Feeding habits of five dominant fish species from Matang Mangrove Estuaries, Malaysia based on stomach contents and stable isotope analyses

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Abstract

The centres of mangrove biodiversity and productivity have been under-represented in studies of fish diet and habitat utilization, particularly in relation to environmental changes between wet and dry seasons. Feeding habits of five dominant fish species (*Thryssa kammalensis*, *Ambassis gymnocephalus*, *Escualosa thoracata*, *Stolephorus baganensis* and *Johnius belangerii*) were investigated from two sites in the Matang Mangrove ecosystem, Perak Malaysia, with sampling encompassing both wet and dry seasons. The stomach fullness of the fish was on average significantly higher in the wet season (48%) than in the dry season (32%) with isopods and copepods forming a more important component of the fish diet during the wet season than the dry season. The stomach contents of each species were, on average: *T. kammalensis* {(Animal based (A) = 50.11%, Plant based (P) = 38.24%)}, *A. gymnocephalus* (A = 50.35%, P = 37.99%), *E. thoracata* (A = 42.09%, P = 44.4%), *S. baganensis* (A = 38.17%, P = 46.55%) and *J. belangerri* (A = 25.35%, P = 58.86%). Therefore, all five fish species can be considered omnivorous. The similarity among diets varied from 60-80% during the wet and dry season. During the dry season, stable carbon and nitrogen isotope values of the samples had less variation, indicating narrow dietary sources compared to the wet season where the distribution of their isotopic values was larger. Seasons should be considered for planning mangrove management, as results of this study found contracted trophic breadth for commercially valuable fish in the dry season.

Introduction

The relatively high abundance and diversity of fish within mangroves (Nagelkerken et al. 2008; Whitfield et al. 2017) suggests a preferential use of mangrove forests as nursery areas (Blaber 2007), particularly given the prevalence of juvenile fish compared to adjacent estuarine habitats (Hindel and Jenkens 2004; Sheaves et al. 2015). However, the literature has been biased towards studies in Australia and the United States (Whitfield et al. 2017) with less consideration given to the global centres of mangrove biodiversity and productivity in tropical SE Asia. Recent Malaysian studies have stressed the importance of fish movements between nearshore feeding habitats (Le et al. 2020) with larger juvenile fish moving to the mangrove fringe during high tide periods to prey on mangrove infauna (Le et al. 2018), in common with subtropical systems (Saintilan et al. 2007), with which they share trophic structural similarities (Mazumder et al. 2019).

Seasonal variability in fish visitation and habitat use in mangrove ecosystems may be more important than diel variability. This is true of subtropical systems subject to thermal controls restricting fish recruitment in winter months, both in the Northern Hemisphere (Wu et al. 2018) and Southern Hemisphere (Mazumder et al. 2005). Tropical wet-dry cycles control the input of nutrients and turbidity from the catchment (Schlacher et al. 2008) and influence thermal and salinity conditions important to the distribution of marine fishes. Seasonal variability in the availability of zooplankton has been linked to recruitment of juvenile fish into mangroves of tropical northern Australia (Robertson and Duke 1987, 1990). This may also be why fish in northern Brazilian estuaries show strong recruitment into mangrove creeks at the onset of the rainy season (Barletta et al. 2003). Previous Malaysian studies have considered diet during the dry season only (Le et al. 2018, 2020). However, one of the most important aspects affecting fish population dynamics is the abundance and availability of food items for fish species in this habitat (Faunce and Serafy 2006) which vary between wet and dry phases. Knowledge of feeding habits of these fish is an indispensable tool in the categorization of fish with respect to their diets and mode of feeding (Allison and Sikoki 2013). The food habits of fish species are fundamental when selecting fish for culturing to prevent competition, which may vary due to seasonal changes in food and between species (Das et al. 2012). In addition, information obtained from feeding habits would be applicable for the protection of the species and the ecosystem at large (Turan et al. 2005; Alhassan and Ansu-Darko 2011).

The standard method of determining diet is through the analysis of stomach contents (Manon and Hossain 2013), which classifies the diet through macroscopic and microscopic examination (Hyslop 1980) and highlights the abundance of each food item found within the stomach integrated over a few hours (Mohan and Sankaran 1988). There is an emerging trend of using stable isotope analysis (SIA) as an alternative or in conjunction with stomach content analysis (West et al. 2003), which integrates food consumption over longer periods (Lewis et al. 2001). As organisms consume sources of stable carbon and nitrogen, the isotopic values are transferred to the consumer in a predictable manner (Fry 2006). SIA can be used to determine the pattern or trend of dietary preferences of samples, and can determine the diets with a higher accuracy (Peterson 1999) as not all items ingested are incorporated into animal tissue. In most circumstances, SIA is used to calculate the values of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in organisms (Livingstone 2002).

