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Original Article

Temporal variation in community structure of Dragnet (*Pukat Tarik*) fishery in relation to ecological variables in an inshore area of Sarawak, Malaysia♣

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Abstract

Inshore waters are crucial for fisheries since such areas show a wide range of variations in ecology, mostly considered to shape biotic ecosystems. Despite major fishing activities off Bintulu coast located along the South China Sea operating in the inshore areas and significantly contributing to local fisheries' economy by *Pukat Tarik* (dragnet), temporal exchange of fisheries composition in terms of ecological parameters has been little studied. Therefore, temporal changes in pull net fisheries composition and assemblages in relation to the ecological parameters in the inshore waters of Bintulu coast, Sarawak, were observed from May 2016 to April 2017. A total of 63 species belonging to 15 orders of 40 families were recorded, and 11 species found ubiquitous. Species diversity (*H´*) was recorded higher (2.61) in northeast monsoon, and lower (0.51) in inter-monsoon season, yet the species richness and diversity did not show temporal differences ($p>0.05$). Among the species *Kurtus indicus* was recorded the most abundant (58% of the total catch) followed by *Photopectoralis bindus* (15%) and *Opisthopterus tardoore* (7%); and the species abundance showed significant temporal differences ($p<0.05$). However, temperature, salinity, pH, dissolved oxygen (DO) and rainfall showed classical temporal differences ($p<0.05$), and no significant difference was found in chlorophyll *a* and water nutrients. ANOSIM indicated that the significant difference of assemblages among season was more apparent than within season (Global R=0.65, $p<0.001$). The canonical correspondence analysis indicated total suspended solids, dissolved oxygen (DO), transparency, rainfall and salinity as the most important ecological factors affecting fish assemblage structure. The inshore fisheries of Bintulu coast were found immensely rich and profoundly related to ecological factors, which will eventually help manage this fishery resource in the future in tropical coastal waters of the South China Sea.

Keywords: pull net, pelagic fisheries, ecological factors, Bintulu fishing industry

1. Introduction

Malaysian marine fishery and major part of the fishing efforts (<40 GRT-gross registered tons) has been carried out mostly in inshore (<30 nautical from shore) and deep-sea (>30 nautical to EEZ) areas (Garces *et al*., 2003; Munprasit *et al*., 2002). The inshore zone is not only acting as a transition zone between estuaries and offshore, but as a habitat for juvenile and adult fish communities. It also provides migratory route for anadromous and catadromous fishes, an important spawning area for some fishes, and acts as a nursery ground for many species as well as a foraging zone for a number of piscivores (Blaber *et al*., 1995, Schafer *et al*., 2002) and some cetaceans (Ponnampalam, 2012). According

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to Malaysia Fisheries Act (1985), inshore waters are identified as critical habitats where aquatic species use them as breeding and nursery grounds (Nuruddin & Isa, 2013; Ogawa, 2004). Fishing in the inshore waters is as old as settlement in the coastal lowlands of Malaysia (Ooi, 1990) and 80% of the total catch is caught from inshore areas within 20 miles of the coast (Viswanathan *et al*., 2000).

Inshore waters support the highest resource abundance for many tropical fish species (Alam *et al*., 2002). Sarawak has the widest fishing area in the South China Sea (SCS), among the Malaysian territories (Abu Talib *et al*., 2003), and the fisheries resources of Sarawak are such that major fishing effort is in muddy areas, mostly in waters near the shore (Garces *et al*., 2003). Furthermore, pelagic fish resources are the single most important fisheries resources of Sarawak in terms of biomass (Gambang *et al*., 2003). According to Hassan and Latun, (2016), there are 43 types of purse seiner at Sarawak near shore waters and two of them are known as *Pukat Tarik* or beach seine net. Munprasit *et al*. (2002) mentioned these gears are bag shaped seine nets with two wings, and are pulled towards a stationary boat or onto a beach. Net pulled towards boat is a boat seine (Mead, 2013) or *Pukat Tarik* Kapal. Meanwhile, net pulled onto a beach is known as beach seine net.

Fish stock assessment is a growing necessity in many countries in the Southeast Asian region neighboring the South China Sea waters, but often lacks readily available methods (Rajali *et al*., 1998). Also in Sarawak, suitable fish stock assessment methods are not readily available for this region (Rajali *et al*., 1998). A number of surveys have been conducted off the Sarawak coast since 1972 (Abu Talib *et al*., 2003; Vidthayanon, 1998). The marine waters and seasonal assemblage structure of fishery resources in Sarawak and Sabah are influenced to a very large extent by monsoon pattern (Garces *et al*., 2003). In fact, almost every feature of the oceanographic environment of the SCS is conditioned by the monsoons (Saadon *et al*., 1997).

