การเปลี่ยนแปลงที่เป็นไปได้ของชุมชีพไลเคน และการสูญเสียชนิดพันธุ์ ภายใต้การเปลี่ยนแปลงสภาพภูมิอากาศ

Possible changes in community structure and species extinction of lichens under climate change

มงคล แผงเพ็ชร*, กัณฑรีย์ บุญประกอบ

Mongkol Pangpet*, Kansri Boonpragob

Department of Biology, Faculty of Science, Ramkhamhaeng University, Bangkapi, Bangkok 10240, Thailand
*e-mail: mongkolpp@gmail.com

บทคัดย่อ: ผลกระทบของอุณหภูมิที่เพิ่มขึ้นและความต้องการใช้น้ำซึ่งมีสาเหตุมาจากการเปลี่ยนแปลงของสภาพภูมิอากาศ ซึ่งคาดว่าจะส่งผลให้เกิดการเปลี่ยนแปลงของระบบนิเวศและมีการสูญพันธุ์ของสิ่งมีชีวิต วัตถุประสงค์ของการศึกษานี้เพื่อศึกษาประสิทธิภาพการปรับตัวของไลเคนแบบแผ่นใบบางชนิดที่อาศัยในป่าเขตร้อนชนิดต่างๆ ตามระดับความสูง ด้วยการย้ายปลูกไลเคนระหว่างระบบนิเวศที่แตกต่างกันในอุทยานแห่งชาติเขาใหญ่ โดยใช้ชิ้นส่วนแทลลัสของ *Pseudocyphellaria argyracea*, *Relicina abstruse, Relicina subconnivens* ซึ่งเติบโตในป่าดิบชื้นที่มีอากาศอุ่นและชื้น และ *Parmotrema rubromarginatum, Dirinaria picta* เติบโตในป่ารุ่นสองที่มีอากาศอุ่น-ชื้นและแสงจ้า ย้ายปลูกไปยังป่าดิบเขาที่มีอากาศเย็นและชื้น ในทางกลับกัน *Hypotrachyna kingii, Heterodermia lepidota, Hypotrachyna osseoalba* และ *Parmelinella chozoubae* จากป่าดิบเขาย้ายถูกปลูกมายังป่าดิบชื้น ป่ารุ่นสอง และป่าดิบแล้ง หลังการย้ายปลูก 43 เดือน เปอร์เซ็นการเหลือรอดสูงสุดพบในป่าดิบเขาร้อยละ 38 รองลงมาคือป่ารุ่นสอง ป่าดิบแล้ง และป่าดิบชื้นร้อยละ 18.7 7.2 และ 5 ตามลำดับ อัตราการเติบของไลเคนที่ย้ายไปยังป่าที่มีอากาศเย็นและชื้นสูงกว่าไลเคนที่ย้ายปลูกในป่าที่มีอากาศอุ่นกว่า โดย *P. rubromarginatum* มีอัตราการเติบโตเฉลี่ยสูงสุดในป่าที่มีอากาศเย็นและชื้น ตรงข้ามกับ *H. lepidota* และ *P. chozoubae* มีอัตราการเติบโตและเหลือรอดต่ำที่สุดตามลำดับ แสดงให้เห็นว่าไลเคนจากพื้นที่ที่มีอากาศอบอุ่นกว่า สามารถปรับตัวและเติบโตในพื้นที่อากาศเย็นกว่าเฉลี่ย 2-3 องศาเซลเซียลได้ดี ตรงข้ามกับไลเคนจากพื้นที่อากาศเย็นเติบโตได้น้อยและถูกคุกคามจากอุณหภูมิที่สูงขึ้น นำไปสู่การสูญพันธุ์เนื่องจากการเปลี่ยนแปลงสภาพภูมิอากาศในอนาคต

Abstract: Impacts of temperature increase and water availability caused by climate change is expected to engage in ecosystem changes and species extinction world wide. The objectives of this study focused on adaptive capacities of some tropical foliose lichens inhabited various types of tropical forest along altitudinal gradient in Thailand. The study was performed by transplantation of lichens among different ecosystems at Khao Yai National Park, Thailand. Thallus fragments of lichens which grew in warm – wet habitats of tropical rain forest (TRF); *Pseudocyphellaria argyracea*, *Relicina abstruse* and *Relicina subconnivens*, and warm –wet sunny environment of secondary forest (SF); *Parmotrema rubromarginatum* and *Dirinaria picta* were transplanted to cooler area is lower montane rain forest (LMF). Whilst lichens from LMF; *Hypotrachyna kingii*, *Heterodermia lepidota*, *Hypotrachyna osseoalba* and *Parmelinella chozoubae* were transplanted to TRF, SF and Dry evergreen forest (DEF).

