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Conservation Measure for an Endangered Fresh Water Goby, *Rhinogobius* sp. BB, in the Upper Stream of Taiho dam on Okinawa Island, Japan.

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ABSTRACT:
On Okinawa Island, the decrease of habitat area and increase of interspecific competition by newly land-locked species, which are originally amphidromous, are major issues for an endangered freshwater goby, "Aobara-yoshinobori" *Rhinogobius* sp. BB. The goby is endemic to northern Okinawa Island. It has intermediate egg size and has direct development from eggs. It is, therefore, considered as important from the perspective of biology and genetics. Taiho dam is located on Taiho River which is one of the main habitats of *R.* sp. BB. Originally, *R.* sp. BB and *R.* sp. DA have inhabited the river and *R.* sp. BB dominated before building the dam. By this monitoring research, most pools on the upper streams of the dam site were observed and the number of Rhinogobius was counted, and this research revealed that no *R.* sp. BB larvae existed in sections where juveniles of *R.* sp. DA were abundant. This result suggested that excess numbers of *R.* sp. DA should affect the reproductive environment of *R.* sp. BB. To inhibit *R.* sp. DA migration, we designed conservation measures, which can block water flows on any wall surfaces as it can crawl on even vertical walls if the walls are slightly wet.

Key Word: fresh water environment, environmental conservations, genus Rhinogobius

1. GENERAL INSTRUCTIONS

In Japan, almost all rivers have artificially transected structure as disaster prevention and/or irrigation facilities, and these structures inhibit the migration of aquatic animals (Morita & Yamamoto, 2004). Especially, the population of amphidromous fish, which spend their juvenile periods in the sea and migrate to fresh water to breed (i.e. salmons, fresh water gobies, fresh water shrimps and so on), would be destructively affected by dam constructions (Morita & Yamamoto, 2004; Shokita, 1990). For example, in the upstream of Hun dam in North Okinawa Island, there has been a marked decrease of *Eriocheir japonica* and Caridea due to the less accessibility to upstream after the dam construction (Shokita, 1990). To mitigate such segmentation of habitat, various fish ways has being devised and studied (Onitsuka, Akiyama & Yamaguchi, 2003). Although some species are decreasing due to dam constructions, the others are extending their habitats. The hatchling larvae of *Rhinogobius* spp., amphidromous gobies, should soon go down the river to the sea due to lack of planktons as food in flowing water. However if a water reservoir was formed, they would be able to use it as their habitats that they spend their larval period and would be land locked accordingly (Igushi&Mizuno 1999). Kochi & Oshiro(1987) reported that *Rhinogobius giurinus*, which originally inhabits from tidal reaches to middle reaches, has been land rocked in a dam and distribute to other dams through regulating waterway tunnels in Okinawa Island. As the result, the land locked *R. giurinus* has extended their distribution to the upper reaches based on water reservoir, and has threatened aboriginal species.

There are at least 12 *Rhinogobius* species. distributing in Japan, and 6 species of that are inhabit in Okinawa Island. *Rhinogobius* sp. BB is endemic to North Okinawa Island. It has intermediate egg size between other land-locked species (e.g. *Rhinogobius flumineus*) and amphidromous spices. The fish has direct development from eggs (Tachihara, 2009). It is, therefore, considered to be important from the perspective of biology and genetics. Its major habitat were Taiho River, Genka River and Hanechi River, however, the population of *R.* sp. had been decreased after Hanechi dam was filled in 2003 and

R. sp. BB has not been observed after 2008. *R.* sp. BB has fatally decreased, but on the other hand, *R.* sp DA has increased rapidly. Therefore, it might be considered that the land locked *R.* sp DA exacerbate interspecific competition between *R.* sp BB and *R.* sp DA, and as the result of that, the habitat became unsuitable environment for *R.* sp BB (Shimodi, 2010). *R.* sp DA widely distributes in Japan, and it is one of *Rhinogobius* spp. that migrates the most upper reaches in Okinawa Island though it is amphidromous fish due to its strong swimming ability.

