Technical Report

FISH DIETS
AS MEASURE OF HABITAT
CONNECTIVITY AT PULAU TINGGI MARINE PARK

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2018

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Contents

Preface	iv
Abstract	v
Introduction	1
Methods	1
Findings	2
Conclusion	19
Recommendations	19
Acknowledgements	19
References	19
Appendix 1	21
Appendix 2	22
Appendix 3	23

Preface

Malaysia's coastal and marine environment houses multiple habitats such as mangroves, mudflats, seagrass beds, coral reefs, shallow coastal and deep marine waters. The coastal habitats are supported by nutrient fluxes from rivers as well as from the marine environment, and together with the multitude of niches, allows for the rich biodiversity in these habitats. The mangroves are found along coasts and islands where there is low wave energy, corals in shallow marine waters along sandy coastlines where the water is clear, while seagrasses are found along sandy and sand-mud coasts. These habitats may exist as single continuous habitats, or as two or three adjacent habitats.

Coastal habitats when existing together are not stand alone entities (foundations) but are actively exchanging nutrients and biomass (interacting systems). Some of these habitats may have multiple ecological roles functioning as breeding, spawning, feeding and nursery grounds. The connectivity may not only be important for biomass movement between closely adjacent habitats, but also between further groups of adjacent habitats, such as between island archipelagos. Larval dispersal, use of habitats by juveniles and adults are some examples that may relate to such movements which are important for fisheries and food security. Commercial (fish and crustaceans) and non-commercial species spend different stages in their life cycle in different habitats with some requiring neighboring habitats. Some species may move between habitats on a daily basis, providing interconnection of biomass and nutrients, and predation effects.

Notwithstanding the importance of the coastal habitats, there are not many studies in Malaysia that have documented connectivity between adjacent coastal habitats. We studied the connectivity of the habitats of Pulau Tinggi, Johor (mangrove, coral and seagrass) by using fish diets to demonstrate their interconnectedness. We hypothesized that fishes move between adjacent habitats to feed and this was determined by studying their stomach contents.

The productivity and diversity of mangroves, corals and seagrasses have high economic value. The value of ecosystem services provided by coral reefs in Malaysia is approximately USD$45 billion annually. The high primary productivity of the habitats is translated to high secondary biomass, but these habitats are not immune to anthropogenic disturbances. Pollution, sedimentation, sea level rise, ocean acidification, reclamation and coastal development are factors that can disturb the interconnectedness of these habitats. It is imperative then to conserve adjacent coastal habitats not only for the ecosystem services that they provide but also their importance for education and research.

Editor

Abstract

TECHNICAL REPORT: FISH DIETS AS MEASURE OF HABITAT CONNECTIVITY AT PULAU TINGGI MARINE PARK

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This paper reports on the fish species sampled from the mangroves, seagrass beds and coral reefs of P Tinggi in order to demonstrate connectivity of the habitats via fish diets. 78 species were sampled from 39 families utilizing gill nets of mesh sizes 1.5", 3" & 5". The total fish biomass was 41.2 g/m^2/hr while the total density was 0.16 no/m^2/hr. The Margalef's index was 11.8, Shannon-Weiner index was 3.36, and Pielou index was 0.77. The length-weight relationship shows that the fishes generally follow isometric (b=3) and positive allometric (b>3) growth patterns. Fishes from mangroves recorded higher empty stomachs (53%) while fishes from the coral habitat showed higher full and gorged stomachs (22%). The important diet types were decapoda (31%), teleost (27%), plant matter (10%) and unidentified materials (14%). Fishes showed diet partitioning between habitats where different food categories were consumed in different habitats, especially for the carnivorous fish. Connectivity of habitats through diets was demonstrated by 7 fish species sampled. Fishes showed three categories with respect to diet shift based on size classes. Fishes demonstrated shift from mixed diet in smaller fish to single diet in larger fish, shift from single diet in smaller fish to a somewhat mixed diet in larger fish, and mixed diet in small fish to larger fish with proportions varying between the sizes of the fish species.

Keywords: mangrove, seagrass, coral, fish diet, habitat connectivity, Pulau Tinggi

FISH DIETS AS MEASURE OF HABITAT CONNECTIVITY AT PULAU TINGGI MARINE PARK

INTRODUCTION

Studies on the marine habitats and the biodiversity of Pulau (P) Tinggi are known (Department of Marine Parks, 2013; Ooi *et al*., 2011 2014, 2017; Ponnampalam *et al*., 2014). The marine habitats of P Tinggi includes mangroves, seagrass beds and coral reefs but there has not been any attempt to show linkages between these habitats. Habitat connectivity between biotopes by fishes has been shown for feeding, nursery, shelter and breeding (Chong & Sasekumar, 2002; Berkström *et al.*, 2012; Lau, 2014), indicating community structure and biomass differences (Mumby, 2006), and juvenile-adult life stages (Ramos *et al.* (2015). This study reports on the fish diversity, morphometrics, length-weight relationships, and the connectivity of habitats of P Tinggi (mangrove, seagrass and coral) through fish diets.

METHODS

Fish Sampling

Fish sampling was conducted between August 2017 to November 2017 at Pulau Mentinggi (coral habitat), Teluk Tereh and Teluk Pinang (mangrove habitat), and at Pulau Apil (segrass habitat) (Fig. 1). Three mesh size of monofilament gill nets [1.5” & 3” (dimensions of 168m X 1.8m) and 5” (dimensions 336m X 1.5m)] were utilized together to sample fish from the three habitats Apendix 2). The net type, location and coordinates of fish sampling is given in Appendix 1. The 1.5” and 3” gillnets were each employed 26 times while the 5” gill net was employed 28 times. Gill nets were placed for a period of between 11 – 13 hours before fish collection.

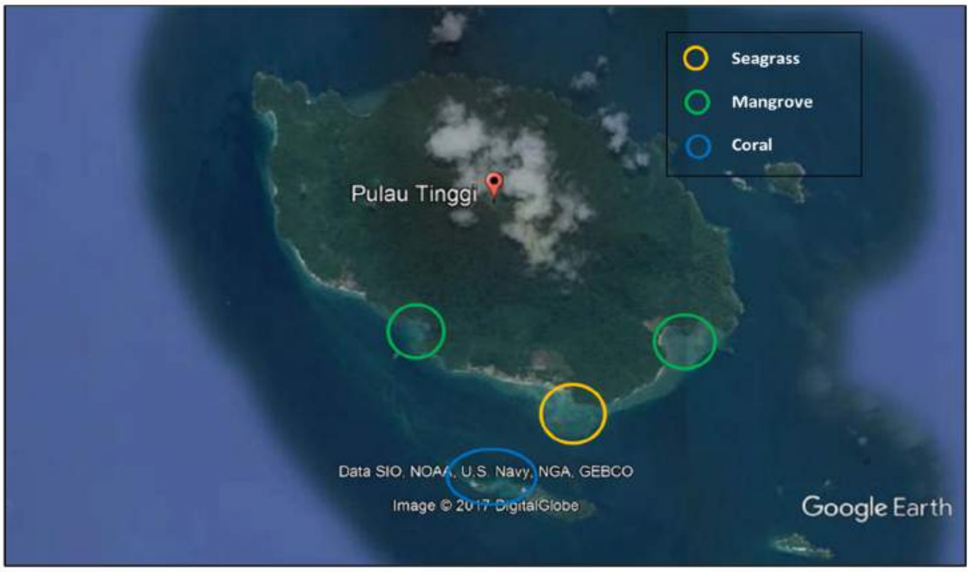


Figure 1 Map of Pulau Tinggi showing seagrass (Pulau Apil), Mangrove (Teluk Tereh - left and Teluk Pinang - right) and coral (Pulau Mentinggi) fish sampling sites

Morphometric Measures

All fishes sampled were enumerated and measured for their standard length (SL) (cm) and weight (g). Enumeration and morphometric measurements of fishes was conducted on the same day post collection.

Stomach Fullness and Stomach Content Analysis

All fishes sampled were noted for their stomach fullness (0-empty, 1-¼ full, 2-½, 3-¾ full, 4- full, 5–gorged) (Singh, 2003) and only stomachs that were half full and above were stored in 10% buffered formalin and later analysed to determine the content in the lab at Universiti Teknologi MARA, Shah Alam. For ease of analysis, the diet items were categorized into 12 groups (teleost, decapod, shrimp, plant matter, echinoderm, mollusk, cephalopod, insect, coral material, annelid, other crustacea and unidentified matter). The index of relative importance (IRI) (Pinkas *et al*., 1971; Hyslop, 1980) was utlised for diet analysis and was modified and expressed as, IRI = (%W)(%F) (Singh, 2003) (%W is percent weight and %F is frequency of occurrence).

Diversity Measures

The Margalef's index, D; Shannon-Weiner index for heterogeneity and diversity, H'; and Pielou's index for eveness, J, were utilized to determine fish community structure.

Statistical Analysis

Significant differences of more than two population groups (means) was determined via ANOVA by utilizing XLSTAT 2017. Primer 6 (version 6.1.18) was utilized to run Principal Components Analysis (PCA) to illustrate 2 dimensional ordination of the fish groupings based on diets consumed while the non-Metric Multidimensional Scaling (MDS) was utilized to show 2 dimensional ordination of the feeding guilds of the fishes.

FINDINGS

Fish Distribution

Thirty nine families comprising 78 species were sampled from the mangrove, seagrass and coral habitats of Pulau Tinggi (Table 1) (Appendix 3). In total, 653 individual fish were sampled. Among the fish families, the Carangidae (7 species), Nemipteridae (5 species), Lethrinidae (4 species), Lutjanidae (4 species) and Dasyatidae (4 species) were the most represented. *Crenimugil buchanani* (n=85), *Sargocentron rubrum* (n=76), *Siganus guttatus* (n=73) and *Lutjanus fulviflamma* (n=62) were the abundant fishes sampled.

