Key Issue:
2- Hydrological regimes

Climate Zone:
Cf: Temperate Humid Climate

Subjects:
- River Maintenance-intended Outlet Structure

Effects:
- Improved Ecological Environment of Fauna and Flora

Project Name: Futagawa Dam
Country: Wakayama Prefecture, Japan (Asia) (N34°05′, E135°22′)

Implementing Party & Period
- Project: Wakayama Prefectural Government
1967 (Completion of construction) -
- Good Practice: Wakayama Prefectural Government
1998 (Commencement of operation) -

Keywords:
Reduced Flow River Caused by Diversion, Ecosystem, Compensation Flow

Abstract :
At the Futagawa Dam located in the middle course of the Arita River, Wakayama Prefecture, an approximately 6.5-km section immediately downstream of the dam had reduced flow river caused by diversion. However, with the recent public interest in the environment, it was decided to discharge compensation flow. Biological surveys were conducted on a continuous basis before and after the start of the discharge, and the results revealed that the ecosystem, which was partially destroyed by the dam, was being restored.

1. Outline of the Project

The Futagawa Dam, located at Futagawa, Shimizu-cho, Arita-gun, Wakayama Prefecture, is a multi-purpose dam intended for flood control and power generation. Construction of the dam started in 1963 as part of the Arita River Overall Development Project, and was completed in 1967.

The dam is a concrete gravity dam. It has a height of 67.4 m, a crest length of 222.8 m and a volume of 209,250 m^3. The design flood discharge at the

Figure 1 Location of Futagawa Dam

dam site is 3,000 m^3/sec. Of this, the dam can flood-control 900 m^3/sec and discharge 2,100 m^3/sec. For power generation, there is a dam-and-waterway type power plant with a maximum plant discharge of 15.0 m^3/sec and a maximum output of 11,000 kW.

The location of Futagawa Dam is shown in Figure 1, and the specifications of the dam are shown in Table 1.

Table 1 Specifications of Futagawa Dam

Classification	Item	Specification
Dam	Type	Concrete gravity dam
	Height	67.4 m
	Crest length	222.8 m
	Dam volume	209,250 m^3
	Elevation of non-overflow section	E.L. 204.40 m
Storage capacity	Catchment area	228.8 km^2
	Ponding area	0.86 km^2
	Gross capacity of reservoir	30,100,000 m^3
	Effective reservoir capacity	19,200,000 m^3
	Flood control capacity	14,400,000 m^3
	Power generation capacity	16,700,000 m^3
Outlet structure	Normal spillway	Constant rate/constant quantity control
	Orifice gates	H8.00 × W8.60 × 2 gates
	Emergency spillway	–
	Crest gates	H10.88 × W11.90 × 2 gates
	Conduit for compensation flow	Main gate (300 dia.)
		Sub-gate (400 dia.)
	Design flood discharge	3,000 m^3/sec
	Design maximum discharge	2,100 m^3/sec
	Compensation flow	0.70 m^3/sec
Power plant	Maximum plant discharge	15.00 m^3/sec
	Maximum output	11,000 kW

