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Diet of African killifish *Aphyosemion gardneri* (Aplocheilidae) in a Nigerian rainforest pond *

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Abstract The diet of *Aphyosemion gardneri* was studied in Mfangmfang pond in Uyo, Nigeria from January to December. The major food components (in decreasing order of dominance) were terrestrial invertebrates, macrophytes, aquatic invertebrates, microcrustaceans, sand grains, and algae. Hymenoptera, Coleoptera, and Diptera were considered secondary items, while fine particulate organic matter (FPOM), which occurred throughout the year, was a primary food item. Males consumed more terrestrial invertebrates than females. The wet-season diet comprised 16 items whereas the dry-season diet comprised only seven items. The relative importance of terrestrial and aquatic invertebrate was higher during the dry season, while that of macrophyte matter microcrustaceans, sand grains and algae was higher in the wet-season. Adults fed on more allochthonous invertebrates than juveniles. Females had higher foraging performance than males. Similarly, the foraging performance of adults was much higher than that of the juveniles [*Acta Zoologica Sinica* 52 (4): 669－675, 2006].

Key words Killifish, *Aphyosemion gardneri*, Africa, Stomach contents, Rainforest fish

尼日利亚热带雨林池塘中茄氏旗□的食性 *

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摘　要　本文逐月研究了尼日利亚 Mfangmfang pond 中茄氏旗□全年的食性。其食谱按优势多寡出现的次序分别是陆生无脊椎动物、大型植物、水生无脊椎动物、小型甲壳动物、沙粒和藻类。我们将膜翅目、鞘翅目和双翅目昆虫作为其食性的次级项，而全年都出现的有机体碎屑作为初级项。雄鱼较雌鱼捕食了更多的陆生无脊椎动物。茄氏旗□在雨季有 16 项食物组成，但旱季只有 7 项。就相对重要性而言，陆生和水生无脊椎动物在旱季更大，而大型植物碎屑、小型甲壳动物、沙粒和藻类则在雨季更大。成鱼较幼鱼更多地以外源性无脊椎动物为食。雌鱼较雄鱼有更强的觅食能力；同样，成鱼较幼鱼的觅食能力强得多［动物学报 52（4）：669－675，2006］。

关键词　□鱼　非洲　胃含物　雨林鱼类

Aphyosemion gardneri is a small, brightly coloured African killifish that commonly inhabits stagnant pools and gently flowing streams, especially where there is a dense aquatic and overhanging vegetation (Sterba, 1962). It occurs abundantly in West Africa (Reid, 1982; Lazara, 1984). There have been few ecological studies of this fish species in the Niger Delta region, Nigerian, probably because its small size precludes its commercial value and deters research interest. Available reports on this species include the observation of Ekwu (1998) as one of the rivulins found in the lower Cross River Basin in Nigeria. According to her the fish was annual in the wild with long zygotic diapause and has high fecundity. Akpan and King (2003) showed that *A. gardneri* occurs throughout the year in Mfangmfang pond, Nigeria.

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This dearth of information on ecology and the size structure of the fish motivated the present study to focus on the food and feeding habits of the populations in a rainforest pond in southern Nigeria.

1 Materials and methods

1.1 Study area

This study used specimens of *A. gardneri* collected from Mfangmfang pond (Fig.1) in Uyo within the rainforest belt of Akwa Ibom State, Nigeria. The pond has a surface area of 2.9 ha and a mean depth of 6.3 m during wet season and 3.9 m during dry season. Detailed descriptions of prevailing environmental conditions in the area were provided by King and Nkanta (1991) and Akpan and Akpan (1994).

