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Response of understory vegetation over 10 years after thinning in an old-growth cedar and cypress plantation overgrazed by sika deer in eastern Japan

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Abstract

Background: Forest management strategies such as thinning have long been used to enhance ecosystem functions, especially in plantations. Thinning in plantations with high deer density, however, may not yield a desired increase in understory vegetation because deer graze on germinating plants after thinning. Here, we examine the changes in understory vegetation after thinning in plantations that have been overgrazed by sika deer to provide insight into the effects of thinning on ecosystem functions such as soil conservation and biological diversity.

Methods: We conducted our survey in the Tanzawa Mountains of eastern Japan. We surveyed the change in understory vegetation within and outside of three deer exclosures on a single slope with three levels of understory vegetation cover: sparse (1%, exclosure "US"), moderate (30%, exclosure "MM"), and dense (80%, exclosure "LD") over 10 years after a 30% thinning of an old-growth cedar and cypress plantation which was overgrazed by sika deer.

Results: Understory vegetation cover, biomass and species richness increased within and outside the "US" and "MM" exclosures after thinning, and biomass was greater within than outside the exclosures at 10 years after thinning. Unpalatable species dominated both "US" and "MM" exclosures before thinning, and trees and shrubs dominated within the exclosures over time after thinning. In contrast, unpalatable, grazing-tolerant, perennial, and annual species increased outside the "US" and "MM" exclosures. No noticeable changes were observed within and outside the "LD" exclosure when compared with the "US" and "MM" exclosures.

Conclusions: Our results suggest that thinning a stand by 30% based on volume resulted in an increase in understory vegetation cover mainly composed of both unpalatable and grazing-tolerant species in a plantation forest where understory vegetation is sparse or moderate and sika deer density is high. We emphasize that establishing deer exclosures or controlling deer is essential to maintaining similar understory vegetation both within and outside exclosures.

Keywords: Biomass, Deer exclosure, Grazing-tolerant species, Understory cover, Unpalatable species

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Background

Forest management has been designed to enhance ecosystem functions such as biodiversity even in plantations in recent decades (Nagaike 2000; Hartley 2002; Carnus et al. 2006; Felton et al. 2010). Thinning as a management tool is believed to enhance understory vegetation (Hartley 2002; Carnus et al. 2006; Brockerhoff et al. 2008), to create a mix of various understory tree species or timber species (Carnus et al. 2006; Felton et al. 2010), to create snags, logs and other woody debris (Hartley 2002; Carnus et al. 2006) and to lengthen rotation periods (Hartley 2002; Carnus et al. 2006). Conifer plantations composed mainly of sugi (*Cryptomeria japonica*) and hinoki (*Chamaecyparis obtusa*) cover about 10 million ha or about 40% of the forested area in Japan (Japan Forestry Agency 2015). However, these include many inadequately-managed plantations (because of low wood prices) and this lack of management has created problems related to ecosystem functions such as soil conservation (Japan Forestry Agency 2015). Therefore, 35 prefectural governments have introduced new tax systems involving forest management that are designed to promote thinning of plantations (Japan Forestry Agency 2015).

Previous studies have demonstrated that thinning in plantations resulted in increases in understory vegetation cover, species richness (Thomas et al. 1999; Ares et al. 2010; Seiwa et al. 2012), and understory biomass (Ito 2006). Thinning also has the indirect potential to enhance ecosystem functions such as soil conservation (Miura et al. 2003; Fukata et al. 2006; Hiraoka et al. 2010). However, inadequate thinning produces only a limited increase in understory vegetation cover (Ito 2006).

It is most important to note, however, that thinning in plantations where deer density is high may not yield an increase in understory vegetation because deer feed on germinating plants after thinning. In recent decades there has been increasing recognition that deer can strongly influence forest ecosystems worldwide (Kirby 2001; Russell et al. 2001; Rooney and Waller 2003; Cote et al. 2004) and may cause serious damage to ecosystem functions such as biodiversity (Fuller 2001; Cote et al. 2004; Bressette et al. 2012) and soil conservation (Furusawa et al. 2003; Mohr et al. 2005; Wakahara et al. 2008). In Japanese plantations, some researchers have examined damage to trees such as the browsing of branches and leaves of juvenile trees (Koizumi 2002) and bark-stripping of adult trees by sika deer (Ueda et al. 2002; Jiang et al. 2005; Akashi and Terazawa 2005). The decline in understory vegetation in plantations inhabited by sika deer has received little attention, because it is often attributed to be a result of inadequate management rather than deer grazing *per se*. Some previous research has shown that thinning in plantations resulted in almost no increase in understory vegetation and this may be caused by grazing by sika deer. Here, we examine the changes in understory vegetation after thinning in plantations heavily overgrazed by sika deer to provide insight into how heavy sika deer browsing may affect understory vegetation and thus ecosystem functions like soil conservation or biological diversity.

