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MANAGEMENT OF THE RIVER ENVIRONMENT PRESERVATION AT HITOKURA DAM RESERVOIR

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ABSTRACT

Over 24 years has passed since Hitokura Dam started its operation in 1983.Thereafter the river environment in the downstream area have been substantially changed. The change can be broadly categorized into three processes; 1) the bedrock directly downstream of the dam was exposed and ayu (sweetfish) fish no longer inhabited in the river as of 2002, 2) a 5 km-long depleted section was created from directly downstream of the dam to the confluence with Ina River due to declining rainfall in recent years. Therefore, it was concerned that the change had adversely affected on the habitat in the downstream of the river and, 3) Exotic fish species had increased rapidly in comparison with native fish species inside the reservoir. It is considered that the dam has influenced the change of the river environment to some extent.
Since 2002, preservation of the upstream and downstream areas as well as reservoir as the entire river environment has been conducted at Hitokura Dam in collaboration with regional residents. This paper describes the process of preservation measures and its effects.

INTRODUCTION

In recent years, it is concerned about not only flood control and water supply but also harmony with the ecosystem around the dam for the dam. Under these situations, the Government has advanced legislation including the revision of the River Law (1997).

Hitokura Dam started its operation 24 years ago (1983). Since the operation started, Hitokura Dam has effectively controlled flood and supplied water as planned, but it has also been pointed out that the environment of its reservoir and the downstream river have been changed. Change of the river environment after dam construction, is classified into the following three items, and various environmental preservation measures have been implemented against these problems at Hitokura Dam since 2002.

(1) Before the dam was constructed, many people were visiting Ina River once as a river, which could do the angling by decoy of the sweetfish near a city. After the dam was constructed for the beginning several years, sweetfish were released and the angling decoy of sweetfish was made like before, but after a few years, the sweetfish disappeared even if they

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were released. And bedrock was exposed in the riverbed of directly downstream of the dam, because the dam had cut off supply of the sediment from upstream. At the same time, reduction and smoothing of the river water level caused transforming the river environment greatly, such as common reeds to flourish along the river banks and so on. (Photo 1).

Photo 1. View of the River Downstream from the Dam in 1982(just after the dam completion) (left), in 2002 (center) and in 2006 (right)

(2) In recent years, particularly since 2000, rainfall has declined and water shortage adjustment is performed for three consecutive years. Thus almost water discharged from the dam has been used to replenish the target flow at downstream reference points. And depleted section (section with extremely low flow) is sometimes happened for 5km from directly downstream of the dam to the confluence with Ina River.

(3)Species of exotic fish had increased rapidly in the reservoir recently and they had preyed on native fish species. It is also feared that abrupt draw down of the water level in the reservoir caused by shifting to the flood season limited water level might decrease suitable spawning areas for native fish species.

EFFORTS TO PRESERVE RESERVOIR AND RIVER ENVIRONMENT AT HITOKURA DAM

Improvement of the Downstream River Environment

Placing Boulders and Removing Common Reeds

Based on the results of a survey of habitat for river life carried out in 2001, boulders were placed in the river and the common reeds flourishing along the water's edge were removed in 2002. The exposure of bedrock and shortage of small stones on the riverbed in downstream of the dam eliminated places to hide from birds and other enemies for fish, so common reeds were removed and boulders were placed in order to artificially restore the ecotone between the land and water and to restore rapids. This measure was taken below the dam between the Hitokura Bridge and the Maekawa Bridge (Fig. 1). In this section, 190m^3 of boulders were placed in the river, and 2000 m^3 of common reeds were removed from the river bank (right bank).