Table 1 Fish species sampled form the mangroves, seagrass and coral habitats of Pulau Tinggi

Family	Species	n	Family	Species	n	Family	Species	n
Apogonidae	*Ostorhinchus chrysopomus*	1	Haemulidae	*Diagramma pictum*	1	Paralichthyidae	*Pseudorhombus arsius*	3
	Sphaeramia orbicularis	4		*Plectorhinchus gibbosus*	5		*Pseudorhombus elevatus*	2
	Yarica hyalosoma	1	Hemiramphidae	*Hemiramphus far*	11	Pempheridae	*Pempheris molucca*	11
Belonidae	*Strongylura incisa*	13		*Hemiramphus xanthopterus*	8	Platycephalidae	*Inegocia japonica*	3
	Strongylura leiura	1	Holocentridae	*Sargocentron rubrum*	76		*Platycephalus indicus*	7
	Tylosurus punctulatus	2	Kyphosidae	*Kyphosus cinerascens*	9	Psettodidae	*Psettodes erumei*	1
Bothidae	*Engyroprosopon grandisquama*	2	Labridae	*Cheilinus trilobatus*	1	Scaridae	*Scarus ghobban*	5
Caesionidae	*Caesio caerulaurea*	1		*Choerodon anchorago*	1		*Scarus globiceps*	3
	Caesio cuning	5	Leiognathidae	*Aurigequula fasciata*	9	Scyliorhinidae	*Atelomycterus marmoratus*	3
Carangidae	*Alectis ciliaris*	24	Lethrinidae	*Lethrinus harak*	3	Serranidae	*Epinephelus coioides*	1
	Alepes vari	2		*Lethrinus lentjan*	10		*Epinephelus corallicola*	7
	Carangoides chrysophrys	1		*Lethrinus mahsena*	1		*Epinephelus tauvina*	2
	Carangoides plagiotaenia	2		*Lethrinus nebulosus*	1	Siganidae	*Siganus guttatus*	73
	Scomberuides tol	1	Lutjanidae	*Lutjanus argentimaculatus*	8		*Siganus javus*	1
	Selar boops	1		*Lutjanus carponotatus*	5		*Siganus virgatus*	3
	Trachinotus blochii	3		*Lutjanus fulviflamma*	62	Sillaginidae	*Sillago ingenuua*	2
Carcharhinidae	*Carcharhinus melanopterus*	17		*Lutjanus lutjanus*	1		*Sillago sihama*	2
Chanidae	*Chanos chanos*	2	Megalopidae	*Megalops cyprinoides*	34	Soleidae	*Phyllichthys punctatus*	1
Chirocentridae	*Chirocentrus dorab*	1	Mugilidae	*Crenimugil buchanani*	85	Sphyraenidae	*Sphyraena barracuda*	4
Dasyatidae	*Himantura uarnak*	3		*Ellochelon vaigiensis*	15		*Sphyraena jello*	2
	Maculabatis pastinacoides	1	Mullidae	*Upeneus tragula*	2	Synanceiidae	*Inimicus cuvieri*	1
	Pastinachus sephen	6	Myliobatidae	*Aetobatus narinari*	1	Terapontidae	*Terapon theraps*	2
	Taeniura lymma	1	Nemipteridae	*Pentapodus bifasciatus*	2			
Diodontidae	*Diodon liturosus*	1		*Pentapodus trivittatus*	7			
Echeneidae	*Echeneis naucrates*	20		*Scolopsis ciliata*	21			
Gerreidae	*Gerres erythrourus*	3		*Scolopsis margaritifera*	1			
	Gerres oyena	1		*Scolopsis monogramma*	7			
	Gerres shima	6	Ostraciidae	*Lactoria cornuta*	1			

(highlighted are abundant fish species)

Twenty six fish species were recorded from the mangrove habitat, 13 species from the seagrass habitat and 14 species from the coral habitat (Table 2). Mixed habitats showed lower number of species as compared to single habitats [mangrove-seagrass = 13; mangrove-coral = 4; seagrass-coral = 2; mangrove-seagrass-coral = 6). With respect to total fish numbers, 52%, 37% and 11% were sampled from the mangrove, seagrass and coral respectively. *Echeneis naucrates, Gerres shima, Lethrinus lentjan, Lutjanus carponotatus, Lutjanus fulviflamma* and *Siganus guttatus* were sampled from all three habitats of Pulau Tinggi. The 1.5” mesh size gill net sampled higher number of fishes [n=381 (58%), 50 species] followed by the 3” mesh size gill net [n=176 (27%), 42 species, 27%] and the 5” mesh size gill net [n=96 (15%), 29 species] (Table 3)

Table 2 Fish species exclusively sampled from mangroves, seagrass and coral habitats of Pulau Tinggi

Mangrove	Coral	Seagrass
Sphaeramia orbicularis	*Ostorhinchus chrysopomus*	*Strongylura leiura*
Yarica hyalosoma	*Engyroprosopon grandisquama*	*Selar boops*
Alectis ciliaris	*Caesio caerulaurea*	*Taeniura lymma*
Carangoides plagiotaenia	*Caesio cuning*	*Gerres oyena*
Scomberuides tol	*Alepes vari*	*Hemiramphus xanthopterus*
Trachinotus blochii	*Carangoides chrysophrys*	*Cheilinus trilobatus*
Chanos chanos	*Chirocentrus dorab*	*Lethrinus nebulosus*
Maculabatis pastinacoides	*Diagramma pictum*	*Pentapodus bifasciatus*
Diodon liturosus	*Lutjanus lutjanus*	*Pentapodus trivittatus*
Gerres erythrourus	*Upeneus tragula*	*Scolopsis margaritifera*
Choerodon anchorago	*Lactoria cornuta*	*Scarus ghobban*
Aurigequula fasciata	*Pseudorhombus elevatus*	*Siganus javus*
Lethrinus mahsena	*Psettodes erumei*	*Siganus virgatus*
Lutjanus argentimaculatus	*Phyllichthys punctatus*	
Megalops cyprinoides		
Aetobatus narinari		
Pseudorhombus arsius		
Platycephalus indicus		
Scarus globiceps		
Epinephelus coioides		
Epinephelus corallicola		
Epinephelus tauvina		
Sillago ingenuua		
Sillago sihama		
Inimicus cuvieri		
Terapon theraps		

Catch Per Unit Effort (CPUE) - (Biomass and Density)

The total fish biomass was 41.2 g/m^2/hr (mean=0.52±0.84 g/m^2/hr) while the total density was 0.16 no/m^2/hr (mean=0.002±0.003 no/m^2/hr) (Table 4). The fish biomass ($p>0.05$) and density ($p<0.05$) was higher from the mangrove habitat [biomass, total=26.94 g/m^2/hr, mean=0.71±1.10 no/m^2/hr, density, total=0.08 no/m^2/hr, mean=0.002±0.003 no/m^2/hr], followed by the seagrass habitat [biomass, total=9.96 g/m^2/hr, mean=0.41±0.49 no/m^2/hr; density, total=0.06 no/m^2/hr, mean=0.003±0.004 no/m^2/hr)] and the coral habitat [biomass, total=4.35 g/m^2/hr, mean=0.24±0.41 no/m^2/hr; density, total=0.02 no/m^2/hr, mean=0.001±0.002 no/m^2/hr].

Diversity Indices

The community indices showed high value for the overall Margalef's index (11.8), medium to high value for the Shannon-Weiner index (3.36) and medium to high value for the Pielou index (0.77) (Table 5). The diversity indices were generally higher for the mangrove fish community and lowest for the coral fish community except for the Pielou index which was highest for the coral fish community (J=0.9)

Table 3 Fish species sampled by gill nets (1.5", 3" and 5") from the mangroves, seagrass and coral habitats of Pulau Tinggi

1.5" Gill Net	n	3" Gill Net	n	5" Gill Net	n
Strongylura incisa	10	*Strongylura incisa*	3	*Hemiramphus far*	1
Strongylura leiura	1	*Hemiramphus xanthopterus*	1	*Hemiramphus xanthopterus*	1
Tylosurus punctulatus	2	*Sargocentron rubrum*	3	*Sargocentron rubrum*	1
Hemiramphus far	10	*Megalops cyprinoides*	8	*Chirocentrus dorab*	1
Hemiramphus xanthopterus	6	*Chanos chanos*	2	*Megalops cyprinoides*	13
Sargocentron rubrum	72	*Crenimugil buchanani*	13	*Crenimugil buchanani*	4
Megalops cyprinoides	13	*Ellochelon vaigiensis*	9	*Ellochelon vaigiensis*	2
Crenimugil buchanani	68	*Ostorhinchus chrysopomus*	1	*Alectis ciliaris*	10
Ellochelon vaigiensis	4	*Sphaeramia orbicularis*	1	*Carangoides chrysophrys*	1
Sphaeramia orbicularis	3	*Caesio cuning*	2	*Scomberuides tol*	1
Yarica hyalosoma	1	*Alectis ciliaris*	14	*Trachinotus blochii*	1
Caesio caerulaurea	1	*Alepes vari*	1	*Echeneis naucrates*	6
Caesio cuning	3	*Trachinotus blochii*	2	*Gerres oyena*	1
Alepes vari	1	*Echeneis naucrates*	3	*Plectorhinchus gibbosus*	2
Carangoides plagiotaenia	2	*Diagramma pictum*	1	*Kyphosus cinerascens*	1
Selar boops	1	*Plectorhinchus gibbosus*	3	*Choerodon anchorago*	1
Echeneis naucrates	11	*Kyphosus cinerascens*	8	*Lethrinus harak*	2
Gerres erythrourus	3	*Cheilinus trilobatus*	1	*Lethrinus lentjan*	2
Gerres shima	6	*Lethrinus harak*	1	*Lutjanus argentimaculatus*	1
Aurigequula fasciata	9	*Lethrinus lentjan*	7	*Scarus globiceps*	3
Lethrinus lentjan	1	*Lethrinus nebulosus*	1	*Siganus guttatus*	15
Lethrinus mahsena	1	*Lutjanus argentimaculatus*	4	*Phyllichthys punctatus*	1
Lutjanus argentimaculatus	3	*Lutjanus carponotatus*	4	*Psettodes erumei*	1
Lutjanus carponotatus	1	*Lutjanus fulviflamma*	19	*Platycephalus indicus*	1
Lutjanus lutjanus	1	*Scolopsis ciliata*	2	*Lactoria cornuta*	1
Lutjanus fulviflamma	43	*Scolopsis margaritifera*	1	*Carcharhinus melanopterus*	12
Upeneus tragula	2	*Scolopsis monogramma*	3	*Himantura uarnak*	3
Pentapodus bifasciatus	2	*Pempheris molucca*	1	*Pastinachus sephen*	6
Pentapodus trivittatus	7	*Epinephelus corallicola*	2	*Aetobatus narinari*	1
Scolopsis ciliata	19	*Epinephelus tauvina*	1		
Scolopsis monogramma	4	*Siganus guttatus*	34	**Total sampled**	**96**
Pempheris molucca	10	*Sillago ingenuua*	1	**29 taxa**	
Scarus ghobban	5	*Sillago sihama*	1		
Epinephelus coioides	1	*Sphyraena barracuda*	2		
Epinephelus corallicola	5	*Pseudorhombus arsius*	3		
Epinephelus tauvina	1	*Pseudorhombus elevatus*	1		
Siganus guttatus	24	*Inegocia japonica*	1		
Siganus javus	1	*Platycephalus indicus*	3		
Siganus virgatus	3	*Inimicus cuvieri*	1		
Sillago ingenuua	1	*Diodon liturosus*	1		
Sillago sihama	1	*Carcharhinus melanopterus*	5		
Sphyraena barracuda	2	*Taeniura lymma*	1		
Sphyraena jello	2				
Terapon theraps	2	**Total sampled**	**176**		
Engyroprosopon grandisquama	2	**42 taxa**			
Pseudorhombus elevatus	1				
Inegocia japonica	2				
Platycephalus indicus	3				
Atelomycterus marmoratus	3				
Maculabatis pastinacoides	1				
Total sampled	**381**				
50 taxa					

