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Wise Management or Mismatch? Lessons from Japan

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Abstract: As a precious resource, wetlands support human life in various profound ways, either explicitly or implicitly. However, the values of wetlands have not been sufficiently recognized and greatly appreciated. Their management approaches are often sectoral, and wise use of wetlands is still more of a catchphrase than a well-used management practice. This paper presents a cross-sectoral case study for the evaluation of the primary management practices in a Ramsar-registered wetland in Japan. It employed a literature review, field and laboratory experiments, and a questionnaire survey as well for assessing the wetland conditions and identifying management problems. It revealed that the management of the wetland is still flood regulation–oriented, without sufficient consideration of bird habitats, and the water level drawdown operation for Lake Yanaka inside the wetland may lead to mass fish deaths. Furthermore, the reed burning practice is effective in maintaining the plant structure in the wetland but controversial from different perspectives. Moreover, the questionnaire survey results indicated that the public were not well informed of the wetland conditions and not convinced of the appropriateness of reed burning. Based on these findings, it was concluded that the registration under the Ramsar Convention did not lead to new strategies for the conservation and wise use of the wetland.

Keywords: wetland; Ramsar Convention; Watarase wetland; reed burning; heavy metal; Lake Yanaka

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1. Introduction

Wetlands are an essential resource because they provide humans with valued functions such as water purification and carbon storage and useful products such as foods and peat. However, they had been regarded as wastelands for centuries and have been subjected to development up to now. As a result, wetlands have become the most endangered natural ecosystem today. Without sufficient efforts for conservation and restoration, wetlands will continue to decline or disappear due to human activities such as farmland and urban development and may also be subject to ecosystem transformation due to the invasion of alien species or become fragile ecosystems due to climate change. In Japan, the total wetland area was 820.99 km^2 as of the 2000 survey, and it appears that 1289.62 km^2, which is 61.1% of the wetland area that existed in the Meiji and Taisho eras, has disappeared [1].

With the aim of promoting the conservation, restoration, and wise use of wetlands, the Convention on Wetlands of International Importance, known as the Ramsar Convention, was adopted internationally in 1971. This intergovernmental treaty provides a framework for the conservation and wise use of wetlands and their resources. At present, almost 90% of UN member states have become "Contracting Parties" and are committed to wetland conservation and wise use [2].

Japan joined the Convention in 1980 and made the Kushiro Wetland as the first Ramsar-registered wetland in Japan. The current number of registrations totaled 53. The requirements for the registration of Ramsar wetlands in Japan are as follows [3]:

1. Be an internationally important wetland.

2. The natural environment will be preserved in the future under Japanese laws such as the Natural Parks Act, the Wildlife Protection and Hunting Law, and the Law for the Conservation of Endangered Species of Wild Fauna and Flora.
3. Gain the consent and support of local communities.

Even if the international standards of the Ramsar Convention are met, relevant domestic laws are sought to provide a legal foundation for the implementation of the registration and related obligations. This is because of the lack of laws specifically dedicated to wetland conservation in Japan [4]. The United States of America, the Republic of Korea, The People's Republic of China, and Taiwan have a wetland conservation act for the protection and wise use of wetlands. However, legal workers in Japan tend to believe that existing domestic laws are sufficient to guarantee the implementation of the Ramsar Convention in Japan. As a result, the need for a new law in Japan specifying its purpose to preserve and restore wetlands has not received sufficient attention and comprehensive analysis.

The existing domestic laws used to legally support the Ramsar wetland registration in Japan include:

- The Natural Park Act.
- The Wildlife Protection Act.
- The Act for the Conservation of Endangered Species of Wild Fauna and Flora.
- The River Act.

Currently, most of the Ramsar wetlands in Japan are provided collateral or guarantee by the Wildlife Protection Act and the Natural Parks Act. A few wetlands are guaranteed by the River Act, together with the Wildlife Protection Act. Therefore, whether such a guaranteeing system is effective in protecting wetlands and promoting the wise use of wetlands is a research question deserving deep consideration. Nevertheless, it has been neglected so far.

