



Restoration Contributes to Maintain Ecosystem Services and Bio-Cultural Linkages Between Wetlands and Local Communities: a Case from a Botanical Diversity Hotspot in Japan

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Abstract

The Circum-Ise Bay region in central Japan is characterized by a high concentration of species-rich seepage wetlands that provide various ecosystem services to local communities. However, the non-native conifers *Cryptomeria japonica* and *Chamaecyparis obtusa* have been widely introduced to the wetlands and compete with native plants. Here, we report the results of a 4-year restoration experiment that involved removing the conifers from a seepage wetland and observing the effects on plant composition, diversity, and ecosystem services to local communities. The experiment was conducted at a seepage wetland in Nakatsugawa city, Japan. The wetland includes many threatened and endemic plants but is also dominated by the conifers. We established three experimental plots within the wetland and removed the conifers from two of them. The stem density of overstory (i.e., canopy-tree) and understory (i.e., sub-canopy to shrub) layers in the conifer-removal plots decreased by 50% while simultaneously increasing the proportion of threatened woody plants by 14.3–50.0%. Despite these changes, plant species diversity in the groundcover layer remained high, and threatened and culturally important species became more concentrated on removal plots than on the control. We did not observe any negative regime shift, such as the establishment of introduced species. The restoration appeared to promote the occurrence of plants associated with bio-cultural linkages between the seepage wetland and local communities and that supply multiple ecosystem services.

Keywords Bio-cultural diversity · Conservation · Seepage · Threatened species · Vegetation

Introduction

Wetlands provide a variety of ecosystem services to local communities (Meli et al. 2014; Mitsch et al. 2015; Behailu et al. 2016; Sims et al. 2019; Tomscha et al. 2021). However, they frequently suffer high pressure from anthropogenic impacts, including land development, eutrophication and water pollution (Brinson and Malvárez 2002; Hájek et al. 2002; Mayers et al. 2009). In particular, wetlands sustained by seeping water, or seepages, are one of the ecosystems

most vulnerable to anthropogenic impacts. The geomorphological process delivering the seeping water is usually complex and invisible underground (Kløve et al. 2011). This makes it difficult to predict the responses of seepages to the effects of human activities. Nevertheless, adequate management of these ecosystems is important for retaining their multiple ecosystem services, especially to people living nearby.

The Circum-Ise Bay region in central Honshu, Japan, is known to have a high concentration of seepage wetlands (Ueda 1994). According to the latest survey, there are more than 1600 seepage wetlands in this region (Study Group of Seepage Marsh 2019). The wetlands are in low to hilly areas, typically at elevations from 100 to 500 m a.s.l. The size of seepage wetlands is usually less than 1 ha. They are characterized by the absence of peat deposits and low nutrient availability. The seepage wetlands have been repeatedly formed in the Circum-Ise Bay region for a long time, continually appearing for at least 1 million years (Ueda 1994; Makinouchi 2001). Substrates deposited since the Pliocene

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contain impermeable silt and clay layers. When the layers become excessively wet, this leads to frequent landslides in mountainous terrain, and this geomorphic process promotes the formation of seepages. The duration of seepage wetlands is variable; small ones can disappear through succession within only 100 years. However, new wetlands sporadically form at low elevations. This geological process has occurred throughout the period of Quaternary climatic oscillations, thereby providing refugia for many native plants. This process has contributed to establishing a floristic group, known as “Tokai Hilly Land Elements” (Ueda 1989, 1994).

One of the major risks threatening the seepage wetlands is the alternation of wetlands to conifer plantations. In the 1960s and 1970s, the Japanese government promoted the expansion of conifer plantations because there was a severe shortage of timber resources for residential construction (Yamaura et al. 2012). The commonly planted species were *Cryptomeria japonica* (L.f.) D.Don and *Chamaecyparis obtusa* (Siebold et Zucc.) Endl. The presence of conifers in the canopy layer reduces the light reaching the forest floor, which inhibits the growth of understory and groundcover plants.

Based upon this situation, we performed a restoration experiment in which we removed non-native conifers from seepage wetlands and then evaluated the effects of this treatment by monitoring plant species composition and diversity for 4 years. In general, the biodiversity of wetlands is highly sensitive to abrupt changes in the physical environment (Hobbs and Huenneke 1992; Davis et al. 2000; Saeki 2007). Therefore, even though changes might be made for conservation purposes, we should be careful to avoid strong impacts on the wetlands, and long-term monitoring is recommended. In the present study, we aimed to examine the changes of plant species composition and diversity after the removal of non-native conifers at a seepage wetland in the Circum-Ise Bay region. We focused in particular on the occurrence of threatened and culturally important plants because the seepage wetlands in this region are known to contain a large number of threatened species, and they have a strong cultural association with local communities (Li and Saeki 2018). One of the reasons why biodiversity should be conserved is that it is a basis of our cultural identity, or bio-cultural diversity (Maffi 2001). This concept is especially important for ecosystems which have a close linkage with local communities, such as seepage wetlands.

