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Assessing Impact of Crab Gill Net Fishery to Bycatch Population in the Lower Gulf of Thailand

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Abstract

This study assessed bycatch composition and some factors affected assemblage from blue swimming crab fisheries in semi-enclosed Pattani Bay and offshore area, the Gulf of Thailand. Samples were collected from May 2013 to September 2014 by using crab gill net. One hundred seventy four of bycatches were found within proportion of 52.2% in the bay and 49.5% from offshore. Moreover, discarded species from the bay and offshore were 26.3% and 47.1%, respectively. The most dominant species in the bay was horse shoe crab (*Carcinoscorpius rotundicauda*) while offshore was scaly whipray (*Himantura imbricate*). Abundance of bycatch in the bay was affected both by habitat ($P<0.005$) and season ($P<0.001$) while abundance from offshore was affected only by season ($P<0.05$). Species richness of bycatch both in the bay and offshore were influenced significantly by season ($P<0.001$ and $P<0.005$, respectively). The most abundance bycatch in the bay was found in the inner bay while at 15m depth for offshore. The result of nMDS ordination indicated a separation of three major groups of assemblage in the bay; inner, middle and outer bay but there was no obvious segregation from offshore.

Keywords: Portunidae; small scale fisheries; coastal habitat; Pattani Bay; discarded species; South China Sea.

Introduction

Artisanal or small-scale fisheries are important worldwide contributing more than 25% of global marine landings (Food and Agriculture Organization of the United Nations, 2014), accounting for about 50% of the landings used as human food, and employing for 90% of the world's fishermen (McGoodwin, 1990; Dıaz-Uribe, 2007). Crab gill net is one of the most important fishing gear of blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) in the Gulf of Thailand. It is a stationary gear that using by the local fishermen. There is traditionally believed that this gear has not much effect to non-target species or bycatch because it is a highly selective methodology of operation. Moreover, it has been assumed that there is not a major risk to marine ecosystem compared with large-scale fisheries due to a lower and more selective fishing capacity (Diaz-Uribe, 2007). However, a recent report by Food and Agriculture Organization of the United Nations (2014) indicated that approximately 30% of world landings were fish trash or non-target species and 40% of them caught by artisanal fishing gears. Gill net is being considered among important fishing gears deployed by small-scale fishermen worldwide capable of matching large-scale fisheries in term of bycatch collection (Bundy and Pauly, 2001; Diaz-Uribe *et al.*, 2007). Unfortunately, fish resources exploited by these fisheries are seldom studied and generally are not taken into account for assessment and management programs (Dıaz-Uribe *et al.*, 2007). Bycatch, referred to an incidental catch causing mortality and injuries to the non-target species or the total catch of non-target animals (Kelleher, 2005), is an issue affecting the ecosystem and survival of marine population (Read, 2013). Awareness of bycatch issue attracted a global interest as it is urged to develop international guideline on bycatch management and reduction of discards (Food and Agriculture Organization of the United Nations, 2014). Whereas, discards or discarded catch is referred as portion of the total animal origin in the catch, which is thrown away, or dumped at sea for whatever reason (Kelleher, 2005). However, it is not a subset of bycatch since the target species is often discarded. In general, there are three types of bycatch; normal, cryptic and ghost fishing (Leland *et al.*, 2013). Normal bycatch is defined as non-target species trapped in gill nets, alive or dead, during hauling process. Cryptic bycatch is meant organisms entangled to fishing gears and having injury, yet died after trying to escape from the gears (Leland *et al*., 2013; Reeves *et al*., 2013). Ghost fishing is referred to active gill nets lost or abandoned by fishers which can cause mortality to the marine species (Campbell and Sumpton, 2009).

Study on bycatch associated with some fishing gears has been established well in many parts of the world. For example, bycatch of fish trawl related with time and its sizes in Atlantic and Australia (Pallson, 2004; Kennelly *et al*., 1998); spatial effect of trawl catch to bycatch in Australia (Svane *et al*., 2008); effect of penaeid shrimp trawl to bycatch related with seasons in US (Belcher and Jennings, 2011), differences in the bycatch assemblages structure between different species of shrimp in Australia (Dell *et al*., 2009); bycatch in trammel net with prawn as target species (Metin *et al*., 2009); bycatch of turbot gillnet as *Phocoena phocoena* was target species (Gönener and Bilgin, 2009) and assessment of fish bycatch species from coastal artisanal shrimp beam trawl fisheries in Nigeria (Ambrose *et al*., 2005) were reported. Campbell and Sumpton (2009) specifically highlighted effect of gears to the non-target species by using different baits in Australia. For bycatch from gill nets, a review on its impact to marine mammals has been exclusively reported (Reeves *et al*., 2013).

Portunus pelagicus can be found in sandy to sandy-muddy substrates in shallow waters down to 50 meters. It is a target species for commercial and recreational fisheries inhabiting the Indo-west Pacific Ocean and Mediterranean Sea (Carpenter and Niem, 1998). Crab gill net is one of the most important fishing gears in Southeast Asia, especially in Thailand and Malaysia. Fishermen generally harvest them from vessels approximately 8 to 15 meters length carrying 100–500 nets with each 120 meters long. They normally set the nets for 24 hours to 72 hours. However, time of setting can be shorter due to tidal current and weather, especially during heavy monsoon seasons, December to February (Chaiwanawut *et al*., 2005). However, Kunsook *et al*. (2014) studied on a stock assessment of blue swimming crabs, *P. pelagicus*, in the eastern Gulf of Thailand, and found several key indicators showed that *P. pelagicus* population was in crisis with high fishing mortality and exploitation rates and decreasing in size of mature females. Besides its popularity, there is hardly any available scientific information describing bycatch composition of this net worldwide. The only study by Kumar *et al*. (2013) reported bycatch associated with this net in India. In Thailand, Pattani fishermen have a long utilization of crab gill nets to catch blue swimming crab (*P. pelagicus*) as the main fishing gears along coastal waters. The practice of discarding non-target species, especially unmarketable fishes, is a common character of this fishing gear. Study on species composition including target and bycatch species is necessary, not only to evaluate the impact to ecosystem, but also to impact of season and habitat.

