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Effect of ecological variables on the population dynamics of sympatric notobranchiid fishes

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Effect of environmental variables on the population dynamics of two sympatric notobranchiid fishes, *Epiplatys bifasciatus* and *E. spilargyreius* in the seasonal Monai Stream of the Kainji Lake Basin in Nigeria were studied for 24 months. In all, 2,544 and 937 specimens of *E. bifasciatus* and *E. spilargyreius* were collected respectively. *E. bifasciatus* was more abundant of the two species throughout the study period. For both species, monthly abundance followed the same pattern; May to October (rainy season) was a period of low abundance while November to April (dry season) was a period of high abundance. Relative abundance was correlated with physical, chemical, and biological factors using regression analyses. The relationship between 12 environmental variables (temperature, transparency, conductivity, hydrology, dissolved oxygen, pH, nitrogen, phosphate, potassium, sodium, $CaCO_3$, chlorine) and abundance of the two species showed that *E. spilargyreius* abundance was strongly correlated with water conductivity (Pearson's coefficient, r = 0.884, P<0.01) but correlated negatively with temperature (Pearson's coefficient, *r* = -0.559 at P< 0.05). *E. bifasciatus* abundance had a slight positive correlation with alkalinity (*r* = 0.501 at P< 0.05). Three habitat types (vegetated pool, vegetated riffle, and marsh) were preferred by both species, whilst unvegetated habitats were avoided. *E. spilargyreius* was fairly specific in its habitat preference, with a significant positive correlation (*r* = 0.65, P < 0.05) to marshy habitat, whereas *E. bifasciatus* showed some flexibility in habitat-use.

Key words: *Epiplatys bifasciatus*, *Epiplatys spilargyreius*, population, abundance, killifish, stream fishes, environmental variables, habitat-use.

INTRODUCTION

Biodiversity, species richness, density of populations are results of a multitude of environmental variables (Wagner et al., 2000). Different studies have investigated the relationships between biotic and abiotic factors, including geological factors, land cover and land use types, hydrological factors, stream habitat characteristics, stream order, and water quality on the biodiversity, individual species and even populations (Shahadat

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et al., 2012; Barros et al., 2013; Yong-Su Kwon et al., 2012; Humpl and Pivnicka, 2006; Kouamélan et al., 2003). According to Yong-Su Kwon et al. (2012), these environmental factors are considered in a hierarchical structure ranging from large scale to small scale. Large-scale factors (that is, landscape features) affect small-scale factors (that is, microhabitat conditions and water quality, which have important influences on the distribution and abundance of organisms). These studies are of importance to fisheries managers and for engineers dealing with stream and river channels (Yong-Su Kwon et al., 2012; Park et al., 2005, 2006; Maret et al., 1997).

Studies on the influence of environmental variables on the existence and abundance of stream fishes has been done in the temperate regions but few has been conducted in the tropics especially Africa (Koel and Peterka, 2003; Toham and Teugels, 1997; Barros et al., 2013; Yong-Su Kwon et al., 2012; Humpl and Pivnicka, 2006; Kouamélan et al*.,* 2003). Streams, swamps, small rivers and seasonal pools are generally extreme and highly variable even when not anthropogenically influenced (Ostrand and Wilde, 2002). Evaluation of the impact of environmental variables on fish in human-altered stream especially in the tropics has been largely overlooked.

Studies on interspecific competition among stream fishes in Africa has received little attention even when such studies provide insight into coexistence of different species in an assemblage and addresses the more general question of how biodiversity is created and maintained. Opinion differs over the major processes affecting coexistence among stream fishes especially among sympatric species, which some investigators attribute to partitioning of resources such as food, space and risk of predation (Paine et al., 1982; Herbold, 1984; Schlosser, 1987; Persson and Greenberg, 1991; Hayse and Wissing, 1996; Jordan et al., 2000; Jordan, 2002; Santos et al., 2004). Others however maintain that resource partitioning may not be of major importance to stream fishes, due to frequency of natural disturbances such as flood and drought (Grossman et al., 1982; Grossman and Freeman, 1987; Heck and Crowder, 1991; Grossman and de Sostoa, 1996; Kramer et al., 1983). Most studies on habitat use have been on temperate fishes while in most tropical streams, habitat preference or factors causing it have received little interest (Grossman and Freeman, 1987; Baltz et al., 1991).

Habitat alteration is one of the consequences of man-made lakes resulting in the loss of diversity, habitat degradation, destruction or the loss of specific habitats. The ecological study of the ichthyofauna confined in reservoirs compared with their counterparts inhabiting streams is of high scientific value, because this constitutes a natural reference for investigating adaptations adopted by species (Oliva-Paterna et al., 2003). Prior to the construction of Kainji Dam in Nigeria (West Africa) and subsequent formation of Kainji Lake in 1968, the order Cyprinodontiformes was represented in the Kainji Lake area (Niger River, Nigeria) by two nothobranchiids (Two-striped panchax, *Epiplatys bifasciatus* (Steindachner, 1881) and the Senegal or green panchax *Epiplatys spilargyreius* (Duméril, 1861), and a poeciliid, *Poropanchax normani* Ahl 1928 (Daget, 1962; Banks et al., 1965). However, following the inundation of the extensive swamps and some tributaries of the Niger River by the newly created lake, these species disappeared in the new lentic environment (Imevbore and Bakare, 1974). In 2001, *E. bifasciatus* and *E. spilargyreius* were located in a small grassy stream, approximately 1.9 km long, flowing into the lower western portion of the lake at 9°53′45″ N, 4°33′14″ E near Monai village, a few kilometers upstream from the Kainji Dam. The Monai Stream is annually inundated by the lake up to half its length, during which period the two species can be found in the lake itself. A survey of the streams around the lake basin shows *E. bifasciatus* alone occurring in perennial riparian streams and *E. spilargyreius* in small marginal swamps but nowhere did the two species occur together except in the Monai Stream. It thus indicates that Kainji Lake constituted in part a geographical barrier that created their sympatry and also prevents the two populations from colonizing and dispersing into nearby adjourning streams. The two populations therefore represent isolated unique relic and the stream, a refuge where both species are found together with potential inbreeding depression and interspecific hybridization.