Our objective was to determine the response of understory vegetation quantity and quality to thinning in an old-growth plantation that was heavily grazed by sika deer. Specifically, we addressed the following questions: 1) did thinning (here, by 30% of stand volume) in an old-growth plantation increase understory vegetation cover, biomass, species richness, and species diversity under severe deer grazing pressure? Additionally, 2) if so, what are the types of species that benefited from thinning, such as palatable or grazing-tolerant species?

Methods

Study area

This study was conducted in Shimo-Dodaira, located northeast of Mount Tanzawa (35°28′28.5″N, 139°9′46.8″E; 1567 m a.s.l.) in the Tanzawa Mountains in eastern Japan. Shimo-Dodaira is an east-facing landslide formation that ranges from 900 to 1056 m in height and 17° to 23° in inclination. The study site supports an old-growth cedar and cypress plantation (planted in 1911) with an area of 13.5 ha and includes some mixed broad-leaved tree species such as *Pterocarya rhoifolia*, *Pterostyrax hispida* and *Zelkova serrata* (Table 1). Sharing a similar microtopography, the understory vegetation on the slopes was divided into three types based on the differences in understory vegetation cover. The upper, middle and lower slope exhibits sparse ("US"; 1% cover), moderate ("MM"; 30% cover), and dense understory vegetation ("LD"; 80% cover), respectively. Prior to thinning in 2000, the understories of "US" and "MM" were initially composed of sparse *Chloranthus serratus* and *Laportea bulbifera* and that of "LD" was composed of dense *Leucosceptrum japonicum*. Thinning to 30% of stand volume was conducted from December 2000 to February 2001. A prior thinning had been conducted at the study site in 1974 and again in 1979. The density of sika deer was 9.2 km^{-2} in 1997 (Sika Deer Survey Group of Tanzawa-Oyama Comprehensive Research Team 1997), 30.0 km^{-2} in 2001, 20.8 km^{-2} in 2005 (Fujimori et al. 2013), and 16.5 km^{-2} in 2012 (Kanagawa Prefecture, unpublished results). Sika deer heavily grazed the understory vegetation during the entire study period.

Trees over 1.5 m in height were surveyed in a 50 × 50-m^2 plot, which included each 10 × 10-m^2 plot within and outside the exclosures with three different vegetation coverages [1%, sparse cover (US); 30%, moderate cover (MM); 80%, dense cover (LD)].

Table 1 Stand structure of the study site 4 years after thinning

Species name	Density (number ha^{-1})			Mean DBH (cm)			Mean Height (m)			Basal area (m^2 ha^{-1})		
	US	MM	LD	US	MM	LD	US	MM	LD	US	MM	LD
Cryptomeria japonica	84	116	220	41.2	51.2	44.7	22.4	24.9	23.2	13.5	28.5	43.3
Chamaecyparis obtusa	176	96	44	28.9	40.3	34.2	17.6	22.8	21.1	16.5	14.9	5.5
Chamaecyparis pisifera			12			34.0			21.7			1.6
Magnolia obovata	52	20	8	29.1	26.0	26.0	19.1	19.0	16.6	4.9	1.5	0.6
Zelkova serrata	8	12	28	32.5	54.3	35.6	19.9	24.9	21.5	1.1	3.4	3.6
Pterocarya rhoifolia	16			58.0			23.3			5.4		
Acer diabolicum	4			23.0			22.6			0.3		
Phellodendron amurense var. *japonicum*	44			39.9			21.5			9.5		
Styrax japonica			4			11.0			4.9			0.1
Pterostyrax hispida			8	59.7		13.5	23.7		10.4			0.3
Conifer trees	260	212	276							30.0	43.4	50.4
broad-leaved trees	124	32	48							21.1	4.9	4.7
Total	384	244	324							51.1	48.3	55.0

Field surveys

Before thinning in 2000, three 10- × 10-m^2 plots were established on "US", "MM" and "LD", one on each representative slope, respectively. After thinning in March 2001, one deer exclosure (10 × 10 m^2, 1.8-m high and made of wire net with 10- × 10-cm^2 mesh) was established on each plot; in addition, three control plots, which were the same size as the fenced plots, were set up, one outside each of the three exclosures but were not fenced. We established three 2- × 8-m^2 sub-plots in each plot and divided each sub-plot into four 2- × 2-m^2 quadrats in 2002 (12 quadrats for each plot).

