HABITATS AND FOOD SOURCES OF *Corbicula* BIVALVES IN A TIDAL RIVER WITH SERIES OF GROINS

Nannan LI¹, Takashi TASHIRO² and Tetsuro TSUJIMOTO³

¹Student Member of JSCE, M. Agri., Graduate School of Environmental Studies, Nagoya University
(#209 Eng. Bldg. 9, Nagoya Univ., 1 Furo-cho, Chikusa-ku, Nagoya 464-8603, JAPAN)

²Member of JSCE, D. Eng., Associate Professor, Disaster Mitigation Research Center, Nagoya University
(#401 Dsst. Mtgn. Res. Bldg., Nagoya Univ., 1 Furo-cho, Chikusa-ku, Nagoya 464-8601, JAPAN)

³Fellow Member of JSCE, D. Eng., Professor, Graduate School of Engineering, Nagoya University
(#201 Eng. Bldg. 9, Nagoya Univ., 1 Furo-cho, Chikusa-ku, Nagoya 464-8603, JAPAN)

This study was performed to clarify the spatial variation of habitat of *Corbicula* bivalves (*C. japonica* and *C. leana*). A series of field investigations were performed in the Kiso River estuary, in October – November, 2012, with particular references to the existence of a series of groins. We compared the differences of water environment, substrate and diet variables in longitudinal and transverse directions (Two-way ANOVA) to grasp the habitat characteristics in different landscapes. Furthermore, correlation and multiple regression analyses for their densities and biomass were applied to clarify the crucial environment variables. As the results, it was clarified that salinity and water depth could be the controlling factors for the biomass of *C. japonica*, whereas the sediment and salinity factors would effect on promoting the biomass of *C. leana* and the density of *C. japonica*.

Key Words : *Corbicula japonica* and *leana*, estuary, a series of groins, diet and environment variables

1. INTRODUCTION

Estuarine ecosystem has been claimed as the most productive ecosystems in the world, characterized by large fluctuating abiotic conditions with temporal and spatial variations¹⁾. The daily fluctuation of salinity, temperature and turbidity in estuary are more extremes than those in rivers and sea. Therefore, a few species could adapt to estuary. However, life in estuary was abundant because large amount of nutrient was transported from river and sea²⁾.

Benthic organisms take a large amount of total biomass in estuary ecosystem. In this kinds of ecosystems, numerous studies had examined the influences of sediment patterns, salinity levels and distributions of terrestrial vegetation on benthic community structures^{3), 4)}. Especially in intertidal water zones, the biomass and the densities were large in coarse aerobic sediments and in the water with high chlorophyll a concentration⁵⁾. Some researchers concluded that salinity strongly affected the distribution of benthic organisms along the longitudinal gradient of estuary⁶⁾, whereas the other ones suggested that periodical inundation and substrate condition were controlled the benthic community structures along the transverse gradient in a tidal river⁷⁾. Consequently, there has been few

findings from the both viewpoints of longitudinal and transverse direction in river estuary.

Suspension-feeding bivalves, *Corbicula japonica* dominated macro benthic community^{8), 9)}, which was considered as one of the most important bivalve fisheries in Japan with characteristic of huge landing. Due to their feeding in brackish waters, the nitrogen load from upstream emissions and leaching could be reduced by around 10.7 %⁹⁾. Recently, the fishery resource of *Corbicula* has appeared downward trend in Japan¹⁰⁾. However, in the Kiso estuary, *Corbicula japonica* was considered as the dominant species and their fishery resource sustained stable¹¹⁾.

In the previous studies of Kiso estuary, it was reported that benthic animals in sub tidal zone is more productive and diverse than those in inter tidal zone^{11), 12)}. However, in sub tidal zone, the environment variables on dominant species has not been clearly understood. In present research, we examined the influence of spatial shift of environment variables on *Corbicula* bivalves' habitat in sub tidal zone of the Kiso river with a series of groins. With this aim, the main effects of longitudinal and transverse directions on environment variables, biomass and density of *Corbicula* bivalves would be discussed. Also, we would try to evaluate their biomass and densities with some environment factors.