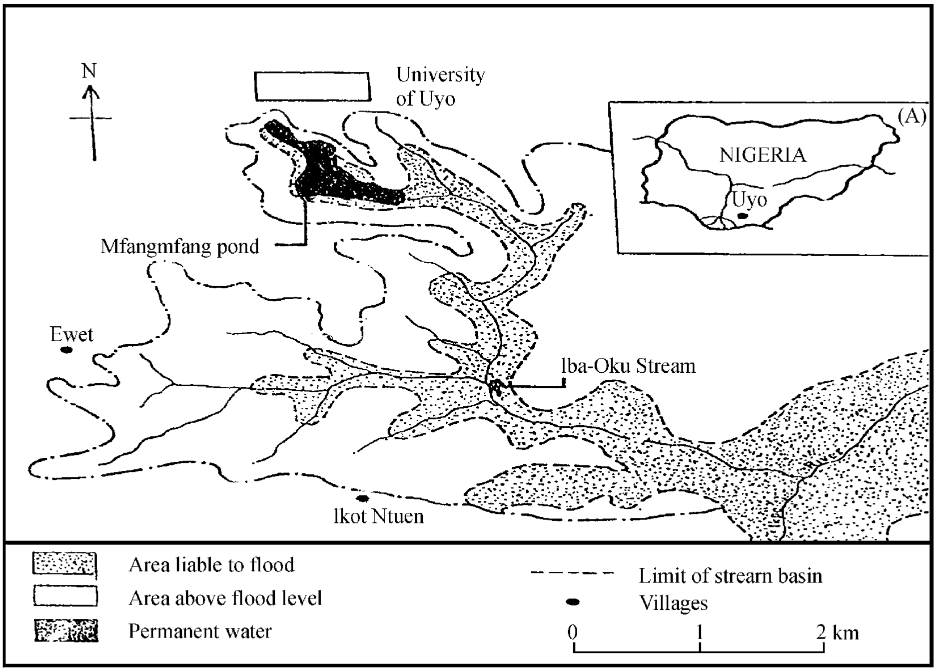

Fig.1 Map of the drainage basin of the Iba-Oku stream showing Mfangmfang pond

1.2 Study species and methods

We collected monthly samples of *A. gardneri* (January – December, 2000) using a circular pond net (15 cm diameter opening, 30 cm bag depth, 15 cm handle length). Sampling was conducted in the open water, littoral zone, and fringing swamps during the day. We measured total length (TL) of specimens (mm). Those measuring >32 mm TL were dissected and sexed after examining the gonads. Smaller size specimens (<32 mm TL) were categorized as juveniles because we could not determine gender by gonad examination. The stomach of each specimen was removed and opened. Stomach fullness was estimated on a 0 – 20 point scale. Thus 0, 5, 10, and 20 points were allotted to empty, 0.25 full, 0.50 full, 0.75 full, and fully distended stomach respectively. The stomach-repletion index (SRI) (i. e., number of stomachs containing food as a fraction of total sample × 100) and mean stomach fullness (MSF) (i. e., average points per stomach), were used to evaluate pattern of feeding activity. The contents of each stomach were placed on a clean slide, a few drops of distilled water were added and examined macroscopically and microscopically (10× – 100×). The relative frequency and relative dominance of the food item were estimated. Temporal, ontogenetic and sex-based overlaps in diet composition were assessed by the percentage similarity coefficient (S) (Moss and Eaton, 1966):

$$S = \sum_{n-1}^{n} \min(X_i Y_i) \qquad (1)$$

where X_i and Y_i are proportions of the components of the series of items comprising the diets of X and Y. The index ranges from zero, for totally dissimilar dietary compositions to 100% for incident diets.

Diet breadth (B) was computed using the formula (Angermeier, 1982):

$$B = [\sum (P_1^2)^{-1} - 1/(n-i)] \qquad (2)$$

where P = proportion of the diet comprised by resource type i and n = number of food categories in the diet.

Food richness was considered as the total number of items recorded in the diet (King, 1989). Mann-Whitney U-test was used to compare feeding activities between seasons and sexes.

2 Results

A total of 615 specimens of *A. gardneri* measuring 12－55 mm TL was examined (Table 1). Specimens ＜32 T, with undetermined sexes, were considered juveniles (Fig.2). Males measured 32－55 mm TL and females 32－45 mm TL (Fig.3). Total length ranged between 14 and 55 mmTL in wet season and 13 and 44 mmTL in dry season (Fig.4)

Table 1 Monthly samples of *Aphyosemion gardneri* in Mfangmfang pond, Uyo, Nigeria

Sex	Months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Ssp.	Oct.	Nov.	Dec.
Male	0	2	1	8	23	17	14	11	18	0	0	3
Female	19	9	11	12	114	69	127	27	92	16	8	14
Total	19	11	12	20	137	86	141	38	110	16	8	17