In Taiho river, the study site, 2 *Rhinogobius* species, *R.* sp BB and *R.* sp DA, originally distributed from middle reaches to upper reaches (Kouchi, 1995)(fig. 1). *R.* sp BB dominated 93% of *Rhinogobius* species in pools and 41~53% in rapid, and the two species showed clear habitat segregation. In this study, 1) the distribution of *R.* sp DA and the breeding condition of *R.* sp BB was observed after Taiho dam was filled with water, and 2) a conservation measure to reduce the affect of *R.* sp DA was reported.

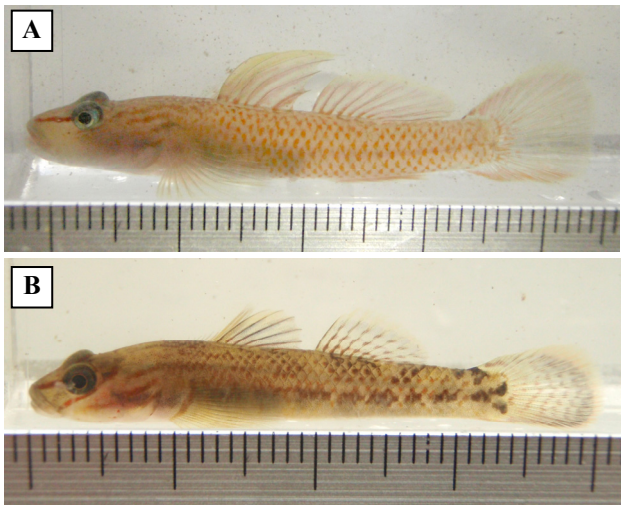

Figure 1. The difference of body colour between (A) *Rhinogobius* sp. BB and (B) *Rhinogobius* sp. DA

2. MATERIAL AND METHODS

2.1. Site Location

Taiho River is located in North Okinawa Island, Japan (fig. 2), and Taiho dam construction was started in March, 2006. It began to be filled with water in April, 2006. it began to be used in March, 2011. Taiho dam is located in 5km upper from a mouse of the river; therefore the downstream of the dam is a tidal reach in general. The length of upper stream from storage is about 4km, and there are some sub streams. The upper streams are generally covered by subtropical rain forest. The vertical interval of storage to the headwaters is about 100m. According to Kouchi (1995), *R.* sp. BB was the dominant species in the region from the dam site to headwaters before the dam construction.

Table 1. Transportation list of Taiho dam

Start of Work:	1990
Completion of Work:	2011
Location:	N26°39"12, E128°08"46
Type:	Gravity dams
Height :	77.5m
Crest Length:	363m
Volume:	400,000m3
Drainage Area:	13.3km2
Submerged Area:	0.89km2
Purpose of Use:	Flood Control
	Maintenance of Normal Function of the River Water
	Specific Irrigation Water
	Water Supply

2.2. Point Survey

The point survey was conducted from 14th to 29th June 2010 and from 22nd to 27th November, 2010. Eight points (St.1-8) were selected as survey point on the upper streams of Taiho dam. To examine the composition of body length of *R.* sp. BB and *R.* sp. DA, the two species were caught using a triangular dip net. The sampling was conducted using visual observation in pools, and the kick and the sweep method in riffles. The period of each sampling was 15 minutes. The fish were quickly released after measuring their body length and taking photo of an individual having a typical body colour.

2.3. Route Survey

The Route surveys were conducted from 14th to 29th June 2010. To examine the distribution of *R.* sp. DD and the breeding condition of *R.* sp. BB, the number of *R.*

