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論　文（Original article）

Tree composition and stand structure in the habitats of a rare tree species, *Acer pycnanthum*, with special reference to the human impact

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Abstract

Twenty-nine stands covering almost all *Acer pycnanthum* habitats in Gifu, Nagano and Aichi prefectures in central Japan were investigated to clarify their tree composition and stand structure. Stands including *A. pycnanthum* were classified into five major types according to tree composition; each type was characterized by the dominance of *Quercus serrata* (Type A), *Cryptomeria japonica* (Type B), *A. pycnanthum* (Type C), *Chamaecyparis pisifera* (Type D) and *Alnus japonica* (Type E), respectively. Types A and E were composed of post-harvest secondary-growth broadleaf stands and Type B was composed of coniferous plantations. Type C included both old-growth without any records of loggings and post-harvest secondary-growth broadleaf stands. Type D was both old-growth and secondary-growth of *C. pisifera* stand. *A. pycnanthum* showed the various types of dbh distribution, affected by the land-use history. The tree composition of old-growth stands was supposed to have retained the features of natural *A. pycnanthum* habitats. As well as strict conservation of existing natural habitats, new habitats must also be created to maintain the population of this species. The expansion and linking of existing habitats is also necessary in order to maintain the local population.

Key words : *Acer pycnanthum*, rare tree species, tree composition, stand structure, human impact, conservation

Introduction

Rare plant species that are geographically and ecologically restricted to local distribution tend to grow at specific sites such as wetlands and areas of serpentine or limestone soil (Synge, 1981). There are two possible explanations for these distributional patterns; firstly, the fact that the plant species have adapted to oligotrophic wet sites and are strongly dependent on specific habitats. Secondly, the plant species concerned barely maintained its population in an unfertile site, evading competition with the other species during the period of geological environment changes despite its wider distribution before the period (Hotta, 1974). Struggling to survive within limited and vulnerable sites, both species now face extinction due to human activity in the form of land-use change and development, and many have been designated as red-data species (Environment Agency of Japan, 2000). To conserve them, we should clarify not only their life-history features such as reproduction, regeneration, and growth processes, both ecologically and physiologically, but also the formation process and maintenance mechanism of their population, especially in relation to the human impact (Washitani and Yahara, 1996).

Acer pycnanthum K. Koch (the Japanese red maple) is an endemic species distributed within a radius of approx. 50 km from Mt. Ena (alt. 2191 m), located on the boundary between Nagano and Gifu prefectures, and at the Iyari Marsh in Ohmachi, Nagano prefecture, central Japan (Hirabayashi and Takahashi, 1969; Barnes *et al*., 2004; Saeki, 2005b). This species grows at the bottom of small stream valleys, wetlands around springs and ponds, and high moors (Barnes *et al*., 2004; Saeki, 2005a and b). In recent years, however, these habitats have been destroyed or reduced by land development and land-use changes. Consequently, the population of *A. pycnanthum* has plummeted and become fragmented (Japanese Red Maple Conservation Group, 2003). At present, this species is designated as a Class II (vulnerable) species in need of conservation

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(Environment Agency of Japan, 2000).

Section *Rubra* Pax of genus *Acer*, under which *A. pycnanthum* is classified, was widely distributed in the cool temperate climate zone at the Northern Hemisphere during the Tertiary Period (Tanai, 1983; Wolfe and Tanai, 1987), but there are now only three species under this section: *A. rubrum* and *A. saccharinum* in North America and *A. pycnanthum* in Japan. Ecologically and morphologically, *A. pycnanthum* and *A. rubrum* are quite similar to each another (Ogata, 1965; Walters and Yawney, 1990; Shimizu, 1989). In terms of ecological distribution, both species were considered to originate in wetlands or poorly drained areas and were formerly minor components of the forest landscape (Abrams, 1998; Barnes *et al.*, 2004; Saeki, 2005b). However, the number of *A. rubrum* rocketed, with its distribution area expanding in the twentieth century following European settlement, and now predominating in upland forests (Abrams, 1998). In contrast, numbers of *A. pycnanthum* fell and its distribution area diminished with increasing human impact (Hiroki, 2002). Clarifying the ecological behavior of *A. pycnanthum* in relation to human disturbances will help facilitate the conservation management of this species.

In this study, we investigated the tree composition and stand structure in almost all habitats of *A. pycnanthum* in Japan. Based on the results, we described the present status of *A. pycnanthum* habitats and local populations and inferred details of the impact sustained from past human activities. In addition, we compared this species with a corresponding maple in North America having undergone remarkable changes in its distribution over the last century. Based on these findings, we discussed management strategies for the conservation of this species.

Study sites and methods

Study sites

The study sites were chosen from all of the growing habitats of *A. pycnanthum* in the Nakatsugawa and Tajimi districts in Gifu prefecture and the Kiso, Ina, and Ohmachi districts in Nagano prefecture. These habitats are located at altitudes ranging from 180 m (Tajimi) to 880 m (Kaure Shrine), which correspond to the upper part of a warm temperate region and the lower part of a cool temperate zone respectively. Some populations of this species are protected as a National Monument and/or Prefectural Natural Heritage (Numata, 1984). Among these habitats, 29 stands were investigated, including natural stands (old-growth) with no explicit records of human disturbances for more than 100 years (Oppara Marsh for example), secondary-growth stands that developed after harvesting for fuelwood, and coniferous plantations (Table 1). Some of the habitats were affected by conservation activities, such as weeding for natural regeneration. Consequently, the populations at Kamado (Mizunami City, Gifu prefecture), which are also a National Monument, were excluded from this study.