Matang mangrove estuaries, are situated at the northern part of Peninsular Malaysia and comprised of mudflats and tidal forested areas (Gan, 1995). There are approximately 8,653 ha of mudflats adjoining the mangrove forest in the foreshore and between islands (Sasekumar et al. 1994). About 85% of the forests are productive forests (logging and timber activities) while the remaining 15% are used for aquaculture purposes, where numerous rivers and waterways have shown to be important nursery areas for commercially-valuable marine organisms like fish and prawns (Sasekumar et al. 1994; Chong 2006; Chew et al. 2007). The coastal area (< 30 nautical miles from shore) is a major contributor to the total annual marine production in Peninsular Malaysia (Anon 2009), and this location has been the subject of numerous studies to elucidate the importance of the environment across various fields of fisheries (Sasekumar et al. 1994; Chong et al. 2001; Ahmad Adnan et al. 2002; Chong 2007; Chew and Chong 2011; Mohd Azim et al. 2017). A limitation in these studies is the lack of stomach content and stable isotope analyses, which are still scarce in Malaysia and neighbouring countries. This is unfortunate because a thorough understanding of the food web and trophic linkages of fish and their dependence on mangroves is not possible without a complete knowledge of their feeding history. The lack of food and feeding habit studies is mainly due to the number of samples needed, the time-consuming examination of fish samples, and the cost of analysing samples using stable isotope procedures. Although there have been several studies examining the stable isotopes of fish in Matang mangrove estuaries (Kiso and Mahyam 2003; Tanaka et al. 2011), they only cover a few targeted species, nor did sampling span the full range of wet and dry season conditions.

The objective of the present study is to expand the previous findings by observing the feeding habits of five dominant fish species, based on stomach contents and stable isotope analyses, documenting changes in stomach fullness and diet composition in wet and dry seasons.. We hypothesize that stomach fullness will be greater and dietary breadth broader during the wet season, corresponding to high productivity and the recruitment of additional food items during this period. This will reveal the primary sources of autotrophic production for these species and the trophic linkages within the marine-mangrove food web of the Matang mangrove estuary.

Materials And Methods

Study Area

The study was conducted in the estuarine waters of Matang mangrove forest reserve (MMFR), Perak, Peninsular Malaysia (Fig.1) between September 2015 and August 2016. This area forms a large crescent-shaped strip along the northern coast of Perak state, stretching as far as 51.5 km from Kuala Gula (4º55’N, 100ºE25’) to the north and to Bagan Panchor (4º40’N, 100ºE40’) to the south measuring about 13 km wide. Matang mangrove is built on deltaic islands (Gula Island, Kelumpang Island, Selinsing Island, Sangga Kecil Island, Sangga Besar Island, Terong Island and Pasir Hitam Island) criss-crossed by major mangrove channels (Tinggi River, Tiram River, Sepetang River, Terusan Gula River, Selinsing River, Sangga Besar River, Sangga Kecil River, Jaha River and Jarum Mas River).

Sample Collection

Fish samples were obtained from local fishermen who operated push net boats in MMFR areas as their main source of income. This medium size of motorized boat was operated by using trawling method but unlike any other common trawling boat, the net was attached at the front side of the boat, with the net specification of 14.0 – 15.0 m in length, 2.0 – 5.0 m in width, and 2.5 – 5.0 cm in mesh sizes. Usually, the fishermen caught the fish during daylight when the tides were high. Five dominant fish species, namely *Escualosa thoracata*, *Thryssa kammalensis, Ambassis gymnocephalus, Stolephorus baganensis* and *Johnius belangerii* were selected for this study as they the were the most abundand species in the area. The sample sizes of the collected samples ranged from 5.0 cm – 20.0 cm.

For stomach content and stable isotope analyses, five most dominant species were collected from two stations (fish landing sites), namely S1 (04°52'41”N, 100°E34‘32”) and S2 (04°44'45”N, 100°E36'26”) (Fig. 1). These geographic locations were considered sufficient enough in covering all fish species available in the study area. The climate in MMFR and the surrounding area consisteds of two main seasons, the wet season from November until January and the dry season between February and April. Five replicate (n=5) samples for each species were collected twice during each season at study sites to obtain the required number of samples.

Stomach Fullness and Content Analysis

In the laboratory, fish samples were cleaned and surface moisture was blotted out using tissue paper. For each fish, the standard and total lengths were measured and dissected using a dissection kit to remove the stomach. The degree of stomach fullness was observed and recorded. This was done using an empirical scale (Table 1). The stomach was then preserved in 5% formalin for further study.

