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Food and feeding habits of three air-breathing fish in its natural habitat

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Abstract
Food and feeding habits of three air-breathing fish namely climbing perch *Anabas testudineus* (Bloch) (Perciformes: Anabantidae), the walking catfish *Clarias batrachus* (Linnaeus) (Siluriformes: Clariidae), and the stinging catfish *Heteropneustes fossilis* (Bloch) (Siluriformes: Heteropneustidae) under natural conditions and the manner in which dietary preferences are influenced by the habitat, seasonal and stage of maturity of the fish are explained, based on data form monthly randomly collected samples for a year. Qualitative assessment of the diet reveals that it is not restricted to a varied range of aquatic fauna, but also encompasses allochthonous fauna. Size or season changes do not alter the diet of these fishes. Range of prey consumed by this fishes does not differ radically, qualitatively as a function of size, but quantitatively exhibits five levels of discrimination and differential exploitation related mainly to prey size. Seasonal fluctuations in feeding are more qualitative than quantitative and seems to be dependent on the occurrence of food organisms. To conclude, the potentiality of these three air-breathing fish as an effective biological control agent of mosquito larvae is indicated by the fact that dipteran larvae are preferred item of its diet mainly in small and medium sized group of fish.

Keywords: *Anabas testudineus, Clarias batrachus*, *Heteropneustes fossilis*, feeding habits, natural habitat, biological control agent

1. Introduction
Importance of prey items in fish diets can be evaluated in a variety of ways [1-5]. Cultured fish species do not provide precise information about the feeding habits of fish [6, 7]. A dietary survey of the fish under natural conditions [7-10] is prerequisite for proper assessment of its biocontrol potentiality. Gut contents of fish ascertain dietary requirements in their natural habitat, the relationship between the fish and the abiotic environment and to establish tropic inter- relationship [11]. Fish exploit food substances in an aquatic ecosystem according to the adaptations possessed (mouth, gill rakers, dentition and gut system) which are related to feeding. According to Miller and Harley [12] food habit of fish could be related to its structural morphology, the way it captures food and how it digests it. Studies on fish structural adaptations could provide useful information on their food habits and management [13, 14]. We analyzed the diet of three indigenous air-breathing fish (*Anabas testudineus, Clarias batrachus*, *Heteropneustes fossilis*) which might provide the clue for their prey preferences as biological control agents for mosquitoes. The climbing perch *Anabas testudineus* (Bloch) (Perciformes: Anabantidae), the walking catfish *Clarias batrachus* (Linnaeus) (Siluriformes: Clariidae), and the stinging catfish *Heteropneustes fossilis* (Bloch) (Siluriformes: Heteropneustidae) commonly occur in different aquatic bodies and can tolerate desiccation and low dissolved oxygen conditions [15-18]. Besides withstanding muddy conditions, these fish can migrate between pools [19, 20]. Therefore, considering the rice fields and temporary pools with moderate to high eutrophication level, these fish can be utilized as a biological control agent to combat mosquito immatures. The prey preference of a natural predator reflects the efficiency to regulate target prey population. Under situations where the target mosquito species are low or absent, alternative prey sustain the predators introduced into habitats [21]. The gut content analysis gives an idea about the actual diet of the fish species. In aquaculture practice, to increase the yield of cultured fish the accurate knowledge of food and feeding is essential. This paper presents the results of an investigation carried out on the analysis of food and feeding habits of three air-breathing fish in its natural habitat.

2. Materials and methods

The fish, *A. testudineus*, *H. fossilis* and *C. batrachus*, were collected from local ditches in Adra (24°28′N and 86°56́ E), Purulia, West Bengal, as needed during the period of experiments. Fish were collected with fish nets of different mesh size and transported to the laboratory in a 10-*l* plastic bucket containing water from the collection site. The size groups of the fishes used in the experiments are presented in Table 1.

The entire gut contents of each specimen, preserved in 5% formalin, were taken into consideration in the analysis of the diet. The fish *A. testudineus*, the walking catfish *C. batrachus*, and the stinging catfish *H. fossilis*, randomly collected from different ditches and ponds, were used for analysis of the gut content [22, 23]. The procedure involved dissection and removal of intestine of the freshly caught fishes in an enamel tray in the laboratory. For each class of the fish twelve fishes were considered. The anterior portion of the intestine was cut open and the contents were washed out with normal saline and were examined under microscope. The identification of the different food item to the generic/specific level was difficult due to the action of the digestive juices. The exoskeleton remains of insects were used as indicator for identification of the taxonomic orders. The formula applied for determining niche breadth [22] were [(i) & (ii)]:

$B = 1/\sum p_{ij}^2$ ………….(i) and

$B_n = [B-1]/[n-1]$ ………..(ii),

where p = proportion of a food type, n= total types of food, B_n = Niche breadth.

