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Monthly Variation Of Fish Density And Diversity In The Three Ephemeral Streams Of Lakhimpur District Of Assam, India

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Abstract

This study is based on assessment of ecological health of the three forested ephemeral streams situated on the Lakhimpur district of Assam using fish as biomonitoring agent and also physicochemical parameters. A total of 23 fish species belonging to 9 families, 4 orders of class Actinopterygii belonging to phylum Chordata have been recorded from the three streams with monthly fluctuation. Monsoon showed comparatively higher density of fish than postmonsoon. Species composition and quantitative characteristics of the fish have been assessed by different diversity indices (Shannon diversity index, Simpson's diversity index, Margalef index, McIntosh index) and evenness indices (Pielou evenness index and McIntosh evenness index).Less stable condition of the three streams was clearly understood through the present assessment.

Keywords: Density, Diversityindices, Ephemeral, Fish,Monsoon, Post Monsoon

1. INTRODUCTI

An ephemeral stream is typically defined as "a stream or portion of a stream which flows briefly in direct response to precipitation in the immediate vicinity and whose channel is at all times above the ground water reservoir." (Levick *et al.*, 2008). Ephemeral stream is often excluded from bio monitoring programmes because of inadequate knowledge about their biological characteristics. These streams are very sensitive to anthropogenic disturbance as they have a disproportionately large interface with terrestrial ecosystems. Fish are important source of food and act as good indicator of ecological health in water body where they inhabit. Fish are suitable as biological indicators (Meador *et al.*, 2008) since their relative longevity in comparison to other biological elements allows them to better integrate long-term impacts (Maceda-Veiga and Sostoa, 2011). Fish assemblages can indicate the quality or presence of many features of environments, such as food or habitat. Today the fish diversity and associated habitats management is great challenge (Dudgeon *et al.*, 2006). Their sensitivities to the health of surrounding aquatic environments form the basis for using fishes to monitor environmental degradation (Fausch *et al.*, 1990). The main objective of the present study was to study the ecological health of the three forested ephemeral streams through fish as biomonitoring agent and analysis of physicochemical parameters.

2. MATERIALS AND METHODS

Study Area

The three different ephemeral streams viz. Baghjan, Singijan and Ghagorjan originate from the foothills of Arunachal Pradesh and located about 20-25 kilometres away from North Lakhimpur of Assam traversed through Dulung reserve forest in the Assam Arunachal border region. Baghjan lies within 27 $^{0}26^{/}522^{//}$N and $94^{0}12^{/}599^{//}$E, while Singijan is located within $27^{0}26^{/}701^{//}$N and $94^{0}12^{/}869^{//}$E and Ghagorjan lies between $27^{0}26^{/}608^{//}$N and $94^{0}12^{/}691^{//}$E. Since the streams are ephemeral, so they completely dependent on monsoon rain. Monsoon starts from June and from the end part of November the streams starts dry up. Therefore the analysis of physicochemical parameters and biological assemblages were done only for two seasons viz. monsoon and post monsoon.

Study Period

All the selected parameters were studied for consecutive three years (June 2011-May 2014) on monthly (June, July, August, September, October and November) basis.

Collection, Identification and quantification of Fish

Sampling of fish was performed at each stream segments with the help of a very fine meshed scoop net (2x2 foot). Preservation of samples was done in some plastic jars containing 10% formalin. A maximum of 10 samples were taken for fish study at all the three ephemeral streams, where ten howls were considered as one sample. Identification was done up to species level by using the keys of Talwar and Jhingran, 1991; Jayaram, 1999 and Vishwanath, 2002.

The densities of abundant species were calculated for every sampling streams segments using the formula:

$$D = n/ A,$$

Where D = Density, n= total number of fish sampled, A= area of sampling unit

Biological Indices

Four diversity indices, Shannon diversity index (Shannon-Weaver, 1948), Simpson diversity index (Simpson, 1949), Margalef diversity index (Margalef 1958) and McIntosh diversity index (McIntosh, 1967) and two evenness indices (Pielou evenness index (Pielou, 1966) and McIntosh evenness index (McIntosh, 1967) were used in the study of fish.