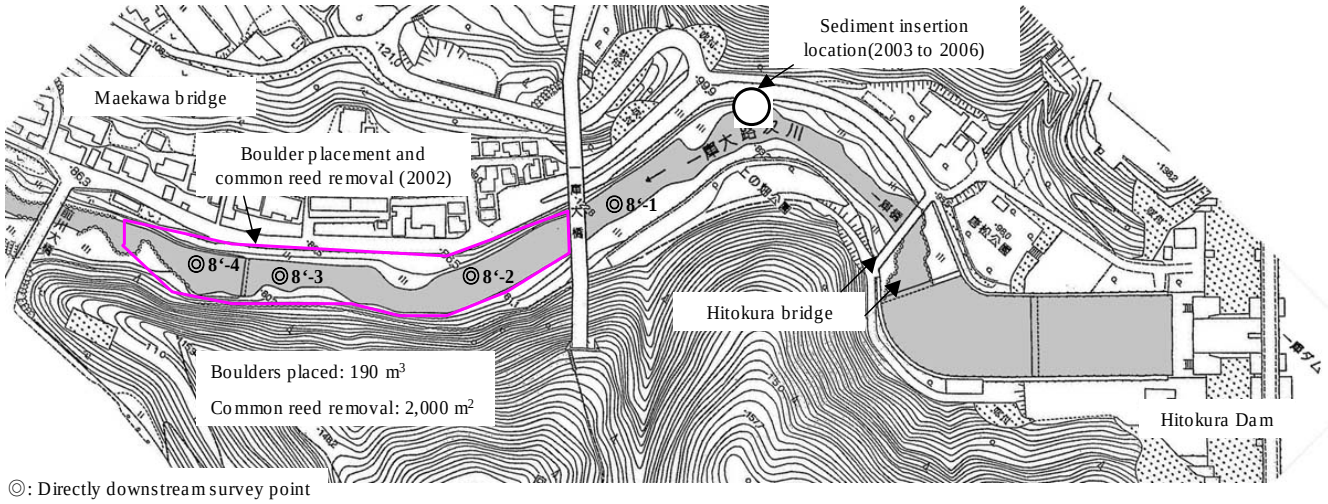


Fig. 1. Locations Map of Countermeasure Execution and Survey Points

Placing sediment and flashing discharge

The results of a river habitat environment survey performed in 2002 revealed the depletion of gravel and the decrease of the renewal of algae that is feed for river life in the directly downstream from the dam. So since 2003, under the guidance of Ikuko Morishita, director of the Institute of Freshwater Biology, river environment restoration measures using the tractive force of supply flashing discharge and supply sediment have been executed. Only supplying sediment was executed in 2004, while bed load sediment transport was limited to natural runoff. With the flashing discharge that was referred here means operating the dam to artificially increase discharge while maintaining operating principles in order to preserve the river environment downstream of the dam; not discharge during rainy weather and that done to supply water for human use.

Flashing discharge was done during a period when water level was lowered from the top water level (EL. 149.00m) to the flood season limited water level (EL. 135.30m) (Draw down period: April 1 to June 15). And to maintain safety, discharge was done during day for between 1.5 and 2.0 hours. The maximum quantity of flash discharge was set at $20m^3/s$ that can be handled only by valve operation without using the crest spillway gate. However, there was a problem: because of the structure of the discharge facilities, when the quantity of discharge exceeds $9m^3/s$, water is withdrawn in the lower layer of the reservoir where the water temperature is relatively low.

Therefore, flashing discharge in 2006 was performed by using the crest gate to discharge water from surface where water temperature is relatively high as the water level was higher than the level of the crest gate (emergency spillway), the effects of discharging cold water downstream were avoided. In 2007, the maximum discharge was limited to $11m^3/s$, to minimize the effect of cold water discharge.

In 2006 and 2007, sediment accumulated at an old weir at the upstream end of the dam reservoir was used in flashing discharge performed. It was found that at the old weir, deposition of sediment and flourishing growth of land vegetation had divided the river bank forests from the surface of water, and separated the habitat of insects used as feed by fish from the water's edge. So the common reeds etc. flourishing along the waterside and the land vegetation along the river were dug up and removed to improve river environment upstream

of the dam. This measure improved river environment, river bank forest, and waterside at the same time as the large diameter stones that appeared during the excavation were piled up directly downstream of the left bank of the weir in order to secure a route for the movement of fish and benthos upstream of the weir (Photo 2).

