RELATIONSHIP BETWEEN MICROENVIRONMENT OF MANGROVE FORESTS AND EPIPHYTIC FERN SPECIES RICHNESS ALONG THE PAN YI RIVER, THAILAND

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HAYASAKA D, KIMURA N, FUJIWARA K, THAWATCHAI W & NAKAMURA T. 2012. Relationship between microenvironment of mangrove forests and epiphytic fern species richness along the Pan Yi River, Thailand. To clarify the habitat dependency of epiphytic ferns in mangrove forests, we surveyed their species composition and habitat requirements along the Pan Yi River, Thailand. In a multiple regression analysis, the Shannon–Wiener diversity index of epiphytic ferns was most strongly related to the diversity index (H') of mangrove trees. *Cynometra iripa*, *Heritiera littoralis* and *Xylocarpus moluccensis* were utilised as host trees by almost all epiphytic ferns. The occurrence of *Nephrolepis acutifolia* has a positive association with *Xylocarpus moluccensis* trees by a chi-square goodness-of-fit test. At the family level, Polypodiaceae and Davalliaceae were most prominent in mangroves of the Pan Yi river basin. Based on canonical correspondence analysis (CCA), the factors associated with the occurrence of epiphytic ferns were distance from the edge of the river ($p < 0.05$), water salinity ($p < 0.05$), relative light intensity (RLI) ($p < 0.05$) and diameter at breast height (dbh) ($p < 0.05$). Our results showed that *Drynaria quercifolia*, *Davallia denticulata*, *N. acutifolia* and *Pyrrosia lanceolata* were dominant species in the mangrove environment, although each of them had a different habitat. *Nephrolepis acutifolia* and *Davallia solida* are epiphytic ferns occurring almost exclusively in mangroves.

Keywords: Epiphytes, habitat differences, host tree, mangroves, Shannon–Wiener diversity index

HAYASAKA D, KIMURA N, FUJIWARA K, THAWATCHAI W & NAKAMURA T. 2012. Hubungan antara persekitaran mikro hutan bakau dengan kekayaan spesies pakis epifit sepanjang Sungai Pan Yi, Thailand. Kami meninjau komposisi spesies serta keperluan habitat pakis epifit di sepanjang Sungai Pan Yi, Thailand untuk menerangkan ketergantungan habitatnya di hutan bakau. Dalam analisis regresi berganda, didapati indeks kepelbagaian Shannon–Wiener (H') pakis epifit paling kuat berkait dengan indeks kepelbagaian pokok bakau. *Cynometra iripa*, *Heritiera littoralis* dan *Xylocarpus moluccensis* diguna sebagai pokok perumah oleh hampir semua pakis epifit. Ujian kebagusuaian χ^2 menunjukkan bahawa *Nephrolepis acutifolia* mempunyai perkaitan positif dengan pokok *Xylocarpus moluccensis.* Pada peringkat famili, Polypodiaceae dan Davalliaceae paling penting di hutan bakau ini. Berdasarkan analisis padanan kanonik (CCA), faktor yang berkait dengan kewujudan pakis epifit ialah jarak dari tebing sungai ($p < 0.05$), kemasinan air ($p < 0.05$), keamatan cahaya relatif ($p < 0.05$) dan diameter aras dada ($p < 0.05$). Keputusan kami menunjukkan bahawa *Drynaria quercifolia*, *Davallia denticulata*, *N. acutifolia* dan *Pyrrosia lanceolata* merupakan spesies dominan di persekitaran bakau meskipun setiap satunya mempunyai habitat yang berbeza. *Nephrolepis acutifolia* dan *Davallia solida* ialah pakis epifit yang hampir secara eksklusif wujud di kawasan bakau.

