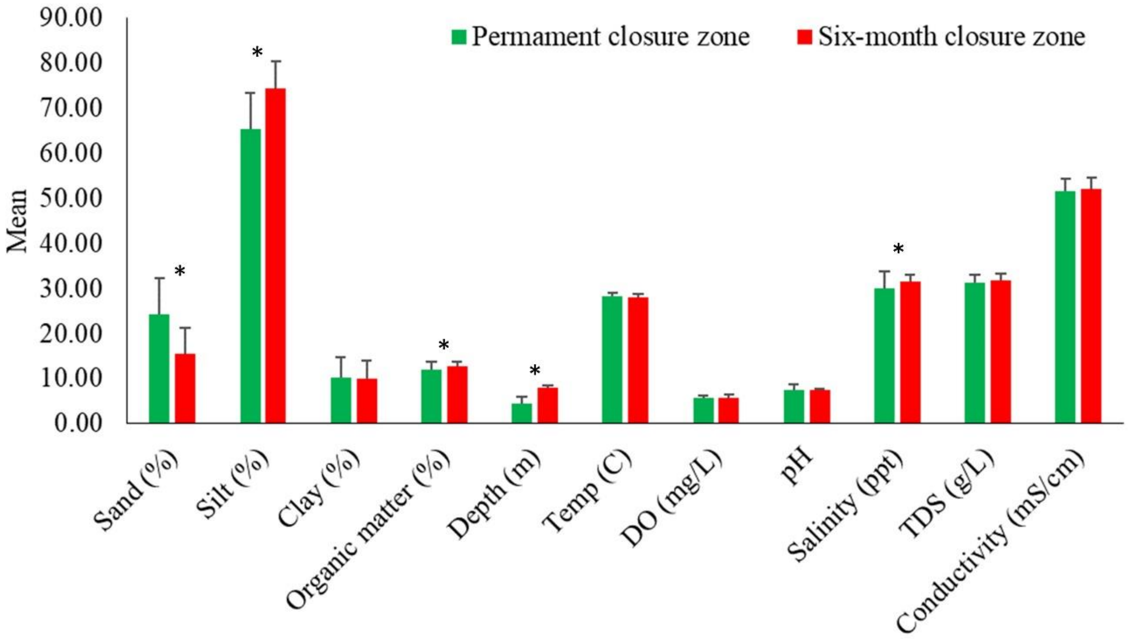


Figure 5 Means (±SD) of some environmental parameters of two zones (*p<0.05)

The DistLM revealed that some parameters can be used as predictors to determine the relationship between environmental parameters and macrobenthic community, including silt (Pseudo-F= 2.72, p-value = 0.023), organic matter (Pseudo-F= 3.36, p-value = 0.01), depth (Pseudo-F= 7.35, p-value = 0.001), dissolved oxygen (Pseudo-F= 2.5, p-value = 0.05), pH (Pseudo-F= 4.54, p-value = 0.01), salinity (Pseudo-F= 8.79, p-value = 0.001). The dbRDA ordination plot explained with the first two axes explained 37.1% and 32.8% of the fitted variation and 10.6% and 9.3% of the total variation. The pattern of the macrofaunal samples in each station suggested two gradients of variation. The first gradient was driven by variable “depth” explaining that the benthic composition on the left of the quadrant, most of the stations in the six-month closure zone, were more influenced by depth. The second gradient was driven by the variable “salinity”, clustering the sampling stations in the lower quadrant explaining that those sampling stations are influenced more by salinity, especially during the dry season (Figure 6).