Understory vegetation shorter than 1.5-m high was investigated in each plot in 2000 and 2001 and in each 2- × 2-m^2 quadrat from 2002 to 2005 and in 2011. The understory vegetation cover and cover classes of vascular plants within each plot or quadrat were recorded. Cover class of each species was determined using the Braun-Blanquet scale (Braun-Blanquet 1964). Scientific nomenclature for all plant species follows *Flora Kanagawa 2001* (Flora Kanagawa Association 2001).

To estimate the understory biomass, five 1-m^2 sub-quadrats were harvested at each plot from 2000 to 2005 and 2010. Sub-quadrats were clipped so that each entire research quadrat would not be disturbed. Samples were oven-dried at 80 ° C for 48 h to obtain dry weight. To determine the light environment at 1-m above ground in each plot, the relative photosynthetic photon flux density (rPPFD) was determined with two quantum sensors (MES-101; Koito-Kogyo, Tokyo, Japan) from 2000 to 2005 and in 2010.

Data analysis

Understory vegetation cover, biomass, species richness (100 m^{-2} and 48 m^{-2}) and Shannon's diversity index (H') were calculated for each plot. Relative dominance of several life forms [(tree, shrub, perennial, annual, and other (vine and bamboo)], and unpalatable, grazing-tolerant, and other species were calculated by summing the coverage values. Table 2 lists unpalatable and grazing-tolerant species. To classify the change in understory vegetation, detrended correspondence analysis (DCA) was conducted in the Vegan package of R ver. 3.0.3 (R Development Core Team 2014) using average dominance based on coverage values for all plant species in every quadrat for each year.

Results

Light environment

The rPPFD of each plot before thinning was under 5%, increased sharply to a maximum value at 1 or 2 years after thinning except outside the "US" exclosure, and then decreased to 6% or less at 10 years after thinning (Fig. 1a).

Understory vegetation cover

Understory vegetation cover within and outside the "US" and "MM" exclosures increased over time after thinning (Fig. 1b). The cover within the "US" and "MM" exclosures tended to be greater than outside the exclosures and the cover outside needed more than 5 years to equal that within the exclosures. The cover both within and outside the "LD" exclosure shifted from 60 to 100% over time after thinning. No difference in the cover between within and outside the exclosure was observed at 11 years after thinning in each plot.

Table 2 List of species that are unpalatable and grazing tolerant to deer in study area

Type	Species name	Family name	Life form	References
Unpalatable	*Dennstaedtia hirsuta*	Dennstaedtiaceae	perennial	1
	Dennstaedtia wilfordii	Dennstaedtiaceae	perennial	6
	Stegnogramma pozoi subsp. *mollissima*	Thelypteridaceae	perennial	1
	Chloranthus serratus	Chloranthaceae	perennial	1, 5
	Arisaema spp.	Araceae	perennial	1, 5
	Arisaema angustatum	Araceae	perennial	1, 5
	Arisaema nikoense	Araceae	perennial	1, 5
	Cocculus trilobus	Menispermaceae	vine	1
	Boenninghausenia albiflora var. *japonica*	Rutaceae	perennial	1, 5
	Pterostyrax hispida	Styracaceae	tree	4, 5
	Cynoglossum asperrimum	Boraginaceae	perennial	1
	Cynanchum caudatum var. *tanzawamontanum*	Apocynaceae	vine	6
	Trachelospermum asiaticum	Apocynaceae	vine	6
	Tubocapsicum anomalum	Solanaceae	perennial	1
	Crassocephalum crepidioides	Asteraceae	perennial	1
	Aster ageratoides var. *ageratoides*	Asteraceae	perennial	3
	Ligularia dentata	Asteraceae	perennial	2, 5
Grazing-tolerant	*Brachypodium sylvaticum*	Poaceae	perennial	5
	Calamagrostis hakonensis	Poaceae	perennial	5
	Festuca parvigluma	Poaceae	perennial	5
	Oplismenus undulatifolius	Poaceae	perennial	5
	Microstegium japonicum	Poaceae	Annual	5
	Microstegium vimineum	Poaceae	Annual	5
	Sasa hayatae	Poaceae	bamboo	6
	Persicaria debilis	Polygonaceae	Annual	5
	Persicaria longiseta	Polygonaceae	Annual	6
	Persicaria nepalensis	Polygonaceae	Annual	6
	Persicaria posumbu	Polygonaceae	Annual	5
	Pilea hamaoi	Urticaceae	Annual	5
	Pilea japonica	Urticaceae	Annual	5
	Clinopodium micranthum var. *micranthum*	Lamiaceae	perennial	6
	Hydrocotyle yabei var. *yabei*	Apiaceae	perennial	5
	Cirsium tenuipedunculatum	Asteraceae	perennial	6