In Malaysia, changes in species composition and abundance over time in marine or other ecosystems are generally not well studied (Choo, 1998; Nyanti *et al*., 2014). Simultaneously studies on species composition and diversity in relation to temporal changes of eco-biological factors are not well documented in Sarawak waters (Abu Hena *et al*., 2016). Thus there is a significant lack of information on inshore fishery that has emerged especially regarding *Pukat Tarik* fishery, as this type of gear is very common in near shore fishing activity along the coast of Sarawak. Therefore, this study addressed the specific objective of observing temporal changes of catch composition and diversity of fish caught by *Pukat Tarik* in relation to the ecological parameters in Bintulu inshore waters, Sarawak, South China Sea.

2. Materials and Methods

2.1 Study area

The study area is located in Bintulu coast of Bintulu, Sarawak, Malaysia between latitudes 30°35′ and 30°43′ N and longitudes 113°15′ and 113°23′ E. Bintulu inshore commercial fishing area spans 0 to 10 km forward to the SCS from near Similajau national park to Kuala Nyalau village. The inshore areas beside Bintulu port and the newly established Similajau Port do not have fishing activities and are strictly restricted.

2.2 Sampling of fishery and ecological (water quality) parameters

Dragnet or *Pukat Tarik* is the most important and major industrial fishing gear in Sarawak as well as in Peninsular Malaysia, for catching fish near the shore in pelagic fishery (Viswanathan *et al*., 2000). This is a type of purse seine net designed with fine mesh to catch pelagic fishes like anchovy (Bailey, 1983; Firth, 1975; Ishak, 1994; Viswanathan *et a*l., 2000; Wilkinson *et al*., 1904) contributing the second most efficient gear to the country's total fish catches, after trawlers (Hassan & Latun, 2016). The operating system is similar to otter board trawling where the net is hauled at 2.5 to 3.0 knots speed behind a 3.7 meter long fiber glass boat suspending with a small wooden trawl door and net opening around 3.1 m with a 2.3 meter mouth head rope and small cod end (Mead, 2013; Munprasit *et al.* 2002).

Fish, crustacean and mollusk samples were collected through *Pukat Tarik* (Figure 1) from May 2016 to April, 2017 covering four seasons sequentially from May to September (South-West Monsoon), October (Inter-Monsoon), November to March (North-East Monsoon) and April (Inter-Monsoon). Hauling was done for 1 hour for each of replication. Three (3) different replicates of each catch were made for each sampling haul and replicates were kept in different bags. All samples were cleaned with seawater and the weights of each replicate were recorded. Species (fish, crustacean, and mollusk) and water samples were preserved on site in two different iceboxes and brought back to laboratory for further analysis. Water quality samples were kept in deep freezer for preservation at laboratory. Identification of fish was done to the species level using published books of Matsunuma *et al.* (2011), and Ambak *et al.* (2010). Crustaceans and Mollusca were identified using Carpenter and Niem (1998). Taxonomic details and habitat origins of all species were checked with FishBase (Froese & Pauly, 2017) and online database World Register of Marine Species (WoRMS).

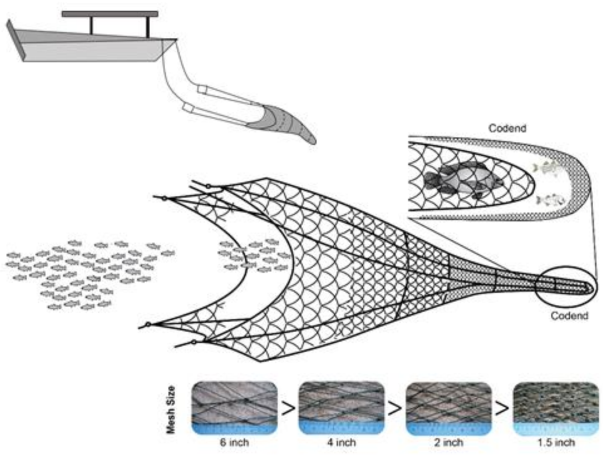


Figure 1. *Pukat Tarik* or dragnet with its different parts indicated, of the type used in sampling for this study

Species diversity (H) and richness index (D) were calculated following Shannon-Weiner (Shannon & Weiner,) and Margalef (1958), respectively. In addition, the evenness index (J´) was calculated as

$J´ = H/H_{max}$ Pielou (1966)

Where H is the calculated value for diversity and H_{max} is the maximum value of H´.

In this study, fisheries abundance was calculated through calculated total catch amount over fishing area (kg km^{-1}). The movement speed of the trawl net during hauling was an estimated 1.5 knot (2.778 km h^{-1}). The estimated fishing area covered (hauled) by trawl is calculated through the Swept area method (Sparre & Venema, 1998) -

Area, $a = D*hr*X^2$

Where D=V*t (V=Velocity/speed of the trawl; t=time spent trawling)

X^2= fraction of the head rope length, in Southeast Asian trawlers X^2=0.5 (Pauly, 1980); hr=length of the head rope (mouth opening of the net).