Methods

Study Area

The experiment was conducted at a seepage wetland in Iwayado village, Nakatsugawa city, Gifu prefecture, Japan

(Appendix S1). The area of Iwayado village is approximately 1 km², and there are several seepage wetlands in the Satoyama, a traditional agricultural landscape in Japan (Takeuchi 2001). The landscape is characterized by a mosaic of rice paddies, agricultural ponds, vegetable-farming fields, deciduous forests, and conifer plantations. We selected one of seepage wetlands in Iwayado privately owned by a local family for this restoration project because the landowner wished to conserve the wetland even though it is not legislatively designated for preservation. The seepage wetland covers about 0.11 ha, which is typical of the seepage wetlands in the Circum-Ise Bay region (Ueda 1994). The site has a gentle slope of 15%. Part of the seepage wetland is forested but the rest is relatively open (Appendix S2). Both forested and open areas were a target of the present restoration project. Vegetation of the study site is characterized by woody and herbaceous vascular plants with occasionally high dominance of sphagnum moss. There is a fine-scale difference in microtopography created by seeping water. No peat deposits were observed. Ground water level was relatively stable through all the seasons; conspicuous fluctuation was not observed during the study period.

Data Collection

In July 2016, we established three 10 m × 20 m plots within the seepage wetland and recorded plant species and diameter at breast height (DBH) for all the stems of woody plants with DBH ≥ 1.5 cm. Both live and dead woody plants were recorded. We then classified each stem as belonging to overstory (≥ 9.0 cm; i.e., canopy-tree) or understory (1.5–9.0 cm; i.e., sub-canopy to shrub) layers. We also established one 5 m × 5 m plot (hereafter, “subplot”) within each 10 m × 20 m plot for investigating groundcover vegetation. This layer includes vascular plants, including woody plants with DBH < 1.5 cm. The location of each subplot was randomly chosen, but avoiding irregular objects on the ground such as large rocks and woody debris. In each subplot, we recorded occurrences of all vascular plants and their coverage. Coverage was recorded using a 10-class scale (class 1, ≤ 0.5%; 2, 0.5–1%; 3, 1–3%; 4, 3–5%; 5, 5–8%; 6, 8–12%; 7, 12–16%; 8, 16–40%; 9, 40–70%; 10, 70–100%). The vegetation data for the groundcover layer prior to the conifer-removal treatment were recorded on 14 July, 10 August, and 30 September 2016. The survey was repeated several times because some plants germinate in different seasons. The results of the 2016 investigation were partially reported by Li and Saeki (2018).

On 26 February 2017, non-native conifers on the two of the three plots described above were cut. We did not do any cutting on the third plot as a control. One of the treatment plots was relatively open with few canopy-size trees, whereas the control plot had a higher density of canopy trees. The other treatment plot was in between these two, with relatively dense

canopy-size trees. The target conifer species to be removed were *C. japonica* and *C. obtusa*, which were either planted in the 1960s and 1970s or established from dispersed seeds from adjacent plantation forests. During the removal treatment, we measured the DBH of stems removed from the two treatment plots. To examine the effects of conifer removal on groundcover species, we performed groundcover vegetation surveys of the three subplots every year from 2017 to 2020 and compared them with the data taken in 2016 before the removal treatment. The exception was the year 2020 when we could only visit the site once because of the COVID-19 pandemic. The surveys after the removal were conducted on 10 July, 12 August, and 6 October 2017, 8 August, 1 September, and 29 September 2018, 27 August and 30 September 2019, and 29 September 2020.

Data Analysis

For the overstory and understory layers, we used the data recorded in 2016 to calculate the stem density (stems/ha) and proportion of non-native conifers of the total number of stems before the treatments. Stem density and proportion of non-native conifers were also estimated after the removal treatment by extracting the stem numbers and basal areas for the removed conifers from the 2016 data. For the groundcover layer, the coverage of each plant species recorded in each of the subplots was input in table format (Appendix S3), and the mean coverage of each species was calculated by year. To quantify plant diversity, we calculated species richness (S) and Shannon index (H' ; Magurran 1988) for each of the plots and subplots. For the overstory and understory layers we used number of stems as an indicator of abundance, whereas for the groundcover layer we used coverage.