1, Takatsuki (1989); 2, Hasegawa (2000); 3, Nomiya et al. (2003); 4, Ninomiya and Furubayashi (2003); 5, Tamura and Katsuyama (2007); 6, Tamura (personal observation)

Understory biomass

Understory biomass within and outside the "US" and "MM" exclosures tended to increase over time after thinning (Fig. 1c); yet, biomass was greater within than outside the exclosures at 10 years after thinning. Biomass outside the "US" and "MM" exclosures peaked at 5 years after thinning and then both these sites had the same amount of biomass at 10 years. Biomass both within and outside the "LD" exclosure tended to increase achieving a steady state at 1–3 years after thinning, and no difference in biomass was observed between within and outside the exclosure at 10 years after thinning (Fig. 1c).

Understory species richness and diversity

Species richness within and outside the "US" and "MM" exclosures tended to increase and achieved a steady state at 2–4 years after thinning (Fig. 1d) and decreased at 11 years after thinning. However, by 11 years after thinning it was greater in both plots than that before thinning. No difference in species richness was observed between within and outside the "MM" and "LD"

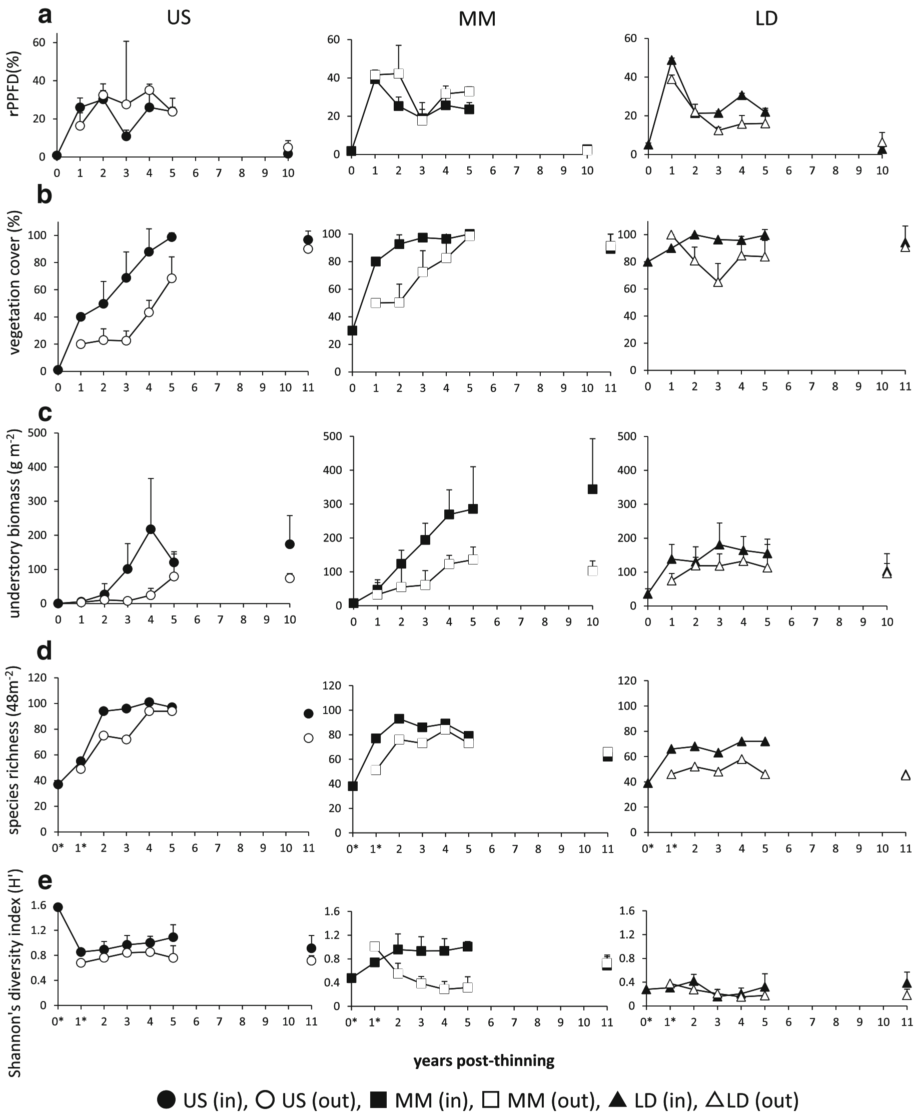

Fig. 1 Changes in light conditions and understory vegetation before and 10 or 11 years after thinning. Three different levels of vegetation cover were used: 1%, sparse cover (US); 30%, moderate cover (MM); 80%, dense cover (LD). **a** rPPFD, **b** understory vegetation cover, **c** understory biomass, **d** species richness, and **e** Shannon's diversity index (*H'*); *in*, within the exclosure; *out*, outside the exclosure. * denotes the value obtained from a $10 \times 10\text{-m}^2$ plot and not a $2 \times 2\text{-m}^2$ quadrat. Error bars indicate SD

exclosures at 11 years after thinning. Species richness both within and outside the "LD" exclosure shifted equally over time after thinning.