Examination of the stomach content was done within 2-3 days of preservation. Prior to stomach examination, the stomach was cleaned and excess moisture blotted out using tissue paper. The stomach was then dissected, and its contents weighed to the nearest 0.01g using a digital weighing balance (Model- AY220, Shimadzu Corporation, Japan). The stomach contents were examined both macroscopically, and microscopically under a microscope (Model- EMT 21444, Labax Co, Japan), for taxonomic classification and identification of the various food items with the aid of standard reference texts of Lovett (1981); Seng, (1994) and Tan and Ng (1994).

The analysis of the stomach content was done using the percentage frequency of occurrence (F_{pi}) and percentage numerical abundance (C_i) for each prey item, according to the method by Chrisfi et al. (2007):

Percentage frequency of occurrence (F_{pi}) = $(N_{1i}/N_p) \times 100$

where:

N_{1i} = number of stomach of which food item i was found

N_p = number of non-empty stomach

Percentage numerical abundance (C_i) = $ni/\sum_{i=1}^{m} ni \times 100$

where:

ni = number of i-th food item

m = number of food items

The relative importance of prey in the diets of the five dominant fish species in the Matang mangrove estuaries was examined by the simple resultant index (% Rs) according to Mohan and Sankaran (1988) as follows:

$$\text{Simple Resultant Index (\% Rs)} = \frac{\sqrt{C_i^2 + F_{pi}^2}}{\sum_{i=1}^{m}\sqrt{C_i^2 + F_{pi}^2}} \times 100$$

Where C_i is the percentage numerical abundance and F_{pi} is the percentage frequency of occurrence.

Multivariate techniques in PRIMER v7 software (Clarke and Gorley 2015) were used to compare stomach fullness and food items composition among major species. The numerical abundance of the identified stomach fullness and food items were square root transformed and a similarity matrix based on the Bray-Curtis similarity index was then constructed and subjected to hierarchical agglomerative clustering (group average linkage) and non-metric multidimensional scaling (nMDS) ordination (Clarke et al.

2014). To assess the composition of food items across seasons, a shade plot was produced by clustering the major species on the *x*-axis based on Bray–Curtis similarity, with the most common and abundant food items on the *y*-axis (Clarke and Gorley, 2015). The similarity profile test (SIMPROF) was applied to determine the significant differences among clusters (Clarke et al. 2008).

Stable Isotope Analysis

Sample processing was undertaken in a filtered-air room laboratory and powder-less laboratory gloves were worn at all times to minimise contamination. The fish brought in from the field were washed with distilled water and kept frozen until processed. White muscle tissue from the dorsal region of fish was collected, as this tissue has been shown to be representative of overall stable isotope signatures in fish and to be less variable than other tissues (Hesslein et al. 1993; Pinnegar and Polunin 1999). Lipid extractions were not undertaken, as delipidation from muscle tissue appears to lead to only small (1%) isotope shifts in $\delta^{13}C$ and $\delta^{15}N$ values (Sotiropoulos et al. 2004). Muscle tissue samples were dried at 60ºC for 72 hours and then ground to a fine powder with a mortar and pestle. 0.5 ± 0.05 mg powdered and homogenised whole-body samples were loaded into tin capsules and were analysed with a continuous flow isotope ratio mass spectrometer (CF-IRMS; Model Delta V Plus; Thermo Scientific Corporation, Waltham, MA, USA) that was interfaced to an elemental analyser (Thermo Fisher Flash 2000 HT EA; Thermo Electron Corporation, Waltham, MA, USA) at ANSTO. Data were reported relative to IAEA secondary standards certified relative to VPDB for carbon and air for nitrogen. A two-point calibration was employed to normalize the isotope data, utilizing standards that bracket the samples being analyzed. Two quality control reference samples were also included in each run. Results were accurate to +/- 1% for both %C and %N and +/- 0.3 parts per thousand for $\delta^{13}C$ and $\delta^{15}N$. Stable isotope values were reported in delta (d) units in parts per thousand (‰) relative to the international standard and determined as follows:

$$X(‰) = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \times 1000$$

where $X = \delta^{13}C$ or $\delta^{15}N$, and $R = {}^{13}C/{}^{12}C$ or ${}^{15}N/{}^{14}N$, respectively. Since the lipid content of tissue is related to the molar ratio of carbon to nitrogen (C:N), when C:N was > 3.5 (e.g. high lipid content), the lipid content for muscle tissues were normalized using mathematical equations suggested by Post et al. (2007): $\delta^{13}C_{normalised} = \delta^{13}C_{untreated} - 3.32 + 0.99 \times C{:}N$.