Measurement of Water Quality (Physical and Chemical Variables)

The location of the three study sites were measured by GPS (GarminGPSMAP76), water temperature was measured by using a Mercury thermometer graduated up to 110°C, pH was measured by portable pH meter (Cyber scan pH 300 series), conductivity was measured by Digital conductivity meter (CD600, Milwaukee), current velocity was measured by Digital flow meter (Swoffer 3000 Flow Meter, GeoScientific Ltd.). Dissolved Oxygen was measured by following the Winkler's modified method (Trivedy and Goel, 1986), free carbondioxide, total acidity, total alkalinity and chloride were measured titrimetrically following the method of (APHA,1995) and (Trivedy and Goel, 1986).

3. RESULT and DISCUSSION:

A total of 23 species of fish (*Badis singenensis, Badis badis, Channa gachua, Channa punctatus, Lepidocephalichthys guntea, Lepidocephalichthys arunachalensis, Lepidocephalichthys berdmorei, Barilius bendelisis, Devario aequipinnatus, Danio rerio, Danio dangila, Puntius ticto, Puntius sophore, Esomus danricus, Amblypharyngodon mola, Heteropneustes fossilis, Olyra longicaudata, Mastacembelus armatus, Macrognathus pancalus, Mastacembelus sp., Macrognathus sp., Pterocryptis berdmorei, Pillaia indica*) belonging to 9 families (Badidae, Channidae, Chaudhuridae, Cobitidae, Cyprinidae, Heteropneustidae, Olyridae, Mastacembelidae and Siluridae) of 4 orders (Perciformes, Cypriniformes, Siluriformes, Synbranchiformes) of class Actinopterygii belonging to phylum

Chordata have been collected from the studied streams.

Percent composition of different fish families are given in **Table 1.** In Baghjan, Cyprinidae of order Cypriniformes was recorded as dominant family (50%) and Heteropneustidae of order Siluriformes (1%) was recorded as least available family. In Singijan, Cyprinidae of order Cypriniformes was recorded as dominant family (44%) and Heteropneustidae (1%) and Siluridae (1%) of order Siluriformes was recorded as least available family. In Ghagorjan, Cyprinidae of order Cypriniformes was recorded as dominant family (53%) and Heteropneustidae (1%) of order Siluriformes was recorded as least available family.

Table 1: Percent composition of different fish families in the three ephemeral streams

Family	Streams		
	Baghjan	Singijan	Ghagorjan
Badidae	24	23	27
Channidae	5	5	5
Chaudhuridae	4	8	3
Cobitidae	7	7	6
Cyprinidae	50	44	53
Heteropneustidae	1	1	1
Olyridae	6	8	5
Mastacembelidae	3	3	---
Siluridae	---	1	---

Table 2: Monthly mean variation of fish density (no./m^2)

Fam	S	Months					
		Jun	Jul	Aug	Sep	Oct	Nov
Cha	S1	5.25± 1.04	2.88± 0.83	3.37±0.52	5.75± 0.83	5.62± 1.41	4.37 ± 0.52
	S2	2.87 ±0.83	2.37± 0.52	2.37±0.52	3.37± 0.52	3.87± 0.83	---
	S3	4.87± 1.64	3.75± 1.49	4.25±1.23	3.51± 1.19	4.25 ±1.23	3.37± 0.52
Cyp	S1	9.25 ± 1.04	5.87± 0.83	6.75±0.88	8.12± 1.12	8.50± 1.41	7.63± 1.41
	S2	7.87 ±0.83	6.37± 0.52	6.25±1.04	8.75± 0.89	8.13± 1.13	7.25± 1.28
	S3	6.13± 1.13	4.87± 1.64	5.26±0.92	4.87± 0.83	4.37± 0.52	4.25± 1.23
Bad	S1	4.87± 0.83	3.75± 0.88	3.37± 0.51	5.37± 0.51	5.01± 1.06	4.25± 1.03
	S2	---	2.5± 0.53	---	4.01± 0.76	3.01± 0.76	---
	S3	2.87± 0.83	3.37± 0.51	3.87±0.83	---	4.25± 1.23	2.37± 0.52
Cob	S1	0.75± 0.71	0.51 ±0.53	---	0.51± 0.21	---	---
	S2	---	---	1.37±0.52	0.87± 0.83	---	---
	S3	1.57± 0.62	---	0.88±0.83	1.69± 0.52	---	---
Oly	S1	1.25± 1.03	---	0.87±0.83	---	---	0.87± 0.83
	S2	---	---	0.63±0.52	---	2.12± 0.83	0.87± 0.83
	S3	---	0.69± 0.53		1.55 ±0.62	---	---
Chd	S1	---	---	0.62±0.51	---	0.51± 0.53	---
	S2	0.79 ±0.91	---	---	1.45± 0.61	---	2.54± 0.53
	S3	---	---	0.75±0.45	0.81± 0.65	---	---