It is crucial to highlight the bycatch composition from crab gill net fisheries to serve as baseline scientific information for future management. An investigation of the impacts of habitat and season on abundance, species composition and community structure of the bycatch from this artisanal fishing gear is ecologically essential. This study is conducted with the aims of assessing and identifying bycatch species composition from blue swimming crab gill net fishery and examining impacts of habitat and season on bycatch community assemblages. It is considered the first attempt for work of this kind, provides a crucial scientific knowledge on bycatch from crab bottom set gill net in two different habitats, semi-enclosed bay and offshore area.

Materials and Methods

Study Area Description

Two different areas along the coast of Pattani, the Gulf of Thailand, were selected for this study, inside the Bay and offshore zone (Figure 1), where a majority of local fishers used crab gill net as a main fishing gear.

Pattani Bay is a small semi-enclosed estuarine bay protected on the northeast side by 12 km long sand spit. The total area of the bay is 74 km^2. The water regime is complex, with tidal influences from the Gulf of Thailand, run-off from the landward side and water drains from the two major rivers, Pattani and Yamu Rivers. Average water depth is between 0.2-1.5m with the maximum of 5m at the bay mouth and deeper gradually outside the bay (Hajisamae *et al*., 2006). There have both natural and replanted (estimated at 900ha), are found in the east of the area. Mangrove forests dominate the surrounding areas of the bay consisting of *Rhizophora micronata*, *R. apiculata*, *Sonneratia alba*, *Avicennia* sp., *A. officinalis*, *Bruguiera gymnorhiza*, *B. cylindrica*, *B. parviflora*, *Kylocarpus moluccensis*, *Acanthus ilicifolius*, *Excoecaria agallocha* and *Nypa fruticans*. Three habitats were selected; inner, middle and outside bays. The inner bay characterized by 1.0-1.5 m deep with a muddy bottom and some coverage of seagrasses and seaweeds. The middle bay habitat is 1.0-2.0 m deep with a combination of sandy-muddy bottom supporting some *Halophila ovalis*, *H. beccarii*, *Halodule uninervis* and algae *Ulva* spp. and *Gracilaria* spp. In the outer bay, it is characterized by 2.5-4.0 m deep with muddy bottom and without any vegetation. In the outer bay, it is characterized by 2.5-4.0 m deep with muddy bottom and without any vegetation. Three sub-stations were located within each habitat.

For offshore zone, an open water area, three different depths contours along coastal area were selected; 5 m, 10 m and 15 m depths. Three sub-

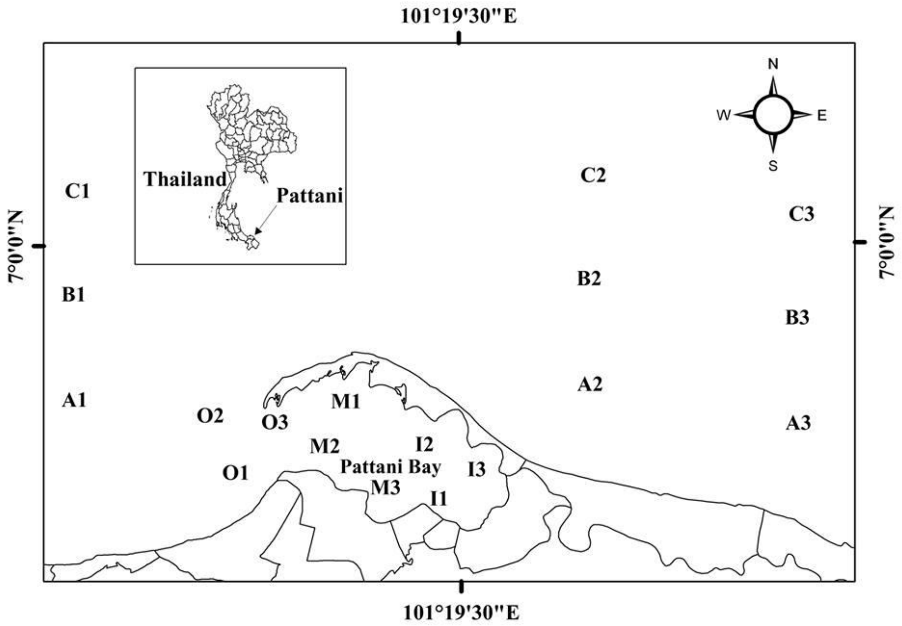

Figure 1. Map of study area showing sites in both habitats; Pattani Bay and offshore area off Pattani coast, the Gulf of Thailand. The legends I, M and O represent inner bay, middle bay and outer bay. The legends A, B and C represent depth contour 5m, 10m and 15m. The legends 1, 2 and 3 represent sub-stations of each habitat; 1 = Bangtawa, 2 = Talokapo, 3 = Panarik.

stations as line transect based on locality; Bangtawa, Talokapo and Panarik, were chosen for each depth contour.

Seasonal division of this area was based on Chaiwanut *et al*. (2005). Three different seasons based on quantity of rain fall were divided; (1) rainy season from September to December, (2) moderate rainy season from May to August and (3) dry season from January to April. Tidal amplitude in Pattani coast varied from 40 cm at neap tide and 90cm at spring tide.

Collection of Samples

In Pattani Bay area, *P. pelagicus* and bycatch samples were collected monthly from May 2013 to July 2014 by crab gill nets simultaneously operated by three commercial vessels of similar dimension (7 m long boat with 9 HP engine power). One unit of net was 1.64 m deep, 180 m long with 8 cm stretch mesh size of monofilament net. It is commonly used by traditional fishermen in the area and has been proven by the locals that it is one of the most effective gears suitable for catching *P. pelagicus*. The nets were set at $06:^{00}$ am, left overnight for 24 hours and hauled on board in the next morning. Three nettings were set covering all area at each site of each habitat. Altogether, a total of 1620 m long netting was used for each habitat. Totally, 27 net units were set all over the bay in three habitats; inner, middle and outer bay, for each month with a total distance of 4860m long for the whole bay sampling.