Simultaneously, water samples were collected (1 Liter) directly from surface water following the United States Environmental Protection Agency (EPA) guidelines (Duncan et al., 2007). Chlorophyll *a* was analyzed within 48 hours according to the standard methods of Parsons *et al*., 1984. Total suspended solids (TSS) were measured following EPA gravimetric 160.2 method. Among the nutrients, ammonium as nitrogen (NH_4-N) was estimated by phenate method (APHA, 2005), phosphate as phosphorus (PO_4-P) by Ascorbic acid procedure (APHA, 2005), and Nitrate as nitrogen (NO_3-N) following the standard methods of Kitamura *et al*. (1982). All water quality parameters except TSS were analyzed with spectrophotometry. *In-situ* water quality parameters were collected including temperature, salinity, pH, conductivity, turbidity, and dissolved oxygen (DO), using a Water Quality Meter (Model Hydrolab, WQC-24).

2.3 Statistical analysis

One-way analysis of variance (ANOVA) was used to test for significant differences of fisheries and ecological parameters among the seasons. Before analysis, data were tested for the assumptions of normality and homogeneity using the Shapiro-Wilk and Levene's tests, respectively. Data that did not show normal distribution were log transformed (natural log) and subjected to non-parametric Kruskal Wallis test for significance. A *post hoc* Tukey and Dunn test was done for ANOVA and Kruskal Wallis, respectively, to determine which means were significantly different at probability level 0.05. All the analyses were done with SAS 9.1 statistical Package.

To determine significance of inter-season variability of community structure, analysis of similarity (ANOSIM) was used to see average dissimilarity among the seasons (Clarke, 1993; Clarke & Gorley, 2006). Canonical correspondence analysis or CCA (Ter Braak, 1986) was analyzed following the weighted-averaging method (Rakocinski *et al*., 1996) and applied for directly relating community data with environmental conditions. All the species abundance data were square root transformed and ecological data were log (natural log) transformed. CCA were done using type-2 scaling method using Multi Variate Statistical Package (MVSP, version-3.1).

3. Results

3.1 Species composition

The fisheries community had 63 species representing 15 orders and 40 families (Table 1). A total number of 21978 individuals were collected and analyzed. Fish community was dominated by *Kurtus indicus* with 12753 individuals (58% of the total catch during the study period). Likewise, *Photopectoralis bindus* (n=3246), *Opisthopterus tardoore* (n=1557), *Leiognathus equulus* (n=735), and *Atule mate* (n=402) were the highest ranked species after *K. indicus.*

Eleven species were found all year round while most other species were only found during a specific season. The eleven species accounted for 91% of the total abundance and thirty-two species were recorded for less than 10 individuals (Table 1). In terms of habitat, the fish community structure was dominated by marine, brackish and fresh water residents that comprised 64.36% of the total catch, followed by marine-brackish resident species (31.67%) and marine resident species 3.97%. However, all the species of crustaceans (n=10), Mollusca (n=3), and cnidarians (n=2) found were marine resident (Table 1). Marine, brackish and fresh resident species were mostly dominated by *Kurtus indicus* (90.36%), while species from marine and brackish habitat were dominated by *Photopectoralis bindus* (47.58%) followed by *Opisthopterus tardoore* (22.82%). In addition, marine residents association was dominated by *Pampus argenteus* (29.12%) followed by *Filimanus similis* (*%*), *Nibea semifaciata* (*%*). In terms of commercial aspects, 53 species were found to be of commercial importance, while 11 species (17%) has a high market demand. According to the observation of FishBase (Froese and Pauly, 2017) length at maximum maturity, 24 species (38%) were found in juvenile stage, whereas only 6 were recorded as matured. The rest of the species do not yet have a length threshold recorded in the maturity database (Froese & Pauly, 2017).

3.2 Temporal community pattern

Species abundance showed significant temporal differences (P<0.05) precisely in IMA with rest of the seasons (Tukey minimum difference 0.7206). The highest mean abundance was recorded in IMA (45.17 kg km^{-1}) and the lowest (5.42 kg km^{-1}) in NEM (Figure 2A). In contrast to abundance, species diversity (Shannon-Wiener, *H´*) was high in northeast monsoon (*H´*= 2.61) and low in inter-monsoon April (*H´*=0.51). However, diversity of species did not show significant (p=0.748) temporal differences (Figure 2B). On the other hand, non-parametric Kruskal Wallis test with Bonferroni (Dunn) t- test revealed no significant temporal difference (p=0.295) in species richness (Figure 2C). The highest number of species was recorded in inter-monsoon October (S= 38) and the lowest in northeast monsoon (S=32).

ANOSIM based on Bray-Curtis similarity index of species presence/absence data revealed that there was a

Table 1. Species composition captured by Pukat Tarik from Bintulu inshore waters, SCS during 2016 - 2017; *Length= wing tip to wing tip; Fish species (1,Order-Perciformes), (2, Clupeiformes), (3, Order-Siluriformes), (4, Order-Myliobatiformes), (5, Order-Aulopiformes), (6, Order-Orectolobiformes), (7, Order-Tetradontiformes), (8, Order-Carcharhiniformes), Crustacea species (9,Order-Decapoda), (10, Order-Stomatopoda), Mollusca (11,Order-Myopsida), (12,Order-Sepiida), (13, Order-Littorinimorpha), Cnidaria (14, Order-Pennatulacea), (15, Order-Rhizostomeae). M=marine, B=brackish, F=fresh. HCP= Highly commercial pelagic, CP= Commercial Pelagic, HCD= Highly commercial demersal, CD= Commercial demersal, LCP= Less commercial pelagic, LCD= Less commercial demersal, NC= Non-commercial, n.e. = Not estimated; NA = Not Available.