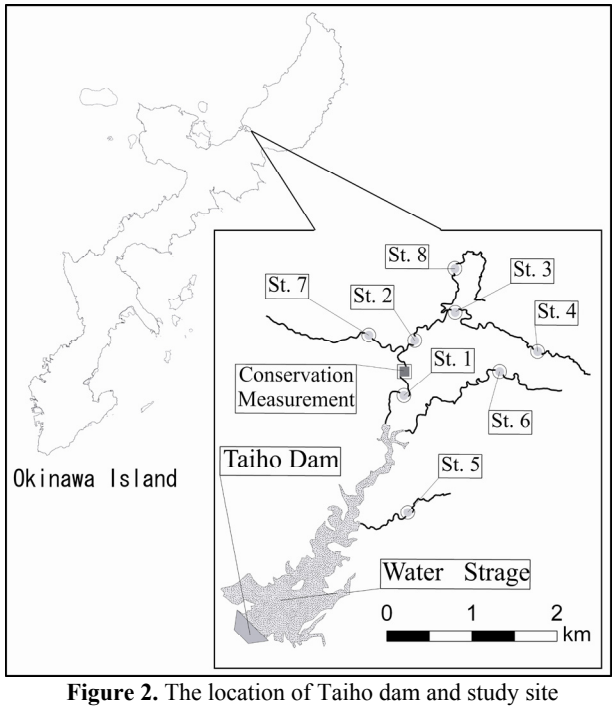

Figure 2. The location of Taiho dam and study site

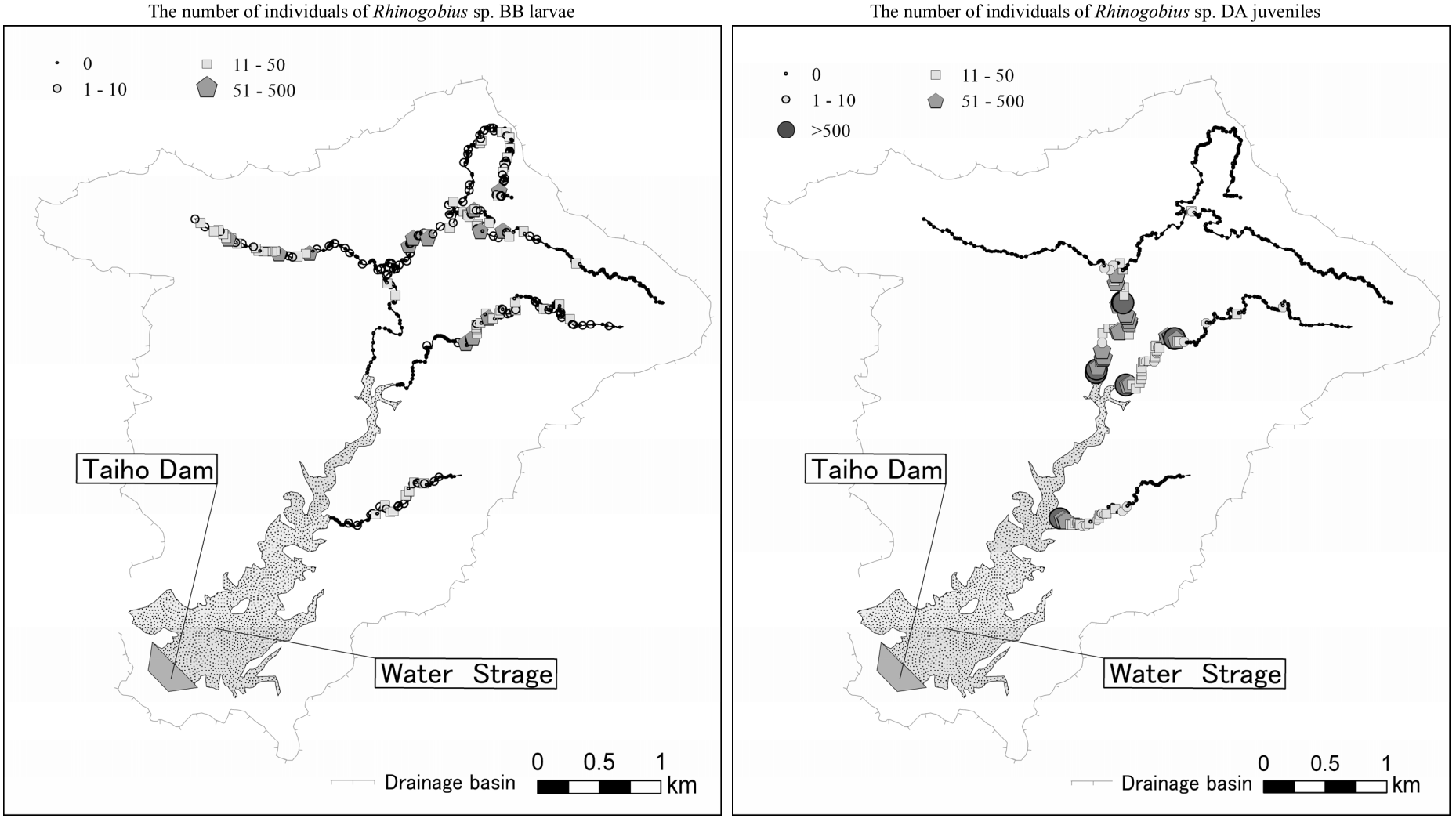

Figure 3. The distribution of larvae of *Rinogobius* sp. BB and juveniles of *Rinogobius* sp. DA.
Each legend indicates the number of individuals. R. sp. BB larvae are limited in upper stream and R. sp.DA juveniles dominated lower stream. Remind that the R. sp.DA juveniles migrate to upper streams nevertheless R. sp. BB larvae never down the streams.

sp. BB larvae and *R*. sp. DA juveniles were counted in every pool in the upstream of Taiho dam. All individuals of the larvae and juveniles in each pool were counted by visual observation. However, when the number of individuals was too large or the objective pool was too deep to swim in, an approximate number was recorded. The location of observed pools were recoded using GPS (GPS map 60CSx produced by Garmin Corporation)

2.4. Conservation Measure

By a pilot study, it is confirmed that *R*. sp. BB is able to climb on the vertical walls with and crawl even if very small amount of water flow is available. Currently, several measures were experimentally constructed. By designing the measures, two issues were recognized. Firstly, *R*. sp. DA is one of the strongest migrants that able to crawl even on vertical walls when the walls are slightly wet. Secondly, only one steep path is available to reach the subject area, although it is unacceptable to deforest for making a new path. Therefore, its construction must be conducted without heavy equipments. For the above reasons, we designed conservation measures with following concepts; 1) blocking water flows on any wall surfaces, 2) providing overhangs, 3) reducing the size of measure so that the construction less likely affect surrounding environments.

3. RESULT

3.1. Point Survey