For offshore area, samples were collected bimonthly from May 2013 to September 2014 using crabs gill nets simultaneously operated by three commercial vessels of similar dimension (8 m long boat with 13 HP engine power). At each sub-station of each depth contour, the monofilament net with 1.54 m deep, 1800 m long and 11 cm stretch mesh size was set at $06:^{00}$, left overnight for 24 hours and hauled on board in the next morning. Altogether 5,400 m of netting were conducted at each depth contour and altogether 16,200 m from all three depth contours were hauled for each sampling month.

The catches were removed from nets, immediately preserved in ice and transported to the laboratory for sorting and identifying by using key of Carpenter and Niem (1998) as the main reference. All bycatch materials were then preserved with 10% formalin and deposited in The Fishery Technology collection, Faculty of Science and Technology, Prince of Songkla University, Thailand for future reference. Two different groups of bycatch were then classified; discarded or non-valuable bycatch (D) and retained or valuable bycatch (R) based on local practice (Alverson *et al.*, 1994).

Verification of Mesh Size of the Net in Two Different Areas

A pre-sampling experiment was conducted to test the effectiveness of different dimensions of crab gill nets used at two different areas; Pattani Bay and offshore. This experiment specifically combined with small (8cm) and large (11cm) mesh sized-nets as a single consecutive net to collect crab and bycatch.

This net was set both in Pattani Bay and offshore areas. It was initially found that the larger mesh size caught almost nothing in the bay, while the smaller net caught almost nothing in offshore area. Moreover, the small size net was heavily damaged by dead shells attached to the net in offshore area. Therefore, designation of different dimensions of net for particular area is essential.

Statistical Analysis

To avoid biasness, raw data from Pattani Bay and offshore areas were analyzed separately for community parameters and univariate statistical analysis. For multivariate analysis data from both areas were simultaneously analyzed in order to reflect bycatch community structure of the whole area with the aid of statistical transformation and standardization of raw data.

A monthly catch data from each habitat for Pattani Bay and a bimonthly catch data from each depth contour for offshore were analyzed for: (1) community parameters; Shannon Weiner's diversity index (H') and mean species richness (SR) per sampling occasion and (2) relative abundance. Data of three different seasons were separated based on reported information of annual rainfall of the area; heavy rainy season occurs in September to December, moderate rainy season, from May to August and dry season, from January to April (Chaiwanut *et al*., 2005). A two-way analysis of variance (ANOVA) was used to compare; (1) abundance of bycatch and numbers of bycatch species or species richness between all habitats for Pattani Bay, depth contours for offshore and seasons. For catch data, both numbers of individuals and numbers of bycatch species were log (X+1) transformed to reduce non-normality prior to analysis.

A non-metric multi-dimensional scaling (nMDS) ordination, to assess the extent to which individual grouping based on habitats or depth contours and seasons for particular areas; Pattani Bay and offshore, was carried out with PRIMER statistical package version 5.0 (Clarke and Gorley 2001). A Bray-Curtis similarity based on log X+1 transformation was used to examine the difference in bycatch community assemblages between all habitats and seasons. Analysis of similarity (ANOSIM) was used to determine whether bycatch assemblage separated by nMDS ordination differed significantly. Once the significant difference was found, a similarity percentage (SIMPER) was used to examine which bycatch species contributed most to the difference. To simultaneously analyze relationship between community structures of bycatch from both areas, a Cluster dendogram was constructed with a Bray-Curtis similarity based on a pooled data from each habitat of each area.

Results

General Catches

The result found that 50.8% of bycatch was caught by crab gill net in this study. The ratio of *P. pelagicus* and bycatch between Pattani Bay and offshore areas are almost similar with Pattani Bay showing slightly higher bycatch proportion (Table 1). Altogether, 147 species of bycatch were identified; 95 species in Pattani Bay and 87 species in offshore area. In the bay, 70 species (73.7%) of bycatch were retained either as own consumption or marketing and 25 species (26.3%) were discarded. In offshore area, 46 species (52.9%) were retained and 41 species (47.1%) were discarded. Species composition and details of bycatch collected from each area were showed in Tables 2 and 3. In Pattani Bay, three main groups of bycatch were collected; Chordata, Arthropoda and Mollusca. Three most dominant bycatch species were horseshoe crab (*Carcinoscorpius rotundicauda*), mud crab (*Scylla serrata*) and spotted catfish (*Arius maculates*). In offshore area, four main groups of bycatch were caught; Chordata, Arthropoda and Mollusca and Echinodermata. Scaly whipray (*Himantura imbricate*), box crab (*Calappa bilineatus*) and golden sandfish (*Holothuria scabra*) were the most dominant species found in that area. Details of ecological attributes for bycatch collected from Pattani Bay and offshore area are in Table 4.