Methods

Study plots of 130-616 m^2 were set at each of the 29 stands (Table 2), at each of which the altitude, slope direction and inclination angle were recorded. All stems > 5 cm in diameter at breast height (dbh) were identified and their dbh was recorded. In 15 of the 29 plots, smaller trees and saplings (h > 1 m and dbh < 5 cm) were also identified and the tree height was recorded. The cores of stems (around five stems per plot) composing the canopy layer were extracted at a height of 0.3m by an increment borer, and the annual rings were counted in order to estimate the stand age. We also investigated the total population structure (stem size structure) of *A. pycnanthum* in selected habitats at Oppara (about 2.0 ha), Hananoko (about 1.5 ha), Iwayado (about 2.0 ha), and Matsunoko (about 0.3 ha), by measuring the stem size (dbh) of the overall populations. In Oppara and Iwayado, the population of this species extended over different forest types, although the other populations remained within a specific forest type. *Acer pycnanthum* usually sprouts multiple stems from the stump after logging operations and/or from stems broken by natural disturbances (Saeki, 2005b). In this field survey, all individuals including stumps with single or multiple stems were checked, and the stem total was noted. Land-use histories in these study sites were studied using local historical documents, and discussion with local residents and landowners. Oppara and Hananoko proved to be natural habitats of *A. pycnanthum* with few previous anthropogenic disturbances, while Iwayado and Matsunoko were habitats that had been strongly influenced by human impact. The field survey was carried out from 2002 to 2006.

Data analysis

To categorize the species composition of the stands, cluster analysis (group average method) was

Table 1. Forest and management type of the studied stands.
The stands are ordered by latitude from north to south, with the plot locations shown below the table.

Stand name	Stand abbreviation	Forest type	Management type
Iyari-1	IR-1	Old-growth	Prefectural natural heritage, mire
Iyari-2	IR-2	Secondary growth	Prefectural natural heritage,mire
Iyari-3	IR-3	Secondary growth	Abandoned paddy field
Tsuchihashi-1	TC-1	Secondary growth	Abandoned fuel wood
Tsuchihashi-2	TC-2	Secondary growth	Failed coniferous plantation
Tsuchihashi-3	TC-3	Secondary growth	Abandoned fuel wood
Tsuchihashi-4	TC-4	Coniferous plantation	Commercial wood
Bicchubara	BC	Coniferous plantation	Commercial wood
Kamigo	KMG	Coniferous plantation	Commercial wood
Ohkuwa	OK	Coniferous plantation	Commercial wood
Magome	MG	Secondary growth	Private Botanical Garden
Iwayado-1	IW-1	Coniferous plantation	Commercial wood, water reservoir
Iwayado-2	IW-2	Secondary growth	Forested wetland, water reservoir
Iwayado-3	IW-3	Secondary growth	Abandoned fuel wood
Iwayado-4	IW-4	Secondary growth	Abandoned fuel wood
Hananoko	HN	Old-growth	National monument
Sakamoto	SK	Old-growth	National monument
Hirukawa	HR	Secondary growth	Abandoned fuel wood, water reservoir
Kamegasawa1	KM-1	Old-growth	Prefectural natural heritage
Kamegasawa2	KM-2	Secondary growth	Abandoned fuel wood
Yudachiyama	YD	Secondary growth	Abandoned fuel wood
Yamaoka	YM	Coniferous plantation	Shrine forest
Matsunoko-1	MT-1	Secondary growth	Abandoned fuel wood
Matsunoko-2	MT-2	Secondary growth	Abandoned fuel wood
Tajimi-1	TJ-1	Secondary growth	Abandoned fuel wood
Tajimi-2	TJ-2	Secondary growth	Abandoned fuel wood
Oppara-1	OP-1	Old-growth	National monument, marsh
Oppara-2	OP-2	Coniferous plantation	Commercial wood
Kaure	KU	Coniferous plantation	National monument, Shrine forest

Iyari:Ohmachi City, Nagano Prefecture; Tsuchihashi: Iida City, Nagano Prefecture; Bicchubara: Achi Village, Nagano Prefecture; Kamigo: Achi Village, Nagano Prefecture; Ohkuwa, Ohkuwa Village, Nagano Prefecture: Magome: Nakatsugawa City, Gifu Prefecture; Iwayado: Nakatsugawa City, Gifu Prefecture; Hananoko: Nakatsugawa City, Gifu Prefecture; Sakamoto: Nakatsugawa City, Gifu Prefecture; Kamegasawa: Ena City, Gifu Prefecture; Yudachiyama: Ena City, Gifu Prefecture; Yamaoka: Ena City, Gifu Prefecture; Matsunoko: Mizunami City, Gifu Prefecture; Tajimi: Tajimi City, Gifu Prefecture; Oppara: Higashi-Shirakawa Village, Gifu Prefecture; Kaure: Toyone Village, Aichi Prefecture.

applied to a matrix of compositional dissimilarity of tree layers among the stands. The relative dominance values in each species based on the basal area of tree layer were calculated for each stand and used to determine the Euclidean distances among the stands. Using these distances, a dissimilarity matrix was prepared as an input for the cluster analysis (STATISTICA: StatSoft, Inc.).

Results

Classification of stands based on the tree composition

Studied stands were classified into five major types (A, B, C, D and E) using cluster analysis at a 0.55 level of dissimilarity (Euclidean distance), and three minor types (A', B' and C') were bound into Types A, B and C at a 0.45-0.55 level of dissimilarity (Fig. 1). Type C comprised the largest group (12 stands), followed by Type B (7 stands).

Types A and E were all secondary-growth broadleaf stands, Type B was all coniferous plantations, Types C was composed of both old-growth and secondary-growth broadleaf stands, while Type D stands were old-growth and secondary growth of *Chamaecyparis pisifera* (Table 1 and Fig. 1).

According to the tree composition of each stand type (Table 3), Type A was characterized by the dominance of both *A. pycnanthum* and *Quercus serrata*, and Type B by the dominance of

Table 2. Stand characteristics of study plots.

