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Effects of catastrophic floods on nocturnal bagrid catfish *Pseudobagrus ichikawai*
- Daytime permanent habitat analysis focusing on substrate shape -

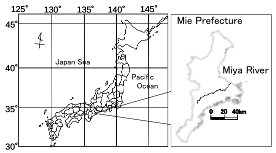
Shiro Sagawa*, Takashi Tashiro, Junjiro Negishi, Yuichi Kayaba
Aqua Restoration Research Center, Public Works Research Institute, Gifu, Japan

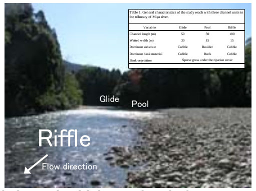
1. The objective

Specific objectives were: (1) to assess the effects of catastrophic floods (>15-fold increase in water level: > 50-year events) on abundance of bagrid catfish inhabitating interstitial habitats, (2) to examine habitat characteristics of bagrid catfish related to the persistence of habitats over the floods, and (3) to elucidate the critical microhabitat factors of abiotic environments for their conservation.

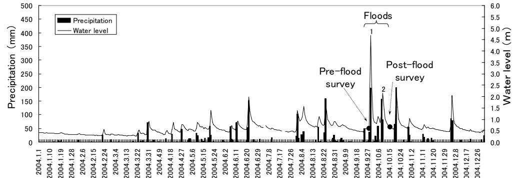
2. Materials and methods

(1) Study design





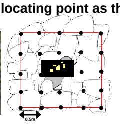
The study reach was a 200-m long alluvial channel, which consisted of two 50-m channel units (glide and pool) and one 100-m channel unit (riffle)

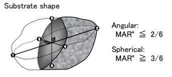


Field survey was conducted over catastrophic floods that occurred as a result of sequential passages of typhoons Meari:1 and Ma-on:2 in the fall of 2004.

(2) Field survey

The daytime interstitial habitat use of bagrid catfish was surveyed by four persons with snorkeling observations in four hours (one hour each for 50-m glide and pool, and two hours for 100-m riffle). When finding the catfish, we set up 2m × 2m quadrate with the fish-locating point as the center (hereafter referred to as "observed site").





Definition of the substrate shape used in this study. MAR: Moderate Aspect Ratio of 6 points on a surface of the substrate. Longest axis: 1-2. Intermediate axis: 3-4 (minimum length), 5-6 (Maximum length)

The quadrate set up for each observed site was divided into 16 of subgrids (0.5m × 0.5m). At every corner of subgrids (a total of 25), current velocity, water depth, and substrate type (coarseness, embeddedness and shape) were measured.

(3) Data analysis

Table 2. 15 environmental variables used for PCA

Variables	Caluculation method
1. Mean water depth 2. Mean current velocity	The average value among 25 measurement points in the quadrate.
3. Mean substrate size	The average value of two diameters (the longest diameter and the shorter one perpendicular to the longest one) of the substrates larger than the size of pebble.
4. Water depth complexity 5. Current velocity complexity 6. Substrate size complexity	The coefficient of variance (CV, the standard deviation divided by the mean).
7. Percentage of substrate area (>pebble) 8. Percentage of substrate area (>cobble) 9. Percentage of substrate area (>boulder)	The percentage of substrate composition larger than pebble, cobble and boulder among 25 measurement points in the quadrate .
10. Percentage of over-lying substrate area (>pebble) 11. Percentage of over-lying substrate area (>cobble) 12. Percentage of over-lying substrate area (>boulder)	The percentage of the substrate composition having presence of interstitial spaces underneath substrate materials among 25 measurement points in the quadrate .
13. Number of substrates (>pebble) 14. Number of substrates (>cobble) 15. Number of substrates (>boulder)	The number of substrate larger than pebble, cobble and boulder among 25 measurement points in the quadrate . As in the case of the coincidence counting by more than 2 measurement points, the substrate were counted as that

Principal component analysis (PCA) with 15 environmental variables (see Table 2) was used to characterize habitat environments of permanent sits relative to temporary sites in multivariate dimensions.

3. Abundance and spatial distribution
: Effects of catastrophic floods

Table3. Observed sites and observations per unit effort (OPUE) of bagrid catfish for each size class. OPUE was calculated as individual counts per 4 persons-1 hour.

Channel-unit type	Observed site No.	Pre-flood survey	Post -flood survey	Shelter type
Glide	G1		I^{1}	cobble
	G2	II^{1}		cobble
Pool	P3	I^{1}		boulder
	P4		I^{1}	boulder
	P5	I^{1}, II^{1}, III^{1}	I^{6}, II^{3}, III^{1}	boulder
	P6	I^{1}	I^{1}	boulder
	P7	I^{1}		cobble
	P8	I^{1}		cobble
	P9		I^{1}	cobble
	P10		I^{1}	boulder
	P11	II^{1}		boulder
Riffle	R12	$I^{0.5}$		cobble
	R13	$I^{0.5}$		cobble
	R14	$I^{0.5}$		cobble
	R15		$I^{0.5}$	cobble
Total		$10^{10.5}$	$7^{15.5}$	

Fish size classes (mm TL): Class I< 50mm TL, Class II= 60-110mm TL, and Class III> 120mm (Board of Education of Mie Prefecture, Mie Prefectural Science and Technology Promotion Center 2003).

The OPUE is indicated as superscripts for fish size class symbols.