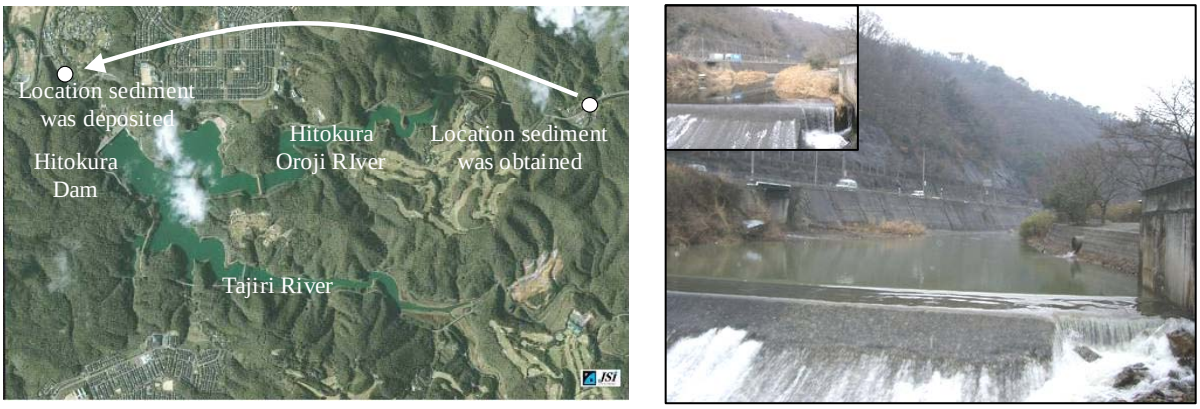


Photo 2. Excavation and Removal of Sediment at the Old Weir at the Upstream End of the Reservoir (Hitokura Oroji River) (left: location map, right: view of weir)

By placing the excavated sediment downstream of the dam and using it for flashing discharge, the lifetime of the dam reservoir capacity was extended longer and at the same time by restoring sediment downstream continuity of the movement of sediment upstream and downstream from the dam was ensured.

And since 2006, heavy equipment has been used during flashing discharge to forcefully agitate and cast the temporarily placed sediment, in order to ensure more efficient sediment bed load transport even small flow (Photo 3).

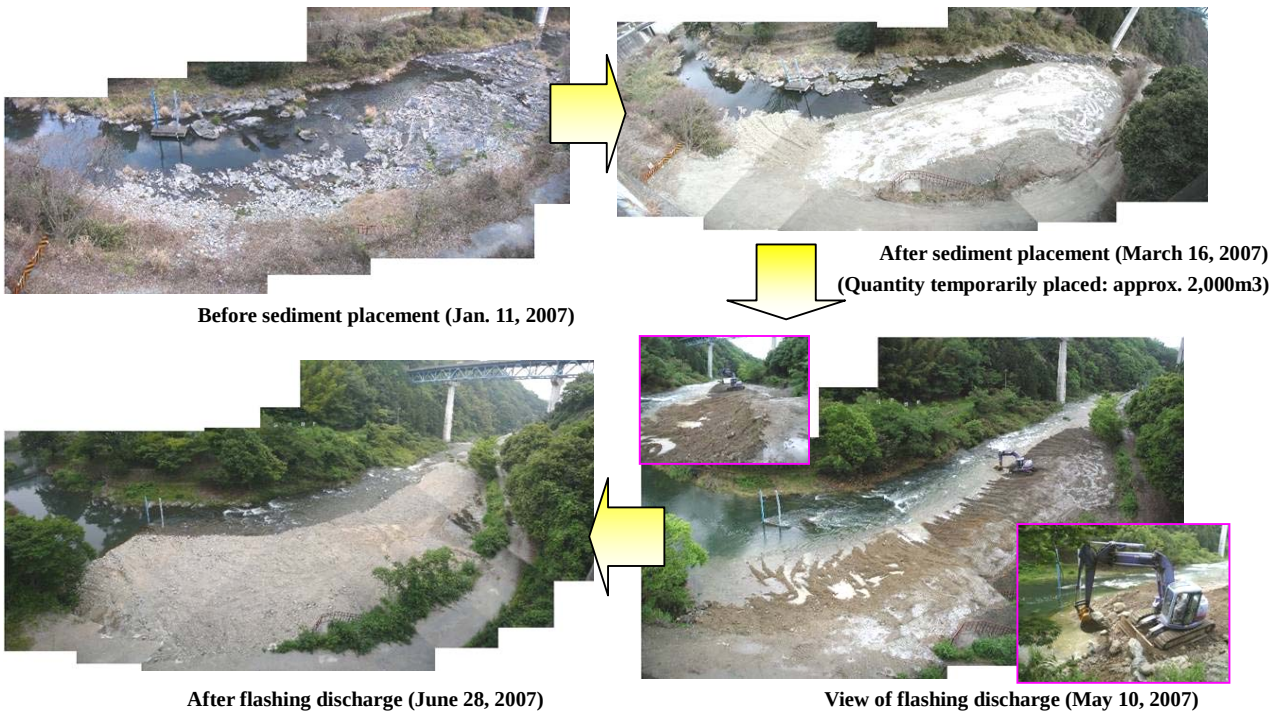


Photo 3. View of Flashing Discharge in 2007

Photo 4 and photo 5 show conditions of downstream of the dam before and after flashing discharge in June 2003 and in May 2007 respectively. It shows that the bed load transport effects have been found at locations where algae etc. are floating at normal time and algae has flourished for long time, and it was found that the transported bed load accumulated downstream.

