INTERNATIONAL SYMPOSIUM ON
DAMS FOR A CHANGING WORLD
-Need for Knowledge Transfer across the Generations & the World
Kyoto, Japan June 5, 2012

Improvement of the Habitat of Sweet Fish by Using Silica-supplemented Concrete in River Structures

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ABSTRACT:
Recently, conservation of river environment becomes more important issue. In the case of fluvial plants and animals, fishes occupy an important role in terms of the food chain and the fishery resources. We should consider designing environment-friendly structures when we construct river structures. The purpose of my work was to improve the habitat of sweet fish *(Plecoglossus altivelis altivelis)* by using silica-supplemented concrete. The purpose of this paper is to report on my work.
We investigated algae and sweet fish in Ohi River. We found that sweet fishes tend to graze on diatom selectively. Previous studies show that silica is important material to grow diatom. Therefore, we focused to grow diatoms by using silica-supplemented concrete. To verify whether the method was effective, experiment of algal growth was performed. We found that diatom content growing on silica-supplemented mortar blocks increased in comparison with a non-silica-supplemented block. In addition, quantity of silicate elution from silica-supplemented blocks that were added fry ash or artificial zeolite was larger than the one without silica-additives did. Effect of silicate elution of these silica-supplemented blocks lasted longer. We conclude that applying silica-supplemented concrete in river structures can increase diatom and improve the habitat of sweet fishes.

Keywords: Algae, Diatom, Silica, Sweet fish, Fishery resources

1. INTRODUCTION

Recently, conservation of river environment becomes more important issue. In the case of fluvial plants and animals, fishes occupy an important role in terms of the food chain in the ecosystem as well as in terms of the fishery resources. We should design environment-friendly facilities for the fishes, when we construct river structure for irrigation and river control and so on. Some herbivorous fishes graze on algae attached to the river bed, and these algae comprise their staple food. The previous studies on algal breeding carried out. However, many of these had focused on the process of exfoliation and regrowth of attached algae caused by changes in river flow that were in turn due to flood or discharge water from the dam. There were few studies that focused on methods to increase algae.

The purpose of my work was to increase diatom which is a kind of algae by using silica-supplemented concrete aiming at improving of the habitat of sweet fish.

Fish that was being studied was a sweet fish *(Plecoglossus altivelis altivelis)*, which is a kind of herbivorous and migratory fish (Fig. 1). Sweet fish is distributed in East Asia and is called “Ayu” in Japan. The body length of a grown sweet fish is usually 20～30cm. Sweet fish was chosen because it is one of important fishery resources with respect to aquiculture and recreational fishing as well as popular fish in Japan. Experiments were mainly performed at Ohi River basin. Ohi River is located in the centre of Japan and 168km long. It flows into the Pacific Ocean.

Fig. 1 Sweet Fishes

First, we investigated the state of gregariousness of algae and the ecology of sweet fishes in Ohi River. We found that sweet fishes tend to graze on diatoms, regardless of occurrence ratio by types of algae in river and growth of it related amount of algae in the river. Hashino reports that silica is indispensable substance for increasing of diatoms. Therefore, we focused to grow diatoms by using silica-supplemented concrete.

Second, to verify whether the method using silica-supplemented concrete was effective, an experiment of algal growth was performed with silica-supplemented mortar blocks. As a result, we found that diatoms content growing on silica-supplemented mortar blocks increased by 57%~74% in comparison with the block without silica-additives did. In addition, we measured the silicate elution into water from silica-supplemented mortar blocks. We found that quantity of silicate elution from silica-supplemented mortar blocks that were added fry ash or artificial zeolite was larger. Effect of silicate elution from these mortar blocks lasted longer than non-silica-supplemented one.

We conclude that applying silica-supplemented concrete in river structures can increase diatom and improve the habitat of sweet fish.