Results

Stomach fullness

Overall, the mean percent of stomach fullness of five dominant fish species varied between seasons (Table 2). However, similarities were found for stomach fullness between wet and dry season; 91.08%, 84.80%, 82.30%, 68.48% and 65.52% for *S. baganensis, E. thoracata, T. kammalensis, J. belangerii* and *A. gymnocephalus*, respectively. Additionally, the cluster analysis showed more than 80% similarity of stomach fullness among the *S. baganensis, E. thoracata* and *T. kammalensis* between wet and dry seasons, while the other two species (*A. gymnocephalus* and *J. belangerii*) were less than 70% similar between the two seasons. The Multi-Dimensional Scaling (MDS) ordination analyses showed three distinct groups at 80% similarity with empty stomach found only in *A. gymnocephalus* and *S. baganensis* during both seasons (Fig. 2).

Diet composition

Analyses of the different prey items by using simple resultant index (% Rs) on the five dominant fish species revealed 19 important items belonging to three major groups: plant based diets, animal based diets and debris (Table 3). According to % Rs, plant based (phytoplankton, algae and plant leave) and animal based (zooplankton, unidentified fish parts, fish & crustacean parts) diets varied between wet and dry seasons for all species. Higher %Rs animal diets were found for *E. thoracata*, *T. kammalensis* and S*. baganensis* respectively in the dry season. *J. belangerii* had higher %Rs animal diet in both wet and dry seasons. *A. gymnocephalus* consumed higher % Rs in plant and debris materials compared to other species in both wet and dry seasons, respectively (Table 3). All these species consuming d both plant and animal diets in both wet and dry seasons indicate their omnivore feeding status. The highest similarity (89.37%) of diet composition was observed between *A. gymnocephalus* and *S. baganensis,* while the lowest similarity (77.45%) was found between *J. belangerii* and *E. thoracata*. Overall, there was an 80% similarity among the five dominant species according to MDS analysis (Fig. 3).

Variation of prey between wet and dry season

Similarities of diet composition between wet and dry season were 85.05%, 77.40%, 72.25%, 70.28% and 60.03% for *S. baganensis, J. belangerii, T. kammalensis, E. thoracata* and *A. gymnocephalus*, (Fig. 4) respectively. The highest similarity (85.05%) of diets between wet and dry season was observed in *S. baganensis*, while the lowest similarity (60.03%) was found in *A. gymnocephalus.* For inter-species comparison, diets similarity of *E. thoracata* and *T. kammalensis* was at 80% in the wet season indicating that both species share 80% similar diets in the wet season (Fig. 5). Additionally, the diet similarity of *S. baganensis* and *A. gymnocephalus* was also 80% in the dry season, suggesting higher competition for these species in getting food. Overall there was 60% similarity of diets between wet and dry season for four species except *S. baganensis* (Fig. 5)

Food web for five major fish species

In the dry season, stable carbon and nitrogen isotope values of five major species had narrow distribution (range from -19.20‰ to -20.96‰ for $\delta^{13}C$ and from 12.96‰ to 13.64‰ for $\delta^{15}N$) indicating a smaller dietary diversity compared to the wet season where the distribution of their isotopic values were larger (Fig. 6). In the dry season, $\delta^{13}C$ and $\delta^{15}N$ values of the species were more enriched compared to the wet season. The only exception was *S. baganesis*, where the $\delta^{13}C$ value was enriched in the wet season. Among the five species analysed, an obvious dietary shift was observed for *E. thoracata* and *A. gymnocephalus* (Fig. 6). The isotopic shift of *E. thoracata* was 3.3 ‰ for $\delta^{13}C$ and 2.3 ‰ for $\delta^{15}N$ and for *A. Gymnocephalus,* this isotopic shift was 2.6‰ for both $\delta^{13}C$ and $\delta^{15}N$ in the wet season. In the wet season, the $\delta^{13}C$ and $\delta^{15}N$ values of *E. Thoracata* and *A. Gymnocephalus* were more depleted, suggesting a higher intake of mangrove sourced materials in the diet.

Discussion

Wet-dry seasonal cycles are characteristic of tropical mangrove coastlines in northern Australia, Indo-china, western Africa, Central and Southern America and parts of North America (Abrantes et al. 2015). Characterisation of the composition and structure of mangrove food-webs must therefore consider changes driven by seasonal climate, and the potential influence of zooplankton recruitment, autotroph productivity and halo-thermal habitat availability. Greater abundance of fish in mangrove creeks during the wet season has been observed in Thailand (Ikejima et al 2003), northern Australia (Robertson and Duke 1990) and Brazil (Barletta et al. 2003). Fish in small northern Australian estuaries subjected to wet-dry seasonality showed greater diet similarity in the wet season than the dry season (Abrantes et al. 2015).

