Chapter 8
Changes in Vegetation in the Ooyamazawa Riparian Forest

Forest Floor Vegetation

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Abstract  Sika deer are responsible for diverse effects in the forest vegetation of the Chichibu Mountains. The lowest level of understory plants in the riparian forest of Ooyamazawa in the Chichibu Mountains covered over 90% of the land area in 1983, but the coverage decreased to 3% by 2004. In 2017, the area seemed to have recovered slightly; the coverage was approximately 10%. The decreases in plant populations could be attributed to sudden increases in deer population density, detected post-2000 by cervid research in this area. The plants that remained as of 2017 shared characteristics which could have contributed to their survival in the presence of deer overpopulation. They were either I: toxic plants, II: small herb species which do not increase in plant height, or III: perennial herbs in which the aerial portion withers until the summer and enters yearly dormancy at an early date.

Keywords  Deer fence · Ferns · Forest floor vegetation · Grazing · Herbs · Sika deer · Species diversity · Toxic plants · Understory plants
8.1 Introduction

In recent years, the number of sika deer (*Cervus nippon*) broadly distributed throughout the Shikoku, Kyushu, and Honshu districts in Japan has increased, and their negative impact on various forest vegetation is evident (e.g., Hattori et al. 2010; Ishida et al. 2012; Otsu et al. 2011; Shimoyama 2012; Planning Committee-The Society of Vegetation Science 2011; Ohashi et al. 2014). The influence of deer grazing in forests appears in the forest floor vegetation at an early stage; unpalatable plants begin to dominate as the grazing effects intensify (Takatsuki 2009).

A long-term monitoring study that began before the vegetation damage increased in Kanto district (Okutama region) by Ohashi et al. (2007) showed that the height and coverage of the herbaceous layer had tended to decrease in cool-temperate forest communities and grassland. Furthermore, species richness decreased in subalpine *Abies* forests, riparian *Fraxinus* forests, and deciduous *Quercus* forests. If the damage continues for a long time after this stage, the entire forest structure changes (Gill 1992; Kirby and Thomas 2000); therefore, to prevent this, it is necessary to suppress the influence from deer (Akashi 2009).

In a case study on the use of fences to protect cool-temperate natural forests where species composition had already been altered by sika deer grazing, the original vegetation populations recovered. After deer grazing pressure was eliminated by protective fences, the tall perennial herbs and endangered species increased, and tree saplings and dwarf bamboo recovered (Tamura 2007, 2013). Deer protection fences have been used in many areas because they effectively facilitate the recovery of vegetation (Tamura 2008, 2013). However, it is important to quantify the impact of deer grazing on various types of forest vegetation to determine which of these are the most susceptible to the presence of deer. This facilitates determination of areas that need to be fenced.

Riparian forests established along rivers generally show high species diversity (Chap. 1). In particular, many herbaceous plants and ferns grow on the riparian forest floor and form forest floor vegetation unique to various micro-topographies formed by ground movements, such as debris flow and slope failure (Kawanishi et al. 2004, 2005, 2008). Forest floor vegetation within such species-rich forests must be taken into account, because it is susceptible to drastic changes due to the influence of deer.

8.2 Increase in Sika Deer Population and the Change in the Structure of an Ooyamazawa Riparian Forest

Surveys have been conducted in the Ooyamazawa riparian forest since 1983, collecting data on forest floor vegetation, although not every year. Population surveys of sika deer have been conducted while surveying serow populations in 1982 (Saitama Museum of Natural History 1983), 1987, 1992, 2000–2001, 2008–2009 (Gunma, Saitama, Tokyo, Yamanashi and Nagano Prefectural Boards
of Education 1988, 1994, 2002, 2010) in the vicinity of Ooyamazawa. These results show that the deer populations have been rapidly increasing since 2000 (Fig. 8.1). Although the presence of some deer was confirmed by Sakio in a 1982 serow survey, we seldom witnessed sika deer in the Ooyamazawa riparian forest between 1983 and 2000. Generally, the surveys did not report observation of feces or tree bark peeling during this period. Until 1999, the forest floor was covered with large ferns and herbs, and abundant Fraxinus platypoda and Pterocarya rhoifolia saplings also grew (Sakio 1997). However, this flora has disappeared from the forest floor since 2002. In addition, after 2000, we frequently spotted deer and heard cries at the time of investigation. In 2004, we found a deer carcass.