Impacts of Habitat and Season

In Pattani Bay, results from analysis of variance (ANOVA) indicated that season, habitat and interaction between season and habitat significantly affected the abundance of bycatch from crab gill net fishery ($P<0.001$, $P<0.005$ and $P<0.05$, respectively) (Table 5). However, seasonal factor had an impact only on species richness of bycatch ($P<0.001$). In offshore area, only seasonal factor significantly affected both abundance ($P<0.05$) and species

Table 1. A comparison between number of *Portunus pelagicus* and bycatch collected by crab gill net in different areas of Pattani coast, the Gulf of Thailand

Area	Number of individual of bycatch (%)	
	Portunus pelagicus	Bycatch
Pattani Bay	802 (47.8%)	877 (52.2%)
Offshore	914 (50.5%)	894 (49.5%)
Total	1,716 (49.2%)	1,771 (50.8%)

Table 2. Bycatch composition collected by crab gill net in Pattani Bay (D = discarded or non-valuable bycatch, R = retained or valuable bycatch)

Species	Common name	%	Status	Species	Common name	%	Status
Chordata							
Arius maculatus	Spotted catfish	5.8	R	*Opisthopterus tardoore*	Tardoore	0.1	R
Osteogeneiosus militaris	Soldier catfish	5.0	R	*Parastromateus niger*	Black pomfret	0.1	R
Platycephalus indicus	Bartail flathead	4.8	R	*Plicofollis nella*	Smooth-headed catfish	0.1	R
Dendrophysa russelii	Goatee croaker	4.6	R	*Rastrelliger kanagurta*	Indian mackerel	0.1	R
Himantura imbricata	Scaly whipray	4.1	R	*Sardinella gibbosa*	Goldstripesardinella	0.1	R
Triacanthus nieuhofii	Silver tripodfish	3.2	D	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	0.1	R
Hexanematichthys sagor	Sagor catfish	2.4	R	*Siganus canaliculatus*	White-spotted spinefoot	0.1	R
Eleutheronema tetradactylum	Fourfinger threadfin	1.6	R	*Sphyraena jello*	Pickhandle barracuda	0.1	R
Pennahia anea	Bigeye croaker	1.6	R	*Terapon puta*	Small-scaled terapon	0.1	D
Johnius amblycephalus	Bearded croaker	1.5	R	*Terapon theraps*	Largescaledterapon	0.1	D
Scatophagus argus	Spotted scat	1.3	R	*Thryssa dussumieri*	Dussumier'sthryssa	0.1	R
Siganus javus	Streaked spinefoot	1.3	R	*Upeneus tragula*	Freckled goatfish	0.1	D
Rastrelliger brachysoma	Short mackerel	1.0	R	Arthropoda		0.0	
Gonialosa modesta	Burmese river gizzard shad	0.9	R	*Carcinoscorpius rotundicauda*	Horseshoe crab	13.1	D
Thryssa hamiltonii	Hamilton's thryssa	0.9	R	*Scylla serrata*	Mud crab	8.4	R
Otolithes ruber	Tigertooth croaker	0.8	R	*Miyakea nepa*	Smalleyed mantis shrimp	5.0	R
Lutjanusj ohnii	John's snapper	0.7	R	*Harpiosquilla raphidea*	Giant mantis shrimp	4.1	R
Congresox talabon	Yellow pike conger	0.6	D	*Charybdis feriatus*	Crucifix crab	3.1	R
Pampus argenteus	Silver pomfret	0.6	R	*Scylla olivacea*	Orange mud crab	3.1	R
Sillago sihama	Silver sillago	0.6	R	*Charybdis affinis*	Smoothshelled swimming crab	1.8	R
Siganus guttatus	Goldlinedspinefoot	0.5	R	*Matuta planipes*	Flower moon crab	1.8	D
Tetraodon nigroviridis	Spotted green pufferfish	0.5	D	*Charybdis natator*	Ridged swimming crab	1.5	D
Cynoglossus puncticeps	Speckled tonguesole	0.3	R	*Portunus sanguinolentus*	Blood spotted crab	1.0	R
Gerres subfasciatus	Common silver belly	0.3	R	*Podophthalmus vigil*	Sentinel crab	0.8	D
Gerres filamentosus	Whipfin silver-biddy	0.3	R	*Oratosquillina interrupta*	Japanese mantis shrimp	0.6	R
Oxyeleotris marmorata	Marble goby	0.3	R	*Charybdis variegata*	Swimming crab	0.5	D
Plotosus canius	Gray eel cat-fish	0.3	R	*Dorippoides facchino*	Sumo crab	0.5	D
Pseudorhombus arsius	Largetooth flounder	0.3	R	*Parapenaeopsis hardwickii*	Spear shrimp	0.5	R
Scolopsis taenioptera	Lattice monocle bream	0.3	R	*Penaeus monodon*	Asian tiger shrimp	0.3	R
Anodontostoma chacunda	Chacunda gizzard shad	0.2	R	*Galene bispinosa*	Squared-shelled crab	0.2	D
Batrachomoeus trispinosus	Three-spined frogfish	0.2	D	*Ashtoret lunaris*	Yellow moon crab	0.1	D
Carangoides praeustus	Brownback trevally	0.2	R	*Dardanus calidus*	Hermit crab	0.1	D
Cynoglossus lingua	Long tongue sole	0.2	R	*Litopenaeus vannamei*	Whiteleg shrimp	0.1	R
Lagocephalus lunaris	Lunartail puffer	0.2	D	*Macrobrachium rosenbergii*	Giant river prawn	0.1	R
Lethrinuslentjan	Pink ear emperor	0.2	R	*Metapenaeus affinis*	Jinga shrimp	0.1	R
Liza subviridis	Greenback mullet	0.2	R	*Oratosquilla nepa*	Mantis shrimp	0.1	R
Megalaspis cordyla	Torpedo scad	0.2	R	*Penaeus merguiensis*	Banana prawn	0.1	R
Ambassis kopsii	Freckled hawkfish	0.1	R	*Thalamita danae*	Swimming crab	0.1	D
Arius thalassinus	Giant sea catfish	0.1	R	*Varuna litterata*	Pelagic shore-crab	0.1	D
Cynoglossus macrolepidotus	Indian Tongue-sole	0.1	R	Mollusca		0.0	
Dasyatis zugei	Pale-edged stingray	0.1	R	*Pugilina cochlidium*	Spiral melongena	0.6	D
Glossogobius aureus	Golden tank goby	0.1	R	*Murex scolopax*	False venus comb	0.3	D
Halophryne diemensis	Banded frogfish	0.1	D	*Bufonaria rana*	Common frog shell	0.2	D
Himantura gerrardi	Sharpnose stingray	0.1	R	*Anadara granosa*	Blood cockles	0.1	R
Leiognathus equulus	Common ponyfish	0.1	R	*Chicoreus brunneus*	Adusta murex	0.1	D
Lutjanus russellii	Russell's snapper	0.1	R	*Meretrix meretrix*	Asiatic hard calm	0.1	R
Muraenesox bagio	Common pike conger	0.1	D	*Perna viridis*	Asian green mussel	0.1	R
Nibea semifasciata	Sharpnose croaker	0.1	R	*Sepioteuthis lessoniana*	Bigfin reef squid	0.1	R
Nuchequula gerreoides	Decorated ponyfish	0.1	R				

richness (P<0.005) of bycatch.

