Chapter 12

Flood-Control Basins as Green Infrastructures: Flood-Risk Reduction, Biodiversity Conservation, and Sustainable Management in Japan

Nobuo Ishiyama, Satoshi Yamanaka, Keita Ooue, Masayuki Senzaki, Munehiro Kitazawa, Junko Morimoto, and Futoshi Nakamura

Abstract Green infrastructure (GI) is a strategic planning infrastructure that uses the functions of ecosystems. Under an increased river flood risk, flood-risk management utilizing GI is gaining attention from managers and ecologists in Japan. Flood-control basins are facilities that temporarily store river water in adjacent reservoirs to mitigate flood peaks and gradually drain the water back to the main channels after a flood. GI is expected to provide multiple functions, such as flood-risk reduction and habitat provisions. However, there are limited studies on the ecological functions of flood-control basins. In this article, we first introduce the characteristics of flood-control basins constructed in Japan. Next, we show the ecological importance of flood-control basins in terms of wetland organism biodiversity conservation. Finally, to aid the integration of GI into conventional flood-control measures, we highlight ecological and social issues about introducing and managing flood-control basins.

Keywords Climate change · Biodiversity conservation · Ecosystem-based adaptation · Ecosystem services · Flooding · Habitat connectivity · Sustainable development

N. Ishiyama (✉)

Forest Research Institute, Hokkaido Research Organization, Bibai, Hokkaido, Japan

S. Yamanaka

Hokkaido Research Center, Forestry and Forest Products Research Institute, Sapporo, Japan

K. Ooue

Environmental Policy Division, Ministry of Land, Infrastructure, Transport and Tourism, Tokyo, Japan

M. Senzaki

Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Hokkaido, Japan

M. Kitazawa · J. Morimoto · F. Nakamura

Graduate School of Agriculture, Hokkaido University, Sapporo, Hokkaido, Japan

12.1 Introduction

Among disasters triggered by natural hazards, flood disasters have been most frequently reported worldwide. Under a changing climate, an increased flood risk is predicted to affect human and economic losses globally (Dottori et al. 2018). Historical records from 1962 to 2011 in the central United States demonstrated an increase in flooding frequency (Mallakpour and Villarini 2015). In Europe, peaks of 1/100 river floods are projected to double in frequency within the next three decades (Alfieri et al. 2015). Jongman et al. (2012) reported that the amount of the global population exposed to a 1/100 river flood reached 800 million by 2010, of which 73% was living in Asia. Moreover, Dottori et al. (2018) estimated that the population exposed to flooding will increase as a result of anthropogenic warming; an average increase of more than 120% is expected in a 3 °C-warming scenario.

Considering the increased disaster risk, adaptation efforts for flood-risk management are urgently needed. In Japan, heavy rainfall events (e.g., those above 50 mm/h) have increased in the last half a century (Fig. 12.1), and a flood disaster with the most severe economic damage occurred in 2019 (Fig. 12.2). Typhoon Hagibis in 2019 bore down on central Japan and caused 19 billion USD in economic damage. The heavy rainfall event caused 142 levee collapses and overflowed along rivers managed by the Japanese government, resulting in ca. 25,000 ha of inundated land. Flood-control measures in Japan have focused on the construction of dams and artificial levees for the last century. These conventional gray infrastructures usually

Fig. 12.1 Historical occurrence of heavy rainfall events in Japan. The number of monitoring sites is 1300. In the first decade (1976–1985) and last decade (2010–2019), the mean annual occurrences were 226 and 327, respectively. (Data are provided by the Japan Meteorological Agency (https://www.data.jma.go.jp/cpdinfo/extreme/extreme_p.html))

Fig. 12.2 Historical economic damage caused by flood disasters in Japan. (Data are provided by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (<https://www.mlit.go.jp/report/press/content/001359046.pdf>))

assure 100% disaster protection until the magnitude of the disaster reaches an upper limit determined by the prevention plan, but the function will completely fail once the magnitude exceeds the upper limits (Nakamura et al. 2020). Against the backdrop of global warming, it has been widely recognized that conventional measures that depend highly on gray infrastructures are no longer adequate for flood-risk management. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has started to shift conventional measures to basin-wide flood-risk management that focuses on both river and floodplain management using green infrastructure (GI).

