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Foraging behavior and food selection of giant Mudskipper (*Periophthalmodon schlosseri*) at Kuala Gula, Matang Mangrove Reserve, Perak, Malaysia

Mazlan Abd. GHAFFAR[1], Faridah YAKOB[1], Shukor MD. NOR[1] and Aziz ARSHAD[2]

[1] *School of Environmental Studies and Natural Resource Sciences Faculty of Science and Technology Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
[2] *Department of Biology Faculty of Science Universiti Putra Malaysia 43400 UPM Serdang Selangor, Malaysia*

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Abstract — An *in-situ* behavioral study of giant mudskipper (*Periophthalmodon schlosseri*) was conducted in the coastal mudflat of Kuala Gula, Matang Mangrove Reserve, Perak. Observations were made based on scan and focal sampling methods during low tides. The main objective of this study was to understand the foraging behaviors and food selection by assessing the time spend and the frequency of each behavioral activity of this species in the field. The field observations identified five major feeding activities (Searching and Stalking (M1), Leaping and Capturing (M2), Tearing (M3), Moving to Safer Place (M4), and Playing With Prey (M5)) exhibited by *P. schlosseri* where these five feeding activities were later grouped in three different phases occurring consecutively such as Phase 1 or Searching Phase, Phase 2 or Capturing Phase and Phase 3 or Handling Phase. The results showed that, only 9.7% (835 min) of the times were spend on feeding activities. In Phase 1, despite many attempts of capturing preys, only about 58% of the trials succeeded. Results showed that the giant mudskipper is a generalist carnivore that preyed on crab (*Uca* spp.) during the day and shifted to insect at night during low tides. Worms also taken by this species both in day and night during low tides, although the frequencies were slightly lower than crabs and insects possibly due to the difficulty of capturing them. The highest time spend on searching and stalking preys (397 min) and the least time was on capturing for both day and night ($H=7.96$, $df=4$, $p<0.05$). However, the total time spend and efforts (frequencies) on feeding activities were slightly higher during the day compared to the night. Although the total time spend on feeding activities were slightly higher during the day, the allocations of time (mean) of these activities were similar to one another indicating that the species might have a strategy of minimizing the foraging costs (energy spend) in order to maximize the profit.

Key words: foraging behavior, food selection, giant mudskipper, mangrove forest reserve

Introduction

Adaptation with natural habitat will help an organism in searching of food, avoid of predator and also in getting a mate (Ridley 1986). An individual that could manipulate its habitat and the food sources will definitely succeed in reproducing its progeny. Food finding or searching is an important element that will provide energy, water and nutrient to the fish. However, in order to feed the fish should spend a high metabolic energy on the feeding process (Eisner and Wilson 1975).

Giant mudskipper *Periophthalmodon schlosseri* had evolved morphologically in its mangrove habitat and its adaptation could be seen clearly by observing its behaviors. The uniqueness of this species is that it is amphibious (Lee and Graham 2002, Murdy 1986, McGregor 1999). This could be an advantage to the fish species to dominate its habitat that is hard to be exploited by other teleosts. This species is a mean carnivore (Murdy 1986) that preys on small mollusks, insects and other invertebrates. However, unlike other fishes, no clear feeding category has been given to the giant mudskipper that is a fish species that search, hunt, stalk and consume prey "on land". There is a need to understand the feeding in techniques because its preys had a wide range of behavioral and structural adaptations in avoiding of capture (Keenleyside 1979). Information on feeding behavior and time budget on the related activities of this species is still lacking. Therefore this paper aims to understand and discuss the foraging behaviors and food selection by assessing the time spend and the frequency of each behavioral activity in the field.

Methodology

The study was conducted between May and October 2004 at Kuala Gula, Matang Mangrove Reserve, Taiping, Perak. Observations were conducted for 24 hours every month and focusing only on its feeding behaviors and identifying types of foods consumed by each individual observed. All observations made were based on scan and focal sampling methods as suggested by Lehner (1979). The feeding behaviors were categorized in several activities where each of these activities, the total time spend and frequency were recorded. The types of food consumed were also recorded. The data were analyzed using χ^2 and Kruskal Wallis nonparametric ANOVA. In this study only male individuals were observed due to their rigorous activities in the study areas.