The present work is a case study, conducted to examine how a Ramsar-registered wetland has been managed and what improvements the registration has brought to the existing management practices in the wetland. Information synthesis and field measurements revealed that two primary management practices in the wetland under study are controversial regarding to wetland wise use, and the Ramsar-registration did not lead to any meaningful change in the management practices. Furthermore, we reasoned that the domestic law used for supporting the wetland registration under the Ramsar Convention mismatches the site characteristics in the case under consideration. The purpose of the present study is to highlight some fundamental problems in wetland management in Japan and call for further integrated studies.

2. Materials and Methods

2.1. Study Site

The study site is the Watarase wetland, a flood retarding basin where the Watarase, Uzuma, and Omoi rivers meet (Figure 1). The area of the Watarase wetland is 33 km^2, including Lake Yanaka, an artificially constructed heart-shaped lake. It plays an invaluable role in preventing flood damage by temporarily storing water from surging rivers, thus ensuring the safety of both the immediate and downstream metropolitan areas. There are more than 1000 plant species grown in this vast wetland. Over 50 appear on the Ministry of the Environment's red list of endangered wildlife species. From spring to summer, it is a breeding ground for some grassland birds such as great reed warblers and zitting cisticolas. It is also a wintering ground for thousands of ducks, many buntings, and some Eastern marsh harriers, which are cited as "endangered" in the red list of the Ministry of the Environment of Japan.

It became a Ramsar site in 2012 on the grounds that it is representative of reed-dominated low moor wetlands in Japan and has a high level of diversity of wetland flora and fauna. Because it is part of a river system, the registration was done under the collateral of the River Act and the Wildlife Protection Act. It is innovative to use the River

Act for the Ramsar wetland registration because the use of the River Act for guarantee does not affect the main purpose of the retarding basin. On the other hand, the clause of environment conservation in the River Act is general. It does not have concrete terms, such as prohibiting or restricting on the capture of birds and other animals. Meanwhile, the Natural Park Act is not applicable to the Watarase wetland because the wetland does not have the greatest natural scenic beauty as required by the Natural Park Act and it is indeed of a secondary nature. Therefore, the Wildlife Protection Act is needed for the registration. In theory, the combined use of the River Act and the Wildlife Protection Act for the registration of the Watarase wetland under the Rama Convention is expected to lead to a balanced management between flood regulation and wetland conservation. However, the effectiveness of the registration in protecting the ecosystem and promoting the wise use of the Watarase wetland has not been studied so far. In operation, there is indeed a dilemma in this wetland management scheme. Because the main function of the retarding basin is flood regulation, large amounts of water are intentionally diverted into it when large-scale floods occur, and the inundation of the wetland could affect wildlife and destroy endangered plant species inside it.

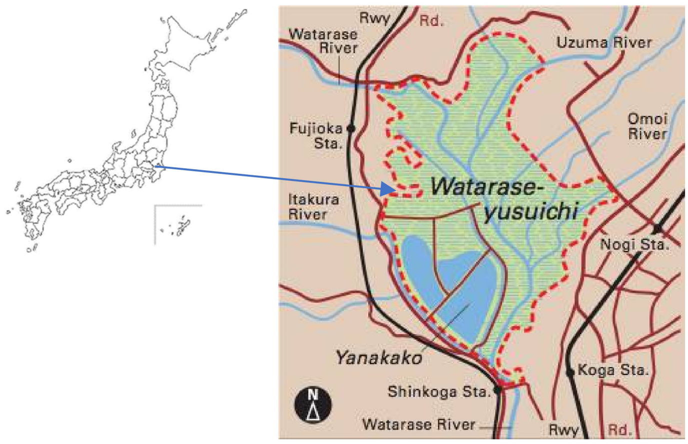


Figure 1. Watarase wetland (Watarase Yusuichi in Japanese).

