

私立東海大學生物學系碩士論文

論文題目：雅美人森林經營對蜘蛛多樣性之影響

Effect of Yami forest management on spider diversity

on Orchid Island, Taiwan

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Chinese abstract

蘭嶼距離台灣的東南方 92 公里，其森林是東亞分布最北的熱帶森林。本研究藉比較四種不同雅美人經營程度棲地中的蜘蛛多樣性來探討其森林經營模式如何影響生物多樣性。棲地分別為天然林、栽培林、次生林及草原，我們在島的北方、東方及南方分別設立獨立的樣區，各棲地分別設置 5 個 5×5 公尺之採樣點。蜘蛛的採集包含地表到樹冠層，以獲得每個採樣點中不同層次微棲地的多樣性資訊。除此之外我們亦測量植被結構及作為蜘蛛獵物之昆蟲生物量，以了解造成蜘蛛多樣性差異之可能機制。各樣區間之蜘蛛組成相似度經由計算 Bray-Curtis similarities 後，以 Analysis of Similarities 來比較四種類型棲地間的蜘蛛群落組成是否一致。不論是利用物種組成或者是功能群組成來進行分析都顯示在島的不同方位所設立之樣區間其蜘蛛組成沒有顯著的差異；但不同棲地類型間確有顯著的差異。樹冠層的覆蓋與林下層植被的複雜度在不同棲地間有顯著的差異 ($P < 0.001$)，而昆蟲生物量卻不隨著棲地而有所顯著的差異。本研究結果顯示雅美人的森林經營活動可增加具不同結構之植被類型而導致較具多樣性的蜘蛛組成。

關鍵字：生物多樣性，功能群，原住民，蛛形綱，達悟，熱帶雨林，蘭嶼

Abstract

Orchid Island is 92 km off the southeast coast of Taiwan and its forests are the northernmost tropical forests in East Asia. In this study, the effects of Yami people forest management are assessed by comparing the spider diversity in four types of habitats receiving different degrees of managements. Habitat types examined in this study included natural forest, cultivated woodland, second growth and grasslands. All habitat types were replicated in the northern, eastern, and southern region of the island. Spiders were collected from the ground to canopy to obtain a comprehensive representation of the diversity from all layers of microhabitats in the sampling plots. In addition, I measured vegetation structure and prey availability to identify possible factors responsible for the observed differences in spider diversity. Analysis of Similarities was used to quantify the degree of overlap in the Bray-Curtis similarity between sampling plots. Species and guild composition did not vary with location on the island but differed significantly among habitats. The variation in spider diversity was correlated with variations in vegetation structures. Canopy cover and the structural complexity of understory plants differed significantly among habitats. Spider diversity did not seem to be determined by prey availability; because, insect biomass did not vary significantly among habitats. Results of this study suggest that the forest management activities of the Yami people increase spider diversity on

Orchid Island by generating habitat types with different vegetation physical structures.

Key words: aborigines, Botel Tabago, Araneae, biodiversity, Dawu, guild, Lanyu, Tao, tropical forest, Yami

1. Introduction

The function of species diversity and the interaction between human activities with biodiversity are very important (Glowka et al., 1994). The aboriginal traditional habitat management by aboriginals has recently being investigated, especially in Austria and tropical Amazon (Phillips et al., 1994; Bowman, 1998). Aboriginals in tropical regions are deeply dependent on forest because the development of agriculture is not so well (Chen et al., 1982). Bowman (1998) suggests that aboriginal managements such as burning can create mosaics in habitats thus may maintain a high biodiversity.

The aboriginals inhabiting Orchid Island, Yami people, are of Malay-Polynesian origin and migrated from Batan Islands, Philippines about 700 years ago (de Beauclair, 1959). Yami people do not perform large scale clear-cut on forests but create small patches of yam plantation beside forests or taro plantations near streams (Chen et al, 1982). Therefore, most areas of Orchid Island are still covered by various types of forests. In contrast, in a nearby 76km to the north of Orchid Island, the Green Island, the vegetation pattern is significantly different. Green Island was originally also inhabited by Yami people but Han people from Taiwan immigrated in this island about two hundred years ago (Chen et al, 1982). The original vegetation had disappeared in Green Island due to large scale clear-cut for agriculture practices and

grazing (Chen et al., 1982). Habitat management by Han people have significantly affected the biodiversity on Green Island. For example, the butterfly and bird diversities are three times higher than those of Green Island. The difference in species richness of various taxa between those two nearby islands implicates that the forest management by Yami people seems to be able to maintain a high diversity (Chen et al., 1982). Although the way how Yami people manage forests in Orchid Island has been well documented (Cheng and Lu, 2000; Wang et al., 2000; Wang et al., 2003; Wang, 2004), how such practices affected biodiversity is still unclear. In this study, we investigated how forest management by Yami people affected biodiversity using spiders as an indicator.

Spider is the dominate predator in terrestrial ecosystems (Nyffeler 2000). It is an appropriate indicator taxa because they are small and thus sufficient quantity can be sampled from a small area. Moreover, they are all carnivores thus do not depend on specific plant as food source and more numbers than other mammals and birds (Hatley and Macmahon, 1980). In addition, spider species and guild composition are greatly determined by vegetation diversity and structural complexity (Hatley and Macmahon, 1980; Greenstone, 1984; Uetz, 1991; Docherty and Leather, 1997; Dennis et al., 1998; Rypstra et al., 1999; McNett and Rypstra, 2000; Raizer and Amaral, 2001). The vegetative architectural structure determines where spiders attach their

webs and the foraging strategy of non-web building spiders (Uetz, 1991). Prey, mostly insects, in different vegetation patches are also major determinants of spider distribution (Moring and Stewart, 1994). Studies from temperate regions have demonstrated that disturbances such as grazing by cattle or sheep produces a fragmentary vegetation pattern, which provides spiders a complex spatial structure and microclimate heterogeneity (van Helsdingen, 1997). Bell et al. (1999) observed greater diversity in sites with light disturbance than sites with heavy disturbance or climax sites.

Although Yami people do not directly utilize spider, the disturbances generated by their habitat management may affect vegetation structure thus influence spider diversity. Chen and Tso (in press) performed a small scale survey between habitats receiving different degree of Yami management and suggested that traditional management can maintain a high spider diversity by introducing moderate disturbances into the system. However, Chen and Tso (in press) did not investigate the relationship between vegetation structure and spider diversity. In this study, we repeated the study by study by Chen and Tso but with a large sample size. We also assessed possible factors responsible for the observed diversity pattern by quantifying the vegetation structures in different habitats.