Habit	Species name	Common name	SWM	IMO	NEM	IMA	Mean size (cm-SL)	Maturity size (Fishbase)
HCP	*Pampus argenteus*[1](*M*)	Silver pomfret	66	75	27	81	11.4	27.5 cm (SL)
	Parastromateus niger[1] (*M*, *B*)	Black pomfret	9	15			5.1	33 (TL)
	Megalaspis cordyla [1] (*M*, *B*)	Torpedo scad			12			n.e.
	Eleutheronema tetradactylum[1] (*M*, *B*, *F*)	Fourfinger threadfin		9	15			n.e.
CP	*Caranx sexfasciatus*[1] (*M*, *B*, *F*)	Bigeye Trevally	3	6		60	7	54 (FL)
	Alectis indica[1] (*M*, *B*)	Indian threadfish	6	6	3		3.7	100 (FL)
	Escualosa thoracata[2] (*M*, *B*, *F*)	White Sardine	27	3			7.1	8 (SL)
	Coilia dussumieri[2] (*M*, *B*, *F*)	GGA	6	3				n.e.
	Nibea semifasciata[1] (*M*)	Sharpnose croaker	93	75	9	12	10.2	20 (SL)
	Otolithes ruber[1] (*M*, *B*)	Tigertooth croaker	39	24	45	12	12.6	22.6 (SL)
	Lactarius lactarius[1] (*M*, *B*)	False trevally		3	15	33	8.2	16.8
HCD	*Trichiurus lepturus*[1] (*M*, *B*)	Large head hairtail	12	42	156		20.2	100 (TL)
	Loliolus uyii[11] (*M*)	NA	12			15		n.e.
	Dasyatis bennettii[4] (*M*)	NA	3	3	3			n.e.
	Hemitrygon parvonigra[4] (*M*, *B*)	Dwarf black stingray		3				n.e.
	Metapenaeus ensis[9] (*M*)	NA	6	9				n.e.
	Penaeus monodon[9] (*M*)	NA			12			n.e.
	Harpadon nehereus[5](*M*, *B*)	Bombay duck		3	42	18	17.55	13
CD	*Scoliodon laticaudus*[8] (*M*, *B*)	Spadenose shark	3	15	9		17.4	n.e.
	Lagocephalus lunaris[7](*M*, *B*)	Lunertail puffer	15	3	84	6	6.5	45 (SL max)
	Arius maculatus[3] (*M*, *B*, *F*)	Spotted catfish	15	12	24	6	11.2	30 (TL)
	Charybdis feriata[9] (*M*)	Crucifix crab	6	9				n.e.
	Portunus sanguinolentus[9] (*M*)	NA	3					n.e.
	Charybdis affinis[9] (*M*)	NA				18		n.e.
	Gymnura poecilura[4] (*M*)	LBR	3	6			30.5*	59.5
	Sepia madokai[12] (*M*)	NA		15	39	6		n.e.
	Planiliza subviridis[1] (*M*, *B*, *F*)	Greenback mullet		3				n.e.
	Saurida tumbil[5](*M*)	Greater lizardfish				3		n.e.
	Panulirus homarus[9] (*M*)	NA		3				n.e.
	Heterocarpus parvispina[9] (*M*)	NA			69			n.e.
	Pomadasys maculatus[1] (*M*, *B*)	Saddle grunt				3		n.e.
	Chiloscyllium punctatum[6] (*M*)	Brown banded				3		n.e.
LCP	*Pampus chinensis*[1] (*M*)	Chinese pomfret		81			3.2	20 (TL)
	Kurtus indicus[1] (*M*, *B*, *F*)	Indian hump head	462	330	447	1151 4	9.1	12.6 (TL)
	Atule mate[1] (*M*, *B*)	Yellowtail scad	147	126	108	21	6.5	25.6 (TL)
	Scomberoides lysan[1] (*M*, *B*)	Two spotted queenfish	3	12	114	12	8.5	54 (TL)
	Spratelloides gracilis[2] (*M*)	SSRH	12	3			5.1	10 (SL)
	Setipinna taty[2] (*M*, *B*)	Scaly hairfin anchovy	15	27	27		10.6	15.3 (TL)
	Opisthopterus tardoore[2] (*M*, *B*)	Tardoore	198	960	210	189	13.4	20 (SL max)
	Raconda russeliana[2] (*M*, *B*)	Raconda			123	75	8.4	19 (SL max)
	Secutor indicius[1] (*M*, *B*)	NA	21			12		n.e.
	Dussumieria elopsoides[2] (*M*)	SRS				21		n.e.
LCD	*Filimanus similis*[1] (*M*)	Indian finger threadfin	72	111	18	3	9.7	13 (SL max)
	Harpiosquilla harpax[10] (*M*)	NA	12		3	75	8.7	17 (TL)
	Photopectoralis bindus[1] (*M*, *B*)	Orangefin ponyfish	2055	1083		108	6.6	8 (TL)
	Leiognathus equulus[1] (*M*, *B*, *F*)	Common ponyfish	726	3		6	5.7	10.7 (SL)
	Secutor interruptus[1] (*M*, *B*)	Pignosed ponyfish	120	246			3.1	6.4
	Ambassis interrupta[1] (*M*, *B*, *F*)	Long-spined glass perchlet	15	81	12		4.2	7.4
	Terapon jarbua[1] (*M*, *B*, *F*)	Jarbua terapon	27			12	4.7	15.3
	Drepane longimana[1] (*M*, *B*)	Concertina fish	15		3	33	6.8	28.3
	Upeneus sulphureus[1] (*M*, *B*)	Sulphur goatfish			6	30		n.e.
	Gerres oyena[1] (*M*,*B*)	Common silver biddy				3		n.e.
	Tripodichthys blochii[7](*M*)	Long tail tripodfish				3		n.e.

