東海大學生命科學系
博士學位論文

指導教授：林 仲 平
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人工林疏伐後蜘蛛多樣性與微棲地環境之變化關係

Relationship between spider diversity and microhabitats in plantations under differential thinning treatments

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中華民國一〇一年六月八日

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誌謝

首先誠摯的感謝指導教授林仲平博士，在我論文寫作期間的指導以及在人倫進行實驗中的協助。也感謝卓逸民老師孜孜不倦的教導使我得以一窺蜘蛛學及多樣性領域的深奧。在這漫長的五年的日子中，不單是學術研究還是日常生活上，滿有愛心和耐心，不時的討論並指點我正確的方向，且總在我迷惘時為我解惑，提出很多不同角度及建設性的思維，使我在這些年中獲益匪淺。

本論文的完成亦要感謝林試所森林經營管理組邱志明組長的大力協助，使我對林業領域及森林管理有更正確而嚴謹的專業知識，使本論文能夠更完整。還要感謝東海大學江智民老師、林宜靜老師、林惠真老師、林良恭老師、汪碧涵老師、關永才老師、及東華大學孫義方老師，在研究所課程上的科學知識傳遞，並不厭其煩的指出我研究中的缺失。也要感謝以色列 Ben-Gurion 大學的 Yael Lubin 老師大力協助，對我及家人在以色列生活時的學術、語文、文化及日常生活的照顧，讓我順利渡過在以色列做訪問學生的一年，開闊國際視野及對蜘蛛行為及社會生態有更進一步的認識。

同時也感謝卓老師實驗室各任助理卓恬瑩老婆大人、林慈怡(一姐)及陳陵霏(霏姐)對於實驗進行以及實驗室事務上的幫忙，也感謝歷任實驗室成員許多人在此期間提供的建議與支援，在研究所期間的相互勉勵，以及的關懷和鼓勵。五年裡的日子，實驗室共同的生活點滴，共同砥礪(墮落)，的陪伴讓研究生活變得絢麗多彩。同時也要感謝在實驗室中幫忙多得數不清的大學生，還有其他實驗室裡一同在人倫進行實驗的夥伴們。

感謝我的摯愛的雙親及哥哥和姐姐，支持我這麼漫長、鉅資的任性，看似完成不了的學業還是給我信心和鼓勵，你們背後的默默付出及支持更是我前進的動

力。還有親愛的老婆大人，大女兒揪崩和小女兒新珏，你們的陪伴和笑容，使我有繼續的動力和後盾，讓我能夠全心投入完成學業。

　　最後，謹以此文獻給我摯愛的雙親及天父。

在你一切所行的事上，都要認定祂，祂必指引你的路。(詩篇 3:6)

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西元 2012 年 6 月

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Chinese abstract

近年來人工林經營管理之策略，已演變為兼顧經濟效益與生物多樣性之經營模式。在針對不同之林相設計適當的人工林經營管理模式之前，需先了解原始林及不同疏伐程度的人工林當中之物種組成特性之差異，且需掌握目前林業之管理模式對不同層面之生物多樣性的影響。蜘蛛在許多陸生生態系中為物種數量及豐度最高的節肢動物捕食者，遍佈生態系中所有棲地。當棲地因森林演替、自然干擾以及林業操作而改變會導致蜘蛛群聚結構的改變，因此蜘蛛適合用來探討棲地異質度與節肢動物多樣性之關係。本研究目標為藉量化及比較不同疏伐程度森林之蜘蛛群聚結構及物種組成，了解由於林業經營所導致之森林改變對生物多樣性的影響。第一個實驗我監測及量化高海拔的原始林及台灣紅檜人工林棲地中之蜘蛛多樣性及各樣微棲地環境及氣候因子。結果為森林的改變對於棲息於其中的蜘蛛不管是物種、科及和功能群等不同階層有極為顯著的改變；溫度及林下層植被密度為造成多樣性差異之主要環境因子；而其蜘蛛組成差異之主要貢獻者則是利用林下植被之圓網型及立體網型種類。第二個實驗於台灣中部日本柳杉人工林進行蜘蛛多樣性之調查及微環境資料之收集，比較未疏伐樣區和25％、50％疏伐強度樣區的差異。針對不同疏伐處理之人工林於疏伐前一年、疏伐後兩年共進行為期三年，每三個月一次的調查及採集。棲地間比較之結果顯示人工林間地表活動的蜘蛛組成在疏伐前後皆有顯著不同，顯示林相改變顯著影響蜘蛛群聚組成。

不同處理人工林棲地間的蜘蛛組成在疏伐前並無不同,但在疏伐兩年後有顯著不同。各處理類型之人工林於疏伐前及疏伐後兩年不同年間的物種及科級組成及數量皆不同，顯示蜘蛛群聚組成有時間上之變化。蜘蛛群聚組成改變的主要貢獻功能群為穴居型、立體網型及地表徘徊型蜘蛛。微環境因子的測量值顯示人工林經疏伐後其過度密集的林下層植被及樹冠層開闊度結構產生改變,可能導致了穴居型蜘蛛物種數及密度之下降並增加立體網及地表徘徊型蜘蛛物種及豐度。而各疏伐處理之人工林其林下植被恢復速度之不同，以及蜘蛛組成在時間上之變化效應，都可能是導致棲地間蜘蛛組成差異的成因。

關鍵字: 生物多樣性、蜘蛛、森林管理、疏伐、紅檜、日本柳杉

Abstract

Current plantation management policies have evolved into focusing on both conserving biodiversity and maximizing economic benefit. Before designing effective strategies for conserving biodiversity of plantations, we need to understand the difference in species characteristics between plantations subjecting to different degree of thinning. In many terrestrial ecosystems, spiders are the most diverse and abundant arthropod predators. Spiders rely on a distinct complex of environmental factors and therefore are sensitive to changes of the habitats due to forest succession, natural disturbances or forestry practice. Therefore, spiders are considered as a good indicator for comparing the biodiversity of various environments and for assessing the effect of disturbances. In the first study I investigated the effects of forest alterations on biodiversity by quantifying and comparing spider diversities and microhabitat parameters of primary and Taiwan red cypress (*Chamaecyparis formosensis*) plantations located at high elevation in central Taiwan. Multivariate analyses were used to examine the relationships between various microhabitat parameters and spider diversities. The results showed significant differences in spider compositions between different forest types and temperature and understory vegetation density were the major determining factors.

Space weavers and orb weavers inhabiting the shrubs were the major contributors of the observed spider diversity differences. In the second study, I compared the spider community structures and guild compositions of plantations under different degree of thinning (0%, 25% and 50%). The study site was located in *Cryptomeria japonica* plantations in central Taiwan. The diversities and compositions of spiders as well as microhabitat structures and microclimates were quantified once every three months one year before thinning and two years after thinning. Results of analyses showed that spider compositions of plantations differed significantly in all three years. Before thinning, spider compositions did not differ significantly among three plantation types. Results of analyses showed that two years after thinning spider species and family compositions of three plantation types differed significantly. In all three plantation types the spider composition differed from year to year, indicating existence of temporal variations in spider diversity. Burrow dweller, space weaver and ground runner were the major contributors of the observed spider composition differences among plantations receiving different treatments. Thinning treatment might have changed the structures of understory vegetation and canopy cover and consequently resulted in abundance and diversity changes of these guilds. Moreover, the heterogeneity in understory vegetation recovery rate and temporal variation of spider diversity might further generate spider composition variations in forests receiving different degree of thinning.

Keyword: biodiversity, spider, forest management, thinning, *Chamaecyparis formosensis, Cryptomeria japonica.*

Chapter 1

Trends of the plantation management and background of study

There is a worldwide concern about involving biodiversity conservation while conducting plantation management, and studies regarding the responses of fauna or flora to plantation management have increased recently (Kerr, 1999; Fermon et al., 2000; Ohsawa, 2004; Waltz and Covington, 2004; Marra and Edmonds, 2005; Ohsawa, 2005; Yuan et al., 2005; Zausen et al., 2005; Ohsawa and Nagaike, 2006; Ohsawa, 2007). Currently thinning is a commonly used practice and such conduct can theoretically restore the ecosystems to the pre-disturbed state in aspects such as structure, function, and biodiversity (Hobbs and Norton, 1996). Several studies showed that thinning might potentially alter the developmental trajectory of young stands, generating a higher structural diversity and an increased understory plant diversity (DeBell et al., 1997; Marañòn et al., 1999; Thomas et al., 1999; Son et al., 2004). Thinning may increase light inputs to the ground and consequently result in a diverse mosaic of microhabitats (Son et al., 2004). Some studies have shown that stands receiving different degrees of thinning exhibit variations in relevant environmental parameters. Alterations in microhabitats in turn influence the animal communities in aspects such as the number and diversity of niches, local abundance and guild compositions (Waltz and Covington, 2004; Homyack et al., 2005; Montaña et al., 2006; Maleque et al., 2007a; 2007b). However, keeping certain areas of unthinned patches is vital because they can provide refuges for particular species that are susceptible to thinning (Montaña et al., 2006). So, to determine appropriate management policies to enhance biodiversity of plantations, it is essential to understand how thinning practices affect various environmental factors and consequently influence the composition and distribution of plant and animal communities.

In the past, in order to improve the commercial values of timbers, thinning is an important component of control system which expands the available growing space of trees which will be harvested later (Fujimori, 2001). Currently, instead of maximizing economic benefit plantation management policies have also focusing on conserving biodiversity. Before designing effective thinning practices for conserving biodiversity of plantations, we need to understand how different ways and intensity of thinning after spatial and temporal characteristics of plantations then affect spider compositions. Depending on Smiths' (1986) definition, crowns or trees are categorized into one of four classes, i.e., dominant, co-dominant, intermediate, or suppressed. According to the timber quality and potential growth rate (usually depending on the class of crowns or trees), thinning practices can be classified into the following four types (Smith, 1986):

(1) Thinning from below

Thinning from below usually removes suppressed, intermediate, and some co-dominant trees, and enhances growing space of dominant trees (Fujimori, 2001). Lower crowns which belong to suppressed or intermediate classes usually die from the illumination competition within the stand. Then the canopy soon closes again by the growing of residual trees. In order to improve the growing space of the residual trees, some co-dominant trees are also removed with the suppressed and intermediate crown. This thinning method is relatively easy to select the trees to be removed and causes less damage to stands when compared to other thinning methods (Fujimori, 2001).

(2) Thinning from above

Thinning from above removes the competitive dominant trees, especially the most competitive dominant trees, to improve the growth space of promising trees (Fujimori, 2001). Thinning from above is generally most effective if it is conducted at trees with a low growth rate and relatively young stage. Because, the crop trees exhibiting low growth rate require a wider space created from removed dominant trees to grow faster. And under such condition young stage trees exhibiting restricted growing are able to grow better during the later stage (Fujimori, 2001). Accelerating the growth rate of crop trees in a short time by thinning from above is useful, but need to avoid practices during bad weather condition. The residual trees after this thinning method are usually intermediate or suppressed trees and may have been eliminated by the bad weather.

(3) Thinning of dominants or selection thinning

The thinning of dominants method removes dominant trees (that already reach a minimum commercial size) to improve the growing space of promising residual trees (that are co-dominants or intermediates) (Fujimori, 2001). This method needs to intensively manage in forestry areas where the subordinate trees can grow to a commercially valuable size to enhance the economic values of trees (Fujimori, 2001). This method is appropriate for markets relying on a constant supply of products and is useful for controlling the width of the growth rings. Similar to the thinning from above method, it is not suitable in areas where the bad weather conditions are common. The residual trees generally belong to intermediate and suppressed crowns with relatively slender stems and therefore are susceptible to bad weathers.

(4) Geometric thinning

In the geometric thinning method, as a defined number of rows trees are removed or retained (Fujimori, 2001). This method is suitable for uniform-sized young and dense single species stands where the trees have relatively slender stems with low commercial value. In such type of plantations, row and distance can be easily to defined and measured to conduct the thinning operations. This method has advantages of easy transportation of felled trees with machines, but has disadvantages of soil protecting problems in stands situated on relatively steep slopes (Fujimori, 2001).

In the second experiment of my study, the specific geometric thinning were used. In this operation, trees are removed or retained according to the criterion of area and is called gap geometric thinning. The intensity of thinning treatments was achieved by removing trees from designated numbers of 10m x 10m quadrats. Nevertheless, after thinning most stands generally have for soil protection problems or the residual trees have less developed crowns. The retained trees generally have relatively slender stems with less developed crowns, making them more susceptible to strong winds. Therefore, the timing of thinning is particularly important to avoid the occurrence of potential bad weathers.

Spiders are suitable ecological indicators to assess the effects of silvicultural practices on biodiversity (Uetz 1975, Hatley and Macmahon 1980, Bultman and Uetz 1982, Oxbrough et.al. 2005). Spiders are one of the dominant arthropod predators in many terrestrial ecosystems and they play an important role in ecosystem functioning (Wise, 1993; Nyffeler, 2000). They occupy an influential niche in terrestrial food webs and regulate the insect populations in various communities (Wise et al., 1999). According to their particular ecological demands, many spiders rely on a distinct complex of microhabitats and their diversity is sensitive to changes in environmental conditions (Cardoso et al., 2004a; 2004b; Ziesche and Roth, 2008). There is evidence that habitat alterations and landscape heterogeneity due to forest succession, natural disturbances, or forestry practices will generate significant changes in spider communities (Clough et al., 2005; Tsai et al., 2006; Ziesche and Roth, 2008). The species richness and abundance of spiders was also reported to be closely associated with large-scale landscape complexities (Gurdebeke et al., 2003; Schmidt et al., 2005). Spider communities were found to be significantly different in plantation stands of various patch types, size scales and age classes (Whitehouse et al., 2002; Finch, 2005; Ziesche and Roth, 2008).

A spiders' ability to colonize new habitats from surroundings depends mainly on its life cycle, dispersal mode, and the distribution of source habitats in the landscape (Topping and Sunderland 1994, Topping 1999). For species with limited dispersal capabilities, the landscape in the closer surroundings is supposed to be of greater importance while for very mobile species the remote surrounding landscape is more relevant (Topping 1999, Schmidt and Tscharntke 2005, Drapela et al. 2008). Habitat isolation, quality and heterogeneity all plays important roles in influencing biodiversity (Leibold et al. 2004). In fragmented landscapes connectivity is critical to the maintenance of biodiversity (Chisholm et. al. 2011). Thinning practices are likely to create a stand with highly heterogeneous microhabitats or a network of stands connected among fragmented habitat patches. From a landscape and metacommunity aspect, spatial heterogeneity within the stand determines the patterns of diversity and habitat network at local scales (Leibold et. al. 2004). Stands receiving various thinning practices can be regarded as a large habitat with heterogeneous microhabitats and could potentially meet the habitat requirements of a wider array of organisms. Therefore, stands receiving different degree of thinning may potentially create heterogeneous habitats and exhibit a regional effect on biodiversity. Consequently, stands with higher heterogeneity will theoretically have higher diversity of organisms (Kerr 1999). However, studies about how different silvicultual systems affect habitat structure and consequently biodiversity are still few.

In Asia, studies about the effects of plantation management on biodiversity are mostly conducted in temperate areas such as Japan. In general, thinning increased the richness and abundance of longhorn beetle (Ohsawa, 2004), Coleoptera (Maleque et al. 2007a), Hymenoptera (Maleque et al. 2007b) and other insect taxa (Ohsawa, 2005; Ohsawa and Nagaike, 2006, Taki et al. 2010), although particular taxa with specific habitat requirements (such as those only inhabiting isolated old primary forests) were unaffected by such treatment (Ohsawa, 2007). Results of studies also showed that among forests receiving different management practices the compositions and community structures of beetles were different (Maeto et al., 2002). Thinning may influence understory vegetation composition in a profound way by creating new gaps (Igarashi and Kiyono, 2008, Taki et al. 2010), although dominant tree species and topographic variation are also major determining factors (Ito et al., 2003). Various functional groups of insects in turn were positively correlated with the species richness of understory vegetation (Maleque et al., 2007a; 2007b). However, all these conclusions were derived from studies conducted in temperate

Northeastern Asian forests with data collected at a discrete time after thinning. The characteristics of temperate plantations are quite different from those of warm and wet subtropical plantations, which constitute a vast area in Eastern/Southeastern Asia. Currently, information about the effects of thinning on biodiversity of subtropical plantations in Asia is very limited.

Understanding the temporal effects of thinning on the community structure, diversity, and abundance of fauna and flora of plantations are also quite important, but such effect had received relatively little study. Generally, one year after thinning species richness and abundance of insects increased in thinned compared to unthinned forest stands (Ohsawa, 2004; Taki et al. 2010) and some studies reported similar results (Maleque et al. 2007a; Maleque et al. 2007b) when the survey of diversity was conducted four to five years after thinning. In contrast, a study in Taiwan showed that four to five years after thinning, bird and mammal communities of thinned stands were similar to those of unthinned stands, although arthropod communities seemed to be enhanced by thinning (Yuan et al., 2005). Other studies have shown little difference in the diversity of leaf beetles and weevils between unthinned and thinned larch plantations in Japan several years after thinning (Ohsawa, 2005; Ohsawa and Nagaike, 2006). The aforementioned diverse patterns reported from various animal taxa might have resulted from these organisms' differential responses to temporal effects of thinning treatments. Therefore, the temporal effects of thinning require careful consideration before applying thinning operations to plantation stands designated to receive conservation-based managements

In this study, the effects of silvculture management were assessed by investigating the spider diversity of subtropical *Chamaecyparis formosensis* and *Cryptomeria japonica* plantations in central Taiwan receiving different thinning treatments. To my knowledge, these are the first studies in Taiwan examining the effects of thinning operations on arthropod species richness and diversity while considering aspects such as spatial heterogeneity and temporal variations of habitats. I compared the spider diversities and communities of plantations exhibiting spatial and temporal changes generated by different degrees of thinning. From the spatial aspect, we investigated canopy, understory and ground spider composition of *C. formosensis* plantations receiving various thinning treatments. From the temporal aspect, we compared spider composition in *C. japonica* plantations one year before and two years after thinning. In addition, biotic and abiotic environmental factors were measured to identify key environmental variables contributing to the observed spider composition variations. The aim of this study is to provide a long-term research platform for a variety of scientific questions related to forest biodiversity and ecosystem processes. Results of this study represent the first demonstration of the effects of thinning on arthropod diversity in East Asian subtropical plantation forests and the potential underlying mechanisms.

Chapter 2

Experiment in *Chamaecyparis formosensis* plantation

2.1 Introduction

The study sites of the first experiment were established in a cypress (*Chamaecyparis formosensis*) plantation . The *C. formosensis* stands were established about 30 years ago. Results of a preliminary survey conducted before thinning showed that the overall density of *C. formosensis* stands density was about 900-1800 trees/ ha. Thinning practice was conducted in 2004 in 2 stands. The silviculture practice used in these stands was thinning from below. This method of thinning favors dominant trees and removes trees from the lower crown classes. The thinning from below method removed suppressed, intermediate, and some co-dominant trees. In two thinning stands, the understory shrubs near the trails were removed frequently (several times per year). These stands also received intensive recreation activities. A broadleaf forest dominated by Lauraceae and Fagaceae near the heavily thinned stand was used to serve as a control.

In this experiment, the effects of silviculture management on biodiversity of plantations in central Taiwan were assessed by comparing the community structure and guild composition of spiders. Spiders are suitable ecological indicators to assess the effects of silvicultural practices on biodiversity. We first compared overall spider diversities between primary forest and plantations which had received different degrees of thinning in central Taiwan. Secondly, we compared spider communities in three height levels (canopy, understory vegetation and ground layer) in four forest types. Thirdly, biotic and abiotic environmental factors were measured and analyzed to identify key environmental variables contributing to the observed spider fauna variations. Results of this study represent the first demonstration of the effects of thinning on arthropod diversity in East Asian subtropical plantations and their potential underlying mechanisms.

2.2 Material and Methods

2.2.1 Study site

The study sites were established in a cypress (*Chamaecyparis formosensis*) plantation forest in Da-Shiue Shan in the middle elevation area of central Taiwan (N 24°15’40, E 120°59’18). The elevation of the study sites ranged from 1,800 to 2,000 m a.s.l. and the gradient from 20 to25°. We set up sampling plots in 3 stands of *C. formosensis* plantations: without thinning (the control stand, 8 ha in area), with moderate thinning (12 ha), and with heavy thinning (10 ha). In the stand under moderate thinning, 35% of the trees were removed, and the after thinning retained trees were around 1000 trees/ha. In the stand under heavy thinning, 45% of the trees were removed, and the trees retained after thinning were about 825 trees/ha. In the unthinned stand, the stand density was around 1,200 trees/ha. In each plantation type, we set up 9 sampling plots, and the distance between the nearest neighbors was about 50 m. Sampling plots were located in the center of each plantation stand, and the distance of any plot to the edge of the stand was more than 100 m to avoid edge effects. In addition, sampling plots were also established in a broadleaf forest near the heavily thinned stand to serve as a control. Overall, 36 sampling plots were established in 4 forest types.

Although the plots in each forest type were located in single stand and thus might incur pseudoreplication problems, we regard those sampling plots as independent to each other. Spiders (weavers and hunters) in general are sit-and-wait predators and therefore most of them exhibit very limited movement range (Foelix 1996). Furthermore, most of the spiders in our study area are rather small (body length smaller than 5 mm). Because of spiders' unique foraging requirements, these small-bodied organisms are very sensitive to fine-scale microhabitat characteristics (Ziesche and Roth 2008). Considering their limited mobility, small size and sensitivity to local microhabitats, sampling plots separated by a distance of 50 meters should be reasonably treated as independent samples.

2.2.2 Specimen collection

Four field trips were conducted in November 2005 and February, May, and August of 2006. In each sampling plot a set of pitfall traps was established to collect ground spiders. Each set of pitfall traps was consisted of four plastic cups and three polystyrene plastic sheets arranged into a Y form. The polystyrene plastic sheets were used to enhance the catching efficiency of traps and each was 40 cm in height and 1 m in length. The cup was 15 cm in height and 10 cm in diameter and was covered by a plastic plate secured with sticks to prevent fallen leaves or rain water from entering. In each field trip each trap was filled with 500 ml of 70% alcohol (evenly distributed among four cups) and was opened for 7 days. Sweeping nets were used to collect spiders in the understory vegetation (from ground level to 2 m high). Collection effort was standardized by sweep-netting each sampling plot for 5 minutes. Spiders in the canopy were collected by sweeping the canopy with insects nets mounted on 8m long fishing poles. While collecting canopy spiders the sampling effort was standardized by shaking all branches in each plot for a total of 10 minutes.

The invertebrate specimens were classified into spiders, insects and other arthropods. Spiders were separated into adult and juvenile, and adult spiders were sorted into morphospecies and if possible identified to species by palpal organ or epigynum. Juvenile spiders were sorted into families. In addition, we used classification systems given in Uetz et al. (1999), Höfer and Brescovits (2001) and Tsai et al. (2006) to categorize adult and juvenile spiders into foraging guilds according to spiders’ web-building and prey catching behavior. Spiders were assigned to the following guilds: (1) orb weaver: Araneidae and Tetragnathidae; (2) space weaver: Dictynidae, Pholcidae and Theridiidae; (3) ground weaver: Hahniidae and Linyphiidae; (4) foliage runner: Clubionidae, Mimetidae, Oxyopidae, Philodromidae, Pisauridae, Salticidae, Scytodidae and Thomisidae; (5) ground runner: Gnaphosidae, Lycosidae, Oonopidae and Zodariidae; (6) ground sedentary weaver: Agelenidae and Amaurobiidae. Insects obtained from each sampling plot were weighed after being oven-dried at 60°C for two days. Their biomass was used as an indication of environmental productivity and was incorporated in subsequent multivariate analyses assessing the relationship between spider diversity and environmental factors.

2.2.3 Quantification of environmental factors

We measured environmental variables to identify the factors responsible for changes in spider composition among forest types. We used data loggers to monitor the temperature and relative humidity of sampling plots. In each sampling plot one data logger (HOBO Pro series, thermograph/hygrometer, Onset, USA) was placed at a height of 1m and in each field trip the data was recorded for a week. Leaf litter was collected from four randomly selected 30cm × 30cm quadrants within sampling sites. The leaf litter was carried back to the laboratory and weighed before and after being oven-dried at 40°C for a week. To quantify vegetation structures, we measured the percent canopy openness (PCO) and understory vegetation structural complexity (UVD) of each sampling plot. A fish-eye lens mounted on a Nikon 4500 digital camera was used to measure the PCO. The camera was mounted on a tripod placed in the center of the sampling plot with the lens facing upward to take hemispheric photographs. The photographs were analyzed by a Gap Light Analyzer, Version 2.0 (Frazer et al. 1999) after being transformed into black-and-white images. To quantify UVD we used a red cloth (1 m × 1 m) as the background and estimated the density of vegetation in front of it. The red cloth was held by one person standing at each of the four cardinal edges of the sampling plot. Another person standing in the center of the plot took pictures of the red cloth and the vegetation in front with a Nikon 4500 digital camera. To represent the vertical stratification of the understory vegetation, the cloth was placed at two different heights (from ground to 100 cm and from 100 to 200 cm) . These photographs were transformed into black-and-white images using Photoshop and data from the four cardinal directions and two heights were averaged to be used as the UVD of the plot.

2.2.4 Statistical analyses

We used Margalef Species Richness (D_{mg}), Shannon-Wiener index (H'), Simpson index (D) and evenness (J) (Krebs, 1989) to quantify the community structures of spiders among different forest types. To compare all these indices one-way ANOVA test and Tukey mean comparisons were used. Diversity index calculations were performed using PRIMER 5 (Clarke and Warwick 2001) and both ANOVA and Tukey tests were performed by SYSTAT 9.