Stand name	Plot size (m^2)	Altitude (m)	Slope Direction	Inclination (°)	Stand age (yrs)	Stem density (No. ha^{-1})	Stem density of *Acer pycnanthum* (No. ha^{-1})	Mean dbh (cm)	Min. dbh (cm)	Max. dbh (cm)	BA (m^2ha^{-1})
IR-1	616	830	-	0	>100	877	130	25.9	9.3	37.9	47.7
IR-2	200	830	-	0	≈80	2200	500	17.7	6.8	24.9	36.5
IR-3	130	830	-	0	≈20	1692	154	10.8	10.7	11.0	14.1
TC-1	616	600	S75°W	10	≈40	1202	406	13.8	5.3	24.3	26.2
TC-2	429	600	S20°E	13	27	2053	490	8.0	5.6	12.6	33.1
TC-3	241	590	N80°E	17	≈60	1411	456	15.4	6.0	32.1	31.5
TC-4	400	580	S80°E	3	≈60	1050	200	21.9	6.8	39.9	26.3
BC	595	550	N15°E	7	≈50	858	101	52.5	34.6	87.4	50.2
KMG	352	530	N50°W	20	41	965	57	55.1	32.2	77.9	42.7
OK	261	630	S20°W	15	≈50	1304	77	54.4	49.1	59.7	69.5
MG	493	600	S20°W	5	≈50	1460	101	29.1	12.3	48.0	36.5
IW-1	500	330	-	0	50	2660	440	15.4	5.9	50.8	39.5
IW-2	400	330	S0°S	1	35	2800	1575	12.5	5.1	24.4	29.3
IW-3	406	320	S20°E	15	≈55	838	123	37.0	5.6	68.5	30.7
IW-4	394	320	S60°W	10	≈60	1396	203	26.9	8.2	35.4	28.5
HN	400	550	N50°E	2	>60	575	400	22.1	10.4	42.1	29.8
SK	288	310	-	0	>100	1284	347	27.4	7.6	53.9	46.1
HR	360	320	N0°N	2	≈50	1306	500	23.8	5.8	37.6	38.3
KM-1	371	380	S30°E	7	>100	539	135	52.9	40.5	62.9	34.8
KM-2	448	430	S30°E	5	≈80	1070	156	31.4	9.7	52.4	26.1
YD	299	620	N50°W	5	≈50	1374	402	27.4	8.9	40.7	36.3
YM	315	470	S15°W	1	≈60	984	286	35.4	17.3	51.6	63.4
MT-1	330	320	-	0	≈50	1333	697	15.4	5.3	40.0	26.0
MT-2	264	320	S10°E	1	≈50	909	379	23.0	6.1	39.0	28.0
TJ-1	240	180	N10°E	3	≈30	2042	500	21.5	7.0	31.0	38.1
TJ-2	232	180	N50°E	15	≈40	1294	216	19.7	5.2	39.2	32.4
OP-1	405	800	N20°E	3	>100	889	198	22.5	5.2	55.9	20.4
OP-2	420	800	N70°E	3	45	1333	143	31.6	21.1	43.7	49.9
KU	416	880	N30°W	8		481	96	59.1	36.2	72.5	58.6

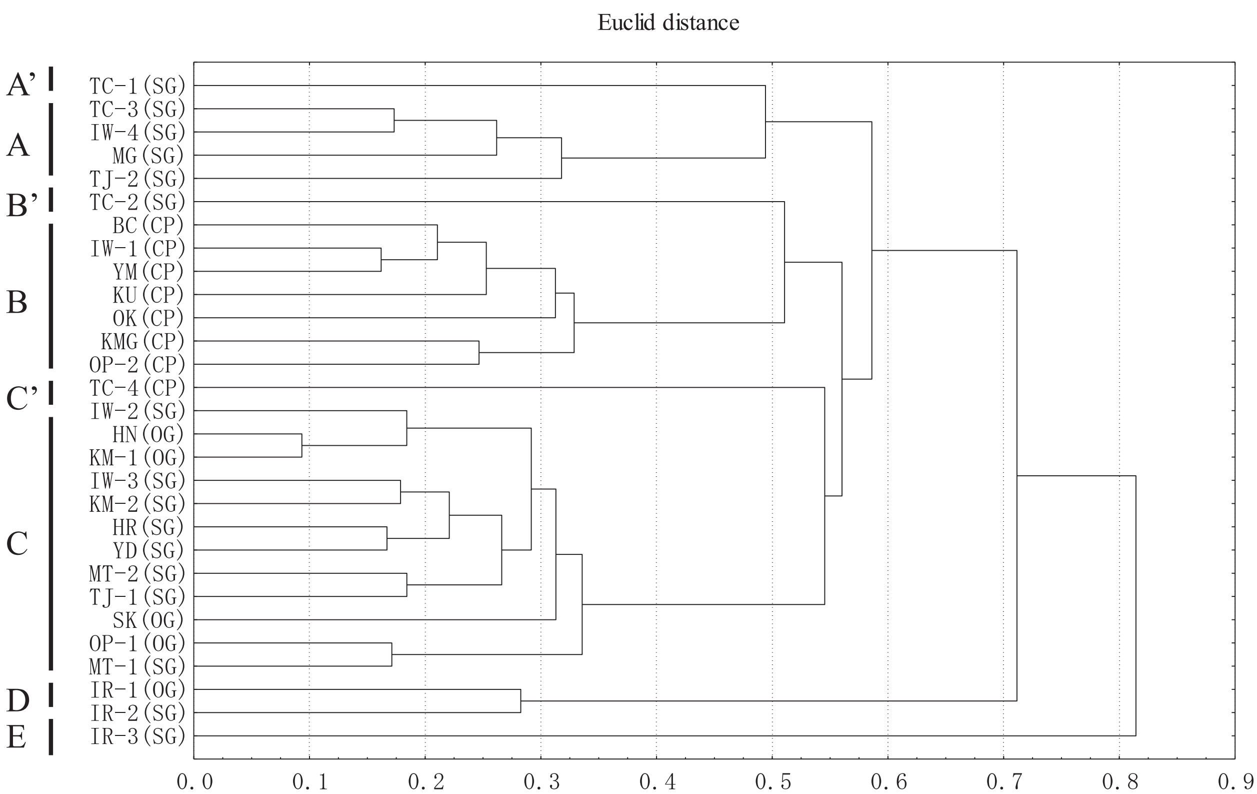

Fig.1 Dendrogram obtained by the Group Average Method, based on data on tree community dissimilarity among the plots. SG: secondary-growth, CP: coniferous plantation, OG: old -growth.