The existence of these two notobranchiid species in a reservoir locked stream provided a natural laboratory to study the impact of man-made lake on inundated streams. The life history and population dynamics of these two fish populations has been studied (Olaosebikan et al., 2006; Olaosebikan, 2007; Olaosebikan et al., 2009; Nwafili et al., 2009). The objective of this present study is to investigate the environmental factors that are important in the survival and abundance of these two fishes in Monai Stream. We hypothesize that: (i) relative abundance of *E. bifasciatus* and *E. spilargyreius* is directly related to environmental factors (Temperature, Transparency, Conductivity, Hydrology, Dissolved oxygen, pH, Nitrogen, Phosphate, Potassium, Sodium, $CaCO_3$, Chlorine); (ii) relative abundance of *E. bifasciatus* and *E. spilargyreius* is directly related to their species-specific microhabitat use.

MATERIALS AND METHODS

Description of the Monai Stream

The Monai Stream in which the *Epiplatys bifasciatus and E. spilargyreius* are found is at the narrow lower portion of the Lake Kainji, Nigeria near the dam site at latitude 09° 53 45'N and longitude 04° 33 14'E by Monai village (Figure 1). Kainji Lake has been described by many authors (Lelek, 1972; Imevbore and Bakare, 1974; Ita, 1978; Sagua and Fregene, 1979). The stream is

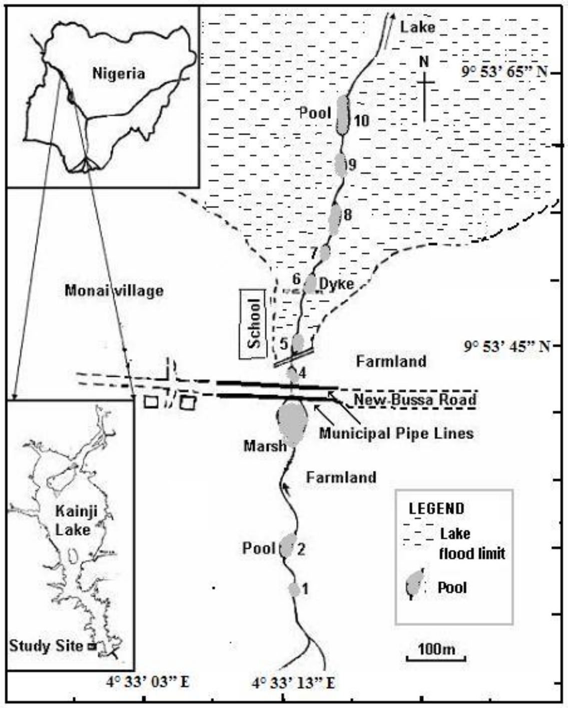

Figure 1. Map showing the location of the Monai Stream.

a seasonal first order stream of about 2 km in length and it can be divided into two parts; the lower half that is flooded annually by Lake Kainji from September to March and upper portion that is fed by rainfall and leaking municipal water pipes. It has ten perennial pools with average surface area of 25 m^2 and average depth of 0.4 m. Two of these pools are located upstream of the leaking municipal water pipes and are usually dry from February to June; the third is situated under the first leaking pipes while the rest are downstream of the two municipal water pipes. The first four pools are never flooded with the lake's water throughout the year while the others are flooded between September and February. The rate of flow is negligible except at the height of rainy season. In between the pools are a narrow ripple of one meter maximum width and marshes. The bottom is muddy in the pools with a lot of decaying organic matter while the ripple bottom is compact clay and sand. The marshy and the stream banks that is sometimes used for rice farming is covered with dense grasses (*Leersia hexandra, Alternanthera sessilis*) and Cyperus (*Mariscus longibracteatus*). The in-stream vegetation include emergent plants (*Ecliptica alba, Echinocloa* spp. *Ipomoea aquatica and Ludwigia* spp.), floating plants (*Azolla, Nympha lotus*) and submerged plants (*Ceratophyllum* spp. and filamentous algae).

The composition offauna varies seasonally but consists principally of *Clarias anguillaris, Hemichromis bimaculatus, H. fasciatus, Oreochromis niloticus, Coptodon zilli, Parachanna obscura,* and *Polyterus senegalus* whilethe invertebrates include rotifer (*Filinia, Brachionus and Asplanchna*); copepods, Cladocerans, Gastropod (*Pila* and *Bulinus*), insects of the orders; Diptera, Coleoptera, Odonata and Hemiptera and aquatic mites.

Sampling design

Four sampling stations were chosen on the longitudinal gradient of the stream: station I (This is situated at pool 2 and is located upstream of the leaking pipes); station II (this is located at pool 3 situated under the first leaking pipes); station III located 50 m downstream of the leaking pipes and station IV situated at the last pool (no. 10) nearest to the Lake. These stations were chosen taking into account the different terrestrial land use, the influence of municipal water pipe leakages and lakes' hydrology.

Fish population abundance estimate

Sampling was conducted monthly from January 2003 to December 2004. Sample reaches (Figure 1) ranged from 10 to 30 m depending on the stream hydrology. On each sampling occasion, both *E. bifasciatus* and *E. spilargyreius* were netted using a scoop-net with a mouth diameter of 30 cm, a net basket of 45 cm in length and a 2 mm mesh size, operated for 30±5 min. The sampling was done by the same person throughout the study to reduce bias in fishing efficiency. A scoop-net was used because the shore-hugging and surface-dwelling habit of these fishes makes them visible and easy to catch, whereas the abundance of aquatic vegetation in the stream makes it difficult to use a seine net and traps are ineffective because the species cannot be attracted into them by bait. The fishes are released back to the stations where they were caught after length, weight and other biological parameters of each fish have been taken. This was done in order not to deplete their population. Simple descriptive statistics were used to report the monthly abundance of the two species.

Physicochemical parameters

Physico-chemical parameters of the stream were taken monthly between the hours of 9.00 - 11.00 a.m. for three years (2002 to 2004). Three 1 L plastic containers were used to take monthly water sample at each site and were analyzed for dissolved Oxygen (DO), pH, Nitrogen, Phosphate, Potassium, Sodium, $CaCO_3$ (mg/L) and Chlorine (mg/L) at the Department of Water Resources Aquaculture and Fisheries (WAFT) Laboratory, Federal University of Technology, Minna, Nigeria.