INTRODUCTION

In recent years, most natural forests in tropical areas, including mangroves, have been transformed for other landuses (FAO 2003). Mangrove forests, in particular, play an important role as nursery grounds for marine and pelagic species. Although mangroves provide habitats

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**Present address: National Institute for Environmental Studies, Onogawa 16-2, Tsukuba, Ibaraki 305-8506, Japan. E-mail: hayasaka.daisuke@nies.go.jp; awayotou@hotmail.com* as well as resources and ecosystem services to humans, including barriers to tsunami disturbance and climate change (Alongi 2008), mangrove trees have been cut down extensively for a long time without regard for their role in coastal ecosystems. More than 35–50% of the world's mangroves have been destroyed over the past 30 years, primarily due to human activities such as aquaculture, rice cultivation, timber production and urban development (Field et al. 1998, Primavera 2000, Primavera et al. 2004). Deterioration of ecosystem functions causes the reduction, fragmentation or even local extinction of biotas. A great deal of work on this topic has already been conducted (e.g. Walters 2005, Alongi & de Carvalho 2008, Granek & Ruttenberg 2008). Localised and regional loss and fragmentation of mangroves decrease the quality of the remaining habitats (Dahdouh-Guebas et al. 2005).

Results of mangrove vegetation research would be beneficial in conservation and management of mangrove ecosystem. However, information about species richness and habitat requirements for vascular epiphytes such as ferns is insufficient. This lack of information on ferns, as one of the primary components of mangroves, is perhaps due to the low diversity of species (Nakamura 2000). Worldwide, nearly 10% of all higher plant species are epiphytes, including many ferns (Kress 1986). The level of epiphytism is notable among ferns, about 29% of which regularly occur in tree crowns (Benzing 1989). However, vascular epiphytes, including ferns, share few qualities beyond their occurrence in tree crowns (the epiphytic environment) that identify them as a single ecological type primarily due to their diverse phylogenic origins and life forms in forest canopies (Benzing 1987). Although epiphytic ferns produce spores which are highly capable of colonising new habitats, ferns have relatively high mortality and slow growth (Sato et al. 1996). Variations in demographic traits among species may allow for the prediction of changes in future composition of species (Zotz 2007). The most relevant abiotic constraint for growth and vegetative function of vascular epiphytes is water shortage, whereas other factors such as irradiation are generally of lesser importance (Zotz & Hietz 2001). Epiphytic communities reflect the interaction between human impact and natural development (Barthlott et al. 2001, Wolf 2005). Thus, understanding the mechanisms of species richness and the habitat requirements of epiphytic ferns in mangrove forests should be useful for the conservation and management of mangroves which take biodiversity into consideration.

The purpose of this study was to collect basic information about the floristic diversity of epiphytic ferns in mangroves for conservation and management. We surveyed the composition of epiphytic ferns occurring on mangrove host trees along the Pan Yi River, Thailand, to elucidate the factors determining species richness and the distribution of epiphytic ferns in mangrove forests.

MATERIALS AND METHODS

Study site

The study was carried out in mangrove forests along the Pan Yi River, Phang-nga, Thailand located at 8° 20'–8° 30' N latitude and 91° 31' E longitude (Figure 1). Although mangrove forests in this study area (ca. 40,000 ha) have been designated as a national park, the trees have been and are still being cut extensively and illegally for fuel by local residents. Phang-nga has a tropical monsoon climate, with a mean annual temperature of 28.3 °C and mean annual relative humidity of 83%. The dry season is from October till April and the wet season, from May till September. Phang-nga Bay faces the Gulf of Thailand and is characterised by karst substrates. Average tidal variation is 1–2 m, with a maximum of 4 m (Miyagi et al. 1999).

Survey methods

We selected eight study plots where epiphytic ferns appeared and forest physiognomy looked pristine. Each study plot was 0.05 ha in size (10 m wide and 50 m long), extending inland perpendicularly from the edge of the river. Each rectangular plot was divided into five subplots (10 × 10 m), for a total of 40 subplots. In October 2003 and September 2004, the horizontal spatial distribution patterns of the epiphytic fern species in each study subplot were surveyed and recorded based on the dominant cover of each species. Nomenclature for the species observed followed that of Hatsusima (1975), Benzing (1989) and Anonymous (2001). Epiphytic ferns on tall trees were identified visually using binoculars. In this study, the Pan Yi river basin was subdivided as