Table 2 shows the composition of body length of *Rhinogobius* sp. DA and *Rhinogobius* sp. BB in June. In June investigation, a number of *R*. sp DA juveniles, which are less than 20mm of its body length, were observed at St.1 and St.2 in the lower stream of the main river. Especially, it was markedly abundant at St.1, where 150 individuals were observed. *R*. sp BB dominated St.3, St.5 and St.6, although *R*. sp DA dominated at other station. Small Juveniles of *R*. sp BB, which are less than 19mm in their body length, were observed only at St.3 and St.5.
Table 3 shows the composition of body length of *Rhinogobius* sp. DA and *Rhinogobius* sp. BB in November. In November investigation, the total number of *Rhinogobius* on each station was decreased compare to that in June except St.5 and St.7. Compared to the result of June investigation, both *R*. sp. BB and *R*. sp. DA showed a trend that those relatively large individuals of them were decreased. Furthermore, the most abundant size of *R*. sp. DA were 20-29mm at all stations. The number of *R*. sp. DA was decreased at St.1, while the number of *R*. sp. BB was not changed. *R*. sp.BB dominated only St.3 and St.6 and *R*. sp. DA dominated other six stations. Among the other six stations where *R*. sp. DA were dominant species, *R*. sp. DA dominate more than 80% of total number of the fish, while there were slight differences between the number of the two species at St.4 and St.7.

3.2. Route Survey

Figure 3 shows the distribution of larvae of *R*. sp. BB and juveniles of *R*. sp. DA. The larvae of *R*. sp. BB were observed mainstream and other sub streams. In all streams, it was mainly found from the middle streams to the upper streams, and was hardly found in headwaters. There were no larvae in the back water. The migrating juveniles of *R*. sp. DA were found up to about 1500m upper stream of storage (about 1500m in main stream, 700m and 900m in left sub streams). In addition, we found them in the right sub stream which is about 2400m upper from the storage during an additional survey in August. This suggested that the migration of *R*. sp. DA had been continuing after June.