Bray-Curtis similarity (Krebs 1989) between sampling plots based upon species, families and guild compositions were calculated (data square root transformed) between each pair of sampling plots. Analyses of similarities (ANOSIM) were performed to test for the statistical significance of the grouping pattern. Similarity percentage (SIMPER) analyses were used to examine the relative contribution of the spider guilds to the observed spider assemblage differences. ANOSIM and SIMPER tests were performed using PRIMER 5 (Clarke and Warwick 2001). Furthermore, we also used one-way ANOVA and Tukey tests to compare the relative abundance of the spider guilds among the four forest types.

The BIO-ENV function of PRIMER 5 was used to determine the subset of variables that were most significantly correlated with spider guild compositions. Temperature, relative humidity, leaf litter, PCO, UVD and biomass of insects were used as the potential environmental variables. The RELATE function of PRIMER 5 was used to determine whether such correlation was statistically significant. We also used one-way ANOVA and Tukey post hoc comparisons to test whether each of the environmental variables differed among the four forest types.

2.3 Results

2.3.1 Spider composition among forest types

From 4 field trips, 3,484 (1,163 from pitfall traps, 1,459 from sweep netting, and 862 from canopy sweep netting) spider specimens were obtained; among them, 1160 (814 from pitfall traps, 214 from sweep netting, 137 from canopy sweep netting) were adults. From the adult specimens, 141 morphospecies belonging to 22 families were identified. The most abundant spider family was the Linyphiidae (28.7%), followed by the Tetragnathidae (15.6%) and Araneidae (13.7%). The Linyphiidae had the greatest number of species (40), followed by the Agelenidae (21) and Theridiidae (17).

2.3.2 Environmental variables among forest types

According to the BIO-ENV function of PRIMER 5, the combination of UVD and temperature were best correlated with the variation pattern of spider family (RELATE test, Spearman rank coefficient *Rho* = 0.264, *p* = 0.003) and guild compositions (RELATE test, Spearman rank coefficient *Rho* = 0.157, *p* = 0.026). Results of ANOVA tests showed that plots in the broadleaf forest had the highest UVD, followed by the control and 2 thinned plantation stands (Fig. 2a, Table 2). Plots in the broadleaf forest also had the highest leaf litter weight (Fig. 2b, Table 2), but the lowest RH and PCO

(Fig. 2c, d, Table 2). Sampling plots in the control plantation stand had the highest mean temperature (Fig. 2e, Table 2). The dry biomass of insects of plots in the 4 forest types did not significantly differ (Fig. 2f, Table 2). Results of the Pearson correlations showed that there were significant inter-correlations among the environmental variables examined (Table 3). The PCO showed a significant positive correlation with RH but negative correlations with UVD and leaf litter. Temperature showed a significant negative correlation with RH, which in turn also exhibited negative correlations with UVD and leaf litter. A significant positive correlation was found between the UVD and leaf litter. Finally, the dry biomass of insects did not show a significant correlation with any of the environmental factors examined in this study.

2.3.3 Specimens collected from pitfall traps

For specimens collected from pitfall traps, the broadleaf forest and heavily thinned plantation had a slightly higher number of species (Table 1a). Plots in the 4 forest types did not significantly differ in overall spider abundances, but those in the heavily thinned plantation had significantly higher adult abundances (Table 1a). Most of the diversity indices of the sampling plots in the 4 forest types did not differ, but those in the heavily thinned plantation stand had a significantly lower evenness and Simpson index than the other 2 plantation stands (Table 1a). Results of the ANOSIM tests showed significant differences in spider species, family, and guild compositions among the 4 forest types (Table 4a and Table 5). Most pairwise comparisons were statistically significant; the only exception was that the guild composition of sampling plots in the broadleaf forest and control stand did not significantly differ (Table 4a). Sampling plots in the heavily thinned plantation stand had significantly more ground weavers, while the abundances of other spider guilds were similar among the 4 forest types (Table 6a). Results of the SIMPER analyses showed that in all pairwise comparisons, ground weavers were the major contributors to the observed variations in the spider guild composition among the forest types (Table 7). For spider specimens collected from pitfall traps, according to the BIO-ENV function of PRIMER 5, the combination of temperature, UVD, and litter weight was best correlated with patterns of variation in spider guild compositions among the forest types (RELATE test, Spearman rank coefficient $\rho = 0.152$, $p = 0.03$)

2.3.4 Specimens collected by sweep netting

For spider specimens collected by sweep netting, plots in the moderately thinned plantation stand had a slightly lower number of species (Table 1b). Plots in the 4 forest types did not significantly differ in overall spider abundances or the diversity indices examined, but those in the control stand had significantly higher adult abundances (Table 1b). Due to the low abundance of adult specimens in sweep-net samples, we only compared spider family and guild compositions between the different forest types. Results of the ANOSIM tests showed that family and guild compositions of sampling plots in the broadleaf forest and control stand did not significantly differ. Similar results were also found between plots in the moderately and heavily thinned stands. All other pairwise comparisons were statistically significant (Table 4b). Sampling plots in the broadleaf forest had significantly more space weavers (Table 6b). However, sampling plots in the heavily and moderately thinned plantation stands had more orb weavers, while those in the control stand had more ground weavers (Table 6b). Results of the SIMPER analyses showed that in most pairwise comparisons, orb weavers were the major contributors to the observed variations in spider guild compositions among forest types (Table 8). For spider specimens collected by sweep netting, according to the BIO-ENV function of PRIMER 5, the UVD was best correlated with patterns of variation of the spider guild composition among forest types (RELATE test, Spearman rank coefficient $\rho = 0.130$, $p = 0.06$).

2.3.5 Specimens collected by canopy sweep netting

For spider specimens collected by canopy sweep netting, sampling plots in the broadleaf forest and control plantation stand had slightly higher numbers of species Table 1c). Adult spider abundances and diversity indices of plots in the 4 forest types did not significantly differ, but those in the heavily thinned plantation stand had a significantly higher overall abundance (Table 1c). Due to the low abundances of adult specimens in sweep-netting samples, we only compared spider family and guild compositions among the different forest types. Results of the ANOSIM tests showed that family and guild compositions did not significantly differ between sampling plots in the control stand and moderately thinned plantation stand. All other pairwise comparisons were statistically significant (Table 4c). Sampling plots in the heavily thinned plantation stand had significantly more orb weavers and foliage runners (Table 6c). However, sampling plots in the broadleaf forest had the highest abundance of ground weavers (Table 6c). Results of the SIMPER analyses showed that in most pairwise comparisons, ground weavers, orb weavers, and foliage runners were the major contributors to the observed spider guild variations among forest types (Table 9). For spider specimens collected by canopy sweep netting, the BIOENV function of PRIMER 5 could not identify any environmental factor that exhibited a significant correlation pattern with observed spider guild variations among forest types.

2.4 Discussion

This study is among the first to systematically examine the impacts of forest management on spider composition and community structures in subtropical plantations in Asia. Results of our study showed that when broadleaf primary forests are transformed to *Chamaecyparis formosensis* plantations, which subsequently received frequent understory shrub pruning and recreation activity, the canopy openness will decrease and leads to changes in environmental factors such as temperature, relative humidity and understory vegetation density. The significant differences in spider species and family compositions between broadleaf and plantations suggest that although 30 years have passed since the broadleaf forests were changed into conifer plantations, their spider communities still differed significantly. However, the similar spider guild composition among these two forest types indicates that different spider taxa occupied similar ecological niches .

Although there was no significant difference in spider diversity among the different forest types, our study revealed that the spider compositions differed considerably. Orb weavers were the major contributors to the observed spider composition differences among the four forest types. For most pairwise comparisons between forest types, orb weavers contributed most to the observed spider composition differences. Congruent with such a pattern was a significant difference in understory vegetation density among forest types. Sampling plots in broadleaf and unthinned plantation had significantly higher space weaver but lower orb weaver abundance than those of the other forest types. The understory vegetation of broadleaf and unthinned plantations was structurally more complex than the two thinned plantations. A more complex vegetation structure might have benefited space weaver (spiders build three-dimensional webs) which need multiple attachment points for webs and consequently resulted in higher abundance of this guild. In contrast, a relatively open and simple vegetation structure of thinned plantations might be suitable for orb weavers (spiders build two-dimensional webs) where the abundance of this guild was enhanced. Ground weaver spiders were another major contributor to the observed spider diversity differences and their contributions were only slightly lower than orb weavers. However, the ground weaver abundance pattern of the four forest types was not congruent with the variation pattern of environmental factors. These results suggest that spider guilds respond differently to forest management practices. While some are sensitive to certain vegetation characteristics (such as space and orb weavers), others (such as ground weavers) are also influenced but their variation pattern exhibits a more complicated relationship with environmental factors.

We also found that although sampling plots in the four types of forests exhibited different structural complexity and canopy openness, they differed only marginally in spider diversity and spider density. Such a result was also reported from spider diversity studies conducted in several tropical forests in Southern Taiwan (Hsieh et al. 2003; Chen and Tso 2004; Tsai et al. 2006). It is possible that the high spider species richness and abundance in various types of plantations were made possible by neighboring broadleaf forests. In our study site, a large area of undisturbed broadleaf forests surrounded the plantation stands. These broadleaf forests might serve as a spider reservoir from which various taxa migrated into adjacent plantations. When they entered respective plantation types those spider taxa which found such habitat favorable remained and increased in abundance, while those who found the habitat inhabitable either dispersed again or died out. Eventually in the three types of plantations spider communities became diversified and formed the current diversity pattern. These patterns are congruent with the sink- source hypothesis, but further sampling on a long term scale is needed to test this hypothesis.

The effects of thinning on forest spider diversities had been examined in several European countries and most of them focused on ground spiders collected by pitfall traps (Bonte et al. 2003; Gurdebeke et al. 2003; Clough et al. 2005; Finch 2005; Schmidt et al. 2005; Pinkus-Rendón et al. 2006; Ziesche and Roth 2008). Results of these studies showed that the dominant tree species significantly influence the composition of epigean spider communities, while microclimatic conditions, understory vegetation density and canopy closure were the major determinants (Pinkus-Rendón et al. 2006; Ziesche and Roth 2008). Results of this present study differ from those of the European ones in that we provided a more comprehensive assessment of components of spider communities that might be impacted by thinning practices. While results of European studies focus on ground-dwelling spiders, we found that arboreal spiders inhabiting understory vegetation such as orb weavers also responded to forest management practices.

In Asia, studies on the effects of thinning on forest arthropod diversity are few and most were conducted in temperate regions such as Japan. Recently, the effects of thinning temperate conifer plantations on herbivorous beetle diversity have been investigated. Certain aspects of the results of these studies are similar to those of this present study, which showed that forests receiving different thinning managements had different arthropod composition and community structure (Maeto et al. 2002; Ohsawa 2004; Ohsawa 2005; Ohsawa 2007; Ohsawa and Nagaike 2006). However, while several studies conducted in Japan showed that thinning may increase the richness and abundance of many herbivorous beetle taxa (Ohsawa 2004; Ohsawa 2005; Ohsawa and Nagaike 2006), such a pattern could not be found for spiders. One reason might be that the practice of thinning differed considerably between temperate and subtropical plantations. Another reason might be that in our study sites the thinned stands experience intensive recreation activity and understory pruning near trails within the stands. Both factors generate considerable differences in environmental characteristics. Studies conducted in Japan showed that new gaps created by thinning may influence understory vegetation structure and composition and such influences lasted from the re-initiation stage through succession pathways to mixed forests (Igarashi and Kiyono 2008). Consequently, thinning in temperate forests created a long-lasting topographic variation which brought new ecological niches for species inhabiting understory vegetation (Ito et al. 2003). In subtropical regions, a higher temperature might enhance rapid growth of understory vegetation after thinning, and the plant community might have reached certain stabilized stage in time periods as short as two years (Weng et al. 2007). The fast growth rate of understory vegetation might have reduced the structural heterogeneity and niche diversity created by thinning. Consequently, several years after thinning the plots exhibited different rather than more diversified ecological niches. This may explain why thinning practices in the subtropical plantations in Taiwan resulted in forests with different but more or less equally diverse spider communities.

This study shows that thinning in an East Asian subtropical plantations created habitats of different spider assemblages. Different degrees of thinning and plantation management generated forests of different canopy openness, understory vegetation structural complexity and microclimates, which in turn affected abundance patterns of spiders with specific environmental requirements. While similar studies conducted in temperate regions in Europe or Japan reported a species richness/abundance enhancing effect of thinning managements, such a pattern was not detected in this present study. Nevertheless, we regard thinning management an effective way of enhancing animal diversity in subtropical plantations. This is because different degrees of thinning generate habitat heterogeneity and novel ecological niches, and therefore organisms in the neighboring broadleaf forests may migrate in and develop into communities different from those of unthinned plantations. Currently, producing high quality timber and enhancing biodiversity have become two equally important goals in plantation management in many subtropical and tropical countries. Since knowledge regarding effects of thinning managements on

Asian subtropical as well as tropical plantations is currently quite limited, we suggest that more manipulative studies should be conducted to generate useful information to design appropriate management policies.

Chapter 3

Experiment in *Cyrptomeria japonica* plantation

3.1 Introduction

In this experiment, the effects of silvculture management on spider biodiversity of a subtropical plantation while considering spatial and temporal influences were assessed by comparing the community structure and guild composition of spiders in *C. japonica* plantations in central Taiwan. The silviculture management was practiced by “gap geometric thinning” method. We first compared spider diversities between plantations and investigated the impacts of thinning treatments. We also considered the effect of temporal spider abundance variation and the interaction of temporal and treatment effects. Secondly, we then compared spider communities before and after thinning operations in species and guild scales. Finally, biotic and abiotic environmental factors were measured to identify key environmental variables contributing to the observed spider composition variations. The aim of this study is to provide a long-term research platform for a variety of ecosystem processes by forest biodiversity and the potential underlying mechanisms. We compared the spider diversities and communities of plantation forests before and after different degrees of thinning.

The study sites were established in a subtropical montane spruce plantation in Taiwan. The *C. japonica* stands were established in 1971. The study area encompasses about 78 ha and extends from 1,200 to 1,500 m in elevation. The air temperature averaged 15^0C and annual precipitation was 2400 mm. Results of a survey conducted before thinning showed that the initial stage stand density of *C. jaonica* stands in Ren-Luen was about 950~1500 trees/ha. The thinning practice was conducted in August 2007. The silviculture practices in these stands were geometric thinning. In this method, trees are removed or retained according to simple criteria such as a defined distance or a defined number of rows. In this study a specific way of geometric thinning called gap geometric thinning was used. In each one hectare plot 25 20m x 20m squares were set up and each square was further divided into 4 10m x10m subsquares. The moderate thinning treatment was achieved by removing trees from one regularly chosen 10m x 10m subsquare from each of the 25 20m x 20m squares. Special attention was paid to prevent chosen subsqares from being adjacent to each other. The heavy thinning treatment was achieved by removing trees from two regularly chosen 10m x10m subquares located on opposite side of each square from each of the 25 20m x20m subquares. Spiders in forests in general have limited dispersal (Topping 1999, Schmidt and Tscharntke 2005, Drapela et al. 2008) ability and therefore are suitable ecological indictors to access how thinning affects various micro-environmental variables and consequently influence arthropod diversity.

3.2 Material and Methods

3.2.1 Study site

The study sites were established in a subtropical spruce *Cryptomeria japonica* plantation in Ren-Luen, Nantou county in center Taiwan (N 23°44′, E 120°53′). We set up 12 100m x100m (1 ha) plots and performed three different degree of thinning treatments to them. The treatments included unthinned, moderate thinning and heavy thinning. The plots receiving unthinned treatment (n=4) were used as control. In the plots receiving moderate thinning treatment (n=4) 25% of trees were removed. In the plots receiving heavy thinning treatment (n=4) 50% of trees were removed. In each one hectare plot we set up three 10m x 10m sampling plots and the distance between neighboring plots was about 20m. Overall, a total of 36 sampling plots were established in three treatments.

3.2.2 Specimen collection

Four field trips were conducted before thinning in November of 2005 and February, May, and August of 2006. Eight field trips were conducted after thinning from 2007 to 2010. In each sampling plot a set of pitfall traps was established to collect ground spiders. Each pitfall trap was consisted of four plastic cups and three polystyrene plastic sheets arranged into a Y form. Four plastic cups were located in the middle and each end of the Y form polystyrene plastic sheets. The cup was 15 cm in height and 10 cm in diameter. The polystyrene plastic sheets were used to enhance the catching efficiency of traps and each was 40 cm in height and 100 cm in length. These cups were each covered by a plastic plate secured with sticks to exclude fallen leaves or rain waters. In each field trip the traps were filled with 500 ml 70% alcohol and were opened consecutively for 7 days.

The invertebrate specimens collected were first classified into spiders, insects and other arthropods. Spiders were first separated into adults and juveniles, and adult spiders were sorted into morphospecies and if possible identified to species by palpal organ or epigynum. All spiders (including juveniles) were identified to families. In addition, we used the classification system given in Cardoso et al. (2011) to categorize both adult and juvenile spiders into foraging guilds according to spiders' foraging strategy, prey range, vertical stratification and circadian activity. Spiders were assigned to the following guilds: (1) orb web weaver: Araneidae and Tetragnathidae; (2) space web weaver: Leptonetidae, Mysmenidae, Pholcidae and Theridiidae; (3) sheet web weaver: Agelenidae, Hahniidae, Hexathelidae, Linyphiidae, Pisaruidae and Psechridae; (4) specialists: Dysderidae and Zodariidae; (5) ground hunters: Gnaphosidae, Liocranidae, Lycosidae and Oonopidae; (6) sensing web weaver: Atypidae, Ctenizidae and Segestriidae; (7) ambush hunters: Tomisidae; (8) other hunters: Clubionidae, Ctenidae, Philodromidae, Oxyopidae, Salticidae and Sparassidae.

3.2.3 Quantification of environmental factors

In order to identify factors responsible for the observed spider diversity variations among plots receiving different thinning treatments, we measured twelve environmental variables in each sampling plot. First we used data loggers to monitor the temperature and relative humidity of sampling plots. In each sampling plot one data logger (HOBO Pro series, thermograph/hygrometer, Onset, USA) was placed at 1m high and in each field trip the data was recorded for a week. Soil temperature (ST) at 5 cm depth was measured with thermometers (T-type, EasyAG 50, Sentek, AU) and the data was recorded every 60min for a week. Decomposition rates (D) were also quantified within each study site. To quantity vegetation structures, we measured illumination within the plantation (I), percent canopy openness (PCO) and understory vegetation density (UVD) of each sampling plot in each field trip. An illumination receptor (Li-Quantum LI190SB-L, 400 to 700 nm) was used to monitor the photosynthetic active radiation (PAR) of sampling plots. In each sampling plot one receptor was placed at 1.5m high. In each field trip the data was recorded every 150 sec and values were average every 5 min for a week. A fish-eye lens mounted on a Nikon 4500 digital camera was used to measure PCO. The camera was mounted on a tripod placed in the center of the sampling plot with the lens facing upward to take hemispheric photographs. The photographs were analyzed by a Gap Light Analyzer, Version 2.0 (Frazer et al., 1999) after being transformed into black-and-white images. We used a red cloth (1 m × 1 m) as the background and the density of vegetation in front of it was used to quantify UVD. The red cloth was held by one person standing at each of the four cardinal edges of the 10m x 10m sampling plot. Another person standing in the center of the plot took pictures of the red cloth and the vegetation in front with a Nikon 4500 digital camera. In each of the four cardinal directions the cloth was placed at two different heights (low: ground to 100 cm; high: 100 to 200 cm) to have a better representation of the vertical stratification of the understory vegetation. These photographs were transformed into black-and-white images using Photoshop and data from the four cardinal directions and two heights were averaged and the mean was used as the UVD of the plot.

3.2.4 Statistical analyses

We used Evenness index (J) (Krebs, 1989) to quantify the community structures of spiders in plots receiving different thinning treatments. Two-way ANOVA tests and

Tukey mean comparisons were used to compare the evenness of various plots and both tests were performed by SIGMAPLOT 11.

Bray-Curtis similarity (Krebs, 1989) between sampling plots based upon species and guild compositions were calculated (data square root transformed). Permutation ANOVA (PERMANOVA) tests which based upon the values of Bray-Curtis similarity were performed to test for the statistical significance of the grouping pattern. Similarity percentage (SIMPER) analyses were used to examine the relative contribution of various spider guilds to the observed spider assemblage differences. In order to demonstrate the relationship between environmental variables and spider composition, the redundancy analysis (RDA) was used to determine the subset of variables that were most significantly correlated with spider guild compositions. Temperature, relative humidity, ST, SM, DL, PCO, UVD and I were used as the potential environmental variables. PERMANOVA, SIMPER and RDA tests were performed using PRIMER 6 and PERMANOVA+ (Anderson et. al. 2008).

Rarefaction analyses (Hurlbert 1971) were used to estimate spider species richness of plots receiving different treatments. To find out the best diversity-enhancing forest managing strategy we performed rarefaction analyses in the following way. The first analysis was performed on plots receiving one type of thinning treatment from each year (n=4 in total). The second one was performed on plots receiving two types of thinning treatments from each year (n=8 in total). The third one was performed on plots receiving all three thinning treatments from each year (n=12 in total). A comparison of expected species richness of these analyses can help us determine whether subjecting all the plots to thinning treatment or leaving some of the plots unthinned could generate higher spider species richness. Moreover, we could realize whether 25% or 50% thinning treatment can generate higher spider species richness. Rarefaction curves were plotted with the number of individuals captured and curves with 95% confidence interval well separated from each other were regarded to be significantly different (Heck et al. 1975).

3.3 Results

A total of 4,339 spider specimens were obtained; among them 2,162 were adults. From the adult specimens 139 morpho-species belonging to 29 families were identified. From the field trips conducted in the year before thinning a total of 979 spider specimens were obtained. From first year after thinning 1,145 specimens were obtained and from the second year after thinning 2,215 specimens were obtained. The most abundant spider family was Lycosidae (42.34%, 1,837 specimens), followed by Linyphiidae (15.00%, 651 specimens), Theridiidae (8.57%, 372 specimens) and Agelenidae (6.52%, 283 specimens). Linyphiidae had the highest number of species (26), followed by Agelenidae (18), Theridiidae (15) and Salticidae (10). The 25% thinning plantation had the highest number of species (91), followed by 50% (90) thinning plantations and the unthinned plantations had the lowest number of species (80).

3.3.1 Comparison of spider community composition among treatments and years

Results of two-way permutation ANOVA tests showed that spider species and guild compositions of plots receiving different thinning treatments differed significantly. Those of plots collected from different years also differed significantly and there was a significant interaction effect between thinning treatment and year (Table 10).

Results of pairwise permutation tests showed that in the year before thinning spider species and guild composition of three types of plantations did not differ significantly (Table 11a, b). However, in first year after thinning spider species composition of unthinned plantation differed significantly from that of 50% thinning plantation and those of two types of thinning plantations did no differ significantly from each other (Table 11a). Spider guild composition of unthinned plantation plots differed significantly from those receiving thinning treatments while those of 25% and 50% thinning plots differed significantly (Table 11b). In the second year after thinning, in most pairwise comparisons spider species or guild compositions differed significantly (Table 10a, b), except that the species compositions of 25% and 50% thinning plots did not differ significantly (Table 11a).

Results of permutation tests examining temporal variation of spider species and guild compositions in each treatment showed that most pairwise comparisons were statistically significant (Table 11c, d). Even in the unthinned plantation plots spider compositions varied significantly from year to year. The only exceptions was that the spider species (Table 11c) and guild (Table 11d) compositions of unthinned plantation plots collected from first and second year after thinning did not differ significantly from each other.

Result of SIMPER analyses showed that after thinning in both years in most pairwise comparisons ground hunter, sheet and space web weavers were the major contributors of the observed variations in spider guild composition (Table 12). Especially the ground hunters were the major contributors which contributed around 42-48% to the observed spider diversity variation in the first year after thinning (Table 12a) and about 62-82% in the second year after thinning (Table 12b).

Analysis of two-way ANOVA tests showed that abundance of ground hunters and sheet web weavers collected from plots receiving different thinning treatments differed significantly. Those of plots collected from different years also differed significantly and there was a significant interaction effect between thinning treatment and year (Table 13). However, abundance of space web weavers only differed significantly from plots collected from different years and did not differ significantly between plots receiving different thinning treatments (Table 13).

Results of pairwise permutation ANOVA tests showed that in the year before thinning abundance of ground hunters, sheet web weavers and space web weavers in three types of plantations did not differ significantly (Table 14). In the first year after thinning, plots receiving thinning treatments had significantly higher abundance of sheet web weavers than those did not (Table 14b), while abundance of ground hunters and space web weavers collected did not differ significantly (Table 14a, c). In the second year after thinning, plots receiving 50% thinning had significantly higher abundance of ground hunters than the other two types of plantations (Table 14a), while abundance of space web and sheet web weavers did not differ significantly (Table 14b, c).

In the second year after thinning plots receiving 50% thinning had significantly higher ground hunters than those collected from the other two years (Table 14a). In the first year after thinning plots receiving thinning treatments had significantly higher abundance of sheet web weavers than those collected from the other two years (Table 14b). Abundance of space weavers of plots receiving different treatments did not differ significantly but differed among three years (Table 13).

3.3.2 Relationship between spider composition and microhabitat variables: assessing treatment and temporal effects

RDA analyses were used to determine the contributors to the observed spider guild composition and micro-environmental variable variations (Figure 4). Result of RDA analyses on spider guilds and environmental factors obtained from plots of three types of plantations sampled in three years showed that about 55.3% of total variation was explained.