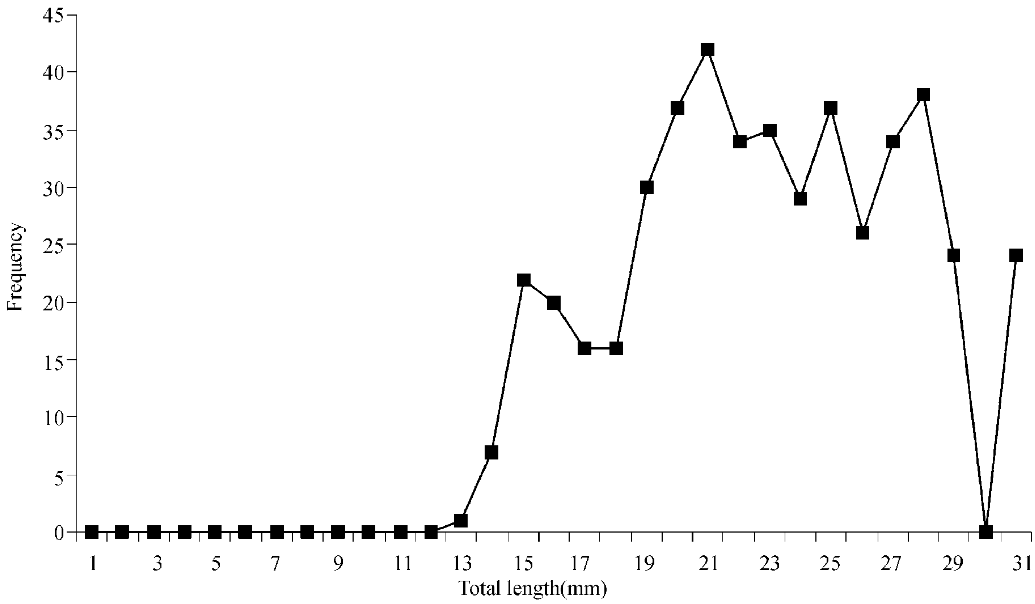

Fig.2 Length Frequency distribution of unsexed juveniles *A. gardnerii* Mfangmfang pond, Uyo, Nigeria

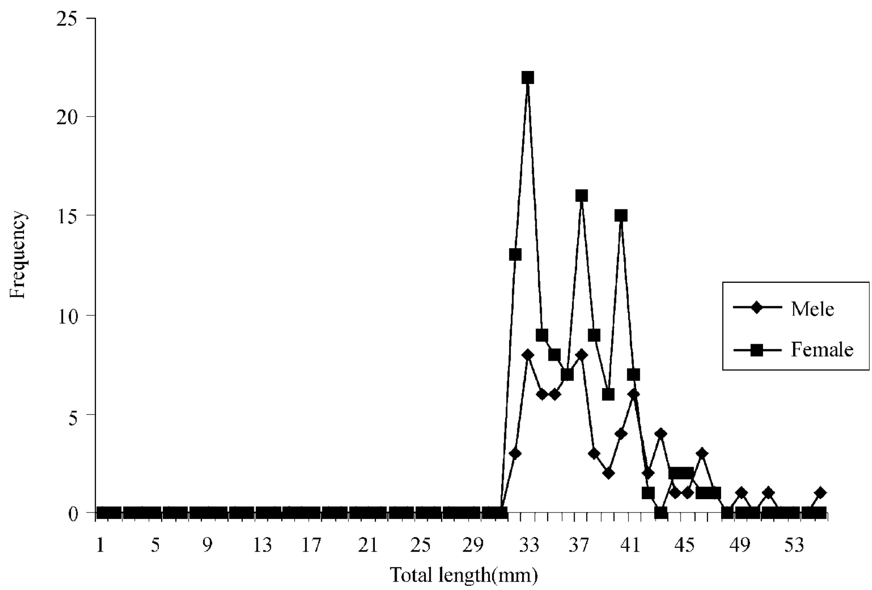

Fig.3 Length frequency distribution of male and female *A. gardnerii* Mfangmfang pond, Uyo, Nigeria

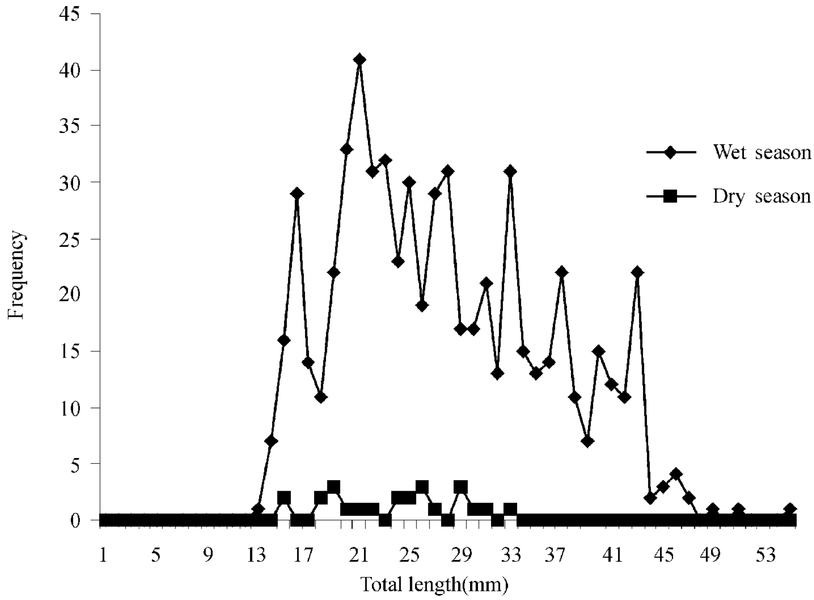

Fig.4 Length Frequency distribution of wet and dry season *A. gardnerii* Mfangmfang pond, Uyo, Nigeria