The stomach fullness of five dominant fish species of the Matang estuary mangrove forest was higher in the wet season (48%) than the dry season (32%). This pattern might be due to the fact that longer rain duration washed a higher abundance of food sources from upstream to downstream compared to the dry season, and the increased occurrence of zooplankton in the estuary during the wet season. Isopods and copepods formed more important components of the fish diet during the wet season compared to the dry season (Table 3). This finding is in agreement with studies from the Bay of Bengal (Bangladesh), KwaZulu Natal (South Africa) Marudu Bay (Sabah, Malaysia) which also showed higher variability and abundance of fish during the wet season (Robertson and Duke 1990; Barletta et al. 2003; Nagelkerken et al. 2008) co-incident with increased zooplankton abundance. In arid-zone mangroves, fish abundances may be higher in winter, though this is also co-incident with a greater range of food sources (Shahrika and Fry 2016).

Our study indicates that *E. thoracata, T. kammalensis, A. gymnocephalus, S. baganensis* and *J. belangerii* were omnivores. It is clear that *J. belangerii* in this study fed on a higher animal based diet (% Rs > 60%) in both seasons than the other four species, confirming its position as the top order predator in the Matang mangrove (Mazumder et al. 2019). This finding is in line with a previous study by Chong (2005), Kiso and Mahyam (2003) and Tanaka et al. (2011) which stated that the coastal and estuarine areas in Peninsular Malaysia especially in the Straits of Malacca were predominantly inhabited by either carnivorous or omnivorous fish that depend highly on smaller items of animal derivatives as their main source of diet.

The stable carbon and nitrogen isotope values of the five species clustered closely in the dry season and had narrow distribution suggesting limitation of dietary sources compared to the wet season. Whereas in the wet season, the dietary diversity for the five species have been increased as revealed by their wider distribution of isotopic values. This is most likely due to a higher abundance of dietary materials available for species in the wet season. This is also in agreement with the findings from stomach fullness, which showed a higher occurrence of full stomach during wet season.

A distinct dietary shift was also observed for *E. thoracata* and *A. gymnocephalus*. In the wet season, mangrove-sourced materials when compared to the dry season mostly influenced the diet of these two species. It could be assumed that during the wet season, a higher amount of mangrove detritus enter the estuary through flood or rain water from the surrounding mangroves, as indicated by depleted C and N isotope ratios for these two species. Previous studies in the same site by Tanaka et al. (2011) and Kiso and Mahyam (2003) showed generally depleted C values in the mangrove estuaries of the targeted fish species because of the higher precipitation during rainy season, which is comparatively similar to the situation in the present study. Furthermore, the findings of this study are also in agreement with the findings of the Australian floodplain study where food supplies in flood plain habitats were restricted during dry conditions and species dietary richness were narrowed down (Mazumder et al. 2006, 2011). The segregation of trophic components in this cluster analysis is a helpful tool in the development of conceptual models of ecosystem functions in a linked mangrove–estuarine ecosystem (Robinson and Frid, 2003; Marguillier et al. 1997).

Declarations

Availability of Data and Material: All data produced or analyzed during this study are included in this manuscript.

Code Availability: Not applicable.

Authors' Contribution: M. K. Mohd Azim conducted sampling, laboratory work and wrote the draft manuscript. S. M. Nurul Amin designed the research, supervised and edited the manuscript. D. Mazumder analyzed the samples of stable isotope and edited the manuscript. A. Arshad, F. M. Yusoff provided financial support, checked the analysis and edited the manuscript. N. Saintilan provided critical insights, interpretations and editing to finalize the manuscript.

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Tables

Table 1 Empirical scale of stomach fullness separated into five classes as outlined for the study of major five species in the Matang mangrove estuaries, Perak, Malaysia

Fullness classification	**Description**
Full stomach	Stomach massively stuffed with enormous amounts of small prey or a few large preys.
¾ full stomach	Stomach adequately stuffed with substantial amounts of small preys or a few large preys.
½ full stomach	Stomach moderately stuffed with adequate amount of prey.
¼ full stomach	Stomach slightly stuffed with a few or substantial small preys.
Empty stomach	Stomach scarcely stuffed with no or/and few small preys.

Table 2 Variation of stomach fullness (%) of five major fish species between wet and dry season in Matang Mangrove Estuaries, Perak, Malaysia

Species	Wet Season						Dry Season					
	N	1	¾	½	¼	0	N	1	¾	½	¼	0
E. thoracata	5	70%	10%	10%	10%	0%	5	40%	10%	20%	30%	0%
T. kammalensis	5	40%	0%	50%	10%	0%	5	20%	20%	50%	10%	0%
A. gymnocephalus	5	30%	10%	30%	20%	10%	5	10%	0%	70%	0%	20%
S. baganensis	5	50%	20%	20%	0%	10%	5	30%	20%	40%	0%	10%
J. belangerii	5	50%	30%	20%	0%	0%	5	60%	0%	20%	20%	0%
% Mean Occurrence	100	48%	14%	26%	8%	4%	100	32%	10%	40%	12%	6%