Bycatch Assemblages in Different Areas

In Pattani Bay, results from nMDS plots revealed that the grouping of bycatch was clustered into three major groups based on habitat; inner bay, middle bay and outer bay and no detection of monthly factor was observed (Figure 2). However, the assemblages in inner bay and middle bay were more similar to each other compared to that of outer bay. Analysis of similarity (ANOSIM) confirmed the difference of assemblages between these three groups (P=0.1%, Global R=0.493). The Similarity percentage (SIMPER) identified three main species of bycatch contributed most to the grouping of inner bay habitat were *Scylla serrata, Carcinoscorpius rotundicorda* and *Osteogeneiosus militaris* (Table 6). A

Table 3. Bycatch composition collected by crab gill net in offshore area of Pattani coast, the Gulf of Thailand (D = discarded or non-valuable bycatch, R = retained or valuable bycatch)

Species	Common name	%	Status	Species	Common name	%	Status
Chordata							
Himantura imbricata	Scaly whipray	10.3	R	*Matuta victor*	Common moon crab	1.2	D
Dasyatis zugei	Pale-edged stigray	2.0	R	*Tachypleus gigas*	Horseshoe crab	1.2	D
Platycephalus indicus	Bar-tailed flathead	1.7	R	*Lauridromia indica*	Cannon ball sponge crab	1.1	D
Otolithes ruber	Tigertooth croaker	1.3	R	*Myomenippe hardwickii*	Stone crab	1.1	D
Pennahia anea	Bigeye croaker	0.8	R	*Dorippoides facchino*	Porter crab	1.0	D
Scolopsis taeniopterus	Lattice monocle bream	0.7	R	*Charybdis affinis*	Smooth shelled swimming crab	0.9	R
Epinephelus coioides		0.6	R	*Conchoecetes artificiosus*	Sponge crab	0.8	D
Oxyeleotris marmorata	Orange-spotted grouper	0.6	R	*Dorippe quadridens*	Dorripid crab	0.8	D
Drepane punctata	Spotted sickle fish	0.4	R	*Portunushaanii*	Red swimming crab	0.7	R
Pseudorhombus arsius	Largetooth founder	0.4	R	*Carcinoscorpius rotundicauda*	mangrove horseshoe crab	0.6	D
Terapon jarbua	Jarbuaterapon	0.4	D	*Doclea armata*	Spider crab	0.6	D
Chiloscyllium punctatum	Brownbandedbamboos hark	0.3	R	*Thenus orientalis*	Flathead locus lobster	0.6	R
Drepane longimana	Concertina fish	0.3	R	*Charybdis hellerii*	Indo-Pacific Swimming Crab	0.2	R
Lutjanus ohnii	John's Snapper	0.3	R	*Miyakea nepa*	smalleyedsquillid mantis shrimp	0.2	R
Terapon theraps	Largescaledterapon	0.3	R	*Harpiosquilla raphidea*	Mantis Shrimp	0.1	R
Alectis ciliaris	African pompano	0.2	R	*Panulirus polyphagus*	Mud spiny lobster	0.1	R
Congresox talabon	Yellow pike conger	0.2	D	*Parthenope longimanus*	Elbow crab	0.1	D
Cynoglossus lingua	Long tongue sole	0.2	R	*Penaeusmonodon*	Giant tiger prawn	0.1	R
Parapocryptes serperaster	serpent mudskipper	0.2	R	Mollusca		0.0	
Platax teira	Longfin batfish	0.2	D	*Melo melo*	Large sea snail	2.7	R
Atule mate	Yellow tail scad	0.1	R	*Murex scolopax*	Woodcock murex	2.6	D
Cynoglossus macrolepidotus	Indian tongue-sole	0.1	R	*Cymbiola nobilis*	Noble valute	2.3	D
Dasyatis uarnak	Reticulate whipray	0.1	R	*Phalium glaucum*	Grey bonet	1.0	D
Glossogobius aureus	Golden tank goby	0.1	D	*Pugilina cochlidium*	Spiral melongena	1.0	D
Megalaspis cordyla	Torpedo scad	0.1	R	*Sepia recurvirostra*	Curvespine Cuttlefish	0.6	R
Mulloidichthys flavolineata	Yellowstripe goatfish	0.1	R	*Chicoreus ramosus*	Ramose murex	0.4	R
Pisodonophis boro	Rice-paddy eel	0.1	D	*Cistopus indicus*	Old woman octopus	0.4	D
Psettodes erumei	Indian halibut	0.1	R	*Malleus albus*	Common Hammer Oyster	0.4	D
Rastrelliger brachysoma	Short mackerel	0.1	R	*Murex trapa*	Rare-spined murex	0.4	D
Siganus canaliculatus	White-spotted spinefoot	0.1	R	*Babylonia areolata*	Babylon shell	0.3	R
Siganus javus	Streaked spinefoot	0.1	R	*Pinna bicolor*	Bicoloured Pinna Shell	0.3	D
Sillago sihama	Silver sillago	0.1	R	*Tonna maculata*	Spotted Tun shell	0.3	D
Taeniura meyeni	Black-spotted Stingray	0.1	R	*Semicassis sulcatum*	Japanese bonnet	0.2	R
Arthropoda		0.0		*Chicoreus brunneus*	Adusta murex	0.1	D
Calappa bilineatus	Box crab	9.4	D	*Cucullaea labiata*	Hooded ark	0.1	D
Calappa philargiu	Spectacled box crab	5.0	D	*Musculus senhousia*	Asian date mussle	0.1	D
Podophthalmus vigil	Long-eyed swimming crab	4.0	D	*Octopus dollfusi*	Common octopus	0.1	D
Galene bispinosa	Square-shelled crab	3.6	D	*Placuna placenta*	Windowpane oyster	0.1	D
Portunus gracilimanus	Swimming crab	3.5	D	*Plicatula simplex*	Kitten Paws	0.1	D
Charybdis feriatus	Crusifix crab	3.4	R	*Rapana rapiformis*	Cantaloupe	0.1	R
Charybdis natator	Ridged swimming crab	2.8	D	*Turritella terebra*	Screw turitella	0.1	D
Ashtoret lunaris	Moon crab	2.3	D	Echinodermata		0.0	
Portunus sanguinolentus	Three spotted swimming crab	2.0	R	*Holothuria scabra*	Golden sandfish	5.8	R
Charybdis variegata	Swimming crab	1.7	R	*Salmaciella dussumieri*	Salmacis urchin	5.1	D
Doclea ovis	Spider crab	1.7	D	*Luidia maculata*	Seven arm sea star	1.0	D