Table 4 Biomass and density of fishes sampled by gill nets from the mangroves, segrass and coral habitats of Pulau Tinggi

Gill Nets	Biomass ($g/m^2/hr$)				Density ($no/m^2/hr$)			
	All Habitats	Mangrove	Coral	Seagrass	All Habitats	Mangrove	Coral	Seagrass
1.5"	0.46 ± 0.62	0.43 ± 0.70	0.18 ± 0.23	0.69 ± 0.63	0.003 ± 0.005	0.003 ± 0.004	0.001 ± 0.002	0.006 ± 0.005
3"	0.73 ± 1.17	1.01 ± 1.55	0.47 ± 0.71	0.43 ± 0.44	0.002 ± 0.003	0.003 ± 0.004	0.002 ± 0.002	0.002 ± 0.002
5"	0.37 ± 0.63	0.69 ± 0.85	0.14 ± 0.22	0.13 ± 0.19	0.001 ± 0.001	0.001 ± 0.001	0.0002 ± 0.0002	0.0003 ± 0.0004
Total	**41.25**	**26.94**	**4.35**	**9.96**	**0.16**	**0.08**	**0.02**	**0.06**

Table 5 Fish diversity indices of the habitats of Pulau

	Diversity Indices			
Habitat	**Species Richness**	**Shanon-Weiner (H)**	**Pielou (J)**	**Margalef (D)**
Mangrove	49	3.01	0.77	8.23
Seagrass	34	2.71	0.76	6.02
Coral	26	2.93	0.9	5.84
All Habitats	78	3.36	0.77	11.87

Morphometric Measures

The SL and the weight of the fishes varied between habitat types (Table 6). Among the fishes sampled from the habitats only *L. fulviflamma* and *S. guttatus* showed any meaningful size difference between habitats where their SL was significantly larger in the coral habitat ($p<0.05$) as compared to the mangrove and seagrasss habitats (Table 7). Fishes such as *E. naucrates, G. shima, L. lentjan,* and *L. carponotatus*, even though were sampled from the three habitats, but their numbers in some habitats amounted to only one individual and thus were not useful for comparison. Fish size may vary between interlinked habitats as fishes may utilize different habitats during their life cycle.

The length weight relationship ($W=aL^b$) of the abundant ($n>50$) fish species indicated that *Crenimugil buchanani* and *Sargocentrun rubrum* growth was isometric ($b=3$), *L. fulviflamma*, *E. naucrates*, *S. guttatus*, *Scolopsis ciliata* growth was positive allometry ($b>3$) () and *Megalops cyprinoides* growth was negative allometry ($b<3$) () (Fig. 2). The length-weight relationship of other fish species was not generated because their numbers were too small to demonstrate any meaningful regression as compared to the above species, where $R^2>0.9$.

Stomach Fullness

Almost half the fishes sampled recorded empty stomachs (Fig. 3, All Habitats). Only 37 species out of the 78 species sampled had stomachs that could be used for diet analysis (stomach fullness index of >2). Fishes from the mangrove habitat recorded higher empty stomachs (53%) while fishes from the coral habitat showed higher full and gorged stomachs (22%) (Fig. 3).

Table 6 Morphometric measures of fishes sampled from the mangrove, seagrass and coral habitats of Pulau Tinggi

Fish Species	Mangrove			Coral			Seagrass		
	n	Mean SL (cm)	Range (cm)	n	Mean SL (cm)	Range (cm)	n	Mean SL (cm)	Range (cm)
Aetobatus narinari	1	21.5							
Alectis ciliaris	24	33.82 ± 7.49	24.6-48.9						
Alepes vari				2	31.60 ± 2.55	29.8-33.4			
Atelomycterus marmoratus	2	47.40 ± 0.14	47.+47.5	1	43.5				
Aurigequula fasciata	9	7.76 ± 0.44	7.4-8.7						
Caesio caerulaurea				1	15.7				
Caesio cuning				5	16.42 ± 1.54	14.6-18.5			
Carangoides chrysophrys				1	39.4				
Carangoides plagiotaenia	2	11.65 ± 0.35	11.4-11.9						
Carcharhinus melanopterus	16	59.11 ± 17.77	44.5-111.2				1	64.7	
Chanos chanos	2	30.20 ± 0.99	29.5-30.9						
Cheilinus trilobatus							1	21.0	
Chirocentrus dorab				1	39.2				
Choerodon anchorago	1	23.1							
Crenimugil buchanani	76	21.58 ± 2.87	16.2-32.5				9	23.69 ± 4.97	13.3-29.5
Diagramma pictum				1	43.2				
Diodon liturosus	1	19.3							
Echeneis naucrates	2	42.65 ± 1.06	41.9-43.4	4	38.15 ± 7.86	32.4-49.4	14	39.61 ± 9.46	28.7-58.5
Ellochelon vaigiensis	14	23.72 ± 6.13	13.6-34.7				1	21.7	
Engyprosopon grandisquama				2	8.90 ± 0.42	8.6-9.2			
Epinephelus coioides	1	24.4							
Epinephelus corallicola	7	17.41 ± 4.33	12.0-24.6						
Epinephelus tauvina	2	19.65 ± 6.43	15.1-24.2						
Gerres erythrourus	3	8.33 ± 0.61	7.8-9.0						
Gerres oyena							1	8.4	
Gerres shima	2	6.80 ± 2.69	4.9-8.7	3	13.60 ± 0.17	13.5-13.8	1	9.7	
Hemiramphus far	2	29.70 ± 0.00	29.7				9	30.46 ± 4.76	17.9-33.7
Hemiramphus xanthopterus							8	28.09 ± 7.07	13.4-35.6
Himantura uarnak	2	34.80 ± 6.65*	30.1-39.5				1	31.7*	
Inegocia japonica	2	19.80 ± 0.57	19.4-20.2				1	30.8	
Inimicus cuvieri	1	17.2							
Kyphosus cinerascens	3	26.07 ± 3.14	22.5-28.4				6	24.53 ± 1.77	22.1-26.8
Lactoria cornuta				1	19.4				
Lethrinus harak	2	22.65 ± 1.63	21.5-23.8	1	23.5				
Lethrinus lentjan	1	14.7		6	20.50 ± 1.05	18.9-21.5	3	18.43 ± 0.40	18.0-18.8
Lethrinus mahsena	1	17.0							
Lethrinus nebulosus							1	28.6	
Lutjanus argentimaculatus	8	18.51 ± 5.05	11.7-23.8						
Lutjanus carponotatus	1	19.6		3	15.60 ± 0.70	15.1-16.4	1	30.4	
Lutjanus fulviflamma	19	13.19 ± 2.46	10.2-19.7	7	18.61 ± 2.59	15.9-21.9	36	13.53 ± 1.44	10.1-17.4
Lutjanus lutjanus				1	5.5				

Table 6 Continued

Fish Species	Mangrove			Coral			Seagrass		
	n	Mean SL (cm)	Range (cm)	n	Mean SL (cm)	Range (cm)	n	Mean SL (cm)	Range (cm)
Maculabatis pastinacoides	1	44.5							
Megalops cyprinoides	34	32.84 ± 3.77	22.7-42.9						
Ostorhinchus chrysopomus				1	9.8				
Pastinachus sephen	4	35.15 ± 1.85	35.6-37.7	2	22.55 ± 19.02	9.1-36.0			
Pempheris molucca	4	12.45 ± 0.62	11.6-13.0				7	12.50 ± 0.77	11.4-13.4
Pentapodus bifasciatus							2	15.00 ± 1.56	13.9-16.1
Pentapodus trivittatus							7	17.10 ± 1.05	15.7-18.5
Phyllichthys punctatus				1	28.0				
Platycephalus indicus	7	26.87 ± 5.32	18.5-33.1						
Plectorhinchus gibbosus	4	31.03 ± 3.59	27.4-34.5				1	21.1	
Psettodes erumei				1	37.5				
Pseudorhombus arsius	3	15.87 ± 1.85	14.0-17.7						
Pseudorhombus elevatus				2	16.05 ± 2.62	14.2-17.9			
Sargocentron rubrum	31	13.14 ± 1.63	10.1-16.5				45	13.65 ± 1.18	10.7-16.7
Scarus ghobban							5	16.64 ± 2.03	13.6-18.7
Scarus globiceps	3	18.87 ± 0.38	18.6-19.3						
Scolopsis ciliata				8	14.98 ± 1.70	11.4-16.5	13	14.08 ± 1.33	10.6-15.6
Scolopsis margaritifera							1	19.0	
Scolopsis monogramma				4	20.10 ± 0.79	19.4-21.2	3	19.53 ± 0.84	19.0-20.5
Scomberuides tol	1	49.1							
Selar boops							1	14.2	
Siganus guttatus	22	18.20 ± 3.61	13.5-27.5	10	24.10 ± 3.50	18.7-27.7	41	19.17 ± 3.36	14.5-29.6
Siganus javus							1	17.9	
Siganus virgatus							3	14.43 ± 1.30	13.1-15.7
Sillago ingenuua	2	19.35 ± 11.95	10.9-27.8						
Sillago sihama	2	18.15 ± 0.929	17.5-18.8						
Sphaeramia orbicularis	4	8.63 ± 1.66	7.6-11.1						
Sphyraena barracuda	2	32.10 ± 3.68	24.7-32.7				2	28.70 ± 5.66	29.5-34.7
Sphyraena jello	1	30.1		1	52.6				
Strongylura incisa	2	62.50 ± 0.28	62.3-62.7				11	62.69 ± 6.63	52.4-70.4
Strongylura leiura							1	49.4	
Taeniura lymma							1	23.2*	
Terapon theraps	2	12.4 ± 0.78	11.3-12.4						
Trachinotus blochii	3	29.67 ± 0.95	28.7-30.6						
Tylosurus punctulatus	1	64.8					1	55.5	
Upeneus tragula				2	19.80 ± 0.57	19.4-20.2			
Yarica hyalosoma	1	5.5							

Table 7 The standard length measures of fish species sampled from at least two habitats with stomach fullness index greater than 2 at Pulau Tinggi