2. Material and Methods

2.1. Study site

Orchid Island is 91 km off the southeast of Taiwan and has a total area of 46 km² (Chen et al., 1982). The forests on this island are the northern most tropical forest in East Asia and can be classified as tropical monsoon rain forest according to its climate (Whitmore, 1998). The study sites are established on the northern, eastern, and southern sides of the island respectively. All three study sites contain four types of habitats generated from various management practices by Yami people. These habitats included: natural forest, cultivated woodland, secondary growth, and grassland (Fig. 1). In each habitat, I selected five 5m × 5m sampling plots and the distance between each two of them were at least 7m.

Tree species in different forest type habitats is most abundance in natural forest (101), followed by cultivated woodland (92) and second growth (58) (Wang, 2004). The basal area is also the highest in natural forest (55 m²·ha⁻¹), followed by cultivated woodland (31 m²·ha⁻¹) and second growth (18 m²·ha⁻¹) (Wang, 2004). The density of woody plants is also lower in cultivated woodland (2163 stem·ha⁻¹) than in natural forest (6478 stem·ha⁻¹) (Wang, 2004). However, cultivated woodland has the highest diversity of herbaceous plants (149 species), followed by natural forest (104) and second growth (71) (Wang, 2004).

The natural forests are usually located on the mountain slopes between villages. In addition to coral reefs, almost 18.4% of area on Orchid Island is covered by areas with slope over 30° (Chen, 1993). Compared with the other two sites, the one in the southern side is comparatively more flat. The trees in the natural forest are subjected to low level of selective logging. Individual Yami use special slash marks on the trees to claim log ownership (Chen et al., 1982). They maintain these marks by slashing periodically until they cut-off the trees. The frequency with which marks are re-slashed is determined by the number of trees owned. Logged trees are used to build boats and houses (Wang, 2004). *Garcinia liniix*, *Bischofia javanica*, and *Ficus benjamina* are dominant trees here. *Freycinetia formosana* and *Cyathea fenicis* are comprise most of ground layer in herbaceous plant (Wang, 2004). *Garcinia liniix* and *Ficus benjamina* are used as fishing gear or a part of boat by Yami people in ethnobotany (Wang et al, 2000). Yami people eat the fruits of *Bischofia javanica* and use *Freycinetia formosana* is use as decoration in cloth and rope (Wang et al, 2000).

The trees in the cultivated woodland, however, are divided among paternal groups. Each group maintains a forest for several generations (Wang, 1984; Huang, 1995). The cultivated woodland receives more disturbance on the ground layer vegetation than does the natural forest. Several times each year, the Yami will clean

up weeds and seedlings and harvest seasonal fruits and thus the resulting tree species composition is relatively simple (Wang, 2004). In this area, *Pometia pinnata*, *Artocarpus incisus* and *Areca catechu* are the dominant tree species (Wang, 2004). Each dominate tree species has at least five to eight usages to Yami peoples (Wang et al, 2000). Herbaceous ground layer is mostly composed of *Oplismenus hirtellus*, *Piper betle*, and *Alocasia odora* in herbaceous plant (Wang, 2004). Yami people eat *Piper betle* and use *Alocasia odora* are forage (Wang et al, 2000). Tree diversity is decreased by the managements of the Yami people because they preferentially maintain certain tree species (it was usefully), but the diversity of herbaceous plants is enhanced by such management pattern (Wang, 2004).

The second growth is a type of secondary forest. *Macaranga tanarius*, *Acalypha caturus* and *Ficus septica* are the dominant tree species (Wang, 2004) and the canopy is more open than in the other habitats. *Macaranga tanarius* and *Acalypha caturus* are used as forage and *Ficus septica* is regarded as a repellent for evil spirits (Wang et al, 2000). *Cyclosorus acuminatus var. acuminatus*, *Piper betle* and *Oplismenus hirtellus* comprised most of herbaceous ground layer (Wang, 2004). Secondary growth is basically a fire wood plantation, from which the Yami regularly harvest branches for fuel. Resulting from natural disturbances or continuous human harvesting, the area of secondary growth is fragmented and small.

The grassland is generated from clear-cut forests and is sometimes evolved from abandoned yam plantations (Cohu, 1998). Yami people periodically set fire on grasslands and the burned weed is used as fertilizer (Cohu, 1998). Therefore, grassland is part of the Yami crop rotation (Cohu, 1998). Yami people usually allow the grass to grow in the abandoned yam plantations for three to five years until the land's productivity is recovered (Wang, 1984). *Ipomoea pes-caprae* and *Miscanthus floridulus* are the two most herbaceous plants. *I. pes-caprae* can be used as firebrand and *M. floridulus* are used in many aspects (Wang et al, 2000).

2.2. Method

Three field trips were conducted in January, April and July 2003. In each sampling plot we collected spiders from canopy to ground to have comprehensive representation of all spiders in the plots. Two pitfall traps were established in each sampling plot and in each field trip the traps were open for five days. Two people hand collected all spiders seen from the ground to 2 m in height. In addition to hand-collection, spiders in the sampling plot were collected by sweep-nets. To standardize the effort in each plot in each field trip, I set a 5 minute limit in sampling time. Spiders in the canopy were collected by sweep-nets mounting on an eight-meter-long fishing poles and the sampling time was 10 minutes.

The collected spiders and insects were stored in 70 % ethanol and spiders were

sorted into family according to available keys (Song et al., 1999; Chen, 2002). Based on female epigyne and male palp, adult spiders were identified into species or morphospecies. Besides, spiders were also categorized into foraging guilds according to their prey catching behaviors. Uetz (1999) classified spider families into 8 behavioral guilds. Since he focused on temperate North America fauna, his classification is not applicable to the spiders in tropical Orchid Island because many Orchid Island families are not listed in his classification. Therefore, I combined the behavioral information (appendix 1) described in Uetz et al. (1999) and Höfer and Brescovits (2001) to classify Orchid Island spiders into suitable guilds. The designation of families into appropriate foraging guilds was performed by unweighted pair-group arithmetic average clustering (UPGMA). First, Jaccard similarity index (Kerbs, 1989) was calculated between family pairs according to shared behavior traits using SYSTAT 9 (SPSS Inc., Chicago, Illinois, USA.). Based upon the Jaccard similarities an UPGMA was performed using PRIMER 5 (Clarke and Warwick, 2001) to visualize the grouping patterns of families.

Insects obtained from sweep-netting conducted in July 2003 were sorted into order and were counted to estimate prey availability of sampling plots. After being oven-dried at 50°C for two days, the insects were weighed to the nearest 0.1 mg. I divided insects into two categories according to their body length (greater or small

than two centimeter). The reason for the division is that most of spiders are small and they may not consume insects greater than two centimeter.

2.3. *Quantification of Vegetation Structure*

Quantification of vegetation structure was conducted in the July 2003 field trip. To measure the canopy cover, I used a fish eye lens mounted on a digital camera to take hemispheric photographs of each plot. The photographs were analyzed by Gap Light Analyzer, Version 2.0 (Frazer et al., 1999) to estimate percent canopy cover of sampling plots. The photographs were transformed into black-and-white images to better distinguish between canopy and sky. This adjustment was decided subjectivity by me to eliminate observer bias following the recommendation of Lin and Chiang (2002).

