

ORIGINAL RESEARCH ARTICLE

Managerial approach for transplanted rare plants: A proposal

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ABSTRACT

The species currently listed as rare plants are roughly divided into two types. The populations of one type of rare plants (including *Pellionia minima* Makino) have decreased due to habitat changes (e.g., from a wet environment to a dry environment) by human-driven development. The populations of the other type of rare plants (including disturbance-dependent species) have decreased because they are unmanaged. The former type of plants is stress tolerance-strategy or competition-strategy species, whereas the latter is only ruderal-strategy species. The stress tolerance-strategy or competition-strategy species do not need management after the protection period ends, but the ruderal-strategy species require adaptive management even after the protection period expires. The protection period of *P. minima* (a stress-tolerant competitor) is estimated to be approximately 1 year after transplant because *P. minima* have sufficient ecological adaptability and resilience, and growth in these plants is confirmed roughly 1 year after transplant.

Keywords: Growth Rate; *Pellionia Minima* Makino; Stress-tolerant Competitor; Survival Rate

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1. Introduction

In Japan, the Ministry of the Environment, local governments and nongovernmental organization (NGOs) together created Japan's Red List of Threatened Species. In Japan's Red List 2017 published by the Ministry of the Environment^[1], the total number of threatened species (animals, fungi and plants) is 3,634 species. The National Biodiversity Strategy of Japan 2012–2020 defines four crises of biodiversity: (1) crises due to human activities such as development; (2) crises due to reduced intervention in nature; (3) crises due to alien species brought by humans and (4) crises due to changes of the global environment^[2]. In the planned construction site of Kochigawa Dam (Wakasa Town, Fukui Prefecture, Japan), the presence of the rare plant *Pellionia minima* Makino was confirmed in July 2004. The *P. minima* was later transplanted from a flooded/submerged area at that site and their growth was monitored. The results of the transplantation and monitoring were presented in Matsui^[3]. Herein I make a proposal concerning the managerial approach for transplanted rare plants based on the results of the *P. minima* transplantation.

Kochi River is located in Wakasa Town, Fukui Prefecture, on Japan's main island of Honshu. Its basin area is 16.3 km², and the length of the river channel is 6.4 km. The Kochi River has undergone from many floods and droughts, and Kochigawa Dam (**Figure 1**) is being constructed to address these problems. The Kochigawa Dam has a catchment area of 14.5 km², a submerged area of 0.37 km², a dam height of 77.5 m, a crest length of 202.3 m, a surcharge water-level

altitude of 197.7 m, a full water-level altitude of 190.5 m, a lowest low-water-level altitude of 162.7 m, and a reservoir capacity of 8 million m³. Construction started in 2012 and is scheduled to be completed in 2019. The construction objectives are flood control, normal functioning of the river water, agriculture water supply, city water supply and industrial water supply.

An evaluation of the animals and plants in the planned construction site of Kochigawa Dam confirmed the presence of *P. minima* in a flooded/submerged area of the planned construction site. This species is a rare perennial herb that grows in wet places in mountains. The stem crawls across the ground, is approximately 10 cm–30 cm long, and the leaf has obtusely saw teeth with dense short hair. The flower season is from April to June, and it is a dioecious plant. This species has shown a declining trend due to the deterioration of growing conditions by deforestation. According to the Fukui red data book, *P. minima* is now classified as near-threatened in Fukui Prefecture. This species is distributed from the west of the main island of Honshu to Okinawa, and only in the south area of Fukui Prefecture^[4].

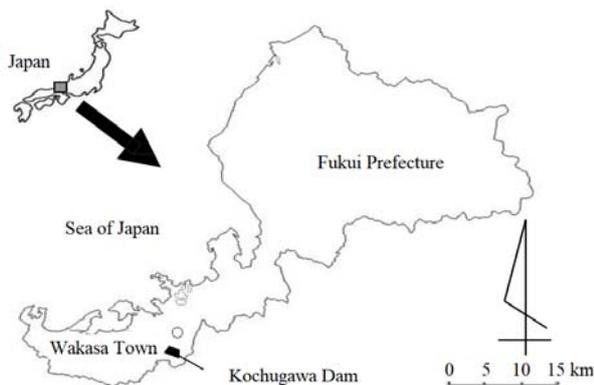


Figure 1. Location of survey area.

As a conservation measure of this species, the plants' transplantation to areas outside the submerged site and subsequent monitoring were selected. Other rare plants have been transplanted as part of road projects' conservation measures^[5,6] and as a compensation method for the impact of dam projects^[7]. However, there has been no case study of *P. minima* transplantation.

