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River and Wetland Restoration in Japan

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ABSTRACT: Japan has densely populated floodplains, steep rivers with flashy flow regimes, and geologically young mountains. Therefore, flood control and river regulation have been critical for securing life and economic growth. More recently, however, people have started to see an increasing need for conservation and restoration. In 1990, therefore, the Ministry of Construction (Ministry of Land, Infrastructure, and Transport since 2001) started the nation-wide program "Nature-Oriented River Work" in order to conserve the country's beautiful landscapes and its rich biodiversity. In the early stage of this program, the influence of restoration schemes in Switzerland and Germany was important. Later, these methods were adapted to the specific situation of Japan. Nowadays, restoration of rivers and wetlands is an important issue throughout Japan and the number of ecologically sound projects has rapidly increased since 1990. In the present paper, we explain the background of nature, history, and institutions in Japan, which is followed by an introduction of selected state-of-the-art case studies of river and wetland restoration.

KEYWORDS: Conservation, Tama River, Kushiro Mire, Lake Kasumigaura, Floodplain, Flood Control

Introduction

Restoration is receiving increasing attention among people and river managers (Brookes, 1996; Kondolf, 1995; Nienhuis, 2001). Over the past 50 years all of the world's major river ecosystems and wetlands have experienced the most intense damage (Davies, 2000). Therefore, interest and public investment in river restoration have increased sharply in developed countries over the past two decades (Shields Jr, 2003). The number of papers on river restoration is also rapidly increasing (Shields Jr, 2003), although most international publications focus on studies in North America and Europe.

In Japan, there already exists a large number of river restoration projects with a strong tendency of further increase. However, little is known or published about restoration in Japan. Gippel and Fukutome (1998) outlined the condition of Japanese rivers in the early 1990s. This paper explains the situation of early restoration projects in Japan well. River and wetland restoration in Japan, however, has progressed since then. Nowadays, many river restoration projects adopt a more holistic approach already at the planning stage, and river managers intensively cooperate with local stakeholders and researchers.

The aim of the present paper is to introduce the state-of-the-art river and wetland restoration in Japan. We start with an introduction of the natural, historical, and administrative situation of Japanese rivers. This is followed by an overview of agendas for river management. Finally, we present a number of representative case studies throughout the country.

Nature background

Japan has geologically young mountains, steep and short rivers with flashy flow regimes, and densely populated floodplains (Yoshimura, in press). Three-quarters of the total land area (377,800 km^2) has slopes >15° (Kornhauser, 1982), and more than 70 % of the country is covered by mountains. Japan is located in the Circum-Pacific Volcanic Belt called the "Ring of Fire" (Iyama, 1993). There are č100 active volcanoes in Japan. Therefore, volcanic eruptions and seismic activities quite frequently produce high sediment yields. Japan suffers from frequent heavy storms. The average annual rainfall is 1,714 mm (1966-1995) exhibiting high seasonality. Generally, the Pacific side of Japan has heavy rain in June and July (rainy season) and between August and October (Typhoons). On the side of the Japan Sea flow peaks during the snowmelt period in spring. The combination of steep catchments and heavy storms results in widespread hillslope failures and landslides and extensive flood discharges (Oguchi, 2001).

History of river management in Japan

Japanese river ecosystems are strongly shaped by paddy fields and irrigation systems. Rice cultivation started ca 2,500 years ago and gradually expanded all over the country. The development of large river floodplains commenced before and during the early Edo Period (1603-1867). During the Edo Period, most alluvial plains were transformed into paddy fields (Kornhauser, 1982).

Modern river management started soon after the Meiji Restoration (1868). In 1896 the first River Law was enacted for flood control after a series of damaging floods in the 1890s (Takeuchi, 2002; Gippel and Fukutome, 1998). The enforcement of the River Law made it possible to control floods by the central government. Until the early Showa Period (middle of 1930s), the courses of all major rivers were engineered.