Stream structure

The stream width was measured using tape rule at every 100 m along the stream length while the depths of the stations were measured using calibrated (0.1 m) stick.

Temperature

The average of three readings of Mercury in glass thermometer (-10 to 110°C) was used as the surface temperature at each site.

Transparency

A secchi disc of 20 cm diameter fitted with calibrated (0.1 m) line was lowered into the water until it just disappears and then raised up to be visible. The average reading of when the disc disappeared and when it reappeared was taken as the transparency of the water at each station. In any station where the stream depth is too shallow to use secchi disc, it is recorded as clear to bottom or the turbidity is inferred from data from other stations.

Conductivity

This was measured using a benchtop conductivity meter, Jenco -

Model EC3175. The average of three readings of conductivity meter (ohms) calibrated to read a value at a standard temperature of 25°C was used as the water conductivity at each station.

Dissolved oxygen (DO)

The dissolved oxygen was measured with a portable Hanna DO meter. The probe was placed in the stream water after calibration at ambient temperature. The average of three readings of DO meter was used as the dissolved oxygen levels at each station.

pH

This was measured using a portable pH meter (TechPro model). The probe was placed in the stream water after calibration at the ambient temperature. The average of three readings of pH meter was used as the pH of the water at each station.

Other chemical parameters

Nitrogen, phosphate and alkanility: Nitrogen and Phosphate were determined colorimetrically using phenol disulfurnic acid and ascorbic acid methods respectively (APHA, 1995).

Potassium and sodium: These were determined using a flame photometer. A little volume of the water sample poured into 50 ml beaker and aspirated into the photometer and digitally read out.

$CaCO_3$ (mg/L): was determined by atomic absorption spectrophotometer.

Alkalinity (mg/L): The method that was used for this water parameter is those described by APHA (1995).

Chlorine (mg/L): The free chlorine in the water was measured using Chlorine colorimeter 1200 Lamotte. The chlorine content of municipal water was compared to those taken at the sampling stations).

The data of physico-chemical parameters were standardized, Correlation matrix (Pearson's method) was performed to know the inter-relationship between these parameters and the abundance of the two killifishes.

Hydrology and precipitation

The hydrological regime of the Lake Kainji from year 2001 were obtained from National Electric Power Authority (NEPA) while the mean monthly rainfall of New Bussa area were obtained from National Institute for Freshwater Fisheries Research (N.I.F.F.R.), New Bussa meteorological station in order to investigate the effect of the Lake hydrology and rainfall on the Monai Stream.

Descriptive statistics were used to describe the relationship between rainfalls, stream and lake hydrology on the abundance of *E. bifasciatus* and *E. spilargyreius.*

Habitat preference

Fish habitat data were collected from January to December, 2003 at four sites – pool 3, 6, 7, 9 and when the Lake floods the stream in the Lake. The stream was separated into microhabitats of pools, riffles and marshes. Except in the Lake where there is no riffle, all the other sites have these macro-units though their sizes vary with the hydrology of the stream. Five microhabitat types were used to know the habitat preference of the two species. They are: Open water of pool; Vegetated portion of pool; Riffle portion with weed; Riffle portion without weed and Marshes. Fish were collected using scoop-net for 30 min at each site divided into 6±1 min at each microhabitat types. The surface dwelling habit of these fish makes it easy to know where a specimen is found and recorded accordingly, even when they escape to another microhabitat before being caught.

Analysis of variance (ANOVA) was used to determine the effects of sites, micro-habitat, month, and the interaction between habitat and month on the abundance of two species.

Subsequently, simple correlations were used to examine relationship between micro habitat, site, month, and fish abundance.

RESULTS

Population dynamics of *E. bifasciatus* and *E. spilargyreius* in Monai Stream

Monthly sampling by catch per unit time of 30 min at each station was done for 24 months from January 2003 to December 2004 and the result is given in Figure 2. In all, 2,544 and 937 specimens of *E. bifasciatus* and *E. spilargyreius* respectively were collected. Figure 2 indicates that *E. bifasciatus* is the most abundant of the two species throughout the 24 months sampling period. The abundance in year 2003 is lower than that of 2004 even though the monthly abundance followed the same pattern of high abundance from October to April and low abundance from May to September.

Physicochemical parameters of Monai Stream and their relationship to fish abundance

Water quality parameters varied from one site to another especially when the stream is not flowing and reduced to series of pools. The average physicochemical parameters of the Monai Stream are given in Table 1.

Mean depth varied on the average with the season and site but not very significantly. Mean temperatures (Table 1) were significantly different by months, and were highest in the months of February to May (32°C), average in months of June to October (27°C) and were lowest when northwest winds of harmattan prevailed from November to January, with a minimum of 21ºC. No site variation was observed (P>0.05). The pH and transparency of Monai Stream did vary significantly from the mean of 7.12 and 0.241 m respectively throughout the sampling period. Dissolved oxygen varied with season being lowest in the months of March, April, May and June and highest from July to February. The lowest mean values occurred in March (4 mg/L). Conductivity indicated significant variations with the season with values ranging from 7.3 to 33 mS/cm. Other variables (Nitrate, Phosphate, Chlorine, Alkalinity, Potassium, Sodium, $CaCO_3$ (Hardness) showed significant