Sakio et al. (2013) reported changes in the forest floor vegetation of the Ooyamazawa riparian forest over 21 years from 1983 to 2004. The monitoring plot of this study is located at the bottom of a flat valley, which is approximately 60 m wide and buried in debris flow at an altitude of approximately 1300 m a.s.l. (Chap. 1). Plant species names and the degree of dominance in each stratum in the valley were recorded using the phytosociological vegetation survey method (Braun-Branquet 1964). The herbaceous layer measured 1 m or less, which is almost same as the height of large ferns (such as Dryopteris crassirhizoma, Polystichum ovatopaleaceum) and large herbs (such as Cacalia yatabei, Spuriopimpinella nikoensis). The four vegetation surveys conducted in 1983, 1998, 2001, and 2004 have been reported in Sakio et al. (2013). In 2016 and 2017, data were obtained in the same manner; these surveys were conducted from June to August in each survey year.

In this chapter, we would like to clarify the change in forest floor vegetation over 34 years by adding the new data from 2016 and 2017.
8.3 Changes in Coverage and Number of Species Over 34 Years

Forest floor vegetation within the Ooyamazawa riparian forest decreased precipitously in the 34 years from 1983 to 2017. The change was particularly significant from 1998 to 2004. In 1988, the plant cover ratio in the herbaceous layer reached about 90% because the forest floor was covered with large ferns and herbs as mentioned above (Fig. 8.2a). However, it decreased to approximately 50% in 2001, and it had plummeted to 3% by 2004 (Fig. 8.3). Through the above changes, most of the originally rich forest floor vegetation has currently disappeared (Fig. 8.2b). The reduction in herb cover followed the same timeline as the increase in deer population. The Ooyamazawa case exemplifies the characteristics of Japanese cold-temperate forest change brought on by deer that Ohashi (2017) pointed out. Even in 2016, which is 12 years after the alarming 2004 survey, the planting rate is less than 5%. Even in 2017, when the forest seemed to have recovered slightly, the cover rate is about 10%. We can recognize that the forest remains under strong grazing pressure from deer.

The number of species also decreased significantly during the same time span. We could observe 76 species in the herbaceous layer in 1983, but these decreased by

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**Fig. 8.2** (a) Physiognomy of forest floor vegetation in 1988 (photograph by Sakio, from Sakio et al. 2013). (b) Physiognomy of forest floor vegetation in 2003 (photograph by Sakio, from Sakio et al. 2013). Left and right picture shows the same site of Photo a, respectively.
half to 40 species in 2004, and further decreased to 30 species by 2017 (Fig. 8.3). The decreasing tendency showed a different pattern among the plant elements (Fig. 8.4). The plants confirmed during the survey period from 1983 to 2017 were 8 species of ferns, 24 woody species, and 57 herbaceous species, with a total number of 89 species. The number of fern species is relatively few and the change in the number of species cannot be clearly read, but the number of species lost has halved from six species to three species between 1983 and 2004, and most recently it was four species in 2017. Although the number of species lost can be as small as two or three species, it represents a significant loss framed within the proportion of total species. This decline in ferns had a significant influence in total vegetation cover in the herbaceous layer because several ferns often occupied large areas as the dominant species in the riparian forest floor (Kubo et al. 2001; Kawanishi et al. 2004, 2008). On the other hand, 21 woody species were confirmed in 1983, but decreased to nine species by 1998. Thereafter, only eight species were observed in 2017; there has been no major change since 2004. Although the cover ratio of saplings, except Fraxinus platypoda, was not large in the herbaceous layer, vanishing numbers of various woody saplings spells the loss of a seedling bank. This is seriously damaging to the regeneration of a forest. The herbaceous plants showed the largest reduction in both number of species number and proportion. There were 48 species of herbaceous

Fig. 8.3 Changes in coverage and number of species within the herb layer over 34 years

Fig. 8.4 Changes in number of species across each type of growth
plants in 1983, but this number decreased by half (24 species) in 1998 and then further decreased to 18 species by 2016.