Lake Yanaka inside the wetland has a surface area of 4.5 km^2 and an average depth of six meters with seasonal changes of about three meters for flood control. The lake became eutrophic in the 1990s, having the musty odor problem (2-MIB) that affected the tap water quality in areas where the water supply depends on the lake. To deal with the problem, a unique countermeasure has been taken since 2004 [5]. Every winter, the water in the lake is drained out, and 80% of the lakebed is exposed to air for a certain period between January and March. This water level drawdown operation results in bed desiccation, which decreases the concentration of 2-MIB in the lake.

Another primary measure for the conservation of the large-scale reed community in the wetland is the annual open-fire event. Every year in March, controlled burning of reeds is carried out to get rid of the worms and arrest succession in reed beds [6]. How the burning affects the soil quality of the wetland has been neglected.

2.2. Assessment Methodology

We evaluated the primary management practices in this wetland from four aspects: (1) effects of flood regulation on animals and plants, (2) water quality of Lake Yanaka, (3) impacts of reed burning on soil and reed growth, and (4) public opinion on reed burning.

To better understand possible effects of flood regulation on wildlife, it took a cross-disciplinary literature review to synthesize knowledge on how flood regulation might affect birds and plants in Ramsar wetlands. Searches were conducted with phrases such as "bird's response to flood regulation" and "wildlife in the Watarase wetland" in PubMed, Web of Science, and J-Stage, which is a database for academic publications in Japan containing more than 3200 Japanese journals. Meanwhile, we conducted water quality measurements at foraging sites to assist the discussion about the wetland habitat conditions.

For the water quality assessment, Dissolved Oxygen (DO), Dissolved Oxygen Saturation Level, and water temperature were measured onsite with Hach's LDO (Luminescent Dissolved Oxygen) probe; electric conductivity and nitrate concentrations were also measured onsite with Horiba's LAQUAtwin. Nutrients and heavy metals were measured in the laboratory with the portable multi-parameter water analyzer of Kyoritsu Chemical-Check Lab., Corp, Tokyo, Japan and the spectrophotometer photoLab of Xylem Analytics Germany, Weilheim, Germany, respectively.

For the soil quality assessment, because the wetland has a history of heavy metal contamination and there are locations in the wetland where the concentrations of heavy metals still exceed the environmental standards of Japan even today [5], two research questions were addressed. One is how reed burning may affect heavy metal concentrations in soil, and the other is regarding the quality of ash resulting from the burning. To answer the two questions, preliminary field work was conducted to measure the change in heavy metal concentrations in the soil before and after burning and the heavy metal contents in ash as well. Soil samples were taken at Point A, as shown in Figure 2, before and after burning. Each time, in a 1 m × 1 m quadrant, five surface soil samples, one at the center and four at corners were taken, then mixed in the same weight proportion afterward. Additionally, soil samples 30 cm below the surface were also taken in the same way.

Figure 2. Quadrant sampling site for investigating burning effect on heavy metals in soil.

The soil samples were dried at 105 °C for approximately 5 hours, then crushed and mixed with a sieve to remove the stone and dead organisms. After the pre-treatment, 1.5 g of homogenized soil sample were digested with 50 mL of extra reagent (hydrochloric acid of 1 mol/L) for the test of contained amount, while another 5 g of sample was treated with 50 mL purified water for the test of elution amount. After 1 min of shaking and 5 min of standing, 30 mL of suspension, primary filtration through a 2.7 µm filter (Whatman GF/D) with a funnel was performed, then secondary filtration with a 0.45 µm filter (ADVANTC 0.45 µm filter). Both test solutions were pH adjusted by sodium hydroxide of 1 g/mL, then measured with the same spectrophotometer as used for water quality testing.

The ash resulting from reed burning at Point A was collected and heavy metal contents in the ash were analyzed using a sequential chemical extraction method [7].

To assess the effect of reed burning on reed growth, measurements of soil pH and reed heights and diameters were conducted randomly at 50 sites in the wetland.

Additionally, a questionnaire survey was carried out to understand the perception of residents toward the management of this wetland. It was a convenience sampling, stopping people randomly in the wetland and asking questions such as "Do you think burning is necessary or not?", and "Do you know that the ash resulting from the burning contains heavy metals?"