In the present study by Matsui^[3], the transplanting of *P. minima* began in 2013 and ended in

2016. A total of 461 individual plants were transplanted: 56 in 2013, 100 in 2014, 205 in 2015, and 100 in 2016 (**Table 1**). The transplant destinations were three districts designated A, B and C outside the submerged area in the Kochigawa Dam's planned construction site. Ten separate transplantation sites (A-1, A-2, A-3, A-4, B-1, B-2, B-3, B-4, C-1 and C-2) were used. Sites B-2 and B-3 and Sites C-1 and C-2 were transplanted in the same year, but they were handled separately because these sites were distant from each other. The leaf size and vitality in each of the four seasons (spring, summer, autumn and winter) were then monitored. Here the results were reported and a proposal regarding the monitoring period for the transplantation of rare plants in future dam projects was made.

Table 1. Number of individuals of *Pellionia minima* bedded out in the transplant sites

Site	2013	2014	2015	2016	Total
A-1	56				186
A-2		50			
A-3			30		
A-4				50	
B-1		50			170
B-2			30		
B-3			40		
B-4				50	
C-1			60		105
C-2			45		
Total	56	100	205	100	461

This table is derived from Matsui^[3].

Alteration of natural ecosystems is often necessary as human societies expand and develop. Mitigation measures such as avoidance, reduction and compensation must then be considered as environmental conservation measures. The transplanting of rare plants described herein corresponds to the compensation. Although wild animals and plants have varying degrees of ecosystem resilience, a protection period is necessary immediately after the transplantation of rare plants. The transplanted individuals can be expected to survive in the natural ecosystem after a protection period ends. If the protection period becomes too long, it will delay the plants' opportunity to return to a natural ecosystem. It is thus necessary to determine the optimal protection period of the transplanted individuals by monitoring their health and growth.

2. Methods

2.1 Survey of transplant candidate sites

As a survey of candidate transplantation sites toward the selection of sites that are similar to the environment of the autogenesis ground of *P. minima*, growth location and physical environment items at the transplant districts A, B and C were examined. The growth location items were vegetation and the presence/absence of damage by wild animals (mainly Sika deer [*Cervus nippon*]). The physical environment items were soil (as soil texture, humus, soil hardness, water wettability and pH), light (as relative light intensity) and terrain. The survey demonstrated that the soil texture of all three transplant districts is composed of clay loam soil, with abundant humus, soil hardness = soft, water wettability = moistened, pH = weakly acidic (4.2–4.8) and relative light intensity = 3%–10% (Table 2). These results confirmed that districts A, B and C provide almost the same environment as the autogenesis ground.

Table 2. Physical environment items in habitat of *Pellionia minima*

Soil texture	Clay loam soil
Humus	Abundant
Soil hardness	Soft
Water wettability	Moistened
pH	Weakly acidic (4.2–4.8)
Relative light intensity	3%–10%

2.2 Transplant period and method

In the typical transplant period of herbaceous plants, the blooming of spring species is from mid-February to early March, or from mid-September to early October; the blooming of summer-to-autumn species is from early March to mid-April^[8]. Since *P. minima* is a species that blooms in spring and its autogenesis area have snow in winter, the optimal transplant period is judged to be from September to October. The activity of the plants is higher in September, and because transplantation result in damage to the roots, all of the transplantations of the individual *P. minima* were done during the month of October in 2013, 2015 and 2016; the exception was November in 2014.

The transplant method was carried out in the order of land-conditioning of the transplant dis-

tricts, digging and transporting at the autogenesis ground, and planting at the transplant sites. First, the removal of fallen leaves and branches, graveling and landscaping were carried out at the transplant sites. *P. minima* was hand-picked from the autogenesis ground one by one. Pot seedlings were placed in order to suppress drying, and transported to the transplant sites. The graft holes were excavated at 30 cm intervals, and a single pot seedling was planted in each graft hole. The irrigation was done by hand, and care was taken to ensure that the soil clogged well between the roots. After the transplanting, mulch with fallen leaves was added to prevent the soil/plant from drying. The transplanting was carried out step-by-step to the A, B and C districts in that order from 2013 to 2016 in order to reduce the risk of transplanting fails.