Photo 4. State of Algae Bed Load Transport Before and After Flashing Discharge (Before discharge (left): June 7, 2003, After Discharge (right); June 10, 2003))

River Environment Survey

The surveys were executed at locations shown in Fig. 2 to clarify how improved river environment by flashing discharge. Table 1 shows the results of a survey performed downstream of the dam from 2001 to 2006. Only 1 sweetfish was caught in 2001, but after the counter measures taken in 2002, 4 sweetfish and 2 sweetfish were caught in August and October respectively, and from May to July in 2003 when flashing discharge was done, sweetfish were found. The survey also revealed that the number of confirmed sweetfish increased from 2004 to 2006.

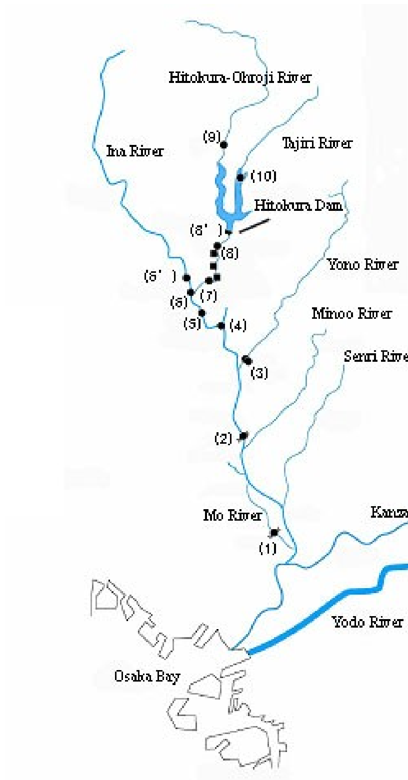
Fig. 3 presents the relationship between the body length and wet weight of oikawa (*zacco platypus*) (index species) a fish plentiful in Ina River, and a type that eats the same algae as sweetfish after it has matured. This shows that the size of oikawa shorter than 5cm were found at two points in the river downstream of the dam.

Photo 5. State of Downstream Riverbed Before and After Flashing Discharge (Before Discharge (left): May 9, 2007, After Discharge (right); May 11, 2007))

Table 1. Results of Fish Survey (Downstream of the Dam): 2001 to 2007

Hitokura Shinbashi Bridge to below the Dam

Data / Species	2001		2002												2003												2004										2005							2006						2007					
Species	7	9	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	4	6	7	8	9	10	11	12	1	6	7	8	9	10	11	6	7	8	9	10	11	6	7	8	9	10	11
Japanese eel			1		1			1			1							1		1		2	1	2		1			4			1			2		1		1			3		2				1			2				
Common carp									1														1								1	1											1												
Carp family fry																																																				1	18	32	
Ginbuna	1		2	1	4			9			1	1											2	1		1	3	2	1			2										6	10												
Gengorobuna																																										2													
Prussian carp genus																																							3																
Oikawa	1	7	3	8	3	3			2	3	14	5				1			1		6	1	2	7		7	4	1			3	5	6	3	11	2	10			2					17	3	2	1	71	9		33	33	25	32
Kawamutsu	1			1	2						1														2																														
Mugitsuku	1		1		3						2							1		1	1		2		1																														
Kamatsuka				3			2																			1	2		1																										
Barbel steed																			3																																				
Sugomoroko											1					1												1													2														
Loach																							1																																
Japanese stone loach				3																						1										1						1	1				1				1				1
Sujisimadojo			3	2	3		2																							1									3				3												
Bagrid catfish	2						1											1	1	5	1		1					1	2	3			2						1		1	2		1						1	2		1		
Cat fish	1																	1				1				1	1		1										2								1								
Sweetfish	1									4		2							1	4	1									18	3	4	1		4			4	17	4				31	5	1				7		5	4	3	
Rainbow trout	1	1				6																												1																					
Blue gill					1											1					1																																		
Large mouth bass																														1																									
Brown Hakeling																																										1													
Ukigori																																							1																
Japanese perch																																																		3	12		13	4	1
Oyoshinobori																							1																																
Kawayoshinobori	4	10	1	2	5	2	1	3		6	3		2			1	2	1	2	1	4	3	6	9	8	4	1	4	16	5	2	1			2	6	5	3	20	4	4	3	9	8	3	25	45	28	6	11	16	21	51	21	7
Number of species	9	3	6	7	8	3	4	3	2	3	7	3	1	0	0	4	1	5	5	5	6	4	9	4	3	7	5	5	6	5	4	6	3	2	4	3	3	2	8	3	3	7	5	4	3	3	4	3	2	5	5	4	6	5	4
Number of fish	13	18	11	20	22	11	6	13	3	13	23	8	2	0	0	4	2	5	8	12	14	7	17	19	11	16	11	9	25	28	9	14	9	4	19	9	16	7	48	10	7	18	24	42	25	29	49	30	77	31	33	60	120	85	41