3. Results

3.1. Water-Animal-Vegetation-Related Results

As a flood retarding basin, inundation is inevitable. However, the ecological response of birds to flooding has been understudied and poorly understood. Ludwig et al. showed that due to the 100-year flood incident of September 1986 in the Saginaw River/Bay ecosystem, the reproduction of Caspian terns collapsed and then slowly recovered [8]. Shimada found that a flood in the Lake Izunuma-Uchinuma wetland had a positive effect on black-crowned night herons and doubling ducks while diminishing the little grebe *Tacbybaputus rucollis Pallas* [9].

In 2019, during Typhoon No. 19 (Hagibis), the Watarase Retarding Basin stored 160 million m^3 of water, which led to the inundation of the whole wetland. After the flooding event, a study using 2319 banded birds of 39 species revealed that the inundation in 2019 reduced the number of rustic buntings in 2020 and affected other species differently [10]. The rustic bunting is not a globally threatened species. However, it has recently been upgraded to "vulnerable" (VU) on the European Red List (Birdlife International 2015b) as the European breeding population of rustic bunting has declined by 30–49% over the last 10 years in Europe [11].

The integrity of wetland habitats depends upon adequate quantity, quality, timing, and temporal variability of water level and flow [12]. Sustainable management of wetlands requires these systems to fluctuate within a natural range of variation. However, in a wetland with flood regulation on the top of its management agenda, the variation of water regime is often controlled for flood management without sufficient consideration of its ecosystem. In Lake Yanaka, the variation of water level can be characterized as having a drawdown in early spring for water quality improvement and lowering in summer and autumn for flood management, as shown in Figure 3. Bird habitat was not considered in the operation of water level in the lake.

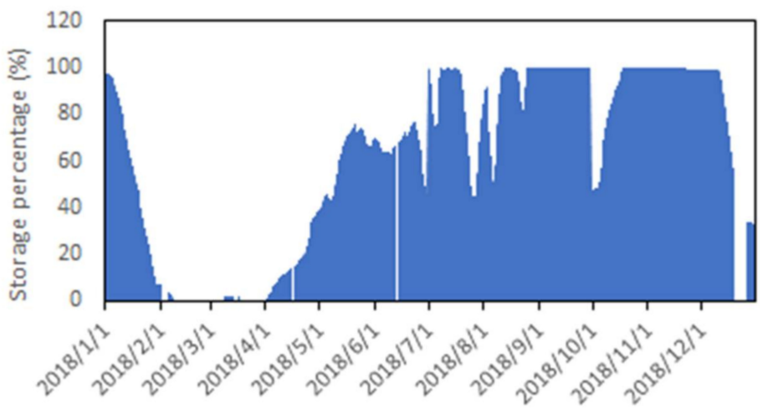


Figure 3. Variation of storage in Lake Yanaka.

The Oriental stork (*Ciconia boyciana*) is an endangered bird rated as a special national treasure of Japan. In 1971, wild Oriental storks became extinct in Japan. Following the release of the birds back into the wild as part of restoration efforts, it was confirmed that the birds have been reproducing in the wild since 2007. On 30 May 2022, two wild Oriental storks were found to be born in the Watarase wetland according to the Oyama city office. This is indeed the first case of Oriental stork hatching in the wild in eastern Japan for more than a century.

Storks forage predominantly in shallow wetlands and open areas, such as paddy fields. The water level drawdown created shallow water bodies, which can be considered good foraging habitat for the Oriental white stork. Nevertheless, the measurement of water quality of remaining water during the drawdown showed that the concentrations of Pb, Cd and Cr6 in the water were 0.35 mg/L, 0.03 mg/L and 0.06 mg/L, respectively, exceeding the environmental standards of Japan. Exposure of birds to heavy metals may increase their susceptibility to diseases and reproductive dysfunction and behavioral changes [13–15]. Moreover, these metals are not only damaging to the adults but also highly nephrotoxic to newly born chicks [16].