H′ within the "US" and "MM" exclosures tended to be greater than those outside exclosures, and H′ both within and outside the "LD" exclosure remained the same over time after thinning (Fig. 1e).

Understory species composition

DCA ordination of all plant species data for every plot in each year showed that both "US" and "MM" were in the first quadrant before thinning; after thinning the plots within and outside of the "US" and "MM" exclosures shifted into the second and fourth quadrants over time (Fig. 2a). Both plots within and outside the "LD" exclosure almost remained near the boundary of the second and third quadrants over time before and after thinning. The first two axes accounted for 45.1 and 21.5% of total variance, respectively.

At the species level, grazing-tolerant *Hydrocotyle yabei* var. *yabei* and unpalatable *C. serratus* were on the edge of the first quadrant; *L. japonicum* was on the left side of the second quadrant; unpalatable *Boenninghausenia albiflora* var. *japonica* and *P. hispida*, and grazing-tolerant *Cirsium*

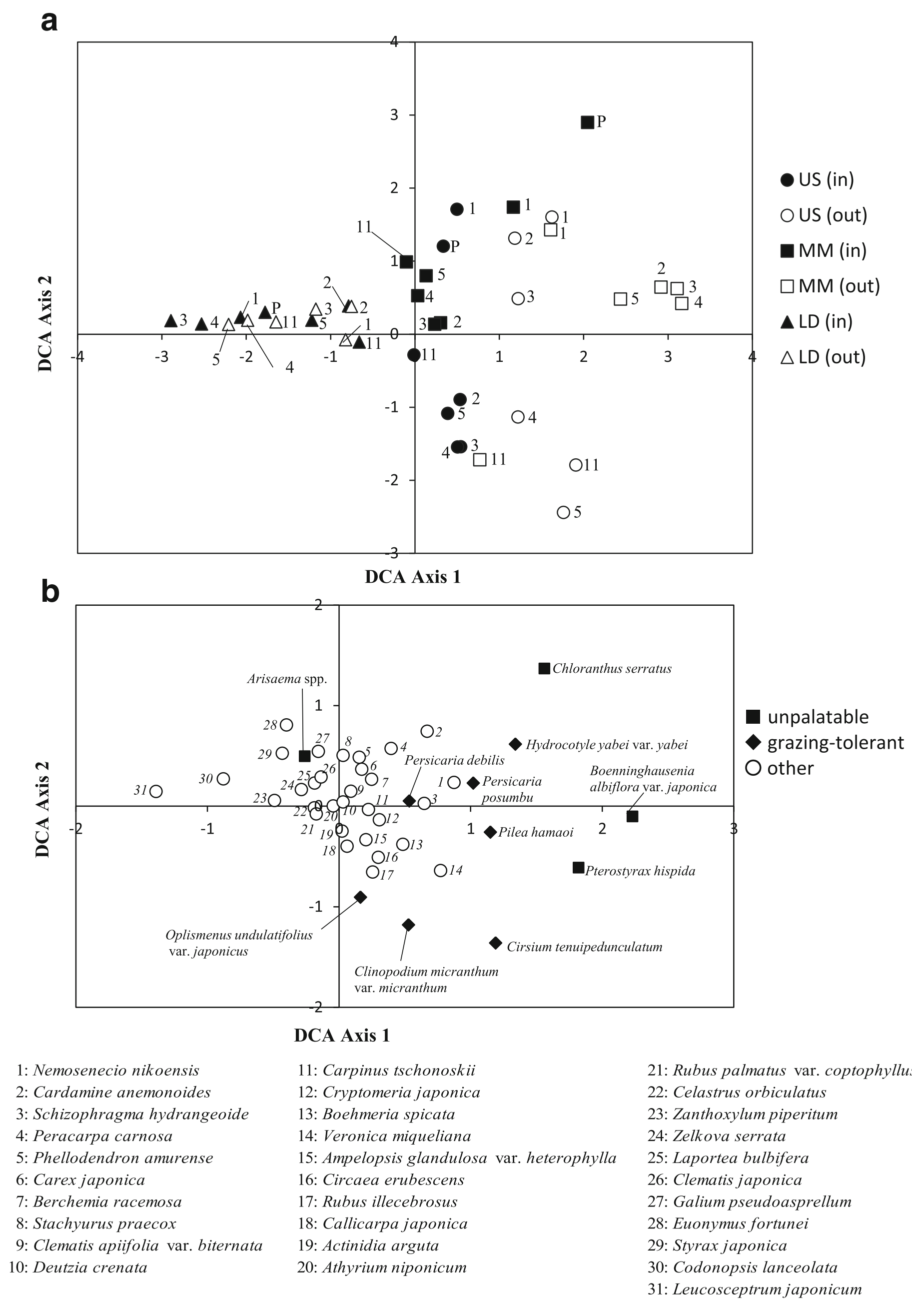

Fig. 2 Ordination by detrended correspondence analysis (DCA) based on the mean coverage of all species. Data are for every quadrat in each year. **a** Plot ordination. The first two axes accounted for 45.1% and 21.5% of the total variance, respectively. *US*, sparse cover (1%); *MM*, moderate cover (30%); *LD*, dense cover (80%); *in*, within the exclosure; *out*, outside the exclosure; *P*, pre-thinning; *numbers* represent years after thinning. **b** Major species ordination; the 42 most frequent species are displayed in the figure

tenuipedunculatum were in the fourth quadrant; and shrubs such as *Rubus palmatus* var. *coptophyllus* were clustered together near the origin (Fig. 2b).

Coverage of trees and shrubs such as *Deutzia crenata*, *Phellodendron amurense*, *R. palmatus* var. *coptophyllus* and *Stachyurus praecox* increased after thinning within both the "US" and "MM" exclosures (see Additional file 1). It is important to note that outside the "US" and "MM" exclosures, unpalatable species such as *B. albiflora* var. *japonica* and *P. hispida*, grazing-tolerant species such as *C. tenuipedunculatum* and *H. yabei* var. *yabei* increased after thinning. *L. japonicum* was abundant during the course of the study period both within and outside the "LD" exclosure.

Relative dominance of understory vegetation

The relative dominance of woody plants, both trees and shrubs, increased over time after thinning within all three exclosures, and was especially notable within the "US" and "MM" exclosures (Fig. 3). Outside the "US" and "MM" exclosures, the relative dominance of annual species increased 2 years after thinning and occupied 15–18% of the coverage 11 years after thinning (Fig. 3). The area outside of the "LD" exclosure was dominated by perennial species throughout the study period.