To illustrate differences in groundcover species composition before and after the treatment, we performed non-metric multidimensional scaling (NMDS) analysis using the data recorded by subplot for each year. We checked for the occurrence of threatened and near-threatened species using prefectural and national Red Lists (Gifu Prefectural Government 2014; Ministry of Environment 2020) and monitored their numbers before and after the treatment. The NMDS was performed with the package “vegan” (Oksanen et al. 2020) in R ver. 4.1.2 (R Core Team 2021).

An interview survey in a previous study in the Iwayado area (Li and Saeki 2018) showed that the wetland landowners had a variety of knowledge and experiences regarding the plants in and around their wetlands. We first identified the plants to which landowners referred in the interviews as culturally important species and then examined their occurrences in the study plots before and after the treatment. The species defined as culturally important were those used for certain purposes (e.g., food, play, traditional events, and horticulture) or recognized as symbols (i.e., representatives) of the wetlands (Appendix S4).

Results

The number of living stems in the overstory and understory layers decreased markedly in the conifer-removal plots; the change from before to after the treatment was 50% in the overstory and 34–38% in the understory (Table 1; Fig. 1). In these plots, we were able to remove almost all of the non-native conifers. Simultaneously, the proportion of stems of threatened (*Acer pycnanthum* K. Koch) and near-threatened (*Magnolia stellata* [Siebold et Zucc.] Maxim.) woody plant species increased (Table 1). S and H' of the control plot were 9 and 1.87, respectively. Those of conifer-removal plots were much smaller than the control.

In the understory layer, S of the forested and open conifer-removal plots decreased from 18 to 16 and 16 to 14, respectively, reflecting the complete removal of the two conifer species (Table 1). H' of conifer-removal plots did not change much, ranging from 2.30–2.35 before and 2.27–2.29 after the treatment. These values are slightly higher than that in the control (2.14). In both the control and removal plots, the stem numbers in the understory were much higher than in the overstory, which are well described by the inverse-J shape of DBH class distributions (Fig. 1).

In the groundcover layer, we recorded a total of 88 vascular plant species/taxa (Appendix S3). Among the 88 taxa, at least 10 are listed in either national or local Red Lists, and 13 were referred to by landowners as culturally important. NMDS analysis of groundcover vegetation demonstrates marked differences in species composition among the three subplots (Fig. 2). The control plot (P1 in Fig. 2) is plotted at the low end of axis 1. The forested (P2) and open (P3) conifer-removal plots are plotted at the high end of axis 1, and at the low and high ends, respectively, of axis 2. Of the 10 threatened and near-threatened species, 9 were placed on the positive side of axis 1 (Fig. 2). Regarding culturally important species, 9 of 13 were placed on the positive side of axis 1.

S and H' of the groundcover layer were consistently high across the three subplots before and after the treatment (Fig. 3). H' was 3.42 in the control plot in the first study year (i.e., 2016), and it did not change much after the removal. The numbers of threatened and near-threatened species listed in the national and prefectural Red Lists were higher in the conifer-removal plots than in the control (Fig. 3). The number of culturally important species also remained high in the conifer-removal plots compared to the control. In the forested conifer-removal plot (P2), however, the numbers were slightly lower because of the disappearance of *Triantha japonica* (Miq.) Baker, *A. pycnanthum*, and *Drosera rotundifolia* L. On the other hand, *Habenaria radiata* (Thunb.) Spreng. (labeled “Hara” in Fig. 2) was newly recorded on the open conifer-removal plot (P3) after the treatment. This species is designated near-threatened, and it was also noted as culturally important by landowners because of its beautiful, heron-like flowers (Appendix S4).

Table 1 Comparison of vegetational characteristics and diversity of overstory and understory layers before and after removal of non-native conifers. DBH, stem diameter at breast height

	Control plot	Conifer-removal plot (closed)		Conifer-removal plot (open)	
	Before	Before	After	Before	After
Overstory (DBH ≥ 9.0 cm)					
No. of living stems (stems/plot) ^a	23	14	7	2	1
Proportion of stems of non-native conifer species (%) ^b	43.5	57.1	14.3	50.0	0
Proportion of stems of threatened endemic species (%) ^c	34.8	14.3	28.6	50.0	100.0
Species richness	9	5	5	2	1
H^d	1.87	1.25	1.55	0.69	NS
Understory (9.0 > DBH ≥ 1.5 cm)					
No. of living stems (stems/plot) ^a	71	122	80	87	54
Proportion of stems of non-native conifer species (%) ^b	11.3	32.0	0	35.6	0
Proportion of stems of threatened endemic species (%) ^c	25.4	5.7	8.8	11.5	14.8
Species richness	13	18	16	16	14
H^d	2.14	2.30	2.29	2.35	2.27