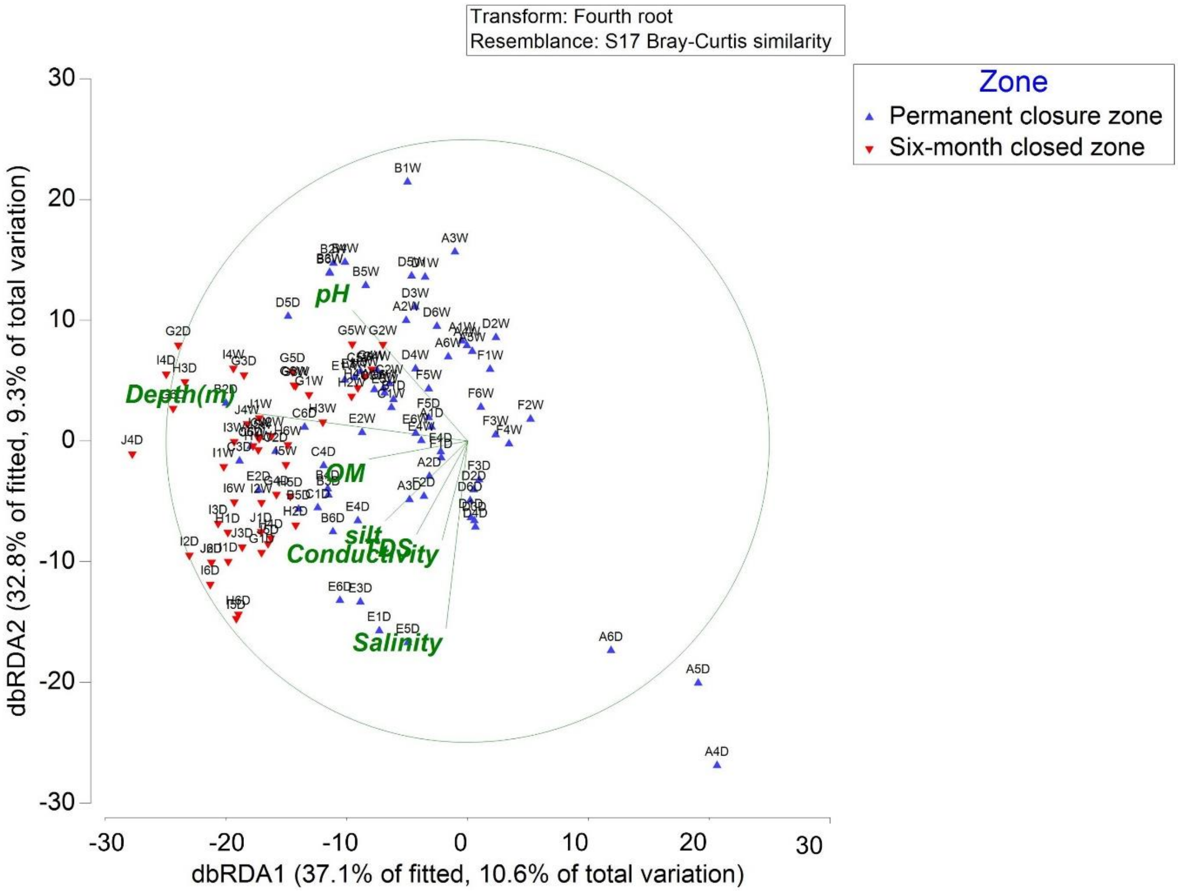


Figure 6 The relationships between the environmental parameters and the abundance of the macrobenthic communities were examined using a distance-based linear model (DISTLM) and distance-based redundancy analysis ordination (dbRDA). The abbreviation code of each point consists of a sampling site (A-J), a replicate number (1 – 6) and a season (Dry or Wet), respectively.

Our results revealed that most environmental parameters observed between two zones were not significantly different except depth, sand, silt, organic matter and salinity. This was because those sampling stations are located in the same micro-region where smaller environmental fluctuation occurs and some benthos can also inhabit in a wide range of environmental conditions (Ysebaert and Herman, 2002). Several environmental variables including sediment structure, organic matter content, temperature, salinity, dissolved oxygen, nutrient concentrations, pH, turbidity, water transparency, and depth have been identified as factors influencing a macrobenthic community (Lamptey and Armah, 2008). Macrobenthic community is shaped by a combination of these factors, and no single factor could be considered as a main influencing factor (Veiga *et al.*, 2017; Zhang *et al.*, 2012).

