Food and Feeding Habits of Fishes in Brunei Bay, Malaysia

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Abstract. The study of the food and feeding habits of fishes is crucial in understanding their ecology. Food and feeding habits of the 30 fish species belonging to 22 families from Bukit Sari and Awat-awat of Lawas in the Bay of Brunei were studied on 11th February 2020 and 12th February 2020 respectively. Samples were collected using “Kabat” nets, casting nets, and seine nets. The dietary components of each species were studied and expressed as a percentage of numerical composition (N), percentage of weight composition (W), and percentage of frequency of occurrence (F). Diet compositions of the species were estimated using the Index of Relative Importance (%IRI) and trophic level (TROPH). The major food and their Index of Relative Importance (%IRI) showed the highest was shrimps (64.25%) followed by crabs (11.78%), zooplankton (6.94%), fish (6.91%), algae (4.21%), plants (1.48%), mollusks (1.01%) and others below 1.0%. TROPH value ranged from 2.0 to 4.2 and the trophic level value of 25 fish species was carnivorous, followed by 2 species (detritivorous and herbivorous) respectively, and 1 species (piscivorous). The findings of the study may offer important data for developing management plans for the region's fishing resources.

1 Introduction

The Malaysian Bay of Brunei is a cupped, indented bay located on the northwest of Borneo Island [1]. Brunei Bay covers an area of 2,500 km2, with East Malaysia owning the majority of the aquatic and terrestrial land [2]. The bay has a lush mangrove cover as it receives freshwater discharge from four major rivers: Limbang, Sundar, Weston, and Menumbok [2]. Brunei Bay area is recognized as an important habitat for marine biological diversity in the South China Sea [3].

The fishes in the Brunei Bay waters are important protein sources for multiple inhabitants in the area. A total of 94 species were recorded and 75 species were considered to be commercially valuable species [4]. In addition, Brunei Bay is home to endangered species such as Irrawaddy dolphins and Hawksbill turtles, with Brunei Bay serving as an essential feeding area for both [5,6]. Certain fish species may be favoured food items for Irrawaddy dolphins and Hawksbill turtles, or they may be commercialized fish that people consume. Regarding the aquatic food web, fish play an important role in trophic flow and are among the top predators in the aquatic ecosystem [7]. This mangrove is part of the wetland and plays an important role for in the fishery production of adjacent neritic waters by exporting organic and inorganic nutrients whereas root habitats provide abundant food for the fishes [8,9,10]. The environmental conditions and the different food substances present in the water body equally affect

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the diet of fish [11]. Blaber [12] stated that the food preference of fish species is very complex and is influenced by many factors such as spatial characteristics, seasonal changes, prey accessibility, prey abundance, prey energy content, and prey size selection.

In Malaysia, many studies have been conducted on the food and feeding ecology of fish species in the estuary and marine habitats [7,13,14,15,16]. No research has been conducted on the food and feeding habits of fish in Brunei Bay. The present study was designed to examine the diet composition and the trophic levels of 30 fish species in Brunei Bay. The data is a baseline information of the species that have been previously unstudied and may contribute to practices of aquatic management, agriculture, aquaculture, and conservation.

2 Methods

2.1 Data Collection

The diets of 82 of 30 fish species were collected in Awat-Awat and Bukit Sari, Lawas, Brunei Bay on the 11th of February 2020 and 12th of February 2020 respectively (Figure 1). Bukit Sari (N 4.94409; E 115.23752) and Awat-Awat (N 5.01623; E 115.19274), which are dominated by seagrass and mangroves, and in Awat-awat, fish collected from a boat at open sea by a fisherman. Samples were collected using “Kabat” nets, casting nets, and seine nets. The “Kabat” nets used were sized in 1-inch mesh size, 300.0 m long, and 1.5 m deep. “Kabat” nets were deployed at the high tide and pulled after the low tide. The casting nets are sized at 7mm mesh size. While, In Awat-Awat, fish were caught by fishermen using seine nets with small mesh sizes (<6mm).