8.4 Changes in Species Composition

The changing species patterns have been classified into six types. These types were made based on the fluctuation patterns seen from 1983 to 2004 reported by Sakio et al. (2013), and the variation in vegetation seen in 2016 and 2017 was added to complete the picture. The dominance of each species in each division is shown in Table 8.1.

“Changeless species”: Species that appeared and did not change their dominance throughout the survey period.

“Species declined since 2001”: Species that appeared throughout the study period, but dominance declined from 2001-onward.

“Disappeared species as of 2017”: Species that were confirmed until 2004 or 2016, but were not present in 2017.

“Disappeared species as of 2004”: Species that were confirmed until 1998 or 2001, but were not present in 2004.

“Species appeared after 2016”: we could not confirm its presence before 2004, but could be observed after 2016.

“Other species”: these species did not have a clear tendency of appearance over time.

There was a tendency for “Changeless species” to include the toxic plants (such as Aconitum sanyoense: Fig. 8.5, Scopolia japonica: Fig. 8.6) and the perennial herbs that wither above-ground early in the summer (such as Adoxa moschatellina: Fig. 8.7, Cardamine leucantha, Trillium spp.: Fig. 8.8, Scopolia japonica). In addition, perennial herbs distributed in unstable sites such as new collapsed areas and terraced scarp, such as Elatostema umbellatum var. majus: Fig. 8.9, Cacalia farfaraefolia (see Chap. 6) were also included in this group.

The group of “Species declined since 2001” includes herbs (e.g., Meehania urticifolia and others) and ferns (e.g., Cornopteris crenulatoserrulata, Polystichum tripteron: Fig. 8.10), and seedlings of canopy tree species (Fraxinus platypoda, Pterocarya rhoifolia, Abies homolepis) that dominated in 1983. As seedlings of these tree species are regenerated by canopy trees almost every year, they might appear continuously.

Although the coverage of Fraxinus platypoda and Pterocarya rhoifolia in 1983 was large and they made dense sapling patches on the sand-gravel land along the ravine channel stream (Sakio 1997), their presence was greatly reduced by the influence of deer.

“Disappeared species as of 2017” includes species that had been eliminated at the time of survey in 2017 though included in the “declined species” category by Sakio et al. (2013). Dryopteris crassirhizoma (Fig. 8.11), Asarum caulescens (Fig. 8.12), Mitella pauciflora, etc. remained (despite their remarkable reduction in coverage).
Table 8.1  Changes in species composition over 34 years