Fig. 1 Location map of Kiso estuary with series of groins, Japan. (source: Google Earth)

2. MATERIALS AND METHODS

(1) Field investigation

In the Kiso river, a series of groins has been installed along the left bank in the sections located at 12 - 25 river kilometer (R km) from the mouth since the Meiji era. This series of groins have two functions: controlling flood and maintaining diverse ecosystem services. Especially in the shallow water zone, diverse landscapes have been formed between two adjacent groins due to sediment accumulation and vegetation invasion. Hence, we set eight stations along longitudinal and transverse directions in the Kiso river as follows: St. 1 and 2 were located at riparian zones with and without a series of groins at the 12 R km cross section. St. 3, 4 and 5 were located in sub tidal zone, at the right bank side, thalweg and the left bank side in the cross section of 17 R km, respectively. The uppermost three stations, St. 6, 7 and 8 in the cross section of 20 R km were set in similar positional relations as St. 3, 4 and 5.

The salinity, chlorophyll *a* concentration (Chl. *a*) and water depth were logged with salinometer, turbidity meter and water depth gauges (COMPACT-CT, -CLW and -TD, JFE Advantech Co., Ltd.). All of the facilities were fixed near the bottom surface. The data were gathered every 5 minutes during a series of tidal motion in all of stations except those in St. 4 and 7. Each of the logged data (salinity, Chl. *a* and water depth) was pooled to get daily average values to conduct the statistics test.

The substrate samples for analyzing organic contents, grain size compositions and *Corbicula* bivalves were gathered at all stations with the Ekman-Birge grab (area = 0.0225 m²). Suspended particulate organic matter (SPOM) samples were collected in all stations by filtrating a certain volume of water (2000 L), sealed in a plastic bottle.

(2) Laboratory procedure

Benthic organisms were separated from each of the substrate samples. The individuals of *Corbicula japonica* and *Corbicula leana* were identified and were counted their numbers. Then these two bivalves were removed from their shell, washed with distilled

water for drying and weighting. They were dried at 60 °C in the oven for 24 hrs to a constant weight and weighed. At last, we estimated the biomass and density for each bivalve in all of the stations.

The residual samples were used to extract the benthic particulate organic matters (BPOM). POM was divided into two fractions: coarse (CPOM > 1mm) and fine particulate organic matters (FPOM < 1mm). Considering that *Corbicula* species only can assimilate the particles from filtration. Hence, only FPOM (SFPOM and BFPOM) were counted and analyzed in this research. SFPOM and BFPOM were estimated by ash free dry weight (AFDW). They were separated from samples by GF/B glass-fiber filters (0.47mm Whatman Janan Ltd., Tokyo. pre-combusted at 400 °C for 24 hrs), dried with thermostat at 105 °C for 24 hrs, and measured to get dry weight. Their AFDW were estimated by lost contents with a muffle furnace (MPN-310, Shimadzu Rika Co., Ltd.) at 400 °C for 4 hrs.

The samples which were removed benthic organisms and BPOM were extracted were undertaken sieve analysis (JIS A 1204). The following parameters of the sediment size distributions were described as: the silt rate, particle size < 75 μm; the median diameter, D50; the coefficient uniformity, $C_u = d_{60} / d_{10}$; and the curvature coefficient, $C_c = d_{30}^2 / d_{10}d_{60}$; where d_x means the representative particle size at the cumulative percentage (*x*).

(3) Data analysis

In order to compare the spatial distribution of diet and environmental variables and the biological data of *Corbicula* bivalves, two-way analysis of variance (ANOVA) was used to test the effects of the longitudinal and transverse directions. The collected data were log₁₀(Y+1) transformed to prevent co-variations with the means if they were not observed either normality or homogeneity of variances. If there were any significant differences in each of the variables due to directional effects, the Scheffe's *F* test was run to confirm where the differences occurred between groups. Furthermore, the principal component analysis (PCA) was utilized to reduce the dimensionality of environmental variables collected in longitudinal or transverse directions.