A flood retarding basin is an open and changeable habitat. Its ecosystem depends on the influence of natural disturbances such as flooding, sediment transport, climatic factors, and historical land use in the retarding basin and the whole catchment. A high degree of disturbance is often accompanied by biotic processes of plant succession, species invasion, and colonization. In addition to affecting birds, flood duration and timing, together with flood energy, are crucial ecological factors affecting the vegetation community in flood retarding basin. Floods can eliminate existing species on the one hand and bring many seeds of different species on the other hand. There are many ways that flooding can damage plants [17,18]. Excessive moisture in soil decreases oxygen levels, causing plant roots to suffocate and die. Moreover, high concentrations of ethanol and hydrogen sulfide are produced in waterlogged soils, which can be damaging to root systems [19]. Therefore, the longer the inundation, the more likely damage to plant communities is fatal.

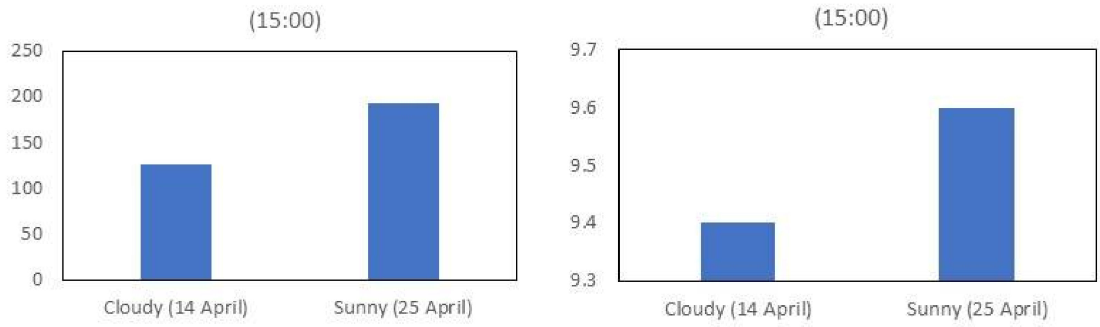
As a matter of fact, plant succession has been recorded in the Watarase wetland. For example, a large colony of *Monochoria korsakowii*, which is an endangered species, was observed in 2004 but disappeared in 2006 according to the Plant Society of Watarase Retarding Basin. In 2019, after the large flood caused by Typhoon No. 19, *Solidago canadensis var. scabra* and *Ambrosia trifida*, invasive species to the wetland, were found to develop quickly in the wetland, according to the author's field inspection.

Wetland hydrology may negatively affect amphibian abundance [20] and alter amphibian community composition [21]. In the Watarase wetland, the number of amphibians and reptiles is very limited. Since the flooding of the Watarase wetland is highly regulated, how such human-mediated hydrology would have affected amphibian and reptile breeding success is another research question to be explored.

In April 2022, mass fish deaths occurred in Lake Yanaka as the lake was being refilled with water. This fish death incident lasted for about one month, although the number had decreased from several thousand to several dozen, as shown in Figure 4. During this incident, water quality measurements were conducted by the author twice on cloudy and sunny days, respectively. The measured data showed very high levels of dissolved oxygen and pH in the water (Figure 5). It has been well documented that low dissolved oxygen is one of the most common reasons for fish death [22]. On the other hand, excess levels of oxygen dissolved in water (oversaturation) may also lead to mass fish death [23–25]. Another possible reason for fish death is the high pH level, because most ammonium in water is converted to toxic ammonia (NH_3) when pH is greater than 9, and NH_3 is toxic and can be fatal to fish. Regardless of the cause, this incident is added evidence that the current water level management needs re-evaluation.

(**a**) (**b**)

Figure 4. Mass fish death. (**a**) 3 April (Simotsuke Original Online News); (**b**) 14 April (Author).



(**a**) (**b**)

Figure 5. DO saturation and pH during the mass fish death period. (**a**) DO Sat. (%), (**b**) pH.