GIs are conceptually classified into fundamental GI (GI-1) and multilevel GI (GI-2) (Nakamura et al. 2020; see Chap. 2 for details). In flood-risk management, GI-1 are natural ecosystems, and GI-2 are seminatural basins that reduce or delay river flooding. In 2016, Hokkaido Island was hit by three typhoons in one summer, which was the first time this occurred since records began in 1952. Nakamura et al. (2020) analyzed Kushiro wetland’s water retention function (GI-1), the largest remnant wetland in Japan. Their study reported that a hydrograph of the simulation case of a partial loss of wetlands (ca. 55% loss) showed 1.5 times higher peak discharge and a 2-day-faster peak arrival. However, natural wetlands have been globally reduced by human activities (Davidson 2014), and the importance of GI-2 would increase in regions where the function of natural ecosystems is degraded. Considering the effectiveness of GI, MLIT tries to integrate both gray and green infrastructures (GI-1 and GI-2) into basin-wide flood-risk management to adapt to the increasing hazard risk. This combination of different GIs is referred to as “hybrid infrastructures” in Nakamura et al. (2020) (see Chap. 2).

In Japan, flood-control basins are rapidly gaining attention as a practical multi-level GI (GI-2). Multifunctionality is a fundamental property of sustainable GI (Lovell and Taylor 2013; Wang and Banzhaf 2018). Biodiversity conservation in a changing climate and landscape is another key challenge, and GI can be a tool for mitigating or restoring declined biodiversity (Nakamura et al. 2020). In this article, we first introduce the characteristics of flood-control basins constructed in Japan. Next, we show the ecological importance of flood-control basins in terms of wetland organism biodiversity conservation. Finally, to aid the integration of GI into conventional flood-control measures in Japan, we would like to raise ecological and social issues about introducing and managing flood-control basins. We believe that this chapter provides insight into the future management of flood-control basins in other Asian countries experiencing rapid urbanization and increased flooding risk.

12.2 Flood-Control Basins in Japan

There are two types of flood-risk management using retention/detention ponds. The first is to store rainwater in floodplain areas to reduce runoff into the main channels and mitigate the flood peak in farmland and urban areas. Urban retaining ponds are examples, and rice paddies also may serve a similar function. Another is to temporarily store river water in adjacent reservoirs to mitigate the flood peak and gradually drain the water back into the main channels after the flood. The latter type is called “*Yusuichi*” in Japanese. In this chapter, we focus on *Yusuichi* and represent it as a flood-control basin.

Flood-control basins generally consist of reservoirs surrounded by artificial levees and an overflow embankment or sluice gate adjacent to rivers (Fig. 12.3). Reservoirs of flood-control basins are used for various purposes, such as sports

Fig. 12.3 Illustration of a flood-control basin. (Adapted from materials provided by the Hokkaido Regional Development Bureau (https://www.hkd.mlit.go.jp/sp/kasen_keikaku/kluh40000001qfy.html)). (a) Normal flow. (b) High flow

grounds, farmland, urban parks, and wildlife habitat, and the presence or absence of permanent water varies depending on the region and the type of usage. In Japan, flood-control basins have been constructed nationwide (Suwa and Nishihiro 2020), and their construction is also planned in several regions to reduce flood risks (e.g., Hitachi River and National Highway Office 2020; Kumamoto Prefecture 2020). These flood-control basins are reported to have mitigated the disaster risk level. For example, the four flood-control basins located in the Tone and Watarase rivers in central Japan are estimated to have stored 250 million cubic meters of river water during Typhoon Hagibis in 2019, resulting in mitigating flood damage downstream (Tone River Upstream Office 2020).

Flood-control basins are also assumed to provide alternative habitats for wetland species. Suwa and Nishihiro (2020) demonstrated that most flood-control basins in Japan are located in floodplains and that 88% of them have natural observation areas, paddy fields, reed marshes, or water surfaces, suggesting that they can potentially provide wetland environments. Therefore, there is a possibility that flood-control basins can be used not only for disaster risk reduction but also for regional biodiversity conservation.

12.3 Case Study: Biodiversity Conservation in Flood-Control Basins

Flood-control basins are assumed to contribute to maintaining regional biodiversity and thus can work as GI. For example, the Watarase flood-control basin in central Japan was designated as a Ramsar site having the largest reed bed and provides wetland habitats for many species, including endangered species (Ministry of Environment of Japan 2020b). However, there are limited studies assessing the importance of flood-control basins for regional biodiversity conservation. Therefore, we examined wetland species in flood-control basins recently implemented in the Chitose River basin in Hokkaido, northern Japan (Yamanaka et al. 2020).