Fishing impacts

Having rich marine and fisheries resources, Chong Ko Chang has served as an important fishing ground for a long time. Both artisanal and commercial fisheries operate throughout this area. The area is as an important fishing ground for undulated surf clams (*Paphia* sp.) in Trat province where clam dredging was generally found to be affecting its population in this area. Due to the decline in fisheries resources in Chong Ko Chang, the Notification of Trat Province went into effect in 2000 to prohibit trawling, dredging, and push net fisheries in the upper part of Chong Ko Chang, while such fisheries were still allowed to operate in the lower part for six months from June to November each year. Since the coastal seas in Thailand were established in 2017 under the Royal Ordinance on Fisheries B.E. 2558 and the Ministerial Regulation on Coastal Seas in Thailand B.E. 2560, all of the areas in Chong Ko Chang, have been automatically protected. As a result, all commercial fisheries are completely prohibited in all coastal seas including the six-month closure zone since then. Because the samplings of this study were conducted in August 2015 and March 2016, the fishing impacts discussed herein refer to the accumulative impacts occurring during 2000 – 2017 or about seventeen years before the newer regulations became effective.

In terms of fishing impacts, the difference in abundance of macrobenthos between the two zones are significantly different and this is probably caused by the combination of fishing activities and environmental factors. The mean total density of macrobenthos in the permanent closure zone was significantly higher than that in the six-month closure zone in both wet and dry seasons. For example, the abundance of bivalves in the permanent closure zone (49.5 ind./m^2) was higher than that in the six-month closure zone (37.7 ind./m^2). This might be because of the activities of clam dredging which used to operate from March to May in the six-month closure zone. In the other parts of Trat province, clam dredging starts from March to October since from November to February, the size of clams is under a marketable size (Suksumran *et al.*, 2014). Many studies revealed that dredging has impacts on the population of the parent clams (Chanrachkij, 2012; Yeemin *et al.*, 2011) and other marine benthos (Sciberras *et al.*, 2018). Some epifaunal species such as brittle stars and sea cucumbers were found in less density in the six-month closure zone than in the permanent closure zone, linking it to the possible impacts of bottom trawling on epifauna and juveniles (Tiano *et al.*, 2020; van Denderen *et al.*, 2015).

Based on this study, mean total density, the number of species and species richness seem to be more responsive in linking the fishing impacts on the macrobenthic communities. The higher mean total density and species richness were observed in the permanent closure zone. This corresponds to the study of Hiddink *et al.* (2020) suggesting that taxa numbers, biomass and species richness responded to the monitoring of trawling impacts, but evenness and Shannon–Wiener diversity (H’) did not. Macrobenthic communities in the two zones can be also influenced by various environmental factors including silt, organic matter, depth, dissolved oxygen, pH, and salinity.

Conclusions

This is exploratory research illustrating the chronic impacts of fishing activities on the macrobenthic community and the application of macrobenthos as a bioindicator for fishing impact assessments in Chong Ko Chang. The abundance of macrobenthos varied considerably among the study sites. The total mean density observed in the permanent closure zone was higher than that observed in the six-month closure zone. The number of taxa and species richness of the permanent closure zone were also greater than those of the six-month closure zone. Species composition varied seasonally and spatially. Based on the results, the abundance and community structure might be influenced by both environmental conditions (mainly driven by depth, salinity, and pH) and fishing pressure, which were illustrated by the differences in macrobenthic abundance and diversity between zones. However, more detailed studies are still required for clear understandings on temporal and spatial changes in macrobenthos in this area. This study also serves as critical baseline information for future studies and the application of ecosystem-based fisheries management.

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