Results and Discussions

Feeding behavior

Foraging is a behavioral process that includes searching and capturing prey and the decision making in how, when and where to search, and when and what prey to capture. The movement of giant mudskipper *Periophthalmodon schlosseri*, on mudflat is an advantage to the species to exploit food source (Lee and Graham 2002), and avoid of competition with other fishes. When foraging, mean carnivores exhibit behaviors such as searching and capturing (Huntingford 1984). In this 6 months observations, 5 major activities were identified, which fall under the category of feeding or foraging. Those activities were adopted and classified based on Lehner (1979) and listed in Table 1. Generally feeding activities can be grouped into 3 different phases; the first phase is 'searching' which includes only searching and stalking activities (M1), 'capturing' the preys is the second phase which includes leaping and capturing (M2), and the final phase is 'handling' of preys after being captured which includes moving the prey to a safer place (M3), chewing (M4) and playing with prey (M5).

For a male giant mudskipper, feeding starts immediately after completing inspecting and mending its hole. A male mudskipper generally starts its quest searching for food by walking around its burrow looking for available prey within 4200 square feet from its burrow (Murdy 1986). After noticing its prey, *P. schlosseri* minimize its movement and slowly stalking and aiming the prey (Phase One). In one instance it stops and wagged its caudal fin before leaping (ambush) in a great speed and capturing its prey with its mouth (M2) (Phase Two) (Fig. 1).

The study indicated that the giant mudskipper feeds primarily during low tide, because food searching becomes difficult during high tide as all the crab holes filled with water. During low tide *P. schlosseri* feeds mainly on fiddler crabs (*Uca* spp.) and during high tide as an alternative feeding strategy, a male mudskipper switched to insect as their major food sources. According to Hoerse and Hoerse (1967), goby (*Gobiosoma bosci*) starts searching food when induced by

Table 1. List of feeding activities that were identified in the field. These activities are in sequence from the beginning of foraging process (M1) until an individual get satiated (M5).

Activity	Description of Behavior
M1	Searching and Stalking
M2	Leaping and capturing.
M3	Tearing
M4	Moving to safer place Tearing.
M5	Playing with prey (satiated).

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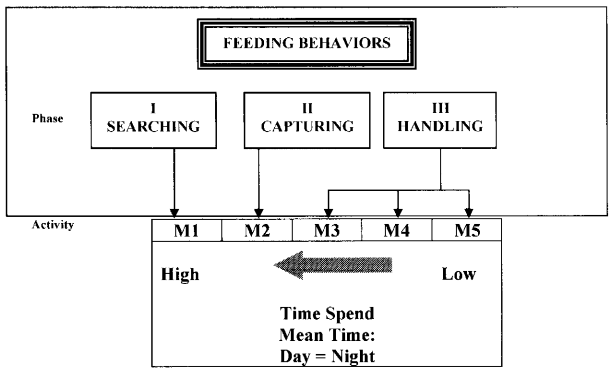

Fig. 1. The flow of feeding behavior in *Periophthalmodon schlosseri* during low tide.

chemical such as glycerine, alanine, glutamine, β-alanine, cystamine, TMA, 2-amino butyric acid, 4-aminobutyric acid, putrescine, and 5-aminovaleric acid. Many researchers believe that preys produce these chemicals and the predators could easily detect their preys even at distance (Hara 1992). However, it is still not known what mechanism controlling the food selection and foraging behaviors of giant mudskipper.

In the final phase, after prey was captured, a male mudskipper immediately moves to a safer place (M4) (such as in its burrow, shallow water holes, under small crevices or even the low tide water line) and start tearing (M3) and swallowing. Sometimes there is evidence that the fish plays with its prey in its mouth (M5) before eating its prey. Very often the fish takes its captured prey to the nearest water line or water hole before eating its prey. Carnivorous fishes do not actually chew but only tear their foods (Keenleyside 1979). For a giant mudskipper, different from any other carnivorous fishes, the movement of its mouth up and down looks more like chewing. During eating process, a giant mudskipper often fills its mouth with water that possibly will make the tearing and swallowing easier (Lorus and Milne 2002). Morphologically the fish's head evolves to a large jaw and sharp teeth in order to accommodate its need in capturing its prey (Murdy 1989) and also tearing of its captured prey before swallowing.