In this region, river flooding often occurred because of the gentle riverbed slope (1/7000 on average). In particular, a heavy rain event in August 1981 led to flooding and caused severe damage to urban areas and farmlands in this region (Hokkaido Regional Development Bureau 2018; Segawa et al. 2008). To mitigate flood risk, MLIT drove the construction of six flood-control basins near the main stream and tributary of the Chitose River (Fig. 12.4). Construction started in 2008 and finished in 2020. The reservoirs of the basins comprise a total of 1150 ha, and they have wetland environments where river water accumulates, except in areas used for pasture and other purposes (Fig. 12.5). In the Chitose River basin, agricultural land use, such as rice paddies and cropland, dominates, and there are many watercourses for irrigation. The expansion of agricultural land in this area began approximately 100 years ago, and most of the natural wetlands have been converted to farmland (GSI 2000), resulting in a massive decrease in habitats

Fig. 12.4 Location of the Chitose flood-control basins

for wetland species. Therefore, flood-control basins consisting of new wetland environments are expected to provide alternative habitats for wetland biota.

We examined the species composition of four wetland taxa, fish, aquatic insects, birds, and plants, in five flood-control basins in summer 2016 (Yamanaka et al. 2020). In 2016, the construction of the basins was not completed except for the Maizuru basin (the construction of all basins was completed and operations started in 2020). Thus, we surveyed the above taxa in a part of the reservoir of each flood-control basin. We also examined the species composition of three other waterbodies in this area (channelized watercourses, drainage pumping stations, and remnant floodplain ponds) to compare the species compositions with those of flood-control basins.

We found that flood-control basins have a comparable or higher species richness and abundance of wetland species than other waterbodies (e.g., remnant floodplain ponds and drainage pumping stations) (Fig. 12.6). We also found that flood-control basins were characterized by some pioneer species that preferred shallow water or adapted to fluctuations in water levels (e.g., herbivorous insects, shorebirds, and hygrophyte plants). However, channelized watercourses, which are widely distributed in the study region, have lower species richness and abundance (Fig. 12.6). This result could be because of their simplified habitats led by channelization.

Fig. 12.5 Chitose flood-control basins

We also found some red list species of each taxon in flood-control basins although there was lower abundance and richness than those in drainage pump stations and remnant floodplain ponds. These results suggest that flood-control basins provide alternative habitats for wetland species, including endangered species. Nevertheless, for fishes, we observed a high abundance of nonnative species, such as *Pseudorasbora parva* and *Rhodeus ocellatus ocellatus*, in some flood-control basins (Fig. 12.6b).

In the Maizuru flood-control basin, whose construction finished in 2016, the breeding of the red-crowned crane, *Grus japonensis*, was observed in 2020 (Ministry of Environment of Japan 2020a). The red-crowned crane is an endangered species whose population in Japan experienced a significant decrease approximately 100 years ago, and is one of the flagship wetland species in Japan. The Ministry of the Environment has implemented conservation measures for this species, such as promoting breeding, and the distribution area is expanding from the east to the west of Hokkaido Island. Therefore, flood-control basins are also expected to contribute to the dispersal and recolonization of this species into uncolonized areas.

Our findings suggest that newly created environments in the Chitose flood-control basins provide suitable habitats for wetland species. However, there is room for future research to evaluate the ecological function of flood-control basins.

Fig. 12.6 (continued)

Fig. 12.6 (continued)

Fig. 12.6 Estimated species richness and abundance of four taxa; **(a)** native fishes, **(b)** nonnative fishes, **(c)** aquatic insects, **(d)** birds and **(e)** plants. *CW* channelized watercourse, *DPS* drainage pumping station, *POND* remnant pond, *FCB* flood-control basin. Black circles denote values estimated by generalized linear models (GLMs). The whiskers indicate the 95% confidence interval (CI). Gray circles denote each observed value. Different letters indicate significant differences in the multiple comparison analysis ($p < 0.05$). The values for species richness and coverage of vegetation indicate values per quadrat (2×2 m). (See Yamanaka et al. (2020) for details)

First, Yamanaka et al. (2020) limited the study season to summer. The importance of flood-control basins for biodiversity conservation can vary with the studied season because wetland species use different environments in different seasons. For example, the importance of flood-control basins as spawning sites for some fishes in spring and as stopover sites for immigrant birds in spring and autumn was not examined in a previous study. Second, Yamanaka et al. (2020) did not consider wetland-plant succession. Accumulated sediment delivered with flooding in reservoirs will change the water level, which could change the vegetation types from hydrophytic to terrestrial plants. Such changes in vegetation will affect habitat qualities for other wetland organisms. For effective biological conservation using flood-control basins, further studies are needed to assess the species composition of flood-control basins with different seasons, and the succession should be monitored over a long-term period.