Table 1. Continued.

Habit	Species name	Common name	SWM	IMO	NEM	IMA	Mean size (cm-SL)	Maturity size (Fishbase)
NC	*Stolephorus tri*[2] (*M, B*)	Spined anchovy	9	51	18	6	7.2	9.5 (SL)
	Coilia borneensis[2] (*M, B, F*)	BGA		21				n.e.
	Ilisha compressa[2] (*M*)	Compressed ilisha			30	39	9.2	23.8 (SL max)
	Monetaria caputserpentis[13] (*M*)	NA	3					
	Ambassis urotaenia[1] (*M, B, F*)	BTGP	3					n.e.
	Pteroeides sparmanni[14] (*M*)	NA	3		3			n.e.
	Catostylus tagi[15] (*M*)	NA		15	12			n.e.
	Scatophagus argus[1] (*M, B, F*)	Spotted scat			9	3		n.e.
	Calappa philargius[9] (*M*)	NA			30			n.e.
	Paradorippe granulate[9] (*M*)	NA				81		n.e.

Silver-stripe round herring; SRS= Slender rainbow sardine; GGA= Gold spotted grenadier anchovy, LBR = Longtailed butterfly ray; BGA= Bornean grenadier anchovy, BTGP = Banded-tail glassy perchlet

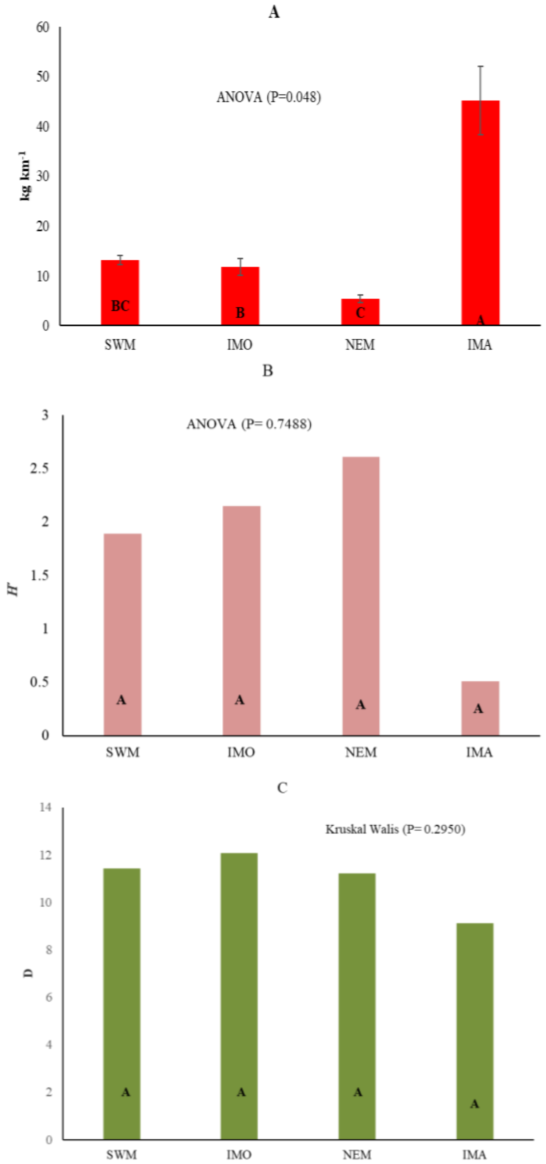


Figure 2. Temporal variations of species abundance (A), Shannon diversity (B) and richness (C). Same letters for columns indicate no significant differences (*post hoc*).

significant difference (global R=0.65, p<0.001) in community structure between the seasons. The positive R-value indicates significant difference among seasons as more apparent than the differences within a season (Table 2).