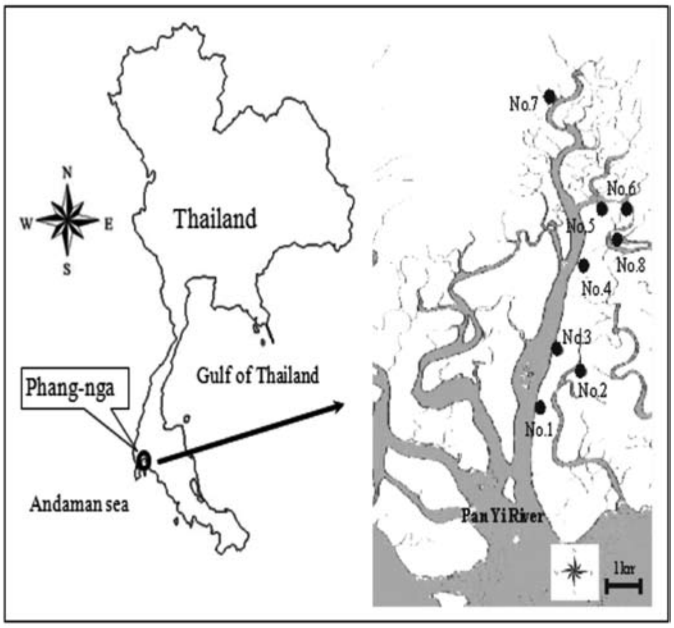

Figure 1 Location of the study sites along the Pan Yi River, Phang-nga, Thailand

follows (Figure 1): (1) a downstream area where *Sonneratia* spp. and *Avicennia* spp. dominate near the edge of the river, (2) a mid-stream area occupied by *Rhizophora* spp. and *Xylocarpus* spp., and (3) an upstream area where the dominant species are back-mangrove and inland forest species such as *Excoecaria agallocha* and *Phoenix paludosa* (Miyawaki et al. 1985, Table 1). We measured diameter at breast height (dbh) of all trees 1.5 m high or taller. Relative light intensity (RLI) was measured at intervals of 5 m in both the x and y directions in each subplot. RLI was classified as follows: (+) under 5%, (1) 5–10%, (2) 10–25%, (3) 25–50%, (4) 50–75% and (5) above 75%. Moss cover on all mangrove trees and water salinity were also recorded for all study subplots. Moss cover on trees was classified as follows: (+) under 5%, (1) 5–10%, (2) 10–25%, (3) 25–50%, (4) 50–75%, and (5) above 75%. These environmental factors were measured once each season (i.e. once each in the dry and monsoon seasons).

Statistical analysis

The difference in species composition of epiphytic ferns among study plots was analysed by cluster analysis based on the Sørensen distance. To test whether occurrences of epiphytic ferns were different between mangrove tree species, we conducted a chi-square goodness-of-fit test (i.e. null hypothesis was that epiphytic ferns occurred evenly across all mangrove trees). To determine factors explaining variation in species diversity of epiphytic ferns among the study plots, we conducted a multiple regression analysis using step-wise selection. The dependent variable was the Shannon–Wiener diversity index (H') for the epiphytic ferns. In general, diversity index is intended to measure biodiversity of an ecosystem. The independent variables employed were the diversity index of mangrove trees, dbh of host trees, moss cover on trees, RLI and water salinity. These data analyses were conducted using SPSS statistical software (version 11.0J, 2001). The relationship between the occurrence of epiphytic ferns and biotic or abiotic factors, including distance from the edge of the river, RLI, water salinity, dbh and moss cover, was analysed by canonical correspondence analysis (CCA) (ter Braak 1986) using PC–ORD statistical software (version 4.0, 1999).