^aPlot size: 200 m²

^bNon-native conifers: *Cryptomeria japonica*, *Chamaecyparis obtusa*

^cThreatened endemic species: *Acer pycnanthum*, *Magnolia stellata*

^d H^d : Shannon index based on no. of stems

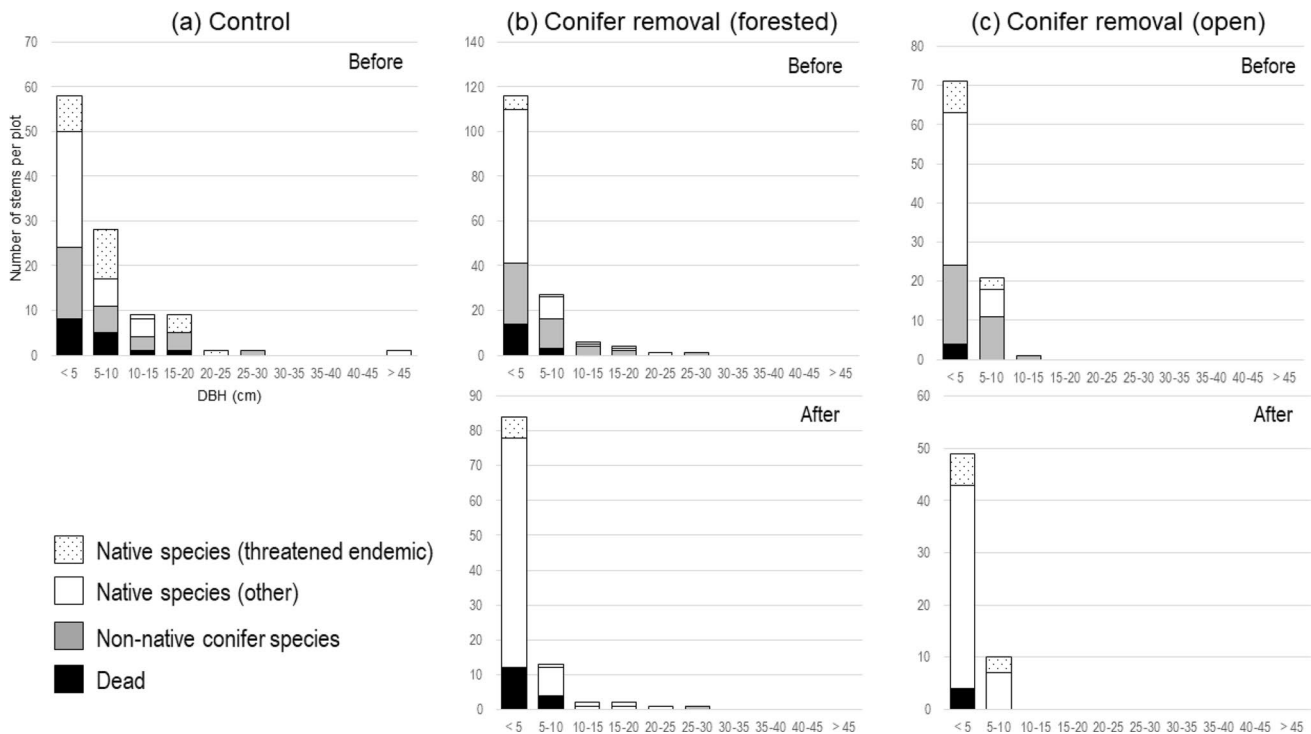


Fig. 1 Comparisons of diameter at breast height (DBH) distribution with and without conifer-removal treatment on a seepage wetland in Iwayado, Nakatsugawa city, Gifu prefecture, Japan. DBH distribution on (a) a control plot without conifer removal, (b) a forested plot with conifer removal,

and (c) an open plot with conifer removal. For (b) and (c), top and bottom charts show distributions before and after the treatment, respectively