To quantify structural complexities of forest understory vegetation, I used methodologies similar to these of canopy cover estimation. While in canopy cover estimation the sky was the background, in quantifying understory vegetation structure a pink cardboard (53 cm × 76 cm) was used as a background. The cardboard was placed on four cardinal edge of sampling plot and the photographer stood in the middle of plot then took down the images of the cardboard. In each cardinal direction the cardboard was placed at three different heights (low: ground to 60 cm; middle: 70 to 130 cm; high: 140 to 200 cm) to have a better representation of the

vertical stratification of the plots. The images were transformed into black-and-white using Photoshop and measurements from four cardinal directions at each height level were total. This total was then standardized to 100 cm². In each sampling plot, I calculated four understory vegetation complexity values: low, middle and high levels.

2.4. *Statistical Analyses*

The similarity between sampling plots was calculated by Bray-Curtis similarities (Kerbs, 1989) using both species and guild compositions. Then multidimensional scaling plots (MDS) were constructed to visualize the level of spread of sampling plots using PRIMER 5. Analysis of similarities (ANOSIM) was performed between each pair of habitats and between study sites. I tested for differences in canopy cover and insect biomass among habitats by two way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) mean comparison using SYSTAT 9 (SPSS Inc., Chicago, Illinois, USA.). To estimate understory vegetation heterogeneity, I used vegetation complexity values of three height levels to calculate Bray-Curtis similarities between each pair of sampling plots then I use ANOSIM to test for significance. In addition, the RELATE function of Primer 5 was used to examine the coupling of vegetation structure and spider guild composition.

I used complexities from three height levels, canopy cover, numbers of insect

and different classes of insect biomass as potential factors relevant to spider guild composition and calculates standardized Bray Curtis similarities for each of them. The combination of factors that best match spider guild composition was determined by BIO-ENV function of PRIMER 5.

I also calculated spider density, Margalef Species Richness, Shannon-Wiener Function, Simpson index and evenness (Krebs 1989) to describe the community structures of spiders among different habitats. In addition, one-way ANOVA tests and Fisher's LSD mean comparisons were used to compare the values of all indices derived from all the plots of four habitats (SYSTAT 9, SPSS Inc., Chicago, Illinois, USA.).

3. Results

3.1. *Spider guild classification*

The behavioral traits and ecological characteristics of Araneae families commonly seen in Orchid Island are listed in appendix 1. The clustering dendrogram of spider families generated by UGPMA is given in fig. 2. Araneae families commonly seen in Orchid Island could be clustered into the following 6 guilds at the similarity at 40 %: (1) Orb weaver: Araneidae, Tetragnathidae, and Uloboridae; (2) Space weaver: Dictynidae, Pholcidae, and Theridiidae; (3) Ground weaver: Hahniidae and Linyphiidae ; (4) Grounder sedentary weaver: Agelenidae and Amaurobiidae ; (5) Foliage weaver: Clubionidae, Oxyopidae, Salticidae, and Thomisidae ; (6) Ground runner: Lycosidae, Gnaphosidae, Oonopidae, and Zodariidae.

3.2. *Comparison of spider compositions between sites and habitats*

The MDS plot generated from relative abundance of different spider species in each study site is given in fig. 3a. Result of a two-way nested ANOSIM test showed no significant differences ($p>0.05$) among study sites located on northern, eastern, and southern regions of Orchid Island (table 1a). The MDS plot generated from relative abundance of different spider species in each habitat is given in fig. 3b. Sampling

plots from each type of habitats were basically clustered with each other and results of pair-wise ANOSIM test also showed significantly different between four habitats (table 1b).

3.3. *Comparison of guild composition between sites and habitats*

The MDS plot generated from relative abundance of different spider guilds in each study site is given in fig. 4a. Again, it is difficult to separate sampling plots of the three sites and results of pair-wise ANOSIM test also showed no significant differences (table 1a). The MDS plot generated from relative abundance of spider guilds in different habitats is given in fig. 4b. Results of ANOSIM tests showed that most habitats were significantly different ($p < 0.001$) from each other, except between cultivated woodlands and second growth (table 1b). Abundance of various spider guilds in different habitats is shown in fig. 5. In the natural forest, orb weavers were the most dominant guild. This result is congruent with that reported by Chen and Tso (in press). Sampling plots in cultivated woodland (fig. 5b) and second growth (fig. 5c) exhibited very similar patterns, both were dominated by space weavers followed by orb weavers and others. Such pattern might explain the non-significant ANOSIM results (table 1b) between these two habitats. In the other habitats the dominated spider guilds varied. In grassland, orb and space weavers were less representative while ground weaver and non-weaver were the most abundant

components of spider communities.

3.4. *Comparison of vegetation structure and insect biomass between habitats*

The results of quantification of various aspects of vegetation structure are given in fig. 6. The canopy cover varied significantly among habitats (table 2a), except between sampling plots of natural forest and cultivate woodland (Fig. 6a). High level understory vegetation complexity varied significantly among habitats (table 2b) when analyzed by two-way ANOVA, while it not comparable in one-way ANOVA test (fig. 6b). When the understory vegetation complexities were compared by one-way ANOVA, no significance was found between habitats (fig. 6b) although the value in cultivated woodland looked considerably smaller than those of the other habitats. Middle level of understory vegetation complexity also varied significantly (table 2b), because the density of cultivated woodland was significantly lower ($p < 0.05$) than those of the others habitats (fig. 6c). Although low level of understory vegetation complexity again varied significantly among habitats (table 2b), three forests habitats exhibited similar values and grassland had significantly higher value (fig. 6d). The results of pair-wise ANOSIM comparing different height levels of understory vegetation complexities between habitats are given in table 3. Understory vegetation complexities varied significantly among habitats (table 3), except between sampling plots of cultivate woodland and second growth. The

results of two-way AONVA tests comparing insect biomass between habitats is given in table 2. The insect biomass was not significantly different between habitats and sites no matter analyzed using combined data or data from different size categories.

The combination of environmental factors that best correlated with spider guild composition patterns generated by BIOENV of PRIMER 5 were canopy cover, middle and high levels of understory vegetation complexities. Results of RELATE test showed that a significant correlation existed between these selected factors and spider guild composition (Spearman rank coefficient $Rho=0.151$, $p<0.05$).

3.5. Comparison of community structures between habitats

The density of adults was the highest in cultivated woodland and lowest in grassland (Table 4). The evenness and Simpson index were not significantly different among the four habitat types (Table 4). However, Margalef Species Richness and Shannon-Weiner function of cultivated woodlands were significantly lower than natural forest and second growth.