Plots sampled from three different years clustered into three different groups on the RDA diagram along the first RDA axis (Figure 4a). Plots of unthinned plantation sampled from three years clustered together and were grouped with thinning plantation plots sampled one year before thinning at the right side of figure. Plots of plantation sampled from first year after thinning clustered together in the middle and second year after thinning group in the left side of figure (Figure 4a). Although the pattern was not obvious, plots of two thinning plantations sampled two years after thinning seemed to separate from each other along the second RDA axis.

The major contributors of the observed spider guild composition differences among thinning treatments and years were ambush hunters (AH), ground hunters (GH), sheet web weaver (SH), sensing web weaver (SE), space web weaver (SW), orb web weaver (OW) and other hunters (OH). Pearson correlation coefficients between spider guild composition and two RDA axes showed significant associations between GH, OW, OH, SE, SW and first RDA axis and significant associations between AH, SH, SW and second RDA axis (Table 15a). The major contributors of the observed environmental factor differences among thinning treatments and sampling years were mean of illumination within the stand (L), decomposition (Dec), temperature (Tm), relative humidity (RHm), percent canopy cover (PCOm), understory vegetation density (UVDm); and standard deviation of temperature(Tsd) and understory vegetation density (UVDsd). Result of RDA analyses showed that the plots sampled from different years were separated from each other. Pearson correlation coefficients between environmental variables and two RDA axes showed significant associations between Lm, Dm, Tm, RHm, PCOm, Tsd, UVDsd and first RDA axis and significant associations between Lm, Dm, Tm, UVDm and second RDA axis (Table 15b).

Plots sampled from three different years with observed spider and environmental factors showing significant associations with first RDA axis was shown in Figure 4b. Pearson correlation coefficients showed significant associations between first RDA axis and GH, SE, OW guilds. These three guilds might be the major contributors of the observed spider guild composition differences among three different collecting years. Pearson correlation coefficients showed significant associations between first RDA and RHm, UVDsd, Dec, I, Tm, Tsd. These factors might be the major contributors of the observed environmental variable differences among three different collecting years. Plots of unthinned plantations and plots receiving two thinning treatments sampled before thinning had higher OW, SE and lower GH abundance than those receiving two thinning treatments sampled two years after thinning. Plots of unthinned plantation and those receiving two thinning treatments sampled from one year before thinning had higher RHm, Dec and lower PCOm, Tm, L than those receiving two thinning treatments sampled from two years after thinning.

Those plots sampled from three different years with observed spider and environmental factors showing significant associations with second RDA axis was shown in figure 4c. Pearson correlation coefficients showed significant associations between second RDA axis and SH spider guild. This guild might be the major contributors of the observed spider guild composition differences among different degrees of thinning treatments. Pearson correlation coefficients showed significant associations between second RDA axis and UVDm, Dec, I and Tm. These factors might be the major contributors of the observed environmental variable variations. Plots receiving 50% thinning treatment sampled after thinning had the highest SH abundance, followed by plots receiving 25% thinning treatment, while plots receiving unthinned treatment had the lowest abundance. Plots sampled two years after thinning receiving 50% thinning treatments had higher Dec, UVDm, Tm and I than those receiving 25% thinning treatment.

Plots sampled from three different years with observed spider and environmental factors showing significant associations between first and second RDA axes was shown in figure 4d. Pearson correlation coefficients showed significant associations between first and second RDA axis and SP guild. Pearson correlation coefficients showed significant associations between first and second RDA axes and Dec, I and Tm environmental variables.

3.3.3 Comparison of spider diversity among treatments and years

Spider abundance (adult and overall) and evenness index of plots receiving different thinning treatments differed significantly. Those of plots collected from different years also differed significantly and there was a significant interaction effect between thinning treatment and year (Table 16).

Before thinning, plots in three plantation types did not differ significantly in spider abundance or evenness (Table 17). In first year after thinning, plots receiving thinning treatments had significantly higher spider abundance than those did not. In the second year after thinning, plots receiving 50% thinning had the highest spider adult and overall abundance, followed by those receiving 25% thinning, and unthinned plots had the lowest spider abundance. In contrast, plots receiving no thinning treatment had the highest spider evenness (Table 17c).

Results of ANOVA tests examining temporal variation of spider abundance in thinning treatments showed that all pairwise comparisons were statistically significant. In the second year after thinning plots receiving 50% thinning had the highest spider abundance (Table 17a,b). In the first year after thinning plots receiving 50% thinning and unthinned treatments had significantly higher evenness than those sampled from the other two years.

Data collected from three years showed that number of spiders in plots receiving various treatments varied temporally. From all the plots we obtained 80 species in the year before thinning, 59 in the first year after and 85 in the second year after thinning. From the specimens collected from the year before thinning, the rarefaction curves of expected number of species of plantations receiving different thinning treatments fell within the 95% confidence interval of each other (Figure 5a). Such result indicated a homogenous species distribution pattern among sampling plots before the conduction of thinning operations. In the first year after thinning the rarefaction curves of expected number of species of 25% and 50% thinning plots fell within 95% confidence interval of each other (Figure 5b). The curve of unthinned plots, however, fell outside the 95% interval of the other two rarefaction curves, indicating significantly higher expected number of species (Figure 5b). In the second year after thinning, the rarefaction curves of expected number of species of three different thinning treatments fell outside the 95% confidence interval of each other (Figure 5c). The unthinned plantation plots had the highest expected number of species, followed by 25% thinning plots, and 50% thinning plots had the lowest expected number of species (Figure 5c).

In the one year before thinning data, the number of species sampled from plots designated to receive either 25% or 50% thinning fell within the 95% confidence interval of the other rarefaction simulations (Figure 6a). Such result indicated a homogenous species distribution pattern among sampling plots before the conduction of thinning operations. In the first year after thinning the rarefaction curve of expected number of species of unthinned + 25% thinning plots and that of unthinned + 50% thinning plots fell within 95% confidence interval of each other (Figure 6b). The curve of 25% +50% thinning plots, however, fell outside the 95% interval of the two rarefaction curves (Figure 6b). Results of rarefaction analyses showed that the expected species number of 25% + 50% thinned plots was the lowest (Figure 4b). In the second year after thinning, the rarefaction curve of 25% + 50% thinning plots fell outside the 95% confidence interval of curves of unthinned + 25% thinning and unthinned + 50% thinning plots (Figure 6c). Results of rarefaction analyses also showed that the expected number of species was higher in unthinned +

25% thinning than in unthinned + 50% thinning plots (Figure 4c).

The number of species captured from all sampled plots in the year before thinning and first year after thinning data fell within the 95% confidence interval of each other, although the abundance of spiders sampled from two years were quite different (Figure 7). In the second year after thinning, the rarefaction curve of expected number of species fell outside the 95% interval of the other two rarefaction curves (Figure 7). Results of rarefaction analyses showed that the expected species number of plots sampled in the second year after thinning was the lowest (Figure 7). Such result indicated a heterogeneous species distribution pattern among three years.

3.4 Discussion

Based on the results of our analyses three major findings can be concluded. First, in our study sites there were temporal differences in species richness and abundance generated by population dynamic and climatological processes. The temporal variation in number of species collected from unthinned plantations in three years reflects dynamic spider community undulations, rather than being caused by different sampling intensities. Spiders in plantations appear to have more or less different “active” years. Secondly, thinning operations generated significant differences in spider compositions at the species as well as guild level. Spider guilds exhibiting narrower tolerance are negatively affected while those with wider tolerance limits may benefit from the disturbance and habitat alteration caused by thinning. Finally, results of our rarefaction analyses showed that plantations composed of combination of unthinned and various thinned stands will support higher spider species richness and abundance and consequently a more diverse spider community.

3.4.1 Spider community change through time

Our analysis revealed that spider communities of *C. japonica* plantations receiving different thinning treatments varied. There is an obvious variability of responses of spider species and guild with different habitat requirements to disturbance. Moreover, we also found that spider species and guild compositions of sampling plots changed remarkably through time. Even in the unthinned plantation plots spider compositions varied significantly from year to year. The irradiation within the stand, decomposition of litter and soil characteristics in the unthinned plantation varied between different investigated years. Although the habitat structures of unthinned plantations appear to be homogeneous, a diverse microhabitat mosaic exists and various relevant environmental parameters such as irradiation, humidity, ground vegetation, litter layer, and other soil characteristics might vary (e.g., Niemelä et al., 1996; Holst et al., 2004; Oheimb et al., 2005). Under the conditions that there is a complex system where many micro-environmental factors interact, or there are increasing edge like habitats which modify spider patterns, the temporal variation of undisturbed habitats might be less obvious (McDonnell et al. 1997, Niemelä 1999, Lövei et al. 2006). In our study, abundance of ground hunter spider increased in the year after thinning in plots receiving different treatments (Table 13a). In the second year after thinning, plots of unthinned plantation also had higher abundance of ground hunters than the other two years (almost twice as many), although the difference was not statistically significant. Based on such knowledge, it is reasonable to assume a spatial and temporal species specific distribution pattern of spiders in a small-scale.

3.4.2 Spider community changes are affected by thinning treatments

After thinning, the spider compositions of plantation stands receiving different thinning treatments differed and GH, SH and SW were the major contributors of the observed spider diversity differences among forest types. Congruent with such a pattern was a significant difference in understory vegetation density and litter decomposition rate among forest types. After thinning, 50% thinning plantations had the highest GH abundance while unthinned plots had the lowest. Similarly, compared with those of unthinned plantation, 25% and 50% thinning plantations had the higher abundance of SH two years after thinning. On the other hand, compared with those of unthinned plantation, two thinned plantations had lower abundance of SW. The thinning practices altered the vegetation structure and the decomposition of litter. The understory vegetation opened in different scales by thinning treatments had different level of fluctuation through time. The fine woody debris left from the thinning operations increased the depth of litter layer and decreased the decomposed ratio of litter. The understory vegetation of 50% thinning plantation was more open than that of the other two plantations. A more open vegetation structure and deeper litter might have benefited GH and SH spiders through the creation of new microhabitat after thinning. In the second year after thinning, the understory vegetation of 50% thinning plantations became more stable and consequently maintained a high GH abundance. Also, a more stable, open and relatively simpler vegetation structure and deeper litter layer of 50% thinning plantations might have limited SW, which had specific spatial need for wed building and prey catching. These results indicate that spider functional groups respond quite differently to forest management practices. While some will closely respond to certain vegetation and ground layer characteristics, others are also influenced but their variation pattern exhibits a more complicated relationship with environmental factors.

3.4.3 Comparison of the thinning practices in Asian and European plantations

The effects of thinning on forest spider diversities were examined in several European and Asian countries in temperate regions. Most of the European studies focused on ground spiders collected by pitfall traps (Bonte et al. 2003, Gurdebeke et al. 2003, Clough et al. 2005, Finch 2005, Schmidt et al. 2005, Pinkus-Rendón et al. 2006, Ziesche and Roth 2008). Results of those studies showed that thinning treatments significantly influenced the composition of epigean spider communities;

and dominant tree species, microclimatic conditions, UVD, and canopy closure were the major determining factors (Pinkus- Rendón et al. 2006, Ziesche and Roth 2008). Pearce et al. (2004) and Magura et al. (2010) both showed that abundance of GH (mainly Gnaphosidae and Lycosidae) were positively correlated with disturbance intensity. Lycosidae, a ground-dwelling spider and a generalist predator, benefited from disturbance and became dominant. In our study, nine morphospecies were identified from Lycosidae (1837 specimens) and two of them were especially dominant in 50% thinning plots two years after thinning (412 specimens). Although results of this study are similar to those conducted in Europe, however, we found thinning to have significant temporal effects on spider communities. Results of studies conducted in Japan showed that forests receiving different thinning intensities had different arthropod compositions and community structures (Maeto et al. 2002, Ohsawa 2007). While several studies conducted in Japan showed that thinning may increase the richness and abundance of certain herbivorous beetle taxa (Ohsawa 2004, 2005, Ohsawa and Nagaike 2006), such a pattern was not found in our study. Other studies conducted in Asia had found a negative or little effect of thinning on the diversity and/or abundance of certain animal groups in plantations (Ohsawa, 2005; Yuan et al., 2005; Ohsawa and Nagaike, 2006). One reason for the incongruence in effects of thinning might be that temperate and subtropical plantations differ in dominant tree species and associated microhabitat/climates. Another major reason might be that the consequences of thinning in terms of temporal changes in environmental characteristics varied considerably between two regions. Studies conducted in Japan showed that new gaps created by thinning may influence the understory vegetation structure and composition, and such influences lasted from the re-initiation stage through succession pathways to the mixed-forest stage (Igarashi and Kiyono 2008). Consequently, thinning in temperate forests creates long-lasting topographic variations which provide new ecological niches for species inhabiting understory vegetation (Ito et al. 2003). In subtropical regions, higher temperatures might enhance the rapid growth of understory vegetation after thinning, and the plant community might have reached a certain stabilized stage in time periods as short as two years (Weng et al. 2007). The high growth rate of understory vegetation might have reduced the structural heterogeneity and niche diversity created by thinning. In our results, compared with those of unthinned plantation, 25% and 50% thinning plantations had higher abundance of SH one year after thinning. After one year, although the abundance of SH were still higher in plantations receiving thinning treatments, the abundance difference was not statistically significant. On the other hand, compared with those of unthinned plantation, plots receiving thinning treatments sampled one year after thinning had lower abundance of SW, although such difference was not statistically significant. Moreover, in the second year after thinning the abundance of SH in unthinned and thinned plots did not differed significantly. Therefore, in subtropical areas such as Taiwan several years after thinning the plots exhibited different rather than more-diversified ecological niches. This may explain why thinning practices in the subtropical plantations of Taiwan resulted in forests with different but more or less equally diverse spider communities.

3.4.4 Spider community as a whole as an indicator

Spiders are sensitive to habitat disturbances caused by forest managements. However, our findings suggest that measuring diversity by overall species richness and abundance is not the most appropriate way of quantifying the effects of disturbance. Several studies examining forest patches with different level of human disturbance found that overall species richness or particular diversity index did not differ among these patches, although the composition of spider assemblages differed considerably among the patches (Pajunen et al. 1995; Alaruikka et al. 2002; Pearce et al. 2004; Maggura et al. 2010). Such results are also reported by relevant studies conducted in Asia (Hsieh et al. 2003; Chen and Tso 2004; Tsai et al. 2006; Huang et al. 2011).We suggest that “functional group” or “guild” concept should be used to obtain an ecologically relevant picture of the effect of disturbance on spiders. Spiders were categorized into various foraging guilds according to their foraging strategy, prey range, vertical stratification and circadian activity (Uetz et al. 1999; Höfer and Brescovits 2001; Cardoso et al. 2011). Different spider guilds have distinct tolerance limits and respond differently to habitat alteration. In our results, some guild such as SE and OE may have narrower tolerance limits and consequently were negatively affected by habitat alteration caused by thinning. However, under the same environmental conditions the abundance of GH and SH are considerably increased.

Chapter 4

Conclusion

Achieving a Long term forest ecological sustainability will be a complex and difficult task because of the difficulties in obtaining comprehensive information of fauna and flora and the increasing demands on forest resources. Due to these reasons, biological conservation and ecologically sustainable forest management must be conducted in the context of solid scientific principles. Therefore, the impact of silviculture practice on plantations in view of the hypotheses and concepts like indicator species and metacommunity dynamics must be rigorously tested using field experiments and other forms of study such as long-term monitoring. The results of these investigations must then be communicated correctly to forest manager and close linkages between research information and management strategies must be established. It will be necessary that conserving biological diversity serves as an inherent goal while managing plantations.

This present study shows that thinning treatments in an East Asian subtropical plantation created habitats of different spider assemblages. The metacommunity concept can be used to assess the effect of thinning on biodiversity of plantations while considering different spatial scales. The overall plantation can be regarded as a large regional biota in which all stands are embedded in it. Results of our study showed that thinning practices in plantation created habitats of different spider assemblages. Different degrees of thinning generated forests of different spatial heterogeneity (canopy openness, understory vegetation structure and ground layer) and microclimates, which in turn affected abundance patterns of spiders with specific environmental requirements. We regard thinning management an effective way of enhancing animal diversity in subtropical plantations. This is because different degrees of thinning generate habitat heterogeneity and novel ecological niches, and therefore organisms in the neighboring broadleaf or undisturbed plantations may migrate in and develop into communities different from those of unthinned plantations. Results of our study indicate that subjecting all plantations to thinning treatments is not the best diversity-enhancing strategy. An optimal strategy is to subject some plantations to one or two different thinning operations while leaving some plantations unthinned. Such practice will generate higher spatial heterogeneity and consequently higher species richness.

Managing biodiversity for maximum species richness or diversity without considering assemblage structure or existence of specific guilds can lead to loss of important biological information (Lindenmayer, 1999). For example, although certain spider guilds composed of several rare species do not seem to contribute much to overall species richness, they are nevertheless an important component of the forest spider fauna. The large area of primary and undisturbed plantation means that these stands could be potentially important habitat for these specialists. Forest managers should enhance the spatial structure of different layer of vegetations with various degrees of silviculture practices. In the same while, features typical of undisturbed forest should be retained in order to enhance the diversity of both general and ingenious forest species within a plantation. At a landscape scale, a mosaic of plantations receiving different thinning treatments will generate heterogeneous habitat types necessary to sustain both generalist and specialists. On the other hand, the temporal distinctiveness of spider assemblages suggests that establishing a dynamic metacommunity with long-term biodiversity monitoring to have an overall view of landscape biodiversity will also be impartment.

In the past, the use of invertebrates in sustainable forest management schemes have long been neglected. Indeed, most current forest biodiversity studies in Taiwan did not involve invertebrates. When considering the implications of managing forests to enhance biodiversity, establishing a set of easily recognizable and quantifiable structural indicators is important. This present study has shown that there are feasible ways to enhance spider diversity through altering vegetation structure and the diversity of other invertebrate groups can also potentially be enhanced.

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Table 1. Number of spider families, species and mean (±SE) abundance (adult and overall), Richness (D_{mg}), Evenness (J), Shannon-Wiener index (H’) and Simpson index (D) of sampling plots in four forest types sampled by three different collecting methods in Da-Shiue Shan, Taiwan and results of ANOVA tests and Tukey mean comparisons (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation).

(a) Pitfall								
Habitat	Families	Species	Adults*	Overall*	D_{mg}	J	H’	D
BLF	14	45	21.4 ± 3.43^{b}	27.9 ± 4.02	3.1 ± 0.28	0.90 ± 0.016^{ab}	2.0 ± 0.12	0.88 ± 0.016
PFC	13	38	17.2 ± 2.30^{b}	30.8 ± 3.58	3.2 ± 0.31	0.93 ± 0.004^{a}	2.1 ± 0.14	0.91 ± 0.012
PFM	11	37	15.6 ± 1.89^{b}	24 ± 2.25	3.1 ± 0.29	0.93 ± 0.009^{a}	2.0 ± 0.13	0.91 ± 0.011
PFH	14	44	29.1 ± 4.17^{a}	37.7 ± 5.22	2.9 ± 0.27	0.87 ± 0.024^{b}	2.0 ± 0.11	0.86 ± 0.018
F-ratio	-	-	3.35	1.973	0.266	3.525	0.200	2.981
P	-	-	0.029	0.136	0.850	0.025	0.896	0.044
(b) Sweep-netting								
BLF	10	27	4.8 ± 0.74^{ab}	35.9 ± 4.01	2.0 ± 0.32	0.82 ± 0.111	1.3 ± 0.20	0.81 ± 0.110
PFC	9	25	8.7 ± 2.65^{a}	35.8 ± 3.96	2.2 ± 0.23	0.92 ± 0.044	1.4 ± 0.15	0.88 ± 0.051
PFM	9	19	3 ± 1.07^{b}	34.6 ± 7.95	1.1 ± 0.53	0.53 ± 0.177	0.7 ± 0.32	0.48 ± 0.173
PFH	7	26	5.7 ± 0.75^{ab}	34.4 ± 5.22	2.3 ± 0.16	1.08 ± 0.006	1.6 ± 0.10	1.01 ± 0.023
F-ratio	-	-	2.53	0.2143	0.405	1.584	1.466	1.433
P	-	-	0.073	0.886	0.751	0.215	0.242	0.253
(c) Canopy sweep-netting								
BLF	8	19	5.3 ± 0.80	24.3 ± 1.84^{ab}	1.8 ± 0.30	0.81 ± 0.109	1.2 ± 0.19	0.77 ± 0.108
PFC	9	19	2.7 ± 1.08	15.2 ± 3.20^{b}	1.1 ± 0.44	0.44 ± 0.173	0.7 ± 0.29	0.43 ± 0.171
PFM	7	12	2.4 ± 0.65	18.0 ± 2.79^{b}	1.1 ± 0.29	0.65 ± 0.162	0.7 ± 0.19	0.60 ± 0.155
PFH	7	13	3.0 ± 0.69	30.3 ± 3.59^{a}	1.2 ± 0.33	0.65 ± 0.163	0.8 ± 0.22	0.63 ± 0.160
F-ratio	-	-	2.95	5.418	0.974	1.091	1.283	0.935
P	-	-	0.046	0.003	0.416	0.366	0.295	0.434

1. Total degrees of freedom = 35, degrees of freedom for each factor = 3

Table 2. Results of ANOVA tests and Tukey mean comparisons comparing various environmental variables among different forest types in Da-Shiue Shan, Central Taiwan. (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate thinning plantation; PFH: heavy thinning plantation; UVD: understory vegetation structural complexity; PCO: percent canopy openness)

Environmental variables	*F*-ratio	*p*	Tukey
UVD	20.332	0.0001	BLF＞PFC＞PFM, PFH
Litter weight	20.385	0.0001	BLF＞PFM, PFH, PFC
Relative humidity	12.574	0.0001	PFH＞PFM, PFC＞BLF
PCO	5.911	0.002	PFM, PFH, PFC＞BLF
Temperature	10.358	0.0001	PFC＞PFM＞BLF, PFH
Insect biomass	0.5036	0.6823	-

1. Total degrees of freedom = 35, degrees of freedom for each factor = 3

Table 3. Results of Pearson correlations examining relationships between various environmental variables in four forest types in Da-shiue Shan, central Taiwan (T, temperature; RH, relative humidity; UVD, understory vegetation).

structural complexity; L, dry litter weight; B, dry biomass of insects; PCO, percent canopy openness)

	T	RH	UVD	L	B
PCO	-0.0446	0.451^{**}	-0.465^{**}	-0.505^{*}	-0.159
T		-0.476^{**}	-0.0943	-0.0573	-0.150
RH			-0.481^{**}	-0.549^{***}	-0.289
UVD				0.749^{***}	0.0772
L					0.284

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 4. Results of pairwise ANOSIM tests comparing spider family and guild compositions between different forest types in Da-Shiue Shan, Central Taiwan (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation).

Comparisons	Family composition		Guild composition	
(a) Pitfall	*R*	*p*	*R*	*p*
Global *R*	0.197	0.001	0.075	0.062
PFC vs. PFM	0.234	0.005	0.019	0.33
PFC vs. PFH	0.429	0.001	0.182	0.03
PFC vs. BLF	0.195	0.018	0.06	0.173
PFM vs. PFH	0.224	0.01	0.157	0.034
PFM vs. BLF	0.023	0.319	-0.046	0.736
PFH vs. BLF	0.159	0.036	0.105	0.08
(b) Sweep-netting				
Global *R*	0.325	0.001	0.163	0.003
PFC vs. PFM	0.333	0.002	0.182	0.008
PFC vs. PFH	0.415	0.001	0.219	0.029
PFC vs. BLF	0.086	0.123	0.013	0.389
PFM vs. PFH	0.046	0.223	-0.052	0.732
PFM vs. BLF	0.454	0.001	0.318	0.001
PFH vs. BLF	0.557	0.001	0.284	0.01
(c) Canopy sweep-netting				
Global *R*	0.301	0.001	0.217	0.001
PFC vs. PFM	0.028	0.298	0.016	0.308
PFC vs. PFH	0.26	0.008	0.24	0.009
PFC vs. BLF	0.34	0.001	0.255	0.01
PFM vs. PFH	0.146	0.045	0.179	0.029
PFM vs. BLF	0.399	0.001	0.25	0.01
PFH vs. BLF	0.535	0.001	0.315	0.004

Table 5. Results of pairwise ANOSIM tests comparing spider species compositions collected from pitfall traps between different forest types in Da-Shiue Shan, Central Taiwan (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation).

