Jurnal
Teknologi

Full Paper

FOOD PARTITIONING AMONG FISHES IN PAHANG RIVER-ESTUARY, MALAYSIA

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Article history
Received
30 June 2015
Received in revised form
18 September 2015
Accepted
19 October 2015

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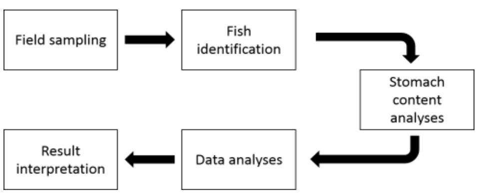
Graphical abstract



Abstract

A study was conducted on the food resource partitioning among fish species in Pahang River-estuary from 2010-2013 during pre-monsoon and post-monsoon period. The area was divided in three strata (upstream, downstream and middle zone), based on environmental features. Stomach contents of all species present were analyzed. From 138 of total stomach analyzed, 24 of them were empty and 114 were with food. From the analysis of prey in the stomachs, various kinds of food items consumed by the different size of fishes included phytoplankton, zooplankton, unidentified materials, fish, fish parts, shrimp, shrimp parts, crab, crab parts, plant parts, mollusk and detritus. Detritus consisted of all types of biogenic materials in various stages of microbial decomposition. Different fishes consume different types of food and feeding habit of fishes varies from season to season. From the percentage of number and occurrence of food resources, zooplankton are important in their own right as a major component of fish diets and are especially important to small and young individuals, even for the detrivore. Nevertheless, it represents an important trophic resource for fish food web of Pahang River-estuary.

Keywords: Stomach, Pahang River-estuary, food partitioning

1.0 INTRODUCTION

In the past two decades, our understanding of the understanding of aquaculture and terrestrial ecology communities has advance considerably. The basic understanding of ecological interaction processes have been well documented [1]. However, progress in defining processes affecting fish assemblages was slow. Among the factors contributing to this slower pace include difficulties in sampling and observation, great diversity, problematic taxonomy, and large differences in life history characteristics [2].

Food habit is useful piece of information in fish ecology, it give an understanding of interaction between predator and prey. Cumulative information on different food item consumed by a specific fish species demonstrated feeding habit and food preferences. This information also illustrates the trophic level in certain ecological structure. This data composition gathered together will produce trophic models that act as a tool to understand complex ecosystem. Understanding the interaction among individual in a complex ecosystem is crucial in managing conservation of biodiversity in any ecological system. Any organism play their important role in ecosystem, from smallest bacteria and plankton to the largest living organism serve their function in creating a balance ecosystem.

For an example of how complex ecology relies on each other is competition. When different species share the food source competition will occur. However, the more source they share the greater the competition between this species. The shift in balance between the species sharing the same source or the availability the food source will give a big impact, most probably the weaker will vanquish.

In fisheries management, trophic interactions are among core issues to be considered in implementing any decision. Among the interaction in trophic level is feeding behavior, the dynamic interaction between organism in the ecosystem as prey and predator. This dynamic interaction of feeding behavior in ecology will illustrate responses to exploitation. Understanding the functional role of a specific species is very important in fisheries management [4]. Therefore, this study was conducted to understand the feeding habit of fishes in Pahang River estuary.

2.0 EXPERIMENTAL PROCEDURES

2.1 Stomach Content Analyses

Fishes were collected with gill net and bubu trap within the sampling area. The stomachs of a total of 138 fishes were excised, they were sexed by gonadal inspection and then preserved in 10% formalin for further studies and identification of the food. A recognized portion of food was found in the stomach, while the rest of the gut was ignored as suggested by Gerking [5].

Food items, partly in the stomach and partly in the esophagus, were included with the stomach contents as done by Baker et al. [6]. In fish species without distinct stomachs, the contents of the whole gut were examined with each specimen considered individually. Data from stomach contents were analyzed in the following ways: (i) percentage in number of the total number of food items eaten; (ii) percentage in volume of the total volume of food eaten; (iii) frequency of occurrence in the number of fish sampled.

Relative importance index (RIa) adopted from Hayes [7] and Jalal [8]. It used to measure the importance of specific organism in the diet of predator, where measurements of numbers, volume and frequency of occurrence in evaluating stomach content will be done.