| Lifeform  | 1983 | 1998 | 2001 | 2004 | 2016 | 2017 |
|-----------|------|------|------|------|------|------|
| **Changeless species**                           |      |      |      |      |      |      |
| Aconitum sanyoense                               | H    | +    | +2   | +    | 1-2  | +    |
| Adoxa moschatellina                              | H    | +    | +    | +2   | +    | +    |
| Cacalia farfararofolia                           | H    | +    | +    | +    | +    | +    |
| Cardamine leucantha                              | H    | +    | +    | +    | +    | +    |
| Chrysosplenium echinus                           | H    | +    | 1-2  | +    | +    | +    |
| Elatostema umbellatum var. majus                 | H    | +2   | +2   | +    | +    | +    |
| Galium paradoxum                                 | H    | +    | +    | +2   | +    | +    |
| Schizophragma hydrangeoides                      | T    | +2   | +2   | +    | +    | +    |
| Scopolia japonica                                | H    | 2-2  | 1-2  | 2-2  | 1-2  | 1-2  |
| Thalictrum filamentosum var. tenurum             | H    | +    | +    | +    | +    | +    |
| Trillium spp.                                    | H    | +    | +    | +    | +    | +    |
| **Declined species since 2001**                  |      |      |      |      |      |      |
| Abies homolepis                                  | T    | 1-2  |      |      |      |      |
| Cornopteris crenulatoserrulata                   | F    | 2-3  | 2-3  | 2-2  | +    | +    |
| Fraxinus platypoda                               | T    | 3-3  | +2   | +    | +    | 1-1  | 2-2  |
| Hydrangea serrata                                | T    | +    | 1-2  | +    | +    | +    |
| Laportea bulbifera                               | H    | 1-2  | 1-2  | +    | +    | +    |
| Meehania urticifolia                             | H    | 1-2  | 1-2  | +2   | +    | +    |
| Polystichum tripterone                           | F    | 1-2  | +    | +2   | +    | +    | +    | +    |
| Pterocarya rhoifolia                             | T    | 1-2  | +2   | +    | +    | +    |
| **Disappeared species as at 2017**               |      |      |      |      |      |      |
| Acer carpinifolium                               | T    | +    | +    | +    |      |      |
| Acer nipponicum                                  | T    | +    | +    | +    |      |      |
| Asarum caulescens                                | H    | 2-2  | 2-2  | 1-2  | +    |      |
| Cacalia delphiniifolia                           | H    | 1-2  | +    | +    |      |      |
| Caulophyllum robustum                            | H    | +    | +    | +    |      |      |
| Chrysosplenium pilosum var. sphaerospermum       | H    | +    | +2   | +    |      |      |
| Deinanthe bifida                                 | H    | 1-2  | +2   | +    | +    |      |
| Dryopteris crassirhizoma                         | F    | 2-3  | 2-3  | 1-2  | +    |      |
| Impatiens noli-tangere                           | H    | +    | +    | +2   | +    |      |
| Laporta macrostachya                             | H    | 1-2  | +    | +    |      |      |
| Mitella pauciflora                               | H    | 2-2  | 2-2  | 1-2  | +    |      |
| Polystichum ovato-paleaceum                      | F    | 1-2  | +    | +    |      |      |
| Sambucus racemosa ssp. sieboldiana               | T    | +    | +    | +    |      |      |
| Smilacina japonica                               | H    | 1-2  | +    |      |      |      |
| Spuriopimpinella nikoensis                       | H    | 1-2  | +2   | 1-2  | +    | +    |
| **Disappeared species as at 2004**               |      |      |      |      |      |      |
| Acer mono                                        | T    | +    | +    |      |      |      |
| Acer rufinerve                                   | T    | +    | +    |      |      |      |
| Athyrium wardii                                  | F    | +2   | +2   |      |      |      |
| Bistorta tenuicaulis                             | H    | +    | +    |      |      |      |
(continued)
Table 8.1 (continued)

| Lifeform | 1983 | 1998 | 2001 | 2004 | 2016 | 2017 |
|----------|------|------|------|------|------|------|
| Cacalia tebakoensis | H+ | 2 | +2 |
| Cacalia yatabei | H | 2-2 | 1 | -2 | +2 |
| Cimicifuga simplex | H+ | + | + |
| Clematis japonica | H+ | + | + |
| Dryopteris polylepis | F | 2-3 | + | + |
| Hydrangea petiolaris | T | + | +2 |
| Osmorhiza aristata | H+ | + | + |
| Rodgersia podophylla | H+ | + | + |

**Appeared species after 2016**

| Lifeform | 1983 | 1998 | 2001 | 2004 | 2016 | 2017 |
|----------|------|------|------|------|------|------|
| Astilbe thunbergii var. thunbergii | H | + | + |
| Chrysosplenium flagelliferum | H | + | +2 |
| Chrysosplenium ramosum | H+ | + | + |
| Deparia pycnosora | F | + | + |
| Enemion raddeanum | H+ | + | + |

