Influence of Point Environmental Conditions to the Present Species Richness of Fish and Mussel of Floodplain Pools in the Kizu River

Mikyoung CHOI(1), Yasuhiro TAKEMON, Kinko IKEDA(2), Kazuhiro NISHII(2) and Tetsuya SUMI

(1) Graduate School of Engineering, Kyoto University
(2) ASIA AIR SURVEY CO., LTD.

Synopsis

The Kizu River ecosystem is characterized by lentic habitats such as pools or wando on the floodplain, providing habitats to Acheilognathus bitterlings and freshwater unionid mussels. In the last decade, however, these habitats have been degraded by the decrease of peak discharge and flood frequency and excessive vegetation expansion on the floodplain. In order to restore the suitable habitat structure for the Kizu River ecosystem, it is needed to find out relations of habitat condition required for bitterlings and mussels. We used principal component analysis (PCA) and generalized linear model (GLM) based on selected data by correlation analysis. Species richness of Bitterling was best explained by a model consist of location, age, transparency, mean grain size and DO one year ago. Species richness of mussel was best explained by a model consist of flooding frequency and depth of mud two years ago. Species richness of resident fish was best explained by low relative height, age, area and vegetation coverage, and species richness of alien fish was explained by model consist of low relative, area, vegetation coverage and DO. Species richness of resident fish and alien fish were significantly correlated with habitat conditions of current year. The results indicate a range of habitat age for maintenance of fish and mussel diversity including more than two years old, is required in the Kizu River.

Keywords: bitterling, mussel, alien fish, species richness, habitat conditions

1. Introduction

The Kizu River has been known lentic habitat such as pool or wando for bitterlings and unionid mussels living in lentic habitats on its' floodplain (ASIA AIR SURVEY, 2009). In the last decade, however, these habitats have been degraded by the decrease of peak discharge and flood frequency and excessive vegetation expansion on the floodplain (Ashida et al, 2008). According to the deterioration of habitat condition, the diversity of bitterling and bivalve decreased, and representative protected bitterling '*Acheilognathus longipinnis'* had disappeared in the Kizu River (Kizu River Research Group, 2003). To restore the habitat structure of species diversity, especially bitterling and mussel, it is needed to find out relations of habitat condition required for bitterlings and mussels. In other to understand the intrinsic reasons for their presence or absence in a pool, it is inevitably important to analyze effects of habitat conditions not only at present but also in the past.The survival of mussels depends on the interaction of several biotic and abiotic factors operating at different spatial and temporal scales (Morales et al., 2006; Haag and Warren, 1998). Because successful reproduction requires the availability of an appropriate host fish at the appropriate time and that juveniles find favorable habitat, mussels had possibility that they were related with spatial diversity as well as time lag. However, there have been only a few works showed empirical interrelations of species richness in a particular habitat to its environmental conditions (Negish et al., 2012; Strayer and Ralley, 1993; Yoshihiro and Takashi, 2010; Holland -Bartels, 1990; Layzer and Madison, 1995).

This paper aims to clarify the amount of time lag between habitat changes having a significant influence on species diversity and bitterling and unionid mussel. In addition, we attempted to figure out habitat parameters having a dominant role on species diversity.

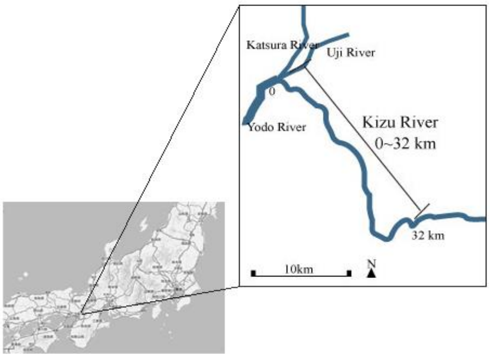

Figure 1 The study site of the Kizu River

2. Method

2.1 Study site

The study area was established in the lower reaches (0~32 km) of the Kizu River, a tributary of the Yodo River in central Japan (Fig.1). A mean of river slope in study area was 1/1180 and mean diameter of bed material was 2 mm ~3 mm (Kizu River Research Group, 2009). The study area was composed of bareland (ca. 21%), bushland (ca. 42%), woodland (ca. 14 %) on the floodplain, and water surface (ca. 23%). Vegetation area on the floodplain increased about 8 times and bareland area decreased about 70% compare with in 1948 (Choi et al, 2012).