The overall trophic spectrum of *A. gardneri* is shown in Table 1. The primary food items were terrestrial invertebrates macrophyte matter and aquatic invertebrates Items of lower importance included zooplankton and sand grains while an alga was only incidental. Among terrestrial invertebrates hymenopterans were dominant followed by collembolans, coleopterans and arachnids. Acridids and lepidopterans were of minor importance (< 1.00% each). Aquatic invertebrates were mainly chironomids, dipterans and dragonflies. Macrophyte matter ingested was comprised largely of fine particulate organic matter (FPOM), while coarse particulate organic matter (CPOM) formed <5.0% of the diet. CPOM comprised mostly fragments of decaying leaves of macrophytes. Zooplankters were mostly copepods and cladocerans (*Daphnia*). The only alga consumed was *Coelosphaerium*. Insects in advanced stages of digestion and thus difficult to identify were categorized as "unidentified insects", and these constituted 0.6% of the diet.

Intersexual variation in diet (Table 2) depicts the absence of culicid larvae and odonata nymphs in the males, while the females did not consume acridids, lepidopterans and algae. Males consumed more terrestrial invertebrates and zooplankton, while females ate more aquatic invertebrate and macrophyte matter.

Seasonal plasticity in diet (Table 2) shows that terrestrial invertebrates were of higher importance in the wet season than in the dry season. The relative importance of terrestrial invertebrates and plant matter increased with increase in fish size, while that of aquatic invertebrates decreased as fish grew (Table 3).

Feeding activity as depicted by mean stomach fullness (MSF) was significantly higher in wet than dry season ($U = 25$, n_1 $n_2 = 5$, 5, $P < 0.05$). There was no significant difference in MSF between males and females ($U = 25$, n_1 $n_2 = 5$, 5, $P < 0.05$). Foraging activity of the fish increased with body size (10 – 19 mm TL, SRI = 41.80; 20 – 29 mm TL, SRI = 43.00; ≥30 mm TL, SRI = 49.40).

There was great similarity in diet of males and females (S = 81.44%), and in diets of the wet and dry season (S=74.330%), considered at 90% overlap where there is dissimilarities (Angermeirer and Karr, 1983). Diets were similar among size groups (S = 59.71%). The diet breadth of males (B = 0.460) expanded more than females diet breadth (B = 0.290). The diet breadth also was greater in the dry season (B = 0.556) than wet season (B = 0.261). The stomach repletion index was higher in males (SRI = 59.30%) than females (SRI = 42.90%). It was also higher in wet season (SRI = 46.90%) than dry season (SRI = 34.33%).

3 Discussion

Aphyosemion feeds mostly on insects, many of which are terrestrial. The dominant insects were terrestrial hymenopterans and aquatic dipterans. About 70% of the insects consumed were terrestrial, indicating some partial dependence of this fish on allochthonous food resources. The role of terrestrial food resources in the trophic ecology of tropical stream fishes has been noted by Welcomme (1979). This source of food supply could be limiting to the

Table 2　Diet composition of *Aphyosemion gardneri* in Mfangmfang pond, Uyo, Nigeria showing dietary variation with sex and season

Food items	Relative frequency (RF)				
	Overall	Male	Female	Dry season	Wet season
Terrestrial Invertebrates					
Hymenoptera	107	14	93	20	87
Coleoptera	11	5	6	5	6
Orthoptera	1	1			1
Lepidoptera	1	1			1
Collembola	12	1	11	5	7
Arachnida	10	3	7	1	9
Subtotal	142	25	117	31	111
Aquatic Invertebrate					
Diptera					
(Chironomidae)	33	3	30	9	24
Culicidae	10		10		10
Odonata	2		2		2
Subtotal	45	3	42	9	36
Unidentified Invertebrate	17	3	14		17
Macrophyte matter					
CPOM	17	8	9	1	16
FPOM	73	9	64	12	61
Subtotal	90	17	73	13	77
Microcrustacean					
Brachiopoda					
Cladocerans	10	4	6		10
Copepoda					
Cyclopoids	5	2	3		5
Subtotal	15	6	9		15
Algae					
Coelosphaerium	1	1			1
Sand grains	6	1	5		6
Food richness	16	14	13	7	16