12.4 Future Issues for the Construction and Management of Flood-Control Basins

12.4.1 *Social Issues for Construction*

To adapt to increased disaster risks caused by climate change, the planning and construction of flood-control basins are urgently needed in Japan. Nevertheless, the construction of flood-control basins in floodplain areas tends to be costly in terms of both time and money. The construction of flood-control basins requires a large space around rivers; however, most areas of floodplains in Japan are used for residential areas and farmland. Managers therefore spend much time negotiating with landowners to acquire land for construction. For the Chitose flood-control basins, lands for each basin were owned by approximately 50 people, and it took 3 years for the land acquisition process. Managers can leave private lands, such as farmland, within reservoirs, but the approach could be costly because they need to establish easements for private lands and provide momentary compensation to landowners. Therefore, a pre-investigation of information on landowners is essential for construction to start quickly. It is not always possible to construct a large flood-control basin due to many landowners and stakeholders (e.g., nature conservation groups), while a large storage capacity is needed for flood-risk management. In such cases, managers need to consider more feasible plans, such as selecting sites for multiple small basins to achieve the total desired storage capacity.

Another solution for rapid construction is utilizing unused land, such as abandoned farmland. Farmland was abandoned after the period of economic growth in the 1950s and 1960s in developed countries, including Japan (e.g., Kobayashi et al. 2020). The use of such degraded lands with depopulation is increasingly recognized as a tool for biodiversity conservation (Ishiyama et al. 2020a; Nakamura et al. 2020). For example, Nakamura et al. (2020) proposed a prioritization technique for construction sites by estimating the distribution of abandoned farmland and the biodiversity of wetland organisms (e.g., birds and plants). In their study, created maps overlapped with a flood hazard map for selection and revealed a financially and ecologically high-priority area.

12.4.2 *Ecological Issues for Constructions*

GI is defined as “a strategically planned network of natural and seminatural areas with other environmental features designed and managed to deliver a wide range of ecosystem services” (European Commission 2013). In human-modified floodplains, the contemporary migration of wetland organisms has been spatially restricted (e.g., Ishiyama et al. 2015b). However, artificial watercourses and remnant wetlands create a seminatural wetland network in current landscapes, and landscape connectivity supports the high biodiversity of wetland organisms (Ishiyama et al.

2014, 2015a). Flood-control basins provide large open water spaces compared to other lentic waterbodies in human-modified floodplains (Yamanaka et al. 2020), suggesting that the construction of flood-control basins potentially contributes to enhancing a habitat network of wetland organisms by interacting with the existing lentic waterbodies (Ishiyama et al. 2017). Spatial network analyses can be a solution for creating “a strategically planned network” (Hermoso et al. 2020). One of the simple methods is site-scale measures that consider direct connections between the focal habitat patch and surrounding patches. The nearest neighbor connectivity measure (e.g., the distance between the focal habitat patch and the nearest patch) and the buffer measure (e.g., the summed area of the habitat patch within a circle around the focal habitat patch) are typical examples (Moilanen and Nieminen 2002). The site-scale measures require little data because the method is simple, as mentioned above, which is a positive aspect of the method for practitioners in the spatial planning of flood-control basins. However, the measures potentially evaluate the connectivity of candidate sites with low precision, especially for highly mobile animals such as insects and waterfowls. This is because the dispersal ranges of such animals are not restricted to the area around the focal habitat patch; they seasonally use multiple patches in the landscape by using stepping-stone patches. That is to say, both direct and indirect connections among habitat patches should be assessed for such animals. Alternatively, regional-scale measures can prioritize candidate sites for flood-control basin construction by considering the importance of stepping-stone habitats (e.g., Saura and Rubio 2010). For instance, a graph-theoretical approach can calculate overall connectivity (i.e., regional-scale habitat availability) by considering the spatial position and size of habitat patches (Saura and Torné 2009). By using the regional-scale measure, practitioners can assess the importance of individual patches in maintaining the entire habitat network (e.g., Ishiyama et al. 2014, 2015a). However, the regional-scale measures may be more strenuous for practitioners compared to buffer measures due to more complicated operations for creating a landscape graph and matrix calculations. More effective sites for improving existing wetland networks can be selected by using the network measures according to the species traits of conservation targets and available conservation resources.