Pearson correlation analysis was used to analyze all of the combination of the collected data. As the result, when the Pearson correlations were significant or their coefficients were larger than 0.8, one of a pair of high correlated variables was selected to conduct the multiple regression analysis. The multiple regression analysis was utilized to predict biomass and density of *Corbicula* bivalves by showing importance of the effect of environmental variables.

Table 1 Mean values (and standard deviation) of water environment, substrate and diet variables in all of the stations.

The same letters in each of the rows are not different at the $P = 0.01$ significant level (Scheffe's F test).

Cross section	Station	Salinity (N=13) (psu)	Chl <i>a</i> (N=13) (μ g/l)	Water depth (N=13) (m)	D50 (mm)	Cu	Cc	Silt rate (%)	SFPOM (AFDW) (g/m ²)	BFPOM (AFDW) (g/m ²)
12km	St.1	2.07 $\pm$ 2.62 ^A	1.49 $\pm$ 2.31 ^B	1.56 $\pm$ 0.55 ^A	0.28	3.29	3.16	2.24	2.59	55.49
	St.2	1.65 $\pm$ 1.32 ^A	11.68 $\pm$ 11.60 ^B	1.23 $\pm$ 0.56 ^B	0.38	5.18	0.63	3.94	7.17	144.11
17km	St.3	0.29 $\pm$ 0.55 ^B	11.72 $\pm$ 7.28 ^B	1.57 $\pm$ 0.49 ^A	0.58	2.04	1.07	0.49	5.51	13.37
	St.4	-	-	-	0.54	2.1	0.94	0.02	1.15	0.63
	St.5	0.04 $\pm$ 0.05 ^B	1.13 $\pm$ 0.58 ^B	1.34 $\pm$ 0.49 ^B	0.58	2.02	1.06	0.02	0.71	0.44
20km	St.6	0.04 $\pm$ 0.01 ^B	34.25 $\pm$ 14.42 ^A	1.17 $\pm$ 0.50 ^C	0.18	2.93	0.8	6.55	2.14	64.5
	St.7	-	-	-	0.57	2.08	1.03	0.03	1.35	0.36
	St.8	0.02 $\pm$ 0.01 ^B	-	0.63 $\pm$ 0.41 ^D	0.21	2.54	1.27	1.29	73.91	86.18

SPSS 16.0 (SPSS. Inc.) was utilized for these all of statistical analysis.

3. RESULTS AND DISCUSSIONS

(1) Water environment conditions

The two-way ANOVA of salinity values performed a non-significant interaction effect ($P = 0.79$) between longitudinal and transverse directions. Salinity showed significant difference along the longitudinal direction ($P < 0.01$). Whereas, there were non-significant differences in the transverse direction ($P = 0.34$). Salinity in the cross section of 12 R km showed significantly higher values than those in 17 R km and 20 R km (Table 1, Scheffe's F test). However, salinity gradient along the longitudinal direction was not clear, such as the between the cross sections of 17 R km (0.29 ± 0.55 psu, 0.04 ± 0.05 psu) and 20 R km (0.04 ± 0.01 psu, 0.02 ± 0.01 psu). Although significant differences in salinity were not found along the transverse direction, salinity values were generally higher at stations located with groins (St. 1 and 3) and lower at stations located without groins (St. 2 and 5) (Table 1). Considering that salinity concentration was affected by relatively high tide in the study area. Especially in the area without groins, the water might be hardly exchanged with that in thalweg zone and the salinity concentration could be conserved near the bottom.

A two-way ANOVA of the Chl. *a* concentrations revealed significant interaction effect ($P < 0.01$). The effect of longitudinal direction was significant ($P < 0.01$), whereas the effect of transverse direction was not significant ($P = 0.14$). Comparison results of Chl. *a* concentration showed that the values in 12 R km and 17 R km were significant ($P = 1.00$, Scheffe's F test). Only the Chl. *a* concentration in St. 6 (at 20 R km) was significantly higher than the other transverse directions, which might correspond with the higher

silt rate deposition (Table 1). It might be suggested that the environment in upper locations with groins were hardly disturbed due to relatively weak tidal effects, which might promote the growth of primary production of phytoplankton.