2.2 Materials

(1) Fish and bivalve data (response variable)

We used species and habitat condition data from ASIA AIR SURVEY CO., LTD. A total of 47 floodplain pools surveyed from 10 to 26 August 2011. Fish and mussel data were classified into bitterling, unionid mussel, resident fish except bitterling, and predatory alien fish (e.g. bass, blue gill, snake head). Because successful reproduction of mussels requires the availability of an appropriate host fish (Morales et al., 2006; Haag and Warren, 1998), and exotic species and degraded water quality influenced declines of fish (Lydeard et al.,2004), we considered resident fish and predator fish as well as bitterling and mussel. The species richness of four groups was used as response variables to detect relations of fish and mussel diversity to habitat conditions.

(2) Habitat condition data (explanatory variable)

Following parameters measured by the field surveys were used for the analyses: habitat size, area of water surface, water depth, area of water depth than low 30 cm, transparency of water, water quality (PH, DO, COD, SS, EC, ORP), Chlorophyll, vegetation coverage, ratio of floating plants, grain size (mean, D60, D50, D30), depth of mud, porosity and ignition loss, relative height (low, mean, high), flooding frequency, age and location. Relative height is height between water level of main channel and level of 5 m buffer around pool. Flooding frequency was calculated by simulation using DEM data and water discharge of 10 years (0: no flooding, 1: one time, 2: eight times, 3: 16 times, 4: 22 times, 5: normally flooding per 1 year) . Age of pool defined by existent period of habitat using aerial photo from 2001 to 2012, and location was section number (0 ~ 32). A total of 27 habitat condition parameters were considered as explanatory variables. Relations of current species diversity to current habitat conditions as well as past conditions were analyzed using data of habitat conditions in 2007, 2009, 2010 and 2011.

2.3 Data analysis

To select representative explanatory variables among many habitat conditions, we used correlation analysis and principal component analysis (PCA). Correlation analysis was conducted for picking out data of habitat conditions statistically. And then, final explanatory variables were selected by PCA.

Relations of fish and bivalve diversity to habitat conditions were analyzed using generalized linear model (GLM) with a Poisson error assumption and a long link function. Values of area and depth as explanatory data were log transformed, because they did not show normal distribution. The best model was selected based on Akaike's Information Criterion (AIC; Akaike, 1974), and Chi-squared (χ^2) was used to compare effect of past and recent conditions on fish and bivalve diversity. All analyses were conducted using SPSS version 19 (SPSS 19.0, SPSS Inc).

3. Results and discussion

Final explanatory variables were selected into low relative height, flooding frequency, age, location, habitat size, water quality (PH, DO), transparency, vegetation coverage, mean grain size, and depth of mud. Species richness of bitterling was best explained by a model consist of location, age, transparency, mean grain size and DO one year ago (χ^2 = 3.83, P = 0.05). Species richness of mussel was best explained by a model consist of flooding frequency and depth of mud two years ago (χ^2 = 12.18, P <0.001). This result showed species richness of mussel was influenced by habitat conditions 2years ago. It may assume that mussels were reproduced or flowed from main channel in the past. Because freshwater unionid mussel was taken about 5 years from reproduction to adulthood(Mahon and Bogan, 2001), a time lag may exist between current species richness and past habitat conditions. In addition, they required appropriate substrate to anchor and burrow, and substrate stability may affect their distribution (Holland-Bartels, 1990; Layzer and Madison, 1995; McRae et al, 2004).Species richness of resident fish was best explained by low relative height, age, area and vegetation coverage (χ^2 = 18.34, P <0.001) and species richness of alien fish were explained by model consist of low relative, area, vegetation coverage and DO (χ^2 = 20.42, P <0.001). Species richness of resident fish and alien fish were significatly related to habitat conditions of current year (Table 1).

Species richness of bittering had no significant

Table 1 Results of generalized linear model tested the relations of species richness in 2011 and habitat conditions in 2007, 2009, 2010 and 2011.