fish population, as it could be irregular and seasonal. From our observations, hymenopterans occurred in the diet throughout the year, FPOM was consumed in 10 months while coleopterans and dipterans occurred in 8 and 7 months respectively. The remaining 12 food items occurred in less than 6 months of the year. The limiting effects of the irregular items has been offset by the four most regular items (hymenopterans, FPOM, colepterans and dipterans) that form the main diet. Secondly, the overlap in availability of irregular items enhance the constant food supply and foraging activity throughout the year.

The increase in food richness in wet season (Table 2) may be linked to the increase in allochthonous input of particulate organic matter and terrestrial invertebrates from the riparian zones through runoff. This finding is further supported by the wider diet breadth observed in the dry season than during the rains (B = 0.556 dry season, 0.261 wet season). Optimal foraging theory (Schoener, 1971; Pyke et al., 1977; Angermeier, 1982) postulates an inverse relationship between diet breadth and food-resources abundance. Diet breadth contracts during periods of increased resource abundance. In the tropics, fishes show greater diet breadth during the dry than wet season (Zaret and Rand, 1971; Welcomme, 1969; Lowe-McConnell, 1975; Angermeier and

Table 3 Ontogenetic variation in the relative frequency of the diet of *Aphyosemion gardneri* in Mfangmfang pond, Uyo, Nigeria

Food items	Size groups (mm TL)		
	10 – 19	20 – 29	≥30
Terrestrial Invertebrates			
Hymenoptera	14	56	37
Coleoptera	1	5	5
Orthoptera			1
Lepidoptera			1
Collembola	3	8	1
Arachnida		5	5
Subtotal	18	74	50
Aquatic Invertebrate			
Diptera			
(Chironomidae)	13	13	4
Culicidae	3	3	
Odonata	1	1	
Subtotal	17	17	4
Unidentified Invertebrate	2	8	7
Macrophyte matter			
CPOM	1	4	12
FPOM	12	41	20
Subtotal	13	45	32
Microcrustacean			
Brachiopoda			
Cladocerans	3	3	4
Copepoda			
Cyclopoids	2	1	2
Subtotal	5	4	6
Algae			
Coelosphaerium			
Sand grains	1	4	1
Food richness	12	13	14

Karr, 1983; King and Akpan, 2002). The diet breadth of *A. gardneri* conforms with these earlier studies. Feeding activity of the fish therefore peaks in wet season like in many tropical waters (Welcomme, 1975, 1979, 1986), as demonstrated by high stomach fullness and repletion index.

There were some similarities in diet between males and females; however, the foraging performance in males is greater than in females because of their higher repletion index (SRI = 59.30% males, SRI = 42.90% females). This could be caused by higher energy demand of the males to support a more active life. The intersexual similarity index (S = 81.44%) showed a significant overlap in diet composition indicating limited differences in diet between the sexes.

More terrestrial invertebrates and macrophytes were consumed by adult stages than juveniles, while more aquatic invertebrates were consumed by juveniles. The observed increase in feeding activity with age is probably due to the fact that larger fishes (with greater body dimensions) have a greater mouth gape to ingest bigger food items; swim faster (King et al., 1990) and have better visual acuity (Mittlebach, 1981, Hairston et al., 1982), hence obtaining greater foraging advantage than smaller ones. Secondly, the spatio-temporal location of the large fishes probably afforded them foraging advantage over the smaller ones. For instance, the increase in RF of terrestrial invertebrates and macrophyte matter in larger size groups suggests that larger fishes may be both more pelagic and littoral where these allochthonous items are more accessible. This ontogenetic diet shift may reduce intraspecific competition for food resources among the size groups, promoting co-existence. Similar reports have been made by Whyte (1975) and Jacob and Nair (1982).

The overall food composition suggests surface, pelagic and bentho/bottom foraging styles in the foraging life of this fish. Terrestrial items (CPOM, spider) and mosquito larvae indicate surface feeding. Plankton and some insects occurring between surface and bottom indicate pelagic foraging while sand grains suggest benthic feeding according to King et al. (1990). The importance of sand grains is not fully known as food items. They were probably ingested with other food items during bottom feeding. The ability of the fish to exploit surface, mid, and bottom water gives the fish a trophic-niche continuum. This is ecologically significant in allowing the fish to fully utilize the food resources available in the entire water column. This could be another reason for the high dietary breadth.

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