Table 1: Body size of the air-breathing fish species

Fish species		Body size of the fish species (in cm)		
		A	B	C
A. testudineus	Range	4.7 – 4.9	5.9 – 8.2	8.6 – 9.0
	Mean ± S.E	4.8 ± 0.58	7.0 ± 6.64	8.7 ± 1.20
C. batrachus	Range	5.5 – 6.0	6.8 – 8.8	9.2 – 9.7
	Mean ± S.E	5.7 ± 1.45	7.9 ± 5.86	9.4 ± 1.53
H. fossilis	Range	6.6 – 6.9	7.2 – 9.5	10.2 – 10.7
	Mean ± S.E	6.7 ± 0.88	8.4 ± 6.74	10.5 ± 1.52

3. Results

The qualitative analysis of the gut contents reveals that the diet of the fish is not confined to aquatic fauna; terrestrial organisms such as moles, red ants are also found. Thus allochthonous fauna form a major nutritional source of the fish. The contents of the gut of the air-breathing fish of different sizes and change of feeding habit with size are presented in (Table 2). Quantitatively, analysis of food preferences reveals distinct differences in the diet patterns in various size groups. A shift in the niche breadth with the size was evident in all the three fish species. It was noted that the fish had a wide range of diet, which includes formicid, insects, dipteran immatures and odonate nymphs. From the observations on the gut content, a difference in the proportion in the prey species and types, between the sizes and the species of the air-breathing fish was evident. For instance, dipteran larvae are favourite food items of small sized fish. As fish size increases, they show preference towards ants. One reason for shifts in prey preference is prey size, smaller food items such as cladocera, ostracoda and hemipterans are preferred food items of the small fish. In the medium sized fish such diet items are lower in preference, while in large sized they are almost eliminated out from the diet. The occurrence of large sized prey such as spiders, odonates, small prawns is most frequent and steadily declines as the size of the predators decreases.

The differences in the niche breadth calculated on the basis of the gut contents exhibited differences in the prey preferences by the fish species (Table 3). The niche breadth was much broader, suggestive of a generalist nature and ability to sustain on a variety of prey items. This is an essential criterion to favour their augmentative release in biological control of mosquito immatures. The results of the repeated measure ANOVA (Table 4) revealed that significant difference exists in the gut contents of the three fish species. When interaction between fish species and different size groups of diet are considered feeding seems to be significant but when the interaction between prey types with fish species are considered they seems to be not significant. Seasonal fluctuations in diet are not discernible in the various groups of fish. Aquatic fauna chiefly, dipteran larvae, hemipterans, coleopterans from substantial components of the diet all round the year, although in varying amounts. The incidence of allochthonous fauna, particularly ants, hymenopterans, orthopterans is non seasonal. Other components of the diet such as fish fry and small prawns are present intermittently, reflecting their abundance in the habitat.

Table 2: The relative number (range, mean ± S.E.) of prey items observed from the gut analysis of *A. testudineus*, *H. fossilis* and *C. batrachus* of three different size groups

Air-breathing fish species	Size of the fish (in cm)	Diet (food type)													
		Dipteran larvae	Insect remains	Formicids	Coleopteran adult	Hymenopetrans other than formicids	Cladocera	Hemiptera	Ostracods	Plant parts	Fish fry	Orthoptera	Areneids	Tadpole larvae	Small prawns
A. testudineus	< 50 mm	15 - 21 18 ± 1.0	10 - 14 12 ± 0.71	8-10 9±0.32	8-11 10± 0.32	0-1 0.6±0.2	4-7 6±0.55	4-8 5.4±0.6	4-6 5±0.45	3-5 4±0.32	1-3 2±0.45	0	0	0	0
	50-85 mm	12-16 14 ± 0.7	4-9 6±0.84	14-18 16±0.71	11-16 13±0.89	6-8 7±0.45	1-5 3±0.71	1-4 2±0.55	0	0	0	8-11 10±0.5	0-2 1±0.4	0	0
	>85 mm	0	9-13 11±0.71	17-21 19±0.89	5-10 7±0.84	1-3 2±0.45	0	6-12 9±1.14	0	0	4-8 6±0.71	4-8 6±0.8	7-10 9±0.6	2-6 4±0.7	2-4 3±0.0
C. batrachus	< 60 mm	18-23 20±0.84	14-18 16±0.71	7-12 10±1.05	12-16 14±0.71	1-3 2±0.32	5-8 6±0.63	4-7 5±0.55	3-7 5±0.63	4-6 4.8±0.37	3-5 4±0.32	0	0	0	0
	60–90 mm	10-16 13±1.10	5-10 7±0.84	19-23 21±0.71	10-14 12±0.71	6-10 8±0.71	2-4 3±0.32	2-5 3±0.55	0	0	0	8-10 9±0.45	0-1 0.6±0.24	0	0
	> 90 mm	0	12-18 15±1.00	23-27 25±0.89	12-14 13±0.45	0-1 0.4±0.24	0	6-9 7±0.55	0	0	2-4 3±0.32	3-5 4±0.45	5-8 6±0.55	2-5 3±0.63	1-4 2±1.00