Forty-three months after transplantation the survival thalli of lichens in LMF, TRF, SF, DEF and were 38, 18.7, 7.2, and 5 respectively. Growth rates of lichens transplanted to the cooler sites were higher than those transplanted to the warmer areas. The highest growth rate of *P. rubromarginatum* transplanted to the cooler area was observed, whereas *H lepidota* and *P. chozoubae* transplanted to warmer sites had the lowest growth rates and low proportion of survive thalli. This study suggested that lichens from warmer sites could acclimate in 2-3^{o}C cooler habitats, whereas species from the cool sites hardly thrive in warmer habitats and may be threaten to extinct under global warming.

Introduction: Climate change caused by increasing greenhouse gases in the atmosphere may lead to elevated temperature of 1.8 – 4.5 ^{o}C.[1] Climate influences lichen growth, survival and distribution through major physiological processes. Insarov and Schroeter (2002) reported that lichens in Antarctica is sensitive to high temperature, as an increase of thallus temperature during the active state of about 0.5-1 ^{o}C may lead to a reduction of annual carbon grain by 90%.[2] Flora and fauna adapt to warming climate by migrating up north or up elevation to appropriate climate. Those at the summits are threatened to extinction because migration to higher elevations is limited.[1] Van Herk et al. (2002) suggest that many species seem to be capable of rather rapid dispersal, as shown by the recent arrival of some (sub)tropical species in temperate area.[3] Aptroot (2009) reported that the most severe effects of climate change, leading to probable extinctions, is expected on high mountains in tropical regions.[4] Extinction of species with low adaptive capacity could occur, as well as changes in species composition of the ecosystems.[1] Our long-term monitoring of 300 lichen thalli in the tropical forests in Thailand revealed that 70% crustose and 80% foliose thalli disappeared from the observed habitats during the past nine years.[5] Plausible causing factors include direct and indirect effects of climatic and biotic factors. The objective of this study focused on adaptive capacities of some tropical foliose lichens inhabited various types of tropical forest along altitudinal gradient in Thailand. The results may provide early warning information for management of bioresources in the tropic and elsewhere under changing climate.

Methodology: Lichen thalli were collected from 3 different types of ecosystem at Khao Yai National Park: Tropical rain forest (TRF) – warm wet (alt. 780 m), Secondary Forest (SF)—warm wet & sunny (alt. 770 m) and Lower montane forest (LMF)—cool humid (alt. 1200 m). Among the collected species, *R. abstrusa* and *D. picta* grew in every ecosystem. The others had been reported to grow only in specific conditions in their natural habitats.[6] Eight species with green-algal photobiont were transplanted on the east sides at the middle of tree trunks and canopies in TRF, DEF and LMF, while at SF the thalli were adhered on tree trunk at level of breast-high for exposing to bright illumination. *P. argyracea*, the species with cyanobacteria as photobiont, specifically found in low light were transplanted at tree-base in LMF. Thalli from warmer sites, e.g. TRF and SF were transplanted to the cooler LMF, and *vice versa* (Table 1). Growth rate and survival were observed by drawing outline of each thallus on transparent overlay sheet and the area was calculated by AxioVision LE Rel. 4.1 software. All-day microclimate conditions (temperature, light and humidity) were recorded every 2 months.

Results, Discussion and Conclusion: Survival of thallus fragments after transplanted for 43 months were shown in Table 1, Figure 1 and 2. Lichens previously inhabited the warmer areas (TRF and SF), thrived in cooler site (LMF) better than those transplanted from the cooler sites to the warmer one. Thirty-eight percent of the total transplanted thalli survived in cooler habitat, whereas only 8.8% of the thalli from the former cool habitat could survive in the warmer climate. Two species from the warm wet habitat of TRF, *R. abstruse* and *P. argyraceae*, seems to adapt well in the cool-wet site, whereby more than half of the transplanted thalli survived. On the contrary, *R.subconivens* from TRF had the lowest survival proportion in the cool-wet habitat with only 14.2% of the transplanted thalli remain intact. Two species from the warm wet and bright habitat of the SF had 21-37 % of survival thalli in the cool-wet site. This result demonstrated that adaptive capability of species varied considerably.