2.1.1 Numerical Score

The numerical methods are relatively fast and simple to operate provided that identification of prey items is feasible [9]. In this method, the large organisms were counted directly, and their proportion was determined by dividing the total number of each food organism by the total number of all food items. For smaller food items such as plankton, a Sedgewick Rafter counting cell was used [10]. The cell holds 100 cm^3 of liquid 1 millimeter deep over an area of 50x20 mm. The base is divided into 1 mm^2. A cover glass traps liquid to the correct depth. By observing the liquid through a low magnification microscope, objects contained in each cm^3 were identified and counted.

2.1.2 Volumetric

This technique probably gives the most representative measure of bulk and may be applied to all food items [11]. In this technique, each of the stomachs was carefully dissected open to get all the food mass as a single lump. To get the volume, the lump of food was then placed on filter paper to remove loose moisture, and was measured by the displacement of water in a graduated cylinder. The food mass was then transferred to a glass petri dish and a considerable amount of formalin was added to it. The food mass was teased apart and a few drops of acetone was added to precipitate the mucus like material. The food items were identified to the lowest taxon according to Pimentel [12]. Volumetric analysis was carried out by direct and indirect methods.

2.1.3 Direct Estimation

In this method, the piles of each food item were dried of excess water or formalin then transferred to the graduated cylinder for volumetric measurement by displacement of water. Thus, the volume of each food item was calculated in relation to the total volume of food.

2.1.4 Indirect Estimation

This method was employed in the case of small food items and well digested matter. It was done by modified method for the estimation of minute contents [5]. In this method, the total volume of stomach contents and volume of each of the separable components were estimated. The differences between the former and the sum of the latter values gave an estimate of the volume of the remaining stomach.

2.1.5 Frequency of Occurrence

The simplest way of recording data gleaned from stomach contents is to record the number of stomachs containing one or more individuals of each food category [5]. In this method, the contents of each stomach were examined and the individual food organisms were sorted and identified. The number of stomachs in which each item occurs were recorded and expressed as a percentage of the total number of stomachs examined.

2.2 Data Analyses

2.2.1 Relative Important Index

Individually, each of the three methods described above can produce different estimates of prey importance and their combination into one index (RI) is an attempt to balance the contribution of each and to gain a more accurate picture of dietary importance. The indices combining values from different sources are more representatives [8]. Thus, percentage of volume, number and occurrence for each item were summed and expressed as an absolute importance index (AIa) which was then substituted into the expression for relative important index (Ria):

$$Ria = 100\ AIa \Big/ \sum_{a=1}^{n} AIa$$

Where,
AIa = the percentage volume + percentage number + percentage frequency of occurrence, for food item 'a',
n = the number of different food types.

3.0 RESULTS AND DISCUSSION

From 138 of total stomach analyzed, 24 of them were empty and 114 were with food. From the analysis of prey in the stomachs, various kinds of food items consumed by the different size of fishes included phytoplankton, zooplankton, unidentified materials, fish, fish parts, shrimp, shrimp parts, crab, crab parts, plant part, mollusk and detritus. Detritus consisted of all types of biogenic materials in various stages of microbial decomposition. Different fishes consume different types of food and feeding habit of fishes varies from season to season (Table 1).

Table 1 Stomach content analysis with Absolute Importance Index (Aia) and Relative Important Index (RIa) for food partitioning of fishes in Pahang River-estuary

Family	Food	Ai_a	Ri_a
Pristigasteridae (n=5)	Detritus	133.34	41.67
	Fish Part	84.87	26.4
	Crab Part	12.96	4.05
	Fish	64.81	27.88
Engraulidae (n=3)	Detritus	68.48	24.3
	Fish Part	176.96	62.79
	Shrimp Part	36.37	12.91
Cyprinidae (n=2)	Zooplankton	29.21	57.3
	Phytoplankton	170.79	42.7
Scieanidae (n=10)	Fish Part	87.04	37.4
	Mollusca	28.74	12.35
	Shrimp	86.76	37.24
	Fish	30.28	13.01
Mugilidae (n=2)	Fish Part	66.67	66.67
	Detritus	33.33	33.33
Polynemidae (n=1)	Fish only	-	-
Latidae (n=5)	Shrimp	255.5	77.93
	Fish	27.57	8.42
	Fish Part	10.27	3.14
	Shrimp Part	11.25	3.44
	Detritus	23.13	7.07
Osphronemidae (n=1)	Plant Part	200	50
	Unidentified	200	50
Eleotridae (n=1)	Crab Part	101.4	27.04
	Fish	44.4	11.84
	Fish Part	28.77	7.67
	Udang	167.94	44.78
	Detritus	32.49	8.66
Scatophagidae (n=1)	Plant Only	-	-
Ariidae (n=79)	Detritus	74.96	21.86
	Unidentified	59.59	17.38
	Mollusca	22.61	6.59
	Crab Part	8.72	2.54
	Crab	2.88	0.84