**Other species**

| Lifeform | 1983 | 1998 | 2001 | 2004 | 2016 | 2017 |
|----------|------|------|------|------|------|------|
| Acer amoenum | T | + | + |
| Acer argutum | T+ | + | + |
| Acer micranthum | T+ | + | + |
| Acer shirasawanum | T+ | + |
| Aconitum locyanum | H | + | + | + |
| Actinidia arguta | T+ | + | + | + | + |
| Anemonopsis macrophylla | H | + |
| Angelica polymorpha | H | + | + | + | + |
| Arisaema ovale var. sadoense | H | + |
| Arisaema tosaense | H | + | + |
| Bistorta suffulta | H | + | + |
| Cardiocrinum cordatum | H | + | + |
| Carpinus cordata | T | + |
| Cercidiphyllum japonicum | T | + | + |
| Chelonopsis moschata | H | + |
| Chrysosplenium album var. stamineum | H | + | + |
| Chrysosplenium macrostemon var. atrandrum | H | + | +2 |
| Chrysosplenium ramosum | H | + | + |
| Cimicifuga acerina | H | + |
| Euonymus melananthus | T | + |
| Euonymus oxyphyllus | T | + |
| Fagus crenata | T | + |
| Fraxinus apertisquamifera | T | + |
| Lamium album var. barbatum | H | + |
| Lepisorus ussuriensis var. distans | F | + |
| Panax japonicus | H | + | (continued) |
through 2004 and had disappeared by 2016. *Acer carpinifolium*, which was a major dominant shrub in the shrub layer of the riparian forest, had also vanished by 2017.

“Disappeared species as of 2004” are included in “disappeared species” in Sakio et al. (2013). We can recognize that these species disappeared at an early stage of deer grazing. Mainly small coverage species (such as *Cimicifuga simplex*, *Clematis japonica*, *Cacalia tebakoensis*) were included in this category, but high-coverage herbs from the 1983 survey such as *Cacalia yatabei* (Fig. 8.13) and *Dryopteris polylepis* were also included. In the case of tree species, *Acre mono* constitutes the tree layer of this riparian forest with a similar pattern.

The plants from the above-mentioned “disappeared species” are characterized as herbaceous and fern plants with tall stems (such as *Deinanthe bifida* (Fig. 8.14),

### Table 8.1 (continued)

| Species                          | Lifeform | 1983 | 1998 | 2001 | 2004 | 2016 | 2017 |
|----------------------------------|----------|------|------|------|------|------|------|
| *Paris verticillata*             | H        |      |      |      |      |      |      |
| *Persicaria debilis*             | H        | +    | +    |      |      |      |      |
| *Philadelphus satsumi*           | H        | +    | +    |      |      |      |      |
| *Pilea hamaoi*                   | H        |      |      |      |      |      |      |
| *Pseudostellaria palibiniana*    | H        | +    | +    |      |      |      |      |
| *Rabdosia umbrosa var. leucantha*| H        | 1-2  |      |      |      |      |      |
| *Rhamnus costata*                | T        | +    | +    |      |      |      |      |
| *Smilax riparia var. ussuriensis*| H        | +    |      |      |      |      |      |
| *Stellaria sessiliflora*         | H        | +    | +    | +    |      |      |      |
| *Tricyrtis latifolia*            | H        |      |      |      |      |      |      |
| *Ulmus laciniata*                | T        | +    | +    |      |      |      |      |
| *Veratrum album ssp. oxysepalum* | H        | +    | +    |      |      |      |      |

Lifeform abbreviations as follows: *H* herbs, *T* trees, *F* ferns. Numerical values in the table show Braun-Blanquet scale derived from phytosociological survey.

Fig. 8.5  New leaves (2003/4/17 Ooyamazawa) and flowers (2002/8/25 Kamikochi, Nagano pref.) of *Aconitum sanyoense*
Cacalia delphiniifolia, Impatiens noli-tangere (Fig. 8.15), and Laportea macrostachya (Fig. 8.16) or large leaf (Cacalia yatabei, Caulophyllum robustum, Polystichum ovato-paleaceum, and Dryopteris polylepis).

On the other hand, the group of “Species appeared after 2016” contained five confirmed species: Astilbe thunbergii var. thunbergii, Chrysosplenium flagelliferum, Chrysosplenium ramosum, Deparia pycnosora, and Enemion raddeanum. However, we cannot conclude whether these could be attributed to the decline in forest floor
vegetation or not, because these species have a coverage rate of less than 1%, even in 2017. The possibility of coincidence cannot be denied.

As mentioned above, the increase in the deer population had such an influence as to drastically alter the forest floor vegetation of the Ooyamazawa riparian forest. The
Fig. 8.10 *Polystichum tripteron* (2016/11/26 Gero, Gifu Pref.)