Table 3. Tree composition of each forest type (Relative abundance based on basel area).

Forest type	A	B	C	D	A'	B'	C'	E	Frequency*
No. of plots	4	7	12	2	1	1	1	1	29
Acer pycnanthum	33.1	38.4	68.9	27.2	26.5	7.8	36.2	10.0	1.00
Quercus serrata	39.6	0.3	2.9		8.5	10.0			0.52
Chamaecyparis obtusa	1.4	15.2	1.1			0.8	5.4		0.45
Cryptomeria japonica	0.1	30.2	1.7			60.7			0.41
Alnus japonica	0.6	1.6	1.5	8.8	22.4			60.0	0.38
Ilex pedunculosa	1.1	0.1	1.6						0.38
Styrax japonicus	1.6	0.3	0.2			0.2	0.5		0.38
Pinus densiflora		6.4	5.0	6.3		14.5	44.3	19.9	0.34
Magnolia tomentosa	0.4	0.2	4.0						0.34
Acanthopanax sciadophylloides	0.5	1.3	2.5			0.2	6.7		0.31
Prunus jamasakura	1.9	0.4	0.7		2.5	0.5			0.31
Prunus grayana	0.5	0.6	0.2		15.8	0.2	2.7		0.28
Evodiopanax innovans	1.6	0.0	0.3		0.2				0.28
Acer crataegifolium	0.5	0.0	0.1		0.9	0.2			0.28
Magnolia hypoleuca	0.4	0.2	0.1	0.2	2.7				0.24
Castanea crenata	0.8	0.4	0.3			4.4			0.21
Carpinus laxiflora			2.5				3.1		0.17
Clethra barbinervis		0.0	1.4						0.17
Sorbus alnifolia	0.3	0.1	0.0						0.17
Chamaecyparis pisifera		1.2		54.2					0.14
Abies firma	2.5	1.8	0.0						0.14
Lyonia ovalifolia var. *elliptica*	0.1	0.0	0.1						0.14
Prunus verecunda	6.7					0.5	0.7		0.10
Hydrangea paniculata					0.6		0.4	1.1	0.10
Ilex crenata			0.4						0.10
Malus toringo	0.2		0.1		0.1				0.10
Pieris japonica			0.4						0.10
Others	6.0	1.2	4.0	3.3	19.8	0.0	0.0	9.0	
No. of species	29	28	37	6	14	12	9	5	56

* Number of plots the species emerged/total number of plots

A. pycnanthum and planted coniferous tree species (*Cryptomeria japonica* and *Chamaecyparis obtusa*) respectively. Type C was a mono-dominant stand in which *A. pycnanthum* peaked (68.9%) compared to the other types of stands (27.2-38.4%) (Table 3). At Types D and E, *C. pisifera* and *Alnus japonica* respectively dominated.

Stand structure

Figure 2 shows representative examples of the dbh size class structure within each type of stand. IW-4 belonging to Type A (secondary-growth stand) showed an inverse J-shaped dbh size distribution as a whole. However, *A. pycnanthum* trees were distributed in classes with dbh relatively larger in size, although not exceeding 40 cm. YM representing Type B (coniferous plantation of *C. japonica* and *C. obtusa*, including *A. pycnanthum*), had a distribution pattern with decreasing stem number in larger size. However, *A. pycnanthum* stems showed irregular distribution in dbh size with peaks in the 40-45 cm size class.

Old-growth KM-1 belonging to Type C (both old-growth and secondary-growth stands; Fig. 1) had a larger number of planted coniferous trees in the smallest size class with a small number of *A. pycnanthum* in the larger size-classes. The maximum size of *A. pycnanthum* was 62.9 cm in dbh, the largest in all plots. In contrast, secondary-growth MT-2, also belonging to Type C, showed bimodal distribution of all trees, and *A. pycnanthum* showed two peaks, namely 5-10 and 30-35 cm.

Types D and E were both observed in Iyari in Nagano prefecture, in old-growth and secondary-growth stands, respectively (Table 1). The dbh distribution of all trees in IR-1 of Type D, however, was unimodal, peaking at the 20-25 cm dbh class. Conversely, the only secondary-growth Type E stand, IR-3, was composed of trees < 20 cm dbh. The stand age was young (Table 2) and the tree density of *A. pycnanthum* was very low.

Population structure of *A. pycnanthum*

Acer pycnanthum populations in the four habitats (Oppara, Hananoko, Iwayado and Matsunoko) showed different patterns of dbh distribution (Fig. 3). The populations in Oppara and Hananoko had unimodal dbh distributions, peaking at 25-30 and 20-25 cm, respectively. Conversely, the populations in Iwayado showed an almost inverse J-shaped pattern of dbh distribution, the mode of which was in the minimum size class (5-10 cm). The population in Matsunoko showed bi-modal distribution with two peaks at 10-15 and 35-40cm. The maximum size of *A. pycnanthum* in the Iwayado population was 65.1 cm in dbh, making it the largest stem among the four populations (Fig. 3).

Acer pycnanthum individuals with multiple stems sprouting from the stump were observed in these populations, while the percentage of individuals with a single stem in the *A. pycnanthum* population exceeded 80% at Oppara, Hananoko and Iwayado. In contrast, individuals with multiple stems comprised 65% of the total Matsunoko population (Fig. 4). Although the mean number of stems per stump was 2.7 (ranging from 1 to 7) in the Matsunoko population, the mean number for the other three populations was 1.2-1.3 (ranging from 1 to 6), less than half that of Matsunoko.