Rivers and their catchments have rapidly been altered since the Second World War because of flood control works, water resource development, and very fast economic and social development. Just after the Second World War, disastrous typhoons struck Japan almost every year. Indeed, large typhoons and heavy rains killed ~20,000 people between 1945 and 1960 (FRICS, 2002). Therefore, the government commenced urgent long-term flood control projects. The flood casualties have decreased since then. However, flood control measurements rapidly modified the river channel environment. In addition, high economic growth produced new agendas for river management such as water resources development, urbanization, and water pollution.

The New River Law enacted in 1964 included new articles on water resources development. Dam constructions for hydropower generation, water resource management, and flood control increased after the 1950s, causing both environmental and social problems. Water pollution peaked in the 1970s, and the Basic Law for Environmental Pollution Control was enacted in 1967. Nowadays, more than 80 % of river waters meet the environmental standards (MLIT, online).

The energy crisis in the early 1970s stopped rapid economic growth, and the Japanese people started to recognize the importance of their natural resources. At that time rivers provided the last open space in urban areas. People demanded to use river space for amenities and recreation. "*Shin-sui*" - playing with water - was the keyword at that time. Many playgrounds and "*Shin-sui*" parks were built along rivers in the 1970s. Landscape improvement projects were also carried out though they were not ecologi-

cally sound projects. In any case, these projects turned people's eyes to the "nature" environment. People realized that they had destroyed nature too much and they felt the necessity for conservation and restoration. At the same time, the River Bureau, Ministry of Construction (Ministry of Land, Infrastructure, and transport (MLIT) since 2001), the authorities for river management, officially mentioned the importance of the river environment as well as of flood control and water resource management in the report of the River Council in 1981. Some pioneer works for river environment were also carried out in the 1970s and 1980s, e.g. the firefly revetment at the Ichinosaka River (1974) and the rehabilitation of urban river at the Itachi River (1982) (Shimatani, 2000).

The River Bureau, launched the initiative "Nature-Oriented River Work" or "*Ta Shizen Gata Kawa Zukuri*" in 1990. It means, literally, "More-nature-type River Works." The project aims to conserve beautiful landscapes and the rich biodiversity in rivers. The project is strongly influenced by "Naturnaher Wasserbau" (Near-natural river engineering (Yamawaki, 2000)) of the Canton Zurich in Switzerland and of Bavaria in Germany. The year 1990 was a turning point for river management in Japan. To date, more than 20,000 projects of "nature-oriented river works" have been completed (MLIT, 2003). This trend was reinforced by the amendment of the River Law in 1997. "Conservation and Improvement of River Environments" was inserted in Article 1 as the principal purposes of the River Law. This amendment also includes an increased involvement of the public and of stakeholders. Since then, additional laws related to nature conservation and restoration have been enacted or amended such as the Nonprofit Activities Promotion (NPO) Law (1998), Seacoast Law (1999), Environment Impact Assessment Law (1999), Land Improvement Law (2001) to mention a few. In particular, the Nature Restoration Promotion Law (2003) is an important law for nature restoration. This law aims to restore the damaged nature and also demands the participation of various stakeholders and requires a sound scientific approach. According to these trends, many nature restoration projects have been initiated since the beginning of the 21st century. Among these projects, river restoration projects are most advanced in terms of quality and quantity.

River management

In Japan almost all major rivers are managed by the central government, i.e. the River Bureau of the Ministry of Land, Infrastructure, and Transport (MLIT). The River Law (amended in 1997) is the basic law for river management. In the order of importance rivers are classified into four groups: Class A Rivers, Class B Rivers, Secondary Rivers, and Regular Rivers. The central government manages Class A Rivers (109 catchments in total). All other rivers are within the domain of the prefectural and municipal government. For the fiscal year 2004 the annual budget of the Central River Bureau amounts to 1,740 billion yen (ca 16.6 bil. USD), of which 131 billion yen (ca 1.2 bil. USD) are being spent for the maintenance and restoration of the natural environment (MLIT, online). The MLIT has ten regional bureaus, and each regional bureau has control over some dozen of local "River Offices" for the management of Class A Rivers.

