INFLUENCE OF SEDIMENT CONTROL DAM ON FISH COMMUNITY LIVING UPPER REACHES

YUKO ISHIDA
Graduate school of Engineering, Kyoto University, Gokasho
Uji, Kyoto-fu 611-0011, Japan

YASUHIRO TAKEMON
Water Resource Research Center, Disaster Prevention Research Institute, Kyoto University, Gokasho
Uji, Kyoto-fu 611-0011, Japan

SHUICHI IKEBUCHI
Water Resource Research Center, Disaster Prevention Research Institute, Kyoto University, Gokasho
Uji, Kyoto-fu 611-0011, Japan

Influence of sediment control dam on fish communities in the backwater reaches was studied in Kamo River, Kyoto Prefecture, Japan. Fish sampling and habitat measurement were conducted in backwater reaches, transitional reaches and control reaches. Japanese chub *Zacco termmincki* was distributed in all reaches. Southern fat-minnow *Phoxinus oxycephalus* inhabited in control reaches mainly. Benthic fish such as fresh water goby, *Rhinogobius flumineus*, dark sleeper *Odontobutis obscura*, pike gudgeon *Pseudogobio (pseudogobio) esocinus esocinus* dwelled in backwater reaches relatively. Japanese chub, southern fat-minnow, pike gudgeon and pale chub lived in pool, while freshwater goby was in riffle. It was suggested that each species selected habitat by combined environmental parameters.

INTRODUCTION

Habitat characteristics are considered as multiple spatial scale consisting of hierarchical structure (Inoue *et al*. [1]). Limiting factors of distribution and behavior of fish are known to different with each spatial scale (Watanabe *et al.* [2]). Therefore, it is required that relationships hierarchy of river structure and each scale are focused when habitat of fish is considered. Phenomenon of fish distribution has understood to correspond to changes of water temperature and gradient following stream, for example. Whereas in reach scale, it is known that composition of species and abundance of fish are different in unit scale of pool and riffle (Inoue & Nakano [3]). And microhabitat scale which is focused on environmental parameters such as water velocity, water depth and substrate and is smaller than unit scale, is useful when habitat selection of each fish and interaction of between species are expressed.

In Japan, most of rivers and streams have been altered by human activities, and the resultant degradation of aquatic habitats for fish and aquatic insects is of great concern. Sediment control dam is one of them. However cases which showed influence of sediment control dam to habitat of organisms specifically are few now. Clearness of habitat-fish relationships and habitat selection of fish are required in conservation and restoration management strategy of river. In the present study, influence of sediment control dam to habitat of fish was cleared with the object of reach scale and unit scale.

MATERIAL AND METHOD

Study area

The study was conducted in 2.8 km reach of Kamo River, Kyoto Prefecture, Japan. Sediment control dam was established in the lower stream of the study reaches. Reaches of study area were classified into three types from lower reaches to upper reaches: i.e., backwater reaches of a sediment control dam characterized by depositional features with low hydraulic gradient, transitional reaches with intermediate amount of sedimentation along the channel, and control reaches without dam effects on stream geography. For sets of pool/riffle unit were selected in each reach type for fish sampling.

Fish sampling and habitat measurement

The study was conducted in 21-30 October 2003. The upper and lower edge of the pool/riffle units were separated by gill nets to prevent fish transference, and the whole of fish were caught by brail net (mesh size 1mm, frontage 40cm) and bag net (mesh size 1-3mm).

Habitat measurements were performed before fish sampling. Gradient, water temperature, dissolved oxygen, pH, electric conductivity, water depth, water velocity and substrate coarseness (Inoue *et al*. [1]) were measured in each unit. Environmental parameters which were measured of each site were shown in Table 1.

Fish number count and morphological measurement

Caught fish were identified on the field, were counted number and measured total length and standard length. Deceased individuals and some individuals of each species which were captured were fixed by 10% formalin solution and they were brought to laboratory. Other individuals were released in the field.