In the following, "Investigation of algae and sweet fish in Ohi river" is described in Chapter 2; "Experiments of diatom growth and silicate elution" is described in Chapter 3; "Conclusion" is described in Chapter 4;

2. INVESTIGATION OF ALGAE AND SWEET FISHES IN OHI RIVER

We investigated the ecology algae and sweet fishes to understand the state of gregariousness of algae and the habitat of sweet fishes. We also investigated the tendency to feeding of sweet fishes. It was performed in Ohi river. Four sites were selected. Koyama (KO) and Tashiro (TAS) are the middle stream of the river. Kunowaki (KU) and Tanbara (TAN) are the down stream of the river.

2.1. Method of Water Analysis

Several water qualities were measured as Table 1. Analyses were performed by following methods of Japanese Industrial Standards (JIS).

Table 1. Item for Water Analysis

Item	Method of analysis
Water temperature	JIS*K 0102
pH	JIS* K 0102 12.1
Dissolved Silicate (DSi)	JIS* K 0101 32.1
Dissolved Oxygen (DO)	JIS* K 0102 44.1
Biochemical Oxygen Demand (BOD)	JIS* K 0102 21

*JIS: Japanese Industrial Standards

2.2. Method of Analysis of Attached Algae

Method of analysis of attached algae was referred to the previous study by Kawanabe. Attached algae were collected from the riverbed of all sites. One sample was collected in the range 25cm×25cm ($125cm^2$). Analysis items are as Table 2. Identifications of algae were performed by using a microscope. Samples were classified into algae and sand, detritus (It is organic particle consisting dead bodies and excreta of living things, etc.) by occurrence area ratio. Furthermore, algae were classified into diatoms and blue-green algae, green algae.

Table 2. Items for Algal Analysis

Item	Index
Identifications of algae	-
Chlorophyll a	Quantity of plant plankton
Pheophytin	Quantity of dead plant cell
Ignition loss	Quantity of organic compound

2.3. Analysis of the Stomach Contents of Sweet Fish

For this analysis, we captured five sweet fishes at each sites as sample. Samples were measured the body length and weigh. Stomach contents of sweet fishes were extracted and classified into algae and sand, detritus by occurrence area ratio. Stomach Fullness Index (SFI) was also culculated. This index culculate as Eq. 1.

$$SFI = \frac{W_{sc}}{W_{fi}} \times 1000(‰) \quad (1)$$

W_{sc}: *Weight of stomach contents*
W_{fi} : *Weight of fish*

2.4. Results and Discussions of the Investigation

Results of water analysis are shown in Table 3. "Environmental standards" in Table 3 are water quality standards that are regulated by Ministry of the Environment. This standard is classified into 6 grades (AA, A, B, C, D, E). AA grade is the best water quality and E grade is worst. Koyama and Tashiro, Kunowaki were classified AA grade. Tanbara was classified A grade. Water temperature of Kunowaki was the higher than that of Tanbara in downstream. That is because water temperature of Kunowaki is increased by Shiogo reservoir that is located closely upstream of Kunowaki and is decreased by inflow of the branch located downstream of Kunowaki. DO was high rate at all sites. It was considered photosynthesis occurred actively. BOD was very low rate. It was assumed water contamination by organic matter was extremely little.

DSi in Ohi River was from 8.0 to 9.9 ($mgSiO_2/l$). It was much lower than average rate in Japan. Kobayashi reports average DSi value of Japanese river is 19.0 ($mgSiO_2/l$). As mentioned earlier, silica relates the growth of diatoms. We assumed that quantity of diatom in Ohi River was fewer than other rivers in Japan.