Family	Food	Ai_a	Ri_a
	Shrimp	5.36	1.56
	Shrimp Part	12.99	3.78
	Fish	52.56	15.32
	Fish Part	87.04	25.35
	Plant Part	16.17	4.72
Plotosidae (n=1)	Mollusca	275.65	78.76
	Unidentified	74.35	21.24
Pangasiidae (n=1)	Mollusca Only	-	-
Clupeidae (n=2)	Phytoplankton	253.93	63.48
	Zooplankton	146.08	36.52

The value of Absolute Importance Index (Aia) and Relative Important Index (RIa) of fishes of Kuala Pahang in all zones of sampling stations are represented in Table 1. In general, it was found that detritus were the major food item from the stomach, followed by fish part and fish throughout the season. From the Relative Important Index (RIa), detritus contribute 18.92%, fish and fish part 13.10% and 16.17%, respectively.

The abundance and availability of various food types differs with time and place [12]. Such variations in feeding were also observed during this study. Fish and fish part are found to be present in all month and were one of the most dominant food items. Fish and fish part are mostly found to be present in the stomach of Ariidae family. In the month of August, shrimp were the major prey found in the stomach of fishes caught in the study area.

Out of 14 families of fishes caught during the sampling period, the number of predator family was 10. The number of specimens caught that is predator was higher that herbivorous. From the stomach content, they are most likely to prey on small fishes, as the food identify from the stomach content. The herbivorous fish were found with food item identify as plant like matter or plankton (Table 2).

3.1 Pristigasteridae

For the Pristigasteridae family, detritus was the dominant food item found in their stomach with the % RIa of 41.67% followed by fish and fish part with the % RIa value 27.88% and 26.40%, respectively.

3.2 Engraulidae

From the analysis of stomach content, Engraulidae is found to feed mostly on fish based on the value of % RIa. Fish part contribute the most for the stomach content of this family with the value of 62.79% followed by detritus (24.30%) and shrimp part (12.91%). This shows that family Engraulidae were carnivorous fish however the high value of detritus is most likely to be accidentally.

3.3 Pangasiidae

The family of *Pangasius pangasius* was most likely to feed only on mollusk. From the analysis of stomach content of fishes sampled, the food item identified from this family only consisted of mollusk. This mean that *Pangasius pangasius* was molluscivore, which is a carnivorous animal, eats mainly mollusks.

3.4 Cyprinidae

From the stomach analysis of family Cyprinidae, phytoplankton and zooplankton were identified from the food item. Zooplankton was found dominant in the stomach of this family with the % RIa 57.30% and phytoplankton was 42.70%, respectively. Family Cyprinidae is a plankton feeder fish, so it occupies the upper region (surface waters) of water body. Cyprinidae feed by filtering plankton from the water (the main part of its diet) with gill rakers adapted to form a filtering apparatus.

3.5 Scieanidae

Investigation on fish stomach content of Scieanidae family shows that this family was carnivorous. The most important prey item for this family was fish and secondly shrimp, as fish and fish part % RIa was 13.01% and 37.40%, respectively, followed by shrimp with 37.24%. This composition was similar to Engraulidae family.

3.6 Mungilidae

The stomach content of this family were containing fish part and detritus, with the % RIa was 66.67% and 33.33%, respectively. This indicates that this family was carnivorous and piscivore that only feed on fish. The high number of detritus found in the stomach of this fish is mostly accidentally.

3.7 Polynemidae

From the analysis of stomach content of this family represent by *Eleutheronema tetradactylum*, only fish was found in the stomach of this species, this mean that this fish was highly piscivore as they only prey on other fishes. *Eleutheronema tetradactylum* are marine fish and inhabit mid to bottom waters. They can be found in estuaries and muddy rivers and occasionally enter freshwater. They are often found in association with mangroves, and form small schools in feeding and spawning habitats in coastal shallows.