Fig. 2 Comparisons of species composition of groundcover vascular plants in three experimental plots on a seepage wetland in Iwayado, Nakatsugawa city, Gifu prefecture, Japan, based on non-metric multidimensional scaling (NMDS). Each plot was 5 m × 5 m. Plot 1 (P1) was a control without removal of non-native conifers. Plots 2 (P2) and 3 (P3) were experimental plots where non-native conifers were removed. Conifers were removed in winter 2017. The numbers after decimal point indicates the chronological information: 1–3, 2016; 4–6, 2017; 7–9, 2018; 10–11, 2019; 12, 2020. Names of recorded plants are abbreviated; see Appendix S3 for full scientific names. The green, bold labels indicate threatened or near-threatened plant species listed in the national and prefectural Red Lists. Characters within ellipses indicate culturally important species identified in interviews with local landowners in a previous study (Li and Saeki 2018). See Appendix S4 for details of culturally important species

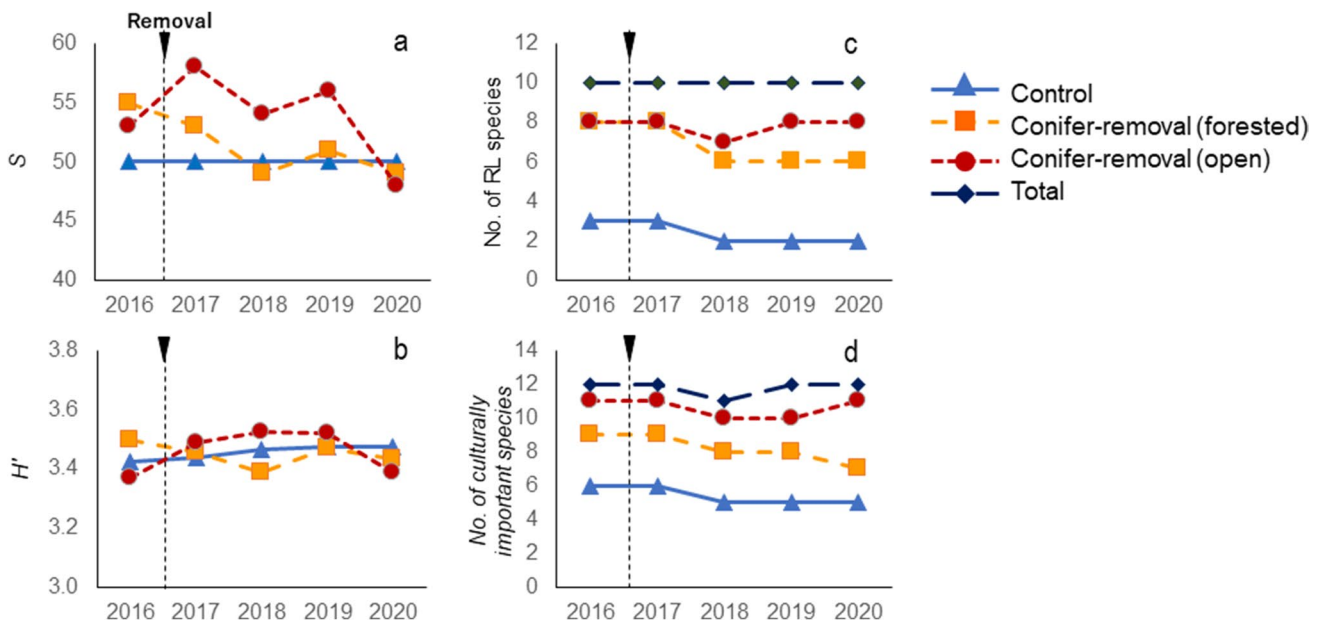
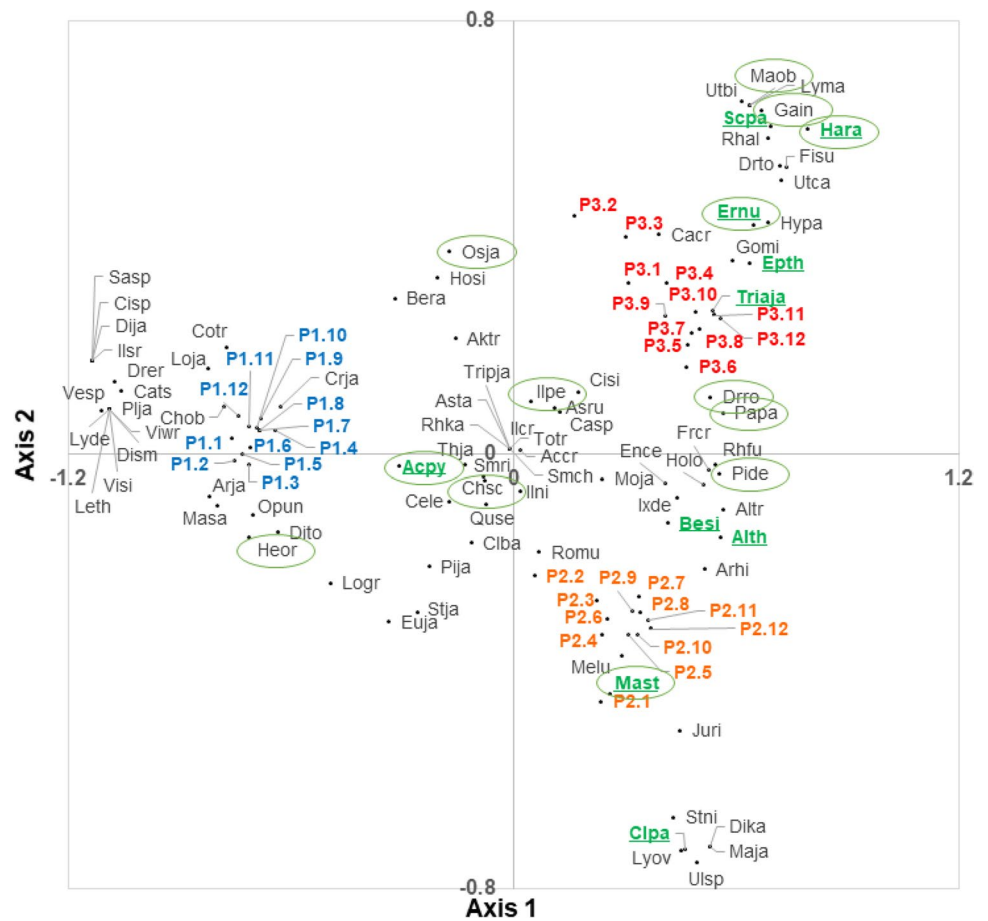