Table 1 Numbers of collected thalli of lichens grew specifically in different types of forests, and transplanted to new habitats at KYNP in June 2005. Survival of thalli were measured in January 2008.

Species	Lobe size (mm)	Collected from	No. of thalli transplanted				Survival (%)			
			TRF	DEF	SF	LMF	TRF	DEF	SF	LMF
P. argyracea	10-30	TRF	-	-	-	35	-	-	-	51.4
R. subconnivens	1-3	TRF	-	-	-	120	-	-	-	14.2
R. abstrusa	1-2	TRF	-	-	-	60	-	-	-	66.7
P. rubromarginatum	8-12	SF	-	30	-	180	-	15	-	36.7
D. picta	0.5-1	SF	-	-	-	180	-	-	-	21.1
H. kingii	6-7	LMF	170	180	150	-	9.4	8.9	23.3	-
P. chozoubae	4-7	LMF	170	150	90	-	2.4	3.3	13.3	-
H. lepidota	0.5-1	LMF	170	120	180	-	1.8	0	19.4	-
H. osseoalba	1-3	LMF	110	90	-	-	6.4	8.9	-	-
Total			620	570	420	575	Average			
SUM			2185				5	7.2	18.7	38

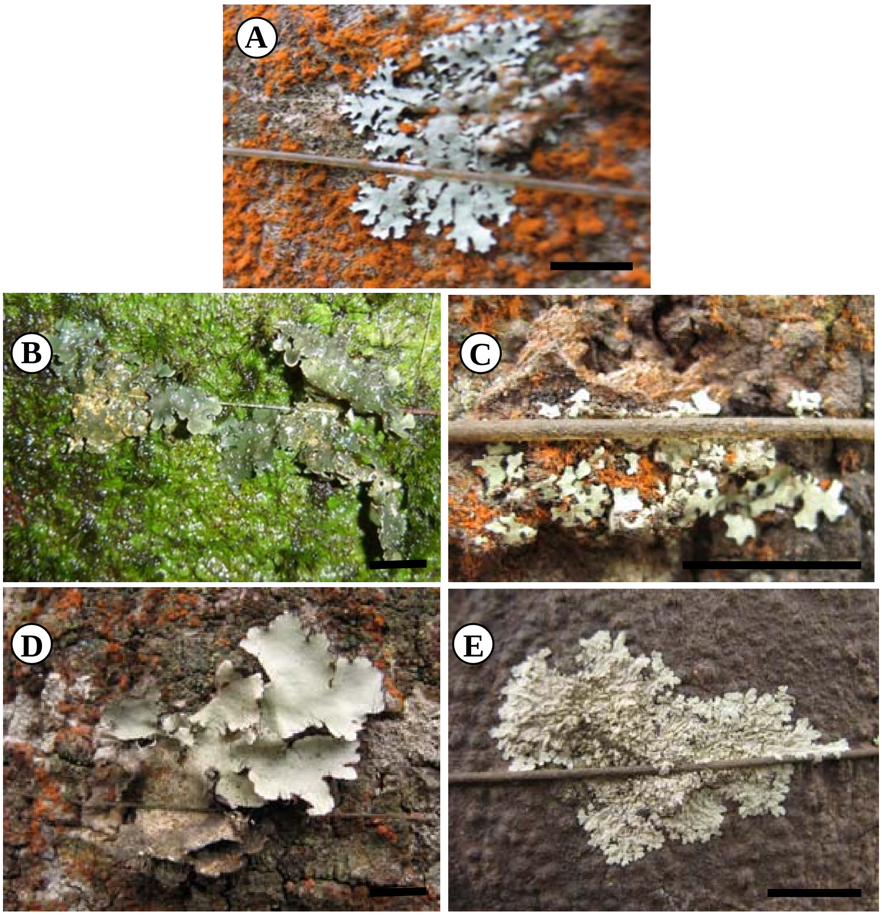

Figure 1 Survived thalli of the lichens transplanted to the cooler site (LMF) from the warmer sites of the tropical forests (TRF, DEF and SF) *Relicina abstrusa* from TRF (A)

Pseudocyphellaria argyracea—TRF *(B)*, *Relicina subconnivens* –TRF *(C), Parmotrema rubromarginatum*—SF (D) *Dirinaria picta* –SF (E). (Scale = 1cm)