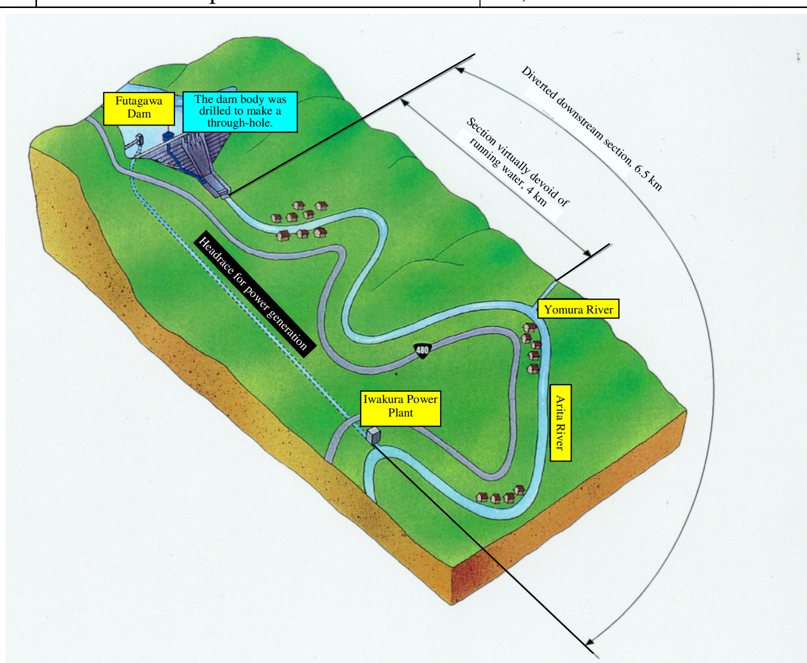

Figure 2 Schematic view of Futagawa Dam

Figure 2 presents

a schematic view showing the Futagawa Dam and the downstream area.

2. Features of the Project Area

The Futagawa Dam is located in the middle course of the Arita River running from Mt. Yoryu, Takano-cho. The Arita River runs from east to west and joins such tributaries as the Yukawa, Yomura, Shuri and Hayatsukitani rivers, and flows into the Kii Channel. It is a second-class river having a stream length of 94 km and a catchment area of 460 km^2. The Arita River is famous for its scenic beauty, and many people enjoy their holidays playing in and along the river or fishing for ayu (Plecoglossus altivelis). Furthermore, every year at the Bon Festival, water is additionally discharged from the dam to help people float their lanterns on the water of the river. Thus, people use the river in a positive manner to enrich their lives.

3. Major Impacts

The power plant at the Futagawa Dam employs a dam-and-waterway type, with the outlet located about 6.5 km downstream of the dam. Without the concept of discharging water for the purpose of compensation flow, the dam was built with a flood-control outlet structure only, and the section of about 6.5 km from the dam to the plant outlet had reduced flow river caused by diversion. In particular, the river course section of about 4 km from the dam to the confluence with the Yomura River joining as a tributary, the Arita River within the 6.5 km section was virtually devoid of any inflowing water. Before the construction of the dam, this section was a very good place to fish for ayu, but after the dam was constructed, few ayu lived there.

In recent years, the regional inhabitants developed an interest in the environment, and the demand for restoring abundant nature in the river intensified. The demand for discharging compensation flow for the downstream section also increased among the local inhabitants of the Futagawa Dam area.

4. Mitigation Measures

Under such a background, the Ministry of Construction (present Ministry of Land, Infrastructure and Transport) started Dam Water Environment Improvement Work in FY1993, to take corrective measures for dams with such reduced flow river caused by diversion. The modification of the Futagawa Dam was the first task of the planned work.

The objective of the Futagawa Dam Water Environment Improvement Project was to embed an outlet pipe (400 mm in diameter) in the dam body, for normally discharging 0.7 m^3/sec of water for compensation flow in the downstream section. The project started in 1993 with a total project cost of 1,410 million yen, and the compensation flow started on May 26, 1998.

With regard to the amount of the compensation flow, the “Technical Criteria for River Works” (draft), supervised by the River Bureau, Ministry of Construction, specifies that the discharge should be examined in reference to nine items: “shipping,” “fishery,” “landscape,” “prevention of damage due to salt,” “prevention of river-mouth closure,” “protection of river management facilities,” “maintenance of groundwater level,” “protection of fauna and flora,” and “keeping the running water clean.” Among these items, at the Futagawa Dam, “landscape,” “protection of fauna and flora,” and “keeping the running water clean,” were influential. The necessary discharge values for the respective three items were calculated, and 0.68 m^3/sec was obtained as the minimum value. Therefore, 0.7 m^3/sec was employed for the compensation flow.

Photo 1 shows the appearance of the completed outlet structure, and Figure 3 shows the schematic view.