RESULTS

Species diversity of epiphytic ferns among the Pan Yi River

In total, 16 species were recorded in the eight plots along the Pan Yi River. The cluster analysis detected four groups along the river (Figure 2). The characteristics of abiotic and biotic factors of each study plot are shown in Table 1. However, classification of epiphytic fern groups did not

Table 1 Overview of the occurrence of epiphytic ferns in eight study plots in mangrove forests along the Pan Yi River basin

Species name	Family	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Asplenium nidus (Aspl.n)	Aspleniaceae	1						4	1
Davallia denticulata (Dava.d)	Davalliaceae		3	1		1		3	
**Davallia solida (Dava. s)*									1
**Nephrolepis acutifolia (Neph. a)*				2	1	7		1	1
Nephrolepis biserrata (Neph. b)								1	
Nephrolepis falcata (Neph.f)									2
Drymoglossum piloselloides (Drym. p)	Polypodiaceae								1
Drynaria quercifolia (Dryn. q)			5		3		5	22	3
Drynaria sparsisora (Dryn. s)								2	
Microsorum punctatum (Micr. p)								1	2
Myrmecophila sinuosa (Myrm. s)								2	
Phymatosorus scolopendria (Phym. s)			2						1
Platycerium coronarium (Plat. c)									1
Pyrrosia lanceolata (Pyrr. lan)		1	2	3			5	7	5
Pyrrosia longifolia (Pyrr. lon)								3	1
Vittaria elongata (Vitt. e)	Vittariaceae							2	2
Portion of the Pan Yi river basin		Down stream	Upstream	Mid-stream	Mid-stream	Mid-stream	Mid-stream	Upstream	Mid-stream
Number of epiphytic ferns		2	4	3	2	2	2	11	12
Shannon-Wiener's diversity index (H') of epiphytic ferns		1.000	1.888	1.459	0.811	0.544	1.000	2.642	3.327
Number of mangrove trees		7	8	7	8	6	7	10	11
Shannon-Wiener's diversity index (H') of mangrove trees		1.744	2.238	2.272	2.430	1.969	1.729	2.686	2.968
Stand position of host trees from the river edge (m)		0.0–33.3	11.4–35.0	11.0–22.6	7.5–11.8	0.0–14.0	0.5–15.0	0.0–59.0	8.0–50.0
Dbh of host tress (cm)		35.5 ± 30.0	19.4 ± 12.9	39.2 ± 24.2	51.0 ± 7.8	88.0 ± 42.2	26.1 ± 16.6	33.1 ± 27.4	56.2 ± 40.4
Water salinity (%)		2.42	0.55	0.87	1.05	1.37	0.85	0.15	0.23
Moss cover on trees (%)		0.0	0.0	23.5	4.4	14.5	0.0	17.1	0.2

Abbreviations of epiphytic fern names are in parentheses; species are listed alphabetically in family order; * indicates epiphytic mangrove ferns

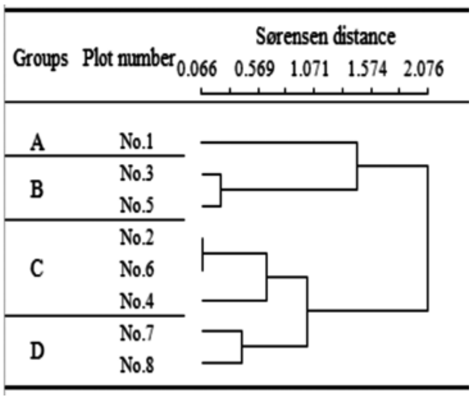

Figure 2 Dendrogram of epiphytic ferns along the Pan Yi River, derived from cluster analysis based on the Sørensen distance, using data for dominant cover of species in each study plot

depend on area of the river basin (Table 1). The number of epiphytic fern species varied from 2 to 12 among study plots. The Shannon–Wiener diversity index (H') was high in plots 7 and 8 (group D) with low water salinity, and low in plots 1 (group A), 5 (group B), and 4 and 6 (group C) with high water salinity. A similar trend was found for the diversity index of mangrove trees. From the 16 epiphytic fern species, *Davallia denticulate*, *Drynaria quercifolia*, *Nephrolepis acutifolia* and *Pyrrosia lanceolata* appeared widely along the river, occurring in more than 50% of all study plots. In addition, many species recorded in this study belonged to Polypodiaceae (9 species, 56.2%) and Davalliaceae (5 species, 31.2%) (Table 1). All ferns of the Vittariaceae are epiphytic (112 species) as well as most Polypodiaceae (93.5%, 1029 of 1100 species) and Davalliaceae (92.7%, 139 of 150 species). This result contrasted with Aspleniaceae reported by Kress (1989) with only 59.3% (400 of 675) epiphytic species.