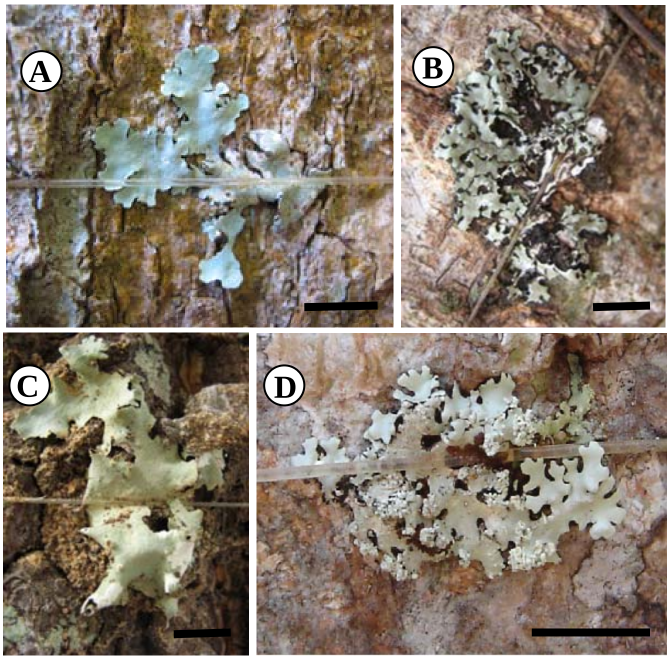

Figure 2 Survived thalli of the lichens transplanted from the cooler site (LMF) to the warmer sites of the tropic (TRF, DEF and SF) *Hypotrachyna kingii* to TRF SF and DEF (A), *Heterodermia lepidota*– TRF SF and DEF (B) *Hypotrachyna osseoalba*—TRF and DEF (C) and *Parmelinella chozoubae*— TRF SF and DEF (D). (Scale = 1cm)

Obviously, four species of lichens from the cool-wet habitat of the LMF hardly adapted in the warmer areas of TRF, DEF and SF. Proportion of survived thalli ranged from 0-23% of the original transplanted materials. Average survived thalli in the three transplanted sites accounted for only 5, 7.2 and 18.7 % (Table 1). Apparently most of the transplanted thalli in the warm wet TRF disintegrated. *H. lepidota* seems to be the most sensitive species in warmer climate since none of the transplanted thalli could survive in TRF and DEF, although 19 % of those remain in the SF where illumination was brighter. The highest adaptive capacity in the warmer climate was observed from *H. kingii* with 23.3% of thalli remain intact.

All transplanted species, except *D. picta*, had no previous record of growth rate in natural habitat. Transplanted thalli of the five species in the cool site had average growth rate higher than the four transplanted species in the warm sites (Table 2). Growth rates of thalli transplanted to the cool LMF ranged from 1.5-2.6 mm/yr, whereas those transplanted to the warm TRF, DEF and SF ranged from 1.02-1.82 mm/yr (Figure 3). The highest growth rate was observed form *P. rubromaginatum* in the LMF accounted for 2.6 mm/yr, whilst the lowest growth rate was noted from *P. chozoubae* in the warm TRF site measured 1.02 mm/yr. The transplanted *D. picta* in LMF grew 1.7 mm/yr, which was lower than that grow in the natural habitat (0.6 mm/month or 7.2 mm/yr).[7] Growth rates of the transplanted species may be lower than those observed in their original habitats because the transplanted thalli were during establishment phase of development.[8] The average growth rate of lichen thalli from cool site transplanted to three the warm sites were lower than those from warm site grow in the cool location. Probably, attribute to photosynthetic rate is generally declined in temperature lower or higher than 23 to 25^{o}C, whilst respiration rates increase parallel with temperature increasing [2, 9]. This condition leads to lesser carbohydrate left for making up growth. *H. lepidota* and *P. chozoubae* from LMF could not survive and had low growth in

TRF and DEF because the remain thalli in the warm transplanted sites disintegrated or left in small quantities (Table 1 and Figure 3). Therefore, it is reasonable to conclude that these two species are threatened to extinction by global warming.