Regeneration

The density of regenerated trees (dbh < 5.0 cm and h > 1.0 m) was less than 2,000 trees ha^{-1} in 15 plots, and the main components of the regenerated tree species were *Acanthopanax sciadophylloides*, *Evodiopanax innovans* and *Camellia japonica* (Table 4). Regenerated trees of *A. pycnanthum* were found in only four plots, and the tree density was very low, fewer than 200 trees ha^{-1}.

Discussion

Characteristics of *A. pycnanthum* stands

Five major types of stands that included *A. pycnanthum* were observed in the study plots

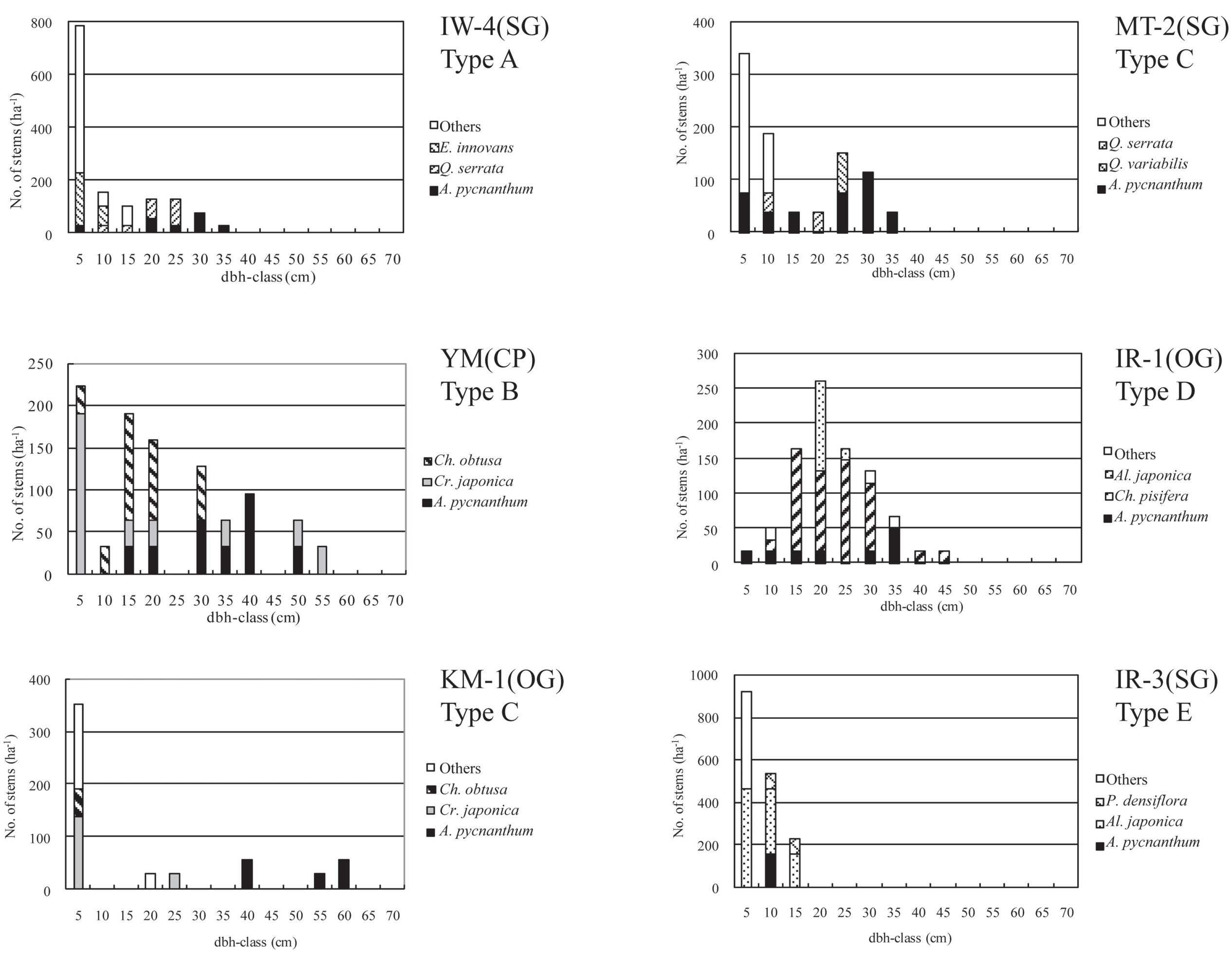

Fig.2 Dbh size distribution of trees in each stand type.
The abbreviations are same in Fig.1.

throughout all habitats of this species with tree composition in mind (Fig. 1 and Table 3). Type A was secondary-growth stands, characterized by the dominance of *Q. serrata* and *A. pycnanthum* (Table 3). *Quercus serrata* is a main component of the typical secondary-growth stands that had developed after repeated short-rotation clear cutting for fuelwood and/or charcoal production (Hoshino, 1996) and are widely distributed in Japan (Yokoi, 2009). While the ecological habitat of *Q. serrata* is in slightly dry habitats (Masaki *et al*., 1992), that of *A. pycnanthum* is in wet sites. The secondary-growth stands of Type A had developed on the lower part of a hilly slope near a spring or small stream. *A. pycnanthum* maintained its population, even under repeated human impacts, in such clear cutting, but could not establish itself outside these wet sites near the valley bottom. In contrast, *Q. serrata* was able to invade and dominate the valley bottom (Saito, 1977).

Type B included coniferous plantations of *C. japonica* and/or *C. obtusa* accompanied by *A. pycnanthum* (Table 3). These stands were established after the clear cutting of broadleaf stands and planting coniferous trees at wetlands, which are natural habitats for *A. pycnanthum*. Individual *A. pycnanthum* trees in this type of stand were considered to establish themselves after clear cutting took place. The unimodal dbh class distribution pattern of *A. pycnanthum* suggests that individual trees of *A. pycnanthum* in these stands were established simultaneously by sprouting from the stamps after the clear cutting (Fig. 2).