4. Discussion

Results of this study demonstrate that management by Yami people change vegetation structures and spider communities of forests. Habitats receiving different degree of management by Yami people varied in spider species and guild compositions and such results might be generated by these management's impact on vegetation structures as were demonstrated in many studies (Hatley and Macmahon, 1980; Greenstone, 1984; Docherty and Leather, 1997; Rypstra et al., 1999; McNett and Rypstra, 2000; Raizer and Amaral, 2001). We also found that although sampling plots in natural forests exhibited highest canopy cover and understory vegetation complexity, they did not have higher spider diversity. Such results were not congruent with previous studies by Greenstone (1984) or Hatly et al. (1980). In Orchid Island, the habitat exhibiting highest spider diversity and density is the cultivated woodland, which has lower level of understory vegetation complexity and less disturbances. Such result confirms the work of Chen and Tso (in press), who also compared the spider diversity of habitats receiving various degree of management but small sample size. However, moderate management can maintain high diversity in cultivated woodland. It is a paradigm on forest management and conservation spider diversity.

A comparison of measurement of canopy covers among habitats indicates that

the long-term management of cultivated woodland by Yami people over several generations did not result in significant reduction of canopy cover (fig. 6). A significantly smaller canopy cover was only seen in second growth, which received substantially more disturbances compared with those of the cultivated woodland. A more open canopy might have enhanced a dense low level vegetation layer (fig. 6b) in grassland habitat thus generated a vegetation structure different from other habitats. The significant difference in spider composition between forest and grassland habitats may result from alternations in microclimates generated by a much more open canopy cover and availabilities of web attachment sites due to a much denser herbaceous layer. Such understory vegetation structure to the vertical vegetation structure could not provide suitable space for web building spiders, so the abundance of this guild was quite low here (fig. 5). Results of this study also showed that similar spider composition was similar between cultivated woodland and second growth (fig. 5a and b). In contrast to that of natural forest, understory vegetation structures were sparser in these two habitats. After the management by Yami people, the high and middle layer of understory vegetation in cultivated woodland were less complexity and this might explain a significant ANOSIM results in vegetation structure between natural forest and cultivated woodland.

While spider species and guild compositions varied among habitats, insect

biomass did not show similar variation pattern (Table 3). This result suggests that prey availability might not affect spider diversity via a bottom up effect (Scheu and Schaefer, 1998). Instead, vegetation structure might be more critical. Such find also agrees with that reported by Greenstone (1984) from studies conducted in Central American tropical forest.

Sampling plots in natural forest were dominated by orb weavers (fig. 5a), which result in congruent with that reported by Chen and Tso (in press). Compared with space web weavers, the webs constructed by orb weavers are more fragile thus are more intolerant of frequent disturbances. Primary forests exhibiting low level of disturbances and their dense understory vegetation provided web attachment site for orb weavers. Compared with orb weaver, space weaver can higher level of tolerate disturbance, which may explain why it is more abundant in cultivated woodland and second growth. The most abundant guild in grassland is the ground runner. Orb weaver and space weaver spiders were few, which probably resulted from lack of suitable microhabitats for web construction (vegetation too density) and alternation in microclimates due to a much more open canopy (such as a stronger wind).

Results of this study showed that spider diversity is highest in cultivated woodland. Since the spider guild composition and understory vegetation structure between woodland and second growth are similar, why second growth have

significantly lower spider diversity.

This might result from different levels of disturbances received by these two habitats. While cultivated woodland seldom experienced clear-cut, second growth was all evolved from clear-cut woodland. In addition, sampling plots in second growth are frequently harvested for twigs, branches to use as fuels and disturbances were much larger (Wang, 2004). Moreover, a significantly more open canopy cover may severely change microhabitats, *Nephila pilipes* is the dominant orb weaver in cultivated woodland while *Thelacantha brevispina*, *Tylorida striata* and *Leucauge decorate* is dominant orb weaver in second growth. Nevertheless, while ground weaver *Hahnina kaisaisa* is abundant in cultivated woodland, they were significantly fewer in second growth.

Results of this study demonstrated that the traditional habitat management by Yami people maintains and even enhances spider diversity in Orchid Island. However, aboriginal people on Orchid Island are currently facing stresses from modernization and development (Severinghaus, 1999). While Yami people did not use money 70 years ago, the use of currency has greatly enhanced commercial activities of this island. Traditionally, natural resources were extracted only to fulfill the needs of individuals or the family groups (Cheng, 2001; Wang, 2004). However, to meet various needs of modern society and tourists some inhabitants are being exploited

natural resources and trade for money (Cheng, 2001). Modernization step by step is changing the traditional values of Yami people. Although older people still follow the traditional way to manage the forest resources, fewer and fewer young generations are involved in such practices (Cheng, 2001). If such down-going trend continues, the traditional management practices maintaining the biodiversity of this island for hundreds of years may gradually disappear. Policies taking into account the roles Yami people's habitat management played in shaping the biodiversity as is revealed by this study are urgently needed to conserve the cultural and biological diversities of Orchid Island.

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Table 1. Results of pair-wise ANOSIM tests comparing spider species and guild compositions between different study sites (a) and habitats (b). (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: non significant at $\alpha = 0.05$ level)

Comparison	Species composition		Guilds composition	
	R	significance level	R	significance level
(a) Among study sites				
Global R	-0.10	NS	-0.11	NS
Northern vs. Eastern	-0.13	NS	-0.13	NS
Northern vs. Southern	-0.09	NS	-0.17	NS
Eastern vs. Southern	-0.10	NS	-0.06	NS
(b) Among habitats				
Global R	0.43	***	0.35	***
Natural forest vs. cultivated woodland	0.37	***	0.24	***
Natural forest vs. secondary growth	0.37	***	0.15	**
Natural forest vs. grassland	0.49	***	0.54	***
Cultivated woodland vs. secondary growth	0.20	**	0.00	NS
Cultivated woodland vs. grassland	0.70	***	0.67	***
Secondary growth vs. grassland	0.59	***	0.64	***

Table 2. Results of two-way ANOVA tests comparing canopy cover (a), understory vegetation structure complexity (b) and insect biomass (c) between different sites and habitats. (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: non significant at $\alpha = 0.05$ level)

	Habitat		Site		Site * Habitat	
	F-ratio	significance level	F-ratio	significance level	F-ratio	significance level
(a) Canopy cover	496.51	***	5.98	***	6.64	***
(b) Vertical vegetation structural complexity						
High level	5.00	**	2.44	NS	3.53	**
Middle level	6.04	***	4.87	***	5.66	***
Low level	3.36	*	37.70	***	1.96	NS
(c) Insect biomass						
Overall	0.53	NS	1.92	NS	4.08	***
Body length > 2 cm	0.07	NS	1.30	NS	1.13	NS
Body length < 2 cm	1.00	NS	2.03	NS	3.62	***

Table 3. Results of pair-wise ANOSIM tests comparing understory vegetation complexity between different habitats in Orchid Island, Taiwan. (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: non significant at $\alpha = 0.05$ level).