Data analysis

For comparison among data, the data which didn’t have normal distribution were transformed into log(x+1) and were examined by ANOVA or t-test. If the date didn’t have normal distribution after transforming, the data were examined by parametric analysis because they were small in number. Pearson’s correlation coefficients were performed to examine between density of each species and each environmental parameter. Relationships between density of each species and environmental parameters were subsequently examined using stepwise multiple regression analysis. In this paper, statistical values were shown in form of mean±SD.

Table 1. Environmental and fish community parameters of the study reaches

	backwater reach				transitional reach				control reach			
	st1	st2	st3	st4	st5	st6	st7	st8	st9	st10	st11	st12
gradient	-0.001	-0.001	0.002	0.004	0.008	0.017	0.009	0.013	0.010	0.014	0.024	0.006
water temperature	15.78	15.80	15.78	15.12	14.38	14.30	14.78	15.57	14.40	13.70	14.33	14.30
dissolved oxygen (%)	104.3	114.0	111.3	103.1	107.5	108.7	118.4	117.4	117.0	116.1	115.1	108.4
dissolved oxygen (mg/l)	10.34	11.30	11.04	10.35	10.96	11.10	12.02	11.76	11.86	12.06	11.75	11.08
pH	6.82	7.29	7.16	7.07	7.32	7.45	7.62	7.31	7.36	7.49	7.28	7.43
electric conductivity	108.3	103.6	117.1	124.0	120.7	128.9	104.4	109.5	123.5	93.6	115.2	113.3
depth (cm)	42.98	22.87	27.42	28.13	8.54	25.27	22.86	15.68	23.33	19.18	26.31	40.76
velocity (m/sec)	0.035	0.099	0.049	0.038	0.067	0.027	0.047	0.083	0.104	0.054	0.173	0.104
substrate coarseness	5.002	4.703	4.720	4.704	5.088	4.925	5.248	5.451	4.529	5.063	4.360	4.611
species richness	5	5	6	4	4	5	4	3	6	4	3	4
diversity index (H')	1.065	0.893	0.798	0.738	0.837	0.619	0.785	0.789	0.457	0.878	0.874	0.409
fish density (/m^2)	-	-	-	-	-	-	-	-	-	-	-	-
total fish	1.289	1.911	4.364	1.718	2.077	3.507	0.660	0.842	3.762	0.499	0.286	1.886
Zacco termmincki	0.630	1.108	3.218	1.239	0.773	2.776	0.264	0.241	3.374	0.339	0.157	1.661
Rhinogobius flumineus	0.482	0.672	0.853	0.406	1.206	0.631	0.381	0.556	0.168	0.116	0.111	0.205
Odontobutis obscura	0.149	0.118	0.140	0.024	0.092	0.069	0.013	0.045	0.084	0.026	0.018	0.014
Phoxinus oxycephalus	0.016	0.006	0.030	0.000	0.000	0.014	0.003	0.000	0.121	0.018	0.000	0.007
Pseudogobio esocinus	0.012	0.006	0.110	0.049	0.005	0.017	0.000	0.000	0.010	0.000	0.000	0.000
Zacco platypus	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000

RESULTS

Comparison of reach scale

Environmental parameters and density of fish were analyzed by canonical correspondence analysis (CCA). Environmental parameters of three reaches were not different (Fig.1). Japanese chub *Zacco termmincki*, southern fat-minnow *Phoxinus oxycephalus*, pike gudgeon *Pseudogobio (Pseudogobio) esocinus esocinus* and pale chub *Zacco platypus* tended to inhabit in deeper, whereas freshwater goby *Rhinogobius flumineus* was in higher substrate coarseness.

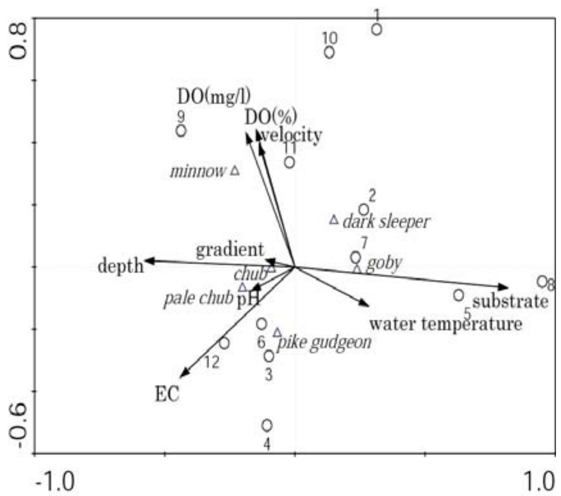

Figure 1. Result of CCA in environmental parameters of each site.
Numeric numbers near opened circle represent site numbers.