The stepwise multiple regression models demonstrated significant variation in species diversity of epiphytic ferns ($F = 12.681$, $p < 0.05$) (Table 2). The Shannon–Wiener diversity index of mangrove trees was the only factor that had significant effect on species diversity of epiphytic ferns (i.e. the diversity index of the ferns) (Table 2).

Host trees of epiphytic ferns

There were 648 individual trees in the eight study plots. Of these, 59 individuals (9.1%) carried epiphytes. Host trees for epiphytic ferns in mangrove forests along the Pan Yi River were *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Ceriops decandra*, *Cynometra iripa*, *Heritiera littoralis*, *Rhizophora apiculata*, *Xylocarpus granatum* and *Xylocarpus moluccensis* (Figure 3). Of these, *H. littoralis* (21.2%), *B. gymnorrhiza* (20.0%) and *X. moluccensis* (19.6%) had high rates of epiphyte colonisation, whereas *X. granatum* (1.5%) and *C. decandra* (1.1%) had few epiphytic ferns. Mangrove species *Bruguiera cylindrica*, *Bruguiera parviflora*, *Ceriops tagal*, *Nypa fruticans*, *P. paludosa* and *Rhizophora mucronata* did not carry epiphytic ferns in this study (Figure 3). *Cynometra iripa, H. littoralis* and *X. moluccensis* were utilised as hosts by almost all fern species (Table 3). Although *D. quercifolia* ($\chi^2 = 40.74$, $p < 0.001$) and *P. lanceolata* ($\chi^2 = 18.52$, $p < 0.001$) could utilise many mangrove tree species as their habitats, they were more frequent on *H. littoralis* and *X.moluccensis*. *Nephrolepis acutifolia* ($\chi^2 = 8.33$, $p < 0.01$) utilised *X. moluccensis* as its host (Table 3).

Relationship between species and environmental factors

The CCA ordination (Figure 4) was used to verify relationships between the distributions of the 16 epiphytic ferns in this study area with respect to environmental variables.

Both axes 1 and 2 showed good separation of species. Eigenvalues for axes 1 and 2 were 0.525 and 0.305 respectively. Monte-Carlo permutation tests were significant for both axes ($p < 0.05$). CCA analysis strongly differentiated the distributions of the ferns, according to distance from the edge of the river, RLI, water salinity and dbh of host trees. Axis 1 was positively correlated with dbh ($r = 0.633$, $p < 0.05$) and RLI ($r = 0.669$, $p < 0.05$) but negatively correlated with distance from the river edge ($r = -0.441$, $p < 0.05$). Water salinity ($r = 0.654$, $p < 0.05$) had positive relationship with axis 2.

Nephrolepis spp., including *N. acutifolia, N. biserrata* and *N. falcata,* were more common on thick trees and at more light-exposed sites such as near the edge of the river. *Asplenium nidus* and *Drynaria* spp., including *D. quercifolia* and *D. sparsisora,* were associated with inland areas. *Davallia denticulata* and *Pyrrosia* spp., including *P. lanceolata* and *P. longifolia,* were associated with low water salinity (Table 1, Figure 4).