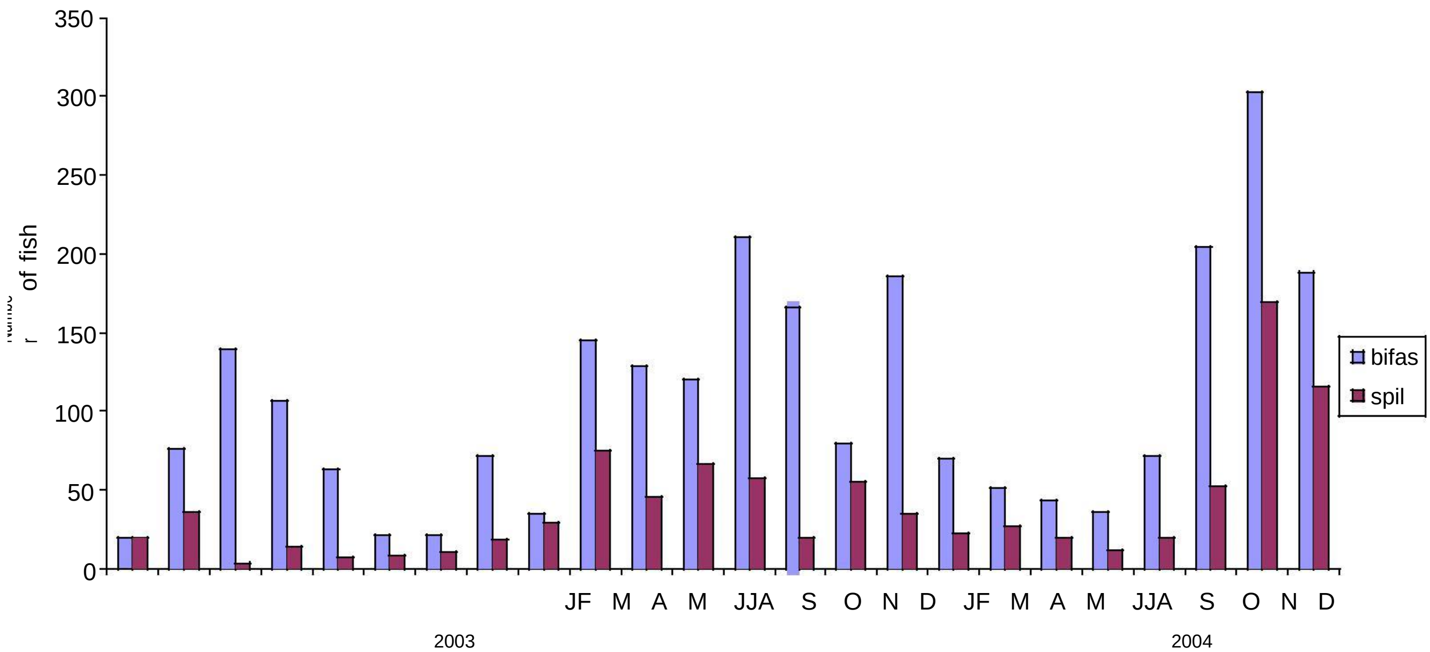

Figure 2. Relative abundance of *E. bifasciatus* and *E. spilargyreius* in Monai Stream.

Table 1. Average physicochemical parameters of Monai Stream.

Parameter	Range	Mean	Standard Error (±)
Stream depth (m)	0.25 - 0.92	0.65	0.16
Temperature (°C)	21 - 32	27.29	0.49
pH	6.25 - 7.6	7.12	0.10
Transparency (m)	0.1 - 0.45	0.241	0.015
Dissolved Oxygen (mg/L)	4 - 7	5.96	0.14
Nitrate (ppm)	2.92 - 86.15	20.71	3.81
Phosphate (ppm)	0.0015 - 5	2.56	2.06
Conductivity (mS/cm)	7.3 - 33.7	18	0.87
Chlorine (mg/L)	3.55 - 10.65	8.48	0.63
$CaCO_3$ (Hardness) (mg/L)	0.03 - 9.4	0.070	0.041
Alkalinity (mg/L)	0.69 - 9.05	1.35	0.15
Potassium (mg/L)	0.05 - 13.5	7.95	0.94
Sodium (mg/L)	12.63 - 121.5	31.85	3.56

variation with season as shown in Table 1.

Correlation between abundance of *E. bifasciatus, E. spilargyreius,* twelve environmental factors (temperature, transparency, dissolved Oxygen, Nitrate, Phosphate, pH, Rainfall, conductivity, Sodium, Potassium, Alkalinity and Calcium carbonate), and the intercorrelations between these variables are presented in Table 2. Abundance of *E. spilargyreius* is highly correlated with conductivity (Pearson's coefficient, r = 0.829 at P< 0.01) but negatively correlated with temperature (Pearson's coefficient, r = -0.559 at P< 0.05). Linear relationship between *E. spilargyreius* abundance and conductivity is given in Figure 3. On the other hand, *E. bifasciatus* abundance had a slight positive correlation with Alkalinity (Pearson's coefficient, r = 0.501 at P< 0.05).

Microhabitat preference

Five microhabitat types were considered (1- Open water of pool; 2- vegetated portion of Pool; 3- Riffle portion with weed; 4- Riffle portion without weed and 5- Marshes) but

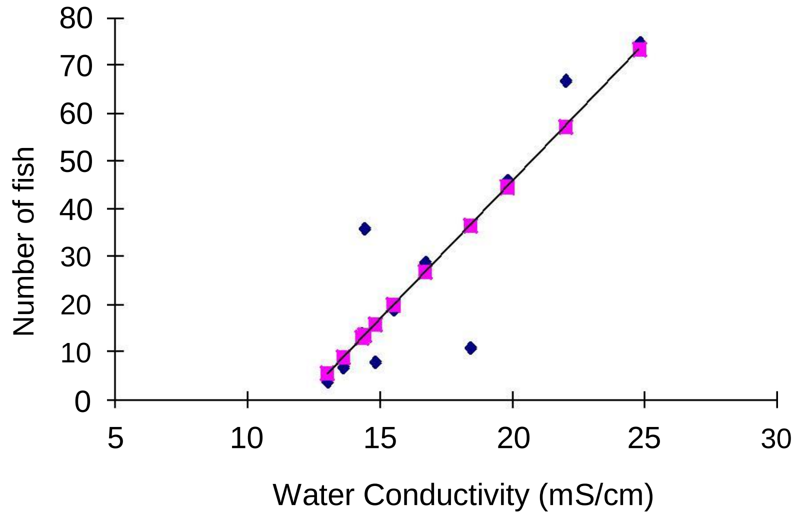

Figure 3. Linear relationship between *E. spilargyreius* abundance and water conductivity.

Table 2. Correlation matrix of *Epiplatys bifasciatus* and *E. spilargyreius* abundance and environmental variables (Pearson's correlation coefficient).