Mas	S1	1.5± 0.53	1.87± 0.83	---	0.51± 0.53	1.37± 0.51	---
	S2	---	1.04± 0.51	---	---	0.75± 0.45	---
	S3	0.95± 0.51	1.65± 0.45	---	2.12± 0.83	---	---
Het	S1	---	---	---	0.62± 0.51	---	---
	S2	---	---	0.82±0.62	---	0.92± 0.71	---
	S3	---	---	0.73± 0.51	---	---	0.69± 0.62
Sil	S1	---	---	---	---	---	---
	S2	---	---	---	---	0.85± 0.61	---
	S3	---	---	---	---	---	---
Tot	S1	23.43±4.03	16.71±3.67	15.89±3.34	18.62±1.03	19.31±2.04	15.61±2.61
	S2	12± 2.39	11.62±1.29	13.79±2.49	17.47±2.09	16.72±3.63	12.43±4.01
	S3	15.74±3.67	16.38±4.21	15.14±5.32	18.76±5.39	14.37±3.91	10.32±2.11

Key: Fam=Family**, Cha=**Channidae**, Cyp=**Cyprinidae**, Bad=**Badidae, **Cob=**Cobitidae, **Oly=**Olyridae, **Chd=**Chaudhuridae, **Mas=**Mastacembelidae, **Het=**Heteropneustidae, **Sil=**Siluridae**, Tot=**Total, **S=**Stream, **S1=**Baghjan, **S2=**Singijan**, S3=**Ghagorjan

Table 3: Monthly mean variation of fish diversity and evenness indices

Indices	Streams	Months					
		Jun	Jul	Aug	Sep	Oct	Nov
Ĥ	Baghjan	1.92	2.28	2.30	1.83	1.91	1.88
	Singijan	1.98	2.36	1.91	1.93	1.89	1.79
	Ghagorjan	1.86	1.91	2.21	1.68	1.74	2.04
J	Baghjan	0.87	0.89	0.89	0.76	0.81	0.80
	Singijan	0.90	0.92	0.83	0.82	0.80	0.80
	Ghagorjan	0.77	0.79	0.89	0.73	0.75	0.82
1-D	Baghjan	0.82	0.87	0.87	0.76	0.81	0.8
	Singijan	0.84	0.89	0.81	0.82	0.80	0.80
	Ghagorjan	0.77	0.79	0.86	0.71	0.77	0.82
Ma	Baghjan	1.56	2.31	2.29	1.73	1.96	1.75
	Singijan	1.63	2.29	1.84	1.79	1.69	1.39
	Ghagorjan	2.11	2.03	2.13	1.56	1.65	2.14
Mc	Baghjan	0.62	0.69	0.69	0.53	0.60	0.59
	Singijan	0.65	0.72	0.64	0.62	0.60	0.60
	Ghagorjan	0.57	0.59	0.67	0.54	0.55	0.62
McE	Baghjan	0.86	0.89	0.89	0.72	0.79	0.80
	Singijan	0.91	0.90	0.89	0.84	0.81	0.85
	Ghagorjan	0.74	0.77	0.88	0.68	0.75	0.81

Key: Ĥ =Shannon diversity index**, J=**Pielou evenness index**, D=**Simpson's diversity index**, Ma=**Margalef diversity index, **Mc=**McIntosh diversity index**, McE=**McIntosh evenness index