H. fossilis	< 70 mm	18-22 20±0.70	10-14 12±0.71	8-12 10±0.70	8-10 9±0.32	7-9 8±0.30	5-8 6±0.55	5-7 6±0.30	3-5 4±0.30	3-5 4±0.30	2-4 3±0.30	0	0	0	0
	70-100 mm	7-13 10±1.30	4-9 6±0.89	14-18 16±0.90	10-14 11±0.77	8-12 10±0.80	4-7 5±0.55	2-6 4±0.70	0	0	0	7-13 10±1.14	2-4 3±0.30	0	0
	>100 mm	0	8-10 9±0.32	20-24 22±0.70	12-19 15±1.22	6-10 8±0.70	0	3-7 5±0.60	0	0	2-4 3±0.30	10-14 12±0.71	2-7 4±1.00	2-5 3±0.60	0-3 1±1.00

Table 3: Niche breadth of three air breathing fishes

	A. testudineus	*C. batrachus*	*H. fossilis*
Niche breadth (B_n)	0.79 – 0.89 0.86 ± 0.02	0.78 – 0.8 0.8 ± 0.01	0.76 – 0.79 0.78 ± 0.01

Table 4: Results of repeated measure ANOVA on the prey type observed in the gut of the air-breathing fishes of three different size groups

Source of variation	Sum of Squares	df	Mean Square	F-value
Between-Subjects Effects				
Fish species (FS)	31.559	2	15.779	9.270
Size (S)	4.350	2	2.175	1.277*
FS * S	13.721	4	3.430	2.015*
Error	61.280	36	1.702	
Within-Subjects Effects				
Prey type (PT)	14288.110	14	1020.579	642.708
PT*FS	723.375	28	25.835	16.269
PT*S	6979.917	28	249.283	156.985
PT * FS* S	720.945	56	12.874	8.107
Error	800.320	504	1.588	

4. Discussions

In the presence of alternative preys, the consumption of mosquito larvae did not differ significantly for the air-breathing fish. A deviation in these regards can be expected if mass weight consumption of alternative preys is considered. The relative proportions of different alternative preys are similar to the observations made in the rice fields and temporary pools [24]. It is noteworthy that the preference for mosquito larvae in presence of alternative preys was low for the guppy, *P. reticulate* [25]. In contrast, all the three air-breathing fish showed a preference (higher consumption) for mosquito larvae in presence of alternative preys. *C. batrachus* was observed to consume less numbers of tadpoles of four different species of frogs and toads, possibly due to their nocturnal tactile, benthic foraging behavior that reduced the prey encounter rates [26]. It has been noted that the climbing perch, *A. testudineus*, consume snails [27] but the mouth gap possibly accounts for the limitation of selection of prey snails of a particular size class. These fishes have the ability to stock food [28], they can accumulate and store more number of preys than they can intake at a time.

The niche breadth was much broader, suggestive of a generalist nature and ability to sustain on a variety of prey items. The wide range of prey items utilized by the fish evident from the analysis of the gut contents and prey selection, considers their adaptability to wide variety of habitats [16, 17, 19].

The wandering occurrence in plant parts (algae) and aquatic plants in the diet of three air-breathing fishes represents either the gut contents of the prey or material attached to prey appendages during prey capture. Plants have nutritional significance, and provide gross ecological energy of the order of 10% [29] and mechanically disrupted and partially digested [30]. Early stages of insects consumption by the fish is of nutritional significance since such material is associated with organic accumulation and possesses a high caloric content [31, 32].

The high incidence of utilization of allocthonous fauna (chiefly terrestrial insects, ants) as a nutritional source is advantageous in the introduction of fishes as biological control agents of mosquito larvae since this major alternate nutritional source restrains the fish from exterminating valuable aquatic fauna, chiefly prawns, tadpoles and other fish frys [32].

The differential exploitation of food with fish size is apparent only to a slight degree in air breathing fish and is related principally to differences in prey size. This orientation by the fish to optimal prey size has been attributed by Hyatt [33] to the fact that any predator which orients visually possesses an upper limit and a lower limit which it will detect and respond positively. Again gape of the mouth dictates the prey size that can be handled by different sizes of fish. Another reason for the shift in preferred food items may be, as found by Nilsson [34], as fish size increases, energy expended in capturing smaller prey becomes uneconomic. This slight alteration in food habits is advantageous as size dependent differences in feeding reduces intraspecific competition [32, 35] and permit more efficient utilization of the habitat resources [32, 36].

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