Agendas for river restoration

Flood Control

Although flood damage has decreased, flood control is still one of the most important issues of national security. Indeed, even nowadays every year (1991-2000) in average

č100 persons are victims of typhoons and floods (FRICS, 2002). The total economic flood damage averages 677 billion yen (ca 6.4 billion USD) per year (1991-2000) (MLIT, online). The protection level against floods is still lower in Japan compared to most OECD countries. Only 66 % of all major rivers are safe for 30 to 40-year floods (WEC, online). To make matters worse, flood patterns seem to be changing these days. Heavy rains >100 mm per hour are more frequent since the beginning of the Heisei era in 1989. Flooding of underground area is recently becoming a serious problem. For example, flooding of the underground shopping area in Fukuoka city in 1999 killed one person and caused enormous economic damage (Takeuchi, 2002). Confronted with these problems, the MLIT has shifted its main emphasis to urban inundation and extreme flows. Nowadays, even in very flood prone areas, river mangers must consider environmental and flood control aspects simultaneously, which demands a high level solution for not only managers but also researchers.

Biodiversity

Human impacts such as river engineering, agricultural development, alien species introduction, and urban development have degraded the aquatic biodiversity throughout Japan. The introduction of alien species is one of the most serious threats for riparian ecosystems. Invasion of plants is facilitated by the extensive environmental change of rivers including the truncation of seasonal floods, abandoned traditional vegetation management, water pollution, and extensive recreational land use. Gravel-bed rivers and moist tall grasslands contain a high proportion of threatened riparian plants (Washitani, 2001). Countermeasures against alien species have been taken recently. Degradation of ecological networks also threatens the riparian biodiversity in Japan. The continuous levees resulting from river engineering have fragmented lateral continuity of habitats, and dams or weirs have interrupted longitudinal connectivity. The modern agriculture system for paddy fields and its irrigation have also negatively affected the ecological network.

Loss of dynamics

Most Japanese rivers exhibit reduced flow and sediment dynamics. As a main consequence, the encroachment of former gravel-bed rivers by riparian trees is a key problem throughout the country. By comparing aerial photographs from the 1950s with those from the 1990s one can quantify these modifications. In the 1950s river channels were covered by bare gravel and sand (exposed riverine sediments: ERS). These habitats are often absent in the 1990s photographs. The main reasons for the disappearance of ERS are: (i) a stabilized flow regime, (ii) river bed degradation by gravel excavation during the rapid economic growth period, (iii) artificial creation of two-stage riverbeds, (iv) truncation of the sediment transport by so-called “Sabo” dams (sediment control dams), hydropower dams, weirs, and by the afforestation of mountain slopes after the Second World War. Today, ERS are highly endangered landscape elements in Japan. They are of primary conservation and restoration interest. Therefore, increasing river dynamics without threatening human life has emerged as a new agenda. New dams, for instance the Unazuki and Dashidaira dams, are equipped with sediment flushing facilities to maintain a near-natural sediment transport regime. Since 1988, the rehabilitation of natural flow regimes has also been carried out downstream of dams by a governmental order. Since that period, the flow regime of č3,100 km Class A Rivers has been partially restored (Okayama, 2001).

Restoration in practice

Outline

River restoration projects have been carried out for a variety of objectives. In the 1990s, projects were primarily stimulated by flood defense measures, although a simultaneous enhancement of the environment was desirable. In the 2000s, the improvement of the ecological integrity has become the main objective for restoration. Methods have shifted from small-scale restoration schemes (habitats) to the management of entire ecosystems (management of the flow and sediment regimes). Gippel and Fukutome (1998) provided an overview of restoration projects prior to 1990. Unfortunately, very few projects in the 1990s have been evaluated. Well-designed pre- and post-project appraisals have been planned only for very recent projects. Below, we introduce three representative restoration projects. In addition to these projects, numerous interesting projects are in progress throughout Japan. For example, the Kita River project in Kyusyu attempts to conserve precious riparian ecosystems though urgent flood protection is also required (Ikeuchi, 2003). Tidal wetland restoration projects are conducted at the river mouths of the Ara (Tokyo) and Ibi (near Nagoya) Rivers (Suzuki, 2003). The "Azame no se" project in the Matsuura River Basin (Kyusyu) is an excellent example for a popular participant project. Generally, NPOs are not well established in Japan compared to most developed countries. On the other hand, local people are often acting as volunteers for river conservation projects, which is not only important for consolidating local communities but also for communication across generations.