●The bagrid catfish were consistently more abundant in the pool and sheltered interstitial spaces formed by cobble and boulder substrates.
●Despite that the tremendous floods did not have recognizable effects on catfish at the reach or channel-unit scales, shifts in spatial distribution of individuals occurred at a microhabitat scale over the floods.
●Only 20% of the patches (permanent habitat) with resident fish before the floods contained individuals after the events whereas individuals appeared or disappeared in other patches (temporary habitat) after the events.
●In one permanent habitat (P5), individuals of various sizes persistently occupied spaces beneath single boulder, and number of individuals increased by more than 3-fold over the events.

4. Permanent microhabitats as flood refuge

Fig.1. The ordination of principal component analysis using for the 15 environmental variables at each observed site of bagrid catfish after flooding.

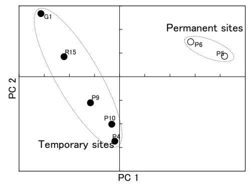


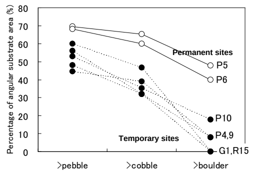
Table4. The results of principal component analysis using the environmental variables measured for each observed site at post-flood survey occasion. The numbers in bold type denotes factor loadings of greater than 0.80.

Variables		Factor loading PC1	PC2
Depth	mean	**0.81**	0.12
	complexity	0.22	-0.45
Velocity	mean	-0.67	0.61
	complexity	-0.76	0.56
Substrate size	mean	**0.95**	0.04
	complexity	0.48	-0.34
Substrate area	>pebble	0.04	**0.87**
	>cobble	0.61	0.66
	>boulder	**0.95**	-0.13
Over-lying substrate area	>pebble	0.54	0.68
	>cobble	0.79	0.41
	>boulder	**0.96**	-0.11
Substrate numbers	>pebble	-0.07	0.79
	>cobble	0.45	0.64
	>boulder	**0.87**	-0.20
Percent of variance (cumulative %)		46.00	72.00

Table5 Comparisons of environmental variables between temporary sites and permanent sites. The ranges of values were shown for temporary sites.

		Temporary sites (N = 5)		Permanent sites (N = 2) P5		P6
Water depth (cm)	mean	25-88	<	104	-	147
	complexity	16-56	inc	50	-	21
Current velocity (cm/sec)	mean	1-12	inc	2	-	2
	complexity	58-136	>	50	-	57
Substrate size (cm)	mean	8-34	<	71	-	43
	complexity	51-109	inc	87	-	81
Substrate area (%)	>pebble	44-80	inc	78	-	72
	>cobble	39-60	<	70	-	64
	>boulder	0-33	<	52	-	40
Over-lying substrate area (%)	>pebble	33-52	inc	65	-	52
	>cobble	28-40	<	61	-	44
	>boulder	0-22	<	48	-	28
Substrate numbers (inds)	>pebble	8-18	inc	12	-	17
	>cobble	7-10	inc	10	-	14
	>boulder	0-6	inc	6	-	8

inc.: the range of values measured for permanent sites were included in or overlapped with the range of values for temporary sites.



●The physical environment of permanent habitat was characterized by greater areas covered by angular (not spherical) boulders and deep water depth.
●The substrates of permanent sites remained in the same position over the events whereas there were apparent signs of bed movement in the riffle and glide.
●The critical diameter for sediment movement is 50cm in the study tributaries(Tashiro et al. 2005) .

Temporary habitat: Unstable spherical substrate area by the transportation and deposition
Permanent habitat: Stable angular substrate area by erosion in the rock bank

Why *P. i.* favored the angular substrate of physical habitat preferences? Stable bed and····

laboratory experiment

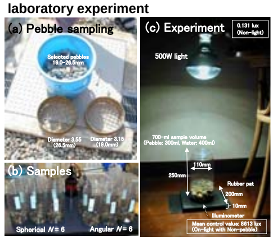
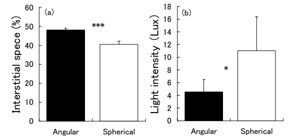


Fig.2. Mean (+1SD) by the comparison experiment between angular and spherical samples for interstitial space (a) and light intensity (b) under the substrate. *$P < 0.05$, ***$P < 0.001$ by t-test as compared with angular and spherical substrate.



Angular substrate provided for larger and darkness spaces, which is the suitable habitat of nocturnal bagrid catfish.

5. Conclusions

These results suggest that it is crucially important to preserve hydraulic refuge habitats with angular boulders in deep pools in order to maintain suitable habitat environments and viable populations of bagrid catfish.

: Management implications for the conservation

●Land use changes in headwater areas that could increase sediment supply may lead to the increase levels of sedimentation in downstream areas, therefore, proper management of land use activities at the watershed scale is necessary to prevent excessive sedimentation in remaining distribution areas of bagrid catfish.

●It is necessary for bagrid catfish in order to preserve the rock bank erosion, which provide angular substrates.

●If streams are to be restored for the conservation of bagrid catfish, therefore, creations of deep pools with substrate materials of sizes that are larger than critical diameters for movements during severe floods might be effective. Furthermore, large substrate materials may be placed in spatial arrangements with which the plugging of interstitial habitats by sedimentation is minimized.

Acknowledgements

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AQUA RESTORATION RESEARCH CENTER
Incorporated Administrative Agency Public Works Research Institute