Photo 1 Intake tower of outlet structure for compensation flow

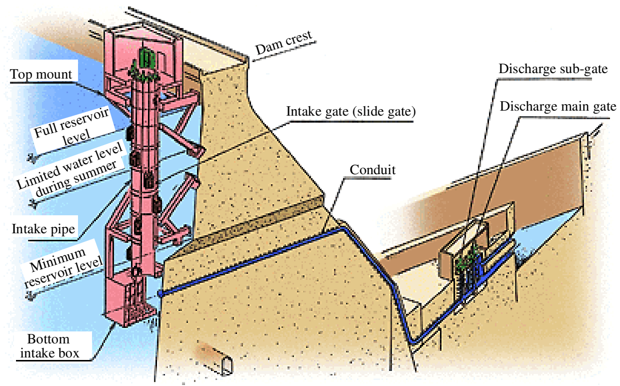

Figure 3 Schematic view of outlet structure for compensation flow (source: Homepage of Kurimoto, Ltd.)

5. Results of the Mitigation Measures

To date, only a few reports have quantitatively clarified the effects of the compensation flow in reduced flow river caused by diversion on the creation and development of river environment. So, for the Futagawa Dam, biological surveys were carried out over a period of four years starting in FY1997 when the outlet structure had not yet been completed, to examine the effects of the compensation flow on the river environment. The biological surveys covered the following items and were carried out according to the methods specified in the “Manual for National Census on River Environments, (in Japanese)” etc. Furthermore, a reconnaissance study was conducted in reduced flow river caused by diversion about 6.5 km from the dam, to be covered by the biological surveys, and four survey stations were established. The locations of the survey stations are shown in Figure 4 and their general conditions are

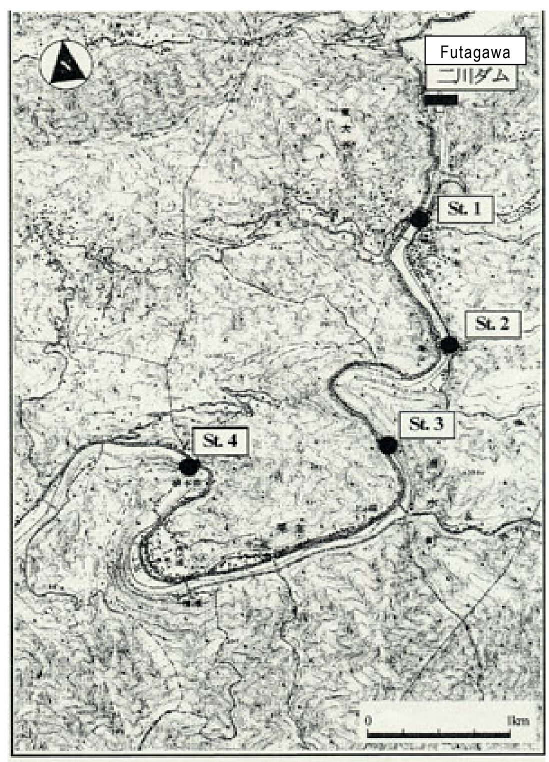

Figure 4 Locations of survey stations

shown in Table 2.

Table 2 General conditions of survey stations

Station	Station Name	General Conditions of Survey Station
St. 1	Futagawa River Upstream Station (1 km downstream of Futagawa Dam)	A weir exists immediately upstream of the survey station, and a pool is formed downstream. On the left bank side, there is a revetment designed to allow easy approach to the water, and on the right bank side, a concrete revetment is constructed. The riverbed is mostly covered with rock masses and large-grain gravel, and where the water runs slowly, sandy gravel is deposited.
St. 2	Hakuba Junior High School Upstream Station (about 1.5 km downstream of St. 1)	A small river joins at this point. On the left bank side, there is a spreading ditch reed (*Phragmites australis*) zone, and on the right bank side lie rock masses. Shallows, rapids and pools are clearly formed, and the riverbed is abundantly covered with rock masses and gravel.
St. 3	Iwakura Bridge Upstream Station (about 1.5 km downstream of St. 2)	*Phragmites japonica* flourishes on both banks. After the start of additional discharge, there are no longer any sections devoid of currents, and shallows, rapids and pools are formed. With many giant stones, complex hydrological regimes are presented.
St. 4	Iwakura Power Plant Station (immediately upstream of the power plant)	On the left bank side lie rock masses, and on the right bank side, a community of *Pueraria lobata* and *Humulus scandens* grows thickly. At this station, the landscape hardly changes as the years elapse.