3.3. Conservative measurement

Although it will be mentioned later, the massive migration of *R*. sp. DA might threat the population of *R*. sp. BB, a conservative measurement came under forward and constructed to prevent the migration of *R*. sp. DA to upper streams. A natural water fall in main stream was chosen as a construction site. The fall was relatively close to storage and had an access path to transport building materials. It flows through a rectangular cut between the bed racks and has about 70cm drop. To build the measurement, we did not draw detail design as the measurement had to be adjusted to the shape of the natural fall. The concepts of the measurement are described below (fig 4). To prevent that discharged water drip along the reverse side of water canal, the water canal was slightly inclined. In rainy season, the water level under the measurement might increase; therefore the head of the fall was kept as much as possible so that the head would not be submerged. The accomplished measurement is shown in figure 5.

4. DISCUSSION

4.1. Point Survey

The result of point survey showed that *R*. sp. DA dominated the study site, except St.3 and St.6. According to Kouchi (1995), *R*. sp. BB had dominated in the middle stream and the upper stream in Taiho River before Taiho dam was built. Furthermore, a monitoring survey had been conducted in 2009using same methods of this study (unpublished data by North dam Office Cabinet Office Okinawa General Bureau), and the result showed that *R*. sp. BB dominated all study sites. This fact indicated that *R*. sp. BB has been decreasing nevertheless *R*. sp. DA has been increasing, and the dominant species changed from *R*. sp. BB into *R*. sp. DA. The breeding season of *R*. sp. DA is around May in main land of Japan (Tamada, 2005), and it might be earlier in Okinawa Island as the temperature is higher. Their larvae stay under the sea for

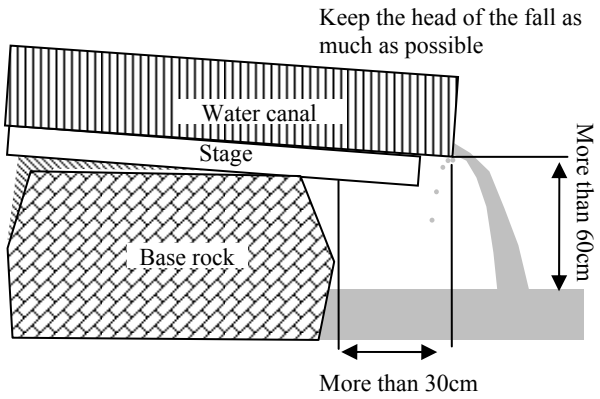

Figure 4. A conceptual design of conservation measurement

Figure 5 The accomplished conservation measurement. This measurement is a about 80cm waterfall with 30cm deep.

Table 2. The composition of body length of *Rhinogobius* sp. DA and *Rhinogobius* sp. BB in June.

Species Name	Body Length(mm)	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	Total
Rhinogobius sp. DA	0＜BL＜10									
	10≦BL＜20	24	1							25
	20≦BL＜30	133	15	2	10	4	5	3	4	176
	30≦BL＜40	4	10	2	8	7	4	5	5	45
	40≦BL＜50		2		5	1	2	9	7	26
	50≦BL＜60							4	2	6
	60≦BL＜70					1		1		2
	70≦BL＜80				1			1		2
Total number of *Rhinogobius* sp. DA		161	28	4	24	13	11	23	18	282
Rhinogobius sp. BB	0＜BL＜10			2		2				4
	10≦BL＜20			15		2				17
	20≦BL＜30	2	7	18	3	11	23		2	66
	30≦BL＜40	2	3	20	8	1	14	3	4	55
	40≦BL＜50	1		1	1		6	2	4	15
	50≦BL＜60								1	1
	60≦BL＜70								1	1
	70≦BL＜80									
Total number of *Rhinogobius* sp. BB		5	10	56	12	16	43	5	12	159

Table 3. The composition of body length of *Rhinogobius* sp. DA and *Rhinogobius* sp. BB in November.