Note that within both the "US" and "MM" exclosures the relative dominance of both palatable and grazing-tolerant species decreased over time after thinning (Fig. 4). In contrast, outside both of these exclosures, these species remained dominant over time. Within and outside the "LD" exclosure, the relative dominance remained unchanged during the study period and was dominated by other species such as *L. japonicum*.

Discussion

The results obtained outside the "US" and "MM" exclosures showed that understory vegetation cover, biomass and species richness of this old-growth plantation increased over time after thinning, even under severe deer grazing pressure. These measurements were greater 10 or 11 years after thinning than before and just after thinning in these plots. However, understory biomass at 10 years after thinning outside the "US" and "MM" exclosures were approximately one-half and one-third of those within the exclosures, respectively indicating that heavy sika deer browsing can indeed have dramatic effects. Furthermore, understory vegetation outside the "US" and "MM" exclosures was dominated by perennial, annual, unpalatable, and grazing-tolerant species, whereas understory vegetation within the "US" and "MM" exclosures was dominated by woody plants (trees and shrubs) over time. Overall, these results demonstrate that thinning led to increased understory vegetation in this old-growth plantation heavily grazed by sika deer, and that most understory vegetation was composed of perennial, annual, unpalatable, and grazing-tolerant species.

Few data are available from previous studies related to the change in understory vegetation after thinning in old-growth plantations and under severe sika deer grazing pressure, although studies had been conducted on young or mature plantations with no or few deer (Ito 2006; Noguchi et al. 2009). Outside Japan, several studies that addressed the effects of thinning on understory vegetation have been conducted in young plantations where thinning was implemented to increase food biomass for deer that would be hunted (Sullivan et al. 2007, 2010; Cole et al. 2010). In general, understory vegetation declines with crown canopy closure in young or mature plantations, even if it initially increased after thinning (Kiyono 1990; Suzuki et al. 2005). In our study, light conditions (rPPFD) at 10 years after thinning were similar to those before thinning; however, understory vegetation cover, biomass, and species richness at 10 or