Table 2 Stepwise multiple regression results for the relationship between species diversity of epiphytic ferns and environmental factors (predictor)[1] in mangrove forests along the Pan Yi River, Thailand

Effect	β	SE	t	p
Species richness of epiphytic ferns ($r^2 = 0.679$, $p < 0.05$)				
Constant	-2.532	1.175	-2.155	ns
Shannon–Weiner's diversity index (H') of mangrove trees	1.825	0.513	3.561	*
Dbh of host trees (cm)			-1.457	ns
Moss cover on tree (%)			-0.611	ns
RLI			-0.741	ns
Water salinity (%)			-1.941	ns

[1] Predictors in the analysis are the Shannon-Wiener diversity index of mangrove trees, dbh of host trees, moss cover on trees, relative light intensity (RLI) and water salinity; ns = not significant, * $p < 0.05$

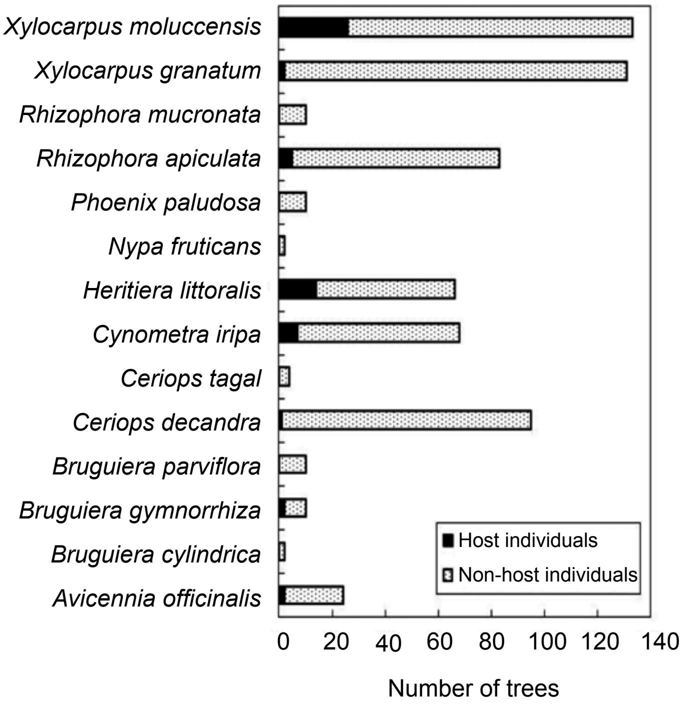

Figure 3 Host and non-host trees for epiphytic ferns along the Pan Yi River

DISCUSSION

Of the 16 epiphytic ferns, 2 species (*A. nidus* and *N. biserrata*) occur widely in tropical to subtropical regions (Hatsusima 1975, Miyawaki et al. 1994), and 14 occur only in tropical regions (Anonymous 2001). There are only eight species of epiphytic ferns in mangroves of Micronesia and there are no epiphytic ferns in mangroves of Tinian in the northern Marianas Islands (Hosokawa 1957). Nine epiphytic ferns occur in mangroves of Sarawak, Malaysia (Chai 1982) and 20 occur in mangroves of Thailand, Malaysia and Indonesia (Nakamura 2000). A total of 16 epiphytes have been described on oil palms in Malaysia (Sato et al. 1996). Our results demonstrated that the species richness of epiphytic ferns in mangroves along the Pan Yi River was similar to that of other tropical regions. *Davallia solida* and *N. acutifolia* were defined as epiphytic ferns occurring almost exclusively in mangroves, i.e. specialists (Nakamura 2000). Others have a wide range of habitats, including mangroves, strand forests, oil-palm plantations and inland forests (e.g. Sato

Table 3 Chi-square goodness-of-fit test results for occurrence of epiphytic ferns on host trees

Host tree Epiphytic fern	*Avicennia officinalis*	*Bruguiera gymnorrhiza*	*Ceriops decandra*	*Cynometra iripa*	*Heritiera littoralis*	*Rhizophora apiculata*	*Xylocarpus granatum*	*Xylocarpus moluccensis*	χ^2	p
Asplenium nidus				1	4	1			3.00	ns
Davallia denticulata					2	1		5	3.25	ns
**Davallia solida*					1					
Drymoglossum piloselloides					1					
Drynaria quercifolia	1	1	1	5	8	5	1	16	40.74	***
Drynaria sparsisora				1	1				0.00	ns
Microsorium punctatum	1				1			1	0.00	ns
Myrmecophila sinuosa			1	1						
**Nephrolepis acutifolia*							1	11	8.33	**
Nephrolepis biserrata							1			
Nephrolepis falcata								2		
Phymatosorus scolopendria					1			2	0.33	ns
Platycerium coronarium								1		
Pyrrosia lanceolata		1	1	2	11			8	18.52	***
Pyrrosia longifolia				3	1				1.00	ns
Vittaria elongata		1			2			1	0.50	ns

ns = not significant, **$p < 0.01$, ***$p < 0.001$; * indicates epiphytic mangrove ferns; species are listed in alphabetical order