However, improving a habitat network can have adverse effects on indigenous species. A key reason for the species decline is expanding introduced species (Rudnick et al. 2012). We therefore should carefully select the construction sites of flood-control basins and the connections with other waterbodies in consideration of the potential negative impacts. In northern Japan, many floodplain waterbodies, such as oxbow lakes and backswamps, are invaded by a small invader cyprinid, *Pseudorasbora parva*. Cyprid abundance is higher in waterbodies with high hydrologic connectivity (Ishiyama et al. 2020b). Ishiyama et al. (2020b) showed that populations of the endangered minnow *Rhynchocypris percunurus sachalinensis*, which has an ecological niche similar to that of *P. parva*, decline with the invasion of *P. parva*, suggesting that small isolated waterbodies function as refuges for the endangered minnow (Fig. 12.7). Nevertheless, small isolated habitats are easily diminished and degraded by human activities. Considering the importance of small-

Fig. 12.7 Biological invasion in a wetland network and decline in endangered species. Example of *P. parva* and *R. p. sachalinensis* in the Tokachi floodplain, northern Japan. (See Ishiyama et al. (2020b) for details)

isolated waterbodies, such remnants should be preserved when managers plan the construction of flood-control basins (Fig. 12.8). As previously mentioned in the third section, we should also remember that the creation of flood-control basins can support the establishment of nonnative species and create new sources for the secondary spread of these species to connected waterbodies in wetland networks.

12.4.3 Sustainable Management of Flood-Control Basins

Various management practices are needed to fulfill both functions of flood-control basins (i.e., disaster risk reduction and habitat provision). In the Maizuru and Watarase flood-control basins, managers have taken measures to conserve endangered species, such as making a breeding site and eliminating invasive species (Chino and Mizuno 2019; MLIT Kantou Regional Development Bureau 2020a). In addition, the Maizuru flood-control basin is legally protected as a wildlife reserve area by the Hokkaido government. Long-term maintenance of wetland environments is also a vital issue for sustaining functions. The accumulation of dead reed plants

Fig. 12.8 Network thinking in biodiversity conservation using flood-control basins. Improvement of existing wetland networks and preservation of small isolated wetlands should be strategically conducted

and the establishment of pioneer tree species can change the setting in flood-control basins from fen to swamp dominated by *Salix* spp., which will decrease the flood-control capacity and amount of habitat for wetland organisms. For example, wetland environments in the Asahata flood-control basins, Shizuoka prefecture, have dried, and the habitat used by endangered wetland species is shrinking (Shizuoka prefecture 2017). Control burning is one of the historical measures for preventing vegetation succession in Japan. In some Japanese flood-control basins, from winter to early spring, control burning is conducted by local communities, including the government, nonprofit organizations (NPOs), and residents, to maintain the function (e.g., MLIT Kantou Regional Development Bureau 2020c). Creating open water and an extended hydroperiod by dredging accumulated sediment and organic material is another option for wetland management (e.g., Stevens et al. 2003). In the Watarase flood-control basin, dredging works were conducted to restore a heterogeneous wetland landscape (MLIT Kantou Regional Development Bureau 2020d). Wetlands with different flood frequencies and multiple open waters were created by this work, which contributed to restoring floodplain vegetation (Ishii et al. 2011) and foraging

sites for a top avian predator, the eastern marsh harrier *Circus spilonotus* (Hirano 2015).

As mentioned above, various types of management are necessary for maintaining the functions of flood-control basins. However, the running cost for deteriorated gray infrastructure is increasing (Council for Social Infrastructure 2020), and it is difficult for the government alone to sustain GI functions. Cooperative management of flood-control basins among the government, researchers, the private sector, NPOs, and residents will be essential to maintain the multiple functions of flood-control basins. For the Watarase flood-control basins, the government has established a council for management that aims to conserve and sustainably use wetland environments. The council is composed of multiple organizations, such as NPOs and local governments, and conducts biological monitoring and environmental education to help local residents to understand the importance of wetland environments and participate in maintenance (MLIT Kantou Regional Development Bureau 2020b). The attraction of private investment to flood-control basins has received growing attention as a useful tool for sustainable management. The council of the Watarase flood-control basin established the fund “Watarase-Mirai-Kikin” in 2001 and raises funds from private companies that are interested in environmental, social, and governance (ESG) investment and corporate social responsibility (CSR). This fund is used for sustainable management, such as restoration of wetland environments and human resource development. In March 2020, MLIT launched the GI Public-Private Partnership Platform to manage GI, including flood-control basins, more sustainably. The platform is organized by multiple stakeholders, such as national and local governments, private companies, research institutes, NPOs, and citizens. Working toward sustainable and attractive city development using flood-control basins, the platform is working on promoting GI, developing construction and management technologies, and financing techniques.