Table 3. Results of Water Analysis

Item	Unit	Site				Environment Standards (AA grade)
		KO	TAS	KU	TAN	
Water temperature	℃	21.3	22.2	26.2	23.6	-
pH	-	8.5	7.8	8.4	8.2	6.5-8.5
DO	mg/l	8.5	8.8	8.7	8.8	7.5 and up
BOD	mg/l	<0.5	0.6	0.5	0.5	1.0 or less
DSi	$mgSiO_2/l$	8.0	8.3	9.1	9.9	-

The results of identification of attached algae are shown in Fig. 2. Blue-green algae were seen at all site and high occurrence area ratio except at Tashiro. Green algae were seen at Tashiro and Tanbara. Only Tashiro shows high occurrence area ratio of diatom. Other sites were fewer than 2%. Ratio of detritus was high in Koyama.

Fig. 3 shows the result of measurement of chlorophyll a and pheophytin. Fig. 4 shows attached substance and ignition loss. Quantity of chlorophyll a was the highest in Tashiro and the lowest in Koyama. Results of attached substance and ignition loss were showed a tendency same as result of Fig. 3. From these result, the state of gregariousness of algae was different according to sites even in same river.

Result of measurements of body length and stomach fullness index are shown in Fig. 5. Samples that were collected at Tashiro were the largest size and the highest SFI of all sites. On the other hand, samples at Koyama were the smallest size and the lowest SFI. It considered that SFI was related to the growth of sweet fishes.

Result of identification of stomach contents of sweet fishes in Fig. 6. Sweet fishes graze diatoms and blue-green algae, green algae. These also graze detritus. Although ratio of diatoms in the river was very low, ratio of diatoms in the stomach contents was relatively high. We found that sweet fishes tend to graze on diatoms selectively, regardless of occurrence ratio by types of algae in the river.

From those described above, we can understand that the growth of sweet fishes related amount of algae. We also understand that sweet fishes tend to eat diatoms selectively. As mentioned earlier, silica relates the growth of diatoms. Therefore, aiming at improving of the habitat of sweet fishes, we proposed a new method for increasing diatoms by using silica-supplemented concrete.