Environmental factors	Temperature	Transparency	Dissolved Oxygen	Nitrate	Phosphate	pH	Rainfall	Conductivity	Na^+	K^+	Alkalinity	$CaCO_3$
Temperature	1.00											
Transparency	-0.202	1.00										
DO	-0.468	0.530	1.00									
Nitrate	0.241	-0.375	-0.420	1.00								
Phosphate	0.522	-0.171	-0.580*	0.737**	1.00							
pH	-0.492	-0.133	0.115	-0.046	-0.411	1.00						
Rainfall	0.263	0.354	0.142	-0.153	-0.189	0.005	1.00					
Conductivity	-0.670*	0.115	0.771**	-0.370	-0.554	0.333	-0.212	1.00				
Na^+	0.734**	0.043	-0.112	-0.046	0.243	-0.411	0.026	-0.431	1.00			
K^+	-0.582*	-0.502	-0.086	0.306	-0.080	0.544	-0.661*	0.265	-0.403	1.00		
Alkalinity	0.435	-0.345	-0.399	-0.065	0.174	-0.196	-0.377	-0.425	0.739**	0.144	1.00	
$CaCO_3$	-0.313	0.479	0.576*	0.591*	-0.686*	-0.337	0.442	0.507*	0.202	-0.258	-0.373	1.00
E. bifasciatus	-0.124	-0.567	-0.130	-0.184	-0.291	0.193	-0.458	0.255	0.050	0.490	0.501*	0.171
E. spilargyreius	-0.559*	-0.216	0.461	-0.354	-0.451	0.252	-0.297	0.829**	-0.496	0.376	-0.229	0.399

(*) Denotes significant at $P< 0.05$ and (**) denotes significant at $P<0.01$.

analysis could only be performed for three sites (*vegetated portion of Pool; Riffle portion with weed* and *Marshes)* where fishes were found abundant enough to merit analysis. Both species afford open pools without vegetation except when they are driven out from the vegetated areas or got stranded in a receding pool. Fish using riffle habitat without weed is uncommon, only two *E. spilargyreius* were recorded from this habitat in the whole year. A total of 1,157 *E. bifasciatus* were collected between January and December, 2003 and One-way Analysis of Variance (ANOVA) was used to determine the effects of habitat, location, month, the interaction between habitat and month, habitat and site on the abundance of the *E. bifasciatus*. There was significant variation in microhabitat preference of *E. bifasciatus* in Monai Stream (F = 4.937, P = 0.0133 at 95% significance level). More of *E. bifasciatus* were found in the vegetated pool microhabitat followed by vegetated riffles and least in the marshes. *E. bifasciatus* were rarely found in the open non- vegetated part of pools and riffles. Habitat type and month interacted weakly (F= 0.65, p = 0.768) to affect *E. bifasciatus* abundance. This means that the abundance of *E. bifasciatus* did not vary significantly between the 12 months in the three habitat types (Figure 4). Abundance of *E. bifasciatus* did not vary between the five sampling locations (F = 1.0127, P = 0.4518) although the availability of these habitat types varies between sampling locations..

There is also significant difference in the microhabitat use of *E. spilargyreius* (F=5.09, p=0.0118) between the three habitats (V*egetated portion of Pool; Riffle portion with weed;* and *Marshes)* analyzed. There is significant difference in the preference of *E. spilargyreius* for the three microhabitats as shown in the LSD in Table 3. This panchax is more abundant in marshes and least in riffle with vegetation. *E. spilargyreius* also showed a significant variation in habitat – month interaction (F=1.18, p= 0.034) with the months of August, September, October, November, December, January, and February differing significantly from other months. The variation between months is graphically represented in Figure 5. Abundance of *E. spilargyreius* varies significantly between the five sampling locations (F = 1.643, P = 0.023) with more fish found in site 11 and 3, sites where marsh is more available.

Table 4 gives the summary of the relationship between abundance of the two fish in the three habitats and the month of the year. The relationship between abundance in the three habitats and months is not significant at p = 0.05 for *E. bifasciatus*. However, the abundance of *E*. *spilargyreius* is positively correlated to marsh microhabitat (r = 0.65, p = 0.022).

Effect of rainfall on fish abundance

The average rainfall in New-Bussa area is 1500 mm per annum spread over 6 months. The rainy season is between May and October while the dry season can be divided into harmattan (November to January) and heat (February to April) periods. The monthly abundance of the two killifish in 2003 and 2004 are compared with the monthly rainfall for the same period (Figure 6). The effect of precipitation on Monai Stream is shown by high water flow during the rainy season and non-flow with the stream breaking into series of pools in the dry season.

It can be deduced that the two species make use of the rainy season for recruitment as can be seen from the increase in their abundance at the height of rainy season from September. The period of least abundance is June and July when the effect of the rainfall is only reflected in stream flow and not in the flooding of the suitable vegetated breeding sites of the two species. The poor rainfall in 2002 that was not enough for the stream to have water precluded the recruitment of the two species during the rainy season of that year resulting in the low abundance of *E. spilargyreius* in early 2003. *E. bifasciatus* on the other hand was able to use the flood of the lake to recruit in 2002/2003 and is indicated by their abundance early 2003 and 2004.

Effect of Kainji Lake hydrology on *E. bifasciatus* and *E. spilargyreius* populations in Monai Stream

Kainji Lake experiences two flood regimes namely the white (flood resulting from rainfall within Nigeria characterized by high turbidity) and black floods (flood resulting from upper reaches of Niger River characterized by high transparency) , the intensity of each flood for the years 2001 to 2004 are shown in Figure 7. The amplitude of the local white flood is usually bigger but is not enough to flood the stream habitat of the killies whereas the black flood resulting from rainfall in the upper catchment of River Niger gets to Nigeria in December and persist enough to flood the Monai Stream.

Kainji Lake has effects on the two populations of notobranchids in Monai Stream in two ways: Firstly, they utilize the lake flood for recruitment (mainly *E. bifasciatus*) as mentioned earlier. Secondly, the lake acts as a geographical barrier preventing lateral connectivity between the Monai Stream and other streams thereby impeding the two killifish from colonizing other streams in the area. The only connection between these streams is the Lake. Although the conditions in these other streams may not be able to sustain these fishes in the dry season as they dry up completely and lack perennial pools that can serve as refugia for these fish in the dry season. During the rainy season when these streams are flowing, the lake on the other hand is at its lowest level and being devoid of protective aquatic plants at this period it presents a hostile corridor for these fish to disperse into adjoining streams. It is at this time also that the two fishes experience their lowest population abundance.