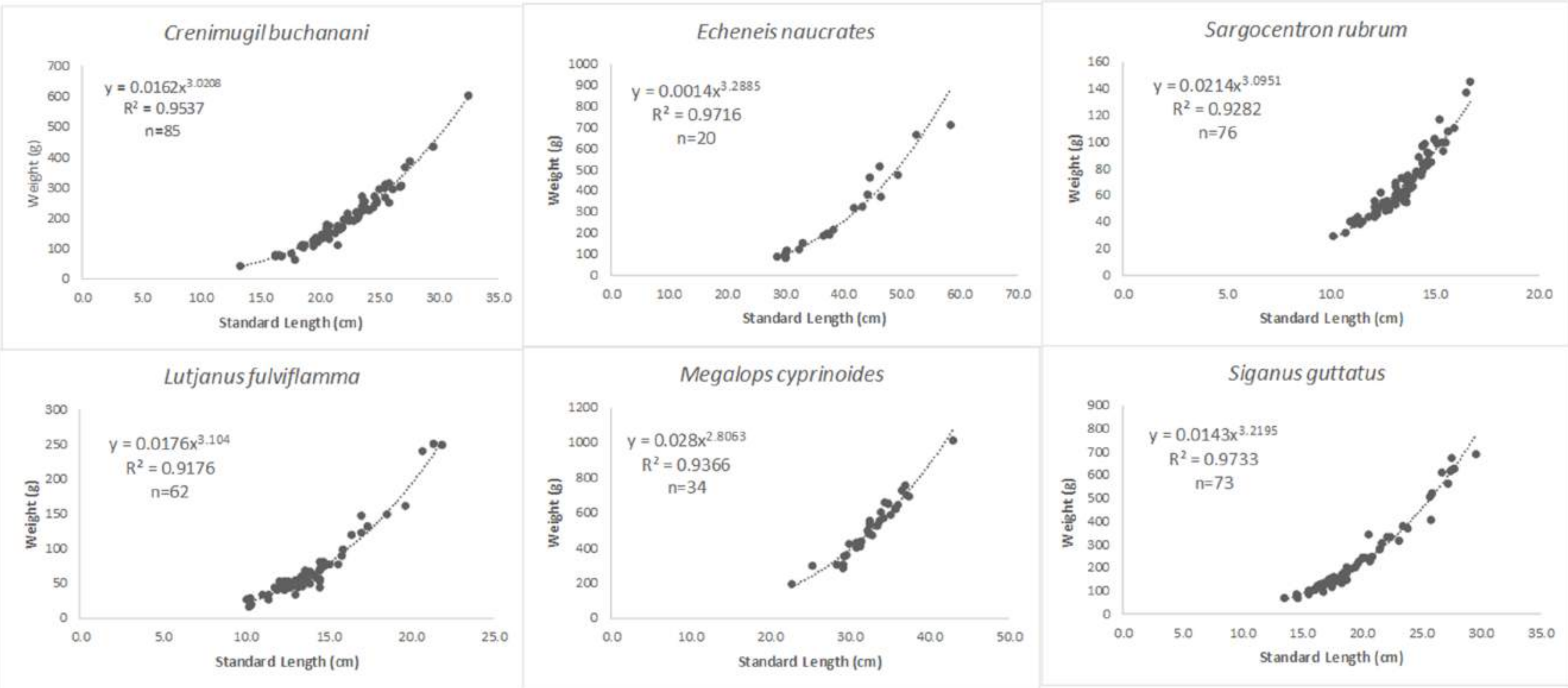
Fish Species	Mangrove			Coral			Seagrass		
	n	Standard Length (cm)	Range (cm)	n	Standard Length (cm)	Range (cm)	n	Standard Length (cm)	Range (cm)
Atelomycterus marmoratus	2	47.40 ± 0.14	47-47.5	1	43.5				
Kyphosus cinerascens	3	26.07 ± 3.14	22.5-28.4				6	24.53 ± 1.77	22.1-26.8
Lethrinus lentjan	1	14.7		6	20.50 ± 1.05	18.9-21.5	3	18.43 ± 0.40	18.0-18.8
Lutjanus fulviflamma	19	13.19 ± 2.46[a]	10.2-19.7	7	18.61 ± 2.59[b]	15.9-21.9	36	13.53 ± 1.44[a]	10.1-17.4
Plectorhinchus gibbosus	4	31.03 ± 3.59	27.4-34.5				1	21.1	
Sargocentron rubrum	31	13.14 ± 1.63	10.1-16.5				45	13.65 ± 1.18	10.7-16.7
Siganus guttatus	22	18.20 ± 3.61[a]	13.5-27.5	10	24.10 ± 3.50[b]	18.7-27.7	41	19.17 ± 3.36[a]	14.5-29.6

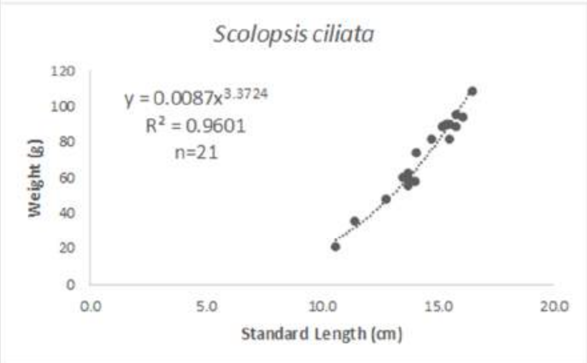
a , b represents significant difference ($p<0.05$)

Fish Diets

Among the fishes with stomach contents, the important diet types were decapoda (31%), teleost (27%), plant matter (10%) and unidentified materials (14%) (Fig. 4, Overall), but varied between habitats. The decapoda (49%) and teleost (20%) were important diets for fish from the mangrove habitat; the teleost (59%) and decapoda (15%) were important fish diets from the coral habitat; the decapoda (25%) and plant matter (19%) were important fish diets from the seagrass habitat.

The PCA shows that decapods, teleost and plant matter is the main component of the diets of the sampled fishes from Pulau Tinggi (Fig. 5). The Eigen values of the principal components is given in Table 8. The first two principal components explain 57% of the variance. Fishes also feed on other diets such as shrimps, cephalopods, coral, echinoderms, annelids, crustacea (other than decapods), insects and unidentified matter. The MDS shows that the fishes of Pulau Tinggi can be grouped into four major feeding guilds: plant feeders (*Scolopsis monograma, Siganus virgatus, S. guttatus, Kyphosus cinerascens*), decapod feeders (*Lutjanus argentimaculatus, L. fulviflamma, Epinephelus corallicola, Therapon theraps, Alectis ciliaris, Lethrinus mahsena, L. harak, L. lentjan, Inegocia japonica, Plathycephalus indicus, Upeneus tragula, Atelomycterus marmoratus, Sargocentrum rubrum, Plectorhinchus gibbosus*), teleost feeders (*Megalops cyprinoides, Lutjanus carponotatus, Sphaeramia orbicularis, Carcharhinus melanopterus, Sphyraena barracuda, S. jello, Lutjanus lutjanus, Strongylura incisa, Chrocentus dorab*) and mixed feeders (*Sillago ingenuua, Pastinachus sepens, Pentapodus trivittatus, Scolopsis ciliata*) (Fig. 6). A majority of the fishes are either teleost or decapod feeders, or both.





Fish Species	a	b	R^2	Growth Type
Crenimugil buchanani	0.0162	3.02	0.95	Isometric
Sargocentrum rubrum	0.0213	3.09	0.92	Isometric
Lutjanus fulviflamma	0.0176	3.10	0.91	Positive Allometry
Echeneis naucrates	0.0014	3.28	0.97	Positive Allometry
Siganus guttatus	0.0143	3.21	0.97	Positive Allometry
Scolopsis ciliata	0.0087	3.37	0.96	Positive Allometry
Megalops cyprinoides	0.028	2.80	0.93	Negative Allometry

Figure 2 Standard length-weight relationship of abundant fishes samples from Pulau Tinggi

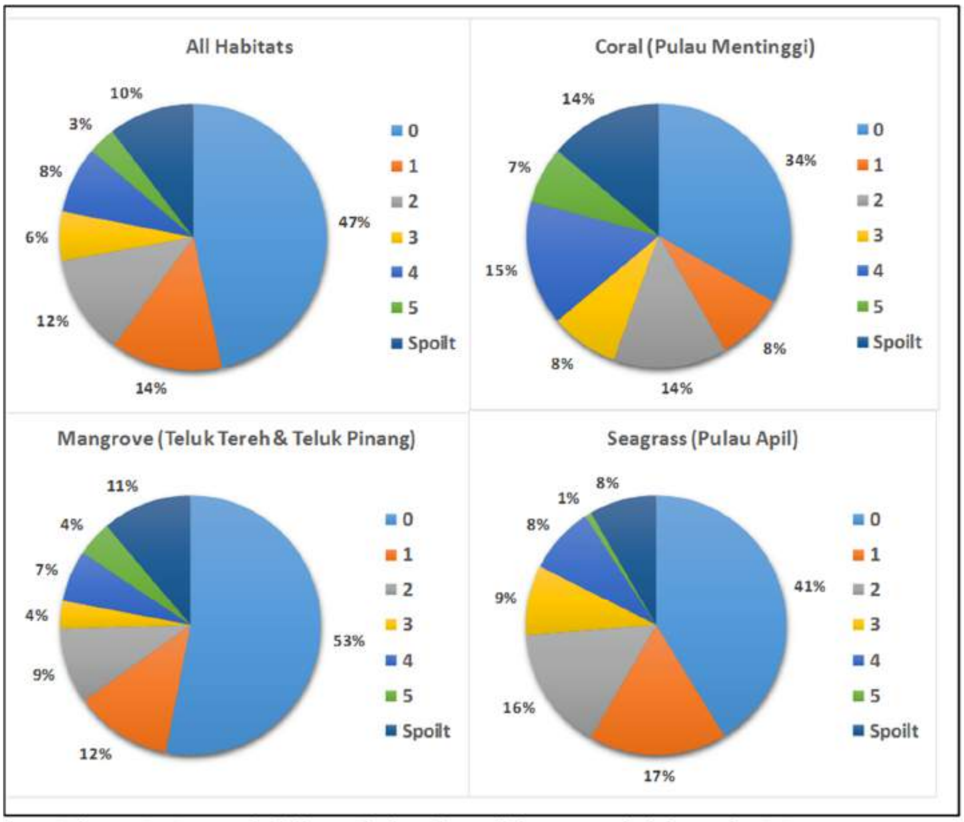


Figure 3 Stomach fullness index from fishes sampled from the Mangrove, seagrass and coral habitats of Pulau Tinggi