Fig. 8.11 *Dryopteris crassirhizoma* (2014/9/13 Kamikochi, Nagano Pref.)

Fig. 8.12 *Asarum caulescens* (2011/9/28 Nikko, Tochigi Pref.)
plant cover rate changed from 90% to 10% or less, and the number of emerging species also declined precipitously from 76 to 30 species. It was also revealed that such a drastic change in the forest floor vegetation occurred in a short period of several years.

8.5 Ecological Characteristics of Forest Floor Vegetation After Deer Impact

Ecological characteristics were observed in the forest floor vegetation under the continued pressure of deer grazing. Considering the remaining species as of 2017, the plants had one of the following characteristics.
Fig. 8.15  *Impatiens noli-tangere* (2016/7/24 Ooyamazawa)

Fig. 8.16  *Laportea macrostachya* (2016/7/24 Ooyamazawa)
8.5.1 Toxic Plants

For example, *Aconitum sanyoense*, *Scopolia japonica*, *Veratrum album* ssp. *oxysepalm* (Fig. 8.17). This trait is recognized as unpalatability. An increase in unpalatable plants was the most frequently reported in the world and a significant relationship has been documented between grazing and palatability (Diaz et al. 2007).

8.5.2 Small Herb Species that do not Increase in Plant Height

For example, small size herbs such as *Galium paradoxum*, *Adoxa moschatellina*, and *Pseudostellaria palibiniana* and creeping plants such as those of the *Chrysosplenium* species fit this description (Figs. 8.18, 8.19, and 8.20). Plant size and growth form are important and effective for estimating deer feeding probability (Diaz et al. 2007; Takatsuki 2015). Herbaceous plants with heights of 30 cm or more which are upright, branched, or on vines are susceptible to feeding and showed larger impacts (Takatsuki 2015). On the other hand, small species such as rosettes and creeping plants have an easier time avoiding deer. Ohashi et al. (2007) showed that the small herbs increase or do not change under deer grazing. Kirby and Thomas (2000) show that the species that increased had the tendency to be more ruderal in Grime’s strategy; they were smaller and less likely to have leafy stems although the differences were not significant.
8.5.3 Perennial Herbs in Which the Aerial Portion Withers Until the Summer and Enters Yearly Dormancy at an Early Date

For example, *Adoxa moschatellina*, *Trillium* spp., and *Cardamine leucantha*. Spring ephemerals plants are representative of this trait. The data of our survey did not include spring ephemerals because the seasons of growth differed. In observations by Sakio in the early spring after snow melting, it was confirmed that two spring ephemeral species, *Corydalis lineariloba* (Fig. 8.21) and *Allium monanthum* (Fig. 8.22) have maintained their populations without serious deer damage.
In this way, plants containing toxic components, small plants, and plants with short growing periods that are difficult to eat whole have remained prolific in the current forest floor vegetation.

The annual grasses, such as *Impatiens noli-tangere* and *Persicaria debilis*, have survived through 2004; they are generally thought to be more resistant to grazing pressures than perennials (Diaz et al. 2007). Therefore, these annual species were recognized as some of the remaining species by Sakio (2013). However, these species have not been confirmed in the most recent survey. It is expected that the life history characteristics of these species are not sufficient to maintain the population under strong grazing pressures. Both plants might be frequently eaten because

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**Fig. 8.20** *Chrysosplenium pilosum* var. *sphaerospermum* (2002/4/18 Ooyamazawa)

**Fig. 8.21** *Corydalis lineariloba* (2010/5/8 Ooyamazawa)
they can grow to or over 30 cm in stem height, and then their flowers and fruits are also lost. As a result, seed dispersal had might be restricted. In addition, seed banks were not rich (Kubo et al. 2008, seed dormancy is unknown). These factors may be related to the decline in both species.