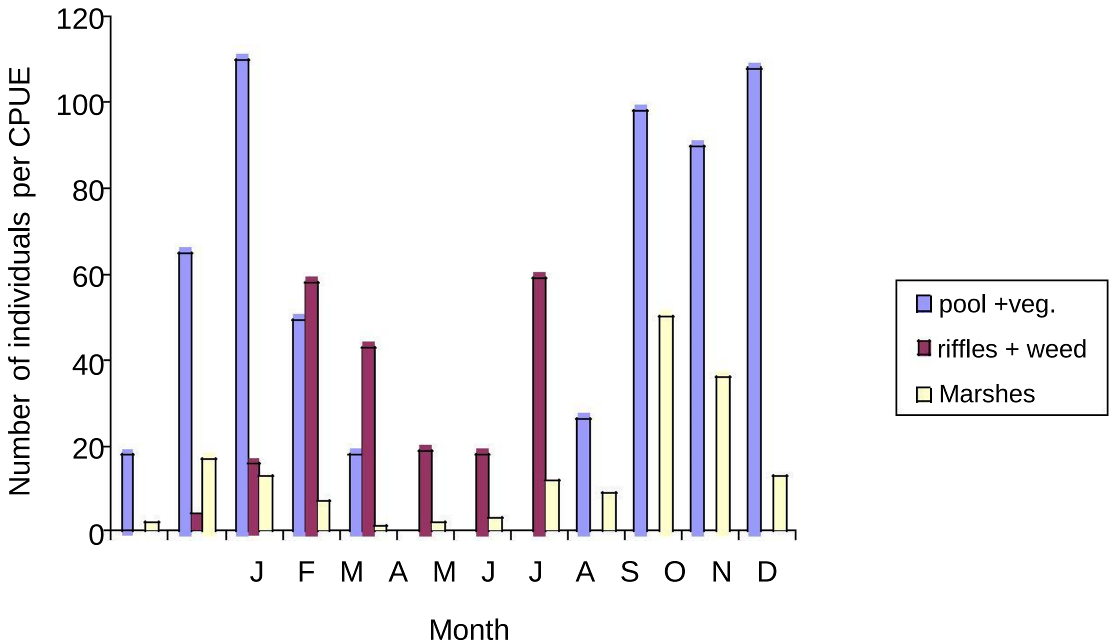

Figure 4. Monthly abundance of *E. bifasciatus* within three habitats types.

Table 3. LSD test for means of habitats at 95% level of significance.

Species	Habitat	Difference between Means	LSD	Declaration
	Marshes	13.75	20.92	Not significant
E. bifasciatus	Riffle + vegetation	18.50	20.92	Not significant
	*Pool + vegetation	48.75	20.92	Significant
	*Marshes	17.25	7.66	Significant
E. spilargyreius	Riffle + vegetation	4.25	7.66	Not significant
	Pool + vegetation	6.00	7.66	Significant

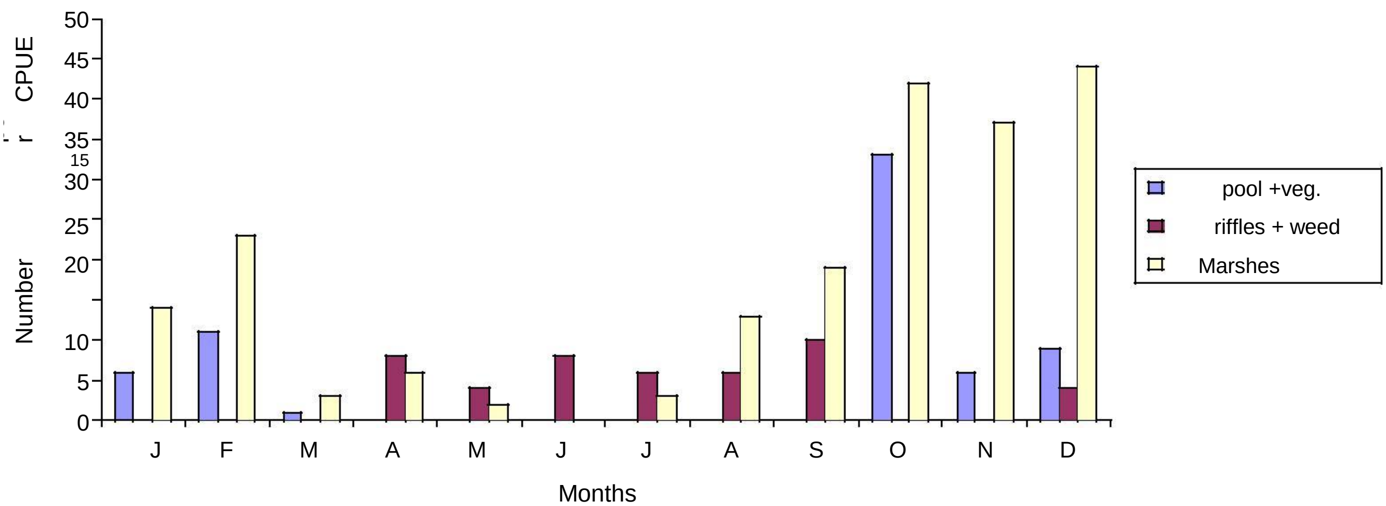

Figure 5. Monthly abundance of *E. spilargyreius* within three habitat types.

Table 4. The relationship between *E. bifasciatus* and *E. spilargyreius* abundance and different microhabitats (Asterisks denote statistically significant correlation when *P*< 0.05).