2.3 Monitoring method

To obtain the size of the leaves of the transplanted individuals, a fold scale was used to measure the length of the longitudinal side (X) and the length of the transverse side (Y), which is orthogonal to X. The vitality of the transplanted individuals was visually evaluated based on the leaf state, flowering, the presence/absence of insect damage. In the transplant year, monitoring was carried out immediately after the transplantation and at ≥ 1 week and at ≥ 1 month, post-transplantation and before snowfall. During the year after the transplantation, monitoring was done once in each of the four seasons (spring, summer, autumn and winter).

3. Results

3.1 Survival rate

The survival rate at each site was determined as followed: the number of individual plants surviving in the winter of 2016 was divided by that of transplanted plants. Table 3 summarizes the sequential changes in the surviving number of *P. minima* bedded out in the transplant sites. The numbers are those of the survivors in the winter of each year. For each transplant year, the number is that of the live individuals before snowfall. In winter 2016, the survival of 452 individual plants

was confirmed (98% average survival rate).

Table 3. Sequential changes in the surviving number of *Pellionia minima* bedded out in the transplant sites

Site	Transplanted number	2013	2014	2015	2016	Survival rate
A-1	56	56	56	51	50	89%
A-2	50		50	50	50	100%
A-3	30			30	30	100%
A-4	50				50	100%
B-1	50		50	49	49	98%
B-2	30			30	30	100%
B-3	40			40	38	95%
B-4	50				50	100%
C-1	60			60	60	100%
C-2	45			45	45	100%
Total	461	56	156	355	452	98%

This table is obtained from Matsui^[3].

3.2 Growth rate

The growth rate was determined as followed: the leaf size in the winter of 2016 was divided by that before the snowfall of the transplanting year, and the median value was omitted from the outlier values. **Table 4** shows the sequential changes in the increases and decreases of the average leaf size of *P. minima* bedded out in the transplant sites. The av-

erage growth rate of the eight transplant sites was 2.1. Student's t-test was used to determine the significance of the changes in the average value of the leaf size of the previous year for each transplant site. Significant changes (i.e., with $p < 0.05$) are shown in **Table 4** as “↗”, and non-significant changes are indicated by “-”.

Table 4. Sequential changes in the increases and decreases of the average leaf size of *Pellionia minima* bedded out in the transplant sites

Site	2013	2014	2015	2016	Growth rate
A-1	Transplantation	-	↗	-	1.2
A-2		Transplantation	↗	↗	5.6
A-3			Transplantation	↗	2.5
B-1		Transplantation	↗	-	5.8
B-2			Transplantation	-	0.9
B-3			Transplantation	-	0.8
C-1			Transplantation	↗	2.1
C-2			Transplantation	↗	3.1
Total					2.1

Note: ↗ : $p < 0.05$; - : $p > 0.05$.

This table is collected from Matsui^[3].

4. Discussion

4.1 Growth rate

The leaf size of many of the transplanted individuals increased in the year following the transplantation, but there were some sites (A-1, B-2 and B-3) where no increase in leaf size was observed in the year after transplantation. The infiltration of *Cervus nippon* and sediments is suspected at these sites, and it is therefore speculated that the growth suppression at these three sites is due to the penetration of *Cervus nippon* and the influx of gravel from the upper slope at the sites.

4.2 Determination of transplant success

The determination of transplant success was based on the survival rate, growth rate and vitality of the transplanted individuals. Overall, the transplanted individuals generally survived in districts A, B and C. The growth rate exceeded 1.0 except for Sites B-2 and B-3. Large growth abnormalities, e.g., feeding damage and insect damage were not observed at any of transplant sites, and the transplanted individuals grew steadily and satisfactorily. From the above results, it is apparent that the transplanted individuals were well established as of this writing in 2017.

4.3 Monitoring period proposal

The optimal monitoring period for the trans-

plantation of *P. minima* originally expected to be 3 years (including two overwintering years) for the plants' complete survival over several dormancy periods after transplantation. However, since the increase in leaf size was confirmed and no major abnormalities were observed in the present monitoring and the plants grew steadily and well, it is apparent that it will be not necessary to monitor *P. minima* for 3 years after they are transplanted. Confirmation of the leaf-size increase can be used to classify the transplanted individuals as established. At the time point at which the transplantation is defined as successful, it could be said that the monitoring period can be discontinued. However, monitoring at dam construction sites is often subject to period restrictions, and it is thus important to judge the success of the transplant at the earliest stage.