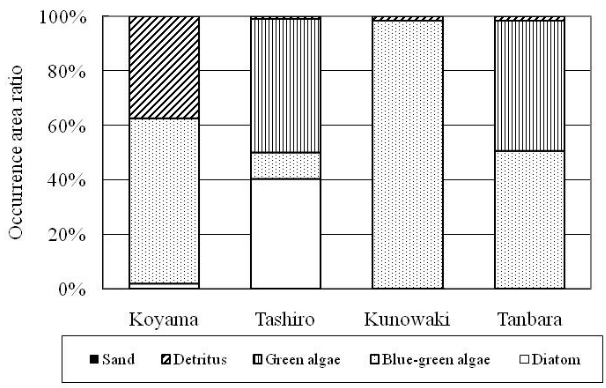


Fig. 2 Comparison of Occurrence Area Ratio

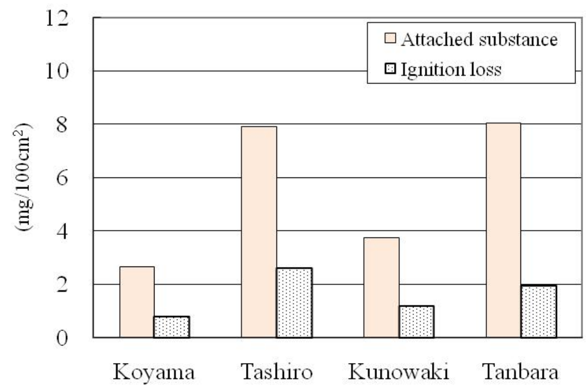


Fig. 4 Comparisons of Attached Substance and Ignition Loss

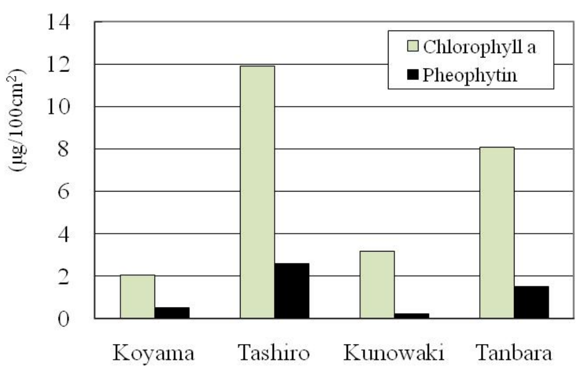


Fig. 3 Comparisons of Chlorophyll a and Pheophytin

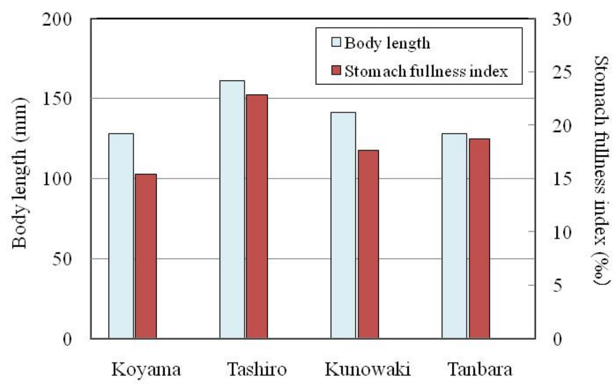


Fig. 5 Comparisons of Stomach Fullness Index and Body Length

Table 4. Mortar Mixture Proportions

Types	W/C	Unit content (kg/m^3)						SiO_2 (kg/m^3)
		Water	Cement	Artificial zeolite	Fry ash	Fine aggregate		
						Sand	Silicate sand	
Standard (ST)	0.500	361	722	0	0	1083	0	838
Silicate sand (SS)		361	722	0	0	422	661	1036
Artificial zeolite (AZ)	0.650	269	414	149	0	1392	0	1039
Fry ash (FA)	0.705	292	414	0	114	1392	0	1039

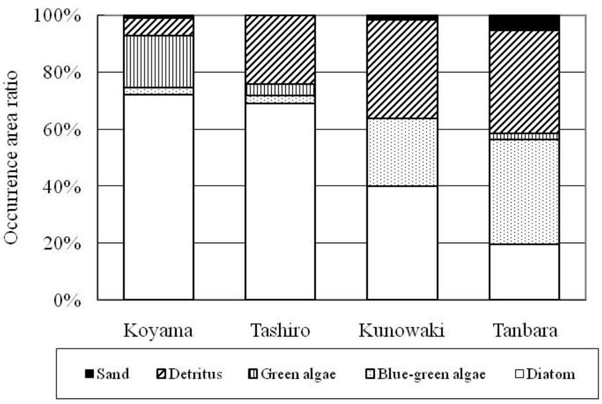


Fig. 6 Comparison of Occurrence Area Ratio of Stomach Contents

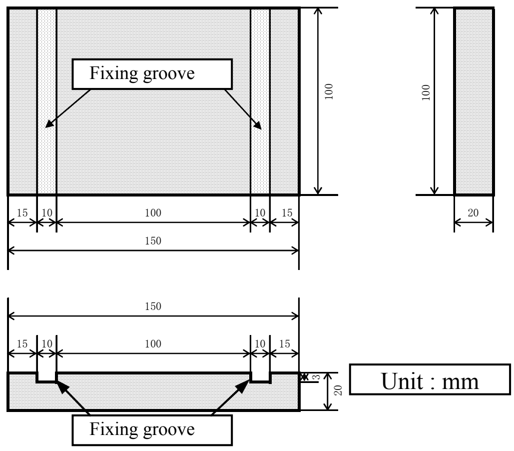


Fig. 7 Size of Algal Growing Block

3. EXPERIMENTS OF ALGAL GROWTH AND SILICATE ELUTION

As we verify the effectiveness of the silica-supplemented concrete, we performed two experiments. These were experiments of algal growth and silicate elution.

3.1. Method of Experiment of Algal Growth

Experiment of algal growth was performed 3steps as shown below.

1. Production of algal growing blocks.
2. Installation of the blocks in the river for two weeks.
3. Analysis of attached algae.