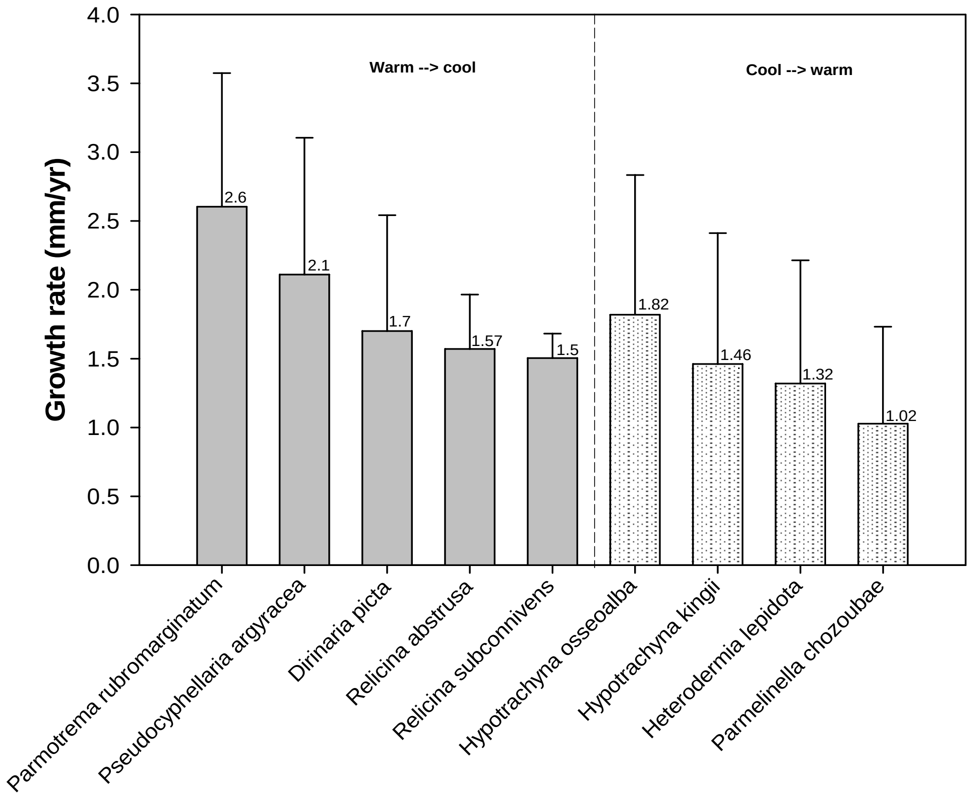

Figure 3 The average growth rates of five species from warm sites transplanted to cold site (shade bar), and four species of cold site transplanted to warm sites (dot bar). Significant difference between warmer and cooler sites is *P=0.001*.

Table 2 the maximum, minimum and average growth rate (mm/yr) and microclimate in various ecosystems (Growth rate were measured during Nov 2005 to Jan 2008).

Ecosystems	Growth rate (mm/year)			Microclimate (average)		
	Mean*	Max	Min	Temperature (^oC)	Relative Humidity (%)	Max. Light intensity ($\mu mol\ m^{-2}s^{-1}$)
LMF	1.85	7.43	-	**21**	87	390
SF	1.26	4.62	-	25	**75**	674
DEF	1.25	3.91	-	23	77	**300**
TRF	**0.69**	**3.24**	-	24	78	390

* Significant difference *P=0.002*

Temperature, humidity and light intensity seems to be trigger factors for lichen survival and growth in each forest. The lowest average temperature in the LMF and the highest humidity (Table 2) probably correlated with higher proportion of survival rate, and the highest average growth rate of the transplanted species. In the SF, the warmest temperature and the lowest humidity were recorded, but illumination was among the highest. The microclimate of this type resulted in the highest survival rates among all transplanted thalli in the three warm sites. The lower survival proportion of the transplanted thalli in the DEF seems to be influenced by the lowest illumination recorded. The lowest of survival and growth rates in the TRF possible due to low light intensity and relatively high temperature of this site.

Warmer areas of SF with sufficient illumination and wet condition (Table 2) seems to provided the best habitats among the warm sites for transplanting lichens from the cool site at KYPN (Figure 3). It led to higher number of survivors and growth rate than the other warm habitats. Upper limit of temperature tolerance of the species inhabited the warmer sites is not known. Those with wide range of tolerance could probably adapt and survive in the warming climate, those with low capacities could be excluded from the habitats. *Parmelinella chozoubae*—the new species reported from Thailand,[10] and *Heterodermia lepidota* tended to be more vulnerable than others in warmer sites. They are most likely to extinct form their habitats as a result of global warming.

In conclusion, this study suggests that lichens that normally inhabit cooler habitats at high elevation in the tropic are threaten to extinction under warming climate that is very likely to occur in the near future. It is possible that species from the lowland warmer condition may migrate to replace the upper ones. Changes in species composition would possibly occur. Magnitude and rates of species changes need further long-term investigation.

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