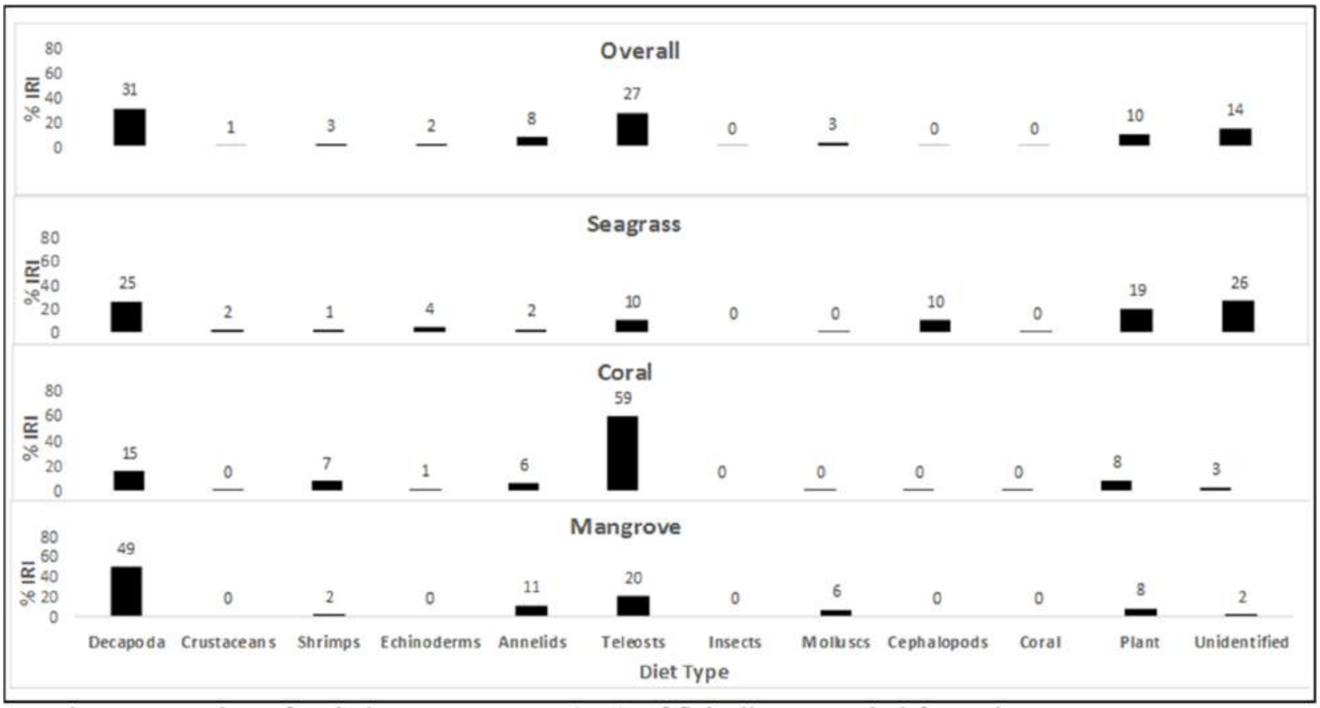


Figure 4 Index of Relative Importance (IRI) of fish diets sampled from the mangroves, seagrass and coral habitats of Pulau Tinggi (pooled data)

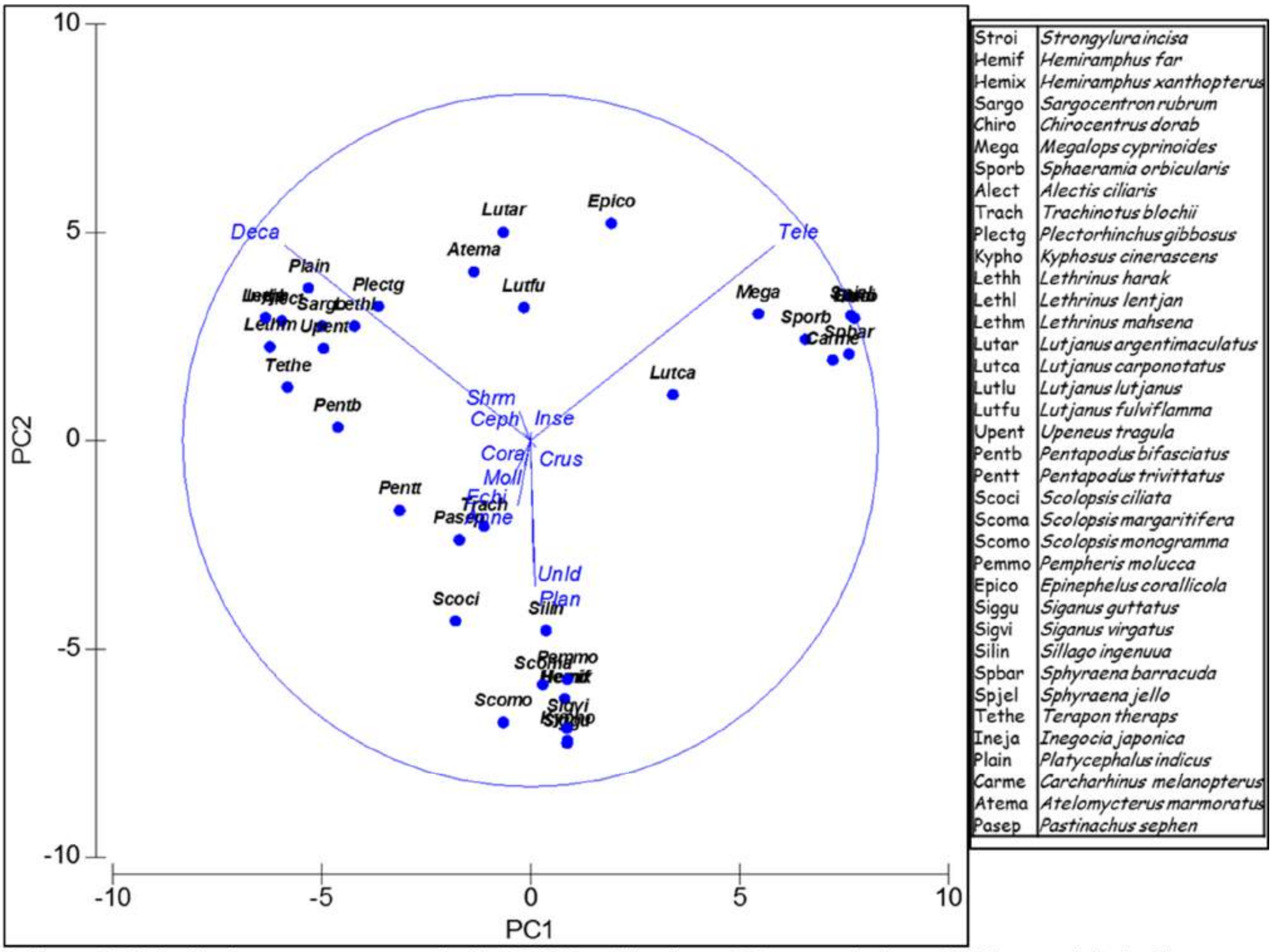
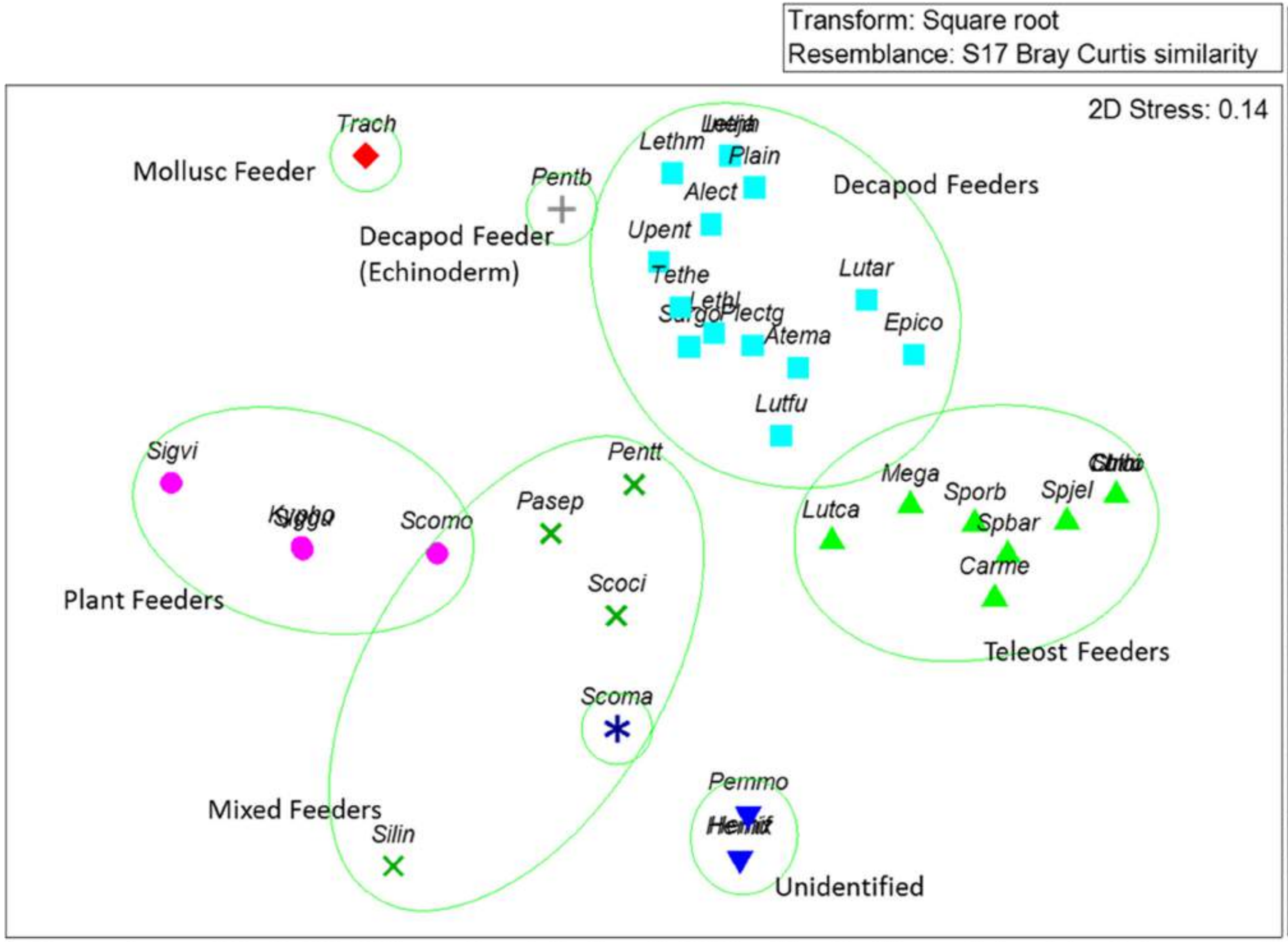


Figure 5 Principal components analysis (PCA) ordination of the correlation of fishes and their diets sampled from Pulau Tinggi (Species acronyms and species names are given on the right)

Table 8 Eigen values and percent variation of principical components

PC	Eigen values	%Variation	Cum.%Variation
1	21.7	32.2	32.2
2	16.9	25.1	57.3
3	10.1	15	72.3
4	7.11	10.6	82.8
5	3.62	5.4	88.2



Stroi	*Strongylura incisa*
Hemif	*Hemiramphus far*
Hemix	*Hemiramphus xanthopterus*
Sargo	*Sargocentron rubrum*
Chiro	*Chirocentrus dorab*
Mega	*Megalops cyprinoides*
Sporb	*Sphaeramia orbicularis*
Alect	*Alectis ciliaris*
Trach	*Trachinotus blochii*
Plectg	*Plectorhinchus gibbosus*
Kypho	*Kyphosus cinerascens*
Lethh	*Lethrinus harak*
Lethl	*Lethrinus lentjan*
Lethm	*Lethrinus mahsena*
Lutar	*Lutjanus argentimaculatus*
Lutca	*Lutjanus carponotatus*
Lutlu	*Lutjanus lutjanus*
Lutfu	*Lutjanus fulviflamma*
Upent	*Upeneus tragula*
Pentb	*Pentapodus bifasciatus*
Pentt	*Pentapodus trivittatus*
Scoci	*Scolopsis ciliata*
Scoma	*Scolopsis margaritifera*
Scomo	*Scolopsis monogramma*
Pemmo	*Pempheris molucca*
Epico	*Epinephelus corallicola*
Siggu	*Siganus guttatus*
Sigvi	*Siganus virgatus*
Silin	*Sillago ingenuua*
Spbar	*Sphyraena barracuda*
Spjel	*Sphyraena jello*
Tethe	*Terapon theraps*
Ineja	*Inegocia japonica*
Plain	*Platycephalus indicus*
Carme	*Carcharhinus melanopterus*
Atema	*Atelomycterus marmoratus*
Pasep	*Pastinachus sephen*

Figure 6 non-Metric Multidimensional Scaling (MDS) of the feeding guilds of the fishes sampled from Pulau Tinggi. (Species acronyms and species names are given on the right)

Fish Habitat Connectivity

The stomach fullness of the fishes that moved between habitats to feed varied between species. High stomach fullness diversity was observed for *L. fulviflamma, L. lentjan, S. guttatus* and *S. rubrum* (Fig 7). *Kyphosus inerascens* and *A. marmoratus* showed low stomach fullness while the lowest was for *P. gibbosus*.