The gap between conservation science and real-world action is a genuine phenomenon (Knight et al. 2008; Osawa and Ueno 2017). The research-implementation gap will impede the success of the sustainable management of flood-control basins regardless of how many academic papers are published. Knight et al. (2008) observed that “conservation planners must facilitate a solution to a specific practitioner’s need; it is generally not effective to conduct a conservation assessment and then attempt to promote it post hoc to a practitioner.” For the Watarase flood-control basins, MLIT established a committee for conserving wetland environments, composed of both practitioners and researchers, that held multiple meetings to develop the restoration plan. One of the key benefits of establishing the committee is facilitating interactions between researchers and practitioners. In such a committee, researchers can formulate research questions collaboratively with stakeholders and understand specific practitioner’s needs and implementation constraints. Indeed, the information on potential impacts of topsoil dredging on the distribution of threatened plant species assessed by one of the committee members (Obata et al. 2012) delivered a management plan for the flood-control basin; practitioners selected dredging sites by referring to the academic evidence.

12.4.4 Importance of Multifunctionality

In this chapter, we introduced that flood-control basins can have environments similar to those of natural wetlands, providing important functions for humans and living organisms (i.e., flood-risk reduction and habitat provision). However, natural wetlands (GI-1) are multiple-value systems (Mitsch and Gosselink 2000) and provide more functions for humans, such as water quality improvement and recreational activities. In future flood-risk management, we should also focus on such functions and wisely utilize flood-control basins (GI-2) to increase residents' quality of life.

In Japan, some flood-control basins located around cities are used for public parks with green spaces (e.g., the Tsurumi River flood-control basins). A growing body of literature has emphasized the importance of people's green space use for mental health during the COVID-19 pandemic (e.g., Soga et al. 2020). Considering lifestyle changes after the global pandemic, flood-control basins around cities can serve as good health and physical resources for citizens. As previously mentioned in the third and fourth sections, spatial planning of flood-control basins would benefit wetland organisms in terms of improving habitat networks. Humans will also profit from the strategic restoration of habitat networks through recreational activities such as fisheries and birdwatching.

Flood-control basins with wetland environments can be a mitigation tool for improving water quality in river networks. Recent work in the USA has shown that a spatially targeted increase in wetland area by 10% (i.e., wetlands are preferentially placed in areas with the highest nitrate surplus) would double wetland nitrate removal (Cheng et al. 2020). For example, farmland expansions in northern Japan cause a decline in juvenile *Oncorhynchus masou*, which is one of the key fishery resources, through nutrient enrichment (Ishiyama et al. 2020a). Strategic spatial planning of flood-control basins can mitigate such degradation in river ecosystems and their delivered services.

As mentioned above, flood-control basins can bring various benefits inside and outside of the GI and possibly contribute to improving residents' quality of life. However, ecosystem services can have trade-off relationships with each other (Bennett et al. 2009). To maximize the multiple functions of flood-control basins and manage them sustainably, scientists and managers should further understand the relationships among the provided functions and the mechanisms behind the relationships.

References

- Alfieri L, Burek P, Feyen L, Forzieri G (2015) Global warming increases the frequency of river floods in Europe. *Hydrol Earth Syst Sci* 19(5):2247–2260
- Bennett EM, Peterson GD, Gordon LJ (2009) Understanding relationships among multiple ecosystem services. *Ecol Lett* 12(12):1394–1404