Fig. 3 Changes in (a) species richness (S), (b) Shannon index (H'), (c) number of Red List (RL) species, and (d) number of culturally important species of groundcover vascular plants in three experimental subplots on a seepage wetland in Iwayado, Nakatsugawa city, Gifu prefecture, Japan

Discussion

Owing to a high concentration of threatened plants, the Circum-Ise Bay region has been selected as one of the hotspots of plant diversity (Yahara 2002). To our knowledge, this is the first attempt to restore seepage wetlands in this region by removing non-native conifers. We perceive that our conifer-removal project, working with private landowners, was fruitful in restoring native plant diversity in the wetland and conserving its cultural association with local people. In the overstory and understory layers, *A. pycnanthum* and *M. stellata* increased in relative dominance after the conifer removal (Table 1; Fig. 1). Both of these species are listed in the national and prefectural Red Lists and also members of the Tokai Hilly Land Elements (Ueda 1989). Seepage wetlands are characterized by high numbers of shrub species (Saeki 2007). In our project, the conifer-removal plots contained 14–16 species within an area of only 200 m² after the treatment (Table 1). The removal of conifers will likely contribute to the long-term conservation of species richness of the understory layer as well.

Prior to this restoration project, we were concerned about the possibility of a negative regime shift, such as the introduction of exotic species or a marked increase in dominance of a particular common native species. However, the diversity indices of the groundcover remained high, and threatened and near-threatened species were continuously present after the conifer removal (Fig. 3). In an experiment restoring a fen in Sweden (Hedberg et al. 2012), sedges, grasses, sphagnum, and wetland vascular plants and mosses all showed a positive response to clear-cutting, with increases in their coverage. We did not observe such remarkable changes for 4 years after conifer removal. One reason for that might be the poor nutrient conditions of the seepage wetland. The electrical conductivity (EC) of seeping water in the Circum-Ise Bay region is usually around < 30 $\mu\text{S}/\text{cm}$ (Study Group of Seepage Marsh 2019). The actual EC values of seeping water at the experimental site after the conifer removal have been 17–25 $\mu\text{S}/\text{cm}$, and total N and P were 1.2 mg/L and < 0.05 mg/L, respectively (I. Saeki, unpublished data). Exotic plants are known to favor nitrogen-rich sites (Chatterjee and Dewanji 2019). It is often difficult to restore wetland vegetation when nitrogen and phosphorus levels are high because this can increase the productivity of invasive species (van der Hoek and Braakhekke 1998; Zedler 2000). Furthermore, there were limited seed sources for exotic and invasive plants within and around our research plots. Except for the two non-native conifers, there were no non-native or invasive plants, such as dwarf bamboo, within the experimental site (Fig. 2; Appendix S3).