Table 4. Summary of ecological indices of bycatch community in Pattani Bay and offshore area along Pattani coast, the Gulf of Thailand, collected by crab gill nets monthly from May 2014 to July 2014 in the bay and bimonthly during May 2013 to September 2014 in offshore area

Areas	Abundance (x±*sd*)	Species richness (x±*sd*)	Total species	Total individual	H'
Pattani Bay					
Inner Bay	26.47±14.49	9.60±4.93	51	397	2.84
Middle Bay	10.87±7.67	6.53±4.34	39	163	3.08
Outer Bay	21.13±17.70	7.53±5.22	47	317	3.14
Total Pattani Bay	20.88±14.66	8.45±4.58	95	877	3.58
Offshore area					
5m	11.37±11.57	4.96±2.94	55	307	3.44
10m	10.30±9.81	6.00±3.65	56	278	3.47
15m	11.44±9.82	5.85±3.27	59	309	3.34
Total offshore	11.04±10.31	5.94±3.26	87	894	3.68
Total	14.40±12.80	6.80±3.93	147	1,771	4.11

Table 5. Results of two-way analysis of variance for the effects of habitats and seasons on abundance and species richness of bycatch collected at two different areas along Pattani coast, the Gulf of Thailand, by crab gill net (P<0.01=highly significant, P<0.05 = significant, P>0.05 = non significant)

Sources		df	Abundance		Species richness	
			MS	P-value	MS	P-value
Pattani Bay	Habitat (h)	2	0.39	0.003	0.052	0.316
	Seasons (s)	2	0.624	2 x 10^{-4}	0.414	7 x 10^{-4}
	h x s	4	0.197	0.017	0.068	0.207
Off shore	Habitat (h)	2	0.24	0.788	0.003	0.938
	Seasons (s)	2	0.487	0.012	0.296	0.004
	h x s	4	0.023	0.921	0.006	0.969

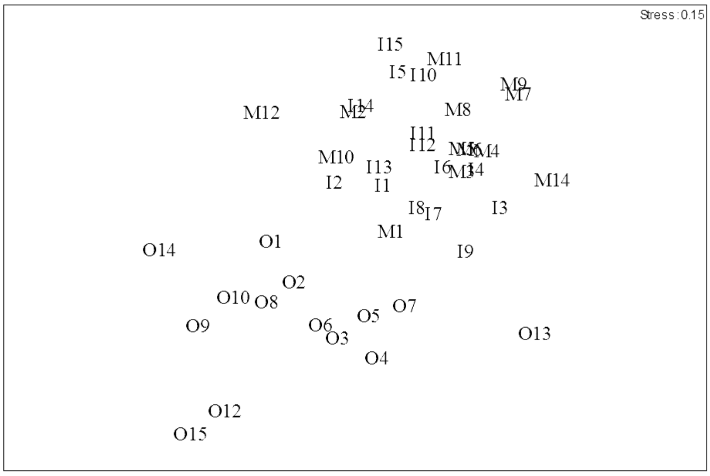

Figure 2. The nMDS plot for assemblage at various habitats and months of bycatch collected monthly by crab gill net in Pattani Bay from May 2013 to July 2014. Symbol "xy" represents habitats and sampling month; o, m and i represents outer bay, middle bay and inner bay; 1-15 represent first sampling month (May 2016) – last sampling month (July 2014). Such as o13 is for outer bay in 13rd month (May 2014).

Table 6. SIMPER results for bycatch assemblages in Pattani Bay based on nMDS plot in Figure 2

Habitat	Species	% contribution
Inner bay	*Scylla serrata*	26.3
	Carcinoscorpius rotundicauda	20.3
	Osteogeneiosus militaris	13.1
	Himantura imbricata	9.8
	Arius maculatus	8.1
Middle bay	*Scylla serrata*	26.4
	Osteogeneiosus militaris	24.5
	Himantura imbricata	22.0
	Platycephalus indicus	6.9
	Scylla olivacea	6.0
Outer bay	*Charybdis feriatus*	24.9
	Dendrophysa russelli	21.6
	Miyakea nepa	19.2
	Hapiosquilla raphidea	5.6
	Charybdis affinis	5.3

combination of *S. serrata*, *O. militaris* and *Himantura imbricata* contributed greatly to the formation of catches from the middle bay habitat. For outer bay habitat, *Charybdis feriatus*, *Dendrophysa russelli* and *Miyakea nepa* were the three major contributors. For offshore area, there was no trend of grouping on nMDS plots based neither on depth contours nor months (Figure 3). Moreover, Analysis of similarity (ANOSIM) detected a non significant difference of assemblages between both months and habitats (P>0.05).