Table 4: Monthly variation of physicochemical parameters of the three streams

Parameter	Streams	months					
		Jun	Jul	Aug	Sep	Oct	Nov
Temp(^{0}C)	Baghjan	26.08±0.08	26.79±0.21	26.37±0.20	25.72±0.55	25.88±0.38	25.63±0.52
	Singijan	24.91±0.13	25.89±0.32	26.01±0.24	25.26±0.16	24.72±0.33	25.43±0.11
	Ghagorjan	25.62±0.12	25.48±0.26	25.31±0.21	25.04±0.53	25.08±0.33	25.13±0.22
pH	Baghjan	5.88±0.03	5.80±0.10	5.71±0.01	6.22±0.04	6.36±0.10	6.46±0.02
	Singijan	6.01±0.06	5.91±0.16	5.77±0.04	6.02±0.04	6.14±0.12	6.13±0.04
	Ghagorjan	5.46±0.05	5.57±0.05	5.51±0.04	6.07±0.03	6.07±0.07	6.11±0.03
Current velocity(m/sec)	Baghjan	0.39±0.02	0.54±0.07	0.63±0.02	0.37±0.02	0.48±0.08	0.57±0.05
	Singijan	0.63±0.03	0.82±0.07	0.84±0.11	0.58±0.01	0.59±0.02	0.31±0.15
	Ghagorjan	0.46±0.03	0.55±0.02	0.56±0.05	0.46±0.03	0.48±0.04	0.44±0.03
Conductivity(µS/cm)	Baghjan	618.19±1.04	618.19±1.33	620.68±2.63	593.21±4.72	597.06±4.39	586.99±2.55
	Singijan	584.51±6.06	577.92±7.22	588.86±1.73	568.72±1.77	574.69±7.13	576.81±19.77
	Ghagorjan	579.66±2.21	580.91±1.77	570.46±3.56	559.03±1.14	565.12±2.48	569.72±4.11
D.O.(mg/l)	Baghjan	3.07±0.16	3.01±0.26	3.16±0.31	5.28±0.24	4.83±0.53	4.36±0.09
	Singijan	4.18±0.12	3.79±0.14	4.01±0.11	4.71±0.18	4.53±0.5	4.61±0.16
	Ghagorjan	3.34±0.28	3.86±0.38	4.16±0.22	3.36±0.24	4.61±0.22	3.54±0.26
FCO_2.(mg/l)	Baghjan	13.64±0.61	16.15±2.61	18.79±1.11	13.14±0.52	13.94±0.67	14.51±0.39
	Singijan	18.08±1.14	18.66±0.49	17.44±1.06	13.66±0.34	14.34±1.28	17.26±1.31

	Ghagorjan	21.23±0.86	19.52±0.72	19.71±1.22	18.61±0.56	18.62±0.59	20.72±0.74
Total Acidity(mg/l)	Baghjan	19.54±0.59	20.96±0.79	19.32±0.18	18.21±0.31	19.43±1.49	20.09±1.13
	Singijan	19.31±0.76	19.93±1.43	21.16±0.88	15.81±0.31	17.12±1.17	18.55±0.31
	Ghagorjan	28.52±1.11	23.84±2.86	22.23±0.86	20.21±1.64	21.11±1.73	20.86±1.43
Total Alkalinity(mg/l)	Baghjan	21.16±0.88	67.17±1.07	68.57±2.31	73.29±0.96	77.31±3.99	82.78±3.01
	Singijan	15.81±0.31	54.52±2.06	55.97±1.08	68.67±1.11	71.87±2.05	71.42±1.15
	Ghagorjan	17.12±1.17	60.07±3.01	61.64±1.37	72.46±1.61	73.89±1.41	70.64±1.37
Chloride(mg/l)	Baghjan	18.55±0.31	19.44±0.77	19.52±0.61	23.41±0.33	22.56±1.19	21.62±0.69
	Singijan	21.26±0.37	20.67±0.72	19.87±1.15	20.93±3.12	22.78±1.01	21.48±0.78
	Ghagorjan	15.84±0.65	15.77±0.39	14.15±0.64	20.15±0.64	19.10±0.52	19.97±0.36
Stream depth(m)	Baghjan	0.38±0.05	0.37±0.04	0.39±0.03	0.29±0.01	0.29±0.01	0.26±0.01
	Singijan	0.41±0.01	0.45±0.05	0.40±0.06	0.36±0.04	0.37±0.01	0.28±0.05
	Ghagorjan	0.35±0.02	0.35±0.07	0.36±0.01	0.34±0.01	0.33±0.01	0.32±0.02
Stream width(m)	Baghjan	10.54±0.41	9.81±1.16	8.16±0.77	7.31±0.32	7.55±0.41	7.86±0.36
	Singijan	5.23±0.11	5.46±0.25	5.77±0.26	4.18±0.19	4.14±0.12	3.04±0.48
	Ghagorjan	3.51±0.16	4.04±0.22	3.80±0.14	2.26±0.08	2.46±0.15	2.21±0.11