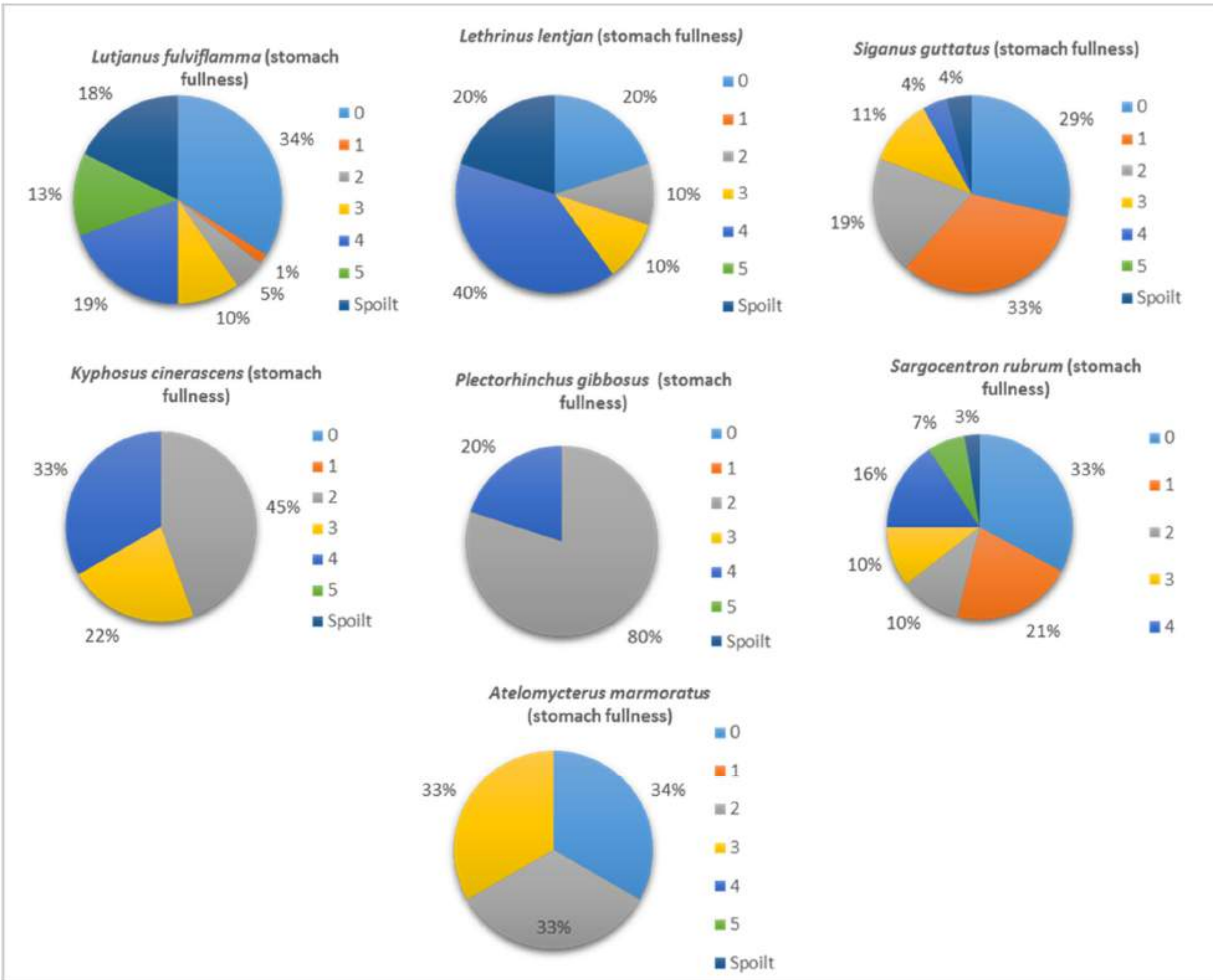


Figure 7 Stomach fullness index of selected fishes sampled from various habitats of Pulau Tinggi

Sargocentrum rubrum & Plectorhinchus gibbosus (mangrove-seagrass habitats); *Atelomycterus marmoratus* (mangrove-coral); *L. llentjan* (seagrass-coral habitats), *S. guttatus* (seagrass-coral habitats); *Kyphosus cinerascens* (mangrove-seagrass habitats) moved between 2 habitats to feed; while *L. fulviflamma* moved between 3 habitats (mangroves-segrass-coral) to feed (Fig. 8). Habitat connectivity of fish may not only be indicated by feeding in different habitats, but also by community structure and biomass (Mumby, 2006), nursery function (Berkström *et al.*, 2012) and juvenile-adult life stages (Ramos *et al.* (2015).

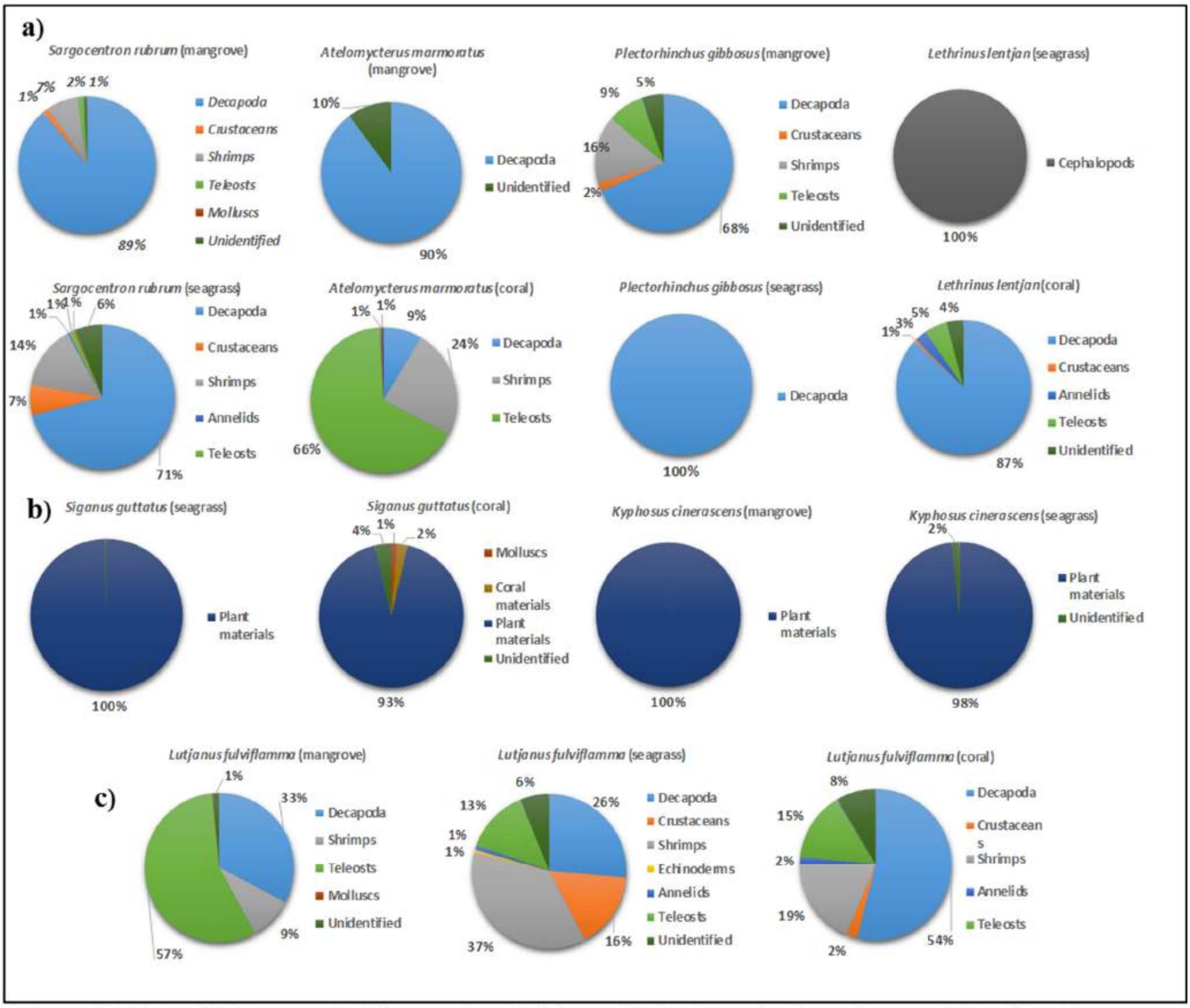


Figure 8 Diets of fishes sampled from various habitats of Pulau Tinggi. a) carnivorous fishes from 2 habitats, b) herbivorous fishes from 2 habitats, and c) carnivorous fish from 3 habitats

Among the carnivorous fish feeding in two habitats, *S. rubrum* fed mainly on decapods in the mangrove (89%) and segrass habitats (71%) but it's diet also comprised of shrimps (14%), crustaceans (7%) and teleost (6%) in the latter habitat (Fig 8). *Atelomycterus marmoratus* fed mainly on decapods in the mangrove habitat (90%) but its diet in the seagrass habitat comprised mainly of teleosts (66%) followed by shrimps (24%). The main diet of *P. gibbosus* was decapods for both the seagrass (100%) and the mangrove (68%) habitats but it also fed on shrimps (16%) and teleosts (9%) at the latter habitat. *Lethrinus lentjan* fed solely on cephalopods (100%) in the seagrass habitat but fed on decapods (87%) in the coral habitat. The diets of *L. fulviflamma* varied between the three habitats. Its diet comprised mainly of teleosts (57%) and decapods (33%) in the mangrove habitat; it was mixed in the seagrass habitat (shrimps=37%, decapods=26%, crustaceans=16% & teleosts=13%); and was dominated by decapods (54%) followed by shrimps (19%) and teleosts (15%) in the coral habitat. Among the herbivorous fish (*S. guttatus* & *K. cinerascens*), the diet mainly consisted of plant material (>98%) in both habitats (seagrass-coral and mangrove-seagrass).