Table 2. Comparison of community structures between seasons by one-way ANOSIM

Season	ANOSIM	
	R	p
SWM vs IMO	0.852	0.001
SWM vs NEM	0.481	0.003
SWM vs IMA	0.889	0.001
IMO vs NEM	0.481	0.02
IMO vs IMA	1	0.001
NEM vs IMA	0.556	0.008

3.3 Temporal patterns of ecological parameters

Among the abiotic factors, total suspended solids (TSS) showed significant temporal differences ($p< 0.05$) where in first two seasons there was gradual decrease and in the next two seasons gradual increase. The highest mean TSS was measured in IMA (0.139 mg L^{-1}) and the lowest in IMO (0.038 mg L^{-1}). Chlorophyll *a* did not show any temporal changes in content during the study period.

Among the *in-situ* parameters, a clear seasonal fluctuation (Table 3) was recorded with significant temporal differences for water temperature, DO, and rainfall at the probability levels of ($p<0.01$) while pH, salinity, conductivity and transparency showed significant differences at probability level of ($p<0.05$). Similarly, water nutrients and Chlorophyll *a* did not show significant temporal differences ($p>0.05$) having only little fluctuations in mean values (Table 4). Yet, TSS showed temporally significant ($p<0.05$) differences among the seasons with the highest mean in IMA (0.139 mg L^{-1}) and the lowest in IMO (0.038 mg L^{-1}).

3.4 Correlation of species composition with ecological parameters

Canonical correspondence analysis on species composition with water quality (explanatory variables)

Table 3. Mean values of *in situ* ecological (water quality) parameters from the study area. Similar letters within a column indicate no significant differences (*post hoc*).

Season	Temperature (°C)	Salinity (psu)	pH	DO (mg/L)	Conductivity (mmohs/s)	Turbidity (mg/L)	Transparency (cm)	Rainfall (mm)
SWM	30.98a	33.65b	8.67a	5.25b	63.93b	95.85a	97.28a	230b
IMO	29.12b	27.75d	7.51c	4.35c	43.03d	109.78a	48.65c	410c
NEM	27.16c	30.7c	7.82b	6.73a	46.7c	101.89a	65.23b	325c
IMA	26.34c	37.44a	7.67c	5.84a	88.17a	103.5a	48.59c	190a

Table 4. Mean values of water quality parameters (TSS, chlorophyll *a* & nutrients) from the study area. Similar letters within a column indicate no significant differences (*post hoc*).

Season	TSS (mg/L)	Chl-*a* (mg/L)	NH_4-p (ppm)	PO_4-P (ppm)	NO_3-N (ppm)
SWM	0.037b	0.005a	0.102a	0.007a	0.010a
IMO	0.016a	0.025b	0.096a	0.009a	0.011a
NEM	0.117c	0.02b	0.043a	0.011a	0.006a
IMA	0.144c	0.023b	0.046a	0.034a	0.009a

showed that TSS had the greatest impact of fishery community structure (Figure 3A). The species *Kurtus indicus* had shown strong response to phosphate-P and *Reconda russeliana* with Chlorophyll *a*. In addition, *Escualosa thoracata* showed positive correlation with ammonium-N. Among the explanatory variables, TSS, Chlorophyll *a*, and phosphate (PO_4-P) showed positive linearity while ammonium (NH_4-N) and nitrate (NO_3-N) showed negative linearity.

The eight explanatory *in-situ* variables explained most of the variation (Figure 3B) in the species composition (cumulative variance 74.22%, r= 0.994) and the first axis had eigenvalue 0.356. From the first axis, the strongest contribution to explanation was made by rainfall (canonical coefficient=0.950) followed by salinity (canonical coefficient =0.741), and conductivity (canonical coefficient=0.338). Species *H. harpax* was likely to reach its maximum availability (the highest abundance) in IMA at high salinity and conductivity, mid to low temperature, transparency, and pH, and low rainfall (projection not shown). Similarly, *K. indicus* and *R. russeliana* were predicted to be found at a maximum rate during IMA at mid to high salinity and conductivity, low temperature, pH, and transparency, and a high DO concentration.