Species of richness	Model		n	Year	Wald χ^2	p-value
	Statistic data	Field survey data				
Bitterling	Location + age	Transparency + mean grain size + DO	5	2011	1.81	.177
				2010	3.83	.050
				2009	1.84	.174
				2007	3.15	.076
Mussel	Flooding frequency	Depth of mud	2	2011	0.56	.454
				2010	1.99	.157
				2009	12.18	.000
				2007	5.90	.015
Resident fish	Low relative height + age	Area + vegetation coverage	4	2011	18.34	.000
				2010	2.14	.143
				2009	1.13	.287
				2007	0.75	.386
Alien fish	Low relative height	Area + vegetation coverage + DO	4	2011	20.42	.000
				2010	0.28	.594
				2009	0.59	.441
				2007	0.55	.456

correlations separately. Although they did not show correlation between bitterling diversity in 2011 and each habitat condition in 2010 (Table 2), Figure 3 showed species richness of bitterling increased with high habitat age. For the preservation of symbiosis between bitterlings and mussels, a stabilized environment as well as immediate disturbance for both animals required. Species richness of mussel positively correlated with depth of mud (R = -0.524, P < 0.5) (Table 1). Although they had negative correlation, also had low R^2value, species richness of mussel had maximized results between 5 ~10 cm. Hence, mussel diversity required some disturbance to maintain depth of mud between 5~10 cm (Fig. 2). Therefore, to determine a target of substrate condition for mussel diversity, we should consider the effect of past conditions as well as current conditions.

Species richness of resident fish had a negative correlations with low relative height (R = -0.394, P < 0.5) and vegetation coverage (R = -0.35, P < 0.5). Species richness of alien fish showed a negative correlation with vegetation coverage (R = -0.341, P < 0.5) and a positive correlation with habitat size (R = .547, P < 0.5) and DO (R = 0.438, P < 0.5) (Table 2). As Jacqueline (1989), predators such as bass prefer the heavily vegetated sites and open areas. Our study also showed species richness of alien fish had a possive correlation with habitat size. However, they were negativly correlated with vegetation coverage. They had maximum values between 10~20 % vegetation coverage in the Kizu River.

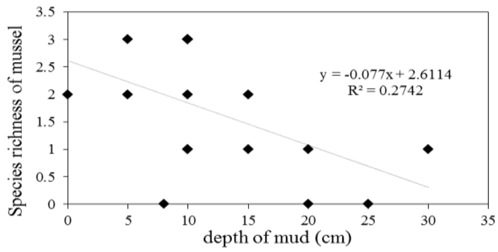

Figure 2 Relation of species richness of mussel in 2011 to depth of mud in 2009. p<0.05

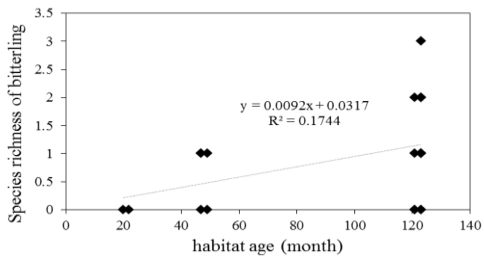

Figure 3 Relation of species richness of bitterling in 2011 to habitat age in 2010. *n.s.*

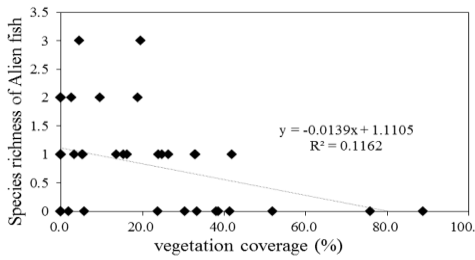

Figure 4 Relation of species richness of alien fish to vegetation coverage in 2011. p<0.05

Table 2 Results of correlation analysis tested relations between species richness and habitat conditions were used in model. Relations between bitterling richness in 2011 and habitat conditions in 2010. Relations between mussel richness in 2011 and habitat conditions in 2009, and relations between fish richness in 2011 and habitat conditions in 2011. (r values. *** p<0.001, * *p<0.01, * p<0.05)

Species of richness	Low relative height	age	location	Flooding frequency	area	Vegetation coverage	DO	transparency	Mean grain size	Depth of mud
Bitterling		.220	.331				-.203	-.151	-.007	
Mussel				-.454						-.524*
Resident fish	-.394**	-.287			.324 *	-.350*				
Alien fish	-.288				.547***	-.341*	.438**			