On the other hand, the habitats change for animals and plants are expected to be stressful. When possible, it is desirable to take evasive measures so that transplantation is not necessary. Transplantation as simply an easy first option should be avoided. In addition, a protection period will be necessary following transplanting, and the length of the period should be optimal. *P. minima* has sufficient ecological adaptability and resilience, and its growth was confirmed herein at roughly 1 year after transplant. Ecosystem adaptability and resilience are truly remarkable.

4.4 Conservation measures other than stock transplant

In the cases of stock transplant as described in this research, most of the practical applications are done as plant environmental conservation measures, and the effect of the measures is easy to grasp. However, there is a risk that target individuals will not settle in at the transplant sites and disappear. It is thus desirable to use multiple methods^[6]. *P. minima* does not accomplish a generation update by seed propagation; it is maintained and expanded by vegetative propagation with stolons. When a seed-propagating plant is being transplanted, it is also possible to collect seeds from the stock and to transplant the soil. Transplanting the soil is a method that can efficiently move many individuals. It has been shown to be effective in the restoration

of lakeshore vegetation using sediment seed banks^[9].

4.5 Management after protection period

The present study's results demonstrated that transplanted *P. minima* will return to the natural ecosystem after a protection period. As this species grows in wet places in the mountains, it can be left to the progress of the undisturbed ecological transition. On the other hand, for species that grow in an environment where disturbances occur (such as wetlands and paddy fields), it is necessary to carry out management similar to conventional farming work such as the plowing of rice fields, the regulation of the water level and the maintenance of ditches and mowing^[10]. In other words, the management after the protection period must differ according to the type of transplant.

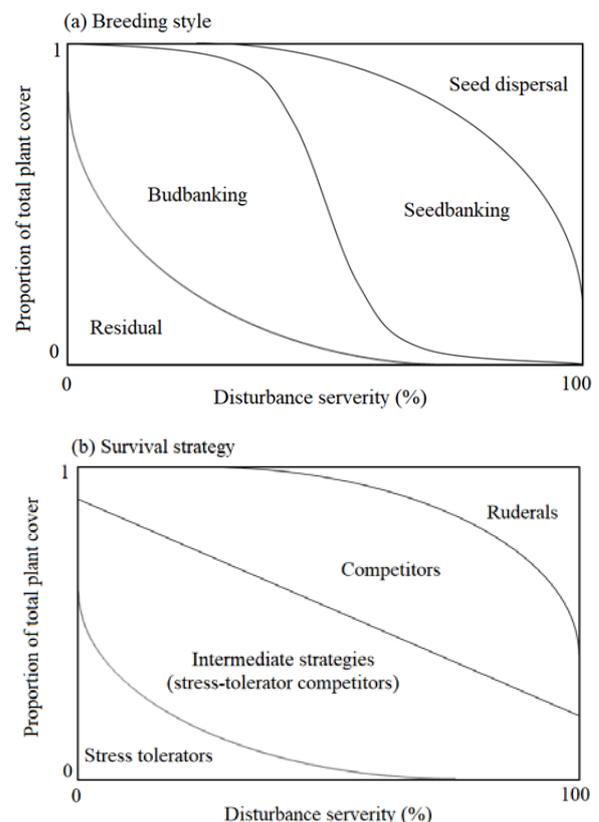


Figure 2. Changes in (a) the breeding style and (b) the survival strategy of plants with increasing disturbance severity. This figure is modified from Haeussler *et al.*^[11]

According to Grime^[11] and Haeussler *et al.*^[12], the breeding style and the survival strategy of *P. minima* are budbanking and stress-tolerant competitor, respectively (**Figure 2**).

The species currently listed as rare plants are

roughly divided into two types. The populations of one type of rare plants (including *P. minima*) have decreased due to habitat changes (e.g., from a wet environment to a dry environment) by human-driven development. The populations of the other type of rare plants (including disturbance-dependent species) have decreased because they are unmanaged. The relationship between rare plant types and management methods is illustrated

in **Table 5**. The former rare plant type is comprised of stress tolerance-strategy or competition-strategy species, whereas the latter rare plant type is comprised of only ruderal-strategy species. The stress tolerance-strategy or competition-strategy species do not need management after the protection period ends, but the ruderal-strategy species require adaptive management even after the protection period expires.

Table 5. Relationship between rare plant types and management methods

Type	Stress tolerance-strategy	Competition-strategy	Ruderal-strategy
Threat	Development	Development	Un management
Management	Unnecessity	Unnecessity	Adaptive management

Conflict of interest

The author declared no conflict of interest.

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