3.2. Burning-Related Results

Reed burning has a long history in the Watarase wetland. Since it became a Ramsar-registered wetland, annual open-fire burning is considered a measure to fulfill the obligation of the Ramsar registration because the burning is effective in arresting succession and maintaining the reed community. It also attracts many visitors to the wetland. However, such a practice is controversial because it may cause air pollution and other concerns. Indeed, high concentrations of PM2.5 were recorded near the wetland in 2015. Furthermore, reeds are well known for their ability to take up heavy metals from contaminated soils. The ash resulting from burning may contain appreciable amounts of heavy metals. Therefore, the dispersion of ash containing heavy metals from the wetland might cause a serious health problem.

As shown in Figures 6–8, the concentrations of heavy metals in soil varied differently with burning. The concentrations of Cu (Figure 6) and Pb (Figure 7) in the surface soil decreased by approximately 30% after burning, while Cu and Pb in the soil 30 cm below the surface increased by 3 to 5 folds. The concentrations of Cd in both surface and deep soils increased by about 200% after burning (Figure 8).

As depicted in Figure 9, the concentration of Pb is much higher than that of Cu and Cd in the ash sample. Additionally, Cd was significantly higher in the ash than in the surface soil at the same site, which implies that the reeds are highly accumulative for Cd. It can be noticed that after two months, the concentration of Cd in the surface soil increased, which might be attributed to the decomposition of ash.

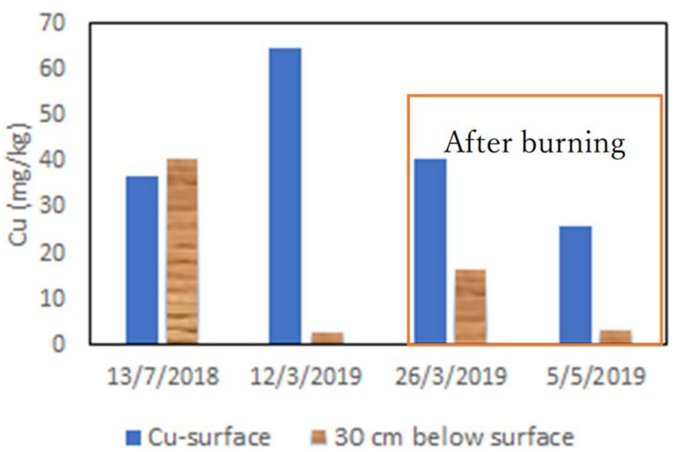


Figure 6. Burning-induced change in the concentration of Cu.

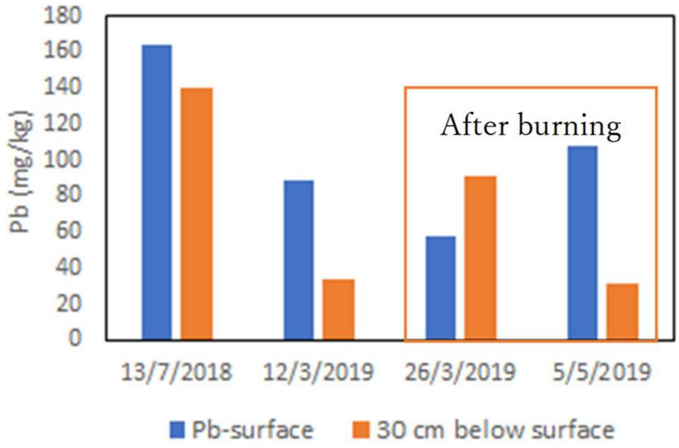


Figure 7. Burning-induced change in the concentration of Pb.

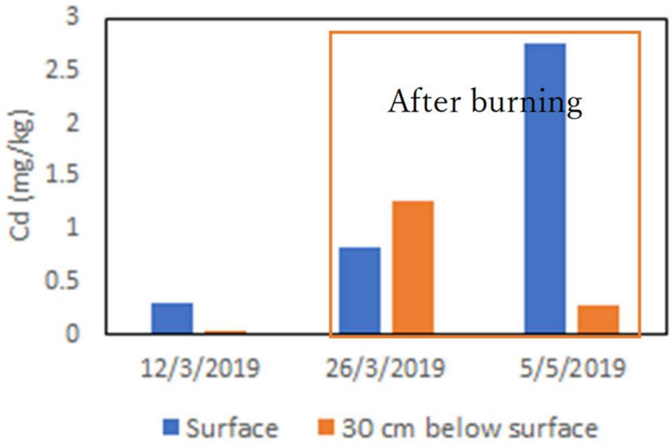


Figure 8. Burning-induced change in the concentration of Cd.