4. Conclusion

We used correlation analysis, principal component analysis (PCA) and generalized linear model (GLM) to find out relations of habitat condition required for bitterlings and mussels . Species richness of bitterling was best explained by a model consist of location, age, transparency, mean grain size and DO one year ago. Species richness of Unionid mussel was best explained by a model consist of flooding frequency and depth of mud two years ago. Species richness of resident fish was best explained by low relative height, age, area and vegetation coverage, and species richness of alien fish was explained by model consist of low relative, area, vegetation coverage and DO. Species richness of resident fish and alien fish were significatly relatived to habitat conditions of current year (Table 1). Range of habitat age for maintenance of fish and mussel diversity including more than two years old, is required in the Kizu River. To maintain a healthy and sustainable habitat for fishes and mussels, a wide range of habitat age should be considered.

Acknowledgements

This study was conducted in a research project "Development of riverbed management techniques for river environments" supported by the Japanese Ministry of Land, infrastructure, Transport and Tourism. We would like to the Yodo River Bureau for providing aerial photo and DEM data

References

ASIA AIR SURVEY CO., LTD (2009) Report of pond research in the Kizu River, part 2

Ashida K., Egashira S. and Nakagawa H. (2008) River Morphodynamics for the 21st Century, Kyoto University Press, pp 40-51

Akaike H. (1974) A new look at the statistical model identification, IEE Automat Contr. Vol 19, pp 716-723

Choi M., Takemon Y. and Sumi T. (2012) The Historical Changes of Aquatic Habitat Structure in the Kizu River, 18th Congress of the Asia and Pacific Division of the International Association for Hydro-Environment Engineering and Research, SS4F-2

Gangloff M.M. and Feminella J.W. (2007) Stream channel geomorpholpgy influences mussel abundance in southern Appalachian streams, U.S.A., Freshwater Biology, Vol 52, pp 64-74

Haag W.R. and Warren M.L. (1998) Role of ecological factors and reproductive strategies in structuring freshwater mussel communities, Canadian Journal of Fisheries and Aquatic Sciences, Vol. 55, pp297-306

Holland-Bartels L.E. (1990) Physical factors and their influence on the mussel fauna of a main channel border habitat of the Upper Mississippi River, Journal of the North American Benthological Society Vol. 9, pp 327-335

Layer J.B. and L.M. Madison (1995) Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs, Regulated Rivers: Research and Management Vol. 10, pp 329-345

Jacqueline F. S. and Roy A.S. (1989) Behavior of fish predators and their prey: habitat choice between open water and dense vegetation, Environmental Biology of Fishes, Vol 24, pp 287-293

Kizu River Research Group, 2003. Integrated research of the Kizu River II, 442pp

MacMahon R.F. and Bogan A.E. (2001) Mollusca: Bivalvia. pp 331-429 *in* H. Thorp and A.P. Covich (editors), Ecology and classification of North American freshwater invertebrates. 2nd edition, Academic Press, San Diego, Califirnia.

MacRae S.E., J.D. Allan and J.B. Burch (2004) Reach and catchment-scale determinants of the distribution of freshwater mussels (Bivalvia: Unionidae) in south-eastern Michigan, U.S.A. Freshwater Biology Vol. 49, pp 127-142

Mills S.C. and Reynolds J.D. (2003) The bitterling –mussel interaction as a test case for co-evolution, Jour. Fish Biology, Vol 63, pp84-104

Morales Y., Weber L.J., Mynett A.E. and Newton T.J.(2006) Effects of substrate and hydrodynamic conditions on the formation of mussel beds in al large river, J.N. Am. Benthol. Soc., Vol 25, pp 664-676

Negish J. N., Sagawa S., Kayaba Y., Sanada S., Kume M. and Miyashita T. (2012) Mussel responses to flood pulse frequency: the importance of local habitat, Freshwater Biology doi 10.111, j.1365-2427

Strayer D.L. and Ralley J. (1993) Microhabitat use by an assemblage of stream-dwelling unionaceans (Bivalvia), including two rare species of Alasmidonta. Journal of the North American Benthological Society, Vol. 12, pp 247-258

Yoshihiro B. A. and Takashi M. (2010), Habitat characteristics influencing distribution of the freshwater mussel *Pronodularia japanensis* and potential impact on the Tokyo bittering, Tanakia tanago, Zoological science, Vol 27, pp912-916

(Received June 11, 2013)