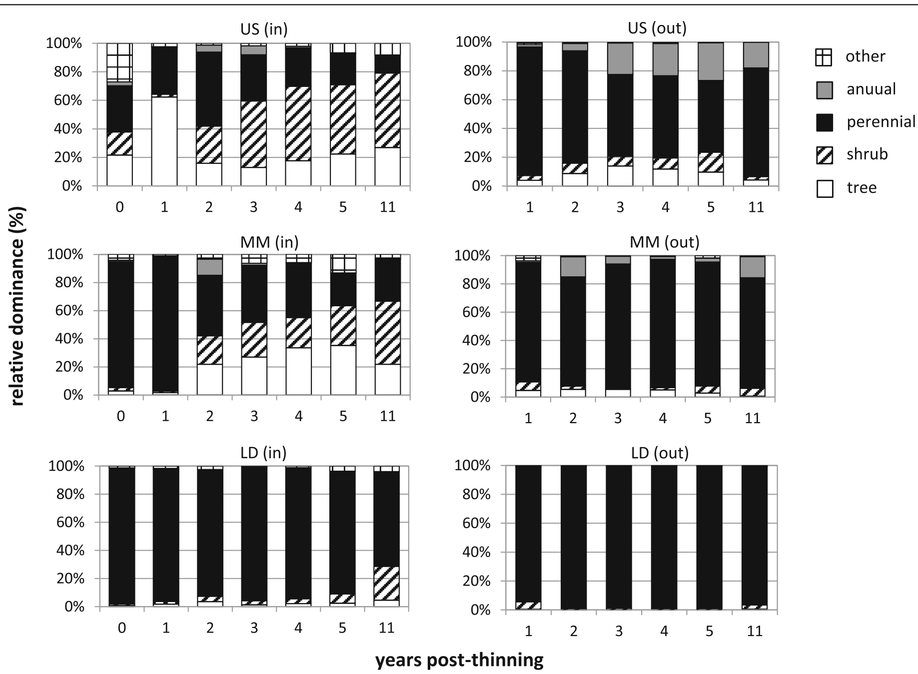

Fig. 3 Relative dominance changes of life forms in vegetation cover before and after thinning. Three different levels of vegetation cover vegetation cover were used: *US*, sparse cover (1%); *MM*, moderate cover (30%); *LD*, dense cover (80%); *in*, within the exclosure; *out*, outside the exclosure

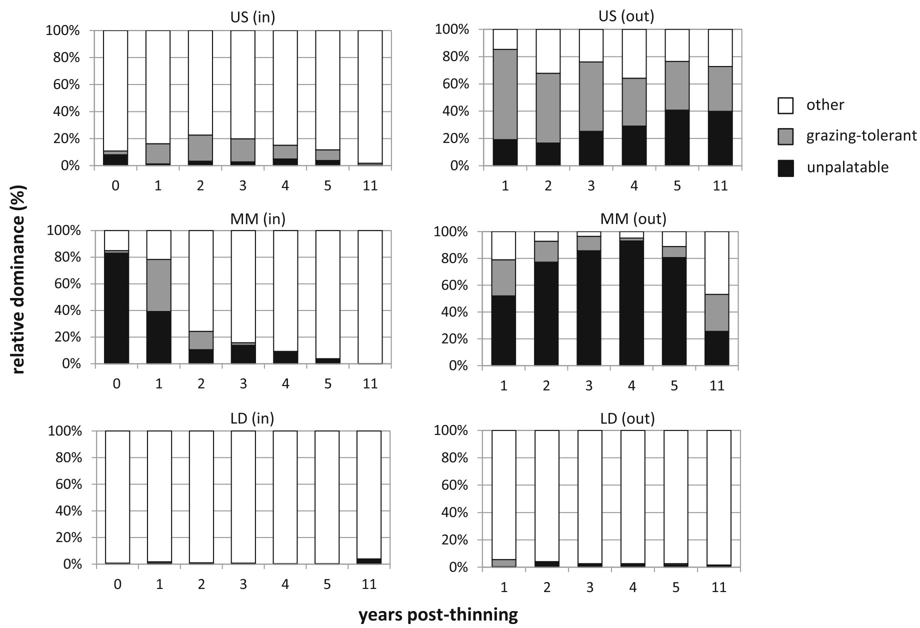

Fig. 4 Relative dominance changes in unpalatable and grazing-tolerant species in vegetation cover. Data represent before and after thinning in three different levels of vegetation cover: *US*, sparse cover (1%); *MM*, moderate cover (30%); *LD*, dense cover (80%); *in*, within the exclosure; *out*, outside the exclosure

11 years after thinning were greater than before thinning even under severe deer grazing pressure, and understory vegetation cover and biomass seemed to have plateaued. Our study also revealed that the tree cover increased within but not outside the exclosures. Additionally, Tamura (2014), who studied regenerated trees at the same site, revealed that species richness was lower and fewer trees regenerated outside the exclosures compared to within the exclosures.