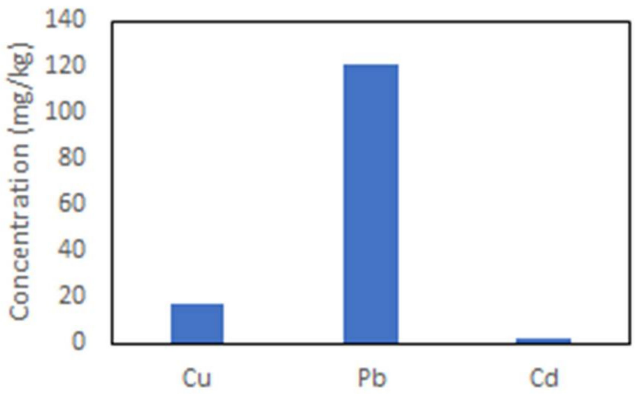


Figure 9. Heavy metal contents in ash.

On the other hand, it can be observed that the concentration of Cu in the ash was only 26% of that in the surface soil before burning. This is probably because the ash was mainly from the burning of reed stems and leaves, and Cu accumulated most in unburnt roots. These findings suggest that more attention should be paid to ash quality to manage reed burning better.

Previous studies showed that fire increases soil pH [26,27], and onsite measurements at Point A before and after the burning found that the pH increased from 6 to 7. Then, to assess the positive effects of reed burning on reed growth, measurements of soil pH, reed heights, and diameters were conducted randomly at 50 sites in the wetland. The measured data were classified into three groups. They are A (pH $\leq$ 6), B (6 < pH $\leq$ 6.5), and C (6.5 < pH < 7.5). As seen in Figure 10, the average reed height in group A is higher than groups B and C. To confirm the differences between the three groups, the Bartlett test was conducted first, and the p value was 0.734 > 0.05, indicating that the variances are not statistically different between the three groups. Then, one-way ANOVA was performed, and the p value was $3.89 \times 10^{-9} < 0.01$, and the F value was 3.19 > 1. Therefore, the difference in height in relation to pH is statistically significant. Similar results were also obtained for reed diameter.

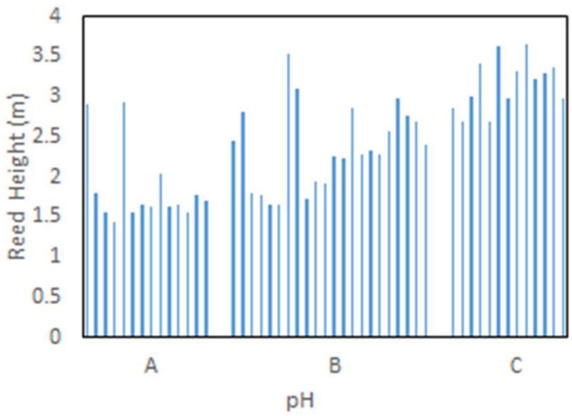


Figure 10. Relation between reed height and soil pH.

As burning increases soil pH, and higher pH leads to better growth, reed burning in the wetland could be justifiable if the soil had not been contaminated by heavy metals and residents living in surrounding areas were not affected by the increase of PM 2.5.

3.3. Public-Related Results

In 2017, after reed burning, the Tone Upstream River Office received 56 complaints about reed burning from residents living nearby; 34, or 61% of them, complained that their houses were tainted by falling ash. Among those who watched reed burning, 13 people demanded to stop the burning and 16 people asked for compensation [28]. In November 2021, we conducted a questionnaire survey in the wetland to evaluate the perception of residents toward reed burning (Figure 11). Among 47 replies, 8 (17%) believed that the burning was not necessary, 11 (23%) thought it necessary, and 28 (60%) replied that they did not care about it. In March 2022, after reed burning, another interview was conducted, asking if there were problems other than unpleasant ash falling and PM2.5 regarding reed burning. In total, 33 visitors to the wetland replied, and 95% answered that they do not know that the ash may contain heavy metals.