Comparison	understory vegetation complexity	
	R	significance level
Global R	0.31	***
natural forest vs. cultivated woodland	0.21	**
natural forest vs. secondary growth	0.1	*
natural forest vs. grassland	0.41	***
cultivated woodland vs. secondary growth	-0.04	NS
cultivated woodland vs. grassland	0.71	***
secondary growth vs. grassland	0.46	***

Table 4. Number of spider species and mean (\pm SE) density, Richness, Evenness, Shannon and Simpson indices of sampling plots in four habitats in Orchid Island, Taiwan and the result of ANOVA and Fisher's LSD mean comparison. (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: non significant at $\alpha = 0.05$ level).

Habitat	Species	Density *	Richness	Evenness	Shannon	Simpson
Natural forest (N)	78	21.20 \pm 2.10	3.96 \pm 0.24	0.93 \pm 0.01	2.36 \pm 0.07	0.93 \pm 0.01
Cultivated woodland (C)	88	24.33 \pm 2.32	4.42 \pm 0.25	0.94 \pm 0.01	2.50 \pm 0.06	0.94 \pm 0.01
Second growth (S)	62	19.73 \pm 1.78	3.57 \pm 0.20	0.94 \pm 0.01	2.27 \pm 0.07	0.93 \pm 0.01
Grassland (G)	70	13.60 \pm 1.59	3.00 \pm 0.19	0.91 \pm 0.02	1.92 \pm 0.10	0.89 \pm 0.02
<i>F</i> -ratio	-	5.24	7.34	0.84	10.79	2.31
Significance level	-	***	***	NS	***	NS
LSD	-	C > N, S > G	C > N, S > G	-	C > N, S > G	-

*: per sampling plot (25m²)

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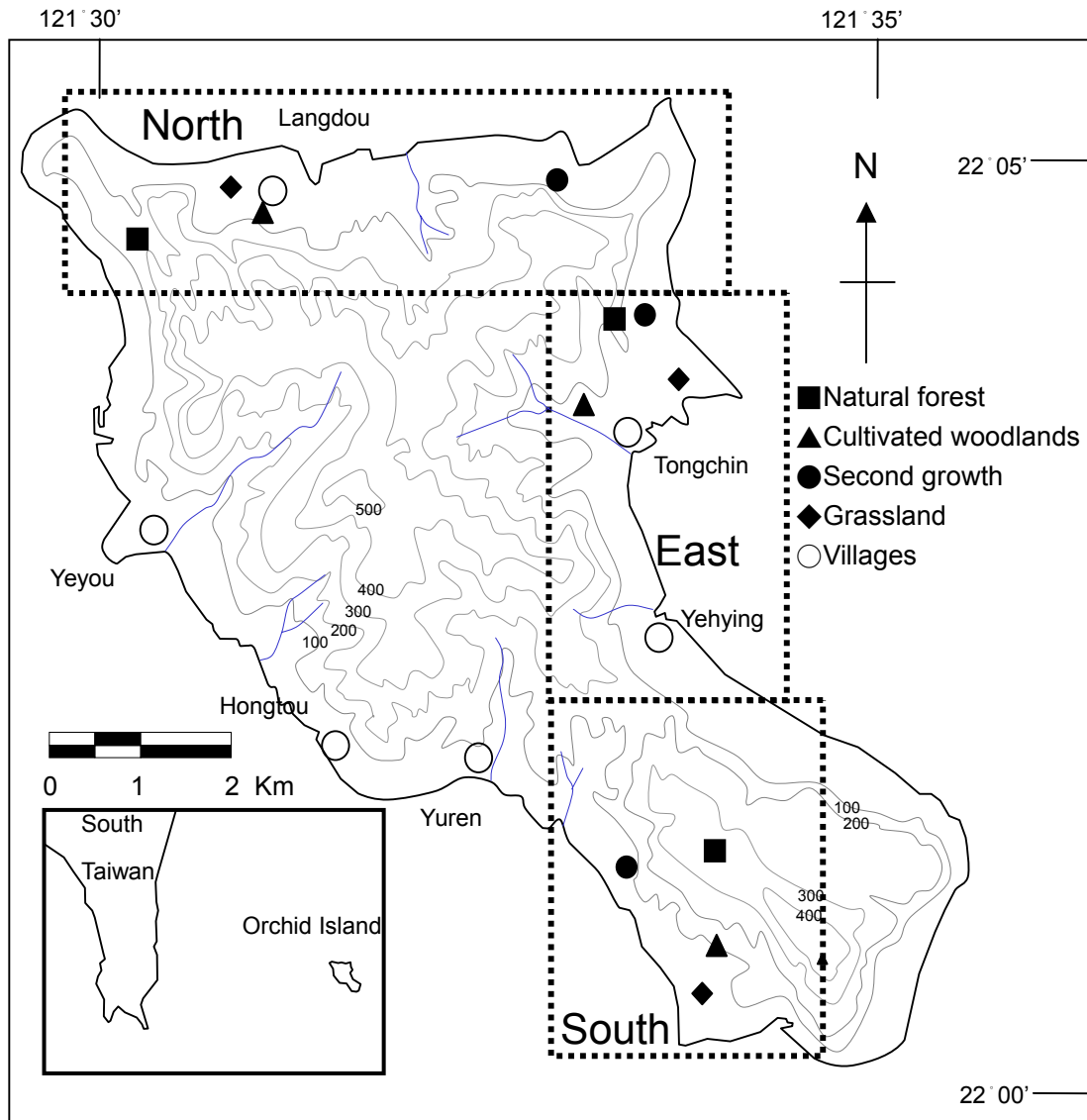


Fig. 1 Map of Orchid Island, Taiwan and the locations of study sites and sampling plots.