Location No.	River name	Location
1	Mo River	Nakazono Bridge
2	Ina River	Gunko Bridge
3		Taka Bridge
4		Convergence with Shio River
5		Tada-in
6		Near Golf Bridge
6'		Ishimichi
7	Hitokura Oroji River	Near Yahata Warning Station
8		Near Hitokura Shinbashi Bridge
8'		Test section downstream from dam
9		Sengen
10	Tajiri River	Kunisaki

Fig. 2. Environmental Survey Locations

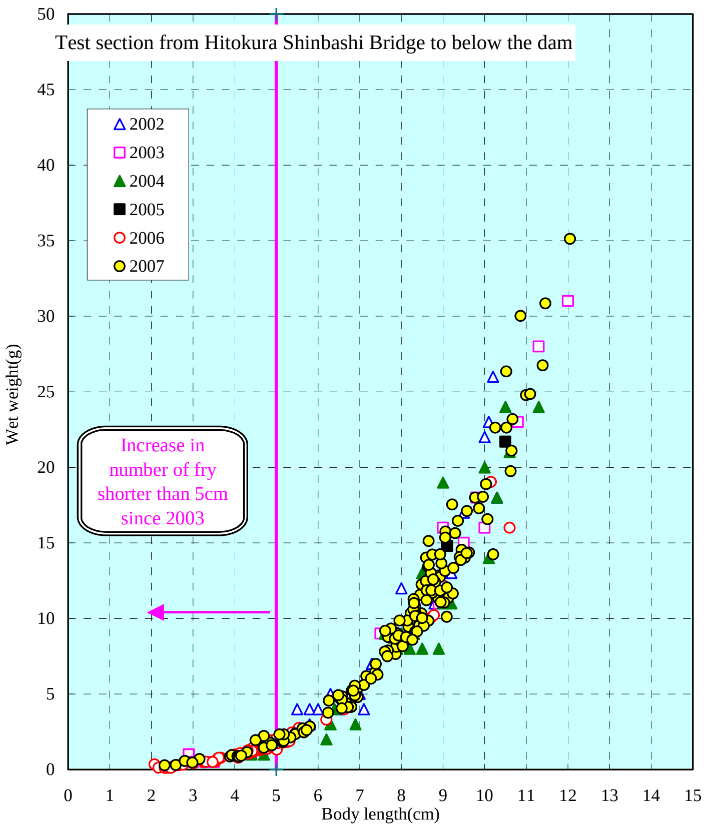


Fig. 3. Wet Weight - Body Length Relationship of Oikawa

The results from survey point 8 show that no fry shorter than 5cm were caught until 2002, but the 2003 and later results confirm fries shorter than 5cm, so it is assumed that environment restoration counter measures had caused sediment to accumulate on the riverbed where bedrock had been exposed, and create new spawning grounds, improve the river environment, enabled the alternation of generation of fish.

Trial of flexible operation based on the limited water level method

The flexible operation method based on the limited water level method was performed in 2006 in order to improve depleted sections of the river downstream of the dam.

The dam administrator lowered the reservoir level from the normal top level (EL. 149.00m) to the flood season limited level (EL. 135.30m) at the Hitokura Dam, in order to ensure flood control capacity in preparation for floods triggered by typhoons or the rain front during the flood period, from June 16 to October 15. Normal water management is performed with the reference point set at Mushu beyond the confluence with the main course of Ina River and Hitokura Oroji River. Therefore, when flow in the main course of Ina River was high, the discharged replenishment quantity from the dam was low. And from the beginning of June to the middle of July when it was the fish spawning season, the river flow was insufficient in an approximately 5km section from below the dam to the confluence with the main course of Ina River and, the depth and flow were found to be insufficient for fish to spawn. During the draw down period (from the middle of April to the middle of June), the reservoir water level was lowered by 13.7m from the normal top water level to the flood season limited level, but fish that spawn during this period may be prevented from spawning and hatching by drying of the fish eggs when the reservoir water level falls.