Type C, characterized by the dominance of *A. pycnanthum*, includes both old-growth and secondary-growth stands. They differed in terms of the size-class structure of *A. pycnanthum* in the stands; old-growth stands had *A. pycnanthum* trees of larger-size stems with low density, and the secondary-growth stands had many smaller-sized *A. pycnanthum* tree stems due to sprouting after clear cutting (Figs. 2 and 4). The tree composition of this stand type may be typical for the natural stands, including *A. pycnanthum*, and also resembled the phyto-sociological vegetation category '*Ilici-Alnetum japonicae* Minamikawa' (Yatoh et Kobayashi, 1974) represented by the widely distributed *Alnus japonica* in the wetlands of the Tokai

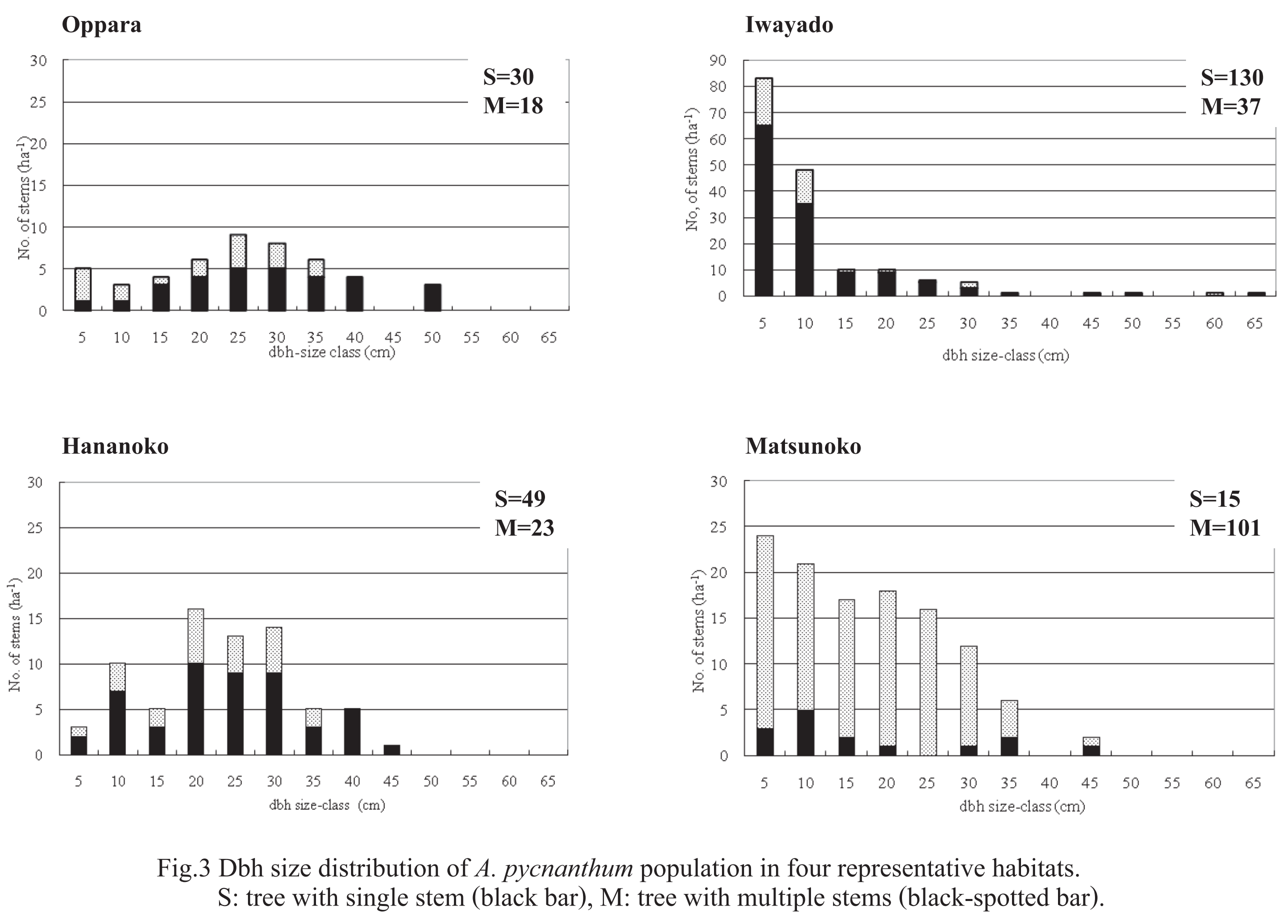

Fig.3 Dbh size distribution of *A. pycnanthum* population in four representative habitats.
S: tree with single stem (black bar), M: tree with multiple stems (black-spotted bar).