Water depth was significantly affected by longitudinal and transverse direction ($P < 0.01$). Significant interaction effect was also revealed ($P < 0.01$). Along the longitudinal direction, the differences of water depth between 12Rkm and 17Rkm were not evident ($P = 0.24$) (Table 1). However, significant differences between the cross sections of 17 R km and 20 R km and between those of 12 R km and 20 R km were found (Table 1, Scheffe's F test). Water depth was shallower in each of the upper locations (at 20 R km) than those in the lower locations (at 17 R km and 20 R km). Along the transverse direction, the water depth was deeper in the area with groins (St. 1, 3 and 6) than without groins (St. 2, 5 and 8) ($P < 0.01$).

(2) Substrate and diet conditions for *Corbicula* bivalves

According to the two-way ANOVA of substrate environment variables (D50, Cu, Cc, silt rate) and diet conditions (BFPOM, SFPOM), they were not significantly affected by the effects of longitudinal and transverse directions (Table 1).

The scatter plot results using the scores of the first two principal components preserved 51.8 % (PC1) and 20.7 % (PC2) for the total variance. PC1 was heavily loaded for D₅₀ (-0.86), Cu (0.83), silt rate (0.83) and BFPOM (0.95). PC2 was loaded for SPOM (0.77). In Fig. 2, the environment variables of 17km cross-section (St. 3, 4 and 5) formed a relatively narrow area, indicated that substrate environment variables and diet conditions were more homogeneous than those in 12 R km and 20 R km cross sections. The environment variables in with groin area (St. 1, 3 and 6) built a relative compact

Fig. 2 Relationship between the first two principal component scores in the principle component analysis with substrate and diet variables.

Fig. 3 Density composition for *Corbicula japonica* (a), density *Corbicula leana* (b) in each of the stations.

cluster, while the environment variables in without groin area (St. 2, 5 and 8) were much more diverse. It was indicated that the differences of substrate and diet conditions among the stations with groins were smaller than those among the stations without groins. Tsubaki et al.¹³⁾ found that in the embayment area flood flow were reduced due to the erosion prevention effects of groins in their 2D flow simulations. We can infer that particular terrain and slowly water flow would promote the fine and single suspended particles to deposit in the stations with groins and form relatively homogeneous sediment conditions there. While in the area without groins, substrate and diet environment variables were greatly changeful due to tidal current motion with frequent water exchanges.

(3) The density and biomass of *Corbicula* bivalves

The biomass and density of these two bivalves in each of the stations was shown in Table 2. *Corbicula japonica* was collected from the stations of 12 R km and 17 R km sections. The two-way ANOVA results showed that the biomass and density of *Corbicula japonica* were significantly affected by longitudinal direction ($P < 0.01$) but not significantly affected by transverse direction ($P > 0.01$). Biomass and density showed significantly higher values in 12 R km

Table 2 Mean values of the biomass and density of two bivalves in all of the stations. The same letters in each of the rows are not different at the $P = 0.01$ significant level (Scheffe's F test).

Station	Biomass(g/m ²)		Density(ind./m ²)	
	<i>C. japonica</i>	<i>C. leana</i>	<i>C. japonica</i>	<i>C. leana</i>
St.1	8.35 ^A	8.75	555 ^A	178
St.2	7.85 ^A	3.21	778 ^A	422
St.3	0.19 ^B	3.06	22 ^B	622
St.4	0.19 ^B	0.97	156 ^B	200
St.5	0.28 ^B	1.58	111 ^B	133
St.6	0	0.385	0	133
St.7	0	0.335	0	267
St.8	0	1.64	0	156

section than in 17 R km section ($P < 0.01$, Sheffe's F test). *Corbicula leana* was found in all of the stations. The biomass and density of this species did not show significant differences neither along longitudinal nor transverse directions (two-way ANOVA, Table 2).