(N, number of fish; 1, full stomach; ¾, three quarters full stomach; ½, half full stomach; ¼, quarter full stomach; 0, empty stomach)

Table 3 Simple Resultant Index (%Rs) of overall diet composition for five major fish species in Matang Mangrove Estuaries, Perak, Malaysia

Food Items	*E. thoracata*		*T. kammalensis*		*A. gymnocephalus*		*S. baganensis*		*J. belangerii*	
	Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
Plant based diet										
1. *Cosinusdiscus* sp.	17.00	9.42	17.00	8.40	5.50	11.00	22.86	14.70	3.05	0.00
2. *Navicular* sp.	12.69	0.00	5.06	2.98	9.08	9.05	3.89	0.00	0.00	0.00
3. *Achanthes* sp.	0.00	8.17	3.18	5.75	0.00	11.21	0.00	13.78	0.00	2.61
4. *Pinnularia* sp.	0.00	7.31	0.00	0.00	0.00	11.92	0.00	4.71	0.00	0.00
5. *Pleurosigma* sp.	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Plant leaves	9.89	31.09	20.43	24.63	37.64	3.96	7.14	3.68	20.00	18.10
Total	41.39	55.99	45.67	41.76	52.22	47.14	33.89	36.87	23.05	20.71
Animal based diet										
7. Mysid	0.00	2.40	5.38	3.12	7.50	11.21	4.60	17.12	0.00	0.00
8. Amphipod	5.87	6.06	8.14	6.41	0.00	15.68	13.21	11.50	2.30	17.69
9. Copepod	0.00	0.00	0.00	2.98	21.03	4.35	3.89	0.00	0.00	0.00
10. Crab larvae	0.00	0.00	0.00	6.37	0.00	4.91	0.00	0.00	1.81	0.00
11. Isopod	3.05	0.00	2.69	0.00	0.00	0.00	8.47	3.64	16.95	3.55
12.Crustacean appendages	5.22	9.90	2.69	24.33	0.00	0.00	0.00	0.00	6.03	8.94
13. Shells	15.31	21.28	7.05	0.00	0.00	0.00	0.00	0.00	1.81	3.97
14. Eggs	4.07	0.00	7.05	2.70	6.34	4.34	8.60	7.23	1.81	1.98
15. Scales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.05	4.15
16. Small fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.63	6.52
17. Small shrimps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.03	9.37
18. Unidentified fish parts	8.94	4.55	7.33	9.76	6.34	8.23	8.60	12.62	7.25	9.37
Total	42.46	44.19	40.33	55.67	41.21	48.72	47.37	52.11	61.67	65.54
19. Debris	16.57	0.28	14.37	2.98	6.85	4.34	19.21	11.50	15.58	14.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Figures

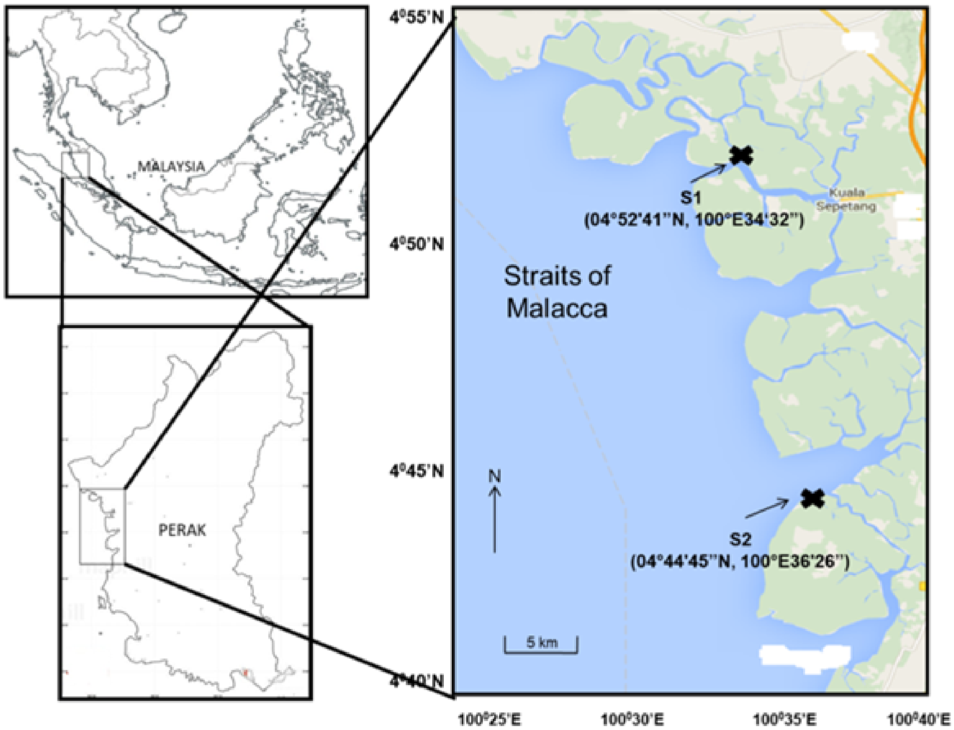

Figure 1

Geographical location of sampling stations (S1 and S2) in Matang Mangrove Estuaries, Perak, Malaysia. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