- Cheng F, Van Meter K, Byrnes D, Basu N (2020) Maximizing US nitrate removal through wetland protection and restoration. *Nature*:1–6
- Chino SK, Mizuno H (2019) Environmental monitoring in the Maiduru flood-control basin (in Japanese). <https://www.hkd.mlit.go.jp/ky/jg/gijyutu/splaat000001t2er-att/splaat000001t2op.pdf>. Accessed 15 Jan 2021
- Council for Social Infrastructure (2020) 44th Planning committee: socioeconomic conditions surrounding social infrastructure development (in Japanese). <https://www.mlit.go.jp/policy/shingikai/content/001342849.pdf>. Accessed 15 Jan 2021
- Davidson NC (2014) How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar Freshw Res* 65(10):934–941
- Dottori F, Szewczyk W, Ciscar J-C, Zhao F, Alfieri L, Hirabayashi Y, Bianchi A, Mongelli I, Frieler K, Betts RA (2018) Increased human and economic losses from river flooding with anthropogenic warming. *Nat Clim Chang* 8(9):781–786
- European Commission (2013) Green Infrastructure (GI) — Enhancing Europe’s Natural Capital. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249>. Accessed 15 Jan 2021
- GSI (2000) National survey of lakes and wetlands. Geospatial Information Authority of Japan (GSI). <http://www.gsi.go.jp/kankyochiri/shicchimenseki2.html> (in Japanese). Accessed 25 April 2018
- Hermoso V, Morán-Ordóñez A, Lanzas M, Brotons L (2020) Designing a network of green infrastructure for the EU. *Landscape Urban Plann* 196:103732
- Hirano T (2015) The effects of newly created ponds on hunting flights of eastern marsh harriers during the wintering season (in Japanese with English abstract). *Bird Res* 11:a21–a30
- Hitachi River and National Highway Office (2020) Emergency flood control project in the Kuji River and the Naka River (in Japanese). <https://www.ktr.mlit.go.jp/hitachi/hitachi00814.html>. Accessed 26 Dec 2020
- Hokkaido Regional Development Bureau (2018) Initiatives for river development: flood control measures in the Chitose River Basin. https://www.hkd.mlit.go.jp/sp/kasen_keikaku/kluhh40000001qfy.html. Accessed 25 April 2018
- Ishii J, Hashimoto L, Washitani I (2011) Early vegetation growth in an experimental restoration site in the Watarase wetland. *Jpn J Conserv Ecol* 16:69–84
- Ishiyama N, Akasaka T, Nakamura F (2014) Mobility-dependent response of aquatic animal species richness to a wetland network in an agricultural landscape (in Japanese with English abstract). *Aquat Sci* 76(3):437–449
- Ishiyama N, Koizumi I, Yuta T, Nakamura F (2015a) Differential effects of spatial network structure and scale on population size and genetic diversity of the ninespine stickleback in a remnant wetland system. *Freshwat Biol* 60(4):733–744
- Ishiyama N, Sueyoshi M, Nakamura F (2015b) To what extent do human-altered landscapes retain population connectivity? Historical changes in gene flow of wetland fish *Pungitius pungitius*. *R Soc Open Sci* 2(7):150033
- Ishiyama N, Nagayama S, Iwase H, Nakamura F (2017) Restoration techniques for riverine aquatic connectivity: current trends and future challenges in Japan (in Japanese with English abstract). *Ecol Civil Eng* 19:143–164
- Ishiyama N, Miura K, Inoue T, Sueyoshi M, Nakamura F (2020a) Geology-dependent impacts of forest conversion on stream fish diversity. *Conserv Biol*
- Ishiyama N, Miura K, Yamanaka S, Negishi JN, Nakamura F (2020b) Contribution of small isolated habitats in creating refuges from biological invasions along a geomorphological gradient of floodplain waterbodies. *J Appl Ecol* 57(3):548–558
- Jongman B, Ward PJ, Aerts JC (2012) Global exposure to river and coastal flooding: long term trends and changes. *Glob Environ Chang* 22(4):823–835
- Knight AT, Cowling RM, Rouget M, Balmford A, Lombard AT, Campbell BM (2008) Knowing but not doing: selecting priority conservation areas and the research–implementation gap. *Conserv Biol* 22:610–617