5.1 Survey Methods

Surveyed items and details are described below.

(1) Fish survey (twice per year in summer and autumn)

1) Catch survey (laying out net, spoon net, line trawl, serving) and visual observation under water
2) Photographing the actual conditions of river modes

   The actual conditions of river modes were photographed so that the entire range of conditions for the respective survey stations could be identified. The distribution of shallows, rapids and pools were recorded as sketches, and flow velocity, water depth, transparency and the like were also measured.

(2) Benthonic animal survey (twice per year in summer and early spring)

1) Quantitative and qualitative collection
2) Photographing the actual conditions of river modes

(3) Flora survey (once per year in summer)

1) Waterfront community composition survey
2) Waterfront community flora survey
3) Photographing the actual conditions of waterfronts

5.2 Evaluation Methods

(1) Fish survey

1) Comparison in reference to population density

From the results of visual observation under water, the number of living fish per unit area was obtained, and the changes with the lapse of years at the respective stations were comparatively examined.

2) Comparison in reference to fatness coefficient

The fatness coefficient as indicator of the nutrition condition of fish was obtained, and the changes with the lapse of years at the respective stations were comparatively examined.

3) Comparison in reference to body length

Since it was considered that the change of the prey environment could affect the growth of fish, the changes of body length with the lapse of years were comparatively examined.

(2) Benthonic animal survey

1) Diversity index

Shannon's diversity index was used for evaluation based on the results of quantitative collection. The diversity index shows a higher value when the number of species is larger and when the individuals of existing species are uniform. The diversity index (H') is obtained from the following formula.

$$H' = \sum_{i=1}^{S} (pi \cdot \log(pi))$$

where S is the number of existing species, and pi is the relative dominancy of the species i.

2) Web-building species coefficient

To identify the changes of the riverbed, the web-building species coefficient for comparing the benthonic animals succeeding in shallows and rapids was used for evaluation.

Web-building species coefficient (%) = A/W·100

A: Wet weight of web-building insects

W: Total wet weight of all benthonic insects

(3) Flora survey

1) Changes with lapse of years in the survey by belt transect method

For the dominant species and the number of confirmed species in each quadrat obtained from the waterfront community composition survey, the changes with the lapse of years were comparatively examined.

2) Changes with lapse of years in flora survey

The changes with the lapse of years in the waterfront flora survey were comparatively examined.

5.3 Results

The results of surveys conducted are shown below.

(1) Fish survey

In the four years from FY1997 to FY2000, five orders, eight families and twenty-eight species of fish were confirmed. Among them, purely freshwater fish consisted of three orders, six families and nineteen species, and migrating fish consisted of four orders, four families and nine species. At every station, Zacco platypus, Rhinogobius flumineus, Leuciscus (Tribolodon) hakonensis, Squalidus chankaensis subsp, and others were confirmed in large numbers, and those fish can generally be observed in the Kinki District (Table 3).