Species	Habitat	*R*	*P*<0.05
	Pool + Vegetation	0.276	0.38
E. bifasciatus	Riffles + Vegetation	-0.21	0.50
	Marsh	0.50	0.096
	Pool + Vegetation	0.28	0.378
E. spilargyreius	Riffles + Vegetation	0.19	0.545
	Marsh	0.65	0.022*

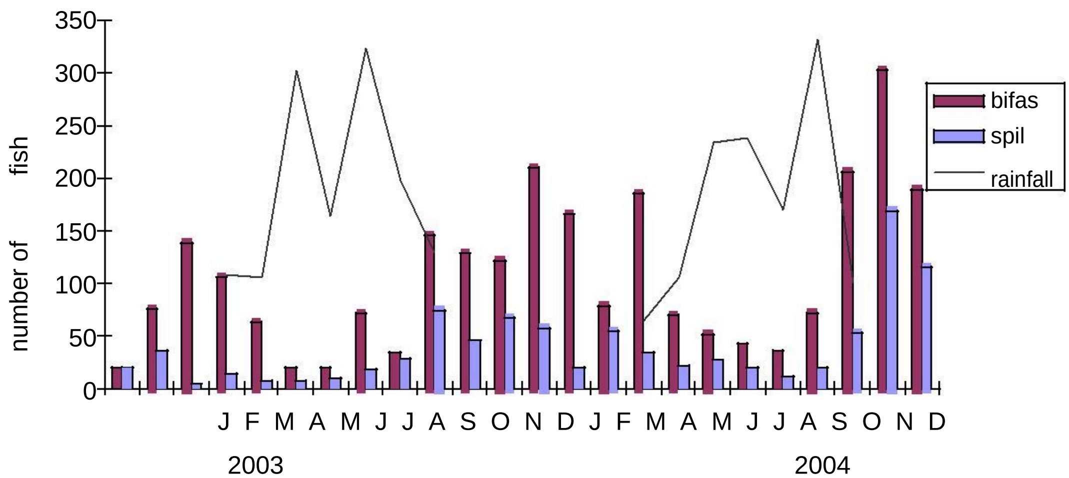

Figure 6. Comparative abundance of *E. bifasciatus, E. spilargyreius* and rainfall in New Bussa area.

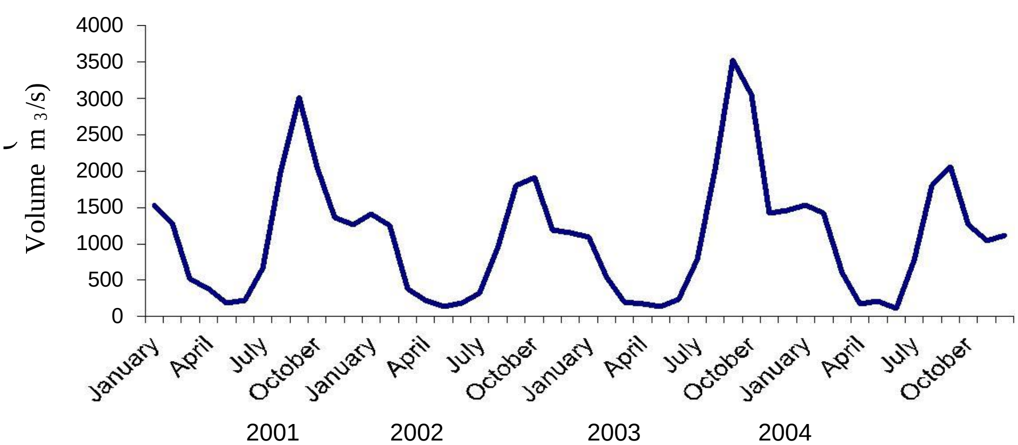

Figure 7. Monthly water inflow into the Kainji Lake from 2001 to 2004.

DISCUSSION

Species could not persist in a specific ecosystem if they are intolerant of the range of variation in environmental and biological conditions that the system naturally faces or creates (Leveque, 1997). Every freshwater ecosystem experiences a combination of ecological factors which include hydrological regime, water chemistry regime, physical habitat condition, connectivity and biological composition. It is these factors that were studied in relation to the habitat restricted populations of *Epiplatys bifasciatus* and *E. spilargyreius* in Monai Stream of Kainji Reservoir in Nigeria. Water quality attributes are prime factors that influences fish survival, abundance, reproduction, growth performance and overall biological production (Harding et al., 1999; Odulate et al., 2014). Of the 12 environmental variables studied in relationship with relative abundance of these two notobranchiids relatively few variables have profound effects them in this stream. The abundance of *E. spilargyreius* which had a strong correlation with conductivity is consistent with its microhabitat preference of marshes. Marshes are characterized by high nutrient load and low dissolved oxygen. The anatomical features of notobranchiids generally, such as flattened head, small body size and upturned mouth enables them to exploit the oxygen-rich surface film of water which is relatively rich in oxygen because of diffusion from the atmosphere. Other fishes like *Synodontis membranaceous* and *S. batensoda* (Green, 1977), as well as *Sarotherodon* (Benech and Lek, 1981) behaviorally utilized the same rich surface oxygen. The Synodontis do this by turning upside down and gulping at water surface. The result obtained for *E. spilargyreius* is similar to those of Ostrand and Wilde (2001) study on the streams of Texas, which shows that two cyprinodonts (Red River pupfish and Plain Killifish), the most abundant fishes in the system have strong relationship with high conductivity, low current flow and turbidity and shallow sites. Gratwicke et al. (2003) also observed similar relationships between conductivity and number of species in Manyame catchment of Zimbabwe, except that the number of species declined above 400 µS cm^{-1}. Taylor et al. (1993) studied the relationships between fish species and environmental factors in the upper Red River basin, southwestern Oklahoma and predicted communities along gradients which were similar to those found important in the present study, including conductivity, stream size, and water clarity.