Food selection and choice

Giant mudskipper is a carnivore that was observed in the field feeding on small crabs, worm and insects (Table 2). Observations also indicated that the giant mudskipper hunts (or feeds) only during low tides. Since *P. schlosseri* is an intertidal organism, this species exhibits its behavior according to the tidal rhythm (Pengelley 1974) and hunts during only low tide where preys are abundant and open mudflat for easy maneuvering is available. During the day, giant mudskipper starts feeding as soon as the small crabs (*Uca* spp.) appear from the burrows. From Table 2, it is clear that during the low tide in the day, giant mudskipper feeds on worms and fiddler crabs, which is 9.6% and 55.8% of the whole capturing success, respectively. At night, insects occupy the highest position in preys chosen (23.1%) and followed by worms (11.5%).

The results also clearly indicated that feeding and diet selections by giant mudskipper are probably influenced by three factors; i) daylight, ii) tides and iii) abundance of the prey. Giant mudskipper foraged during low tide of the day primarily on crabs and switched to insects during the night of low tide (Table 2) ($H=0.29$, $DF=2$, $p>0.05$) when the crabs were scarce. This agrees with the facts that the crabs only active and abundant during low tide of the day and insects (invertebrate) only abundant at night in the study areas. Worms however were available at all time during day and night.

Feeding and diet selection patterns by giant mudskipper described above suggested that this species has higher preference for fiddler crabs as compared to worms and insects (Table 2). Since this species also selects other food items (other than fiddler crab) it is also can be categorized as generalist carnivores that locate, catch and eat food items available on that particular time and space. The species strategically switches food items, when the most preferred food items were scarce or unavailable, to another abundance food items.

It is still not known why giant mudskipper preferred fiddler crabs compared to insects and worms. However, it should be pointed out that fiddler crabs were more abundant and easy to catch compared to other food items on the mudflat. Worms that mingle inside the mud may be difficult to find and catch although they may be highly abundant. On the other hand, insects are easier to catch at night compared to worms. However in all foraging occasions, not all hunting attempts were successful. Although numerous attempts (87 times) were observed during the six months study, only 52 (59.8%) hunting attempts were succeeded.

Table 2. Prey chosen according to availability during low tide. Numerals show the number of *Periophthalmodon schlosseri* observed.

Time	Insects	Worms	Fiddler Crabs	Statistical Analysis
Day	0	5	29	$\chi^2=42.53$, df=4, $p<0.05$
Night	12	6	0	$\chi^2=12.0$, df=4, $p<0.05$
Total	12	11	29	$\chi^2=11.8$, df=4, $p<0.05$

Frequency and time budget

In six months study, a total of 8,640 minutes were spend to observe the general behaviors of the species where apart from that only 835 minutes (9.7%) were classified as feeding activities. Feeding activities were found slightly higher in the day with 66% (548.3 minutes) (statistically significant different; $\chi^2=98.22$, df=4, $p<0.05$) compared to night with 34% (286.8 minutes), indicating that the species actively forages during day (Table 3). Among all the activities that were observed as part of a whole feeding process established by giant mudskipper, the highest time spend was on searching of food (M1; with 396.8 minutes), where generally this species had hard time of finding and choosing the right prey or food item. Since relatively long time was spend on each searching activity (M1), the number of trials or frequencies of this activity is relatively low with only 151 times compared to playing with prey (M5) with 185 times (358.9 minutes). The numbers of trials on all other activities were relatively low with chewing (M4) with only 38 times (65.9 minutes), moving prey to a safer place (M3) with 52 times (8.5 minutes), and leaping and capturing prey (M2) with 87 times (5 minutes) (Table 3).

Based on the number of trials, as indicated above only about 59.8% were succeeded in capturing the preys. Bearing in mind that not all the preys captured were taken to safer places (52 out of 87), and not all of the preys captured and taken to safer places were eaten (38 out of 52) (Table 3). Among these feeding activities (M1 to M5) the number of trials and duration of each trail were different ($\chi^2=192.4$, df=5, $p<0.05$), and the most important activity is probably leaping and capturing prey (M2) because the overall success of the feeding process is determined by the ability of individual to hunt. Generally capture success is directly influenced by the speed of attack (Croy and Hughes 1991), the faster the better. This argument is supported by the data collected in this study where leaping and capturing of prey required only an average of 3.5 seconds in one attempt. Further high in playing with prey (M5) with 185 times, is a strong indication that the species (generally male) can easily get satiated or bored with the prey/food, or it can be translated as an indication of high abundance of food resources within the area that were available for the species to feed on.