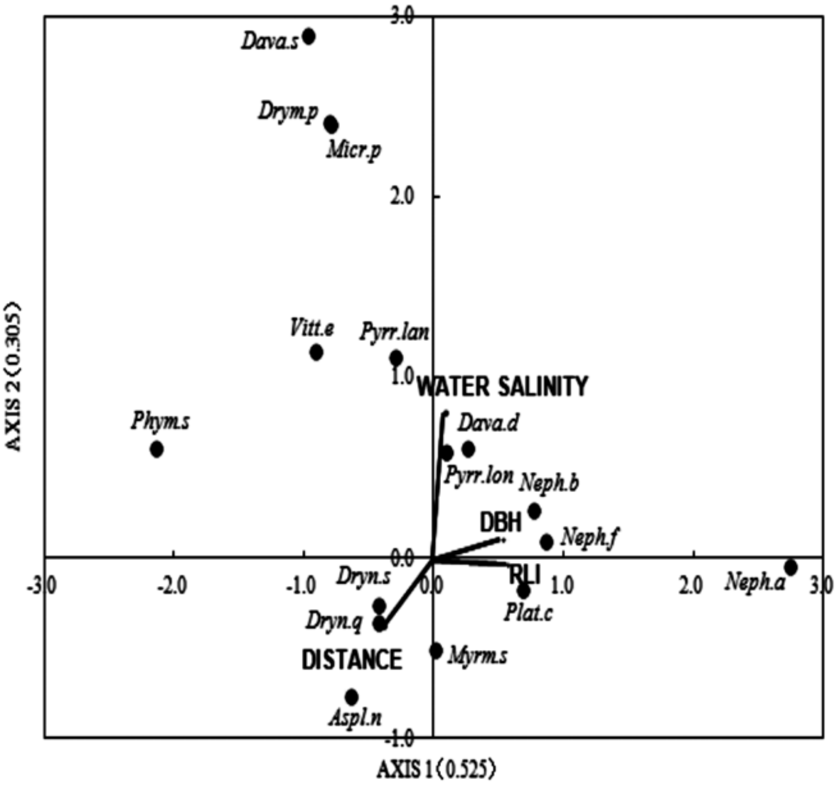

Figure 4 Canonical correspondence analysis (CCA) diagram for epiphytic ferns in all study subplots and for all environmental factors (bold characters). Eigenvalues for the axes are shown in parentheses. Before the CCA was carried out, environmental variables that were mathematical combinations of others were excluded (the amount of garbage and moss cover), as was one member of each highly correlated variable pair, in order to reduce multi-collinearity. Abbreviations of species names are shown in Table 1; extracted environmental variables: DISTANCE = distance from the river edge, DBH = diameter at breast height, WATER SALINITY = water salinity of the study plots, RLI = relative light intensity.

et al. 1996, Nakamura 2000). Polypodiaceae and Davalliaceae were most prominent in mangroves of the Pan Yi river (Table 1). These two families seemed to have advantageous distribution strategies for their occurrence in mangrove environments, at least in this study area.