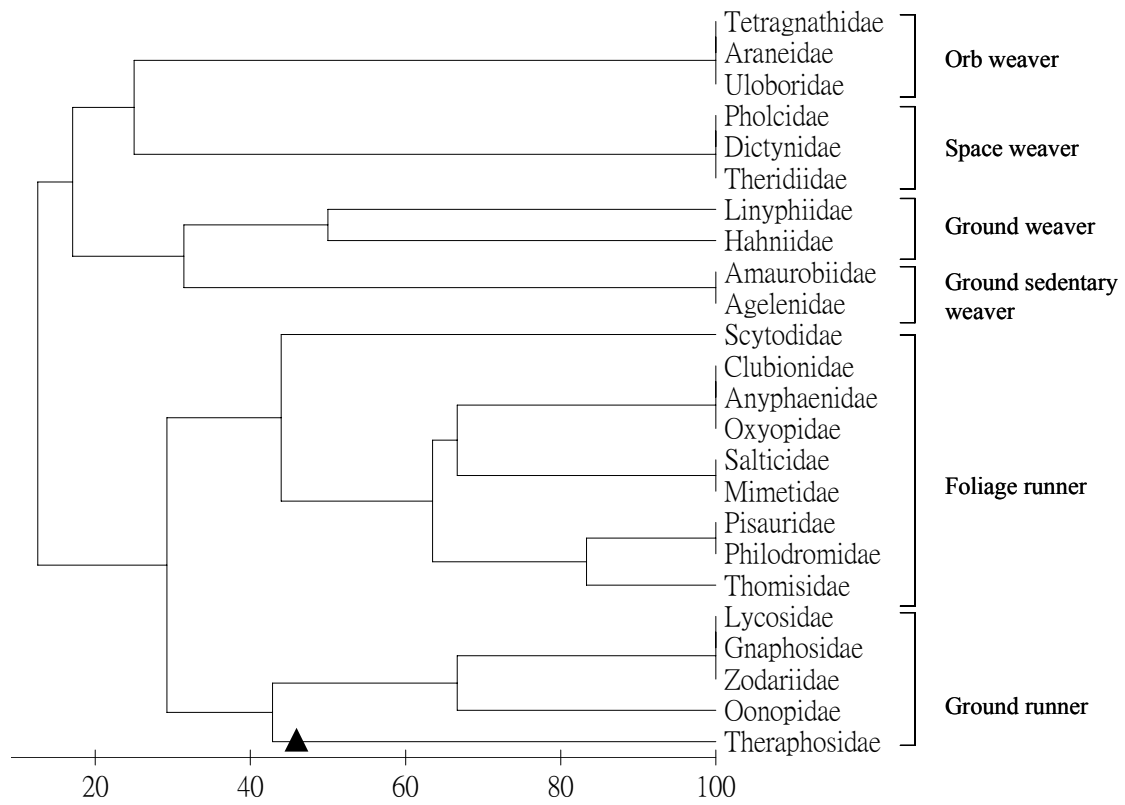


Fig. 2. Clustering dendrogram of Orchid Island spider families generated by UPGMA. Families are categorized into six guilds at the similarity of 40%.

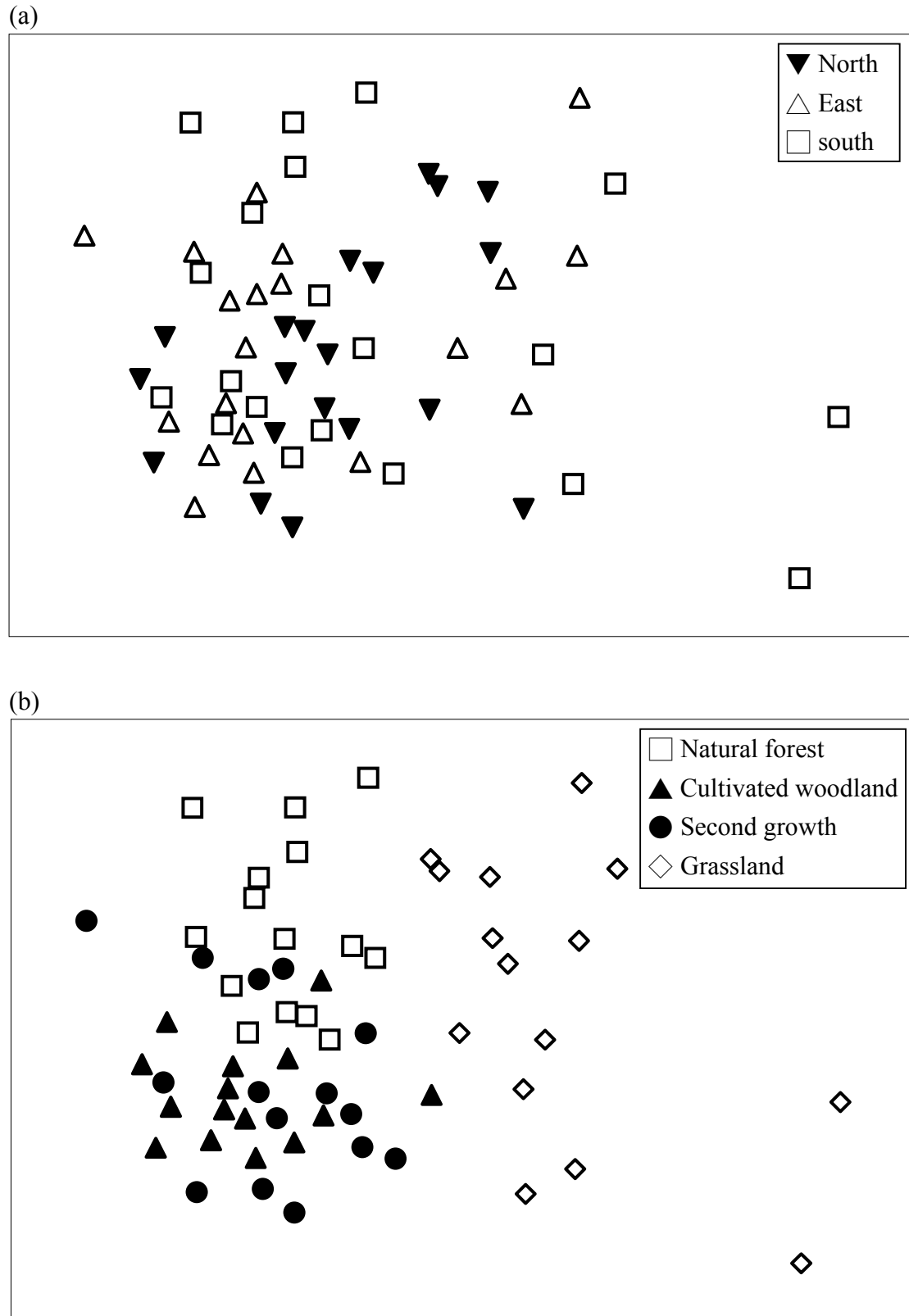


Fig. 3. MDS plots of sampling plots in Orchid Island, Taiwan generated by species composition sorted according to study sites (a) and habitats (b).