The occurrences of all the feeding activities decreased

Table 3. Frequency and time budget of activities associated with feeding. Time is shown as seconds.

Feeding activity	Freq.	Statistical analysis	Time Budget	Statistical analysis	Mean Time	Percent
	Whole					
M1	151		23808		157.7	48.5
M2	87	(χ^2=192.4,	300	(H=25.48,	3.5	0.1
M3	52	df=4,	509	df=4,	9.8	1.0
M4	38	p>0.05)	3953	p<0.05)	104.0	7.9
M5	185		21532		116.4	43.0
Total	513		50102		97.7	
	Day Low Tide					
M1	96		16307		169.9	49.56
M2	44	(χ^2=98.26,	185	(H=27.15,	4.2	0.6
M3	34	df=4,	363	df=4,	10.7	1.1
M4	27	p>0.05)	2539	p<0.05)	94.0	7.7
M5	114		13501		118.4	41.0
Total	315		32895		104.4	
	Night Low Tide					
M1	55		7501		136.4	43.6
M2	43	(χ^2=63.6,	115	(H=26.89,	2.7	0.7
M3	18	df=4,	146	df=4,	8.1	81.1
M4	11	p>0.05)	1414	p<0.05)	128.6	8.2
M5	71		8031		113.1	46.7
Total	198		17207	86.9		

about 25.8% between the day and night, although no differences was detected through statistical test (χ^2=9.99, df=1, p>0.05). Fairly high in feeding activities during the day might be associated with the types and availability of foods within the study area. As indicated above this species had higher preference for the crabs that are available only during the day. Since the preys were abundant and easy to catch, giant mudskipper might spend more time hunting until reached the stages where too many preys were captured during the day than the night (Table 3). Since the type of foods taken during the night and day were different, (e.g. crabs primarily during the day and insects during the night), it is still not clear, why less feeding time (activities) and frequency occurs at night? However, generally the process of feeding is not influenced by any physical factors but it is automatically stops when the fish is satiated (Eisner and Wilson 1975). In this study, an individual giant mudskipper may have to maximize the capture/feeding activities during the day that might act as a compensation strategies to reduce feeding at night during the consecutive low tides at night. Other possibility was the fish got satiated by eating whole fiddler crab body during the day, of which it may prolonged the return of appetite as the results of longer digestion process that contributes to reduce feeding at night (Mazlan and Grove 2003, Mazlan and Grove 2004, Mazlan et al. 2004). Although more total time was spend and frequency of each feeding activity was recorded more during the day, the mean time spend on each activity was almost similar between the day and night low tide (H=8.73, df=9, p>0.05; H=9.00 df=9, p>0.05 respectively) (Table 3). The diet differs accordingly, i.e. crabs during the day and insects at night low tide. During the day, the giant mudskippers spend an average of about 157.7 seconds for activity M1, M2 for 3.5 seconds; M3 for 104 seconds; M4 for 9.8 seconds and M5 for 116.4 seconds (Table 3). The main factor that generally influenced feeding behavior is energy that is gain per unit time. Predators generally try to minimize the time spend on each behavior where profit (energy) can be maximized (Huntingford, 1984). Apart from feeding time (of all feeding activities), the size of predator also directly influenced the profit (energy gain) (Giles 1984). Generally, smaller individual has higher rate of energy requirements compared to bigger individual (Grizmek 1972).

In mudskipper reduction in time spend on each feeding activity probably is one of strategy to maximize the profit (energy gain).

Conclusion

Five feeding activities of *P. schlosseri* were identified in the field from observation study conducted at Kuala Gula, Matang Forest Reserve, Perak. Observation indicated that *P. schlosseri* feeds during only low tide after finished repairing and mending its burrow. These five feeding activities are grouped in three different phases namely Phase 1 which is Searching, Phase 2 which is Capturing and Phase 3 which is Handling. Flexibility in food selection and choice makes this species a generalist carnivore, fed on crabs (*Uca* spp.) during the day low tide and shifted to insect at the night low tide. Noted that flexibility make the fish a short term specialist carnivore that differs according to the tide rhythm (Campbell, 1992). Giant mudskipper also preyed on other available food items such as worms. Like most other predators, giant mudskipper foraging strategy is probably to minimize its foraging costs (energy spend) in order to maximize the profit.

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