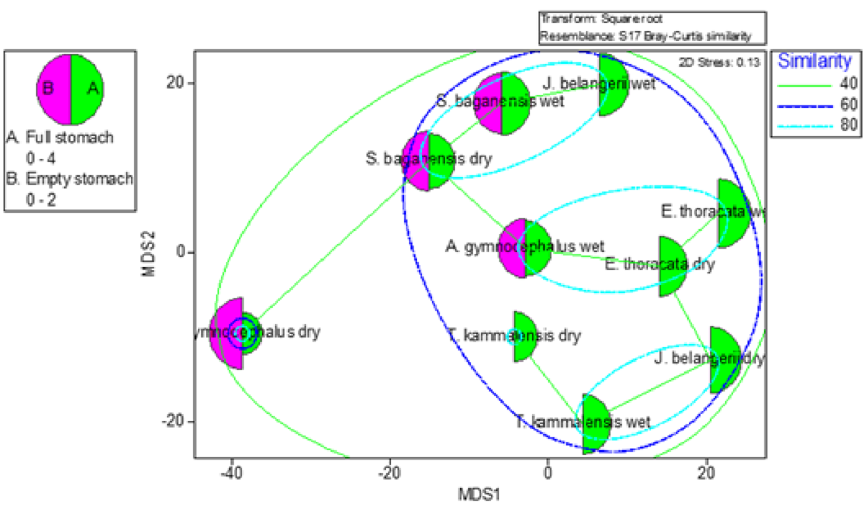

Figure 2

Ordination plot of stomach fullness for five dominant fish species for using Multi-Dimensional (MDS) analyses in Matang Mangrove Estuaries, Perak, Malaysia (Wet = wet season; Dry = Dry season)

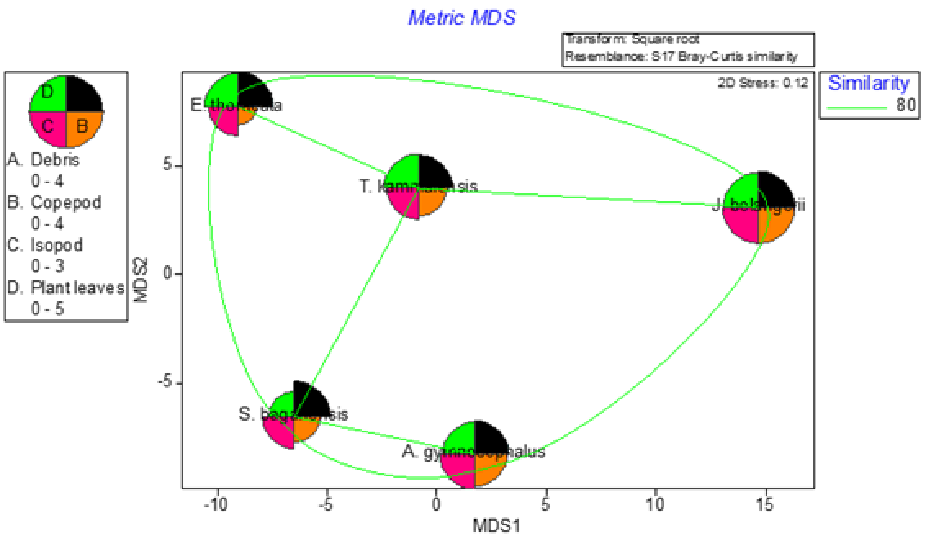

Figure 3

Ordination plot for dominant diet (debris, copepod, isopod and plant leaves) of five dominant fish species using Multi-Dimensional Scalling (MDS) analyses in Matang Mangrove Estuaries, Perak, Malaysia