Distance from the edge of the river, RLI, water salinity and dbh were important environmental factors associated with species composition and distribution of epiphytic ferns in this study area (Figure 4). Similar findings have been reported by many researchers, who documented microclimatic conditions such as light and humidity and distance from shore as principal factors determining spatial distribution patterns of epiphytes (e.g. Ellison & Farnsworth 2000, Padmawathe et al. 2004, Zotz 2007). Our results showed that the non-mangrove epiphytic ferns *D. quercifolia*, *D. denticulata* and *P. lanceolata* which appeared widely in various forest types could be dominant species in the mangrove environment, i.e. the most abundant (Table 1). *Drynaria quercifolia* seemed to be influenced more by distance to the river (which would suggest a strong affinity to flowing water) while *D. denticulata* and *Pyrrosia* spp. seemed to have a stronger affinity to the mangrove environment and its saline water. The major abiotic constraint of many other species was also water salinity (Figure 4). There are many studies that have examined salt-tolerance of vascular epiphytes, especially relating to their germination and vegetative growth in forests adjacent to the sea (e.g. Zotz & Reuter 2009). The abundance of epiphytes in these habitats is not due to any particular adaptation by these plants but rather to the high levels of local precipitation which dilute the constant input of salts (Gomez & Winkler 1991). Species richness of epiphytic ferns increased at sites with low water salinity, regardless of microsite conditions along portions of a river basin (Table 1, Figure 2). Moreover, differences in the Shannon–Wiener diversity index of epiphytic ferns between the study plots strongly depended on the diversity index of mangrove trees (Table 2). This suggests that various trees, including back-mangrove (ecotone between mangroves and inland) and inland species, which can act as hosts for epiphytic ferns, can establish on sites with low water salinity.

Epiphyte species richness and host-tree preferences are well linked to host properties, including tree size (Merwin et al. 2003, Flores-Palacios & García-Franco 2006). In this study, of the 14 mangrove trees examined, inland trees *C. iripa*, *H. littoralis* and *X. moluccensis* played an important role as hosts to many epiphytic ferns in mangroves (Tables 3, Figure 3). In particular, close relationship was found between the presence of *N. acutifolia* and mature *X. moluccensis* (dbh above 88 cm, ca. 90-year-old trees) (Table 3, Figure 4). Increase in species richness is due to the age of the tree and not to its size (Yeaton & Gladstone 1982). The stems of mangrove trees in Thailand grow about 1 cm per year (Higaki & Shiokura 1985). Basic information such as species composition and biological indicators of ecosystem health is required for effective management of mangroves. From these results, we suggest that the abundance of mature host tree species, in particular *H. littoralis* and *X. moluccensis*, may influence the distribution and species richness of epiphytes, including mangrove ferns *D. solida* and *N. acutifolia*, which have affinity to mangroves in Thailand.

Deterioration of mangrove forest health due to anthropogenic disturbances causes the extinction of local and regional taxa. Although the mangrove area can be increased by reforestation and restoration efforts in some locations (Alongi 2002), successful regeneration is generally achieved only by planting monocultures of fast-growing species, such as *Rhizophora* spp. or *Avicennia* spp. (Polidoro et al. 2010), which are less utilised by epiphytic ferns in this study area (Table 3). Success in replanting slow-growing species such as inland trees *C. iripa, H. littoralis* and *X. moluccensis* is not easily achieved. Species and ecosystems cannot be restored effectively once the stability and health of the mangrove ecosystems have deteriorated (Polidoro et al. 2010). Furthermore, climate change is also a threat to the biodiversity of mangroves, especially to species found primarily near the shoreline and in the low intertidal region. The habitats of mangrove trees will be disrupted with a rise in sea level, and species will suffer mortality in their present tidal zones and attempt to re-establish at higher elevations in areas that were previously inland zones occupied by back-mangrove and inland forest trees (Ellison 2005). Mangrove tree species growing on the inland margin are particularly vulnerable to effects of climate change (Polidoro et al. 2010). Close relationships between mangrove epiphytic ferns *D. solida* and *N. acutifolia* and inland trees *H. littoralis* and *X. moluccensis* were found in this study (Table 3). Many epiphytic ferns utilised these mangrove trees as their hosts too (Table 3).

From these results, we conclude that it is essential to maintain the natural vegetation zonation of mangrove forests along the river gradients and to protect mature host trees, especially *H. littoralis* and *Xylocarpus* spp. from anthropogenic disturbances, including coastal development and deforestation. This is necessary for mangrove conservation, considering the diversity of epiphytic ferns.

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