Comparisons	Species composition	
	R	*p*
Global *R*	0.339	0.001
PFC vs. PFM	0.466	0.001
PFC vs. PFH	0.813	0.001
PFC vs. BLF	0.425	0.001
PFM vs. PFH	0.294	0.002
PFM vs. BLF	0.101	0.084
PFH vs. BLF	0.103	0.066

Table 6. Results of ANOVA tests and Tukey mean comparisons comparing the abundances of various spider guilds among different forest types in Da-Shiue Shan, Central Taiwan. (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation)

(a) Pitfall trap

Habitat	Space weaver	Orb weaver	Foliage runner	Ground runner	Ground weaver	Ground sedentary weaver
BLF	0.6 ± 0.28	0.3 ± 0.13	1.8 ± 0.59	3.5 ± 1.10	12.9 ± 2.08^{ab}	8.7 ± 1.39
PFC	2.2 ± 0.79	0	1.9 ± 0.35	2.9 ± 0.89	17.6 ± 2.56^{ab}	6.2 ± 1.30
PFM	0.1 ± 0.1	0	1.3 ± 0.33	2.9 ± 0.65	12.7 ± 2.42^{b}	6.0 ± 1.22
PFH	0	0.1 ± 0.1	1.1 ± 0.42	1.6 ± 0.47	24 ± 4.36^{a}	8.9 ± 1.41
F-ratio	-	-	0.641	0.787	3.296	2.27
P	-	-	0.594	0.509	0.032	0.0975

(b) Sweep-netting

Habitat	Space weaver	Orb weaver	Foliage runner	Ground runner	Ground weaver	Ground sedentary weaver
BLF	5.3 ± 1.21^{a}	12.3 ± 1.49^{b}	10.3 ± 1.26	0	8.3 ± 1.35	0
PFC	1.4 ± 0.38^{b}	12.1 ± 1.52^{ab}	10.1 ± 1.47	0	12.1 ± 3.43	0
PFM	0.7 ± 0.36^{b}	22.9 ± 5.26^{ab}	8.3 ± 1.65	0.1 ± 0.11	5.2 ± 1.23	0
PFH	1.1 ± 0.45^{b}	25 ± 4.43^{a}	9.3 ± 0.85	0	5.5 ± 0.84	0
F-ratio	7.42	4.335	0.722	-	2.69	-
P	0.0005	0.01	0.546	-	0.06	-

(c) Canopy Sweep-netting

Habitat	Space weaver	Orb weaver	Foliage runner	Ground runner	Ground weaver	Ground sedentary weaver
BLF	2.3 ± 0.73	6.9 ± 0.97^{b}	6.7 ± 0.99^{b}	0	6.9 ± 1.19^{a}	0
PFC	1.6 ± 0.94	5.6 ± 1.18^{b}	5.1 ± 1.32^{b}	0.1 ± 0.11	2.8 ± 0.43^{b}	0
PFM	1.3 ± 0.37	8.9 ± 1.46^{ab}	5.2 ± 0.88^{b}	0	2.6 ± 1.13^{b}	0
PFH	1.6 ± 0.47	13.2 ± 2.04^{a}	12.1 ± 1.49^{a}	0	2.2 ± 0.80^{b}	0
F-ratio	0.438	5.242	7.352	-	9.274	-
P	0.728	0.004	0.0006	-	0.0001	-

1. Total degrees of freedom = 35, degrees of freedom for each factor = 3

Table 7. Results of SIMPER analyses determining the relative contribution of the spider guilds to the observed diversity variation of spiders collected from pitfall traps among forest types in Da-Shiue Shan, Central Taiwan (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate thinning plantation; PFH: heavy thinning plantation).

	Dissimilarity/average	Dissimilarity/SD	Contribution(%)	Cumulative contribution(%)
PFC vs. BLF				
Ground weaver	15.60	1.40	41.73%	41.73%
Ground sedentary weaver	8.83	1.71	23.62%	65.36%
Ground runner	5.69	1.31	15.21%	80.57%
Space weaver	3.83	0.81	10.24%	90.81%
PFC vs. PFM				
Ground weaver	16.39	1.50	48.23%	48.23%
Ground sedentary weaver	6.51	1.02	19.16%	67.38%
Ground runner	4.57	1.29	13.43%	80.82%
Space weaver	4.29	1.89	12.62%	93.43%
PFC vs. PFH				
Ground weaver	18.97	1.52	50.65%	50.65%
Ground sedentary weaver	9.16	1.28	24.46%	75.11%
Space weaver	3.65	0.88	9.75%	84.85%
Ground runner	3.31	1.02	8.85%	93.70%
PFM vs. PFH				
Ground weaver	23.48	1.66	60.28%	60.28%
Ground sedentary weaver	9.17	1.20	23.55%	83.83%
Ground runner	3.89	1.09	9.98%	93.81%
PFM vs. BLF				
Ground weaver	15.89	1.44	43.85%	43.85%
Ground sedentary weaver	9.17	1.41	25.30%	69.15%
Ground runner	6.45	1.50	17.79%	86.94%
Foliage runner	3.09	1.12	8.54%	95.48%
PFH vs. BLF				
Ground weaver	22.52	1.55	56.04%	56.04%
Ground sedentary weaver	8.83	1.09	21.96%	78.00%
Ground runner	4.77	1.08	11.88%	89.88%
Foliage runner	2.68	1.10	6.66%	96.55%

Table 8. Results of SIMPER analyses determining the relative contribution of the spider guilds to the observed diversity variation of spiders collected from sweep-netting among forest types in Da-Shiue Shan, Central Taiwan (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate thinning plantation; PFH: heavy thinning plantation).

	Dissimilarity/average	Dissimilarity/SD	Contribution(%)	Cumulative contribution(%)
PFC vs. BLF				
Ground weaver	10.08	1.03	34.15%	34.15%
Orb weaver	7.18	1.27	24.34%	58.49%
Foliage runner	6.62	1.33	22.44%	80.93%
Space weaver	5.63	1.20	19.07%	100.00%
PFC vs. PFM				
Orb weaver	15.59	1.37	42.14%	42.14%
Ground weaver	11.65	0.97	31.47%	73.60%
Foliage runner	7.87	1.27	21.27%	94.87%
PFC vs. PFH				
Orb weaver	17.13	1.42	50.42%	50.42%
Ground weaver	9.91	0.94	29.18%	79.59%
Foliage runner	5.15	1.22	15.17%	94.76%
PFM vs. PFH				
Orb weaver	18.71	1.48	58.96%	58.96%
Foliage runner	6.44	1.49	20.31%	79.27%
Ground weaver	4.89	1.26	15.41%	94.68%
PFM vs. BLF				
Orb weaver	15.83	1.38	41.52%	41.52%
Foliage runner	8.11	1.22	21.27%	62.79%
Ground weaver	7.60	1.17	19.92%	82.71%
Space weaver	6.59	1.23	17.29%	100.00%
PFH vs. BLF				
Orb weaver	17.60	1.51	50.86%	50.86%
Ground weaver	6.03	1.18	17.42%	68.28%
Space weaver	5.75	1.21	16.63%	84.91%
Foliage runner	5.22	1.17	15.09%	100.00%

Table 9. Results of SIMPER analyses determining the relative contribution of the spider guilds to the observed diversity variation of spiders collected from canopy sweep-netting among forest types in Da-Shiue Shan, Central Taiwan (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate thinning plantation; PFH: heavy thinning plantation).

	Dissimilarity/average	Dissimilarity/SD	Contribution(%)	Cumulative contribution(%)
PFC vs. BLF				
Ground weaver	15.64	1.41	35.08%	35.08%
Foliage runner	12.01	1.25	26.94%	62.02%
Orb weaver	10.84	1.31	24.32%	86.34%
Space weaver	6.09	1.04	13.66%	100.00%
PFC vs. PFM				
Orb weaver	16.20	1.32	38.24%	38.24%
Foliage runner	12.47	1.39	29.42%	67.66%
Ground weaver	9.01	1.63	21.25%	88.91%
Space weaver	4.70	0.93	11.09%	100.00%
PFC vs. PFH				
Orb weaver	18.13	1.47	39.92%	39.92%
Foliage runner	17.95	1.59	39.53%	79.45%
Ground weaver	5.10	1.13	11.23%	90.68%
PFM vs. PFH				
Foliage runner	15.28	1.84	39.95%	39.95%
Orb weaver	13.21	1.33	34.55%	74.50%
Ground weaver	6.81	1.43	17.80%	92.30%
PFM vs. BLF				
Ground weaver	16.02	1.57	39.74%	39.74%
Orb weaver	10.91	1.23	27.08%	66.83%
Foliage runner	8.74	1.26	21.69%	88.52%
Space weaver	4.63	0.99	11.48%	100.00%
PFH vs. BLF				
Orb weaver	12.58	1.30	32.71%	32.71%
Foliage runner	11.47	1.61	29.83%	62.54%
Ground weaver	10.65	1.38	27.69%	90.22%

Table 10. Results of two-way permutation ANOVA examining the effects of thinning treatments and year (and their interaction) on spider species and guild compositions in Ren-Luen, Central Taiwan.

Comparisons	Morpho-species		Guild	
	Pseudo-F	*p*	*Pseudo-F*	*P*
Thinning	2.8493	0.0001	7.3137	0.0001
Year	8.2415	0.0001	13.856	0.0001
Thinning × Year	1.3247	0.0326	1.9062	0.0274

1. Total degrees of freedom = 35, degrees of freedom for each factor = 2, and degrees of freedom for the interaction = 4.
2. Spider composition data were collected from 12 plots for three years.

Table 10. Results of pairwise permutation tests comparing spider compositions of plots receiving different thinning treatments and those sampled from different years in Ren-Luen, Central Taiwan. (a) Morpho-species composition between different forest types in three years. (b) Guild composition between forest types in three years. (c) Morpho-species composition between years in three forest types. (d) Guild composition between years in three forest types. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation; B1: one year before thinning; A1: first year after thinning; A2: second year after thinning).

	Morpho-species composition						Guild composition					
	Pseudo-t	*p*	*Pseudo-t*	*p*	*Pseudo-t*	*p*	*Pseudo-t*	*p*	*Pseudo-t*	*p*	*Pseudo-t*	*p*
	(a) B1		A1		A2		(b) B1		A1		A2	
UP vs. 25%	1.07	0.35	1.39	0.08	1.48	0.06	0.58	0.81	2.28	0.03	1.78	0.05
UP vs. 50%	0.92	0.69	1.64	0.02	2.09	0.03	1.22	0.22	2.75	0.02	3.38	0.02
25% vs. 50%	0.96	0.52	0.76	0.80	1.25	0.12	0.78	0.72	0.52	0.66	1.77	0.05
	(c) UP		25%		50%		(d) UP		25%		50%	
B1 vs. A1	1.91	0.03	1.62	0.02	2.00	0.03	1.78	0.03	2.13	0.03	2.19	0.02
B1 vs. A2	1.94	0.02	1.94	0.03	2.50	0.03	2.36	0.02	2.63	0.03	4.07	0.03
A1 vs. A2	1.29	0.11	1.69	0.02	2.63	0.03	1.58	0.09	1.92	0.06	2.94	0.03

1. Degrees of freedom in each pairwise test = 6

Table 11. Results of SIMPER analyses determining the relative contribution of various spider guilds to the observed diversity variation among plots receiving different treatments in Ren-Luen, Central Taiwan. Data presented are from first and second year after thinning. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation).

	Contribution	Cumulative contribution
(a) First year after thinning		
UP vs 25% (50.44)##		
Ground hunter	42.34%	42.34%
Sheet web weaver	38.86%	81.20%
Space web weaver	8.50%	89.70%
Other hunters	4.71%	94.41%
UP vs 50% (54.61)		
Ground hunter	48.59%	48.59%
Sheet web weaver	34.65%	83.24%
Space web weaver	7.48%	90.73%
(b) Second year after thinning		
UP vs 25% (40.07)		
Ground hunter	62.83%	62.83%
Space web weaver	11.38%	74.20%
Sheet web weaver	10.93%	85.13%
Other hunters	10.51%	95.65%
UP vs 50% (58.94)		
Ground hunter	82.84%	82.84%
Sheet web weaver	7.07%	89.92%
Space web weaver	6.06%	95.98%
25% vs 50% (38.56)		
Ground hunter	78.94%	78.94%
Space web weaver	7.37%	86.31%
Sheet web weaver	7.07%	93.38%

average dissimilarity between two treatment

Table 12. Results of two-way ANOVA examining effects of thinning treatments and years (and their interaction) on various spider guild abundance of sampling plots in Ren-Luen, Central Taiwan.

	Ground hunter		Sheet web weaver		Space web weaver	
	F	*p*	*F*	*p*	*F*	*p*
Thinning	12.676	0.0001	8.479	0.001	0.127	0.881
Year	17.864	0.0001	7.026	0.003	28.102	0.0001
Thinning × Year	5.496	0.002	2.232	0.092	0.643	0.637

1. Total degrees of freedom = 35, degrees of freedom for each factor = 2, and degrees of freedom for the interaction = 4.
2. Spider composition data were collected from 12 plots for three years.

Table 13. Abundance of major spider guilds (mean ± SE) of sampling plots receiving various thinning treatments in different years in Ren-Luen, Central Taiwan. Letters represent results of Tukey post-hoc tests. Lower case letters represent comparisons between different treatments in the same year. Capital letters represent comparisons between different years for particular treatment. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation; B1: one year before thinning; A1: first year after thinning; A2: second year after thinning).

Comparisons		B1	A1	A2
(a) Ground hunter	UP	11.5 ± 4.78	13.8 ± 4.37	36.0 ± 18.26^{b}
	25%	16.0 ± 5.35	42.8 ± 12.79	87.3 ± 27.10^{b}
	50%	27.3 ± 9.10^{B}	63.0 ± 18.19^{B}	233.0 ± 50.16$^{a, A}$
(b) Sheet web weaver	UP	23.0 ± 3.65	16.8 ± 3.30^{b}	14.5 ± 2.40
	25%	25.8 ± 4.96^{B}	45.5 ± 9.40^{a,A}	21.3 ± 4.64^{B}
	50%	29.3 ± 4.92^{B}	48.8 ± 5.66^{a,A}	27.8 ± 5.68^{B}
(c) Space web weaver	UP	11.8 ± 1.43	12.0 ± 3.14	27.3 ± 4.01
	25%	11.8 ± 2.36	6.3 ± 2.14	29.5 ± 5.49
	50%	9.8 ± 1.65	8.5 ± 3.92	33.8 ± 6.71

Table 14. Pearson correlation coefficients of various variables and RDA axis. (a) Spider guild composition. (b) Environmental factors. (AH: ambush hunters; GH: ground hunters; OW: orb web weavers; OH: other hunters; SE: sensing web weavers; SH: sheet web weaver; SW: space web weavers; SP: specialist; m: mean; sd: standard deviation; I: illumination with in the stand; D: decomposition of litter; T: temperature; RH; relative humidity; PCO: percent canopy openness; UVD: understory vegetation density.)

(a)	AH	GH	OW	OH	SE	SH	SW	SP
RDA1	-0.263	-0.877^{***}	0.355^{*}	0.338^{*}	-0.416^{**}	-0.002	0.531^{***}	-0.175
RDA2	-0.496^{**}	0.001	-0.008	0.197	-0.002	-0.796^{***}	0.549^{***}	-0.302
(b)	Im	Dm	Tm	RHm	PCOm	UVDm	Tsd	UVDsd
RDA1	-0.588^{***}	0.468^{**}	-0.430^{**}	0.539^{**}	-0.474^{**}	0.193	0.362^{*}	-0.411^{*}
RDA2	0.617^{**}	0.462^{**}	-0.413^{*}	0.281	-0.010	-0.372^{*}	-0.007	0.172

*p<0.05,**p<0.01,***p<0.001

Table 15. Results of two-way ANOVA examining effects of thinning treatments and years (and their interaction) on spider abundance (adult and overall) and Evenness index of sampling plots in Ren-Luen, Central Taiwan.

	Adults		Overall		Evenness index		Shannon-Wiener index		Simpson index	
	F	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Thinning	10.895	0.0001	18.055	0.0001	5.862	0.008	0.0873	NS	1.106	NS
Year	19.744	0.0001	19.032	0.0001	5.220	0.012	1.975	NS	0.164	NS
Thinning × Year	5.759	0.002	6.123	0.001	4.467	0.007	2.190	NS	2.322	NS

1. Total degrees of freedom = 35, degrees of freedom for each factor = 2, and degrees of freedom for the interaction = 4.

2. Spider composition data were collected from 12 plots for three years.

Table 16. Mean (± SD) spider abundance (adult and overall) and Evenness index of sampling plots receiving various thinning treatments in different years in Ren-Luen, Central Taiwan. Letters represent results of Tukey post-hoc tests. Lower case letters represent comparisons between different treatments in the same year. Capital letters represent comparisons between different year for particular treatment. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation; B1: one year before thinning; A1: first year after thinning; A2: second year after thinning).

Comparisons		B1	A1	A2
(a) Families	UP	19/19	20/21	21/23
	25%	19/19	16/20	20/23
	50%	21/21	21/24	21/25
(b) Species	UP	41/41	34/59	51/80
	25%	53/53	30/68	54/91
	50%	51/51	41/70	56/90
(c) Adults	UP	43.0 ± 5.48	16.8 ± 6.85	37.0 ± 15.90^{c}
	25%	47.5 ± 15.11^{AB}	25.8 ± 6.85^{B}	96.8 ± 30.48^{b,A}
	50%	49.5 ± 7.73^{B}	43.0 ± 4.18^{B}	181.0 ± 82.55^{a,A}
(c) Overall	UP	73.3 ± 11.95	52.0 ± 23.11^{b}	85.8 ± 47.95^{b}
	25%	79.5 ± 18.65^{B}	101.5 ± 6.24$^{ab, AB}$	157.5 ± 41.84$^{b, A}$
	50%	91.8 ± 27.11^{B}	132.8 ± 31.75$^{a, B}$	310.5 ± 104.27$^{a, A}$
(d) Evenness index	UP	0.83 ± 0.104^{B}	0.95 ± 0.039^{A}	0.93 ± 0.038^{a,AB}
	25%	0.90 ± 0.034	0.86 ± 0.097	0.79 ± 0.084^{b}
	50%	0.84 ± 0.017^{A}	0.89 ± 0.017^{A}	0.72 ± 0.049^{b,B}
(e) Shannon-Wiener index	UP	2.36 ± 0.51	2.36 ± 0.42	2.85 ± 0.06
	25%	2.77 ± 0.23	2.07 ± 0.36	2.54 ± 0.25
	50%	2.77 ± 0.12	2.56 ± 0.14	2.46 ± 0.09
(f) Simpson index	UP	0.85 ± 0.126	0.95 ± 0.045	0.95 ± 0.020
	25%	0.93 ± 0.023	0.85 ± 0.112	0.88 ± 0.048
	50%	0.93 ± 0.012	0.91 ± 0.019	0.85 ± 0.025

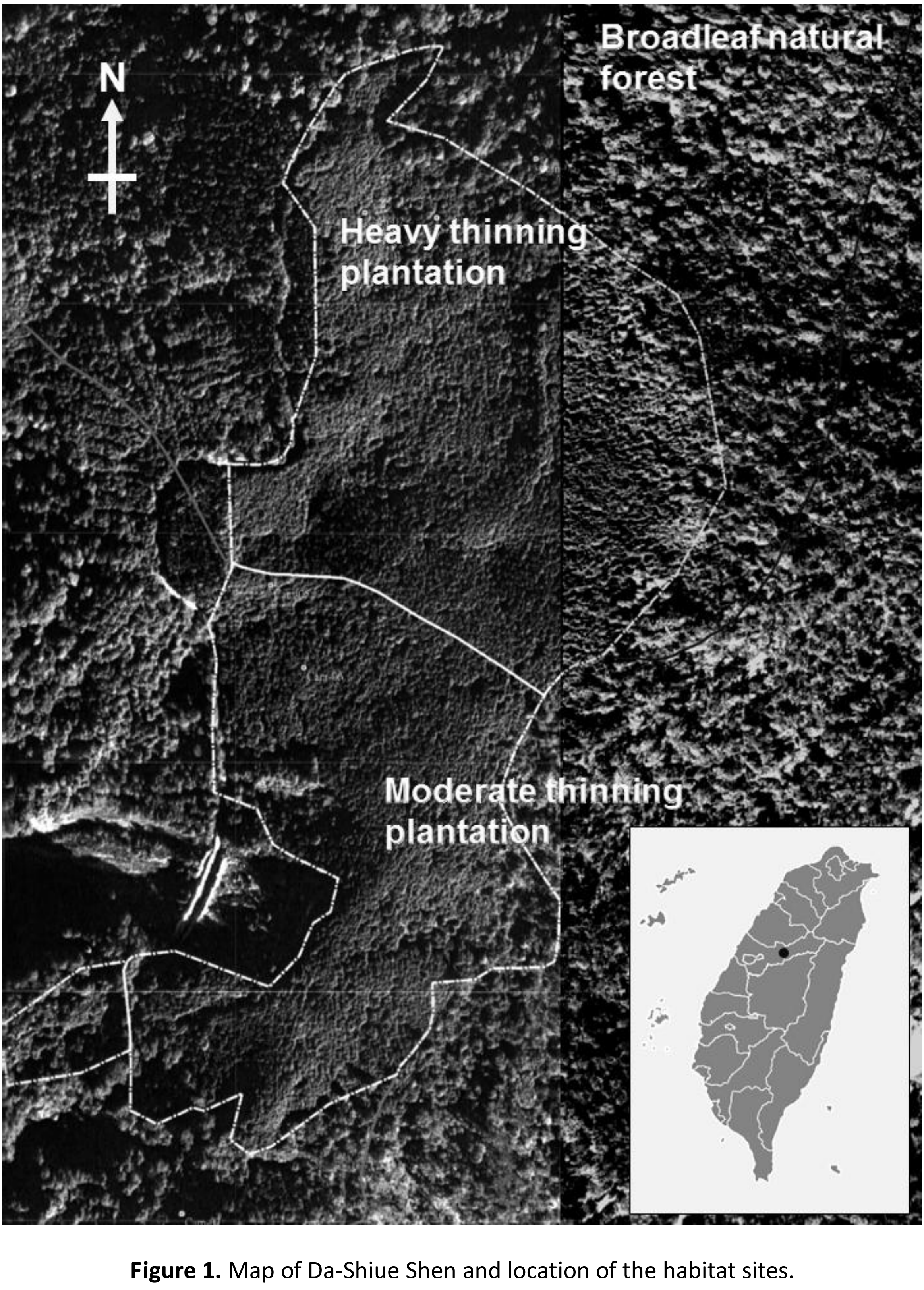

Figure 1. Map of Da-Shiue Shen and location of the habitat sites.

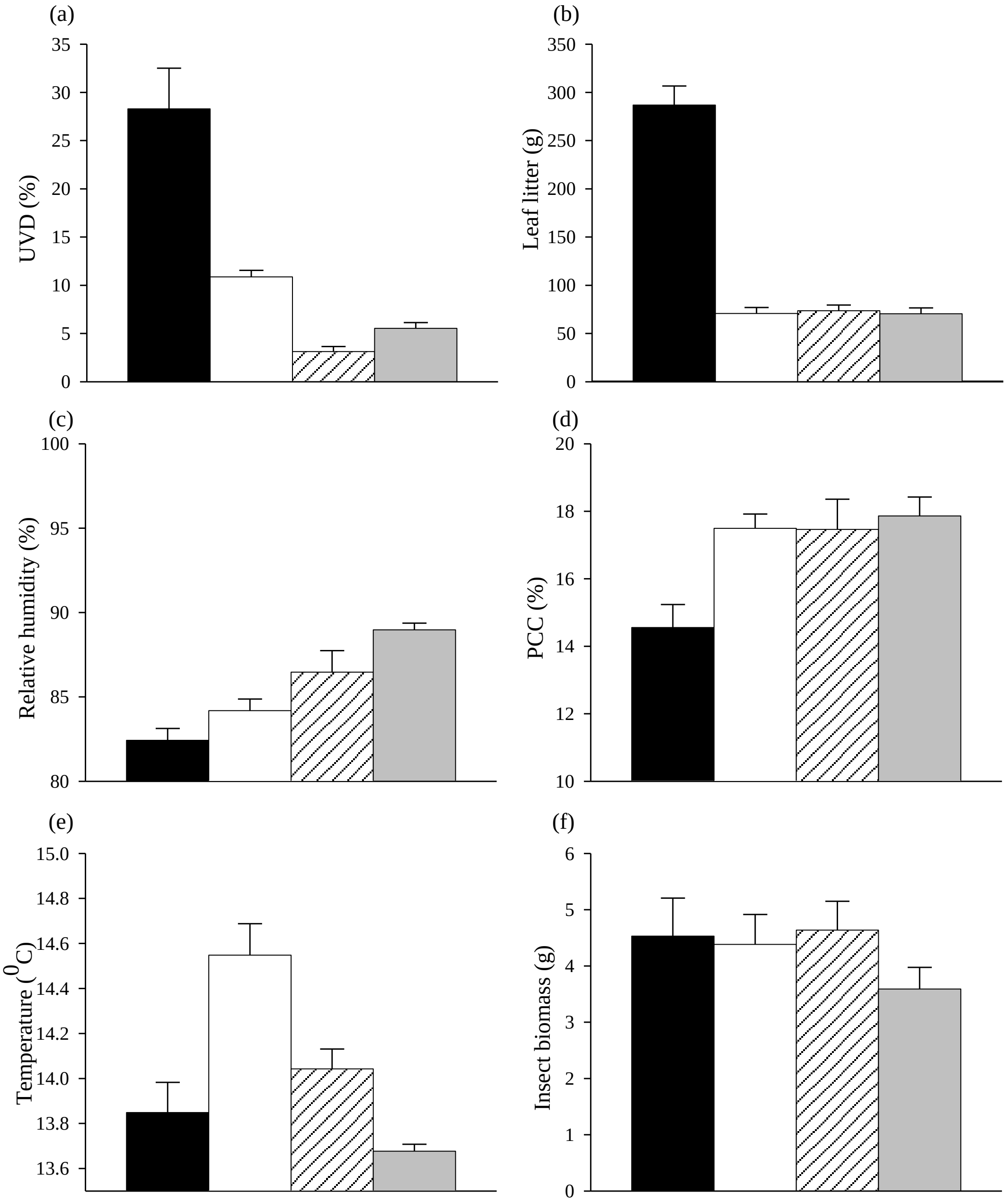

Figure 2. Mean (±SE) of different environmental variables in sampling plots in Da-Shiue Shen, central Taiwan. Understory vegetation density (UVD) (a), leaf litter weight (b), relative humidity (c), percent canopy openness (d), temperature (e) and insect biomass (f). (■: broadleaf forest; □: unthinned plantation; ▨: moderate-thinning plantation; ▒: heavy-thinning plantation)

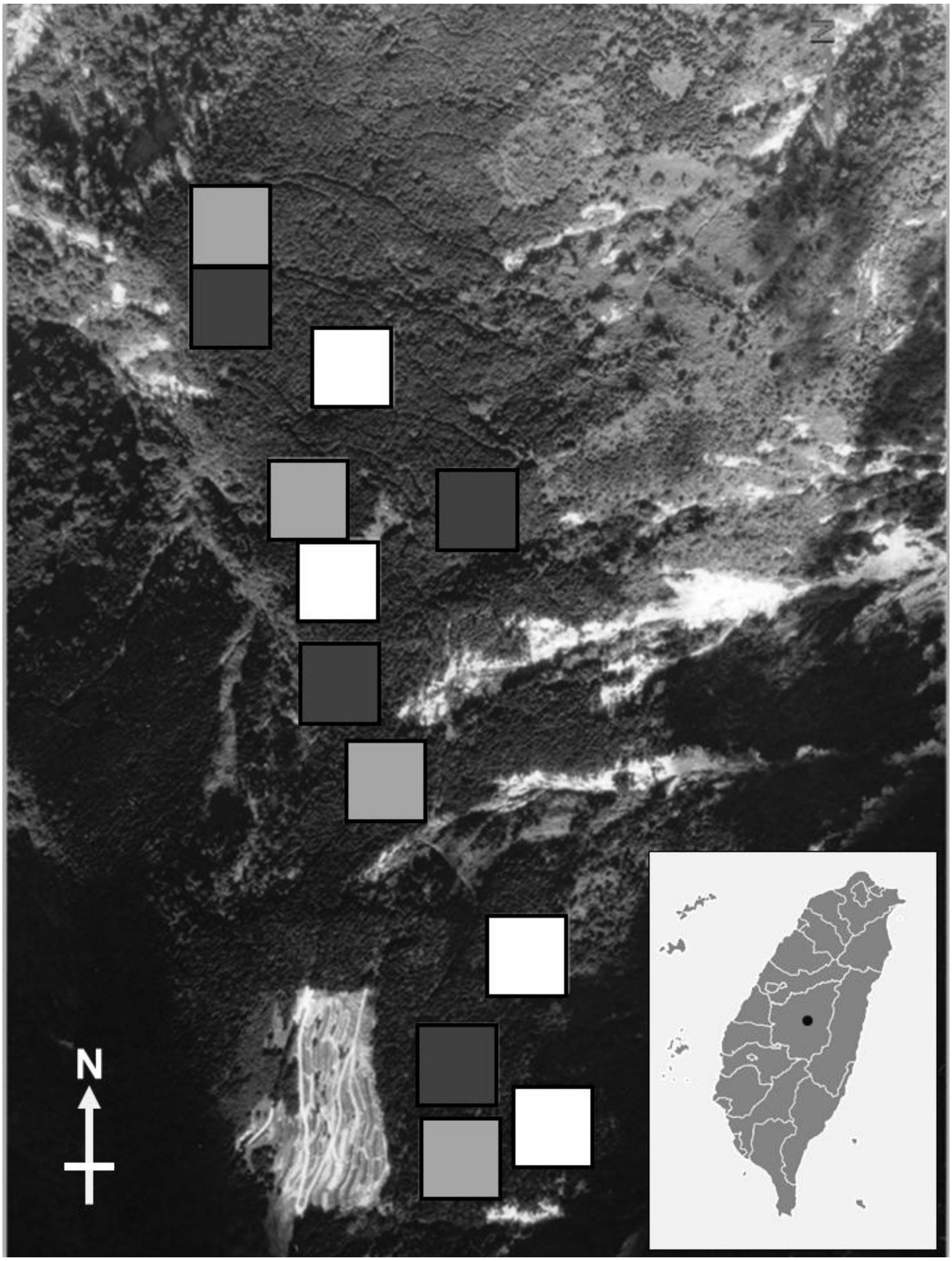

Figure 3. Map of Ren-Luen and location of plots receiving three different thinning treatments.