There are many reports that forest floor vegetation declines due to increasing deer density in many forests, and vegetation is simplified by the proliferation of unpalatable plants in Japan (Tamura 2007; Hattori et al. 2010; Ishida et al. 2012; Otsu et al. 2011; Shimoyama 2012) and the rest of the world (Diaz et al. 2007). Furthermore, when there is a decrease in edible plants, unpalatable plants are also eaten (Ishikawa 2010). In the Ooyamazawa riparian forest, the cover ratio of plants declined rapidly in the 6 years from 1998 to 2004, and then the number of species further decreased after 2004 (Fig. 8.2). Most palatable plants were eaten by 2004, and the number of species seemed to increase temporarily afterwards, but it seems that the number of unfavorable species also decreased until 2016. It has been recorded that poisonous, diminutive, and spring ephemeral plants are avoided (Diaz et al. 2007) as mentioned above. The future change in the plant cover will depend on whether these species will be able to survive or recover in the future. On the other hand, forest regeneration will be very difficult because tree seedlings will be eliminated from the forest floor if damage by deer grazing continues over a long period of time (Takatsuki and Gorai 1994). At our study site, the seedlings of the dominant canopy tree species have continuously appeared from the seeds supplied by the canopy. However, the patch of saplings from the dominant species is disappearing, and seedlings from some tree species, especially the maple family, have not appeared. For this reason, some tree species may disappear from the forest floor entirely.
8.6 Conservation of Species Diversity Within the Forest Floor Vegetation

Ideally, rare plants and communities should be conserved by managing the populations of deer and/or installing deer fences before the number of deer increases (Osawa et al. 2015). Protection of plant communities through the installation of deer fences is an effective method under the conditions where high deer densities and strong grazing pressures are present (Tamura 2008). However, it is important to carefully select installation points within the protected areas because the cover area of the deer fence is relatively small.

Species that disappeared or decreased since 2001 in the surveyed area are ferns with large leaves such as Cornopteris crenulatoserrulata, Dryopteris crassirhizoma, and Polystichum ovato-paleaceum, high stem grasses such as Caulophyllum robustum, Spuriopimpinella nikoensis, and shrubs like Hydrangea serrata and Sambucus racemosa ssp. Sieboldiana, etc. These species tend to be distributed in relatively stable habitats like the debris flow terraces in Ooyamazawa (Kawanishi et al. 2004, Chap. 6). Such locations can be also an update site for species such as Fraxinus platypoda (Sakio 1997), so it is desirable to preferentially protect this community in this habitat.

However, as mentioned above, the forest floor vegetation of the Ooyamazawa riparian forest has already undergone significant changes, and the species diversity has been greatly reduced. Sasa borealis, which covered the forest floor at the upper part of the slope, has started to die in large areas (Fig. 8.23). Therefore, protecting the remaining individuals is very important. In the investigation area, large herbs and shrubs, such as Angelica polymorpha and Hydrangea serrata remained only on large riverbed rocks (Fig. 8.24). This is a location unaffected by grazing because deer cannot reach the rocky riverbed. In contrast, outside the survey area, the rocky cliffs along the valley slope are also noteworthy (Fig. 8.25). Although the species that can grow in such places seem to be limited, these habitats seem to be functioning as

Fig. 8.23 Dead patch of Sasa borealis due to the deer grazing (2017/7/22 Ooyamazawa)
reprieves from deer grazing for some high stem herbs such as *Deinanthe bifida* and *Elatostema umbellatum* var. *majus*. When installing a deer fence, it would be desirable to position it in a manner that facilitated proliferation of seeds from these plants.

In Ooyamazawa, a deer fence was installed at the valley slope in 2017 (Fig. 8.26). We could find many herbs within the deer fence. As of 2017, they are found in the steep sloping rock walls only. However, these herbs had also grown in the riparian forest originally; therefore, we expect a recovery in the forest floor vegetation within

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**Fig. 8.24** Fragmentary community of large herbs remained on the large rocks of the riverbed (2016/7/24 Ooyamazawa)

**Fig. 8.25** Community of large herbs established on the rocky cliff along the stream. (2017/7/22 Ooyamazawa)
the fence. In my future studies, I would like to focus on changes in vegetation within and outside the deer fence.

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Fig. 8.26 Deer fences installed in Ooyamazawa since 2017 (photograph-A by Kubo in spring 2018, photograph-B in 2017/7/22 Ooyamazawa)
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