Landowners living near the wetlands have rich cultural associations with a wide range of plants (Li and Saeki 2018; Appendix S4). Conifer-removal treatment helps with conserving these associations because culturally important species

remain after the treatment. One of the symbolic species, *H. radiata*, newly occurred in one of the subplots after the treatment (Fig. 2, Appendix S4). According to interviews with landowners, there used to be no conifers in the seepage wetlands when they were young, and wetlands were more open than today and held *H. radiata*. The landowners wanted to restore the wetlands to match those in the past, which motivated their agreement for this restoration project. For long-term conservation of the seepage wetlands, positive actions by local communities are essential because it is often difficult to pass legislation to conserve small but local-scale biodiversity hotspots like the seepage wetlands. Note that culturally important species linked with local people are not necessarily threatened species (Fig. 2), which are often targeted for conservation by scientists, conservation organizations, and governments. We argue the importance of paying attention to local perceptions of the value of biodiversity. When trying to conserve the plant communities of these seepage wetlands, we should focus not only on species with scientific and conservation importance as monitoring indicators, such as threatened, local-endemic species, but also on those having cultural value to local people.

In the conifer-removal plots, the number of species appearing or disappearing was relatively high, and thus plant species composition may be changing over the short term. The rapid change in species composition after the treatment is typical in similar restoration projects (e.g., Glennemeier et al. 2020), and this implies that long-term monitoring is necessary. We conclude that conifer removal on the biodiversity-rich seepage wetlands in the Circum-Ise Bay region can be a prioritized option for managers to conserve their unique plant composition, diversity, and cultural association with local people.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s13157-022-01639-2>.

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Data Availability Vegetation data we used for the analyses are available from Appendix S3.