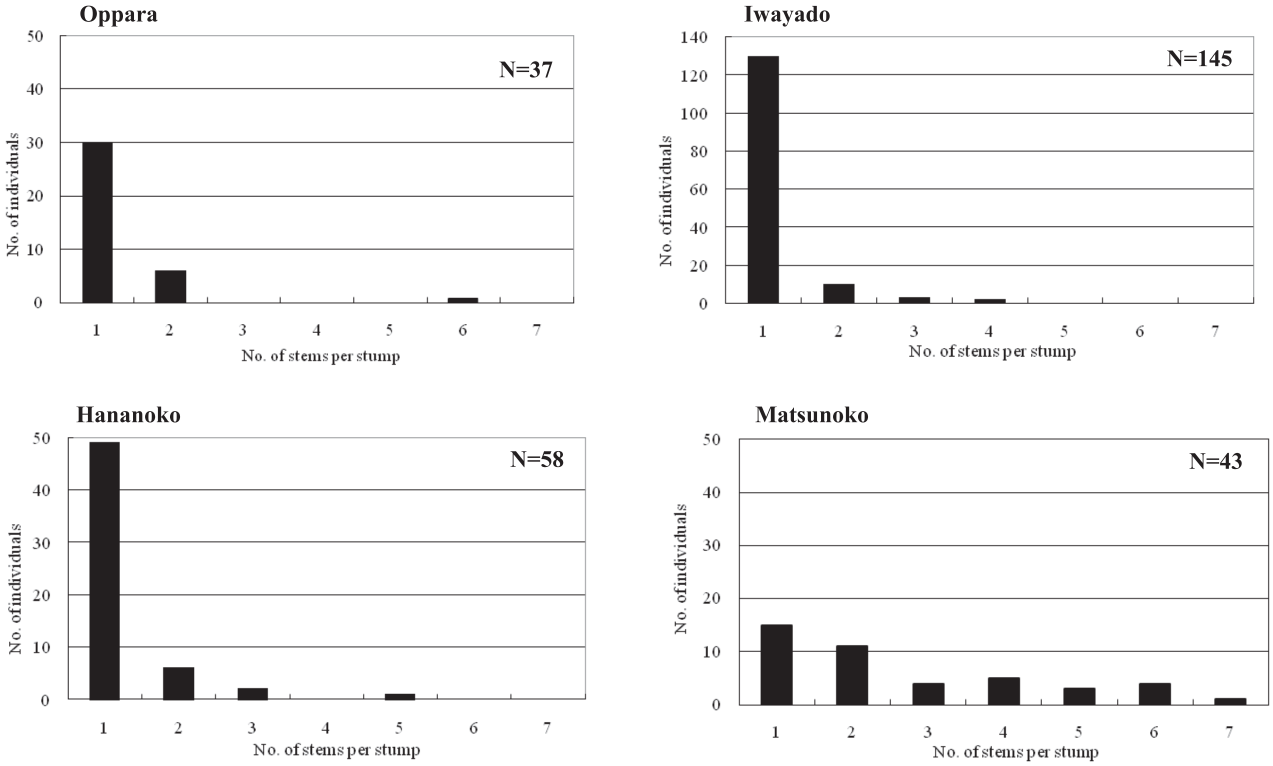

Fig.4 Number of individuals with different stem number sprouting from a stump in four representative habitats.

Table 4. Density of regenerated sampling of tall tree species in each plot (ha^{-1}).

Forest type	A	A	A	B	B	B	B'	C	C	C	C	C	C'	D	E
Species name	TC-3	IW-4	Tajimi-2	OK	YM	KU	TC-2	IW-3	HR	KM-1	TJ-1	YD	TC-4	IR-2	IR-3
Acanthopanax sciadophylloides	290.5	660.1		153.4		24.0			55.6	53.9		501.9	175.0		
Evodiopanax innovans		431.6						98.6	1166.8	458.0					
Acer pycnanthum							186.6	98.6					75.0		76.9
Carpinus laxiflora									333.4			267.7	25.0		
Quercus serrata									27.8			200.8	25.0		
Quercus glauca			43.1							80.8	41.7				
Sorbus alnifolia	41.5									53.9			25.0		
Cleyera japonica			215.7								125.0				
Styrax japonicus	41.5											167.3			
Castanea crenata									138.9			33.5			
Quercus sessilifolia		25.4							138.9						
Acer sieboldianum									55.6		41.7				
Chamaecyparis obtusa												33.5	50.0		
Fraxinus lanuginosa var. *serrata*										26.9		33.5			
Camellia japonica											1125.1				
Chamaecyparis pisifera														900.0	
Cryptomeria japonica	83.0														
Benthamidia japonica												33.5			
Illicium anisatum										26.9					
Magnolia hypoleuca													25.0		
Ilex macropoda													25.0		
Kalopanax pictus						24.0									
No. of Species	4	3	2	1	0	2	1	2	7	6	4	8	8	1	1
Total number of saplings	456.5	1117.2	258.8	153.4	0.0	48.1	186.6	197.2	1916.8	700.4	1333.4	1271.5	425.0	900.0	76.9

region of central Japan (Miyawaki, 1985; Hirabayashi and Takahashi, 1969).

Type D, characterized by the dominance of *C. pisifera*, was distributed only in the Iyari Marsh and isolated from the other habitats (Barnes *et al*., 2004), with its original habitat considered to be wetland in which old-growth *C. pisifera* stand had developed. Type E was a secondary-growth stand that had developed on abandoned paddy fields near the Iyari Marsh.

Few saplings of *A. pycnanthum* were observed in most stands of every type, although there were many saplings of tree species with shade torelance, such as *Acanthopanax sciadophylloides* and/or *Evodiopanax innovans* (Table 4). One of the reasons for the low density of this *Acer* species may be due to its lower shade tolerance (Suzuki, unpublished data).

Effect of human activity on *A. pycnanthum* stands

Acer pycnanthum habitats have been strongly influenced by human activity, such as clear cutting for fuelwood production, selective cutting and previous conversion to coniferous plantations for lumber production (Table 1). Therefore, tree composition and stand structure, in the old-growth stands as well as those of secondary-growth and coniferous plantations, including *A. pycnanthum*, may differ to a greater or lesser extent from the original ones (Table 3 and Fig. 2). Even in old-growth stands protected as National Monuments or Prefectural Natural Heritage, there was evidence of previous human activities, with many underplanted trees of *C. japonica* in KM-1, and many *C. pisifera* stumps observed in IR-1 (unpublished data). Larger-sized stems of *A. pycnanthum* were rare, even in the old-growth stands, although this species can grow larger than 70 cm (Table 2 and Fig. 3). This is strongly suggestive of previous human impact in the old-growth stands.