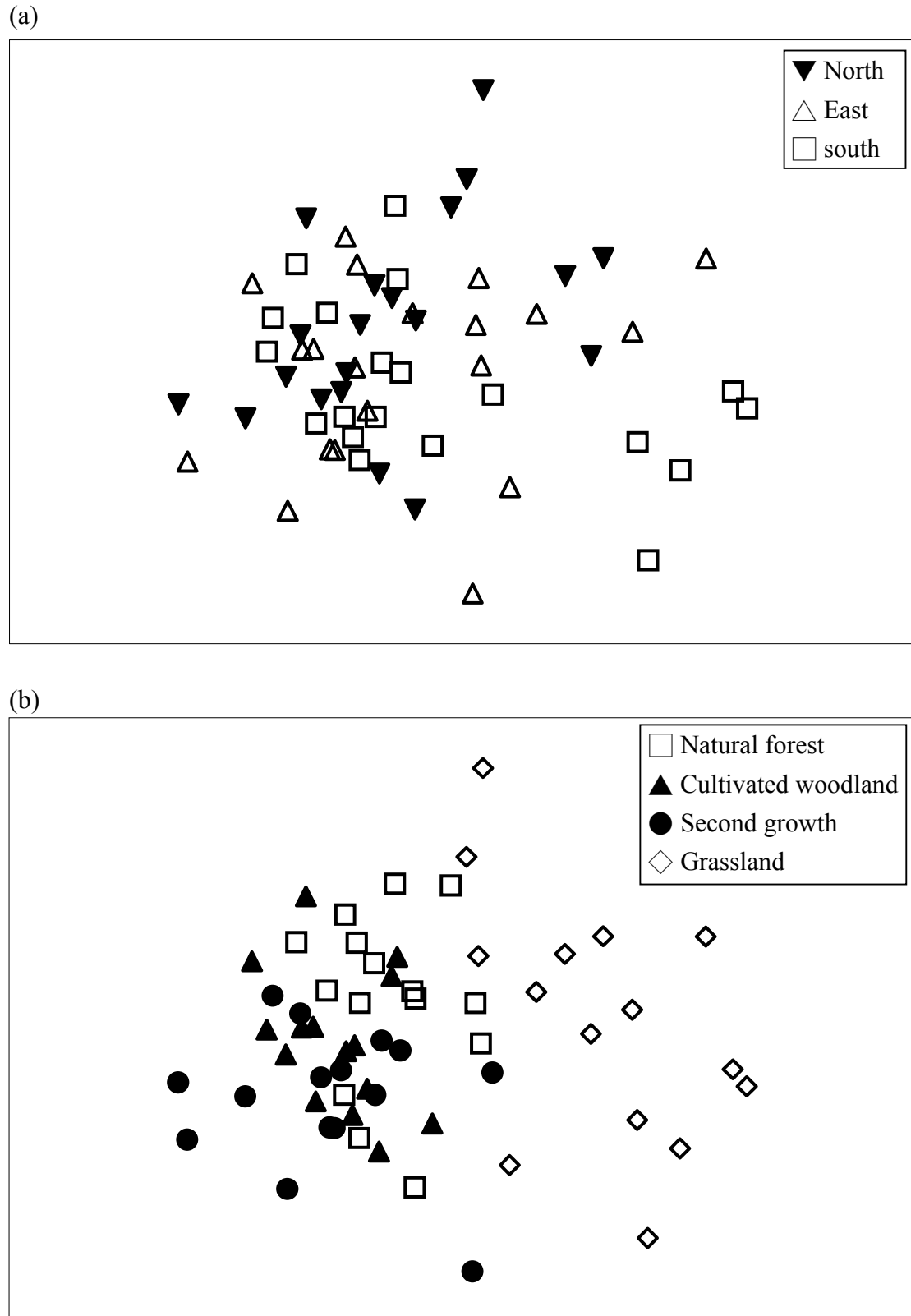


Fig. 4. MDS plots of sampling plots in Orchid Island, Taiwan generated by guild composition sorted according to study sites (a) and habitats (b).

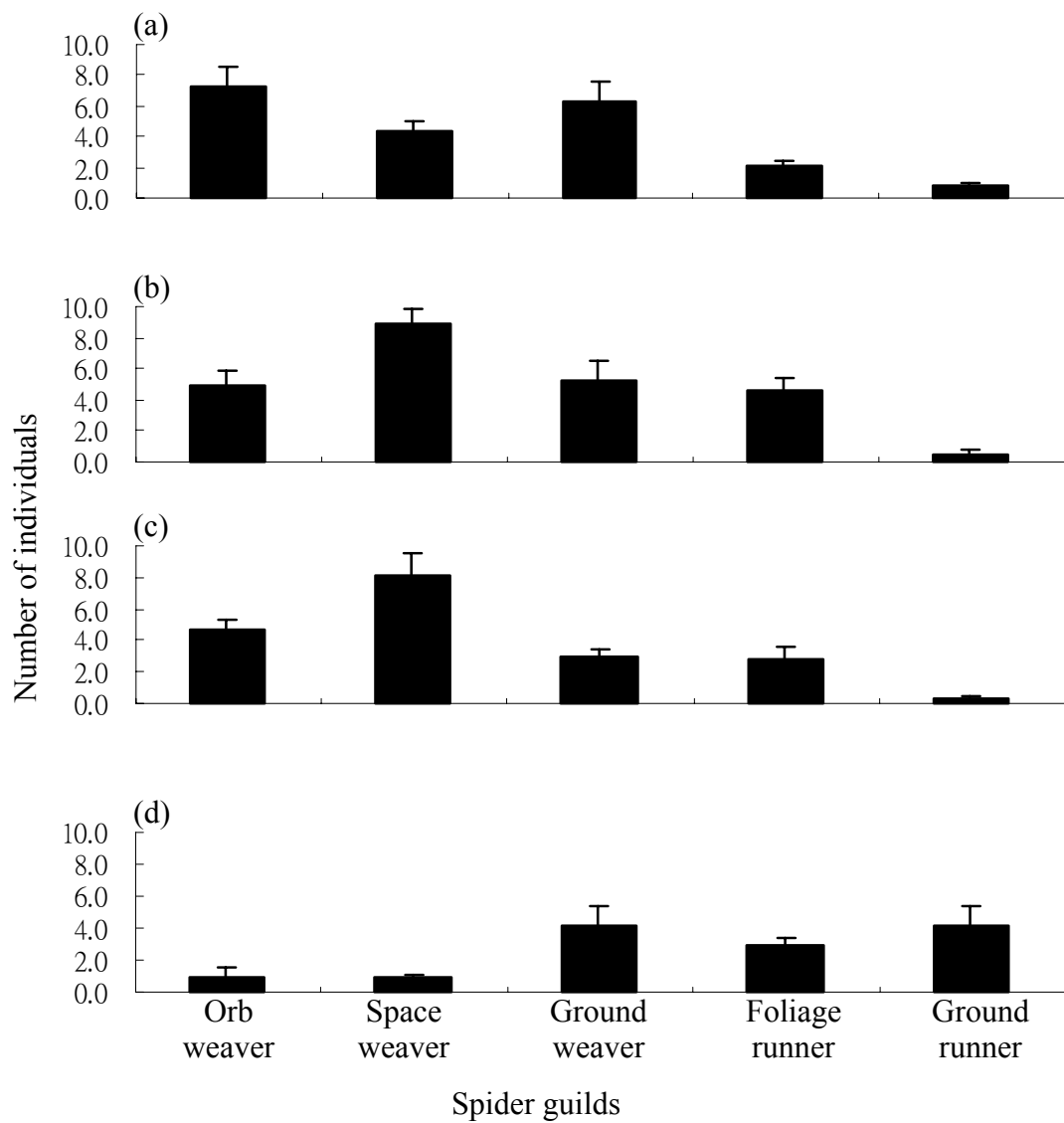


Fig. 5. Abundance (Means \pm SE) of various sampling plots of habitats receiving various degree of Yami forest management. (a) natural forest, (b) cultivated woodland, (c) second growth, (d) grassland.