The carnivorous fish showed diet partitioning between habitats where different food categories were consumed in different habitats. This diet shift behaviour is important to minimize intra and inter specific competition for food (Singh, 2003; *Tanaka et al*., 2011; Cachera *et* al., 2017). Lau (2014) showed that fish movement (for feeding) and outwelling of extruded mucus (from corals) and zooplankton connected coral reefs to mangroves in the north eastern part of Langkawi Island.

Diet Shift Based on Standard Length Size Class

The fishes of Pulau Tinggi demonstrated diet shift between the different size standard length size classes (Fig 9). Fishes like *A. ciliaris, C. melanopterus, E. corallicola, Trichinotus blochi* and *M. cyprinoides* shifted from a mixed diet in smaller fish to single diet in larger fish while *L. argentimaculatus, P. indicus* and *P. gibbosus* shifted from single diet in smaller fish to a somewhat mixed diet in larger fish. The diet of *L. lentjan, K. cinerascens, L. fulviflamma, S. rubrum, Scolopsis monogramma* and *S. guttatus* was mixed from small fish to larger fish but the proportions varied between sizes of the fish species.

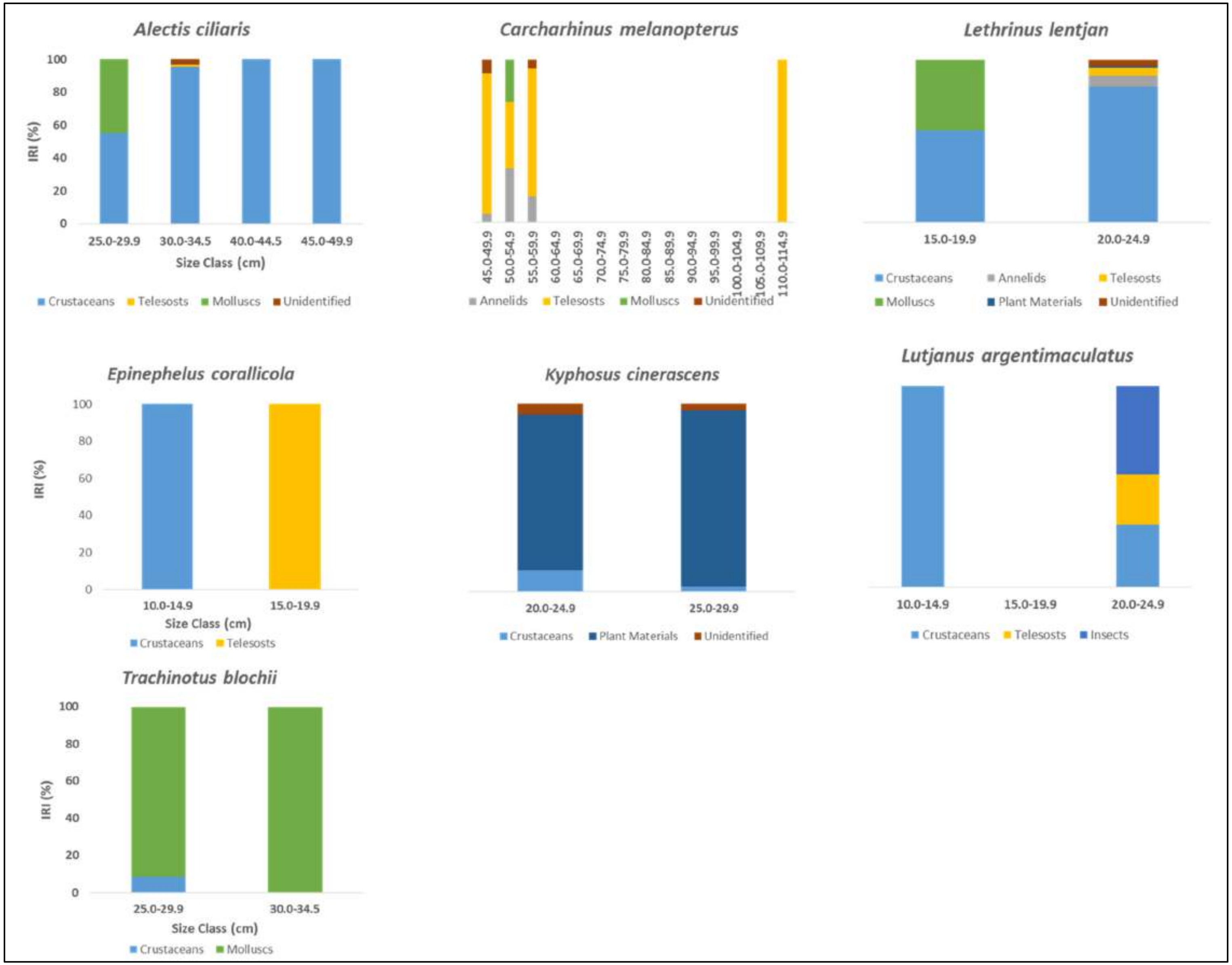


Figure 9 Fish size class and diet type consumed by fishes sampled from Pulau Tinggi

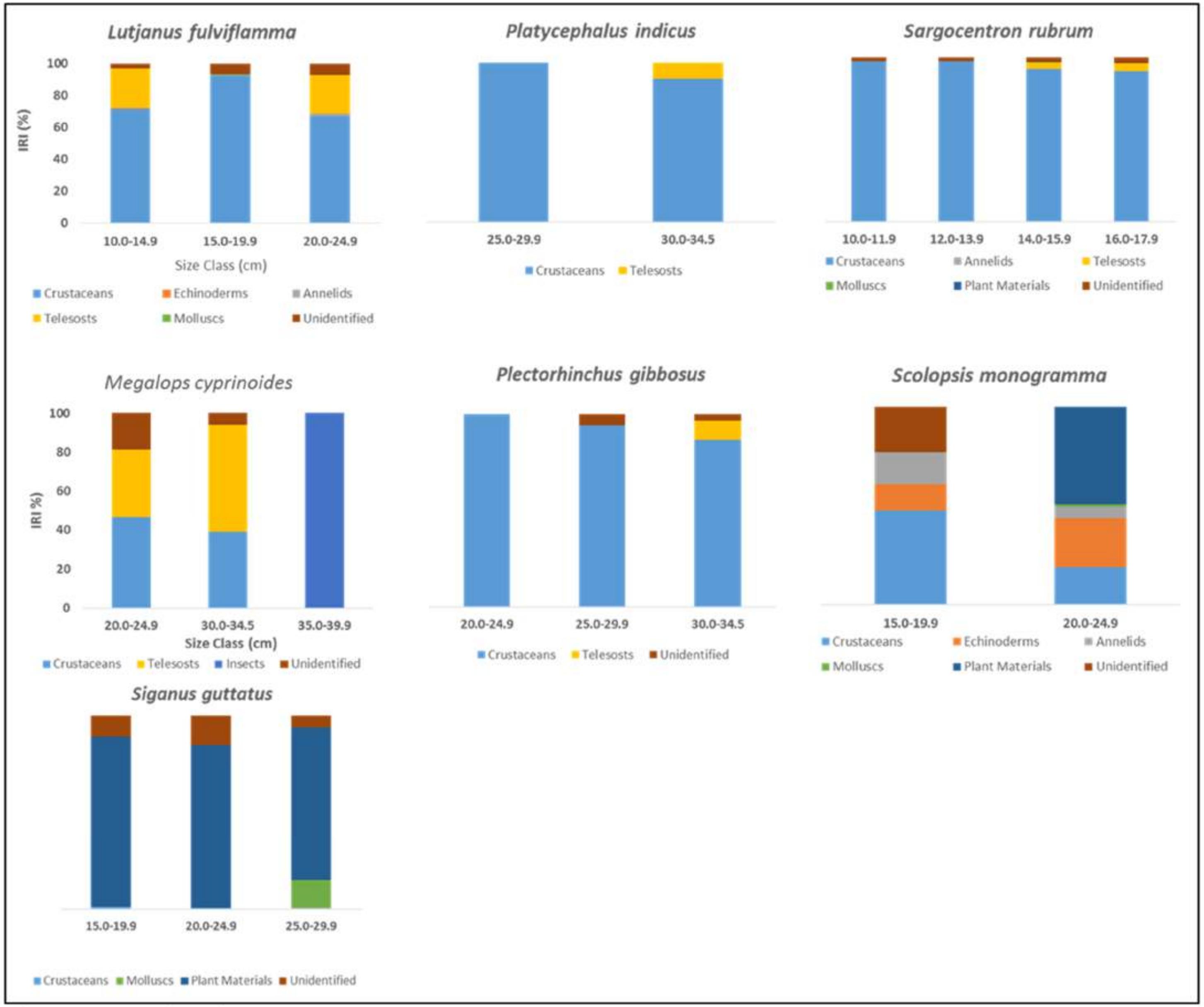


Figure 9 Continued

CONCLUSION

The diversity of the fishes of Pulau Tinggi is high. Size difference of fishes between habitats was shown and this suggests the differential utilization of the habitats of Pulau Tinggi. The length-weight relationship suggests that the fishes are in good condition as the growth factor b, was 3 and above. Fishes move between habitats (mangrove, seagrass and coral) to feed but their diet vary between habitats. A large number of the fishes are carnivores feeding mainly on decapods and teleosts. Four main feeding guilds were noted primarily, decapod feeders, teleost feeders, mixed feeders and plant feeders. The inter habitat movement and feeding by fishes shows connectivity of the habitats of Pulau Tinggi. Fishes demonstrated some aspects of diet shift with respect to their standard length size classes.

RECOMMENDATIONS

Further studies are needed to document long term feeding movements of the fishes not only between habitats of Pulau Tinggi but also fish movement between the islands of the Tinggi Archipelago. Diel and nocturnal movement, and feeding, as well as seasonal change in diet and movement should also be studied to determine niche and habitat partitioning among the fishes. Further studies into the ontogenetic diet shift in fishes between habitats will further enhance the connectivity of the habitats. As some measure of habitat connectivity was established in the current study, the conservation and management of the habitats of Pulau Tinggi and their biodiversity is imperative not only for their sustainability but also for the livelihoods of the local populace and for the ecotourism industry of the island.