Table 3 Changes of confirmed fish species with lapse of years

No.	Species Name	St.1				St.2				St.3				St.4			
		97	98	99	00	97	98	99	00	97	98	99	00	97	98	99	00
1	*Anguilla japonica*				○												
2	*Cyprinus carpio*	○	○	●	○			○	○	○	○		●			○	
3	*Carassius carassius buergeri*	○	●	●	●	○											
4	*Carassius cuvieri*	●	●	●		●	●	●		●		●					
	Crucian carps	○	○	○	○	●	○	○	○	○	○	○	○	○	○		
5	*Opsariichthys uncirostris*		●	●		●	●				○				●		
6	*Zacco platypus*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
7	*Zacco temmincki*		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Zacco	●	●			●	●	●		●	●	●		●	●	●	
8	*Leuciscus (Tribolodon) hakonensis*	●	●	○	○	●	●	○	○	○	●	●	○	●	●	●	●
9	*Pungtungia herzi*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
10	*Gnathopogon elongatus*		●														
11	*Pseudogobio esocinus*	●	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●
12	*Hemibarbus longirostris*					○											
13	*Hemibarbus labeo*	●	○	●	●	●	○	○		○	○	○	○	○	○	●	●
14	*Squalidus chankaensis subsp*	●	●	●	●	●	●	●		●		●	●	●	●	●	
	Squalidus chankaensis biwae	○	○	○	○			○		○	○	○		○	○	○	
15	*Cobitis (Misgurnus) anguillicaudatus*			○													
16	*Cobitis biwae*	●	●	○	●	●	●	●	○	●	○	○			●	○	●
17	*Pseudobagrus aurantiacus*		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
18	*Silurus (Parasilurus) asotus*	●	●	●	○	●	●		●		●			○			
19	*Plecoglossus altivelis*	●	○	●	●	●	○	●	●	●	●	●	●	●	●	●	●
20	*Lepomis macrochirus*	○		●	●					○				○		○	
21	*Micropterus salmoides*	○	●	●	●		●	○	○	○	○	○	○	○	○	○	○
22	*Chaenogobius annularis*														●		○
23	*Sicyopterus japonicus*												○				●
24	*Rhinogobius sp. CB*		●	●	○		●		○					●	●	●	●
25	*Rhinogobius sp. LD*									●	●	●	●		●	●	●
26	*Rhinogobius sp. OR*			●					●						●		
27	*Rhinogobius flumineus*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Rhinogobius	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	●
28	*Tridentiger obscurus*	●	●	○	●	○	○	○	●	○	●	○	○	●	●	●	●
Total number of species		16	20	22	19	17	17	15	15	17	16	15	15	16	19	17	16

* An open circle (○) indicates that the species was confirmed only by visual observation under water. A closed circle (●) indicates that the species was confirmed by a catch survey alone or by both a catch survey and visual observation under water.
The halftone ( ) indicates migrating fish.

In reference to the species confirmed in FY1997 to FY2000, there were no large differences in either the species confirmed or the number of species confirmed. However, the number of species confirmed in shallows and rapids tended to increase, although the number of species confirmed before the start of the compensation flow was smaller (Figure 5).

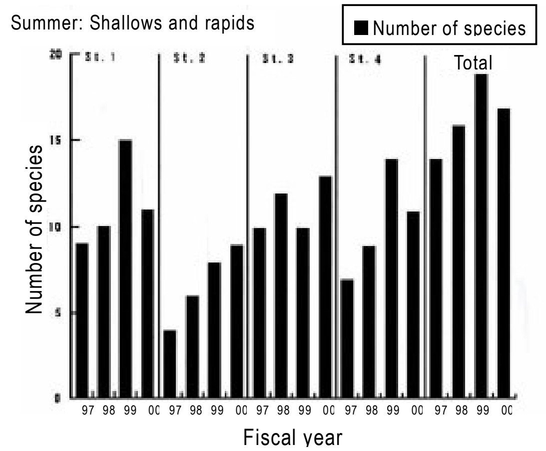

Figure 5 Number of species with lapse of years

From the above, it can be considered that although only some fish could live in shallows and rapids due to the small water depth before the start of the compensation flow, the compensation flow increased the water depth and promoted the thick growth of vegetation along the waterfronts, allowing more species of fish to live there. Furthermore, at St. 1 and St. 2, Rhinogobius sp. CB and Rhinogobius sp. LD, migrating fish that were not confirmed in FY1997 before the start of the compensation flow, were confirmed after FY1998 inclusive subsequent to the start of the compensation flow. The reason for this is considered to be that since there are no longer any sections devoid of running water in St. 3, fish can always migrate into a section to which they could migrate only when water was discharged from the dam, and therefore Rhinogobius, considered less anadromous than Plecoglossus altivelis, could also migrate upstream. The conditions at St. 1 and St. 3 before and after the start of the compensation flow are shown in Photos 2 through 5.