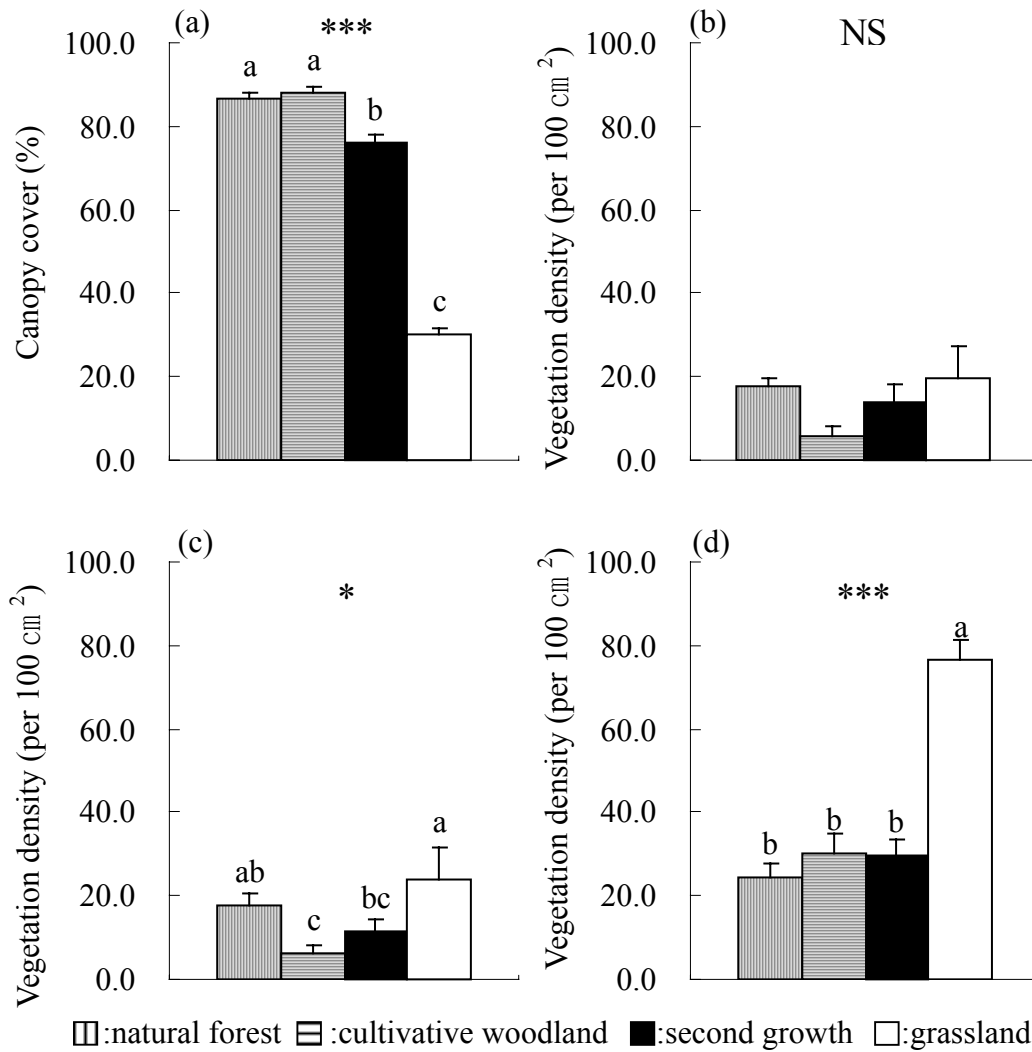


Fig. 6. Mean (±SE) canopy cover (a) and high (b), middle (c), and low (d) level of understory vegetation complexities estimated from four types of habitats in Orichid Island, Taiwan. The labels above each graph are the result of ANOVA and Fisher's LSD mean comparison (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: non significant at $\alpha = 0.05$ level).

Appendix 1. Behavioral traits and ecological characteristics of Orchid Island Araneae family and guilds designated by various studies (modified from Uetz et al, 1999 and Höfer and Brescovit, 2001).

Family	web use			web type			hunting manner			stratum		vegetation dependence			site tenacity			Guild category		
	No web use	sit on web	hunt off web	Sheet web	Space web	Orb web	Ambush	Stalk	Pursue	Ground	Vegetation	No Plant use	On foliage	between plants	Site sedentary	frequent site change	Site mobile	Uetz et al, 1999	Höfer and Brescovit, 2001	This study
Agelenidae	0	1	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	sheet web	-	ground sedentary weavers
Amaurobiidae	0	1	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	sheet web	-	ground sedentary weavers
Anyphaenidae	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	foliage runners	nocturnal aerial runners	foliage runners
Araneidae	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	orb web	aerial orb weavers	orb weavers
Clubionidae	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	foliage runners	nocturnal aerial runners	foliage runners
Dictynidae	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	space web	aerial space web builders	space weavers
Gnaphosidae	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	ground runners	nocturnal ground runners	ground runners
Hahniidae	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	sheet web	nocturnal ground weavers	ground weavers
Linyphiidae	0	0	1	1	1	0	0	0	0	1	1	0	1	0	0	1	0	sheet/space web	diurnal ground orb weaver	ground weavers
Lycosidae	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	ground runners	sedentary sheet weaver	ground runners
Mimetidae	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	stalk	nocturnal aerial runners	foliage runners
Oonopidae	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	-	litter stalker	ground runners
Oxyopidae	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	stalk	diurnal aerial hunters	foliage runners
Philodromidae	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	ambush	diurnal aerial hunters	foliage runners
Pholcidae	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	space web	sedentary sheet weaver	space weavers
Pisauridae	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	ambush	ground ambushers	foliage runners
Salticidae	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	stalk	nocturnal aerial runners	foliage runners
Scytodidae	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	1	0	-	nocturnal aerial runners	foliage runners
Tetragnathidae	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	orb web	aerial orb weavers	orb weavers
Theraphosidae	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	-	ground ambushers	foliage runners
Theridiidae	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	space web	aerial space web builders	space weavers
Thomisidae	1	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	1	ambush	nocturnal aerial runners	foliage runners
Uloboridae	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	orb web	aerial orb weavers	orb weavers
Zodariidae	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	-	nocturnal ground runners	ground runners