3.8 Latidae

From the stomach content analysis of this family, the diet composition of the family represent by *Lates calcarifer* was consisted of fish, shrimp and detritus. The % RIa of this family was dominated by shrimp with 77.93%, followed by fish 8.42% and detritus with 7.07%, respectively. Others are from fish parts and shrimp part by the value of 3.14% and 3.44%, respectively. This fish was a carnivorous feeder that feed mostly on fish and shrimp. The high number of detritus found in the stomach of this fish mostly was accidental.

3.9 Osphronemidae

The family of Osphronemidae that is represented by *Osphronemus goramy* was classified by herbivorous fish, as the stomach content of this family was consisted of plant like matter and unidentified food item. The value of % RIa for plant part of this family was 50% which is similar as the unidentified food item found in the stomach of this fish.

3.10 Eleotridae

The stomach content of this family was represented by *Oxyeleotris marmorata*. From the stomach analysis of this family shrimp was identify to be dominant as the % RIa for this food item was 44.76% followed by crab part 27.04%, fish 11.84%, detritus 8.66% and fish parts 7.67%, respectively. The feeding habit of this family can be categorized as carnivorous and the occurrence of detritus found in the stomach of this fish mostly was accidental. From other studies, this species was feeding on small fishes, shrimps, aquatic insects, mollusks and crabs [13].

3.11 Scatophagidae

The family Scatophagidae was represented by *Scatophagus argus*. The analysis of stomach content of this fish consisted of plant like matter alone, this suggested that this fish was highly herbivorous. This fish inhabit harbor, natural embayment, brackish estuaries and the lower reaches of freshwater streams, frequently occurring among mangroves. Several researchers [14] reported that this fish was also feed on worms, crustaceans, insects and plant matter.

3.12 Ariidae

There were varieties of food item identified from stomach content of Ariidae family, there was fish, shrimp, plant part, crab, detritus and unidentified food item in their stomach. The dominant food item identified based on % RIa from this family was fish parts with 25.35%, followed by detritus 21.86%, unidentified food item 17.38%, fish 15.32%, mollusk 6.59% and the lowest value was crab 0.84%, respectively. This fish was a carnivorous type based on their feeding habit as they mostly feed on fish, shrimp, crab and mollusk.

3.13 Plotosidae

Plotosus canius were representing family Plotisidae, they are highly molluscivore as their food item found was only consisted of mollusk and unidentified food item. They are found mostly in estuaries and lagoons, and sometimes up rivers in nearly fresh waters.

3.14 Clupeidae

The family Cluepeidae was represent by *Anodontosoma chacunda* which show that this fish was plankton feeder. Based on analysis of stomach content on this fish, there was only phytoplankton and zooplankton identified from the stomach content. The value of % RIa for phytoplankton was 63.48% and zooplankton was 36.52%, respectively.

The large category and the fish prey composition analyses provided interesting feeding habits of Kuala Pahang fishes. Analysis of the gut content shows that fish, detritus and shrimp was the major part of the diet in Kuala Pahang. Nikolsky [15] recognized the following three main categories of food on the basis of their importance in the diets of fishes: (i) basic food, which normally eaten by fish and accounted for the most of the stomach content; (ii) secondary food, which frequently found in the stomach, but in the smaller amounts; (iii) incidental food, which found rarely in the stomach content.

According to the definition, fish and shrimp can be consider as the basic food item for the fishes in Pahang Estuary and shrimp are secondary and based on volume, detritus are incidental.

Table 2 Food item analysis of Pahang Estuary fishes

Items	Volume		Number		Occurrence			
	N	(%)	N	(%)	N	(%)	Aia	Ria
Fish	104	34.13	22	0.94	14	12.28	47.35	13.10
Fish Parts	46	15.10	193	8.26	40	35.09	58.44	16.17
Shrimp	88	28.88	69	2.95	11	9.65	41.48	11.48
Shrimp Parts	2.3	0.75	27	1.16	6	5.26	7.17	1.98
Crab	2	0.66	1	0.04	1	0.88	1.58	0.44
Crab Parts	4.5	1.48	9	0.39	6	5.26	7.12	1.97
Plant Part	5.9	1.94	151	6.46	10	8.77	17.17	4.75
Mollusca	29	9.52	310	13.26	7	6.14	28.92	8.00
Zooplankton	0.01	0.00	280	11.98	15	13.16	25.14	6.96
Phytoplankton	0.01	0.00	618	26.44	15	13.16	39.61	10.96
Detritus	0.01	0.00	491	21.01	54	47.37	68.38	18.92
Unidentified	23	7.55	166	7.10	5	4.39	19.04	5.27