In the longitudinal direction, there was a landward reduction tendency of biomass and density for *Corbicula japonica*, which was positively affected by the mean of salinity (Table 2). In contrast, there were no significant differences in the biomass and density of the bivalve along transverse direction because the mean of salinity showed considerable values in the area with and without groins and the mean of water depth did not show obvious differences between the area with and without groins. *Corbicula leana* is known to be a kind of a freshwater bivalves and also more tolerant of water pollution than other mussels¹⁴⁾. We can infer that the mean of salinity could positively affect the biomass of *Corbicula leana* when it fluctuated during lower range (0.04-2.07psu).

(4) Density composition for *Corbicula* bivalves

The number of middle size and large size ($> 7\text{mm}$) of *Corbicula japonica* accounted for 72, 86, and 100 % in St. 1, 2 and 3 respectively, whereas, smaller

Table 3 Pearson correlation coefficients between biomass/density of *Corbicula* bivalves and environmental variables (* $P < 0.05$ and ** $P < 0.01$).

	Biomass (<i>C.j</i>)	Biomass (<i>C.l</i>)	Density (<i>C.j</i>)	Density (<i>C.l</i>)	Chl a (Mean)	Chl a (STDEV)	Salinity (Mean)	Salinity (STDEV)	Water depth (Mean)	Water depth (STDEV)	D50	Cu	Cc	Silt rate	SFPOM (AFDW)	BFPOM (AFDW)
Biomass (<i>C.j</i>)	1	0.756	.949*	-0.071	-0.022	0.311	.986*	0.877	-0.151	.985*	-.967**	0.852	0.505	.915*	0.445	0.831
Biomass (<i>C.l</i>)		1	0.646	0.107	-0.599	-0.485	.851*	.959**	0.532	0.539	-0.232	0.366	.877**	0.047	-0.099	0.247
Density (<i>C.j</i>)			1	0.163	-0.389	-0.01	.923**	0.785	0.313	0.792	-0.166	.868**	0.308	0.28	-0.224	0.639
Density (<i>C.l</i>)				1	-0.063	0.207	0.141	0.129	0.439	0.257	0.424	0.166	-0.234	-0.137	-0.182	0.079
Chl a (STDEV)					1	.890*	-0.425	-0.489	-0.619	-0.214	-0.585	0.08	-0.502	0.832	0.056	0.258
Salinity						1	-.960**	0.441	0.782	-0.127	0.71	0.589	0.143	-0.32	-0.32	0.463
Salinity (STDEV)							1	0.542	0.715	-0.093	0.493	0.767	0.025	-0.334	0.245	
Water depth								1	0.737	0.56	-0.009	0.34	-0.121	-0.677	-0.427	
Water depth (STDEV)									1	0.144	0.641	0.231	0.349	-0.809	0.24	
D50										1	-0.44	-0.274	-.753*	-0.486	-0.678	
Cu											1	0.008	0.616	-0.024	.901**	
Cc												1	-0.087	-0.004	-0.042	
Silt rate													1	-0.062	0.662	
SFPOM (AFDW)															1	0.376
BFPOM (AFDW)																1

individuals (< 7mm) occupied 86 and 60 % of the total number in St. 4 and 5 respectively (Fig. 3(a)).

The number of middle size of *Corbicula leana* (7-15 mm) took up 67 to 92 % in all stations, which controlled the density variability (Fig. 3(b)).

Yamazaki et al. suggested that the larvae of *Corbicula japonica* had the capacity to choose less silt rate area to settle down¹⁵⁾. In this study, the smaller size of *C. japonica* (under 7 mm) was abundant (>72% of total) in St. 4 and 5 where BFPOM (AFDW) was less (Table.1, Fig.3) which was corresponded with previous suggestions¹⁵⁾.

(5) Pearson correlation coefficients between biomass / density and environment variables

Pearson correlation analysis between each of the bivalves and environmental variables were calculated (Table 3). The biomass of both of two bivalves had a significantly positive correlation with the mean of salinity. In addition, the standard deviation of water depth (water depth (STDEV)) and silt rate were positively correlated with biomass of *C. japonica*. D50 was negatively correlated with the biomass of *C. japonica*. The standard deviation of salinity (salinity (STDEV)) and Cc were positively correlated with biomass of *C. leana*.