Restoration of a gravel-bed river: The Tama River

The 135.6 km long gravel-bed Tama River (Tokyo area) has a catchment of 1,248.6 km^2 and a human population of 4.4 million. The Tama River exemplifies the problems typical for Japanese rivers, which include gravel excavation, dam construction, flow stabilization, loss of ERS, and the invasion of alien species. The restoration of the Tama River began in 2001 (Shimatani, 2003). Restoration focuses not only on the improvement of habitat heterogeneity but also on the restoration of ERS (Shimatani, 2003). The restoration area (Nagata) is situated on an alluvial fan. It has a slope of 0.46 %, a riparian width of 300 m and a channel width of 30 m. The Hamura weir, 0.5 km upstream of the restoration site, maintains a downstream constant flow of č2 m^3 s^{-1} except during flood events. In the last 20 years, the river shifted from braided gravel bed style to an incised stream with a forested terrace (Figure 1) (Shimatani, 2003). This geomorphic transformation was caused by (i) gravel excavation during the rapid economic growth period in the 1950s and 1960s, (ii) a decrease of sediment supply from upstream sections, and (iii) the stabilization of the flow regime by the construction of the Hamura weir (Shimatani, 2003; Minagawa, 1999). The two-staged river cross section has further enhanced fine sediment deposition on the river terrace and, therefore, decreased the gravel bed area (Lee, 1999). As a result, the density of native plants common to bare gravel sediments (e.g. *Aster kantoensis*) has declined. Simultaneously, alien woods (e.g. *Robinia pseudo-acacia*) have increased (Kuramoto, 1992).

The main goal of the project is the transformation of the woody and shrubby river channel back to a gravel bed channel. The sediment-hydraulic calculations and detailed historic analyses of river bed changes revealed the following main results (Shimatani, 2003): (i) River bed degradation is a consequence of a decreased sediment supply from

upstream sections (excavation), an enhanced sediment transport through the narrowed river channel, and the sediment trapping by the Hamura weir. (ii) Natural lateral bank erosion is prevented because the low-flow channel is covered with erosion-proof Neocene or Pleistocene soft rock. (iii) It will take a few hundred years to upgrade the river bed naturally at this area because of the huge sediment trap capacity of the Hamura weir. Therefore, it was concluded that artificial widening and the addition of sediments are necessary for restoring the gravel river bed. The restoration was conducted at two sites within a 1 km reach. At the upstream site the conservation of *Aster kantoensis*, an endangered species typical for ERS, was the main goal. Therefore, *Robinia pseudo-acacia* (an alien species) and fine sediment were removed. At the downstream site, a 2.4 x 10^4 m^2 gravel bed was restored. The inundation frequency of the restored gravel bed ranges from several times a year to every five years. To increase the sediment supply from upstream sections, sediment was artificially added at the upstream end (downstream of the Hamura weir). This program has just started, therefore, the success has not yet been evaluated.

Figure 1 Tama River (Nagata area) in 1974 (Left; courtesy of GSI) and in 1994 (Right; photo: PWRI)