The natural habitat of this *Acer* species, except for the marsh, has long been recognized as unsuitable for agriculture and plantation forestry, and has thus been used only for fuelwood and charcoal production as secondary-growth stands, managed by short-rotation clear cutting (approx. every 20-30 years). Consequently, the natural vegetation in these habitats was completely destroyed and replaced by secondary growth stands mainly composed of tree species with light-demanding characteristics and sprouting ability (Miyawaki, 1985). Only in the wetland marshes did the features of the original vegetation remain in fragmented form.

However, there is considerable variation in the tree composition of secondary-growth stands among the stand types (Fig. 1 and Table 4), affected by differences in the land-use history as well as the site conditions (Saito, 1977). These differences are also reflected in the size-class distribution of *A. pycnanthum* populations in habitats where stands used for fuelwood production were managed by short-rotation clear cutting operations (Figs. 3 and 4).

A. pycnanthum populations in Oppara and Hananoko had unimodal dbh distribution, suggesting simultaneous regeneration following a large scale disturbance or desiccation of a marsh and riparian area. The *A. pycnanthum* population in Matsunoko included many individual trees with multiple stems through sprouting after repeated clear cuttings, and this management system formed a dbh distribution pattern with a few larger-sized stems. Conversely, the inversely J-shape distribution of the Iwayado population suggests the continuous regeneration of this *Acer* species in unsuccessful areas of this coniferous plantation, especially those flooded around reservoirs (Kanazashi, unpublished data).

Forestry operations conducted to create coniferous plantations for timber production generally strove to eliminate the other tree species. However, some *A. pycnanthum* trees remained in these plantations (Fig. 1). In some cases, this may be due to intentionally avoiding their removal during silvicultural processes, especially in and around National Monuments or Natural Heritage Sites, and the other cases may be the results of successful natural regeneration from seedlings which occurred when afforestation was implemented.

Acer rubrum, closely related to *A. pycnanthum*, is now widely distributed in North America (Walters and Yawney, 1990). However, this species was a relatively minor component in most forests in eastern North America before European settlement (Nowacki *et al*., 1990; Palik and Pregitzer, 1992; Whitney, 1994; Abrams, 1998). This species migrated to the adjacent uplands after old-growth stands were clearcut during European settlement, and predominated as a main component of secondary-growth stands in the area (Abrams, 1998). This may have involved the accelerated succession from early or mid-successional tree species to late successional trees as a result of human disturbances (Abrams, 1998). The expansion of the red maple may also be a result of fire suppression during the twentieth century (Lorimer 1984, Abrams 1992). From these results, *A. rubrum* is regarded as an opportunistic tree species that was originally distributed in sites of unfavorable growth such as non-pyrogenic, wetlands, avoiding fire and competition with other tree species, such as *Quercus* (Abrams, 1998).

In contrast, *Acer pycnanthum* is strongly associated with wetlands; no expansion of its ecological distribution into the disturbed area around its original habitat has been observed (Barnes *et al*., 2004; Saeki, 2005b). The Japanese species takes refuge in wetlands or riparian areas that are scarcely fertile, to avoid competition with other tree species. However, this species cannot invade and expand to the uplands and/or drier sites, because of its geographical dependence on wetlands and lower shade tolerance (Suzuki, unpublished data). This species could only survive after clear cutting in the old-growth and secondary-growth stands, including *A. pycnathum* trees through adaptation to open wetland sites with the physiological traits of light-demand and/or sprouting ability, although large-scale land development and drastic land-use changes in the original habitats may facilitate the reduction, isolation and fragmentation of its population (Kanazashi, 2008). These differences between the two *Acer* species belonging to the same taxonomic section appear to be attributable to their own ecological and ecophysiological characteristics;

Conservation of *A. pycnanthum*

The *Acer pycnanthum* is facing a crisis of extinction and was recently designated as a Class II vulnerable species (Environment Agency of Japan, 2000). The natural habitats of *A. pycnanthum* are now too small to maintain the local populations (Table 2 and Fig. 3), and are isolated from other habitats and populations for pollination and gene flow (Young *et al*., 1996). In addition, urbanization and land development around these habitats have reduced the number of potential new habitats. To maintain the local populations of *A. pycnanthum*, efforts must be made to extend the potential habitats around the original habitats and connect them to neighboring habitats and populations.

Conversely, few regenerated seedlings and saplings exist in the stands, even in and around National Monuments and other Forest Reserves (Table 4 and Fig. 3). Therefore, disturbances to create canopy gaps for regeneration by thinning and/or selective cutting should be introduced to these stands, and periodic weeding is also necessary at sites where dwarf bamboo predominates.

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希少樹種ハナノキ自生地における樹木群集の組成および林分構造とその人為的影響

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要 旨

ハナノキ自生地の樹木群集の組成と林分構造を明らかにするため、岐阜、長野、愛知県にある自生地の２９林分を対象に調査を行った。ハナノキを含む林分は、群集組成的に５タイプに類型化することが出来た。すなわち、コナラの優占するタイプＡ、スギの優占するタイプＢ、ハナノキの優占するタイプＣ、サワラの優占するタイプＤ、そしてハンノキの優占するタイプＥである。タイプＡとタイプＥは二次林であり、タイプＢは針葉樹人工林であった。また、タイプＣは、皆伐履歴のない老齢林と二次林から構成されていた。タイプＤは、サワラの老齢林と二次林から構成されていた。各調査区におけるハナノキは、林分の取り扱い履歴を反映し、様々な直径階分布を示した。老齢林の樹種組成は、ハナノキ自生地の本来の姿をとどめる一方、針葉樹人工林はもとより二次林では、群集組成や林分構造に伐採や植林などの人為的な影響が明らかに認められた。ハナノキの厳格な保全のためには、現存する自然の自生地を保護するだけでなく、新たな自生地の創出が求められる。また、地域集団の維持のためには、自生地の拡大あるいは自生地どうしを結び付けることも必要である。

キーワード：ハナノキ、希少樹種、群集組成、林分構造、人為的影響、保全

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