Therefore the dam administrator decided to try out flexible operation based on the limited water level method to store flowing water using part of the flood control capacity, setting the usable water level, and use this to improve flow in the approximately 5km section from directly below the dam to the confluence with the main course of Ina River.

The trial performance of flexible operation based on the limited water level method differs from the conventional method that set usable water level throughout the period. That is the preset usable water level (usable capacity) is used to increase the quantity discharged then it is lowered progressively during the usable period to improve downstream flow.

The limited water level method was adopted to ensure the total flood control capacity after the usable period, because part of downstream river of the dam is not protected by levees and flow capacity in this section is low, which means there is a high risk that lowers flood control capacity of the dam. Clarifying the period when past floods have occurred has shown that floods occur mainly after the middle of July and considering the spawning season etc. of fish in the river downstream from the Hitokura Dam,especially that of the reference fish, Oikawa, the usable period was set until July 15 (Table 2). According to preliminary study performed to set the usable water level, when a flood has been predicted, it is possible to surely lower water level to the flood season limited level from based on the prior discharge, and the water level was set as flood season limited level (EL. 135.30m) + 1.40m (usable capacity 1.13 million m^3) considering the capacity shortfall from necessary flow for fish until the middle of July.

Table 2. Ideal Flow Rate by Month by Fish Species

Species	Conditions and grounds	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Oikawa	Ecological properties	Traveling				Spawning season				Traveling			
	Required depth(cm)	10	10	10	10	15	15	15	15	10	10	10	10
	Required flow rate(m^3/s)	0.171	0.171	0.171	0.171	0.438	0.438	0.438	0.438	0.171	0.171	0.171	0.171
	Required flow speed(cm/s)	-	-	-	-	5	5	5	5	-	-	-	-
Sweetfish	Ecological properties	Traveling									Spawning season		
	Required depth(cm)	-	-	15	15	15	15	15	15	15	30	30	30
	Required flow rate(m3/s)	-	-	0.438	0.438	0.438	0.438	0.438	0.438	0.438	2.420	2.420	2.420
	Required flow speed(cm/s)	-	-	-	-	-	-	-	-	-	60	60	60
Barbel steed	Ecological properties	Traveling			Spawning season			Traveling					
	Required depth(cm)	20	20	20	30	30	30	20	20	20	20	20	20
	Required flow rate(m3/s)	1.218	1.218	1.218	2.420	2.420	2.420	1.218	1.218	1.218	1.218	1.218	1.218
	Required flow speed(cm/s)	-	-	-	-	-	-	-	-	-	-	-	-
Yoshinobori group	Ecological properties	Traveling				Spawning season				Traveling			
	Required depth(cm)	10	10	10	10	20	20	20	20	10	10	10	10
	Required flow rate(m3/s)	0.171	0.171	0.171	0.171	1.218	1.218	1.218	1.218	0.171	0.171	0.171	0.171
	Required flow speed(cm/s)	-	-	-	-	10	10	10	10	-	-	-	-
Required maximum flow rate(m^3/s)		1.218	1.218	1.218	2.420	2.420	2.420	1.218	1.218	1.218	2.420	2.420	2.420
Remarks		Untio June 15:Before flood season					Flood season:June 16 to Oct.15				After Oct.16:After flood season		
							Draw down(April 1 to June 15)	Usable period(June 16 to July 15)					

Fig. 4 shows flow during the flexible management trial at Uneno district that is between the dam and the confluence point with the main course of Ina River. This reveals that it was possible to constantly ensure necessary flow for fish at the Uneno district during the trial. According to period the trial of flexible operation based on the limited water level method carried out in 2006, it has confirmed that reducing reservoir water level reduction rate from 18cm/day to 5cm/day by July 15 has formed approximately 2.1ha of new spawning beds on the reservoir slopes that have a shoal topography in the Kunisaki district upstream from the reservoir, and that there are many kinds of fish including freshwater goby (Fig. 5).