(□ : unthinned plantation; ▒ :25% thinning pla▨ion; ■ : 50% thinning plantation.)

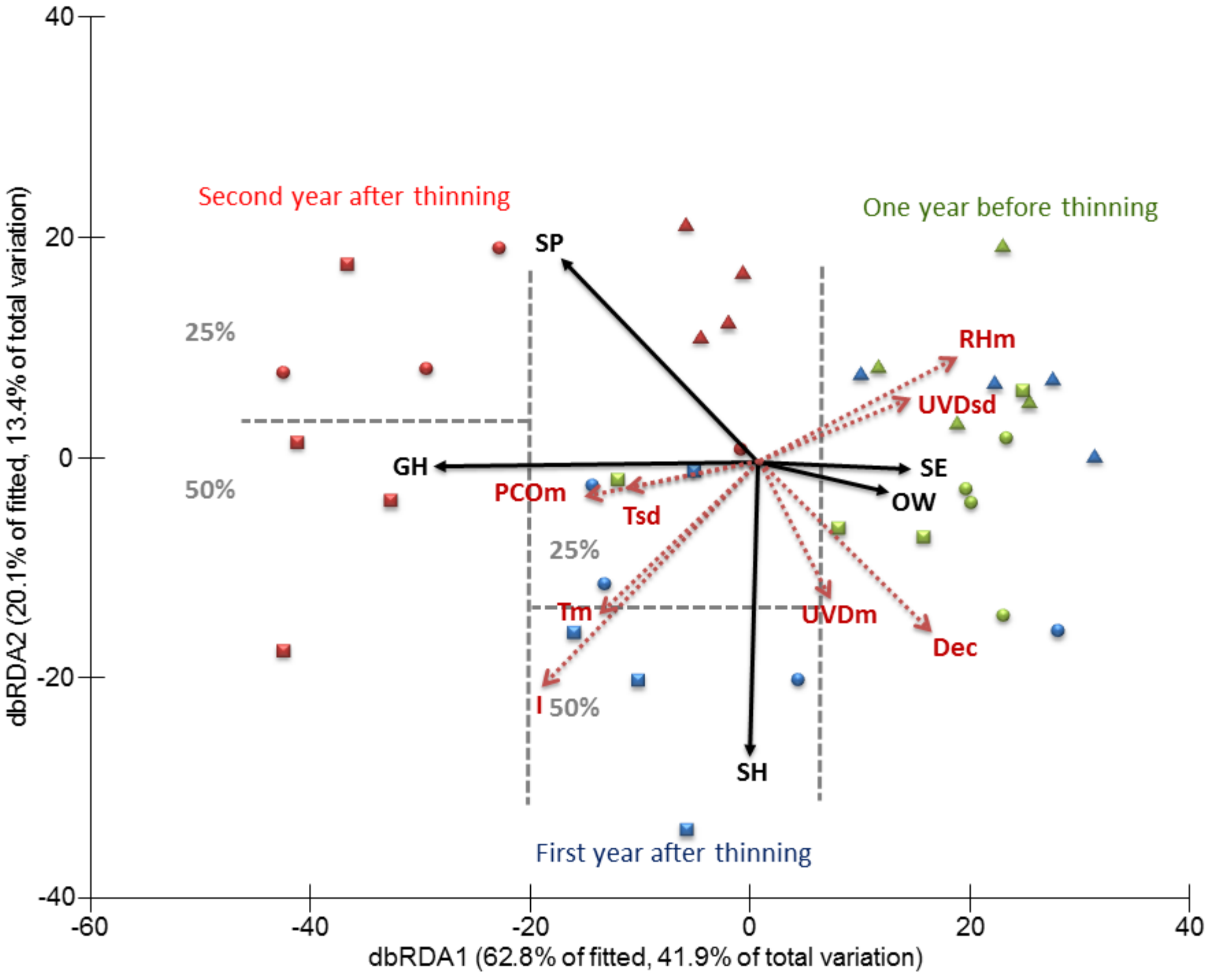

Figure 4. RDA plots generated by spider guild composition of sampling plots receiving different thinning treatments in three years in Ren-Luen, central Taiwan. Axis 1 explains 41.9% of total variation and Axis 2 explained 13.4% of total variation. (Green symbols: one year before thinning; blue symbols: first year after thinning; red symbols: second year after thinning. ▲: unthinned plantation forest; ●: 25%-thinning plantation; ■: 50%-thinning plantation; GH: ground hunters; OW: orb web weavers; OH: other hunters; SE: sensing web weavers; SH: sheet web weaver; SP: space web weavers; m: mean; sd: standard deviation; I: illumination within the stand; D: decomposition of litter; T: temperature; RH; relative humidity; PCO: percent canopy openness; UVD: understory vegetation density.)

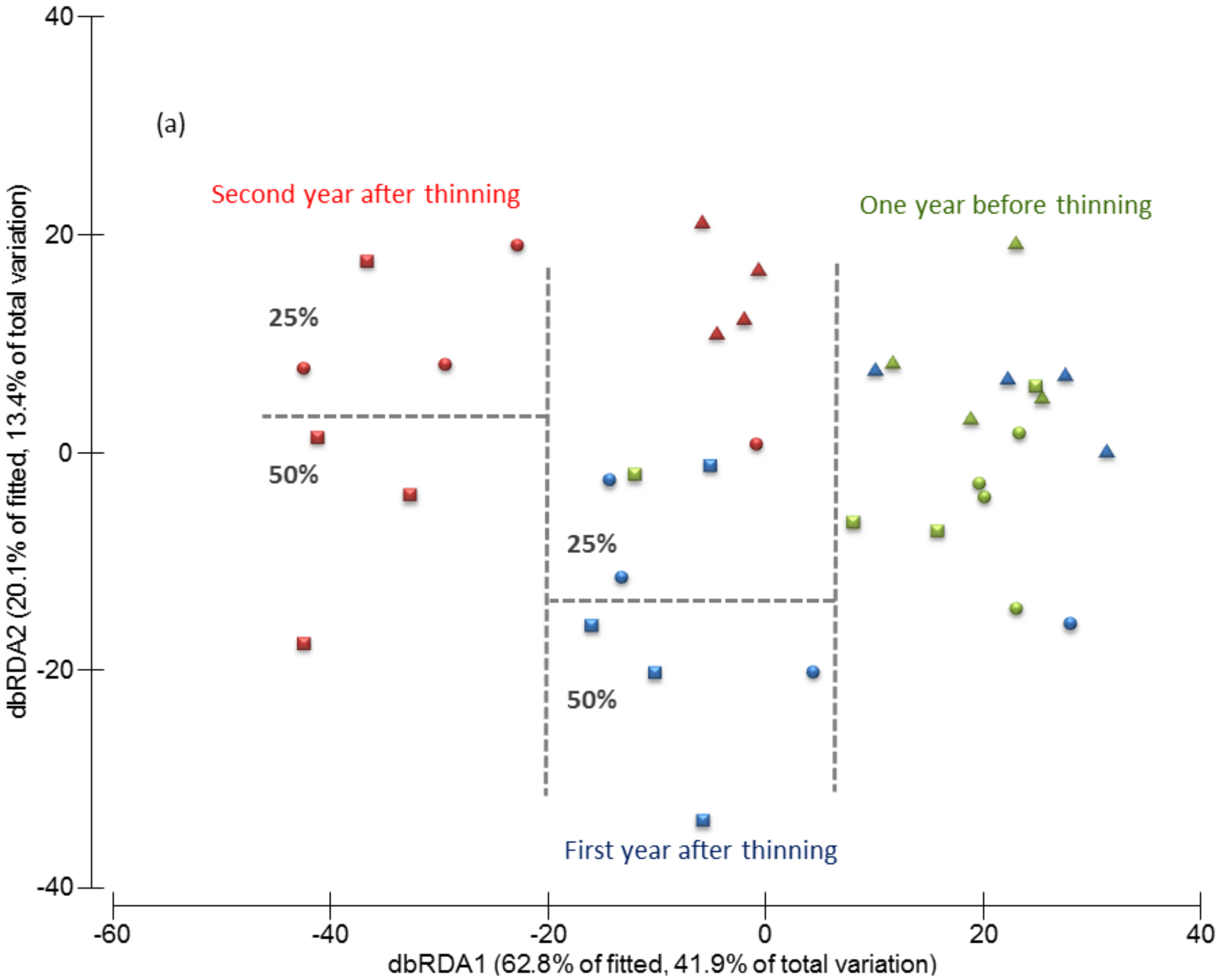

Figure 4(a). RDA plots generated by spider guild composition of sampling plots receiving different thinning treatments without vector in three years in Ren-Luen, central Taiwan. The dotted lines showed the patterns of different treatments and three years data. (Green symbols: one year before thinning; blue symbols: first year after thinning; red symbols: second year after thinning. ▲: unthinned plantation forest; ●: 25%-thinning plantation; ■: 50%-thinning plantation.)

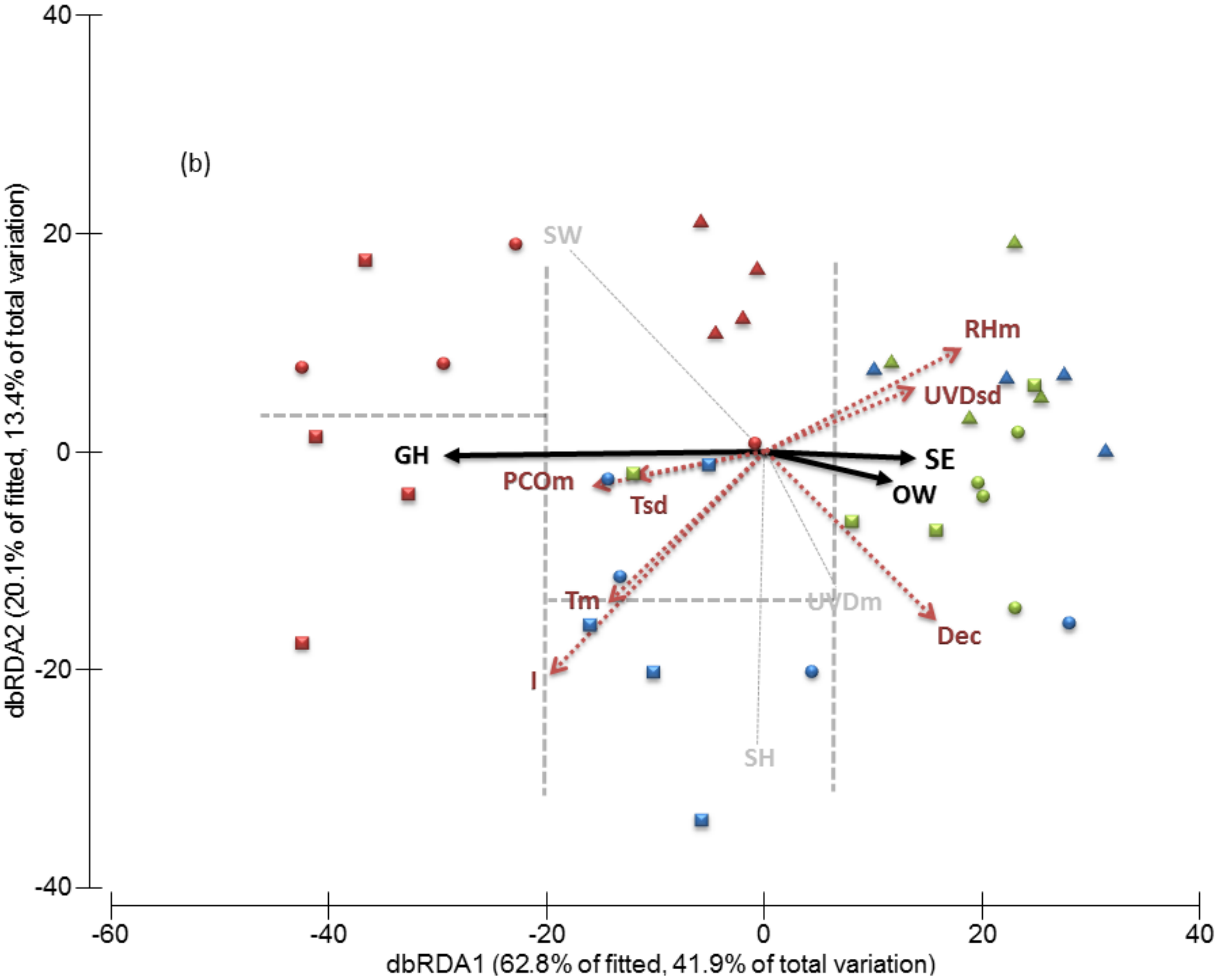

Figure 4(b). RDA plots generated by spider guild composition of sampling plots receiving different thinning treatments in three years in Ren-Luen, central Taiwan and with the correlated vectors with axis 1 shown. The black and red arrows represent the vectors correspond significantly with axis 1. The black solid arrows showed the spider guilds and red dotted arrows showed the environmental factors. (Green symbols: one year before thinning; blue symbols: first year after thinning; red symbols: second year after thinning. ▲: unthinned plantation forest; ●: 25%-thinning plantation; ■: 50%-thinning plantation; GH: ground hunters; OW: orb web weavers; SE: sensing web weavers; m: mean; sd: standard deviation; I: illumination within the stand; Dec: decomposition of litter; T: temperature; RH; relative humidity; PCO: percent canopy openness; UVD: understory vegetation density.)

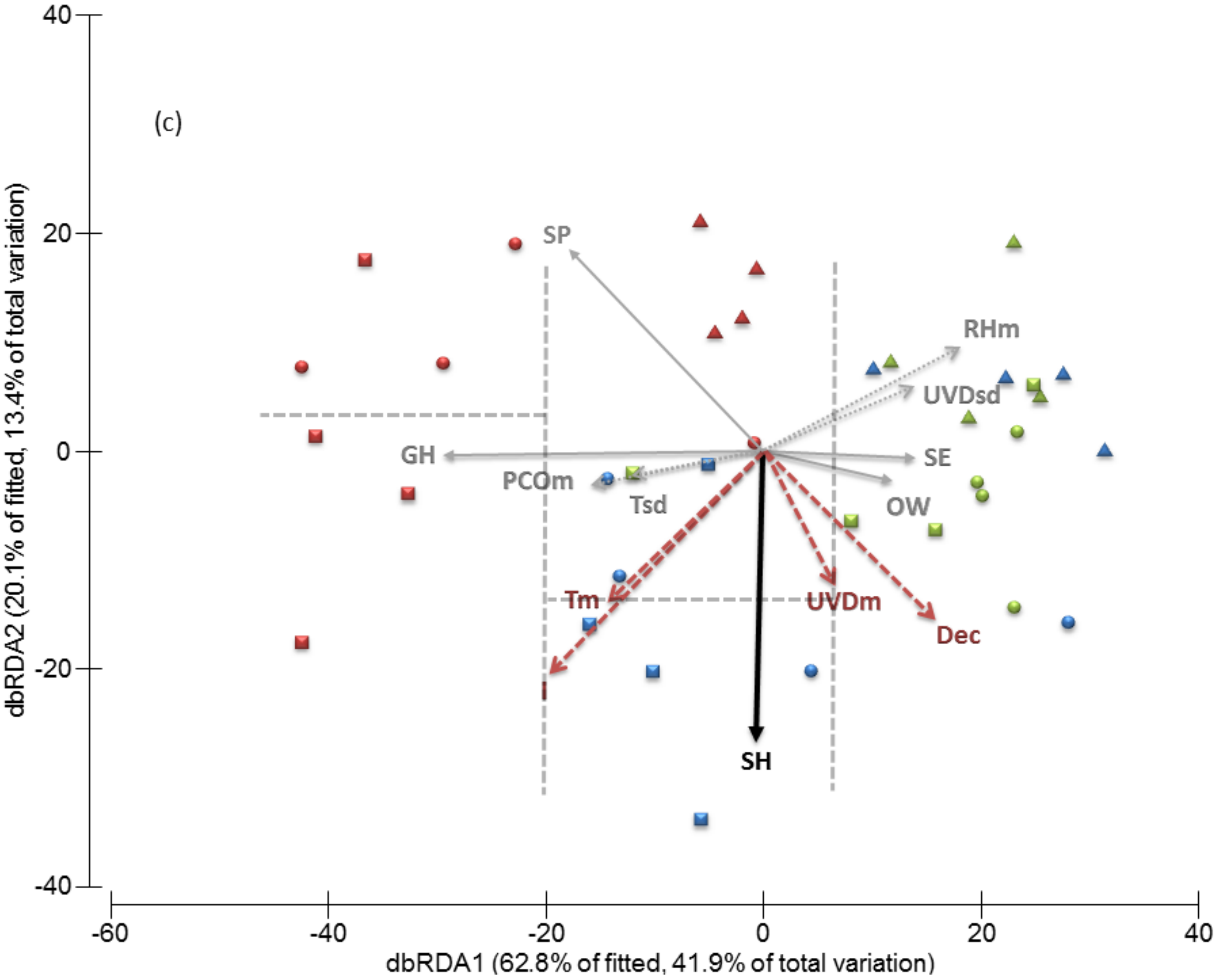

Figure 4(c). RDA plots generated by spider guild composition of sampling plots receiving different thinning treatments in three years in Ren-Luen, central Taiwan and with the correlated vectors with axis 2 shown. The black and red arrows represent the vectors correspond significantly with axis 2. The black solid arrows showed the spider guilds and red dotted arrows showed the environmental factors. (Green symbols: one year before thinning; blue symbols: first year after thinning; red symbols: second year after thinning. ▲: unthinned plantation forest; ●: 25%-thinning plantation; ■: 50%-thinning plantation; SH: sheet web weaver; m: mean; sd: standard deviation; I: illumination within the stand; Dec: decomposition of litter; T: temperature; UVD: understory vegetation density.)

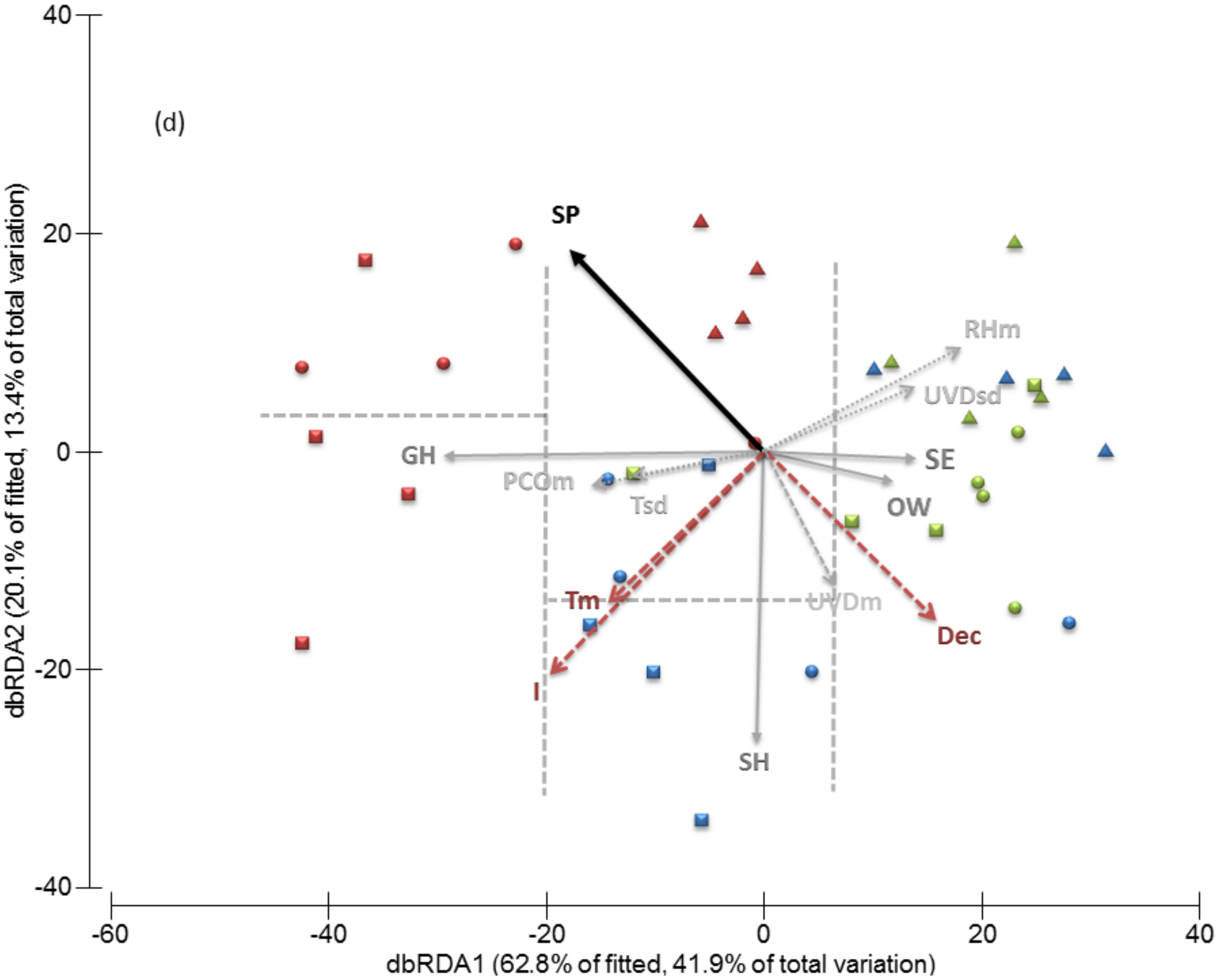

Figure 4(d). RDA plots generated by spider guild composition of sampling plots receiving different thinning treatments in three years in Ren-Luen, central Taiwan and with the correlated vectors with both axis 1 and 2 shown. The black and red arrows represent the vectors correspond significantly with both axis 1 and 2. The black solid arrows showed the spider guilds and red dotted arrows showed the environmental factors. (Green symbols: one year before thinning; blue symbols: first year after thinning; red symbols: second year after thinning. ▲: unthinned plantation forest; ●: 25%-thinning plantation; ■: 50%-thinning plantation; SP: space web weavers; m: mean; sd: standard deviation; I: illumination within the stand; D: decomposition of litter; T: temperature.)