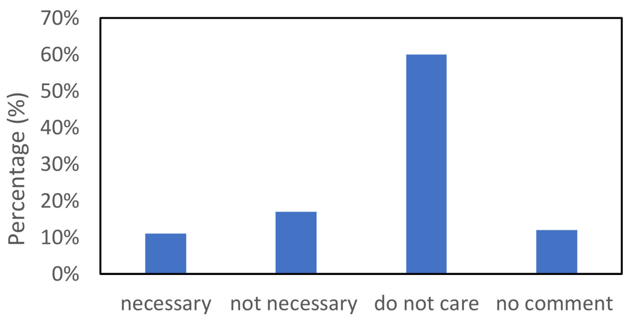


Figure 11. Results of questionnaire survey about reed burning.

4. Discussion

Transforming a flood regulation–oriented wetland to a multi-functional Ramsar wetland is technically and legally challenging. Technically, flood management is carried out in response to meteorological conditions and social needs, while environmental conservation should focus on site characteristics. The timing of floodwater diversion could be fatal to some plants and animals. Wise use of wetlands requires a balanced approach to meet both needs. However, such a balanced approach has not been developed for flood regulation–oriented wetlands. The legal guarantee in the Ramsar wetland registration in Japan is superficial because it does not provide sufficient momentum to promote integrated management, as evidenced in the case of the Watarase wetland. The water level drawdown practice for Lake Yanaka inside the wetland started about 10 years before the registration and was not re-assessed following the registration. Reed burning in the Watarase wetland has a long history, although suspended due to concerns of radiation resulting from the Fukushima nuclear incident for 2 years and restarted due partially to the registration. Nevertheless, the restart of reed burning was not used as an opportunity to develop a better operation scheme. Ash containing heavy metals may fall on nearby farmlands causing a new problem. Burning-induced PM2.5 issues should also be examined thoroughly.

The North American Wetlands Conservation Act was enacted in 1989 to provide federal cost-share funding to support wetlands conservation projects in the U.S., Canada, and Mexico. It stimulates public–private partnerships to protect, restore, and manage wetland habitats for diverse migratory birds and other wildlife. Japan needs such an act for collaborative, incentive-based, and voluntary programs to develop integrated wetland management approaches.

Although the social survey was limited in scope and number, it revealed that CEPA (communication, capacity building, education, participation, and awareness), one of the three pillars in the Ramsar Convention, should be further promoted for wetlands.

5. Conclusions

The main findings from the present study are summarized as follows.

- The use of existing domestic laws for the Ramsar wetland registration did not lead to new strategies for the conservation and wise use of the Watarase wetland.
- The management of water regimes in the wetland is still flood-oriented, without sufficient consideration of bird habitats. The water level drawdown operation may also lead to mass fish deaths as it can cause oversaturation and high alkalinity, which are harmful to fish.
- The reed burning practice is effective in maintaining the plant structure in the wetland but controversial from different perspectives because it did not sufficiently consider its impact on air quality and totally ignored the issue of heavy metal in the ash.
- The burning-induced change in heavy metal concentration in soil is both metal and depth dependent. The concentration of Cd in both surface and deep soils increased by about 200% after burning. The concentrations of Cu and Pb in the surface soil decreased by approximately 30% but increased by 3 to 5 folds in the soil 30 cm below the surface after burning.
- In the ash resulting from reed burning, the concentration of Pb is highest. Further studies are needed for generalization.
- The public's involvement in managing the wetland should be further promoted.

These findings highlight a concern that the existing domestic laws may not function well to guide and support wetland conservation and wise use and could even cause mismanagement. Therefore, the need to have a comprehensive Wetland Conservation Act in Japan for the wise management of wetlands should be seriously evaluated.

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