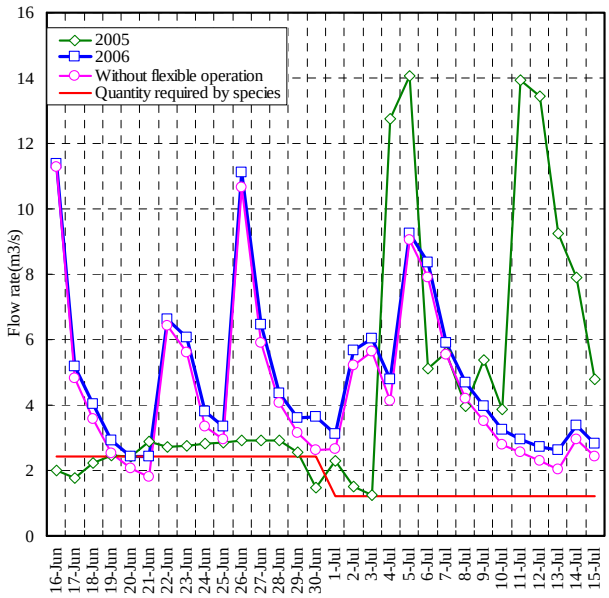


Fig. 4. Flow Regime at Downstream Reference Point (Uneno) beginning 2006

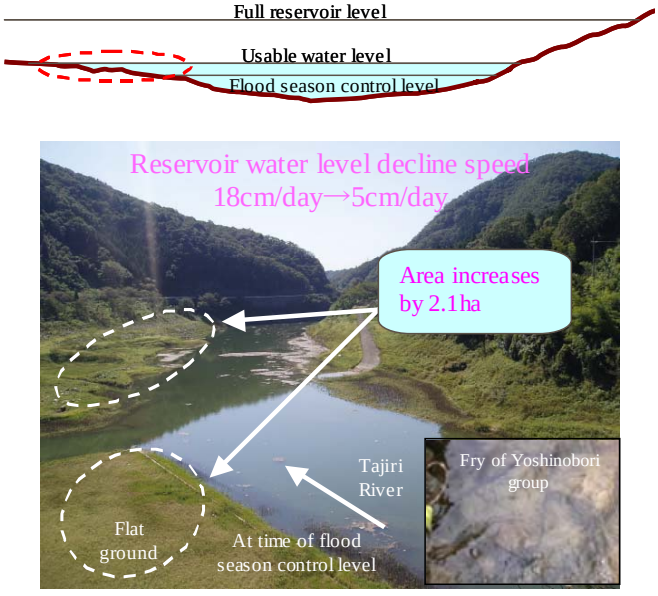


Fig. 5. Effects of Creating a Spawning Bed Inside the Reservoir

The flexible operation trial was performed for three years from 2006, and after problems have been identified and confirmed, and countermeasures taken during the trial period, it will be decided whether a full-scale operation will perform.

Survey of fish species and recycling of exotic fish species by fixed nets that can utilize water level change

Fig. 6 shows change over years of fish fauna inside Hitokura Dam reservoir from 1991 to 2005 (National Census on River Environment). According to this figure, the percentage of the number of exotic species occupied to the whole has risen steadily since the survey of 1991, and a result particularly in 2005 is extremely undesirable from perspective of diversity of species that is to say about 40% of the fish were exotic species. So a fish survey has been carried out at Hitokura Dam from 2005 by using type fixed nets that can utilize water level change.

The fish capture survey by using fixed nets which can utilize water level change was performed by installing a number of tunnel nets linked by wing nets near the upstream end of the reservoir to completely enclose the shallows upstream in the crossing direction. And then by the reservoir water level lowering a huge numbers of fish that have traveled downstream are holed and captured (Fig. 7). This method sharply minimized the impact of the fishing skills of surveyors, and at the same time it reduced damage to fish species by gill nets that severely damage fish, so that almost all captured fishes could be released (Photo 6).

Each of the captured fish was measured and weighed, then the native species were released and exotic species such as the largemouth bass, bluegill, and others were killed and disposed of. These measures have continued since 2005, and the result of the fish survey of 2007 (National Census on River Environment) has confirmed that the percentage of exotic fish has fallen to about 4%, and the recovery tendency of the native species was indicated.

Of the exotic fish captured by using fixed nets which can utilize water level change, it is reported that when the bluegill is used as fertilizer, its rich calcium content tends to improve the taste of vegetables (red beets)[7)], so after they were captured, they were dried and pulverized in a household use raw garbage desiccators and used as feed for the native species or supplied for a trial of their use as fertilizer on private vegetable gardens or dry fields. The dam administrator wishes to construct a system for recycling exotic fish species as fertilizer (Photo 7).