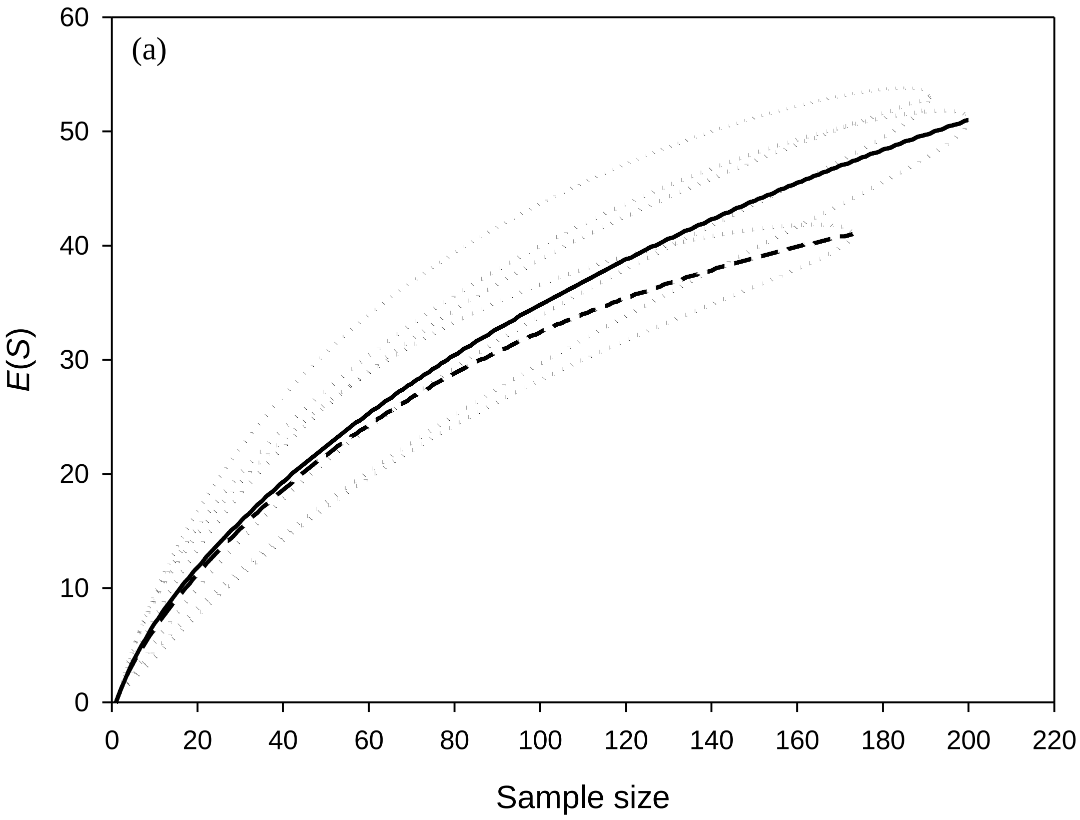

Figure 5(a). Rarefaction curves of expected number of species generated from sampling plots of three thinning treatments at Ren-Luen, central Taiwan, sampled in one year before thinning. The dotted line depicts the 95% confidence interval (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

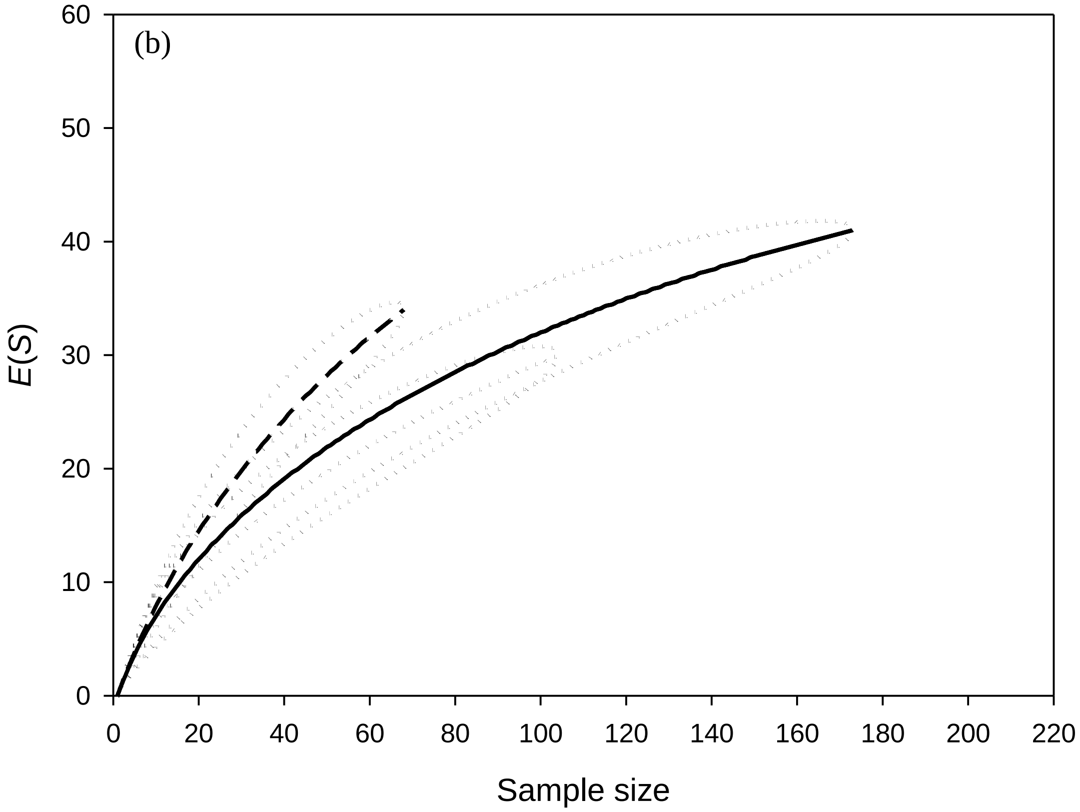

Figure 5. Rarefaction curves of expected number of species generated from sampling plots of three thinning treatments at Ren-Luen, central Taiwan, sampled in first year after thinning. The dotted line depicts the 95% confidence interval. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

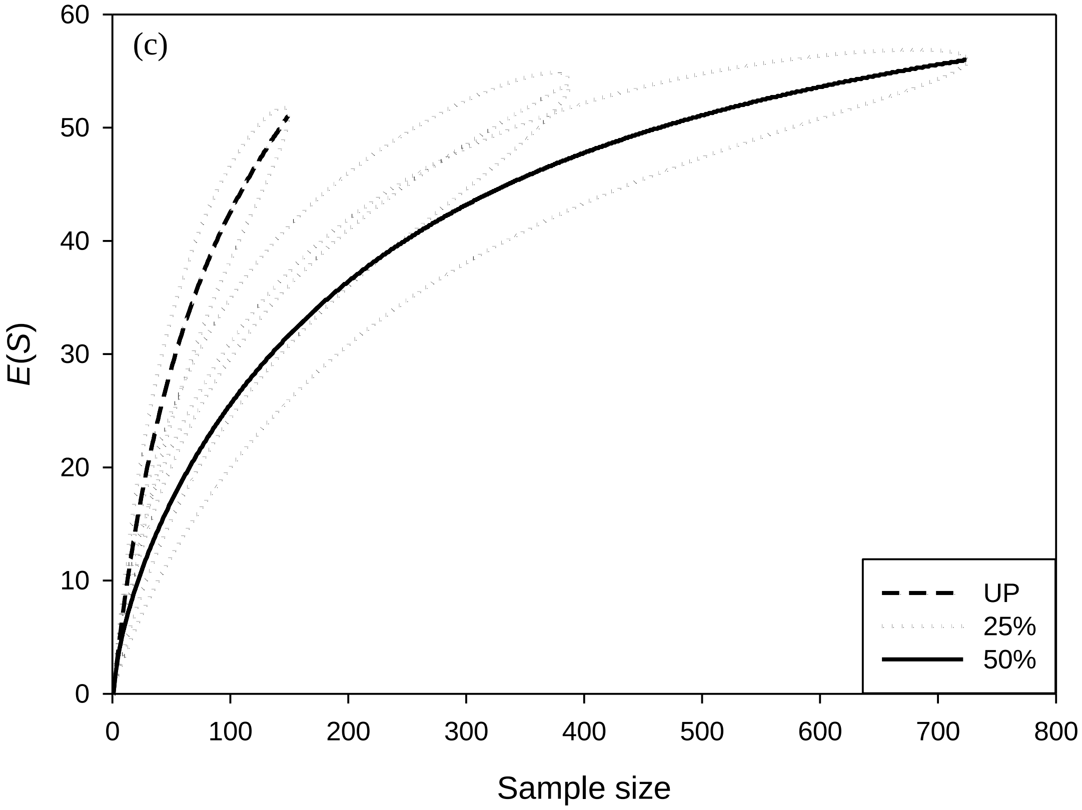

Figure 5. Rarefaction curves of expected number of species generated from sampling plots of three thinning treatments at Ren-Luen, central Taiwan, sampled in second year after thinning. The dotted line depicts the 95% confidence interval. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

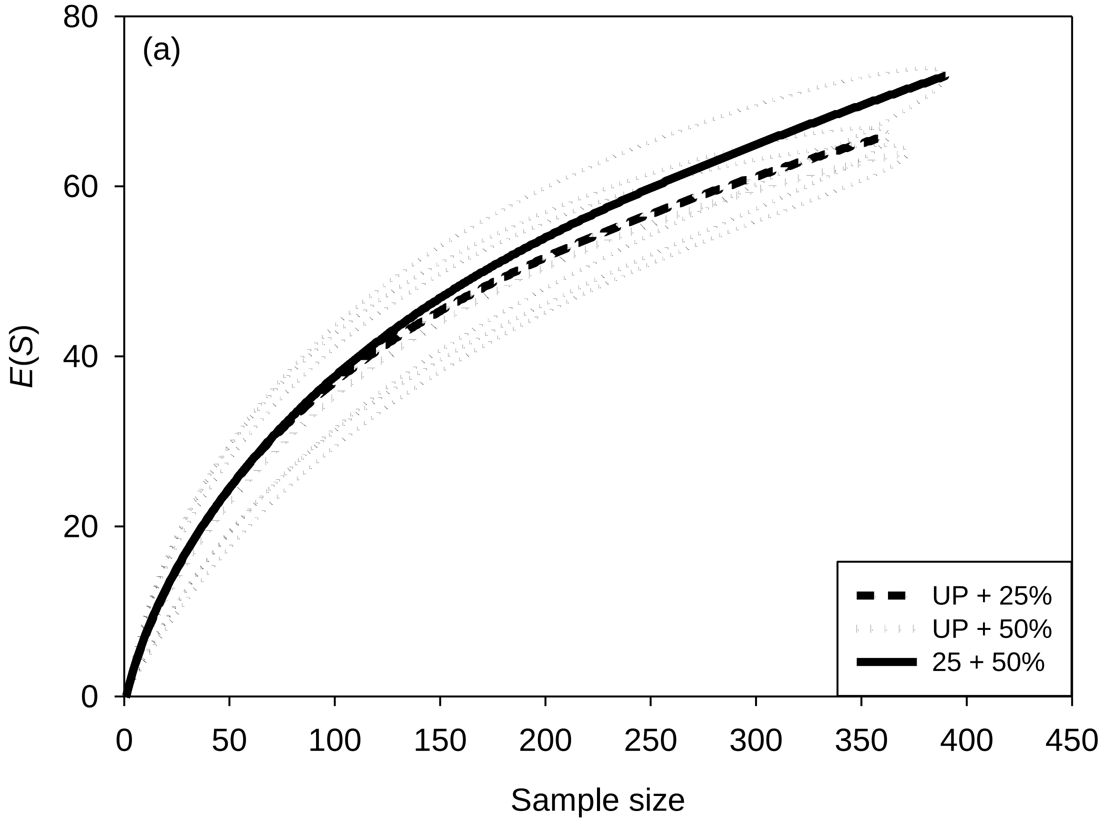

Figure 6(a). Rarefaction curves of expected number of species. Each rarefaction curve is generated from sampling plots of two thinning treatments at Ren-Luen, central Taiwan, sampled one year before thinning. The dotted line depicts the 95% confidence interval. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

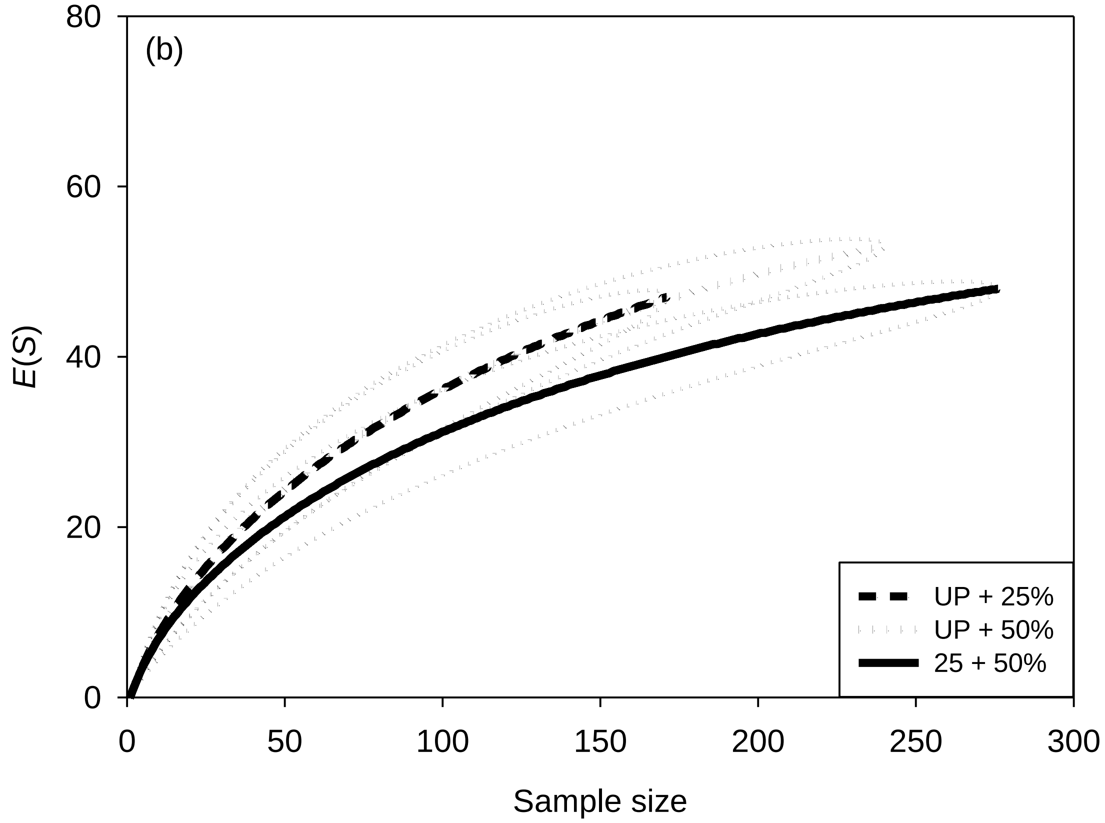

Figure 6(b). Rarefaction curves of expected number of species. Each rarefaction curve is generated from sampling plots of two thinning treatments in Ren-Luen, central Taiwan, sampled in first year after thinning. The dotted line depicts the 95% confidence interval. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

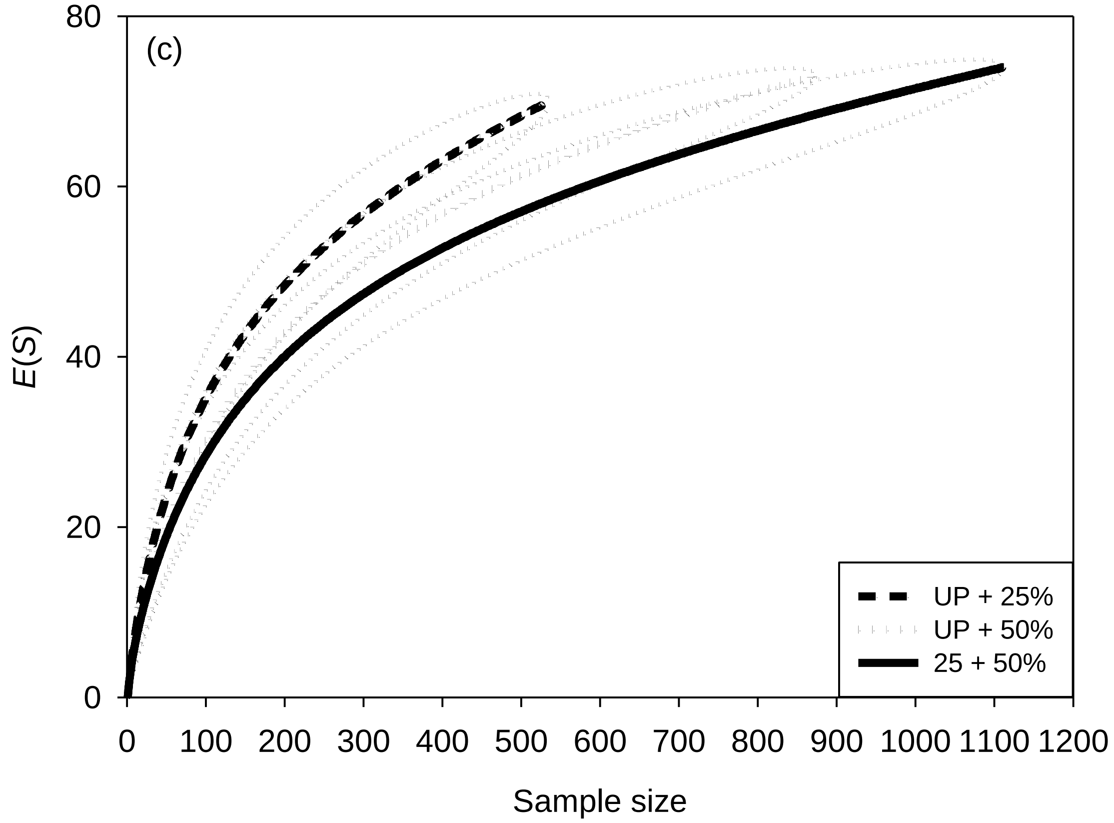

Figure 6(c). Rarefaction curves of expected number of species. Each rarefaction curve is generated from sampling plots of two thinning treatments in Ren-Luen, central Taiwan, sampled in second year after thinning. The dotted line depicts the 95% confidence interval. (UP: unthinned plantation forest; 25%: 25%-thinning plantation; 50%: 50%-thinning plantation)

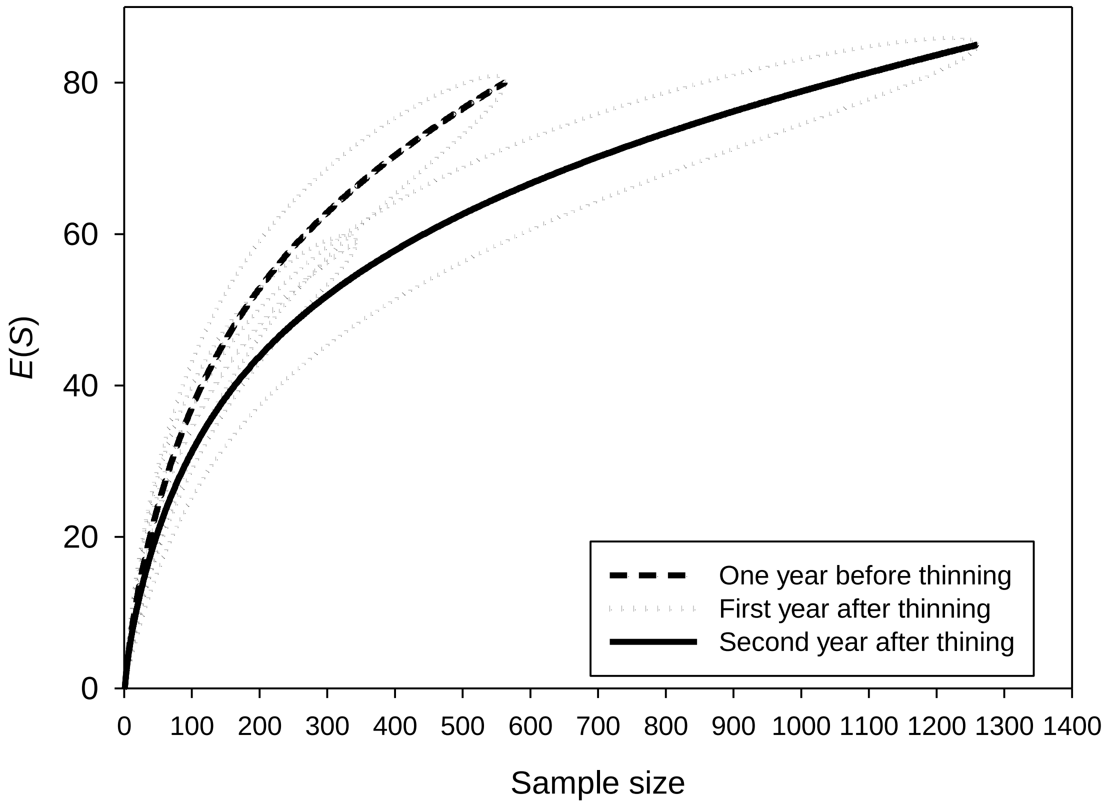

Figure 7. Rarefaction curves of expected number of species. Each rarefaction curve is generated from sampling plots of all thinning treatments in the same year in Ren-Luen, central Taiwan. The dotted line depicts the 95% confidence interval.

Appendix 1. Composition and number of individuals of spider guild, family and morpho-species collected from all kind of collecting methods at each habitat types in Da-Shiue Shan, central Taiwan. (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation)

Collecting method			Canopy sweeping net				Sweeping net				Pitfall				TOTAL
Habitat types			PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	
Guild	family	morphospecies													
Space web weavers	Dictynidae	Juv	0	0	0	0	1	0	0	0	0	0	0	0	1
	Theridiidae	The 01	0	0	0	0	0	0	0	0	0	0	0	1	1
		The 02	0	0	0	0	0	0	0	1	0	0	0	1	2
		The 03	0	0	0	2	1	0	0	0	0	0	0	0	3
		The 05	0	0	0	0	0	1	0	0	0	0	0	0	1
		The 06	0	1	0	0	0	0	0	0	0	0	0	0	1
		The 07	0	0	0	0	0	0	0	1	0	0	0	0	1
		The 08	0	0	0	5	0	0	1	2	0	0	0	0	8
		The 09	1	0	1	0	0	1	0	0	0	0	0	0	3
		The 10	3	2	3	0	0	0	1	0	0	0	0	0	9
		The 11	1	0	0	0	0	0	0	0	0	0	0	0	1
		The 13	1	0	1	0	0	1	0	0	0	0	0	0	3
		The 14	2	0	0	0	2	0	1	0	0	0	0	0	5
		The 15	0	1	0	0	0	0	0	0	0	0	0	0	1
		The 16	0	0	0	0	0	0	1	0	0	0	0	0	1
		The 32	0	0	0	3	0	0	0	4	0	0	0	0	7
		The 41	0	0	0	0	0	0	0	1	0	0	0	0	1
		The 43	0	0	0	0	0	1	0	0	0	0	0	0	1
		The 45	0	0	0	0	0	1	0	0	0	0	0	0	1
		Juv	6	8	10	18	9	2	6	54	20	1	0	6	140
Burrow dwellers	Agelenidae	Age 01	0	0	0	0	0	0	0	0	26	23	63	54	166
		Age 02	0	0	0	0	0	0	0	0	1	4	2	7	14
		Age 03	0	0	0	0	0	0	0	0	3	11	5	6	25
		Age 04	0	0	0	0	0	0	0	0	0	0	1	0	1
		Age 05	0	0	0	0	0	0	0	0	1	2	0	0	3
		Age 06	0	0	0	0	0	0	0	0	0	0	0	2	2
		Age 07	0	0	0	0	0	0	0	0	0	0	1	3	4
		Age 08	0	0	0	0	0	0	0	0	0	2	0	0	2
		Age 09	0	0	0	0	0	0	0	0	2	4	0	8	14
		Age 10	0	0	0	0	0	0	0	0	0	1	0	0	1
		Age 11	0	0	0	0	0	0	0	0	0	0	0	2	2
		Age 12	0	0	0	0	0	0	0	0	1	0	2	2	5
		Age 13	0	0	0	0	0	0	0	0	3	2	1	0	6
		Age 15	0	0	0	0	0	0	0	0	3	0	2	0	5
		Age 16	0	0	0	0	0	0	0	0	0	1	1	0	2
		Age 18	0	0	0	0	0	0	0	0	0	0	6	0	6
		Age 19	0	0	0	0	0	0	0	0	0	1	0	0	1
		Age 20	0	0	0	0	0	0	0	0	1	0	0	0	1

Appendix 1.(continued)