Gradient, water temperature, pH and substrate coarseness were significant in three reaches on each parameter. Gradient was higher in control reaches (0.0057±0.0034) than in backwater reaches (0.0005±0.0010) (P<0.05, Scheffe's F test). Water temperature was higher in backwater reaches (1.2206±0.0089) than in control reaches (1.1813±0.0094) (P<0.01, Scheffe's F test). pH was lower in backwater reaches (0.9074±0.0107) than in transitional reaches (0.9255±0.0076) (P<0.05, Scheffe's F test). Substrate coarseness was higher in transitional reaches (0.7906±0.0158) than in control reaches (0.7509±0.0227) (P<0.05, Scheffe's F test). Dissolved oxygen (mg/l) was not significant, but it tended to low in backwater reaches (P=0.0508, One-way ANOVA).

Species richness, total fish density and Shannon's diversity index (H') were not significant in three reaches (N.S., One-way ANOVA respectively). Density of each species were subsequently compared among three reaches. Japanese chub which was dominant species in the study area was distributed throughout three reaches. Freshwater goby inhabited in backwater reaches (0.2025±0.0538) and transitional reaches (0.2221±0.0866) rather than in control reaches (0.0603±0.0169) (P<0.01, One-way

ANOVA). Density of dark sleeper, *Odontobutis obscura* was not significant, but was increscent from control reaches (0.0150±0.0135) to backwater reaches (0.0440±0.0229) (P=0.1009, One-way ANOVA). Southern fat-minnow was also not significant, but tended to high in control reaches (0.0151±0.0231) rather than in backwater reaches (0.0557±0.0557) and transitional reaches (0.0018±0.0028) (P=0.4142, One-way ANOVA). Pike gudgeon tended to high in backwater reaches (0.0184±0.0195) rather than in control reaches (0.0011±0.0023) and transitional reaches (0.0025±0.0035) (P=0.1139, One-way ANOVA). Pale chub was not significant, but they dwelled in backwater reaches and control reaches only.

Comparison of pool/riffle unit scale

Environmental parameters and density of fish were analyzed by CCA. Environmental parameters were categorized into approximately pool and riffle (Fig.2). Japanese chub, southern fat-minnow, pike gudgeon and pale chub dwelled in deeper pool, whereas freshwater goby inhabited in riffle where substrate coarseness and water velocity were high. Environmental parameters and density of fish in pool and riffle were subsequently analyzed by CCA respectively. Difference was not significant in reaches both pool and riffle.

Gradient, water depth, water velocity and substrate coarseness were significant in pool/riffle unit on each parameter. Gradient was significantly higher in riffle (0.0068±0.0059) than in pool (0.0018±0.0027) (P<0.01, Scheffe's F test). Water depth was larger in pool (1.5602±0.2106) than in riffle (1.0825±0.1357) (P<0.0001, Scheffe's F test). Substrate coarseness was higher in riffle (0.7943±0.0168) than in pool (0.7326±0.0495) (P<0.0001, Scheffe's F test), and interaction was shown with reach factor (P<0.05, Two-way ANOVA). No difference of reaches was shown in riffle, but substrate coarseness was higher in transitional reaches (0.7792±0.0179) than in control reaches of pool (0.6943±0.0585) (P<0.05, Scheffe's F test).

Pool unit and riffle unit were analyzed severally, because they were divided by CCA.

Densities of each species were compared in three reaches in riffle unit. Total fish density was higher in backwater reaches (0.5118±0.1909) than in control reaches (0.1341±0.1010) (P<0.05, Scheffe's F test). Densities of Japanese chub and dark sleeper were not significant, but they tended to be higher from control reaches to backwater reaches (Japanese chub: P=0.0526, dark sleeper: P=0.2511, One-way ANOVA). Fresh water goby was not significant, but the fish tended to live in backwater reaches and transitional reaches (P=0.0774, One-way ANOVA). Pike gudgeon was not significant, but the fish dwelled in backwater reaches only. Southern fat-minnow and no pale chub inhabited in all reaches.