The total length (mm) and body weight (g) of fish were recorded. All fish were dissected in the field to extract the gut sacs and properly labelled at the bottle for the name of fish species, locations, and dates of each individual. A longitudinal cut was made across the belly to remove the stomach and digestive tract. Then, the stomach and digestive tract were preserved in a 10% buffer formalin solution. In the lab, the stomach and digestive tract contents were transferred into a petri dish and then kept in water for five minutes to remove excess formalin. Individual stomach and digestive tract of specimens were cut open in the petri dish with the aid of surgical ocular scissors.

After removing surface water by blotting them on tissue paper, each specimen was sorted, examined using a stereo microscope, and weighted to the nearest 0.1 mg [17]. The food items were identified by following the 13 taxonomic or ecological categories (shrimp, crab, squid, fish, polychaetes, nematodes, molluscs, insects, algae, plants, sands and mud, detritus and zooplankton). The abundance of sands, plants and digested matter were not quantified because it was impossible to count individual items.

2.2 Data Preparation

The diets were determined by using the frequency of occurrence of food items (%Oi), numerical abundance (Ni) and gravimetric composition (Wi) [17]. Food compositions of the species were finally estimated using the Index of Relative Importance (%IRI) [18]. The Index of Relative Importance (IRI) of Pinkas et al. [18], as modified by Hacunda [19]. The trophic level (TROPHi) analysis was performed using Troph-Lab. The frequency of occurrence of food items (%Oi) data was used for the estimation of trophic levels. Trophic level (TROPHi) was functioning to define the position of organisms within the food webs that largely described for aquatic ecosystems [20] in Brunei Bay. Trophic level (TROPHi) was functioning to define the position of organisms within the food webs that largely described for aquatic ecosystems [20]. The trophic level analysis was performed using Troph-Lab introduced and developed by ICLARM-FAO [21]. The trophic level of primary consumers (herbivorous) mainly consumes plants or detritus. The trophic positions value between 2.00 and 2.19 (Troph = 2.00 - 2.19) as for omnivorous which consume plants or detritus as well as animals, have trophic positions between 2.20 and 2.79 (2.2 < Troph > 2.79). The secondary (Troph > 2.8) and tertiary (Troph > 4) consumers (carnivores) are assigned trophic positions greater than 2.8 [20,21,22].

3 Result and Discussions

3.1 Food and Dominant Food Items

The fish species in Brunei Bay can be grouped into four various trophic guilds namely carnivorous, detritivorous, herbivorous, and piscivorous. Examination of fish diets on 82 fishes suggested the presence of 13 types of dietary
samples of stomach content based on their index of relative importance (%IRI). The major food showed the highest was shrimps (64.25%) followed by crabs (11.78%), zooplankton (6.94%), fish (6.91%), algae (4.21%), plants (1.48%), molluscs (1.01%) and other prey items (<1.0%) (Table 1). Due to the great portion of shrimps in the diet, they were considered the most important food for those fishes. The TROPHj value ranged from 2.0 to 4.2. The trophic guilds of 25 fish species were carnivorous, followed by 2 (detritivorous and herbivorous) respectively, and 1 species (piscivorous). The higher fish species as a carnivorous group provided evidence of the importance of aquatic invertebrates to the well-being of the fish community in Brunei Bay. The bay provides a habitat for aquatic invertebrate species such as prawns, crabs, fish, zooplankton, molluscs, nematodes, polychaetes, insects, and squids, which are vital to the ecosystem's maintenance and energy flow. Carnivorous animals are predators and play an important role in the food web, as they devour other creatures in the wild to survive. The predator-prey ratio, according to NYSFOLA [23], could also be used to monitor the equilibrium of the fish population.

3.2 Carnivorous (Feed on Animals)

Aquatic invertebrates were the most important sources of food in the biotopes which contribute 85.6 (%IRI) of the diet of 25 fish species (Table 1). Similar to previous studies the dominance of aquatic invertebrates in the diets of fishes [7,16,24,25,26]. From this study, aquatic invertebrates were the highest food component consisting of shrimps, crabs, squids, polychaetes, nematodes, mollusks, insects, and zooplankton. They were mainly represented by the species of the families Ambassidae, Apogonidae, Ariidae, Belonidae, Carangidae, Clupeidae, Cynoglossidae, Dasyatidae, Engraulidae, Haemulidae, Leiognathidae, Lutjanidae, Pristigasteridae, Sciaenidae, Sillaginidae, Synodontidae, Toxotidae, and Trichiuridae (Table 1). The trophic level (TROPHj) values for all species ranged from 2.95 ± 0.50 for Brevitrygon walga to 3.60 ± 0.60 for Thryssa mystax and Otolithes ruber (Table 1). The TROPHj value for 25 fish species was categorized as mid-level carnivorous as a secondary consumer which the TROPHj values less than 4 ranging from 2.95 to 3.60.