Declarations

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

References

- Behailu BM, Pietilä PE, Katko TS (2016) Indigenous practices of water management for sustainable services: case of Borana and Konso, Ethiopia. *SAGE Open* 6:2158244016682292. <https://doi.org/10.1177/2158244016682292>
- Brinson MM, Malvárez AI (2002) Temperate freshwater wetlands: types, status, and threats. *Environmental Conservation* 29:115–133. <https://doi.org/10.1017/S0376892902000085>
- Chatterjee S, Dewanji A (2019) Soil nutrients can influence exotic species richness in urban areas: a case study from the city of Kolkata. *American Journal of Plant Sciences* 10:2052–2069. <https://doi.org/10.4236/ajps.2019.1011145>
- Davis MA, Grime JP, Thompson K (2000) Fluctuating resources in plant communities: a general theory of invasibility. *Journal of Ecology* 88:528–534. <https://doi.org/10.1046/j.1365-2745.2000.00473.x>
- Gifu Prefectural Government (2014) Red data book of Gifu prefecture (Plant). <https://www.pref.gifu.lg.jp/page/11109.html>. Accessed 31 March 2022
- Glennemeier K, Packard S, Spyreas G (2020) Dramatic long-term restoration of an oak woodland due to multiple, sustained management treatments. *PLoS ONE* 15:e0241061. <https://doi.org/10.1371/journal.pone.0241061>
- Hájek M, Hekera P, Hájková P (2002) Spring fen vegetation and water chemistry in the Western Carpathian flysch zone. *Folia Geobotanica* 37:205–224. <https://doi.org/10.1007/BF02804232>
- Hedberg P, Kotowski W, Saetre P, Mälson K, Rydin H, Sundberg S (2012) Vegetation recovery after multiple-site experimental fen restorations. *Biological Conservation* 147:60–67. <https://doi.org/10.1016/j.biocon.2012.01.039>
- Hobbs RJ, Huenneke LF (1992) Disturbance, diversity, and invasion: implications for conservation. *Conservation Biology* 6:324–337. <https://doi.org/10.1046/j.1523-1739.1992.06030324.x>
- Kløve B, Ala-aho P, Bertrand G, Boukalova Z, Ertürk A, Goldscheider N, Ilmonen J, Karakaya N, Kupfersberger H, Kværner J, Lundberg A, Mileusnić M, Moszczynska A, Muotka T, Preda E, Rossi P, Sergieiev D, Šimek J, Wachniew P, Angheluta V, Widerlund A (2011) Groundwater dependent ecosystems. Part I: hydroecological status and trends. *Environmental Science & Policy* 14:770–781. <https://doi.org/10.1016/j.envsci.2011.04.002>
- Li Y, Saeki I (2018) Values of seepage wetlands: relationship between wetlands and local communities in Iwayado, Nakatsugawa-city, Japan. *Wetland Research* 8:81–97. <https://doi.org/10.24785/wetlandresearch.WR008010> (In Japanese with English summary)
- Maffi L (2001) *On Biocultural Diversity: Linking Language, Knowledge and the Environment*. Smithsonian Institution Press, Washington, D.C
- Magurran AE (1988) *Ecological Diversity and Its Measurement*. Princeton University Press, New Jersey
- Makinouchi T (2001) Stratigraphy of the Tokai Group and evolutionary process of the Lake Tokai sedimentary basin. *Science Report of Toyohashi Museum of Natural History* 11:33–39 (In Japanese with English summary)
- Mayers J, Batchelor C, Bond I, Hope RA, Morrison E, Wheeler B (2009) Water ecosystem services and poverty under climate change: Key issues and research priorities. In: *Natural Resource Issues*. International Institute for Environment and Development, London
- Meli P, Rey Benayas JM, Balvanera P, Martínez Ramos M (2014) Restoration enhances wetland biodiversity and ecosystem service supply, but results are context-dependent: a meta-analysis. *PLoS ONE* 9:e93507. <https://doi.org/10.1371/journal.pone.0093507>
- Ministry of Environment (2020) Red list of vascular plants in Japan. <http://www.env.go.jp/press/files/jp/114457.pdf>. Accessed August 13, 2020
- Mitsch WJ, Bernal B, Hernandez ME (2015) Ecosystem services of wetlands. *International Journal of Biodiversity Science, Ecosystem Services & Management* 11:1–4. <https://doi.org/10.1080/21513732.2015.1006250>
- Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H (2020) *Vegan: Community Ecology Package (Version 2.5–5)*. URL <https://cran.r-project.org/web/packages/vegan/vegan.pdf>
- R Core Team (2021) R: a language and environment for statistical computing. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Saeki I (2007) Effects of tree cutting and mowing on plant species composition and diversity of the wetland ecosystems dominated by the endangered maple, *Acer pycnanthum*. *Forest Ecology and Management* 242:733–746. <https://doi.org/10.1016/j.foreco.2007.02.009>
- Sims S, Hilberg L, Reynier W, Kershner J (2019) Seeps and Springs: Northern California Climate Change Vulnerability Assessment Synthesis. Version 1.0. *EcoAdapt*. <http://ecoadapt.org/projects/adaptation-consultations/norcal>. Accessed 8 Aug 2021
- Study Group of Seepage Marsh (2019) Seepage marshes in Tokai area, Japan. (In Japanese)
- Takeuchi K (2001) Nature conservation strategies for the 'SATOYAMA' and 'SATOCHI', habitats for secondary nature in Japan. *Global Environmental Research* 5:193–198
- Tomscha SA, Bentley S, Platzer E, Jackson B, de Roiste M, Hartley S, Norton K, Deslippe JR (2021) Multiple methods confirm wetland restoration improves ecosystem services. *Ecosystems and People* 17:25–40. <https://doi.org/10.1080/26395916.2020.1863266>
- Ueda K (1989) Phytogeography of Tokai hilly land element I. Definition. *Acta Phytotaxonomica Geobotanica* 40:190–202. <https://doi.org/10.18942/bunruichiri.KJ00001078646> (In Japanese with English summary)
- Ueda K (1994) The Origin and evolution of the Tokai hilly land element. In: Okada H, Ueda K, Kadono Y (eds) *Natural History of Plants: Evolutionary Studies of Diversity*. Hokkaido University Press, Sapporo, pp 3–18 (In Japanese)
- van der Hoek D, Braakhekke WG (1998) Restoration of soil chemical conditions of fen-meadow plant communities by water management in the Netherlands. In: Joyce CB, Wade PM (eds) *European wet grasslands: biodiversity, management and restoration*. Wiley, pp 265–275
- Yahara T (2002) Evaluation of extinction risk in the plant red data book and its application. In: Yahara T, Kawakubo N (eds) *Biology of Conservation and Restoration*. Bun-ichi Sogo Shuppan, Tokyo, pp
- Yamaura Y, Oka H, Taki H, Ozaki K, Tanaka H (2012) Sustainable management of planted landscapes: lessons from Japan. *Biodiversity and Conservation* 21:3107–3129. <https://doi.org/10.1007/s10531-012-0357-4>
- Zedler JB (2000) Progress in wetland restoration ecology. *Trends in Ecology & Evolution* 15:402–407. [https://doi.org/10.1016/S0169-5347\(00\)01959-5](https://doi.org/10.1016/S0169-5347(00)01959-5)

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