As the measure of other environmental preservation, the dam administrator is planning to cultivate vegetation using vegetated floating island type booms reconstructed in 2006. This project planned for future is the creation of habitat space for fish and other living organisms on floating islands as a measure to prevent eutrophication of the reservoir and to reuse old booms (Photo 8).

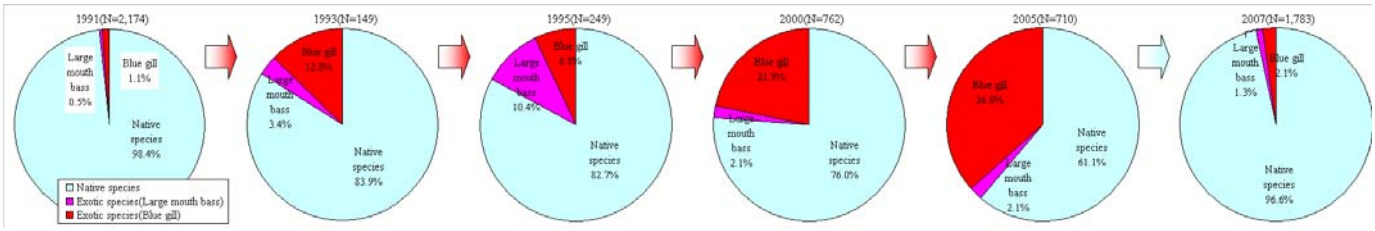


Fig. 6. Change Over Time of Fish Fauna in the Reservoir

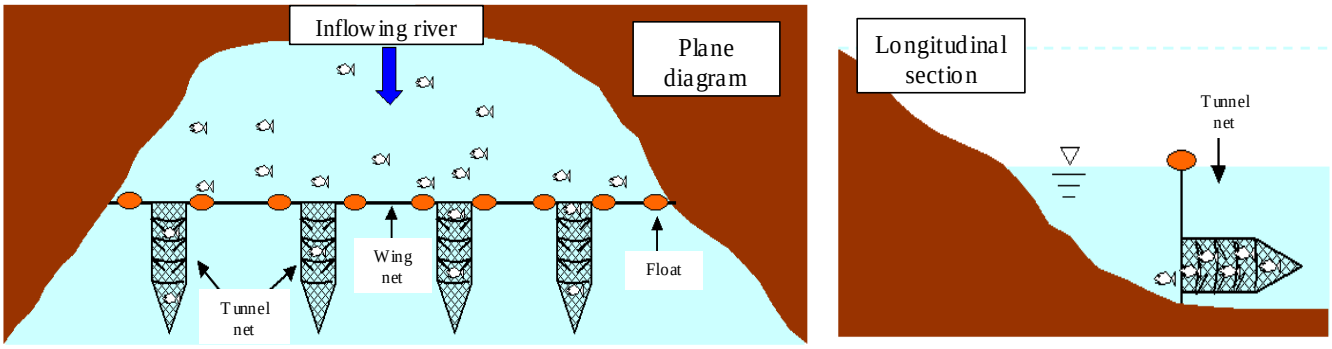


Fig. 7. Image of Catching Fish Using Low Water Level Type Fixed Net Method

Photo 6. Views of Catching Fish and Measuring Native Species

Photo 7. Views of the Recycle of Exotic Species that have been Taken

Photo 8. Vegetated Floating Island Type Boom and Floating Island Reusing an Old Boom

CONCLUSIONS

At Hitokura Dam, reservoir and river environment conservation management that considers the dam reservoir and the upstream and downstream river to be an integrated environment has been implemented since 2002.The effects of the integrated reservoir and river environment conservation management measures have begun to appear gradually, for example, the number of confirmed oikawa including fry that is indicator species of monitoring have increased.

These measures will continue in the future, and monitoring surveys is conducted to verify the effects of the counter measures. At the same time meetings will be held with regional residents to exchange views that will be fed back and reflected in the planning of future measures in order to build better environmental preservation management system.

At Hitokura Dam, in addition to these environmental preservation measures, environmental restoration measures guided by new ideas that go beyond the bounds of conventional concepts of the theme will be considered and implemented by a trial and error process.

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Raw garbage utilization method of the Moriyama Fisheries Coop of Shiga Prefecture