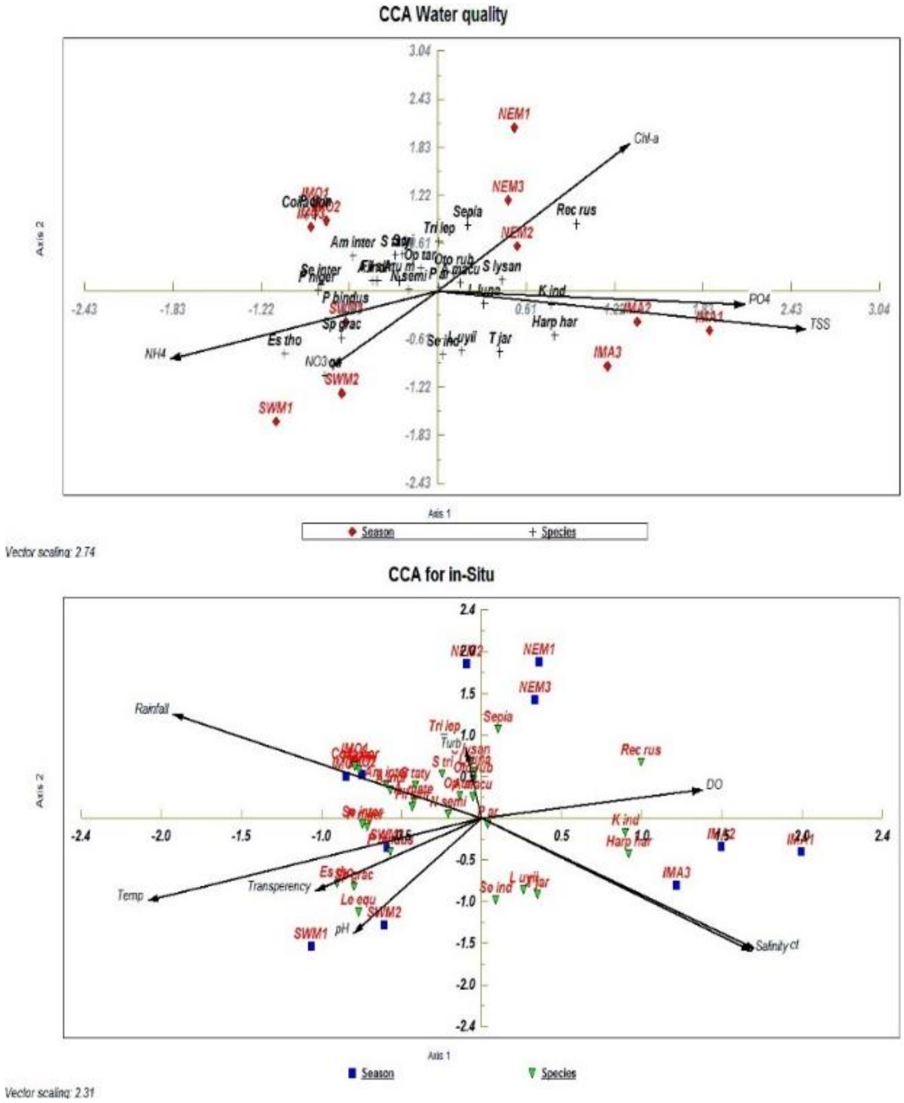
On the other hand, *E. thoracata* and *S. gracilis* were found with the highest abundance in SWM at higher temperature and transparency, and lower or mid DO and rainfall. However, *R. russeliana* in relation to the *in-situ* variables showed a different pattern, as it has a large Chi-square distance to all other species. According to this, *K. indicus*, *H. harpax*, and *R. russeliana* behaved similarly in terms of abundance and response to the *in-situ* variables, and were positively related to each other having species scores 0.875, 0.896 and 0.972 respectively; but correlated negatively with *A. interruptus*, *C. bornensis* and *P. niger* having species scores -0.581, -0.774 and -0.700 respectively in the first axis.

4. Discussion

This study has recorded phenomenal characteristics of ecological parameters and fisheries data during the study period. Most importantly, higher species abundance did not imply higher richness and diversity. Similarly, higher species richness and diversity did not contribute to significant temporal variations. Next, although *Pukat Tarik* has been used for pelagic fisheries, there were a considerable number of demersal species as well as non-regular benthic species (for example, *P. spermanni*). Similarly, species composition as well as abundance have shown significant fluctuations with seasons. In other words, species that were abundant in one season were found unavailable in another season. About 30% of the species that were found were juvenile based on the maturity size reference by Froese and Pauly (2017) indicating unhealthy fishing practices by Pukat Tarik fishery, which is a significant revelation from this study. In addition, a wide range of species that were captured by Pukat Tarik represented marine, brackish and freshwater species, so that the inshore areas serves as a nursing and foraging area, and a mixing ground that supports the established information of tropical estuaries and inshore areas acting as unlimited food provider (Cyrus & Blaber, 1992; Ruiz *et al*., 1993).

The species compositions in this study were similar to a few other studies of southern Yellow sea (Xu & Jin, 2005), west coast of Peninsular Malaysia (Alias, 2003), and studies on SCS (Yu *et al*., 2013). A study conducted in Similajau (Nyanti *et al*., 2014), adjacent to the present study area, has reported similar patterns of dominant species abundances except for Kurtidae (Perciformes). Kurtidae was the single most abundant species in the present study while study by Nyanti *et al*., (2014) recorded negligible count of it, which might be because Kurtidae is a marine species and the study on Similajau took samples from different fresh and brackish areas at river mouth and Nyalau estuary. The number of species found was however less (63 species) in this study than in the Similajau study (120 species) maybe because that study examined two nonconsecutive years.

Regarding species diversity, a higher diversity was found during monsoon compared to inter-monsoon, whereas a study at Pahang estuary had higher diversity in non-monsoon than in monsoon season (Jalal *et al*., 2012). In this study, among the ecological parameters, TSS showed significant temporal differences ($p<0.05$) with a higher mean in IMA (0.139 mg L^{-1}) than in IMO (0.038 mg L^{-1}), which is comparable to Sidik *et al.*, (2008).