The density of *Corbicula japonica* was significantly positively correlated with the mean of salinity and Cu, which indicated that their higher densities occurred in higher salinity area and diverse sediment particle size area. However, there were not significant correlations between environmental variables and density of *Corbicula leana*.

SFPOM (AFDW) did not show significant correlation coefficients with biomass and density for these two bivalves (Table 3). The higher particulate organic matter did not correspond with higher biomass and density. SFPOM might not be controlling factors for the distribution of *Corbicula* bivalves. Kasai et al. pointed out terrestrial

particulate organic matter was the primary food source for *C. japonica*, based on stable isotope of carbon and nitrogen analysis¹⁶⁾. Our results could not be consist with the study that the SFPOM was an essential diet for these two bivalves. The organic matter derived from vegetation along the riparian or upstream (terrestrial organism) should be considered by taking into account of their findings¹⁶⁾.

(6) Multiple regression analyses

The results of derived formulae with the multiple regression analyses were showed in Table 4. The density of *Corbicula leana* could not be described by regression equation probably due to their random distribution.

Regarding the biomass of *Corbicula japonica*, the standardized coefficients of the mean of salinity and water depth showed 1.03 and -0.14 respectively. Salinity was the most significant environmental factor and showed a positive correlation with the biomass, whereas water depth showed negatively response to the biomass. In the estimated equation, there were no substrate environmental and diet variables that we selected to input the stepwise regression equation, which implied that water environmental factors were more important on affecting the biomass of *Corbicula japonica*.

The standardized coefficients of Cc and the mean of salinity for describing biomass of *Corbicula leana* showed 0.64 and 0.45 respectively, which indicated that they were positively correlated with the biomass of *Corbicula leana*, also, the impact of Cc on the biomass was more important than salinity. Therefore numerous *Corbicula leana* probably occurred in well-graded sediment area or lower reach of the estuary.

The standardized coefficients of the mean of salinity and Cu for describing density of *Corbicula japonica* showed 0.62 and 0.43 respectively, which indicated that they positively affected on *Corbicula*

Table 4 Equations and statistics of stepwise multiple regression between environment variables and biomass / density of bivalves.

	stepwise regression equation	R ²	F	P
Biomass (<i>C. japonica</i>)	$y = 4.196 + 4.632\text{salinity} - 3.383\text{water depth}$	0.99	176	0.06
Biomass (<i>C. leana</i>)	$y = -0.48 + 1.947\text{Cc} + 1.496\text{salinity}$	0.98	24.6	0.04
Density (<i>C. japonica</i>)	$y = -280.338 + 224.336\text{salinity} + 123.661\text{Cu}$	0.91	25.9	0.01

japonica density. Moreover the salinity was more efficient. Therefore, density of *C. japonica* probably observed in the lower reach accumulated diverse sediment grain. Additionally, there were significant correlation ($R^2 = 0.90$, $P < 0.01$, Table 3) between Cu and BFPOM. These results demonstrated that BFPOM might be a positive environmental variable in affecting density of *Corbicula japonica*. Although the previous studies suggested that the AFDW of substrate component negatively controlled *C. japonica* distribution¹⁴⁾, the present research could not support this relation because our data of BFPOM (AFDW) ranged from 0.44 to 144.11 g/m² might not be considered as a critical substrate condition in impacting their distributions.

5. CONCLUSION

This research conducted to clarify the influence of diet and environment variables on biomass and density of *Corbicula* bivalves in the Kiso River (12 – 20 R km) with a series of groins. It could be clarified that there were not significant differences among the various landscapes, by comparing in sub tidal zones.

According to some statistical analyses, we discussed the importance of each environmental factor on habitat of *Corbicula* bivalves as follows:

- 1) Along the transverse direction, there were no significant differences both in biomass and in density of *Corbicula japonica* between the area with and without groins in sub tidal zones.
- 2) The biomass and density of *Corbicula japonica* could be positively affected by salinities. Furthermore, water depth has a negative effect on their biomass, whereas diverse distributions of substrate has a positive effect on their density.
- 3) The biomass of *Corbicula leana* might not dependent on the transverse and longitudinal directions (in the salinity range, 0.04 -2.07 psu). Cc plays the most important role in supporting higher biomass of *C. leana*.