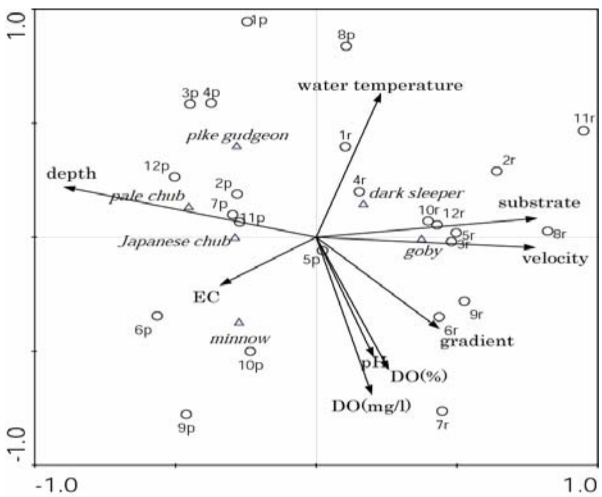

Figure 2. Result of CCA in environmental parameters of each unit. Numeric numbers near opened circle represent site numbers and letter of “p” or “r” mean pool or riffle.

Densities of each species were subsequently compared in three reaches in pool unit. Density of Japanese chub was higher in backwater reaches (0.4269±0.1671) than control reaches (0.0616±0.0432) and transitional reaches (0.0990±0.0903) ($P<0.01$, Scheffe’s F test). Density of pike gudgeon was also higher in backwater reaches (0.0234±0.0186) than in control reaches (0.0015±0.0030) and transitional reaches (0.0036±0.0042) ($P<0.05$, One-way ANOVA). Total density, densities of freshwater goby and dark sleeper were not significant in three reaches. Southern fat-minnow was not significant, but it tended to lived in control reaches. Pale chub was lived in control reaches and backwater reaches.

Influence of environmental parameters

Stepwise multiple regression analysis was performed to examine combined environmental parameters on density of each species on each unit.

In riffle, density of Japanese chub was best modeled by a combination of gradient, dissolved oxygen (mg/l), dissolved oxygen (%), water velocity and substrate coarseness, in which the relative importance of dissolved oxygen (%) and substrate coarseness was greater (Table 2). Japanese chub increased with dissolved oxygen and decreased with substrate coarseness. Density of freshwater goby was best modeled by a combination of gradient, water temperature, dissolved oxygen (mg/l), dissolved oxygen (%), pH, electric conductivity, water depth and substrate (Table 2). Density of southern fat-minnow was best modeled by a combination of gradient and water velocity (Table 2). Southern fat-minnow was increased with gradient and decreased with water velocity. Density of pike gudgeon was best modeled by a combination of water dissolved oxygen (mg/l), pH, depth and substrate coarseness, in which the relative importance of dissolved oxygen and pH was greater. Pike gudgeon was increased with dissolved oxygen and decreased with pH. Dark sleeper was not significant by stepwise multiple regression analysis.

The stepwise analysis was subsequently conducted on pool. Density of Japanese chub was best modeled by a combination of dissolved oxygen (mg/l), dissolved oxygen (%), pH and water temperature (Table 3). Density of pike gudgeon was best modeled by a combination of dissolved oxygen (%), water velocity and substrate coarseness, and the density was decreased with those parameters (Table 3). The other fish densities were not significant.

DISCUSSION

Table 2. Results of stepwise multiple regression analysis using density of each species as a dependent variable (n=12) on each site of riffle. Data were transformed prior to the analysis.