Collecting method			Canopy sweeping net				Sweeping net				Pitfall				TOTAL
Habitat types			PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	
Guild	family	morphospecies													
Burrow dwellers	Agelenidae	Age 21	0	0	0	0	0	0	0	0	0	0	0	1	1
		Age 23	0	0	0	0	0	0	0	0	5	1	1	1	8
		Age 25	0	0	0	0	0	0	0	0	0	0	1	4	5
		Juv	0	0	0	0	0	0	0	0	10	11	11	15	47
Ground runners	Ctenizidae	Cte 01	0	0	0	0	0	0	0	0	6	0	3	0	9
		Juv	0	0	0	0	0	0	0	0	1	0	0	0	1
	Dysderidae	Juv	0	0	0	0	0	0	0	0	0	0	1	4	5
	Gnaphosidae	Gna 01	0	0	0	0	0	0	0	0	5	5	4	3	17
		Gna 06	0	0	0	0	0	0	0	0	0	1	1	1	3
		Juv	1	0	0	0	0	0	0	0	1	2	2	1	7
	Lycosidae	Lyc 01	0	0	0	0	0	0	0	0	0	0	1	0	1
		Juv	0	0	0	0	0	1	0	0	0	0	0	0	1
	Oonopidae	Juv	0	0	0	0	0	0	0	0	1	3	0	2	6
		Oon 01	0	0	0	0	0	0	0	0	0	1	1	2	4
		Oon 02	0	0	0	0	0	0	0	0	0	0	0	3	3
	Zodariidae	Juv	0	0	0	0	0	0	0	0	1	3	1	1	6
		Zod 01	0	0	0	0	0	0	0	0	8	10	0	23	41
		Zod 02	0	0	0	0	0	0	0	0	2	1	1	2	6
		Zod 06	0	0	0	0	0	0	0	0	1	0	0	0	1
Ground weavers	Atypidae	Aty 01	0	0	0	0	0	0	0	0	0	2	0	0	2
	Hahniidae	Hah 01	0	0	0	0	0	0	0	0	0	0	3	12	15
		Juv	0	0	0	0	0	0	0	0	1	0	0	0	1
	Hexathelidae	Hex 01	0	0	0	0	0	0	0	0	3	0	0	0	3
	Linyphiidae	Lin 01	0	0	0	0	0	0	0	0	1	20	44	30	95
		Lin 02	1	0	0	10	25	0	0	6	0	0	0	0	42
		Lin 03	0	0	0	0	4	1	1	1	7	11	22	5	52
		Lin 04	0	0	0	0	0	0	1	0	0	0	0	0	1
		Lin 05	0	0	0	0	0	0	0	0	0	9	26	16	51
		Lin 06	0	0	0	0	0	0	0	0	0	0	4	1	5
		Lin 07	0	0	0	0	0	0	0	0	2	4	2	6	14
		Lin 08	0	0	0	0	1	0	0	0	2	1	1	2	7
		Lin 08-1	0	0	0	0	0	0	0	0	0	1	1	2	4
		Lin 08-2	0	0	0	0	1	0	1	0	0	2	2	1	7
		Lin 09	0	0	0	0	0	0	0	0	0	0	1	0	1
		Lin 10	0	0	0	0	0	0	1	0	0	0	0	1	2
		Lin 11	1	0	0	0	1	0	2	0	0	0	0	0	4
		Lin 12	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 13	0	0	0	0	0	0	0	0	1	3	0	0	4
		Lin 14	1	0	0	0	0	0	0	0	6	0	2	0	9
		Lin 15	0	0	0	0	0	0	0	0	16	0	0	0	16
		Lin 16	0	1	0	0	1	0	0	0	0	0	0	0	2

Appendix 1.(continued)

Collecting method			Canopy sweeping net				Sweeping net				Pitfall				TOTAL
Habitat types			PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	
Guild	family	morphospecies													
Ground weavers	Linyphiidae	Lin 17	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 18	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 19	0	0	0	0	0	0	1	0	0	0	0	0	1
		Lin 21	0	0	0	2	0	0	0	3	1	0	0	0	6
		Lin 23	0	0	0	3	3	1	0	7	0	0	0	0	14
		Lin 25	0	0	0	0	0	0	0	1	0	0	0	0	1
		Lin 26	0	0	3	0	0	0	0	0	0	0	0	0	3
		Lin 27	1	0	0	0	0	0	0	0	0	0	0	0	1
		Lin 28	1	1	0	0	0	0	0	0	0	0	0	0	2
		Lin 29	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 30	0	0	0	0	0	0	0	2	0	0	0	0	2
		Lin 31	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 32	0	0	0	0	0	0	0	1	0	0	0	0	1
		Lin 33	0	0	0	0	0	0	0	0	0	0	26	23	49
		Lin 34	0	0	0	0	0	0	0	0	0	0	0	1	1
		Lin 35	0	0	0	0	0	0	0	0	0	0	3	0	3
		Lin 36	0	0	0	0	0	0	0	0	0	1	10	0	11
		Lin 37	0	0	0	0	0	0	0	0	0	0	1	0	1
		Lin 38	0	0	0	0	0	0	0	0	0	1	2	0	3
		Lin 39	0	0	0	0	0	0	0	0	0	0	0	1	1
		Lin 47	0	0	0	0	0	0	0	0	0	0	3	1	4
		Lin 49	0	0	0	0	0	0	0	0	1	1	1	0	3
		Juv	20	21	27	82	73	43	41	75	67	37	55	28	569
	Liocranidae	Lio 01	0	0	0	0	0	0	0	0	0	0	0	1	1
		Lio 02	0	0	0	0	0	0	0	0	10	1	1	2	14
		Lio 03	0	0	0	0	0	0	0	0	20	3	1	8	32
		Juv	0	0	0	2	0	0	0	3	11	1	1	2	20
	Segestriidae	Seg 01	0	0	0	0	0	0	0	0	0	0	1	0	1
		Seg 02	0	0	0	0	0	0	0	0	0	1	0	0	1
		Seg 03	0	0	0	0	0	0	0	0	0	6	0	1	7
		Seg 05	0	0	0	0	0	0	0	0	2	0	2	9	13
		Juv	0	0	0	0	0	2	0	0	2	8	1	2	15
Orb weavers	Araneidae	Ara 01	1	2	1	2	1	0	1	1	0	0	0	0	9
		Ara 10	0	0	0	0	0	0	0	1	0	0	0	0	1
		Ara 12	0	0	0	0	1	0	2	0	0	0	0	0	3
		Ara 15	0	0	0	1	0	0	0	0	0	0	0	0	1
		Ara 19	0	0	0	0	0	0	1	0	0	0	0	0	1
		Ara 02	0	0	0	4	1	0	4	2	0	0	0	0	11
		Ara 04	0	0	0	0	0	0	1	0	0	0	0	0	1
		Ara 05	0	0	0	0	0	1	0	0	0	0	0	0	1
		Ara 06	0	0	0	0	2	0	0	1	0	0	0	0	3

Appendix 1. (Continued)

Collecting method			Canopy sweeping net				Sweeping net				Pitfall				TOTAL
Habitat types			PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	PFC	PFM	PFH	BLF	
Guild	family	morphospecies													
		Ara 07	0	0	0	0	0	1	0	0	0	0	0	0	1
		Ara 08	0	0	1	0	1	1	0	1	0	0	0	0	4
		Ara 09	0	0	0	2	0	0	0	0	0	0	0	0	2
		Juv	19	33	42	43	35	117	72	74	0	0	1	3	439
	Pholcidae	Juv	0	0	0	0	0	0	0	1	0	0	0	0	1
	Tetragnathidae	Tet 11	1	0	0	5	0	0	0	2	0	0	0	0	8
		Tet 13	0	0	1	0	0	0	0	0	0	0	0	0	1
		Tet 15	0	0	0	0	0	1	0	0	0	0	0	0	1
		Tet 02	3	3	3	2	5	3	7	5	0	0	0	0	31
		Tet 04	0	0	0	0	0	0	0	1	0	0	0	0	1
		Tet 07	0	0	0	0	1	0	0	0	0	0	0	0	1
		Tet 09	1	0	1	1	4	2	8	4	0	0	0	0	21
		Juv	26	42	70	23	57	80	129	54	0	0	0	0	481
Foluage runners	Clubionidae	Clu 01	0	0	0	0	0	0	0	0	0	0	0	1	1
		Clu 02	0	0	0	0	0	0	0	0	0	0	0	1	1
		Clu 04	0	0	0	0	0	0	0	0	0	0	1	0	1
		Clu 05	0	0	0	0	0	0	0	0	2	1	1	0	4
		Clu 06	0	0	0	1	1	0	0	0	0	1	0	0	3
		Clu 07	0	0	0	0	0	0	0	0	0	0	0	1	1
		Clu 08	0	0	0	0	0	0	0	0	0	0	0	1	1
		Clu 09	0	0	0	0	0	0	0	0	5	0	2	0	7
		Juv	4	0	0	8	19	5	3	12	6	9	4	12	82
	Heteropodidae	Het 01	0	0	0	0	0	0	0	0	1	0	0	0	1
		Het 02	1	0	0	0	0	0	0	0	0	0	0	3	4
		Het 03	0	0	0	0	0	0	0	0	1	0	2	0	3
		Het 04	0	0	0	0	0	0	0	0	1	0	0	0	1
		Juv	0	1	2	0	1	0	0	2	1	0	0	0	7
	Salticidae	Sal 02	1	1	3	9	8	1	1	1	0	0	0	0	25
		Sal 24	0	0	0	0	1	0	1	0	0	0	0	0	2
		Sal 03	1	5	4	6	6	0	1	2	0	0	0	0	25
		Sal 04	0	2	0	3	2	5	4	2	0	0	0	0	18
		Sal 05	0	0	0	0	1	0	0	0	0	0	0	0	1
		Sal 07	0	1	0	0	0	0	2	2	0	0	0	0	5
		Sal 08	0	0	0	0	0	0	0	0	0	0	0	1	1
		Juv	15	3	25	33	27	15	7	71	0	1	0	2	199
	Thomisidae	Tho 01	2	2	5	2	3	2	1	0	0	0	0	0	17
		Tho 10	0	0	0	0	0	0	2	0	0	0	0	0	2
		Tho 02	0	0	0	1	0	1	0	1	0	0	0	0	3
		Tho 04	0	0	0	0	0	1	2	2	0	0	0	0	5
		Tho 06	0	0	0	0	0	1	0	0	0	0	0	0	1
		Juv	22	32	70	17	22	44	60	28	0	0	0	0	295
TOTAL			137	162	273	290	321	336	367	432	277	215	339	335	3484

Appendix 2. Mean (±SD) of different environmental variables of sampling plots at each habitat types in Da-Shiue Shan, central Taiwan. (BLF: broadleaf forest; PFC: unthinned plantation; PFM: moderate-thinning plantation; PFH: heavy-thinning plantation; D: decomposition of litter; T: temperature; RH; relative humidity; PCO: percent canopy openness; UVD: understory vegetation density; LW: litter weight; BS: biomass of sweeping net; BC: biomass of canopy sweeping net; BP: biomass of pitfall; BA: biomass of all methods.)

	PCO	T	RH	UVD	LW	BS	BC	BP	BA	D
PFC1	16.530	14.431	83.807	12.527	204.40	0.352	0.051	2.124	2.527	0.391
PFC2	15.608	14.403	85.426	12.132	97.13	0.235	0.076	2.515	2.826	0.720
PFC3	19.743	14.363	81.067	12.103	190.05	0.194	0.114	3.221	3.530	0.226
PFC4	17.923	14.503	83.291	9.543	117.58	0.232	0.430	6.066	6.727	0.631
PFC5	17.308	14.265	84.904	7.157	100.88	0.280	0.121	3.512	3.913	0.465
PFC6	18.228	14.285	85.081	9.861	109.55	0.342	0.109	5.010	5.460	0.482
PFC7	18.265	14.440	88.045	8.886	123.80	0.370	0.105	6.586	7.060	0.530
PFC8	16.125	14.616	84.192	13.039	113.00	0.225	0.138	3.616	3.980	0.498
PFC9	17.723	15.627	81.847	12.539	118.08	0.243	0.197	2.984	3.424	0.704
PFM1	14.350	14.403	81.586	1.392	130.43	0.254	0.057	4.334	4.645	0.222
PFM2	13.613	13.866	89.790	1.560	145.48	0.145	0.411	3.635	4.191	0.172
PFM3	16.700	14.271	81.686	4.278	97.55	0.266	0.083	7.036	7.385	0.343
PFM4	17.907	14.474	81.381	3.145	124.20	0.146	0.135	3.209	3.490	0.188
PFM5	16.770	13.788	89.147	1.155	163.60	0.122	0.079	6.128	6.329	0.285
PFM6	21.518	13.952	88.132	3.270	117.43	0.126	0.195	1.910	2.231	0.329
PFM7	19.793	13.959	87.259	6.047	133.00	0.376	0.086	4.355	4.817	0.373
PFM8	20.355	13.849	90.827	3.753	127.43	0.394	0.165	3.306	3.865	0.178
PFM9	16.155	13.820	88.430	3.494	127.73	0.189	0.094	4.498	4.781	0.345
PFH1	19.608	13.696	88.483	6.353	143.18	0.198	0.141	3.195	3.534	0.255
PFH2	18.033	13.587	90.651	6.873	75.10	0.161	0.112	2.590	2.863	0.603
PFH3	18.965	13.709	88.751	3.479	146.15	0.154	0.113	4.283	4.551	0.181
PFH4	18.920	13.550	88.294	5.578	124.93	0.180	0.212	4.951	5.342	0.409
PFH5	20.088	13.739	88.429	3.872	152.30	0.167	0.131	2.351	2.648	0.227
PFH6	17.223	13.598	91.164	3.990	105.58	0.097	0.196	2.147	2.440	0.397
PFH7	15.560	13.671	88.790	6.587	113.18	0.169	0.082	2.342	2.592	0.364
PFH8	16.820	13.680	88.822	8.876	57.88	0.214	0.147	2.686	3.048	0.612
PFH9	15.555	13.860	87.438	4.178	98.58	0.154	0.118	5.024	5.296	0.291
BLF1	11.270	14.104	79.832	65.367	415.20	0.330	0.127	6.791	7.248	0.240

Appendix 2. (Continued)

	PCO	T	RH	UVD	LW	BS	BC	BP	BA	D
BLF2	11.995	13.752	82.970	19.401	240.63	0.213	0.163	5.695	6.070	0.200
BLF3	17.145	14.057	78.772	11.767	279.65	0.432	0.091	5.455	5.978	0.097
BLF4	14.878	14.013	80.307	26.688	307.38	0.507	0.127	11.394	12.028	0.182
BLF5	12.820	15.025	80.151	24.052	241.60	0.280	0.129	2.844	3.253	0.328
BLF6	14.915	13.618	85.704	27.696	324.40	0.449	0.160	1.935	2.544	0.320
BLF7	16.990	13.700	82.470	32.052	231.58	0.186	0.101	3.047	3.333	0.349
BLF8	12.235	13.778	81.638	26.700	181.60	0.244	0.120	1.211	1.575	0.318
BLF9	18.868	13.422	86.837	45.750	203.33	0.218	0.189	1.781	2.188	0.288
BLF10	14.348	13.848	83.296	15.524	251.10	0.194	0.154	3.172	3.519	0.215
BLF11	16.030	13.078	83.511	26.706	142.18	0.285	0.192	2.292	2.769	0.450
BLF12	13.185	13.784	83.708	17.786	220.00	0.285	0.193	3.385	3.863	0.263

Appendix 3. Composition and number of individuals of spider guild, family and morpho-species sampled from one year before thinning at each sampling plot in three different thinning treatments in Ren-Luen, central Taiwan.

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Ground hunter			24	9	1	12	8	6	22	28	32	1	43	33	219
	Gnaphosidae		1	0	0	1	1	3	2	1	3	0	1	0	13
		Gna 001	0	0	0	0	0	2	0	0	1	0	1	0	4
		Gna 003	0	0	0	0	0	0	1	0	0	0	0	0	1
		Gna 006	0	0	0	0	1	0	1	0	0	0	0	0	2
		Juv	1	0	0	1	0	1	0	1	2	0	0	0	6
	Liocranidae		0	3	0	7	1	1	4	6	0	1	6	7	36
		Lio 001	0	0	0	0	0	0	1	0	0	0	0	0	1
		Lio 002	0	0	0	1	0	0	0	0	0	0	0	1	2
		Lio 003	0	0	0	4	0	0	0	4	0	0	2	0	10
		Lio 010	0	0	0	0	0	0	1	0	0	0	2	1	4
		Juv	0	3	0	2	1	1	2	2	0	1	2	5	19
	Lycosidae		21	6	1	4	5	2	16	21	27	0	35	26	164
		Lyc 001	0	0	0	0	0	0	0	0	0	0	1	0	1
		Lyc 003	5	2	0	0	3	0	6	4	8	0	5	12	45
		Lyc 004	0	0	0	0	0	0	0	1	0	0	4	1	6
		Lyc 005	2	0	0	0	0	1	2	0	0	0	0	0	5
		Lyc 006	2	0	0	2	1	0	4	6	3	0	3	2	23
		Lyc 007	0	0	0	0	0	0	0	1	0	0	7	0	8
		Lyc 008	3	0	0	0	0	0	1	0	0	0	0	0	4
		Juv	9	4	1	2	1	1	3	9	16	0	15	11	72
	Oonopidae		2	0	0	0	1	0	0	0	2	0	1	0	6
		Oon 001	0	0	0	0	0	0	0	0	1	0	0	0	1
		Oon 002	0	0	0	0	1	0	0	0	0	0	0	0	1
		Oon 008	0	0	0	0	0	0	0	0	0	0	1	0	1
		Juv	2	0	0	0	0	0	0	0	1	0	0	0	3
Orb web weaver			1	1	2	2	1	4	0	4	0	0	1	2	18
	Araneidae		1	1	1	2	1	4	0	4	0	0	1	1	16
		Juv	1	1	1	2	1	4	0	4	0	0	1	1	16
	Tetragnathidae		0	0	1	0	0	0	0	0	0	0	0	1	2
		Tet 005	0	0	0	0	0	0	0	0	0	0	0	1	1
		Tet 010	0	0	1	0	0	0	0	0	0	0	0	0	1
Other hunters			14	8	3	5	8	7	13	8	10	3	11	19	109
	Clubionidae		2	2	0	3	1	1	5	3	3	2	1	11	34
		Clu 010	0	2	0	1	1	0	2	0	1	0	0	0	7
		Clu 011	0	0	0	0	0	1	0	0	0	0	0	0	1
		Clu 014	0	0	0	0	0	0	0	0	1	0	0	0	1
		Clu 017	0	0	0	0	0	0	1	0	0	0	0	0	1
		Clu 021	0	0	0	0	0	0	0	0	0	0	0	2	2

Appendix 3. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
	Clubionidae	Clu 023	0	0	0	1	0	0	0	1	0	0	0	3	5
		Juv	2	0	0	1	0	0	2	2	1	2	1	6	17
	Ctenidae		9	2	0	1	4	6	5	4	6	1	5	5	48
		Cte 001	1	0	0	0	2	5	3	1	4	0	4	3	23
		Cte 002	0	0	0	1	2	0	1	2	0	0	0	1	7
		Juv	8	2	0	0	0	1	1	1	2	1	1	1	18
	Salticidae		3	4	3	1	2	0	1	1	1	0	4	3	23
		Sal 011	1	0	0	0	0	0	0	1	1	0	0	1	4
		Sal 012	1	2	1	0	2	0	0	0	0	0	1	1	8
		Sal 031	0	0	0	0	0	0	0	0	0	0	0	1	1
		Sal 032	1	1	0	0	0	0	0	0	0	0	1	0	3
		Juv	0	1	2	1	0	0	1	0	0	0	2	0	7
	Sparassidae		0	0	0	0	1	0	2	0	0	0	1	0	4
		Spa 008	0	0	0	0	0	0	1	0	0	0	0	0	1
		Juv	0	0	0	0	1	0	1	0	0	0	1	0	3
Sensing web weaver			10	12	25	24	12	14	21	8	15	12	17	10	180
	Atypidae		1	0	0	2	2	5	3	0	0	0	3	3	19
		Aty 001	1	0	0	0	0	4	0	0	0	0	0	0	5
		Aty 003	0	0	0	2	1	1	1	0	0	0	0	2	7
		Juv	0	0	0	0	1	0	2	0	0	0	3	1	7
	Ctenizidae		9	12	25	18	9	8	18	7	15	12	14	7	154
		Cten 001	9	11	24	8	8	8	18	4	15	11	13	3	132
		Juv	0	1	1	10	1	0	0	3	0	1	1	4	22
	Segestriidae		0	0	0	4	1	1	0	1	0	0	0	0	7
		Seg 005	0	0	0	2	1	1	0	1	0	0	0	0	5
		Juv	0	0	0	2	0	0	0	0	0	0	0	0	2
Sheet web weaver			31	19	27	15	21	39	27	16	44	24	24	25	312
	Agelenidae		19	10	12	11	6	23	9	4	31	16	14	4	159
		Age 001	0	0	0	0	0	6	1	0	0	3	1	1	12
		Age 002	0	0	0	0	1	0	0	0	0	0	0	0	1
		Age 005	0	0	0	0	0	3	0	0	0	0	0	0	3
		Age 012	0	0	2	0	0	0	0	0	0	0	1	0	3
		Age 015	1	1	0	1	1	1	2	0	0	0	1	0	8
		Age 017	2	0	2	4	0	4	2	1	1	2	1	1	20
		Age 019	10	7	4	3	2	4	3	0	10	8	5	2	58
		Age 020	0	0	0	0	0	0	0	0	1	0	0	0	1
		Age 022	0	0	1	1	0	0	0	0	0	0	0	0	2
		Age 024	0	0	0	0	0	0	0	0	1	0	1	0	2
		Age 027	0	0	0	1	0	0	0	0	0	0	0	0	1
		Juv	6	2	3	1	2	5	1	3	18	3	4	0	48
	Hahniidae		1	0	0	0	0	0	0	0	1	0	0	0	2
		Hah 004	1	0	0	0	0	0	0	0	0	0	0	0	1
		Juv	0	0	0	0	0	0	0	0	1	0	0	0	1

Appendix 3. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Sheet web weaver	Hexathelidae		2	3	3	0	1	1	4	0	1	1	0	3	19
		Hex 003	0	3	2	0	1	1	2	0	1	0	0	2	12
		Juv	2	0	1	0	0	0	2	0	0	1	0	1	7
	Linyphiidae		9	6	12	4	14	15	12	10	11	7	9	18	127
		Lin 001	0	0	0	0	0	0	1	0	0	0	0	0	1
		Lin 003	0	0	0	0	0	1	1	1	2	0	0	0	5
		Lin 003	0	0	0	0	1	0	1	4	1	0	0	0	7
		Lin 008	1	0	0	1	1	1	0	0	0	1	3	0	8
		Lin 008-2	1	0	0	0	0	0	0	0	1	0	0	0	2
		Lin 022	0	1	0	1	0	0	0	0	0	0	0	1	3
		Lin 024	0	2	0	0	2	0	3	0	0	0	0	1	8
		Lin 035	0	0	0	0	0	2	0	0	0	0	0	0	2
		Lin 040	1	1	0	0	0	0	1	0	0	0	0	0	3
		Lin 048	0	0	0	0	0	1	0	0	0	0	0	0	1
		Lin 049	0	0	2	0	1	0	0	0	0	0	0	0	3
		Lin 050	0	0	0	0	0	1	0	0	0	0	0	0	1
		Lin 055	0	0	0	0	0	0	0	0	0	0	1	0	1
		Lin 057	0	0	1	0	0	0	0	0	0	1	0	1	3
		Lin 059	0	0	0	0	0	1	0	0	0	0	0	2	3
		Lin 063	0	0	0	0	0	0	0	0	0	1	0	0	1
		Lin 073	0	0	0	0	0	0	0	0	1	0	0	0	1
		Juv	6	2	9	2	9	8	5	5	6	4	5	13	74
	Pisauridae		0	0	0	0	0	0	2	2	0	0	1	0	5
		Juv	0	0	0	0	0	0	2	2	0	0	1	0	5
Space web weaver			10	16	11	10	5	13	16	13	12	12	5	10	133
	Pholicidae		1	8	6	0	1	1	9	7	2	1	1	4	41
		Pho 005	1	3	2	0	0	1	1	0	1	0	1	2	12
		Pho 006	0	1	0	0	0	0	0	0	0	0	0	0	1
		Juv	0	4	4	0	1	0	8	7	1	1	0	2	28
	Theridiidae		9	8	5	10	4	12	7	6	10	11	4	6	92
		The 001	1	1	0	1	1	0	0	0	1	0	0	0	5
		The 002	0	0	0	0	0	1	0	0	0	0	0	0	1
		The 010	0	0	0	1	0	0	0	0	0	0	0	0	1
		The 019	0	0	0	0	0	0	0	0	0	0	0	1	1
		The 029	2	1	0	0	1	1	0	0	0	0	1	0	6
		The 030	0	0	0	0	0	1	0	0	1	0	0	0	2
		The 046	2	0	0	0	0	0	0	0	0	0	0	0	2
		The 048	1	1	0	3	0	2	0	1	1	0	0	1	10
		The 052	0	0	0	0	0	0	0	0	0	0	1	0	1
		The 053	0	0	0	0	1	0	0	0	0	0	0	0	1
		Juv	3	5	5	5	1	7	7	5	7	11	2	4	62

Appendix 3. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Specialist			1	0	0	0	0	4	0	0	0	0	0	3	8
	Dysderidae		0	0	0	0	0	0	0	0	0	0	0	1	1
		Juv	0	0	0	0	0	0	0	0	0	0	0	1	1
	Zodariidae		1	0	0	0	0	4	0	0	0	0	0	2	7
		Zod 001	1	0	0	0	0	3	0	0	0	0	0	2	6
		Zod 002	0	0	0	0	0	1	0	0	0	0	0	0	1
TOTAL			91	65	69	68	55	87	99	77	113	52	101	102	979

Appendix 4. Composition and number of individuals of spider guild, family and morpho-species sampled from first year after thinning at each sampling plot in three different thinning treatments in Ren-Luen, central Taiwan.