This study showed that the stomach of Thryssa mystax and Otolithes ruber contained 100% of shrimps, followed by Harpodon nehereus, Ambassis nalua, Fibramia amboinensis, Dendrophysa russelli, Thryssa dussumieri, Lepturacanthus savala, Scomberoides commersonianus, and Dussumieria elopsoides consumed 95.0%, 94.6%, 91.1%, 87.9% 85.0%, 82.5%, 80.9%, 80.3% mainly of shrimps respectively and other 13 fish (<80.0%) of shrimps as main diets. Alepes kleinii consumed main 100% of the zooplankton, followed by Ilisha megaloptera (87.7%) and Ostorhinchus fasciatus (76.6%). While molluscs were the primary source of food for the other three species, Sillago asiatica (80.0%) followed by Opisthopterus tardoore (61.3%), and Pomadasys argenteus (31.5%). Crabs were mostly consumed by Hexanematichthys sagor, and polychaeta was primarily consumed by Setipinna taty (66.7%).
Table 1. Relative important (%IRI) of fish community from Brunei Bay, Sarawak.

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<td>Torpedo marmorata*</td>
<td>3</td>
<td>125-370</td>
<td>82.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.34 ± 0.76 Carnivorous</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: NSE = Number of Stomach Examined; S = Shrimp; C = crab; Sq = Squid; F = Fish; Poly = Polychaetes; Nema = Nematod; Moll = Mollusk; Ins = Insect; Alg = Algae; P = Plant; S&M = Sand & Mud; Det = Detritus; Zoop = Zooplankton; TROPHj = Trophic level; and TropG = Trophic group; Bukit Sari*; Awat-Awat**.
The trophic level values of both two species *Thryssa mystax* and *Otolithes ruber* were similar to Froese and Pauly [27], 3.6. Froese and Pauly [27] noticed a variety of prey that they consumed on planktonic organisms, and juvenile fish in mangroves consumed prawns and fish larvae. The *Otolithes ruber* also consumed a variety of prey, including fish, prawns, and crustaceans [27] and as piscivorous [28]. According to Froese and Pauly [27] both species are found throughout the Indo-West Pacific region's coastal waters and are classified as a pelagic-oceanic and benthopelagic species respectively. Most pelagic predators consume epibenthos, which is a generalist diet, and this may be responsible for the wide variety found in deep-sea infauna to Sedberry and Musick [29]. Sedberry and Musick [29] stated that some demersal fishes on the continental slope depend largely on the mesopelagic fauna for feeding. Demersal is the most dominant type of water column of the species caught in Brunei Bay where it is followed by reef-associated by only a small margin. Demersal fishes live on the bottom and consume benthos [27,30]. Some demersal fishes on the continental slope feed on the mesopelagic fauna [30]. Meanwhile, living on or near coral reefs is referred to as reef-associated, as reefs supply food, shelter, and breeding grounds [27,31]. Many juveniles are found in inshore due to it is near the estuaries, which is the preferred habitat for juvenile fish. According to Blaber [12] the diets of most fishes change with growth however the timing of these changes differs from species to species and is related to changes in lifestyles or habitats.

External factors such as water depth and season had significant impacts on the diets of the majority of planktivorous fish, prawn feeders, and *Lucifer* sp. feeders [29]. Beasley et al. [33] stated that the rainfall fluctuations are an important factor in the distribution of benthic organisms. The characteristic of fish is the mouth shape of feeding as factors in fish which was specifically suited for selecting aquatic invertebrates such as shrimp. The adaptability of fish species in sharing food resources or the adaptive variety of particular species that can only feed on one type of prey are caused by morphological, anatomical, or physiological characteristics [34]. The terminal mouth type is the most widespread among Brunei Bay species, comprising more than half of all species caught [35]. The terminal mouth is the most common form when compared to other forms. The upper and lower jaws, as well as the centre of the head, are all the same length in terminal-mouth fish [36]. This mouth position enables fish to feed in almost any environment, which explains their dominance among the species collected and the wide diversity of habitats observed [36].