From the stomach analysis, fish and shrimp are major food item found in the stomach of the fishes caught in Pahang estuary, according to % RIa they contribute most of the diet composition of the fishes. Fishes that are identified from the stomach mostly consisted of small fishes, where predatory fishes are shown to choose prey that maximize the energy yield against energy expanded to locate and subjugate it. Fish and shrimp are known to supply high energy and protein [16], they are also easy to locate in the study area.

The detritus are important for fish and extensively used [16, 17]. This resource represents an important food item due to the presence of large amounts of microorganisms associated [17]. The large numbers of species that use detritus in the Córrego Fundo stream confirm that detrivore may be one of the most important forms of obtaining food by fish in tropical streams, as proposed by Lowe-McConnell [18]. A fact related to the high velocity of the stream, this intensive flows transport plant matter from upstream to the mangrove area thus the availability of this food item is high.

Regardless of variables feeding habit assessed, predatory have been most of the times the main group within coastal systems, Espinosa *et al*. (1997) reported carnivorous fish that feed on fish, crustacean predator as reported by Wootton [19], diet based on polychaeta, tunicates and bivalves by Layman and Siliman [20], and fish that feed mainly upon echinoderms and mollusks as reported by López-Peralta and Arcila [21]. For many carnivorous fishes, vision is the most important sense for prey detection and water clarity is one of the factors affecting their occurrence [5]. That explains stomach content of fishes caught in April to August filled with fish and shrimp.

Opportunism within a defined food niche is a common phenomenon in fish [22, 23]. Some fishes are known to be piscivorous or moluscivorous, but the stomach content seems different. This is due to opportunism in some fish, they naturally anticipate not finding food for days so when they do find food they will eat almost anything they can. As for *Scatophagus argus*, they are known to feed on worms, crustaceans, insects and plant matter. But from this study the stomach content analysis identify only plant part in their stomach, this may due to low availability of other food item they prefer, so they just take whatever they can.

Winemiller [24] recognized that food availability is a primary driver of size-related patterns of feeding among fish. According to this author, an ontogenetic switch from invertebrate (zooplankton and benthic invertebrates) to fish prey in piscivorous fish coincides with changing food availabilities associated with seasonal environmental changes. Furthermore, fish consistently selected prey that appeared to be larger, either because of their absolute size or because the prey item was closer to the fish [19]. This explains the feeding behavior of small fish to big fish of the same family to pick on different food item.

Within the 20,000 fish species that have been recognized [25], only 6% have been designated as herbivores. The use of aquatic macrophytes by fish is uncommon when viewed in the context to the total complex of herbivorous feeding patterns in fish. The giant gourami (*Osphronemus goramy*) provides the most convincing evidence of adaptive mechanisms for the selection and processing of vascular tissues of higher aquatic plants. Well-developed pharyngeal teeth: two upper and lower opposing rows of comb or file like teeth of four and five each on the right and left pharyngeal bones, respectively. In this study, the giant gourami (*Osphronemus goramy*) is evidently herbivorous fish as the stomach content of this fish was filled with only plant part food item.

From the percentage of number and occurrence of zooplankton and phytoplankton, it represents an important trophic resource for fish food web of Pahang Estuary. Zooplankton are important in their own right as a major component of fish diets and are especially important to small and young individuals, even for the detritivore. Zooplankton form an important trophic link between primary production [26] and consumers, as suggested by Winemiller [24] in other aquatic systems. Though in the % RIa the plankton percentage value are considered to be high as they contribute 6.96% for zooplankton and 10.96% for phytoplankton, respectively.

4.0 CONCLUSION

Biological monitoring can give information about the ecological conditions for a longer period. The findings of this study concluded that the water body of Pahang River-estuary still can support the aquatic life such as fish, zooplankton, phytoplankton and macro-benthos even though only the abundance of tolerant species appeared due to slightly polluted river water classification. However, the study portrays that a long term continuous monitoring could be instrumental to document the data base of ecological parameters in the Pahang estuary for the sustainable development of fish and fisheries resources.

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