To simultaneously analyze relationship between community structures of bycatch from both offshore and Pattani Bay areas, it was found that sampling sites could be clustered into areas and line transect rather than depth contour (Figure 4). Result from the cluster

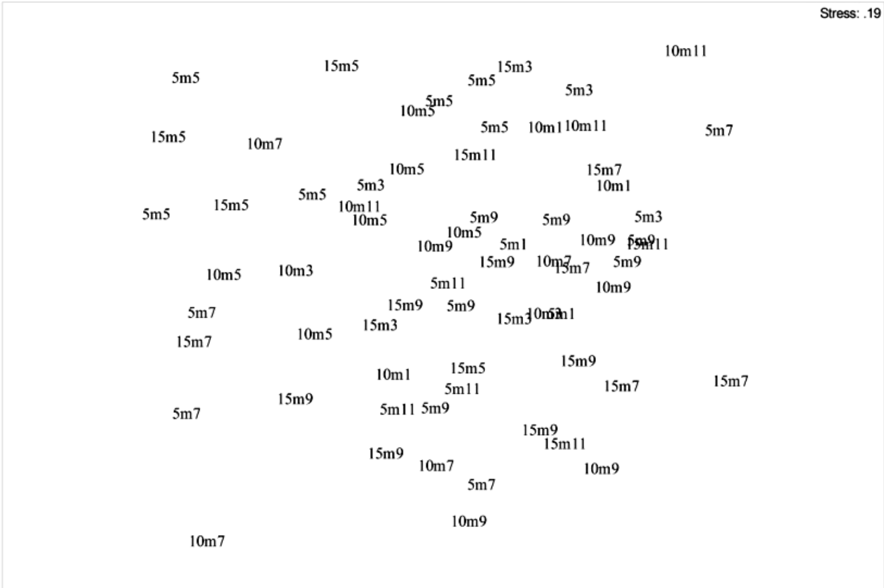

Figure 3. The nMDS plot for assemblage at various depth contours and months of bycatch collected bimonthly by crab gill net in offshore area from May 2013 to September 2014. Symbol "x/y" on the ordination; x (5, 10 and 15) represents depths of 5, 10 and 15 meters, respectively; y (1, 3, 5, 7, 9 and 11) represents the months of January, March, May, July, September and November, respectively. Such as 15/9 = 15 meter depth in September.

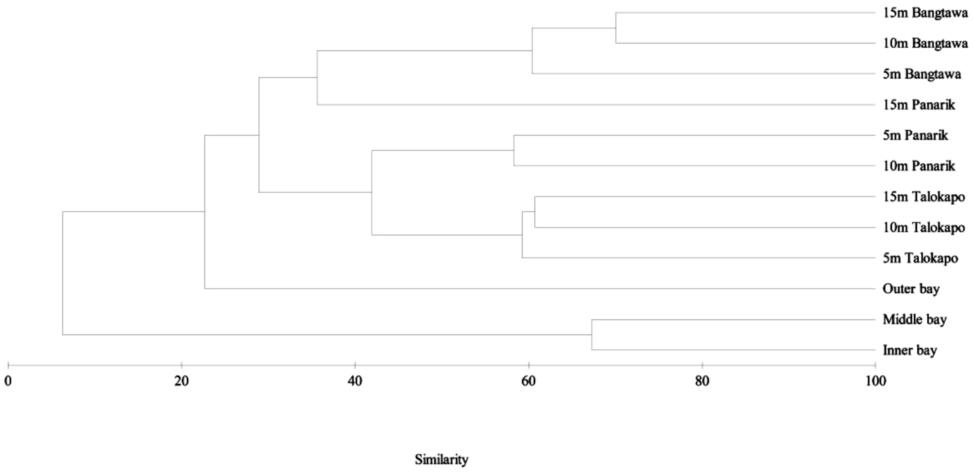

Figure 4. The cluster dendogram indicating relationship between assemblages of bycatch collected by crab gill net at different habitats in both Pattani Bay and offshore area from May 2013 to September 2014. A symbol "15m Bangtawa" represents the habitat of 15 meter depth at Bangtawa station.

dendogram indicated that four main groups of habitat and two interconnecting sites were separated at 50% similarity. The four clusters included a group of inner bay and middle bay, three talokapo stations, three bangtawa stations and 5m and 10m of panarik stations. The outer bay was considered as interconnecting site between inner bay and outer bay with offshore habitats. It was significantly confirmed by ANOSIM that the grouping of bycatch assemblages was significantly difference (Global R =1.0, p = 0.1%)**.** Bycatch species responsible for a formation of each cluster on the dendogram was identified by SIMPER in Table 7.

Discussion

It was found that crab gill net designed and exploited by fishermen in Pattani, Thailand was efficient in selecting primary target species, the blue swimming crab, in both shallow semi-enclosed habitat and open offshore areas. The ratios of bycatch or non-targeted species found in both the bay and offshore areas were almost similar, 52.2% and 47.8%, respectively, although different size and dimension of nets were used at these two different areas. It is meant that every *P. pelagicus* caught by the net, 0.93 to 1.05 of bycatch was also simultaneously collected.