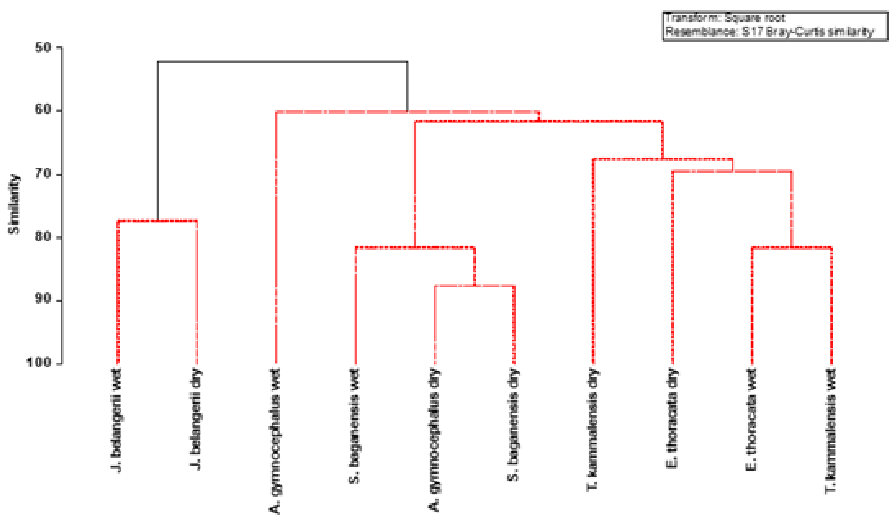

Figure 4

Dendrogram of cluster analysis showing similarities percentage of diet composition in wet and dry season of five dominant fish species in Matang Mangrove Estuaries, Perak, Malaysia (wet = wet season; dry = dry season)

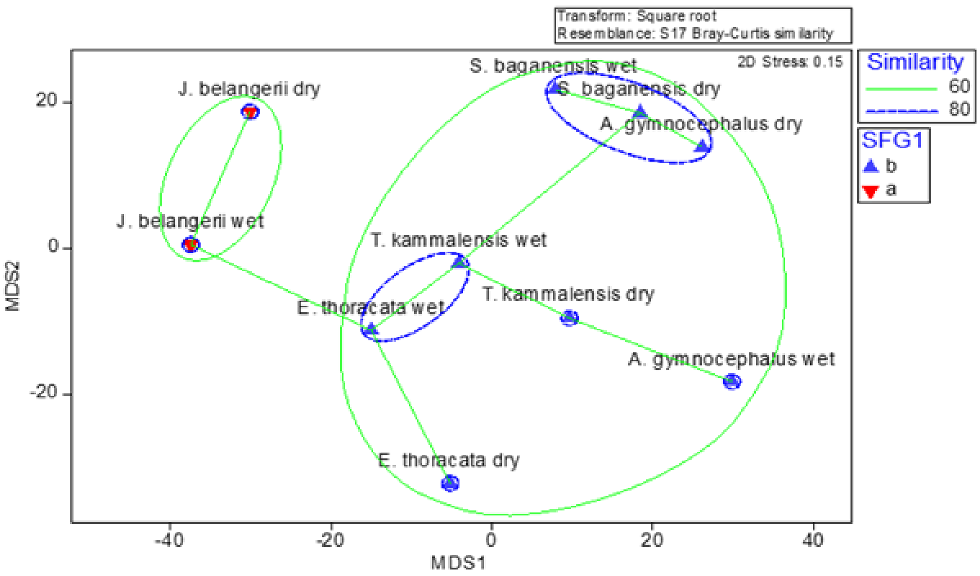

Figure 5

Ordination plot between wet and dry season for diet composition data of five dominant fish species using Multi-Dimensional (MDS) analyses in Matang Mangrove Estuaries, Perak, Malaysia (wet = wet season; dry = dry season)

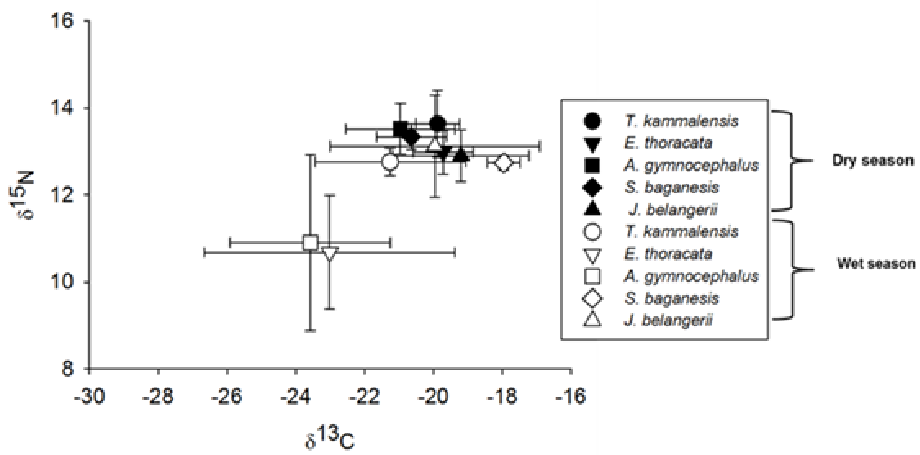

Figure 6

Dual isotope plot of δ13C and δ15N showing trophic interactions between wet and dry season in five dominant fish species in Matang Mangrove Estuaries, Perak, Malaysia