Species	Independent variable	Standardized coefficient	Model significance		
			r^2	*F*	*P*
Z. termmincki	gradient	0.67	0.98	52.61	<0.001
	DO (mg/l)	-0.70			
	DO (%)	1.16			
	velocity (m/sec)	-0.11			
	substrate coarseness	-0.80			
R. flumineus	gradient	0.42	0.97	10.92	0.037
	water temperature	4.57			
	DO (mg/l)	12.99			
	DO (%)	-11.44			
	pH	-0.44			
	EC	0.92			
	depth (cm)	-0.68			
	substrate coarseness	-0.94			
P. oxycephalus	gradient	0.45	0.50	4.47	0.045
	velocity (m/sec)	-0.54			
P. esocinus	DO (mg/l)	1.66	0.84	9.00	0.007
	pH	-1.35			
	depth (cm)	-0.37			
	substrate coarseness	-0.86			

Multiple environmental character was not different in three reaches by CCA. These factors didn’t show influence of sediment control dam, and units were divided into pool and riffle. It was suggested that water depth influenced as environmental parameter. The other parameters were not significant in reaches, because the study reaches were short in 2.8km. However, gradient was higher and water temperature was lower in control reaches which were in upper stream.

In reach scale, benthic fish such as freshwater goby, dark sleeper and pike gudgeon dwelled in backwater reaches and transitional reaches, whereas southern fat-minnow inhabited in control reaches. The minnow was known as living in upper stream, and result of this study showed the reason. Japanese chub which was dominant species in this study reaches lived in all reaches.

In unit scale, distribution patterns of each species were different. Density of Japanese chub increased in backwater reaches of pool and riffle. A significant negative correlation between the density and substrate coarseness was found by stepwise multiple regression analysis. That was why Japanese chub lived in backwater reaches which has relatively small substrate of river bed. Pike gudgeon also dwelled in backwater reaches. Dark sleeper was not correlated with environmental parameters, but the fish lived in backwater reaches of riffle. Few freshwater goby was dwelled in upper control reaches of riffle. Few southern fat-minnow lived in riffle, and most of the fish was in pool of control reaches. In riffle, however, minnow density has positive correlation with gradient, and the fish preferred to control reaches which had high gradient.

Table 3. Results of stepwise multiple regression analysis using density of each species as a dependent variable (n=12) on each site of pool. Data were transformed prior to the analysis.

Species	Independent variable	Standardized coefficient	Model significance r^2	F	P
Z. termmincki					
	DO (mg/l)	-16.27	0.88	12.72	0.003
	DO (%)	14.08			
	pH	0.94			
	water temperature	-2.94			
P. esocinus					
	DO (%)	-0.55	0.70	6.31	0.017
	velocity (m/sec)	-0.57			
	substrate coarseness	-0.51			

It was shown that southern fat-minnow preferred to control reaches, the other fish dwelled in backwater reaches and near transitional reaches. It was thought that the other species distributed in midstream of river basin in comparison with southern fat-minnow. Nektonic fish such as Japanese chub and pale chub were dwelled in pool especially. Pike gudgeon which has nature of ducking in sand also lived in pool which has low substrate coarseness. Freshwater goby which selected cobble bed as habitat (Takemon *et al*. [4]) inhabited in riffle which has high substrate coarseness.

These results didn't show that difference of three reaches was expressed influence of sediment control dam. Relationships other environmental parameters and density of fish will be examined as a future tasks.

REFERENCES

[1] Inoue M., Nakano S. and Nakamura F., "Juvenile masou salmon (*Oncorhynchus masou*) abundance and stream habitat relationships in northern Japan", *Canadian journal of fisheries and aquatic sciences*, Vol.54, (1997), pp 1331-1341.

[2] Watanabe K., Nakamura F., Kamura K., Yamada H., Watanabe Y. and Tsuchiya S., "Influence of stream alteration on the abundance and distribution of benthic fish", *Ecology and civil engineering*, Vol.4, (2001), pp 133-146. (In Japanese and English summary).

[3] Inoue M. and Nakano S., "Physical environment structure of a small stream with special reference to fish microhabitat", *Japanese journal of ecology*, Vol.44, (1994), pp151-160. (In Japanese and English summary).

[4] Takemon Y., Ishida Y. and Tanida K., "Habitat selection and food habits of *Rhinogobius flumineus* and *Rhinogobius* OR sp. in downstream of Yodo River basin", *Multidisciplinary research of Kizu River*, (2003), pp517-527.