Algal growing blocks were produced with mortar (Fig. 7). We selected Silicate sand (SS) and Artificial zeolite (AZ), Fry ash (FA) as silica-additive material. We also prepared standard proportion mortar (ST) for control test. Silica-supplemented mortars were controlled to be equal SiO_2 content. SiO_2 content was determined to secure minimum strength and performance of fresh concrete. Mortar mixture proportions are shown in Table 4. Blocks were installed in cage to prevent fish from grazing algae. Blocks and cage are shown in Fig. 8.

Experiment was performed at Osawa site where was about 3km upstream from Koyama. Blocks were laid underwater for two weeks. After that, attached algae were collected and analysed by following method of Chapter 2.2.

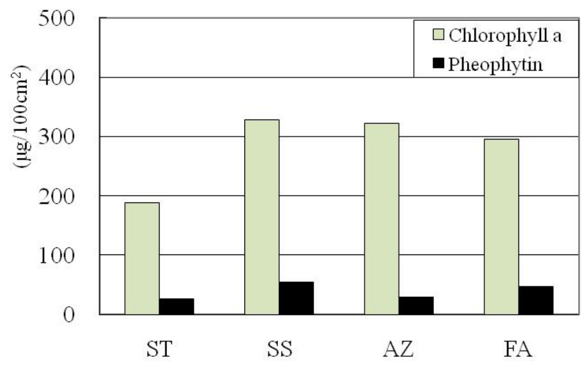
Fig. 8 Algal Growing Blocks and Cage for Experiment of Diatom Growth

3.2. Method of Experiment of Silicate Elution

Experiment of silicate elution was performed in order to confirm the content of silicate elution into water from silica-supplemented concrete. We experimented 4 mixture mortar blocks that shown as Table 4. Experiment was performed following methods of elution test of the notification No.46 of Ministry of the Environment. Mortar blocks were separately soaked in pure water (silica-free) for each periods of time. Ratio of sample to pure water is 1 [g] to 10 [ml]. After that, DSi of the water measured. The measurement was carried out 1day and 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6 months later. Pure water was changed after every measurement.

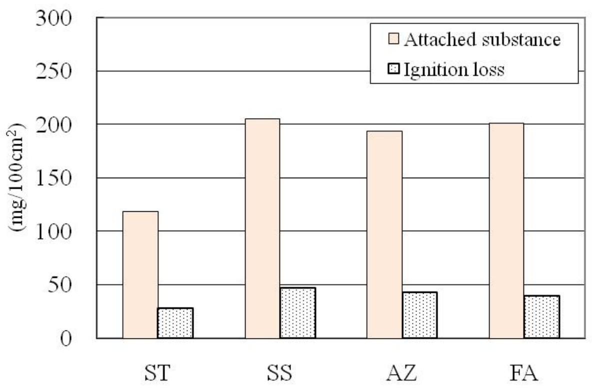
3.3. Results and Discussions of Experiments of Algal Growth and Silicate Elution

As the result of identifications of attached algae, we confirmed almost no algae except diatoms in all blocks. That is because that diatom is dominant species at early stage in vegetation succession of algae. Results of measurement of chlorophyll a and pheophytin are shown in Fig. 9. Results of measurement of attached substance and ignition loss are shown in Fig. 10. Chlorophyll a contents growing on silica-supplemented mortars (SS, AZ, FA) were larger than Standard mortar (ST). The difference between silica-supplemented mortars was small. It was found that diatom content growing on silica-supplemented blocks increased by 57%~74% (determined by measuring chlorophyll a content) in comparison with the block without silica-additives did.