Olaosebikan (2007) and Olaosebikan et al. (2009) reported that *E. bifasciatus* and *E. spilargyreius* have a density-independent have recruitment patterns, which depended on abiotic factors like the availability of food, space, rainfall and flood seasonality. The importance of environmental factors on recruitment is widely recognized (Eckmann et al., 1988; Welcomme, 2001). Loftus and Kushlan (1987) observed that small-sized fishes living in an unstable environment such as an intermittent stream, recruit throughout the year, with the effect of seasonality usually mediated by such factor like the water level. Hydrology is one of the main driving forces in aquatic ecology and this is strongly depended on the amount of rainfall, its fate and distribution patterns. Small streams generally show considerable variation in flow rate in relation to rainfall over the year and in Nigeria savannah region tends to concentrate within the June to September of each year. The two nothobranchiids exhibit flexibility in utilizing both the stream and lake hydrology for their recruitment. Although the lake's hydrological regime produces more recruits into the populations of the two fishes than does the stream, many of them usually ended up in the in hostile environment of the lake when the water draws down between March and July. The bulk of these recruits are therefore not available when the stream's water level is conducive for recruitment in July and September. Besides at drawdown the exposed stream channel is devoid of in-stream vegetations cover for these fish thus exposing them to aerial predation from birds and other animals. Increasing multi-sectoral demands on water resources have led to water abstraction and transfer activities, and the construction of dams and embankments that have significantly altered the flood regimes of rivers throughout the world resulting in the loss of fish production and biodiversity (Welcomme, 2001). According to Rosenfeld (2003), understanding and managing human impacts on fish require a clear understanding of the relationship between a species and it environment. Despite a long history of study, predicting and assessing the impact of anthropogenic activities on stream fish communities is still difficult (Wootton et al., 2000). The current emphasis on sustainable development and biodiversity conservation is leading efforts to mitigate these impacts by means of interventions such as the release of artificial floods downstream of dams and the manipulation of water levels within impounded floodplains (Matthews et al., 1992). Whilst much work has been done to determine the hydrological requirements for the maintenance of salmonid populations, few equivalent studies are available from which to develop criteria for the management of hydrological regimes for fishes and fisheries in river systems (Welcomme, 2001). There were about 500 km^2 of seasonal swamps in the Niger River area now covered by Lake Kainji. Though they had an annual life of six to nine months, they had a great effect on the general biological economy of the river (Imevbore and Bakare, 1974). Reed et al. (1967) estimated that these swamps contributed over 50% of fish catch made by the fishermen in the middle Niger valley besides serving as both breeding and feeding ground for most of the riverine fishes. However, the large drawdown of the Lake water prevented the formation of marginal swamps resulting in the decline of swamp species (Imevbore and Bakare, 1974). In Southern Florida, small-sized fishes (<50 mm mainly cyprinodonts) like *E. bifasciatus* and *E. spilargyreius,* that have short life span and respond quickly to environmental perturbations have been used as indicators of habitat alteration and ecosystem function (Jordan et al., 1997, 1998).

The abundance of the two notobranchiids in synchrony with increase in water level and precipitation agreed with what has been observed for cyprinodonts of Okavango River, Namibia by Hoccut and Johnson (2001).

Microhabitat use is among the most easily observed manifestations of specialization and plasticity in freshwater fishes, and availability of suitable habitat can influence fish behaviour and metabolism (Fischer, 2000). Recent studies of patterns of habitat use include (Jordan et al., 1998; Jordan et al., 2000; Mallet et al., 2000; Yu and Lee, 2002; Copp, 1992; Santos et al., 2004; Gursoy et al., 2010). In the Monai Stream studied, *E. bifasciatus* and *E. spilargyreius* are found in vegetated pool, vegetated riffle and marshes depending on the availability of these habitats in the year. However, there is clear preference for a particular habitat by the two species in months in which the three habitat types are available. This study indicates that *E. bifasciatus* prefers vegetated pool followed by vegetated riffle while *E. spilargyreius* on the other hand prefers marshes followed by vegetated pool. Observation of the microhabitat use of other *E. bifasciatus* populations in Shagwa and Auna (northeast of Kainji Lake) indicated they prefer ripples with weeds. However in Monai Stream, which is not perennial in terms of flow, the two tend to use vegetated pool, which is available throughout the year in the stream, especially during the dry season when other preferred habitats are scarce. This agrees with Grossman and Freeman (1987) that when habitat is largely unstable and unpredictable due to occurrence of natural or human disturbances, species display high microhabitat overlap. Guma'a (1982) reported that *E. bifasciatus* in southern Sudan are restricted to slow-flowing and stagnant waters, usually taking shelter underneath floating weeds such as *Eichhornia crassippes* and water lilies and never recorded from open water. Loiselle (1969) found them in both shallow areas and fringes of dense masses of *Ceratophyllum sp.* and *Myriophyllum* of Zio River in Togo. Considering that *E. bifasciatus* and *E. spilargyreius* have the same geographical range (Wildekamp, 1996) and belongs to the same genus it will suggest that they will have similar pattern of in-stream distribution and abundance but *E. bifasciatus* is more abundant in Monai Stream and widely distributed among perennial streams around the Kainji lake basin than *E. spilargyreius.* This may be due to greater specialization in microhabitat preference, which is reflected in *E. spilargyreius* relative rarity in the streams around the Lake and its low abundance in Monai Stream. Even though many environmental variables have been considered to be important for influencing habitat preference by fish in aquatic ecosystems, fish innately still prefers one to others (Hynes, 1970; Moyle and Cech, 1988; Yu and Lee, 2002). Yu and Peters (1997) indicate that habitat availability affects habitat selection by fish. There is considerable overlap between the habitat preferences of these two species even when having their preferred habitat available.

Preference for vegetated portion of stream by the two fishes appears to be either an innate or learned anti-predatory response. This is confirmed by the study of Jordan (2002) on the rainwater killifish (*Lucania parva*) in the St. Johns River Estuary, Florida. This may also account for inability of the two species to disperse into streams adjourning Monai Stream through the Lake. According to Gilliam and Fraser (2001), predators fragment stream fish on two spatial scales, emigration from predator-occupied pools in streams and increased abundance of prey fish in riffles or shallow areas than deeper water.

Differences in the risk of predation, availability of food resources, and physiological conditions among these habitats may result in a specific form of risks and opportunities for organisms and often generate patterns of differential habitat use (Jordan, 2002). In Monai Stream the choice of habitat may be to reduce interspecific competition for space and food. *E. bifasciatus* have succeeded in adapting to the lentic environment even though it cannot survive in it during the yearly drawdown it's able to utilize the annual flood to recruit.

Habitat fragmentations or loss of habitat connectivity have been shown to have harmful influence on population persistence (Wilcox and Murphy, 1985). The damming of Niger River at Kainji resulted in alteration of the stream habitat of *Epiplatys bifasciatus* and *E. spilargyreius* populations in the Monai Stream by reducing its availability, changing it flow regime and curtailing routes of dispersal. This study suggest that relatively few environmental variables have profound effects on the abundance of these short-lived, small-sized, early-maturing and multiple spawning notobranchiids. Their life history traits however enables them to adapt to changes in their altered habitat meanwhile their continuous existence depend on the persistence of the stream which is presently threatened by adjoining terrestrial land use and water abstraction for farming and domestic use.

Conflict of Interest

The authors have not declared any conflict of interest.

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