Photo 2 Conditions at St. 1 before start of compensation flow


Photo 3 Conditions at St. 1 after start of compensation flow


Photo 4 Conditions at St. 3 before start of compensation flow


Photo 5 Conditions at St. 3 after start of compensation flow

Zacco platypus is a typical fish species for shallows and rapids. The changes in the body length of Zacco platypus at the respective stations with the lapse of years are shown in Figure 6. At St. 1 to St. 3, compared with the values of FY1997, the values of FY1998 and 1999 are remarkably larger. However, the values of FY2000 do not differ from those of FY1997.

Figure 7 shows the population density of Zacco platypus per unit area. It can be seen that compared with the values of FY1997, the number of individuals per unit area increased significantly.

These results suggest that up to FY1999, the prey quantity per fish was so large as to increase the body length, since the population density remained unchanged while the prey environment was improved. However, in FY2000, the prey quantity per fish became so small that the FY2000 body lengths did not differ from those of FY1997, since the population density became higher while the prey environment in FY2000 was the same as that in FY1999.

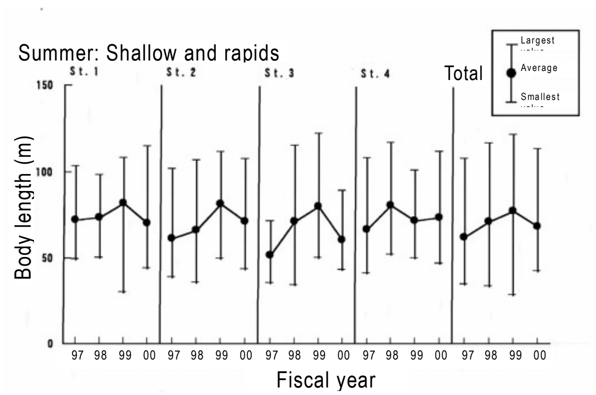

Figure 6 Changes in body length of *Zacco Platypus* with lapse of years (summer survey: shallows and rapids)

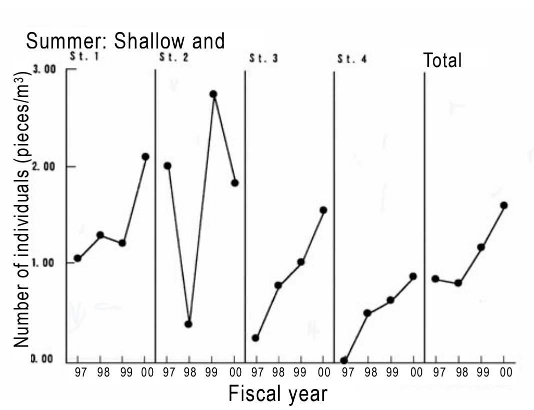

Figure 7 Changes in population density of *Zacco Platypus* with lapse of years (summer survey: shallows and rapids)

(2) Benthonic animals

In the four years from FY1997 to FY2000, nineteen orders, fifty-nine families and one hundred and fifty-two species of benthonic animals were confirmed. Compared with the results of FY1997 before the start of the compensation flow, no large differences were observed in FY1998 or FY1999, but in the survey conducted in FY2000, the number of species increased at every station (Figure 8). As a special matter to be noted, among the