### 3.3 Detritivorous (Feed on Compost) and Herbivorous (Feed on Plant or Algae)

The detritivorous and herbivorous were the second highest food components for the diet of 4 fish species (Table 1). They were mainly represented by the species of the families Gerreidae, Hemiramphidae, Scatophagidae, and Siganidae. The stomach of two fish species, *Hyporhamphus dussamieri* (100%), and *Gerres erythrous* (76.5%) mainly contained detritus (Table 1). Whereas herbivorous was mainly represented by algae preferable food in 2 fish species, *Scatophagus argus* (84.6%) and *Siganus guttatus* (66.7%). The trophic level (TROPH)j values for detritivorous ranged from 2.00 ± 0.00 for *Hyporhamphus dussamieri*, and 2.21±0.22 for *Gerres erythrous* (Table 3). However, the TROPHj value for herbivorous ranged from 2.00±0.00 for *Scatophagus argus* and 2.03± 0.13 for *Siganus guttatus*.

Benthic microalgae and macroalgae, phytoplankton, and vascular plants are primary productions for of estuarine food webs [37]. The presence and a preference for algae and other aquatic invertebrates in the guts of most *Scatophagus argus* and *Siganus guttatus* indicate that these species inhabit seagrass beds. As a result, it suggests that the diet of both fish may be related to the availability of food resources and the greater seagrass patches in Bukit Sari. Furthermore, there were ontogenetic changes in many species as indicated by the
greatest of plankton and detritus in the early stages of their life and swift to benthic invertebrates in the largest class. Blaber [38] stated that the actual timing of the switch in the diet generally relates to juveniles becoming sub-adults or adults and leaving estuaries, or changes in the morphology of jaws, teeth, or size.

3.4 Piscivorous (Feed on Fish)

Fish food component for the diet of one fish species (Table 1). They were mainly represented by the *Nibea soldado* of the families Sciaenidae. The trophic level (TROPHj) values for *Nibea soldado* was 4.20± 0.61. The TROPHj value was categorized as piscivorous as a tertiary consumer which are the TROPHj values more than 4. *Nibea soldado* belonging to the family Sciaenidae popularly known as Soldier croaker inhabits shallow coastal waters and estuaries while juveniles occur in brackish estuaries and often ascend the lower reaches of large, turbid rivers [28]. The piscivorous fishes were mostly fed on small resident fishes such as perchlet, snapper, catfish, ponyfish, and gobiids, all of which are consumed by piscivorous fishes in other mangrove environments [39]. According to Mihalitsis and Bellwood [40], the piscivory is a key ecological process in aquatic ecosystems, allowing energy to pass across trophic networks. Diet change due to physical and chemical variations in the habitat, or biotic interaction, such as competition or predation [26].

4 Conclusion, Limitation, and Future Works

In conclusion, this study has demonstrated that the 82 fish species in Brunei Bay may be classified into various trophic guilds. The trophic guilds of 25 fish species were carnivorous, followed by 2 (detritivorous and herbivorous) respectively, and 1 species (piscivorous). The TROPHj value ranged from 2.0 to 4.2. The higher fish species by carnivorous group showed how crucial aquatic invertebrates are to the functioning of the fish habitats in Brunei Bay. Shrimps had the greatest index of relative importance (%IRI), followed by crabs, zooplankton, fish, algae, plants, mollusks, and other prey, which are essential to the ecosystem's maintenance and energy flow. Due to the great portion of shrimps in the diet, they were considered the most important food for those fishes. Our work suggests that future studies may require the dietary contents to be identified at the species or genus level, 2) a larger number of fish samples collected, and 3) stomach processes as soon as possible after collecting the sample. The findings of the study may offer important data for developing management plans for the region's fishing resources.

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