Species Name	Body Length(mm)	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	Total
Rhinogobius sp. DA	0＜BL＜10									
	10≦BL＜20	1								1
	20≦BL＜30	39	12	7	7	17	2	8	9	101
	30≦BL＜40	11	9	7	5	4	2	6	7	51
	40≦BL＜50	4	5	2	3	2	1	2	1	20
	50≦BL＜60	1				1		1		3
	60≦BL＜70							1		1
Total number of *Rhinogobius* sp. DA		56	26	16	15	24	5	18	17	177
Rhinogobius sp. BB	0＜BL＜10									
	10≦BL＜20					1	6	1		8
	20≦BL＜30	1	2	6		10	7	9	4	39
	30≦BL＜40	5	3	17	12	3	6	4	7	57
	40≦BL＜50	1			1		1	2		5
	50≦BL＜60									
	60≦BL＜70									
Total number of *Rhinogobius* sp. BB		7	5	23	13	14	20	16	11	109

about 2 months and start migrating to the upper stream. The abundant juveniles of *R*. sp. DA after the peak of migration period might suggest that the migration to the upper stream had become easier.

It was revealed that yearling juveniles (less than 20mm in body length) have clearly decreased, although there were juveniles of *R*. sp. BB in the upper streams. The number of individuals of *Rhinogobius* has been decreased since June. This might suggest that the competition on food resources and available habit have been exacerbated due to increased population density by excess recruitment of *R*. sp. DA in June. Consequently, the population might have been exceeded the carrying capacity and the exceeded individuals had been reduced as the result of natural selections in November. At least in St.1, *Rhinogobius* population obviously had exceeded an appropriate density as the number of individuals had shown 30% decrease since June to November. The excess density would influence their breeding condition. In contrast, *R*. sp. BB might not be expected to increase their fertility has shown decrease of population, *R*. sp. DA is likely to abundantly migrate from the reservoir. Therefore, it is unpredictable that *R*. sp. BB is able to maintain its population or not.

4.2. Route Survey

A monitoring survey, which conducted using same methods of our study in 2009, showed that larvae of *R*. sp. BB were distributed through whole survey area (unpublished data by North dam Office Cabinet Office Okinawa General Bureau). However, they were not observed in the lower stream, which is less than 500m from the storage in our survey. In addition, *R*. sp. DA were abundant in the section which is less *R*. sp. BB larvae. This fact might suggest that the juveniles of *R*. sp. DA possibly feed the larvae.

4.3. Conclusion

Our survey revealed that 1) the decline of the population of *R*. sp. DA, and 2) the decrease of the distribution area of *R*. sp. BB larvae. This might be because the dam storage was used as an alternative breeding area for *R*. sp. DA and make easier to migrate to upper stream. As the result, *R*. sp. DA had increased migrating population to upper stream, and the population density has exceeded a carrying capacity. Furthermore, the excess density caused the lack of food resources and an increase of interspecific competition, and consequently the reproductive condition of *R*. sp. BB has been threatened. Similar examples of decreasing habitat and/or population by other competitive species have been reported (Kouchi, 1995; Ishida et al, 2006). Our survey might suggest that the migrating juvenile of *R*. sp. DA might possibly feed the larvae of *R*. sp. DA.

According to the survey on Hanechi dam (Simodi, 2010), small individuals including larvae were disappeared before population decline of *R*. sp. BB. Our result indicated that the breeding condition has become degenerate. Therefore, it might be assumed that the same situation in Hanechi dam would occur to population in Taiho River. These situations have been occurred by the increase of *R*. sp. DA as the result of facilitating migration of *R*. sp. DA to the upper stream. In that case, *R*. sp. DA continues to increase its migration, and it will be necessary to inhibit the migration soon.

In March 2011, a short observation was conducted. It was observed that the juveniles of *R*. sp. DA were not able to climb the measurement; therefore our conservative measurement is seemed to be effective. Studies on fish ways, which assist migration to upper stream, have been developed in Japan decades ago (Onitsuka, Akiyama & Yamaguchi, 2003), however there seems to be few studies on structures to inhibit migration. Land locked *R*hinogobius distribute not only Okinawa Island but also widely distribute in Japan. These fresh water gobies are also concerned to be affected by dam construction. (Ishida et al, 2006; Tachihara, 2009). Studies on such measurements for inhibiting migration to the upper stream are seemed to contribute to presserbed aquatic ecosystems in the upper stream from newly land locked species.

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