Conservation of the Kushiro Mire

The Kushiro Mire in Hokkaido is the largest remaining wetland in Japan. It has an area of č20,000 hectares, which corresponds to č60 percent of the total wetland area of Japan. Although the Kushiro Mire is still one of the most natural landscapes in Japan (Figure 2), its area is rapidly shrinking. Moreover, increased sedimentation is transforming the reed-sedge community into an alder (*Alnus japonica*) dominated community (Nakamura, 2002; Nakamura, 2004). To develop countermeasures, the "Committee for the Conservation of the River Environment in the Kushiro Mire" was established in 1999. In 2001 the Committee presented a proposal for the conservation of the Kushiro Mire River (CCREKM, 2001). This proposal sets up the key targets for the next three decades, in particular that the mire should be preserved in the state of the year 2000. To achieve this goal, sediment yields from the catchment need to be reduced at least to levels recorded 20 years ago (CCREKM, 2001). This means that annual sediment transport needs to be reduced by 40 % (from 1400 m^3 to 800 m^3) and total nitrogen load by 30 % (Nakamura, 2003). To put the measures into practice, the Nature Restoration Council for the Kushiro Mire was founded in November 2003 under the Nature Restoration Promotion Law. The council consists of six subcommittees, and it is responsible for the planning and the operation of the restoration measures. Almost all the subcommittees carry out experiments or projects based on clear hypotheses (Nakamura, 2003).

Figure 2 Kushiro Mire (Photo: K. Nakamura)

Restoration of the littoral zone: Lake Kasumigaura

Lake Kasumigaura (ca 60 km northeast of Tokyo) is the second largest lake in Japan. The area of the lake and its catchment is 220 km^2 and 2,157 km^2, respectively. Mean water depth is, however, only 4 m. The lake is eutrophic. The lake vegetation has deteriorated since the 1970s because of water pollution, artificial bank construction, and water level control. The banks have been fortified and a barrage was built at the outflow, which artificially controls the water level for both flood defense and for maintaining water resources (industrial, drinking and irrigation water). From the 1970s to the 2000s, the area covered by emergent plants decreased by 50 %, submerged plants completely disappeared (former area: 700 x 10^4 m^2), and water transparency decreased from 150 to 30 cm. Algae blooms have also damaged the young shoots of emergent plants. The Kasumigaura River Office, MLIT, initiated large-scale lakeshore restoration measures in 2001. The rapid decline of "Asaza", *Nymphoides peltata*, was the main turning point. This project aims to conserve *Nymphoides peltata* and to restore lake littoral zones. The project is conducted in close cooperation between NPO groups, civil engineers, and ecologists. The alignment and slope (ca 1 to 100) of the lakeshore were designed using old reference maps, photos, and information from natural lakes. Excavated offshore bottom sediment was used for restoration. They were covered with a thin layer (10 cm) of littoral sediment that contained important "seed banks" for vegetation regeneration. Restoration work was completed in spring 2002. Surprisingly, vegetation has partially

recovered in summer 2002 (Figure 3). Many locally extinct plants successfully recovered by natural seed banks (Table 1) (Nakamura, online; Nakamura, 2002; Nishihiro, 2003). Indeed, *Chara* has appeared for the first time since 30 years. The success of this restoration project indicates that even locally extinct species can be restored, which again encourages those people who wish to restore nature in Japan.

Table 1 Occurrence of selected species before (1899-1999) and after (2002) restoration (Nishihiro, 2003)

	Year									
Species name	**1899**	**1958**	**1971**	**1972**	**1978**	**1996**	**1997**	**1998**	**1999**	**2002**
Chara braunii	o	o		o						o
Limnophila sessiliflora	o	o	o		o					o
Vallisneria denseserrulata		o	o		o					o
Hydrilla verticillata	o	o	o	o	o					o
Potamogeton oxyphyllus	o				o	o				o
Potamogeton perfoliatus	o	o	o	o	o		o			o
Vallisneria asiatica	o	o	o	o	o		o			o
Potamogeton malaianus	o	o	o	o	o	o	o	o		o
Potamogeton crispus	o	o	o	o	o		o	o		o
Ceratophyllum demersum	o	o	o	o	o			o		o
Potamogeton pectinatus	o	o	o	o	o			o		o

Figure 3 Lake Kasumigaura: Restoration of the littoral zone. Left: Banks are covered with concrete (during construction). Right: Recovery of natural vegetation (about three months after restoration) (Photos: K. Nakamura)

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