The difference in the response of understory vegetation to thinning among the three types of plots analyzed here indicate that understory vegetation conditions before thinning may affect the changes observed after thinning. Understory vegetation responses in the “LD” exclosure were slightly different from those in “US” and “MM” exclosures. Understory cover, biomass, and species richness both within and outside the “US” and “MM” exclosures increased over time after thinning. However, the changes in the “LD” exclosure were limited when compared with those observed within and outside the “US” and “MM” exclosures. In addition, understory species composition in “LD” was also different from that of the “US” and “MM” exclosures. This occurred as a result of the density of *L. japonicum*, a perennial tall herb, before thinning. The species was grazed by sika deer during late summer, but did not disappear (Tamura, personal observation), potentially because it can multiply by rhizomes. Previous studies have reported that dense understory vegetation prevents plant species from invading and growing (Royo and Carson 2006; Tamura 2014). In our study we suggest that *L. japonicum* may have prevented the invasion of other species.

The different ratios of unpalatable to grazing-tolerant species outside the “US” and “MM” exclosures may also be attributable to the difference of understory vegetation before thinning, because fewer unpalatable species occurred outside the “US” exclosure when compared with species growing outside the “MM” exclosure. These results indicated that the composition of unpalatable and grazing-tolerant species before thinning likely influenced the composition and structure of understory vegetation after thinning under the severe deer grazing pressure in our study. Noguchi et al. (2009) also found that understory vegetation conditions before thinning affects the developmental of understory vegetation after thinning.

Understory vegetation outside the exclosures would probably remain consistent, such as with a high proportion of perennial or unpalatable species, even if sika deer density decreased. This would be expected to occur because, in general, the species composition of forest vegetation changes if deer have been overgrazing, and unpalatable and grazing-tolerant species increase (Husheer et al. 2003; Rooney and Waller 2003). The density of unpalatable species rarely decreases once they have become well established (Kirby 2001; Husheer et al. 2003). Dense understory vegetation, even if palatable, prevents other plant species from invading and growing, and diminishes tree generation, thus altering the rate and direction of forest succession (Royo and Carson 2006). In our study, understory vegetation outside the “US” and

"MM" exclosures was mainly composed of unpalatable *B. albiflora* var. *japonica* 11 years after thinning, and understory vegetation of "LD" was composed of *L. japonicum* during the course of study period. However, at 10 years after thinning the light conditions (rPPFD) had decreased to the same level as that before thinning. Note that while *B. albiflora* var. *japonica* and *L. japonicum* are forest floor species (Flora Kanagawa Association 2001) and can grow under low rPPFD, in contrast, we predict that annual or small perennial grazing-tolerant species would decline if there were a substantial expansion of tall perennial species such as *B. albiflora* var. *japonica* and *L. japonicum*.

Our study was conducted in a single old-growth plantation with three different levels of understory vegetation cover, so one must be cautious in extrapolating our conclusions to other situations even if there is similarly severe sika deer grazing pressure. Nevertheless, our results which reveal that understory vegetation cover, biomass, and species richness increased after thinning even under severe deer grazing pressure represents a new finding, and one which we hope will be studied further, especially as this relates to factors that maintain important ecosystem functions like soil conservation.

Conclusions

Thinning in old-growth conifer plantations can increase in understory vegetation cover that is mainly composed of unpalatable and grazing-tolerant species in a plantation forest where understory vegetation is sparse or moderate and sika deer density is high. We emphasize that establishing deer exclosures or controlling deer is essential to miantaining similar understory vegetation both within and outside exclosures.

Additional file

Additional file 1: Change in the mean cover (%) of major species at pre-thinning and 1, 3, 5, and 11 years post-thinning. Species that had frequencies over 60% in the 12 2 × 2-m2 plots, and palatable and grazing-tolerant are shown. US, sparse cover (1%); MM, moderate cover (30%); LD, dense cover (80%); in, inside the exclosure; out, outside the exclosure; UP, unpalatable species; GT, grazing-tolerant species. (DOCX 73 kb)

Abbreviations

ANOVA: Analysis of variance; DCA: Detrended correspondence analysis; LD: 80%, dense understory vegetation cover; MM: 30%, moderate understory vegetation cover; US: 1%, sparse understory vegetation cover

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Availability of data and materials

The datasets supporting the conclusions of this article are included within the articles.

Authors' contributions

AT was involved in all parts of this research from the study design to the manuscript writing. MY provided critical revisions and final approval of the article. Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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