REFERENCES

- 1) Yamamuro, M., Nakamura, M., and Nishimura, M.: A method for

detecting and identifying the lethal environmental factor on a dominant macrobenthos and its application to Lake Shinji, Japan. *Marine Biology* 107: 479-483, 1990.

- 2) McLusky, D.S. and Elliott, M.: *The estuarine ecosystem*. Oxford University, 2004.
- 3) Otani, S. and Kozuki, Y.: Relationship between Macrobenthos and Physical Habitat Characteristic in Tidal Flats at Two River Mouths in Shikoku Island. *Advances in River Engineering* 13: 195-205, 2007.
- 4) Mannino, A. and Montagna, P.A.: Small-Scale Spatial Variation of Macrobenthic Community Structure. *Estuaries* 20(1): 159-173, 1997.
- 5) Chester, A.J., Ferguson, R.L. and Thayer, G.W.: Environment Gradients and Benthic Macroinvertebrate Distributions in a Shallow North Carolina Estuary. *Bulletin of Marine Science* 33(2): 282-295, 1983.
- 6) Matsumasa, M.: The relationship between water environment especially salinity variation and distribution of benthos in Kitakami estuary, Study on Water Environment of Estuary. *River Environmental Management Foundation*, pp.87-101, 2000. (in Japanese)
- 7) Nakamura, M., Yamamuro, M., Ishikawa, M. and Nishimura, H.: Role of the bivalve *Corbicula japonica* in the nitrogen cycle in a mesohaline lagoon, *Marine Biology* 99: 369-374, 1998.
- 8) Yamamuro, M. and Koike, I.: Nitrogen metabolism of the filter feeding bivalve *Corbicula japonica* and its significance in primary production of a brackish lake in Japan, *Limnol. Oceanogr.* 38: 997-1007, 1993.
- 9) Furuhashi, H., Ohno, Y., Tashiro, T., Tsubaki, R. and Tsujimoto, T.: Estimation of ecosystem services by brackish bivalve in the Kiso River tidal reach. *Advances in River Engineering* 14: 479-484, 2008 (in Japanese).
- 10) Mizuno, T. and Sekiguchi, H.: Catch fluctuation of brackish water clam *Corbicula japonica* in Kiso estuary, Japan. *NIPPON SUISAN GAKKAISHI*, The Japanese society fisheries science 72(2): 153-159, 2006.
- 11) Tashiro, T., Furuhashi, H., and Tsujimoto, T.: Benthic animal community in a tidal embayment of the Kiso River, Japan. *Limnology in Tokai Region of Japan*, 43: 61-69, 2010. (in Japanese)
- 12) Furuhashi, H., Kohno, S., Tashiro, T., Tsujimoto, T.: Habitat characteristic of *Corbicula japonica* in sand bar of the Kiso river tidal reach, *Advances in River Engineering* 14: 479-484, 2008. (in Japanese)
- 13) Tsubaki, R., Furuhashi, H. and Tsujimoto, T.: Flow structure on groins during flood event and morphological evolution of topography. *Annual Journal of Hydraulic Engineering, JSCE*. 52: 691-696, 2008. (in Japanese)
- 14) Hwang, S.J., Kim, H.S., Shin, J.K., Oh, J.M. and Kong, D.S.: Grazing effects of a freshwater bivalve (*Corbicula leana* Prime) and large zooplankton on phytoplankton communities in two Korean lakes, *Hydrobiologia* 515: 161-179, 2004.
- 15) Yamazaki, Y., Suno, N., Nemoto, T.: Relationship between distribution of the brackish-water Bivalve, *Corbicula japonica* and sediment environments in Lake Hinuma, *Report of Freshwater Fisheries Experiment Station Ibaraki Prefecture* 41: 25-31, 2008. (in Japanese)
- 16) Kasai, A., Toyohara, H., Nakata, A., Miura, T. and Azuma, N.: Food sources for the bivalve *Corbicula japonica* in the foremost fishing lakes estimated from stable isotope analysis, *Fishery science* 72: 105-114, 2006.

(Received September 30, 2014)