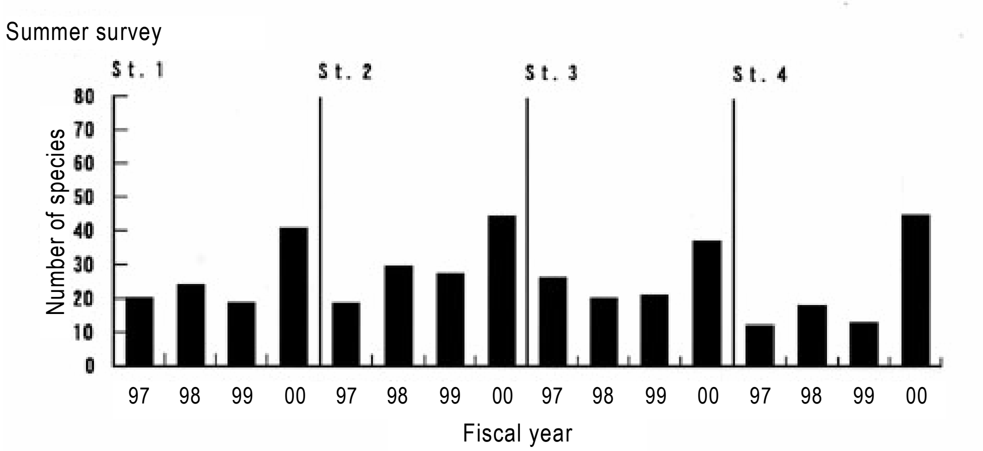

Figure 8 Changes in number of species with lapse of years

species confirmed in FY2000, four species, Epeorus uenoi, Potamanthus kamonis, Oyamia gibba, and Stenopsyche sauteri, are designated as endangered species in this district in "Japanese Important Insects in the Kinki District, Report of National Survey on the Natural Environment (in Japanese)" (1980, edited by the Environment Agency), and two species, Fossaria trancatula and Radix japonica, are designated as information-deficient species or virtually endangered species in "Red List (in Japanese)" (2000, edited by the Environment Agency).

Figure 9 shows the changes in the web-building species coefficient with the lapse of years. The web-building species coefficient indicates the rate of web-building insects that build catching webs or immobile nests, such as Hydropsychidae and Stenopsychidae, and it indicates the stability of the riverbed.

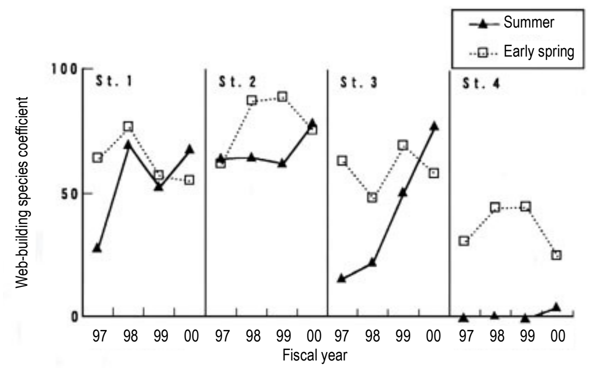

Figure 9 Changes in web-building species coefficient with lapse of years

In reference to the values of the web-building species coefficient in FY1997 to FY2000, after FY1998 inclusive subsequent to the start of additional discharge, relatively high values suggest that the riverbed tended to be stabilized. In the early spring survey of FY2000, values lower than those of FY1997 are shown, probably because large water was discharged from the dam at the rate of 159 m^3/sec, the largest since the start of the summer survey.

Before the start of the compensation flow, the river environment was such that the riverbed was exposed when no water was discharged from the dam, but was disturbed when water was discharged from the dam. However, after the start of the compensation flow, the increase in water quantity improved the environment so that constant discharge has been stably maintained except during flood.

(3) Flora

In the four years from FY1997 to FY2000, fifty-nine families and one hundred and fifty-four species of plants were confirmed. Compared with the data before the start of the compensation flow, the number of species increased, and the species newly confirmed to have rooted were mainly species of waterfront plants. The species confirmed at multiple stations include Phragmites japonica, Alnus serrulatoides, Salix chaenomeloides, and so on that are constituent species of riverside sprout forest.