Table 5: Correlation matrix between physicochemical parameters and fish density of Baghjan:

Para	DO	FCO_2	T.Acid	T.Alk	Chl	W.T.	pH	C.V.	Cond	S.D.	S.W.	F.d.
DO	*1*											
FCO_2	-	1										

	0.49*											
T.Acid	-0.09	0.32	1									
T.Alk	0.37	0.49*	0.13	1								
Chl	0.64**	-0.32	-0.12	-0.43	1							
W.T.	-0.32	0.22	-0.32	0.41	-0.55*	1						
pH	0.68**	-0.6**	-0.3	-0.05	0.51*	-0.13	1					
C.V.	-0.24	0.18	0.04	-0.24	-0.08	0.14	0.04	1				
Cond	-0.64**	0.45	0.04	0.17	-0.69**	0.37	-0.83**	-0.09	1			
S.D.	-0.35	0.23	-0.13	0.07	-0.56*	0.23	-0.49*	0.22	-0.09	1		
S.W.	-0.45	0.45	-0.16	0.33	-0.75**	0.44	-0.53*	0.07	0.22	0.75**	1	
F.d.	0.62*	-0.16	-0.02	0.36	-0.08	0.25	-0.32	0.51*	0.07	0.25	0.14	1

Table 6: Correlation matrix between physicochemical parameters and fish densityof Singijan:

Para	DO	FCO_2	T.Acid	T.Alk	Chl	W.T.	pH	C.V.	Cond	S.D.	S.W.	F.d.
DO	1											
FCO_2	-0.55*	1										
T.Acid	-0.21	0.67	1									
T.Alk	0.13	0.46*	-0.49	1								
Chl	0.42**	-0.02	-0.16	0.23	1							
W.T.	-0.06	0.09	0.12	-0.33	-0.59*	1						
pH	0.5 6**	-0.65**	-0.53	0.35	0.6*	-0.43	1					
C.V.	-0.08	0.18	0.33	-0.63	-0.29	0.27	-0.43	1				
Cond	-0.71**	-0.08	-0.36	0.06	-0.73*	0.44	-0.87	0.04	1			

					*		*					
S.D.	-0.03	0.26	0.33	-0.22	-0.61*	0.54	-0.53*	0.28	0.09	1		
S.W.	-0.17	0.09	0.18	-0.79	-0.75**	0.33	-0.59*	0.37	0.16	0.81**	1	
F.d.	0.59*	-0.49	-0.51	0.32	-0.28	0.56	-0.18	0.58*	0.15	0.15	0.11	1

Table 7: Correlation matrix between physicochemical parameters and fish density of Ghagorjan:

Para	DO	FCO_2	T.Acid	T.Alk	Chl	W.T.	pH	C.V.	Cond	S.D.	S.W.	F.d.
DO	1											
FCO_2	-0.45*	1										
T.Acid	-0.02	0.72	1									
T.Alk	0.14	0.52*	-0.3	1								
Chl	0.6**	-0.22	-0.13	-0.05	1							
W.T.	-0.06	0.11	0.31	-0.32	-0.52*	1						
pH	0.43**	-0.57**	-0.2	-0.32	0.54*	-0.04	1					
C.V.	-0.47	0.06	0.13	-0.52	-0.43	0.24	-0.13	1				
Cond	-0.59**	-0.51	-0.29	-0.05	-0.62**	0.16	-0.78**	0.01	1			
S.D.	-0.34	0.34	0.5	0.58	-0.51*	0.07	-0.47*	0.53	0.24	1		
S.W.	-0.02	0.36	0.63	-0.57	-0.68**	0.37	-0.48*	0.49	0.17	0.71**	1	
F.d.	0.42*	-0.19	-0.17	0.07	-0.14	0.18	-0.03	0.48*	0.26	0.08	0.18	1

*** Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)**

Key: Para=Parameter, **D.O.=**Dissolved Oxygen, **FCO_2=**Free Carbondioxide**, T.Acid.=**Total Acidity**, T.Alk=**Total Alkalinity**, Chl=**Chloride**, W.T.=**WaterTemperature**, C.V.=**Current Velocity**, Cond=**Conductivity**, S.D.=**Stream Depth**, S.W.=**Stream Width**, F.d=**Fish Freshwater fish are one of the most threatened taxonomic groups (Darwell and Vie, 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habits (Laffaille *et al.*, 2005). As a consequence, they are often used as bioindicator for the assessment of water quality, river network connectivity or flow regime (Chovance *et al*., 2003). The distribution of fish families in all the three ephemeral streams showed an interesting pattern in which cyprinidae was recorded to be the most abundant family but the fish species belongs to families like siluridae, mastacembelidae and heteropneustidae showed very restricted distribution.

Monsoon showed higher fish density as compared to postmonsoon. Actually gradual drying of stream channel occurs in late post monsoon and hence connectivity naturally declines. In ephemeral streams, hydrological connectivity becomes loss which is because of cessation of surface flow occurring for a certain period. Fish species starts movement to other water body with the contraction of wetted areas, which may be permanent or perennial stream and may have to confine in discontinuous pools. Fish in the studied ephemeral streams generally use some other habitats during dry period apart from few species like *Channa gachua, Channa punctatus* ,*Heteropneustes fossilis* etc. Hydrological connectivity in ephemeral stream persist only for a short period of the year which is not actually an ideal habitat for fish but their lifecycle seems to become adapt to periodic drying and rewetting cycle and thus maintains their lifecycle. In the three studied streams, density was found higher in early monsoon compared to post monsoon because flow path become re-emerge and it facilitate migration from some other persistent habitat. With the availability of dietary resources and low competition among different fish species in the studied streams the ephemeral habitat become an ideal habitat for spawning, rearing, colonization and redistribution. The fish community of the studied streams is an excellent example of how fish use permanent and temporary habitats and migration corridors in ephemeral streams. In the studied steams, fish are abundant throughout the entire wetted area, extending downstream to the lower end of flow.

The value of diversity and evenness indices clearly reveal moderate pollution of the studied streams and unequal distribution of fish species .The low values of diversity indices fairly indicate degradation of habitat which is due to various human activities such as removal of riparian vegetation, sand and gravel mining, over fishing etc. Removal of riparian vegetation leads to increased sedimentation and silt depositions in the stream bed which results formation of homogenous sandy substrate not suitable for spawning, breeding and other essential life activities of fish fauna. Sand and gravel mining along stream channels leads to destruction of habitat of different invertebrate community and ultimately affect resource availability for fish species. Comparatively higher value of diversity and evenness indices recorded during monsoon season, which is because monsoon harbors suitable refugia as well as spawning, breeding and colonization ground to the fish species and also hydrologic connectivity immediately facilitate infiltration of different hill stream fishes like *Olyra longicaudata, Devario aequipinnatus, Pterocryptis berdmorei* etc to these forested streams.

Different physical and chemical factors such as temperature, dissolved Oxygen, pH etc and their regular or irregular fluctuations, have been identified as determinants in stream fish ecology. In the present study, fish density showed positive correlations with DO ($p<0.05$), total alkalinity ($p>0.05$), water temperature ($p>0.05$), current velocity ($p<0.05$), conductivity ($p>0.05$), stream depth ($p>0.05$), stream width ($p>0.05$); negative correlations with FCO_2 ($P>0.05$), total acidity ($p>0.05$), chloride ($p>0.05$) and pH ($p>0.05$).

4. CONCLUSION

Tropical ephemeral streams are often poorly understood but they are critical to the ecological health of the watershed and are placed at an interface between water and land through maintaining a unique flow regime. Monthly fluctuation was observed in physicochemical variables as well as density, abundance, diversity of fish in the three forested ephemeral streams. The value of density and diversity indices of fish revealed less stable condition of the studied streams. Also the present study fairly revealed the inter relationship between fish distribution and physico-chemical variables in the three ephemeral streams.

Although these ephemeral streams lack year around surface flow, with the onset of monsoon season, fish along with other aquatic organisms use this seasonal flow for balancing their lifecycle and also to avoid predator influence, high competition as well as to get proper refugia for spawning, breeding and other necessary life processes and become able to reconstruct a living system through interdependence among them.

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