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APPENDIX 1

Date, gill net type, habitat and coordinates of fish sampling at Pulau Tinggi

Date	Net type	Habitat Type	Coordinates
3-Aug-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.409' E104º07.172'
4-Aug-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.286' E104º06.700'
5-Aug-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.286' E104º06.700'
21-Aug-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.330' E104º06.777'
21-Aug-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.305' E104º06.705'
21-Aug-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.341' E104º07.673'
22-Aug-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.777'
22-Aug-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.777'
22-Aug-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.305' E104º06.705'
22-Aug-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.305' E104º06.705'
22-Aug-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º17.560' E104º05.957'
23-Aug-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.777'
23-Aug-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.777'
23-Aug-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.305' E104º06.705'
23-Aug-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.305' E104º06.705'
23-Aug-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.400' E104º06.472'
23-Aug-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.343' E104º06.592'
7-Sep-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.317' E104º06.760'
7-Sep-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.317' E104º06.760'
7-Sep-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.369' E104º06.625'
7-Sep-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.369' E104º06.625'
7-Sep-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.365' E104º06.689'
7-Sep-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.365' E104º06.689'
8-Sep-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.413' E104º07.191'
8-Sep-17	Gillnet 1.5"	Pulau Mentinggi (Coral)	N02º16.297' E104º07.262'
8-Sep-17	Gillnet 3"	Pulau Mentinggi (Coral)	N02º16.298' E104º07.209'
9-Sep-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.827' E104º07.647'
9-Sep-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.827' E104º07.647'
9-Sep-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.885' E104º07.464'
9-Sep-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.885' E104º07.464'
9-Sep-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.852' E104º07.701'
9-Sep-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.852' E104º07.701'
26-Sep-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.360' E104º06.758'
26-Sep-17	Gillnet 1.5"	Teluk Tereh (Mangrove)	N02º17.360' E104º06.758'
26-Sep-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.721'
26-Sep-17	Gillnet 3"	Teluk Tereh (Mangrove)	N02º17.332' E104º06.721'
26-Sep-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.396' E104º06.694'
26-Sep-17	Gillnet 5"	Teluk Tereh (Mangrove)	N02º17.396' E104º06.694'
27-Sep-17	Gillnet 1.5"	Pulau Mentinggi (Coral)	N02º16.469' E104º07.001'
27-Sep-17	Gillnet 1.5"	Pulau Mentinggi (Coral)	N02º16.481' E104º07.006'
27-Sep-17	Gillnet 3"	Pulau Mentinggi (Coral)	N02º16.470' E104º07.085'
27-Sep-17	Gillnet 3"	Pulau Mentinggi (Coral)	N02º16.413' E104º07.205'
27-Sep-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.480' E104º06.940'
27-Sep-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.553' E104º06.829'
28-Sep-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.798' E104º07.665'
28-Sep-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.798' E104º07.665'
28-Sep-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.817' E104º07.618'
28-Sep-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.817' E104º07.618'
28-Sep-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.792' E104º07.700'
28-Sep-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.792' E104º07.700'
11-Oct-17	Gillnet 1.5"	Teluk Pinang (Mangrove)	N02º17.300' E104º08.257'
11-Oct-17	Gillnet 1.5"	Teluk Pinang (Mangrove)	N02º17.300' E104º08.257'
11-Oct-17	Gillnet 3"	Teluk Pinang (Mangrove)	N02º17.359' E104º08.320'
11-Oct-17	Gillnet 3"	Teluk Pinang (Mangrove)	N02º17.359' E104º08.320'
11-Oct-17	Gillnet 5"	Teluk Pinang (Mangrove)	N02º17.202' E104º08.413'
11-Oct-17	Gillnet 5"	Teluk Pinang (Mangrove)	N02º17.202' E104º08.413'
12-Oct-17	Gillnet 1.5"	Pulau Mentinggi (Coral)	N02º16.249' E104º07.059'
12-Oct-17	Gillnet 1.5"	Pulau Mentinggi (Coral)	N02º16.283' E104º06.974'
12-Oct-17	Gillnet 3"	Pulau Mentinggi (Coral)	N02º16.222' E104º07.105'
12-Oct-17	Gillnet 3"	Pulau Mentinggi (Coral)	N02º16.506' E104º06.615'
12-Oct-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.445' E104º06.717'
12-Oct-17	Gillnet 5"	Pulau Mentinggi (Coral)	N02º16.232' E104º07.097'
13-Oct-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.840' E104º07.585'
13-Oct-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.840' E104º07.585'
13-Oct-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.800' E104º07.576'
13-Oct-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.800' E104º07.576'
13-Oct-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.830' E104º07.624'
13-Oct-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.830' E104º07.624'
13-Nov-17	Gillnet 1.5"	Teluk Pinang (Mangrove)	N02º17.221' E104º08.266'
13-Nov-17	Gillnet 1.5"	Teluk Pinang (Mangrove)	N02º17.221' E104º08.266'
13-Nov-17	Gillnet 3"	Teluk Pinang (Mangrove)	N02º17.282' E104º08.241'
13-Nov-17	Gillnet 3"	Teluk Pinang (Mangrove)	N02º17.282' E104º08.241'
13-Nov-17	Gillnet 5"	Teluk Pinang (Mangrove)	N02º17.323' E104º08.253'
13-Nov-17	Gillnet 5"	Teluk Pinang (Mangrove)	N02º17.323' E104º08.253'
14-Nov-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.774' E104º07.661'
14-Nov-17	Gillnet 1.5"	Pulau Apil (Seagrass)	N02º16.774' E104º07.661'
14-Nov-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.789' E104º07.568'
14-Nov-17	Gillnet 3"	Pulau Apil (Seagrass)	N02º16.789' E104º07.568'
14-Nov-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.774' E104º07.661'
14-Nov-17	Gillnet 5"	Pulau Apil (Seagrass)	N02º16.774' E104º07.661'

APPENDIX 2



Fish Sampling adjacent to mangroves utilising gill nets

Fish Sampling in coral area adjacent to Pulau Mentinggi

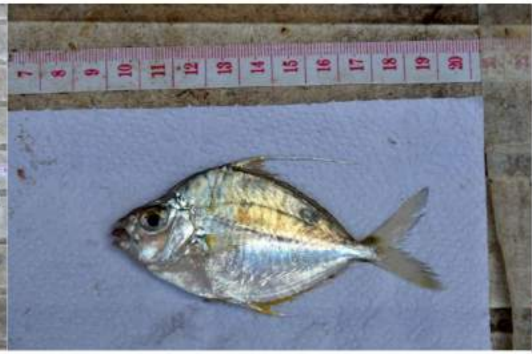
APPENDIX 3
FISHES SAMPLED FROM THE HABITATS OF PULAU TINGGI

Alectis ciliaris

Alepes melanoptera

Alepes vari

Atelomycterus marmoratus



Aurigequula fasciata

Caesio caerulaurea

Caesio cuning

Carangoides chrysophrys

Carangoides plagiotaenia

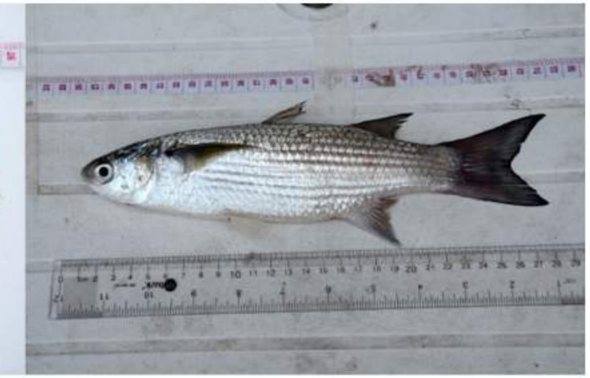
Carcharhinus melanopterus

Cephalopolis boenack

Chanos chanos

Chirocentrus dorab

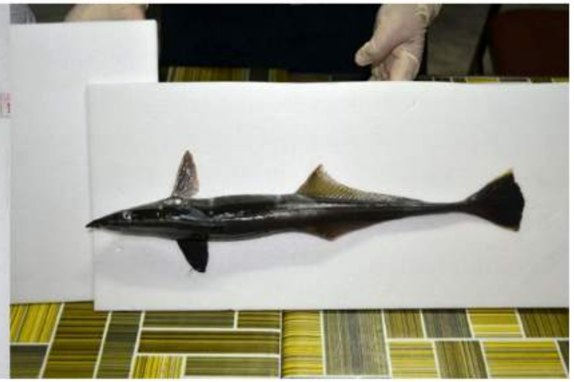
Choerodon anchorago



Crenimugil buchanani

Diagramma pictum

Diodon liturosus



Echeneis naucrates

Epinephelus areolatus

Engyroprosopon grandisquama

Ellochelon vaigiensis

Epinephelus quoyanus

Epinephelus corallicola

Epinephelus coioides

Gerres shima

Gerres erythrourus

Epinephelus tauvina

Gymnocranius griseus

Hemiramphus far

Himantura uarnak

Inegocia japonica

Inimicus cuvieri

Kyphosus cinerascens

Lactoria cornuta

Lethrinus harak

Lethrinus lentjan

Lutjanus argentimaculatus

Lethrinus nebulosus

Lethrinus mahsena

Lutjanus lutjanus

Lutjanus fulviflamma

Lutjanus carponotatus

Nemipterus fucosus

Maculabatis pastinacoides

Lutjanus vitta

Pempheris molucca

Parapercis synedri

Pastinachus sephen

Pentapodus bifasciatus

Pentapodus setosus

Pentapodus trivittatus

Pseudorhombus elevatus

Phyllichthys punctatus

Platycephalus indicus

Plectorhinchus chrysotaenia

Plectorhinchus gibbosus

Psettodes erumei

Pseudorhombus arsius

Sargocentron rubrum

Scarus ghobban

Scarus globiceps

Scolopsis ciliata

Scolopsis margaritifera


Scolopsis monogramma


Scomberoides tol


Selar boops


Siganus guttatus

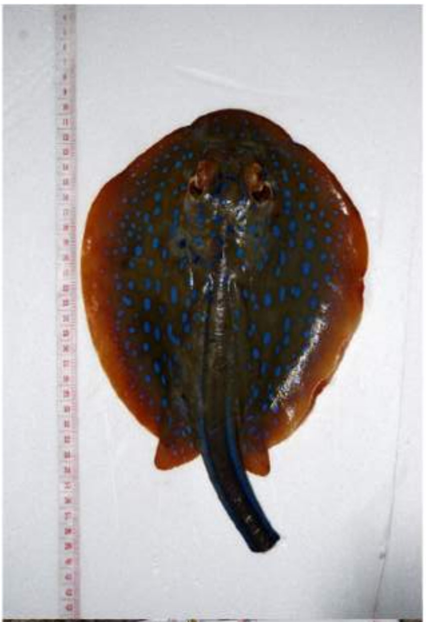

Siganus punctatus


Siganus virgatus


Sillago ingenuua


Sillago sihama


Sphaeramia orbicularis



Taeniura lymma

Sphyraena jello

Sphyraena barracuda

Tylosurus punctulatus

Trachinotus blochii

Terapon theraps

Gerres oyena

Megalops cyprinoides

Upeneus tragula

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