Item	Unit	ST	SS	AZ	FA
Chlorophyll a	μg/100cm^2	188.5	327.5	322.5	295.5
Pheophytin	μg/100cm^2	26.6	54.2	28.7	46.6

Fig. 9 Comparisons of Chlorophyll a and Pheophytin of Experiment of Algal Growth



Item	Unit	ST	SS	AZ	FA
Attached substance	mg/100cm^2	118.7	205.0	194.0	201.0
Ignition loss	mg/100cm^2	24.5	24.8	22.9	21.0

Fig. 10 Comparisons of Attached Substance and Ignition Loss of Experiment of Diatom Growth

Result of experiment of silicate elution is shown in Fig. 11 and Fig. 12. Quantity of DSi of AZ and FA were larger than ST in most measuring periods. Quantity of DSi of ST decrease after three month, while quantity of DSi of AZ and FA kept constant value. SS was lower value during measuring period. It assumed silicate sand has more stable structure than other silica-supplemented material. But attaching diatoms content was same as others. This issue needs further study.

From those described above, quantity of silicate elution into water from silica-supplemented concrete that were added fry ash or artificial zeolite was larger quantity than the one without silica-additives did. Effect of silicate elution into water from these silica-supplemented concrete lasted longer than the one without silica-additives did.

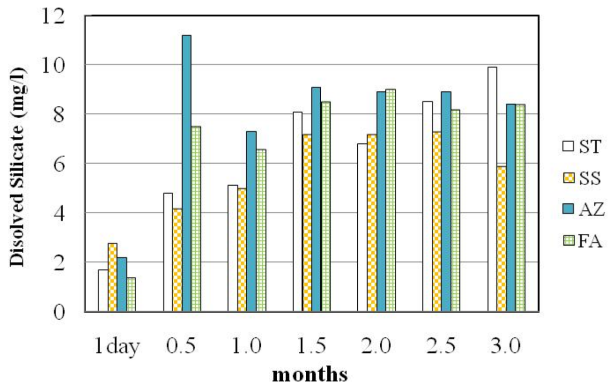


Fig. 11 Comparison of DSi of Experiment of Silicate Elution (0~3month)

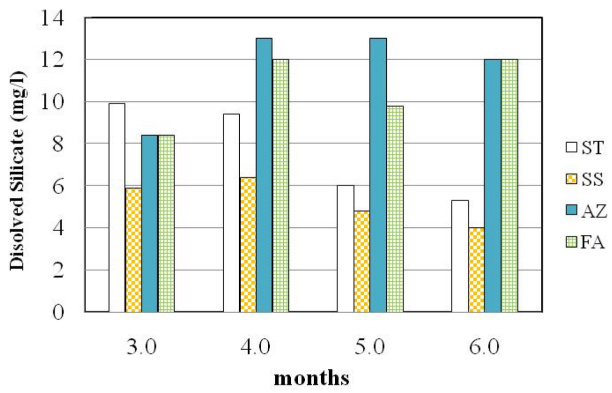


Fig. 12 Comparison of DSi of Experiment of Silicate Elution (3~6month)

4. CONCLUSION

We investigated algae and sweet fishes in Ohi River. We also experimented of algal growth and silicate elution to confirm the effectiveness of the method by using silica-supplemented concrete to glow diatoms.

In conclusion, we have obtained the following from investigations and experiments:

1) Water quality of Ohi River was very good. But dissolved silicate was half of the average in Japan.
2) Growth of sweet fishes related amount of algae in the river. Sweet fishes tend to graze on diatoms selectively, regardless of occurrence ratio by types of algae in river.
3) Attaching diatom content increased on using silica-supplemented mortar block more than the block without silica-additives did.
4) Quantity of silicate elution into water from silica-supplemented mortar that was added fry ash or artificial zeolite was larger than the one without silica-additives did. Effect of silicate elution from these silica-supplemented mortar blocks lasted longer than the one without silica-additives did.
5) Above that, we conclude that applying silica-supplemented concrete in river structures can increase diatoms and improve the habitat of sweet fishes.

We will perform further studies to investigate the effect of this method and to identify supplemental materials that can be more effectively and practically use. We will also contribute to constructing more environment-friendly river structures.

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