A

B

Figure 3. (A & B): CCA ordination triplot. Blue rectangles represent object (sampling season), Green triangles represents response variables (species abundance) and Arrows (Vector) represent quantitative explanatory variables (*in-situ*) and point in the direction of increase. The results are based on square root transformed species abundance data and log transformed in-situ data. Species which fall into center of the axis have very little or no effect from the *in-situ* variables. Arrows that are parallel to an axis indicate a correlation and the length of the arrow shows the strength of that correlation.

Chlorophyll *a* did not show any temporal differences ($p>0.05$) similar to Saifullah *et al*. (2014b) (mean range 0.02 to 0.16 mg m^{-3}) and Saifullah *et al.* (2014a) (mean range 0.12 - 0.23 mg m^{-3}), whereas studies in Matang mangrove estuary (Chew & Chong, 2011), Peninsular Malaysia, showed significant temporal differences ($p<0.05$) with the mean range of 9.2 -22.8 µg L^{-1}. The water nutrients analyzed in this study did not show any significant temporal differences. NH_4-N ($p>0.1157$) and NO_3-N ($p>0.522$) had the highest mean concentration in SWM (±0.10 and 0.013 mgL^{-1}, respectively) and the lowest in NEM (0.05 to 0.007 mgL^{-1}, respectively) and PO_4-P ($p>0.06$) had the highest mean concentration in IMA (0.033 mgL^{-1}) and the lowest in SWM (0.009 mgL^{-1}). Studies on Kuala Sibuti and Kuala Nyalau mangrove estuaries (Saifullah *et al*., 2014a) showed similar results where NO_3-N concentration ranged in 0.34-0.68 mg L^{-1} and in 0.41-0.99 mgL^{-1}, PO_4-P ranged in 0.04-0.08 mgL^{-1} and in 0.04-0.06 mgL^{-1}, NH_4-N in 0.18-1.00 mgL^{-1} and in 0.76-1.11 mgL^{-1}, in Kuala Sibuti and Kuala Nyalau, respectively. Again, the study of Saifullah *et al*. (2014b) did not show any significant temporal differences except for NO_3-N ($p=0.04$) with the NH_4-N concentration range 0.06-1.24 mgL^{-1}, PO_4-P range 0.01-1.92 mgL^{-1}.

All *in-situ* data in this study showed significant temporal differences except for the water turbidity ($p> 0.0808$). Surface water temperature, DO, rainfall, salinity and conductivity showed large significant temporal differences ($p<0.01$). Study on Merbok estuary (Mansor *et al*., 2012) showed similar patterns in salinity and conductivity, and had the highest concentration in IMA and the lowest in IMO. Temperature was the highest in SWM and IMA, and DO was higher in NEM and lower in IMO. In contrast, the study in Matang estuary (Chew & Chong, 2011) showed no significant temporal differences in temperature ($p>0.736$) probably due to environmental and delta discharge differences, but showed differences in turbidity ($P<0.001$) along with salinity, pH and DO. Other *in-situ* parameters showed similarity with the present study.

In CCA ordination, this study estimated that TSS had the largest influence on the fish assemblages. Factors like salinity, conductivity, DO, chlorophyll *a*, PO_4-P had positive correlation with species, while temperature, rainfall and NH_4-N showed negative correlation with species composition and assemblages. Turbidity and NO_3-N did not show any correlation with species structure. Compared to the present study, Hoque *et al*. (2015) revealed that nitrate (NO_3-N) had the maximum influence on fish assemblages. Salinity, turbidity, DO, phytoplankton abundance positively correlated with chlorophyll *a* followed by phosphate and zooplankton density. In another study of fish composition DO has the highest impact on fish assemblages in Kuala Nyalau river estuary (Abu Hena *et al*., 2016). The other ecological factors like Chlorophyll *a* and turbidity showed positive and salinity showed negative but strong correlation with fisheries community in the coastal waters elsewhere.

5. Conclusions

Understanding the marine fisheries composition is essential as the fisheries stock is declining from the world's oceans especially from inshore areas with no exception for the Malaysian inshore fisheries. Studies on ecological patterns simultaneously enable to identify which factors govern the fisheries ecosystem. In tropical near shore areas, seasonality however has been largely ignored in community study and masked by large variances in catch data (Robertson & Duke, 1990). The current study has introduced temporal variations of catch composition, diversity and abundance along with ecological parameters for future reference. The composition of fish, crustaceans and mollusks were diverse and rich in Bintulu inshore waters ($H'=2.5$). In this study, in total 63 species of fish, crustaceans and cnidarians belonging to 40 families were identified. Ecological guild info revealed that majority of the species residing in Bintulu inshore waters were from marine-brackish origin. Among the ecological parameters, TSS had the most influence on the fish species assemblages. Species *H. harpax* showed robust correlation with salinity and conductivity, and strong but negative correlation with rainfall. This study identified some most effective ecological parameters that influence the aquatic ecosystem of Bintulu inshore area, which will help better understand fisheries ecology research and further measures for aquatic resource management in Bintulu coastal water fisheries, in Sarawak, South China Sea.

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