Since the start of the compensation flow, the habitat range of Phragmites japonica has expanded (Photo 6), accompanying the deposition of soil, and in this connection, Alnus serrulatoides, Salix chaenomeloides, and so on were confirmed by the FY1999 survey to have taken root. Furthermore, in the FY2000 survey, their seedlings were confirmed, and successively up to the last fiscal year, the number of species of waterfront plants and the expansion of their habitat ranges were confirmed.

In FY2003, plants rooted in the moss on exposed rocks and the like were confirmed (Photo 7). This is considered to be the result of the rising water level and abundant water in the river course, further indication that the compensation flow has been effective.

Photo 6 Phragmites Japonica having growing runners

Photo 7 Herbaceous plants confirmed on exposed rock

6. Reasons for Success

For fish, in reference to such results as the expanded habitat ranges, increased number of species in shallows and rapids, and increased population density of Zacco platypus, it can be evaluated that the habitat environment has been improved both in quality and quantity.

For flora, in reference to such results as the increased number of specifies confirmed as waterfront plants in St. 1 to St. 3 and the expanded habitat ranges, it can be evaluated that the river flora have been enriched.

For the benthonic animals, the riverbed shows a tendency toward stabilization, and at all stations, the increase in the number of species was confirmed. So, the environment is being improved but not as remarkably as observed with the fish.

In conclusion, the compensation flow has provided such water environment improvement effects that the habitat ranges of flora have expanded to create hiding places and spawning grounds for aquatic life; that since the water area has expanded, the prey environment of fish has been improved to increase the number of individuals; and that since there are no longer any sections virtually devoid of running water, the landscape has been improved while the fish habitats have become continuous.

Our confirmation efforts are not limited to short-term effects, and our surveys will be continued to examine the long-term effects.

Photo 8 River regimes before start of compensation flow (St. 2)

Photo 9 River regimes after start of compensation flow (St. 2)

7. Outside Comments

1) Evening edition in Osaka of the Asahi Shimbun (Newspaper) dated November 12, 1996 (Tues)
   The newspaper presents a report that praises the task as a water environment-improving project. In the report, a third party comments as follows:
   Ms. Reiko Amano, an outdoor writer who represents the Citizens' Forum for Stopping the Construction of the Nagaragawa Estuary Barrage says, "Some advanced nations have already begun to remove dams. This project must be the result of the nation-wide movement of citizens who wish to restore the rivers as theirs. The Ministry of Construction is changing, but one further push is necessary."
2) The Sankei Shimbun (Newspaper) dated May 23, 1999 (Sun)
   One year after the start of the compensation flow, the newspaper reported that the environment has been recovered.
   The report says, "The body of the Futagawa Dam (total storage capacity about 30 million cubic meters) in the upper course of the Arita River at Shimizu-cho, Wakayama Prefecture was drilled one year ago to make a through-hole for discharging water from the dam with the intention of restoring a clear stream. This was a rare attempt in Japan. Since then, life surveys have been conducted to confirm that river fish, river crabs, river shellfish and the like have increased in number. Inhabitants who had petitioned for about a decade are pleased that a clear stream has been restored.

8. Further Information

8.1 References

1) The effect of the water environment improvement work of the Futagawa Dam (in Japanese), Dam Enginnering No. 181, Japan Dam Engineering Center, October 2001
2) Homepage of Futagawa Dam (Futagawa Dam Control Office, Construction Department, Arita Promotion Bureau, Wakayama Prefecture)
   http://www.pref.wakayama.lg.jp/prefg/130400/kensetsu/futagawadam/
3) Homepage of Kurimoto, Ltd.: Completion of Futagawa Dam Outlet Structure (Water Environment Improvement Work)
   http://www.kurimoto.co.jp/j08/sui3.htm

8.2 Inquiries

International Affairs Department,
Hydroelectric Power Development Center
New Energy Foundation (NEF)
Shuwa Kioi-cho Park Building 6F,
3-6, Kioi-cho, Chiyoda-ku, Tokyo 102-8555, Japan
Tel: 81-3-5275-9824
Fax: 81-3-5275-9831
E-mail: hydropower@nef.or.jp