Table 7. SIMPER results for bycatch assemblages in Pattani bay and offshore areas based on cluster dendogram in Figure 4

Group	Species	% contribution
A	*Himantura imbricata*	13.7
(Bangtawa 5, 10 and 15m depths)	*Podopthalmus vigil*	9.3
	Dasyatis zugei	7.0
	Galene bispinosa	6.7
	Cymbiola nobilis	6.7
B	*Himantura imbricata*	15.0
(Panarik 5 and 10m depths)	*Charybdis natator*	13.8
	Calappa bilineatus	12.4
	Calappa philargius	11.4
	Otolithes ruber	10.4
C	*Calappa bilineatus*	14.8
(Talokapo 5, 10 and 15m depths)	*Portunus gracilimanus*	12.4
	Calappa philargius	10.0
	Ashtoret lunaris	9.4
	Charybdis natator	7.3
D	*Carcinoscorpius rotundicauda*	16.3
(inner and middle bay)	*Arius maculatus*	14.0
	Osteogeneiosus militaris	14.4
	Himantura imbricata	13.5
	Platycephalus indicus	11.8

Furthermore, from a total of 147 species identified as bycatch, of which 26.3% or 25 species collected in the bay was considered discarded species and 47.1% or 41 species in the offshore area. These figures are considered much lower than the ratios produced by trawlers worldwide (Perez and Wahrlich, 2005) but higher than that of a spot prawn trap (16.8%) (Favaro *et al*., 2009). Comparing to the net of similar principle, only study on trammel net was well reported. The previous study found that 78 species were discarded in trammel nets fishery in the southern Portugal (Erzini *et al*., 2002). A slightly similar diversity of discarded species was found in study on trammel nets fishery in the Mediterranean with the ratio of 15% to 49% discarded (Goncalves *et al*., 2007). However, the study from India by Kumar *et al*., (2013) reported that approximately 76% of bycatch by weight were collected from crab gill net.

The results obtained in this study revealed a great diversity of marine species. Apart from *P. pelagicus*, 147 species were caught by crab gill nets. It is observed that most of them are mobile bottom dwellers. However, pelagic and demersal finfish, elasmobranches and benthic invertebrates, although vulnerable, were less frequently entangled in the immersed nets. Fishes, mainly demersal species are the most diverse bycatches collected in both areas followed by crabs, shrimps and mollusks. However, there are three species of echinoderms found in offshore area but not in the bay habitat. Three most dominant bycatch species in Pattani Bay were *C. rotundicauda*, *S. serrata* and *A. maculatus* and in offshore area were *H. imbricata*, *C. bilineatus* and *H. scabra*. Other major crab species caught together with *P. pelagicus* were different between catches from Pattani Bay and offshore area. *Scylla serrata*, *Charybdis feriatus*, *Scylla olivacea* and *C. affinis* dominated the catch in the bay, and *C. bilineatus*, *C. philargiu*, *Matuta victor* and *Lauridromia indica* in offshore area. Some bycatches are non-target species with high commercial value such as *S. serrata*, *H. scabra* and *Peneaus monodon*. Larger mollusks were more abundant in offshore area with *Melo melo*, *Murex scolopax and Cymbiola nobilis* as the three most dominant species. High abundance of *Murex* spp. has created a serious problem to fishermen as it can heavily destroy the nets when the crowd of them stuck on the nets. The consequence is that the fishermen cannot throw them in the sea and they have to discard on land. This problem leads to serious level when fishermen are unable to go fishing during the blooming season of this species. Stakeholders should have to solve this problem by the making of policy, regulation, law etc.

Quantitatively, abundance of bycatch in Pattani Bay was influenced by habitat, season and interaction between habitat and season. Species richness or number of species per sampling was affected only seasonal variation. For offshore area, the season had affected to abundance and species richness. In term of species assemblages based on nMDS ordination, the response of bycatch assemblages was different in each habitats. Three major groups were clearly identified in the bay catch based on inner bay, middle bay and outer bay. Species of bycatch at each habitats identified by similarity percentage were showed in Table 6. However for offshore area, there was no obvious segregation of species assemblage observed. Data analysis from each sampling based on habitat or depth contour distributed all over the plot without trend of grouping. This may lead to a conclusion that bycatch species assemblage collected by crab gill net fisheries from different depths in offshore area; 5m, 10m and 15m, in Pattani coastal area is generally not different.

However, when simultaneously analyzing bycatch regardless of the different dimension of net used, a trend of difference of assemblage between habitats either offshore and Pattani Bay was found (Figure 4). The catch assemblage collected from the bay and offshore areas were well separated and a trend of geographically interconnecting was clearly detected. It is observed that composition of bycatch from the outer bay, which is geographically connected to offshore area, is relatively similar to that of offshore habitats although different dimension of net was used. This reflects that community structure of marine organisms inhabiting in those particular areas, offshore area and outer bay, is very much identical or close geographically connected. However, a characteristic of Pattani Bay is a unique community structure as it is open to offshore area of the South China Sea. The outer bay site can be referred as a connecting point for marine organisms to offshore area as a reflection from this study. Moreover, this study showed that the grouping of bycatch from offshore area, based on cluster dendogram, was influenced by the position of line transect of the sampling sites rather than depth contour. This means that geographical locality has a potential impact on species composition and community structure of bycatch from crab gill net fishery.

There are many reasons for fisherman to discard the catches particularly bycatch (Cabral *et al*., 2003). Generally, the decision making is driven by economic factors and low or less value of the catch in market (Alverson *et al*., 1994). Moreover, it was observed that discarded in tropical regions were mostly dominated by small bodied animals, whereas temperate and sub-polar fisheries discarded mainly commercially important larger bodied species (Alverson *et al*., 1994). Normally, fishermen retains all species that have some commercial value but when they can harvest only one or a few individuals, they will keep them for personal consumption, due to the low selling value (Batista *et al*., 2009; Goncalves *et al*., 2007). A similar practice, based on direct observation, is also observed for crab gill net fishermen in this area.

In conclusion, the result of this study helps to clarify the ranges of habitats and seasons of bycatch species found from crab gill net fisheries in Pattani coastal area, the Gulf of Thailand, and delivers crucial scientific information to the usage of selective fishing gear and fish community in tropical coastal area. Although crab gill net was considered as selective fishing gear, but it still had the effect to many non-target species or bycatch. Policy maker or stakeholders in this fisheries should implement proper regulation such as liming mesh size or number of crab gill net or making preserved area and educate crab fishermen for sustainable utilization of fisheries resources in the area.

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