- Kobayashi Y, Higa M, Higashiyama K, Nakamura F (2020) Drivers of land-use changes in societies with decreasing populations: a comparison of the factors affecting farmland abandonment in a food production area in Japan. *PLoS One* 15(7):e0235846
- Kumamoto Prefecture (2020) Pamphlet for special emergency project as the countermeasures against terrible disasters in the Shira river and the Kuro River (in Japanese). <https://www.pref.kumamoto.jp/soshiki/105/5723.html>. Accessed 26 Dec 2020
- Lovell ST, Taylor JR (2013) Supplying urban ecosystem services through multifunctional green infrastructure in the United States. *Landsc Ecol* 28(8):1447–1463
- Mallakpour I, Villarini G (2015) The changing nature of flooding across the Central United States. *Nat Clim Chang* 5(3):250–254
- Ministry of Environment of Japan (2020a) The birth of a red-crowned crane chick at the Maizuru flood-control basin in Naganuma (in Japanese). http://hokkaido.env.go.jp/pre_2020/post_123.html. Accessed 26 Dec 2020
- Ministry of Environment of Japan (2020b) Ramsar sites in Japan. https://www.env.go.jp/en/nature/npr/ramsar_wetland/pamph/index.html. Accessed 26 Dec 2020
- Mitsch WJ, Gosselink JG (2000) The value of wetlands: importance of scale and landscape setting. *Ecol Econ* 35(1):25–33
- MLIT Kantou Regional Development Bureau (2020a) The birth of a stork chick at the Watarase flood-control basin (in Japanese). https://www.ktr.mlit.go.jp/river/news/river_news00000009.pdf. Accessed 15 Jan 2021
- MLIT Kantou Regional Development Bureau (2020b) Council for conservation and utilization of the Watarase flood-control basin (in Japanese). https://www.ktr.mlit.go.jp/tonejo/tonejo_index028.html. Accessed 15 Jan 2021
- MLIT Kantou Regional Development Bureau (2020c) Information of the Watarase flood-control basin (in Japanese). <https://www.ktr.mlit.go.jp/tonejo/tonejo00081.html>. Accessed 15 Jan 2021
- MLIT Kantou Regional Development Bureau (2020d) Wetland restoration plan in the Watarase flood-control basin (in Japanese). <https://www.ktr.mlit.go.jp/tonejo/tonejo00661.html>. Accessed 11 May 2021
- Moilanen A, Nieminen M (2002) Simple connectivity measures in spatial ecology. *Ecology* 83:1131–1145
- Nakamura F, Ishiyama N, Yamanaka S, Higa M, Akasaka T, Kobayashi Y, Ono S, Fuke N, Kitazawa M, Morimoto J (2020) Adaptation to climate change and conservation of biodiversity using green infrastructure. *River Res Appl* 36(6):921–933
- Obata T, Ishii J, Kadoya T, Washitani I (2012) Effect of past topsoil removal on the current distribution of threatened plant species in a moist tall grassland of the Watarase wetland, Japan: mapping of selected sites for wetland restoration by topsoil removal. *Jpn J Conserv Ecol* 17:221–233
- Osawa T, Ueno Y (2017) Research-implementation gap in Japanese ecology field. *Jpn J Ecol* 67:257–265
- Rudnick D, Ryan SJ, Beier P, Cushman SA, Dieffenbach F, Epps C, Gerber LR, Hartter JN, Jenness JS, Kintsch J (2012) The role of landscape connectivity in planning and implementing conservation and restoration priorities. *Issues Ecol* 16:1–20
- Saura S, Rubio L (2010) A common currency for the different ways in which patches and links can contribute to habitat availability and connectivity in the landscape. *Ecography* 33:523–537
- Saura S, Torné J (2009) Conefor Sensinode 2.2: a software package for quantifying the importance of habitat patches for landscape connectivity. *Environ Model Softw* 24(1):135–139
- Segawa A, Minato T, Yoshikawa K (2008) The history of flood plain development and the levee construction of the Ishikari River down stream (in Japanese with English abstract). *J Construct Manage JSCE* 15:429–440. <https://doi.org/10.2208/procm.15.429>
- Shizuoka Prefecture (2017) Action plan for the conservation and utilization of the Asahata flood-control basin (in Japanese). <http://asabata.org/wp-content/uploads/2017/04/4fad93fec4e8c2ca38736fb06cf4bb38.pdf>. Accessed 15 Jan 2021
- Soga M, Evans MJ, Tsuchiya K, Fukano Y (2020) A room with a green view: the importance of nearby nature for mental health during the COVID-19 pandemic. *Ecol Appl* e2248

- Stevens CE, Gabor TS, Diamond AW (2003) Use of restored small wetlands by breeding waterfowl in Prince Edward Island, Canada. *Restor Ecol* 11:3–12
- Suwa Y, Nishihiro J (2020) Distribution and location characteristics of flood-control reservoir in Japan (in Japanese with English abstract). *Ecol Civ Eng* 23:85–97
- Tone River Upstream Office (2020) Report on the outflow of water in Typhoon No. 19 (in Japanese). <https://www.ktr.mlit.go.jp/tonejo/tonejo00367.html>. Accessed 26 Dec 2020
- Wang J, Banzhaf E (2018) Towards a better understanding of green infrastructure: a critical review. *Ecol Indicators* 85:758–772
- Yamanaka S, Ishiyama N, Senzaki M, Morimoto J, Kitazawa M, Fuke N, Nakamura F (2020) Role of flood-control basins as summer habitat for wetland species-a multiple-taxon approach. *Ecol Eng* 142:105617

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.