Thinning treatment			0%				25%				50%				TOTAL
	Plot No.		3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Ambush hunter			0	0	0	0	0	0	0	0	0	1	0	0	1
	Thomisidae		0	0	0	0	0	0	0	0	0	1	0	0	1
		Juv	0	0	0	0	0	0	0	0	0	1	0	0	1
Ground hunter			26	7	14	8	58	7	64	42	67	11	94	80	478
	Gnaphosidae		1	0	0	2	0	3	1	2	1	1	1	1	13
		Gna 001	1	0	0	1	0	0	0	1	0	1	0	0	4
		Gna 002	0	0	0	0	0	1	0	0	1	0	0	0	2
		Gna 008	0	0	0	0	0	2	1	0	0	0	0	0	3
		Juv	0	0	0	1	0	0	0	1	0	0	1	1	4
	Liocranidae		1	0	3	1	0	0	0	3	2	2	5	10	27
		Lio 002	0	0	0	0	0	0	0	0	0	0	0	2	2
		Lio 003	0	0	0	0	0	0	0	1	0	0	0	2	3
		Lio 010	0	0	0	1	0	0	0	0	0	0	0	0	1
		Juv	1	0	3	0	0	0	0	2	2	2	5	6	21
	Lycosidae		23	7	11	4	57	4	63	36	63	7	88	66	429
		Lyc 001	0	0	0	1	0	0	0	0	0	0	0	1	2
		Lyc 002	0	0	1	0	0	0	1	0	0	0	1	0	3
		Lyc 003	0	0	0	1	7	1	3	3	6	1	9	7	38
		Lyc 004	0	0	0	0	0	0	0	0	0	0	4	0	4
		Lyc 006	3	1	0	1	6	0	4	5	7	2	5	7	41
		Lyc 010	0	0	0	0	0	0	0	0	1	0	0	0	1
		Juv	20	6	10	1	44	3	55	28	49	4	69	51	340
	Oonopidae		1	0	0	1	1	0	0	1	1	1	0	3	9
		Juv	1	0	0	0	1	0	0	1	1	1	0	2	7
		Oon 001	0	0	0	1	0	0	0	0	0	0	0	0	1
		Oon 007	0	0	0	0	0	0	0	0	0	0	0	1	1
Orb web weaver			3	2	3	1	1	0	1	1	4	0	2	0	18
	Araneidae		3	2	3	1	1	0	1	1	4	0	2	0	18
		Ara 049	0	0	0	0	1	0	0	0	0	0	0	0	1
		Juv	3	2	3	1	0	0	1	1	4	0	2	0	17
Other hunters			9	6	2	1	2	10	3	2	9	4	6	8	62
	Clubionidae		2	0	0	0	0	0	0	0	1	0	1	0	4
		Clu 010	2	0	0	0	0	0	0	0	0	0	0	0	2
		Clu 019	0	0	0	0	0	0	0	0	1	0	0	0	1
		Juv	0	0	0	0	0	0	0	0	0	0	1	0	1
	Ctenidae		3	1	1	0	2	4	1	1	4	3	2	1	23
		Cte 001	0	1	1	0	0	0	1	1	3	2	2	1	12
		Cte 002	1	0	0	0	2	0	0	0	0	0	0	0	3
		Juv	2	0	0	0	0	4	0	0	1	1	0	0	8

Appendix 4. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
	Plot No.		3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Other hunters	Oxyopidae		0	0	0	0	0	0	0	0	0	0	0	1	1
		Juv	0	0	0	0	0	0	0	0	0	0	0	1	1
	Salticidae		3	4	1	1	0	5	2	1	4	1	3	4	29
		Sa1 012	0	1	0	0	0	0	0	0	0	0	0	0	1
		Sal 006	0	0	0	1	0	0	0	0	0	0	0	0	1
		Sal 011	1	0	0	0	0	0	0	0	1	0	0	0	2
		Sal 012	0	0	0	0	0	1	0	0	2	0	0	0	3
		Sal 037	0	0	0	0	0	0	0	0	1	0	0	0	1
		Sal 046	0	0	0	0	0	2	0	0	0	0	1	1	4
		Juv	2	3	1	0	0	2	2	1	0	1	2	3	17
	Sparassidae		1	1	0	0	0	1	0	0	0	0	0	2	5
		Juv	1	1	0	0	0	1	0	0	0	0	0	2	5
Sensing web weaver			1	0	3	0	0	1	0	4	0	1	3	1	14
	Atypidae		0	0	1	0	0	0	0	0	0	0	1	0	2
		Juv	0	0	1	0	0	0	0	0	0	0	1	0	2
	Ctenizidae		0	0	2	0	0	1	0	4	0	1	2	1	11
		Juv	0	0	2	0	0	1	0	4	0	1	2	1	11
	Segestriidae		1	0	0	0	0	0	0	0	0	0	0	0	1
		Seg 001	1	0	0	0	0	0	0	0	0	0	0	0	1
Sheet web weaver			24	14	9	20	46	69	23	44	49	64	45	37	444
	Agelenidae		4	1	2	4	5	3	1	1	7	6	5	3	42
		Age 001	0	0	0	1	2	0	0	0	0	3	0	0	6
		Age 006	0	0	0	0	0	0	0	1	0	0	0	0	1
		Age 010	1	0	0	0	0	0	0	0	0	1	0	0	2
		Age 012	0	0	0	0	0	0	1	0	0	0	0	0	1
		Age 015	1	0	1	0	0	0	0	0	2	0	1	2	7
		Age 017	0	0	0	1	1	0	0	0	1	1	1	0	5
		Age 019	1	0	0	1	1	0	0	0	1	0	1	0	5
		Juv	1	1	1	1	1	3	0	0	3	1	2	1	15
	Hahniidae		1	0	0	1	0	0	0	0	1	0	1	0	4
		Hah 003	0	0	0	0	0	0	0	0	1	0	1	0	2
		Hah 006	1	0	0	0	0	0	0	0	0	0	0	0	1
		Juv	0	0	0	1	0	0	0	0	0	0	0	0	1
	Hexathelidae		0	3	2	0	0	0	3	1	1	0	4	0	14
		Hex 001	0	0	1	0	0	0	0	0	1	0	0	0	2
		Juv	0	3	1	0	0	0	3	1	0	0	4	0	12
	Linyphiidae		19	10	5	15	41	66	19	42	40	58	35	34	384
		Lin 003	1	0	0	2	3	13	1	5	7	13	4	6	55
		Lin 008	0	0	0	0	5	0	1	0	3	2	0	3	14
		Lin 024	0	0	1	1	3	0	0	2	2	1	2	1	13
		Lin 037	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lin 039	0	0	0	0	1	0	0	2	1	3	1	0	8
		Lin 040	1	0	0	1	0	0	0	0	0	0	2	0	4

Appendix 4. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Sheet web weaver	Linyphiidae	Lin 044	0	0	0	0	0	0	0	0	0	1	0	0	1
		Lin 055	1	0	0	0	0	0	0	0	0	0	0	0	1
		Lin 057	0	1	0	0	1	0	0	0	0	1	0	0	3
		Lin 059	0	0	0	0	0	0	0	0	0	0	2	0	2
		Lin 063	0	0	0	0	1	0	0	0	0	0	0	0	1
		Lin 081	0	0	0	0	0	1	0	0	1	0	0	1	3
		Juv	16	9	4	11	27	52	17	33	25	37	24	23	278
Space web weaver			20	7	14	7	1	5	11	8	20	3	4	7	107
	Leptonetidae		1	0	0	0	0	1	0	0	8	0	0	2	12
		Lep 001	1	0	0	0	0	1	0	0	3	0	0	1	6
		Juv	0	0	0	0	0	0	0	0	5	0	0	1	6
	Pholicidae		16	5	10	2	0	0	9	7	11	2	2	1	65
		Pho 001	2	0	0	0	0	0	0	4	2	0	0	0	8
		Pho 002	0	1	1	0	0	0	0	0	0	0	0	0	2
		Pho 005	0	2	5	2	0	0	4	1	3	0	1	1	19
		Pho 006	2	0	1	0	0	0	1	1	1	0	0	0	6
		Juv	12	2	3	0	0	0	4	1	5	2	1	0	30
	Theridiidae		3	2	4	5	1	4	2	1	1	1	2	4	30
		The 019	0	0	0	0	0	0	0	0	0	0	0	2	2
		The 023	0	0	0	0	0	1	0	0	0	0	0	0	1
		The 048	0	1	0	3	0	0	0	0	0	0	0	0	4
		The 050	1	0	0	0	0	0	0	0	0	0	0	0	1
		Juv	2	1	4	2	1	3	2	1	1	1	2	2	22
Specialist			3	2	2	0	0	1	0	2	2	4	5	0	21
	Zodariidae		3	2	2	0	0	1	0	2	2	4	5	0	21
		Zod 001	2	2	2	0	0	0	0	1	2	3	4	0	16
		Zod 002	0	0	0	0	0	0	0	0	0	1	0	0	1
		Juv	1	0	0	0	0	1	0	1	0	0	1	0	4
TOTAL			86	38	47	37	108	93	102	103	151	88	159	133	1145

Appendix 5. Composition and number of individuals of spider guild, family and morpho-species sampled from second year after thinning at each sampling plot in three different thinning treatments in Ren-Luen, central Taiwan.

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Ambush hunter			0	0	0	0	0	0	0	0	0	1	0	0	1
	Thomisidae		0	0	0	0	0	0	0	0	0	1	0	0	1
		Juv	0	0	0	0	0	0	0	0	0	1	0	0	1
Ground hunter			11	17	90	26	94	17	89	149	133	206	372	221	1425
	Gnaphosidae		0	2	1	4	7	2	5	8	5	21	11	6	72
		Gna 001	0	0	0	3	5	2	3	5	5	15	8	3	49
		Gna 002	0	0	0	0	0	0	1	0	0	0	0	0	1
		Gna 003	0	1	0	0	1	0	1	1	0	1	2	2	9
		Gna 004	0	1	0	0	0	0	0	0	0	0	0	0	1
		Gna 008	0	0	0	0	1	0	0	0	0	2	0	0	3
		Juv	0	0	1	1	0	0	0	2	0	3	1	1	9
	Liocranidae		0	7	0	11	3	2	2	19	10	3	17	15	89
		Lio 002	0	0	0	0	0	0	0	0	1	0	0	0	1
		Lio 003	0	0	0	3	1	0	0	4	0	1	3	2	14
		Lio 010	0	0	0	3	0	0	1	4	0	1	6	2	17
		Juv	0	7	0	5	2	2	1	11	9	1	8	11	57
	Lycosidae		11	7	87	5	81	13	82	119	116	180	344	199	1244
		Lyc 001	0	0	0	0	0	2	0	17	3	15	37	4	78
		Lyc 002	0	0	0	0	0	0	1	2	3	5	34	3	48
		Lyc 003	0	1	3	0	33	3	30	24	15	58	72	59	298
		Lyc 004	0	0	3	0	0	0	0	0	0	0	3	1	7
		Lyc 005	1	2	0	0	0	0	0	0	0	0	0	0	3
		Lyc 006	3	1	12	0	13	1	23	34	26	43	63	32	251
		Lyc 007	0	0	4	0	0	0	0	0	0	0	14	6	24
		Lyc 008	0	0	0	0	18	0	0	0	0	0	0	0	18
		Lyc 010	0	0	0	0	0	0	0	0	0	1	1	0	2
		Juv	7	3	65	5	17	7	28	42	69	58	120	94	515
	Oonopidae		0	1	2	6	3	0	0	3	2	2	0	1	20
		Oon 007	0	0	0	0	2	0	0	0	0	0	0	0	2
		Oon 008	0	0	2	0	1	0	0	1	2	1	0	1	8
		Juv	0	1	0	6	0	0	0	2	0	1	0	0	10
Orb web weaver			0	0	0	1	1	0	0	0	1	0	0	0	3
	Araneidae		0	0	0	1	1	0	0	0	0	0	0	0	2
		Juv	0	0	0	1	1	0	0	0	0	0	0	0	2
	Tetragnathidae		0	0	0	0	0	0	0	0	1	0	0	0	1
		Juv	0	0	0	0	0	0	0	0	1	0	0	0	1

Appendix 5. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Other hunters			6	3	10	8	9	19	24	11	7	11	12	17	137
	Clubionidae		1	0	1	1	1	2	1	0	0	0	1	0	8
		Clu 010	0	0	0	1	1	2	1	0	0	0	0	0	5
		Clu 022	0	0	0	0	0	0	0	0	0	0	1	0	1
		Juv	1	0	1	0	0	0	0	0	0	0	0	0	2
	Ctenidae		3	2	1	3	2	12	13	3	3	8	4	7	61
		Cte 001	0	1	0	0	1	0	2	0	1	3	1	0	9
		Cte 002	0	1	1	1	1	4	6	0	0	2	0	0	16
		Juv	3	0	0	2	0	8	5	3	2	3	3	7	36
	Philodromidae		0	0	0	0	0	0	1	0	0	0	0	0	1
		Juv	0	0	0	0	0	0	1	0	0	0	0	0	1
	Salticidae		1	1	2	1	5	3	6	5	4	2	5	8	43
		Sal 001	0	0	0	0	0	0	1	0	0	0	0	0	1
		Sal 006	0	0	0	0	0	0	0	0	0	0	0	1	1
		Sal 011	1	1	0	0	1	2	0	1	0	1	1	1	9
		Sal 012	0	0	1	0	1	1	0	2	1	0	0	0	6
		Sal 025	0	0	0	0	0	0	0	0	1	0	0	0	1
		Sal 031	0	0	0	0	0	0	0	0	0	0	1	0	1
		Sal 046	0	0	0	1	0	0	1	0	0	1	0	2	5
		Juv	0	0	1	0	3	0	4	2	2	0	3	4	19
	Sparassidae		1	0	6	3	1	2	3	3	0	1	2	2	24
		Spa 001	0	0	1	0	0	0	0	0	0	0	0	0	1
		Spa 007	1	0	0	0	1	0	0	0	0	0	0	0	2
		Spa 008	0	0	0	1	0	0	0	0	0	0	0	0	1
		Spa 010	0	0	1	0	0	0	0	1	0	0	0	0	2
		Juv	0	0	4	2	0	2	3	2	0	1	2	2	18
Sensing web weaver			0	1	1	0	0	2	0	1	1	2	2	2	12
	Atypidae		0	0	1	0	0	0	0	0	0	1	2	1	5
		Aty 003	0	0	0	0	0	0	0	0	0	1	0	0	1
		Aty 005	0	0	0	0	0	0	0	0	0	0	2	1	3
		Juv	0	0	1	0	0	0	0	0	0	0	0	0	1
	Ctenizidae		0	1	0	0	0	2	0	1	1	1	0	1	7
		Juv	0	1	0	0	0	2	0	1	1	1	0	1	7

Appendix 5. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Sheet web weaver			15	10	21	12	26	32	14	13	36	39	19	17	254
	Agelenidae		8	0	5	5	8	11	2	2	15	21	2	3	82
		Age 001	1	0	0	0	0	5	0	0	1	3	1	0	11
		Age 003	0	0	0	0	0	0	0	0	0	5	0	0	5
		Age 009	0	0	0	0	0	1	0	0	0	0	0	0	1
		Age 010	1	0	0	0	0	0	0	0	0	0	0	0	1
		Age 012	1	0	0	0	0	0	0	0	0	0	0	0	1
		Age 015	0	0	0	0	0	0	0	1	4	0	0	0	5
		Age 017	1	0	0	0	0	1	0	0	1	2	0	1	6
		Age 019	1	0	1	1	4	0	0	0	4	7	0	1	19
		Age 022	0	0	1	0	0	0	0	0	0	1	0	1	3
		Age 024	0	0	0	0	1	0	0	0	0	0	0	0	1
		Age 026	0	0	0	0	0	0	0	0	1	0	0	0	1
		Age 027	0	0	1	0	0	0	0	0	0	0	0	0	1
		Age 030	0	0	0	1	0	0	0	0	0	0	0	0	1
		Age 033	2	0	0	1	1	0	0	0	0	0	0	0	4
		Juv	1	0	2	2	2	4	2	1	4	3	1	0	22
	Hahniidae		1	1	1	0	0	0	1	0	2	0	0	0	6
		Hah 005	0	1	1	0	0	0	1	0	0	0	0	0	3
		Hah 006	1	0	0	0	0	0	0	0	0	0	0	0	1
		Juv	0	0	0	0	0	0	0	0	2	0	0	0	2
	Hexathelidae		1	2	4	1	1	1	1	0	5	1	4	4	25
		Hex 001	0	1	0	0	0	0	0	0	3	0	2	2	8
		Hex 002	0	0	0	0	1	0	0	0	1	0	0	1	3
		Hex 003	0	0	0	0	0	1	0	0	0	0	0	0	1
		Juv	1	1	4	1	0	0	1	0	1	1	2	1	13
	Linyphiidae		5	7	10	6	17	20	10	11	14	17	13	10	140
		Lin 003	1	1	2	0	3	2	2	3	2	1	1	2	20
		Lin 007	0	0	0	0	0	1	0	0	0	0	0	0	1
		Lin 008	0	1	1	0	3	3	0	0	1	2	1	0	12
		Lin 029	0	0	2	1	0	0	1	0	0	0	0	0	4
		Lin 035	0	0	0	0	0	0	0	0	0	1	0	0	1
		Lin 040	1	0	0	2	0	0	0	1	0	0	0	1	5
		Lin 044	0	1	0	1	0	2	4	3	1	5	2	1	20
		Lin 057	1	0	0	0	2	0	0	0	0	2	0	2	7
		Lin 061	1	1	2	1	2	1	1	1	0	1	1	0	12
		Lin 065	0	0	0	0	0	1	0	0	0	0	0	0	1
		Lin 097	0	0	0	0	0	0	0	0	1	0	1	0	2
		Juv	1	3	3	1	7	10	2	3	9	5	7	4	55
	Psechridae		0	0	1	0	0	0	0	0	0	0	0	0	1
		Juv	0	0	1	0	0	0	0	0	0	0	0	0	1

Appendix 5. (Continued)

Thinning treatment			0%				25%				50%				TOTAL
Plot No.			3	6	10	12	1	4	7	11	2	5	8	9	
Guild	Family	Morphspecies													
Space web weaver			16	33	33	27	39	20	39	20	14	44	39	38	362
	Leptonetidae		1	2	2	2	0	1	0	0	4	0	0	5	17
		Lep 001	1	0	1	2	0	1	0	0	2	0	0	2	9
		Lep 002	0	1	1	0	0	0	0	0	1	0	0	1	4
		Juv	0	1	0	0	0	0	0	0	1	0	0	2	4
	Mysmenidae		0	1	1	1	0	1	2	1	2	2	1	3	15
		Mys 001	0	0	0	0	0	1	2	0	1	0	0	0	4
		Mys 002	0	1	0	0	0	0	0	0	0	0	0	0	1
		Mys 003	0	0	0	0	0	0	0	1	0	0	1	1	3
		Juv	0	0	1	1	0	0	0	0	1	2	0	2	7
	Pholicidae		2	12	15	3	7	2	7	3	3	10	6	10	80
		Pho 005	1	1	9	1	1	2	2	1	0	5	4	6	33
		Pho 006	0	6	4	2	5	0	3	2	1	2	1	2	28
		Juv	1	5	2	0	1	0	2	0	2	3	1	2	19
	Theridiidae		13	18	15	21	32	16	30	16	5	32	32	20	250
		The 001	3	0	0	1	15	7	4	1	1	6	6	1	45
		The 019	0	0	0	0	0	0	0	0	0	0	1	2	3
		The 020	0	0	0	0	0	0	0	0	0	0	0	2	2
		The 023	0	0	2	0	0	0	0	0	0	0	0	0	2
		The 048	1	1	1	1	1	0	3	0	0	5	5	0	18
		The 073	0	0	1	4	0	0	1	2	0	0	0	4	12
		The 076	0	3	2	3	0	0	1	2	0	0	3	1	15
		Juv	9	14	9	12	16	9	21	11	4	21	17	10	153
Specialist			1	0	1	0	1	8	0	0	0	5	2	1	19
	Zodariidae		1	0	1	0	1	8	0	0	0	5	2	1	19
		Zod 001	1	0	0	0	1	8	0	0	0	5	1	1	17
		Zod 003	0	0	0	0	0	0	0	0	0	0	1	0	1
		Juv	0	0	0	0	0	0	0	6	0	0	0	0	6
TOTAL			49	64	156	74	170	98	166	196	192	308	446	296	2215

Appendix 6. Different environmental variables measured from three years at each habitat type in Ren-Luen, central Taiwan. (m: mean; sd: standard deviation; L: illumination within the stand; Dec: decomposition rate of litter; T: temperature; RH; relative humidity; UVD: understory vegetation structural complexity; PCC: percent canopy cover)

	L	Dec	Tm	RHm	PCOm	UVDm	Tsd	RHsd	PCCsd	UVDsd
0%-B1-1	4554.7393	59.3261	15.4709	97.4676	11.8590	24.9466	3.6950	1.6726	1.0961	12.4277
0%-B1-2	1853.8560	61.7836	15.4685	100.0462	10.3108	32.3692	3.5880	1.9874	1.5386	18.7268
0%-B1-3	2897.1576	59.7026	15.6349	98.7689	11.6925	34.0905	3.5935	2.3897	1.4000	11.7634
0%-B1-4	2021.7561	61.5361	15.3113	99.0128	11.1167	40.6135	3.5785	1.4439	1.7904	13.7499
0%-A1-1	5526.8145	78.9467	16.0168	93.0520	15.6358	8.6056	5.5206	1.6328	1.8510	7.4282
0%-A1-2	2145.4696	79.4718	16.1278	92.2012	20.6942	11.7094	5.4940	2.7389	1.0606	12.1085
0%-A1-3	2384.0334	76.2733	15.8090	96.9707	11.6175	23.4106	5.1283	0.8315	2.2251	15.5562
0%-A1-4	1815.5815	82.1067	15.9287	90.0119	18.3158	9.8237	5.4552	3.2447	1.9129	9.2580
0%-A2-1	2674.1781	59.3261	15.7964	93.4272	15.9706	10.2861	5.5090	1.4767	1.6367	6.0291
0%-A2-2	2114.0268	61.7836	15.9080	93.2249	20.7444	14.1026	5.4824	2.7267	1.0526	10.4131
0%-A2-3	2301.4759	49.7026	15.5669	97.6449	11.5769	28.4675	5.1115	0.9234	2.2226	8.4568
0%-A2-4	2002.8952	61.5361	15.8071	88.0501	18.0781	11.5836	5.4417	3.1790	1.8118	8.0662
25%-B1-1	3381.4033	59.3261	15.4046	98.6926	12.7266	36.9778	3.5874	1.4043	2.5381	7.4794
25%-B1-2	1291.6800	61.7836	16.1979	94.1750	11.7842	38.2742	3.2866	7.9643	1.8751	11.7919
25%-B1-3	3531.3441	59.7026	15.8106	93.0899	11.9618	35.1542	3.6671	8.0293	1.0480	8.7964
25%-B1-4	1964.0576	61.5361	15.9668	96.4679	11.4833	50.4342	3.6892	5.0574	1.6901	11.1362
25%-A1-1	10603.9861	75.9467	16.2469	84.7680	27.7500	13.6424	5.5160	16.1993	3.3456	10.9009
25%-A1-2	4441.8811	78.5449	15.8981	95.4400	12.6450	44.9023	5.2862	2.6459	0.8550	7.8360
25%-A1-3	9042.0889	76.2132	16.5235	92.7303	21.2533	27.8877	5.4750	0.9573	1.4345	14.8881
25%-A1-4	6193.1474	69.6324	16.4244	90.4199	25.5633	17.2549	5.7474	2.2920	4.3486	9.6867
25%-A2-1	8814.6517	55.7886	16.0609	81.5051	27.0500	15.7800	5.4887	15.5562	2.8153	9.4005
25%-A2-2	4591.8789	54.2129	15.2712	93.6954	12.8613	44.2526	4.9608	2.7244	0.6475	7.6544
25%-A2-3	3002.4475	54.6936	16.5673	92.4498	20.9442	25.2227	3.9306	1.0474	1.1919	13.2026
25%-A2-4	5647.6088	43.2931	15.7379	90.1036	25.8333	18.6844	5.3505	1.9135	4.2924	8.9560
50%-B1-1	965.4154	59.3261	15.7682	97.4451	12.3183	54.6681	3.6236	1.7873	4.5434	12.0323
50%-B1-2	2157.5966	61.7836	15.3849	97.5638	11.9078	30.5971	3.6672	1.5687	0.7276	11.0683
50%-B1-3	1633.6701	49.7026	16.8136	98.9780	9.9589	49.0134	4.1643	1.1174	1.4975	4.6617
50%-B1-4	1977.6883	61.5361	16.4616	97.8675	11.6511	33.6844	4.1127	1.0926	2.5105	4.9576
50%-A1-1	9725.5716	77.0098	16.4810	87.4664	26.2917	17.7101	5.3546	4.2150	2.4112	7.8023
50%-A1-2	17324.1951	77.9287	16.1117	87.5922	12.9542	43.1261	5.2593	13.3764	2.2589	10.7167
50%-A1-3	9612.7628	73.1360	16.6315	91.9705	17.8467	32.0108	5.5517	1.8334	1.7718	7.6640
50%-A1-4	7725.0291	66.1152	15.9079	93.2156	11.2933	18.2204	5.1603	0.5890	0.7916	5.8651
50%-A2-1	7465.1173	57.6850	16.7587	88.6772	25.6054	19.2821	4.2710	3.0754	1.6354	6.6634
50%-A2-2	17246.9992	60.4992	16.7873	85.9010	13.5552	40.8268	4.0875	12.6444	1.6414	8.9219
50%-A2-3	9007.6561	53.1740	16.3407	93.0959	17.9442	31.1550	5.5424	1.7094	1.7538	7.3386
50%-A2-4	6758.7073	33.9081	15.1301	94.0857	11.4833	20.0775	4.8378	0.7557	0.6212	3.3773