CHAPTER 5

DISCUSSION

5.1 Lichen Diversity

As the result, the number of foliose lichen diversity was low in comparison with crustose diversity, which correspond with Pomphueak (2005), Pruksakorn (2007), Runnawut (2008), Kanjoem (2010) and Kheawsalab (2010). Crustose group is tightly attached to the substrate and water loss is restricted primarily to the upper, exposed surface only. Saipunkaew *et al.* (2005) found that lowland sites where altitudes were about 260- 370 m had crustose lichen frequency more than foliose lichens. Range of altitude was similar to this study (250- 370 m) which crustose was also found to be dominant. In this study, a lichen species, *Phyllopeltula* cf. *corticola*, was found only in areas with highly anthropogenic impacts. Some of foliose lichens were found in polluted areas. These included *Hyperphyscia adglutinata* and *Pyxine cocoes,* and some was found in less polluted areas, such as *Dirinaria picta. H. adglutinata* which had the highest frequency, followed by; *P.* cf. *corticola*, *P. cocoes*, *Rinodina roboris* and *Chrysothrix xanthina*, respectively. *D. picta* had less frequency if compared with previous species. Pomphueak (2005) also found lichens *H. adglutinata* and *P. cocoes* in polluted area while Saipunkeaw *et al.* (2005), Saipunkeaw *et al.* (2007), Runnawut (2008), Kanjoem (2010) and Kheawsalab (2010) found *P. cocoes* distributed in areas with anthropogenic effects which associated with increasing population. These studies found that *P. cocoes* had been widely distributed in areas with altitude between 250- 400 m in Northern, Thailand. *D. picta* was widespread in both agricultural and urban areas with less anthropogenic effects.

The dendrogram was produced by using lichen species and frequency values. It was classified to six groups of study sites (Figure 4.1). The first group was 7B (AQI class 4) where the highest values of lichen frequency and average lichen frequency were found. This group was clearly distinguished from the other sites. Lichens *Candelaria concolor* and *Physcia* sp. 2 were only found in 7B. This site had the highest frequency of lichen *D. picta*, *Hyperphyscia pruinosa* and *P. cocoes*. *C. xanthina* ,*H. adglutinata* and *P.* cf. *corticola* were also found in this sites. *H. adglutinata* and *P. cocoes* contributed most in urban areas (Saipunkaew *et al.*, 2007). Purvis *et al.* (1992) and Van Herk (2001) accepted that *H. adglutinata* and *Candelaria* sp. are nitrophytic species and are associated being nutrient- enriched. From previous study, this species was not found in the upland forest but presented in all lowland. *D. picta* was the species contributing most in less polluted area but are also tolerant to pollution in urban sites (Saipunkaew *et al.*, 2005). The second group was 6A (AQI class 4), the only one of A site in a separated group. Site 6A also had the highest values of lichen frequency and average lichen frequency as same as 7B. Lichen *Lecanora* sp. 1, *Rinodina pyrena*, *Rinodina roboris* and *Rinodina teichophila* had the highest values of lichen frequency, while *P. cocoes*, in 6A had lower frequency compared with 7B. *P. cocoes* was second ranked from 7B. *C. xanthina* and *H. adglutinata* also were found while *P.* cf. *corticola* and *D. picta* were not found in 6A. *Lecanora* sp. 1 is the species which usually widely distributed in the area with low frequency in urban areas (Subsri, 2001; Chaithaswad, 2002; Pruksakorn, 2007;

Kanjoem, 2010; Kheawsalab, 2010). *Rinodina* spp. was found with high frequency in densely community or anthropogenic impacts (Pruksakorn, 2007 and Kheawsalab, 2010). This site was Ping river bank where Scorpion tailed pier was located. Tourists would come to the Scorpion tailed pier, some come for fishing, resting or exercising. That may cause anthropogenic effects. The third group was 26B (AQI class 4) where lichen *C. xanthina, D. picta Glyphis* sp.1, *Lecanora* sp.1, *L.* sp.2 and *P. coces* were found. The frequency value of *D. picta* was second ranked from *D. picta* in 7B. The frequency of lichen values in 26B was 131. Lichen *C. xanthina and P. cocoes* were found in this site while *P.* cf. *corticola* and *H. adglutinata* were not found. Six lichen species in this area were found in the highest frequency which always contributes most in less polluted areas, as reported from previous studies (Subsri, 2002; Chaithaswad, 2002; Saipunkaew *et al.,* 2005; Pruksakorn, 2007; Kanjoem, 2010; Kheawsalab, 2010). This site was military area with controled entry from the vehicle outside the area. Compared to the other area, this area had less anthropogenic effect. The fourth group was 2B (AQI class 5), lichen frequency value was 187. These value was second ranked from 7B and 6A. *Arthothelium* sp., *Buellia efflorescens, Graphis* sp.2 *Lepraria* sp. 3 and *Opegrapha* sp. had the highest frequency value in this group. *D. picta* and *C. xanthina* were found for a few frequencies. *H. adglutinata*, *P. cocoes* and *P.* cf. *corticola* were not found in this group. The characteristic of this area was an open area and not densely residential area. But construction had been done for a while. It may cause less occurrence of *D. picta* found in less frequency. Fifth group consisted of 17B, 5B, 3B, 9B and 1B (AQI class 3 and 4). These sites also had similar species in each site such as *Arthonia* sp.2, *C. xanthina*, *H. adglutinata*, *Lecanora* sp.2 and *P. cocoes. Arthonia* sp.2 had the highest frequency value. *D. picta* and *Glyphis* sp.

were only found in 9B and 1B while *Parmotrema gardaneri* and *P.* cf. *corticola* were found only in 9B and 1B, respectively. *D. applanta, Physcia* sp.1 and *R. roboris* were found only in 5B. Site 3B had the highest of shannon's diversity index value and the number of species. For this group, it could be a moderate polluted area. Because both of high tolerant, *P.* cf. *corticola*, and sensitive species (*D. picta* and *Parmotrema gardaneri*) were found in this group. The other species mostly found in group 1-5 besides *C. xanthina, D. picta, H. adglutinata*, *P. cocoes* and *P.* cf. *corticola* was *Lecanora* spp. which tended to be an indicator of good air quality. Group sixth was the last group consisting of 64 sites. Thirty three were from A site and 29 were from B site. The highest evenness value was found in 28B while 18A was the site with lower Shannon- Wiener's diversity index value, evenness value and number of species. Because site 18A had only one species i.e. *P.* cf. *corticola* which was similar to study of Bačkor *et al.* (2003). They found lichens which were more tolerant to pollution in the city center and sites closed to steel factory. *C. xanthina*, *H. adglutinata*, *P. cocoes*, *P.* cf. *corticola* and *Rinodina roboris* were mostly found in this group while *D. picta* was found sparsely. *H. adglutinata, P. cocoes, P.* cf. *corticola* and *Rinodina roboris* were found in densely community and high traffic area.

5.2 Lichen Mapping

Air quality in Chiang Mai City was evaluated base on air quality index (AQI) which was calculated from lichen frequency value. AQI (Table 4.4) were used for assessing air pollution and to indicate the abundance or species of lichen. Air quality map was created based on the AQI of each site. The result was shown in two maps.

First, each site was colored according to the AQI value (Figure 4.3). Second, isolines were draw to represent the air quality class zone (Figure 4.4).

The air quality zones indicated by lichens corresponded with the land use type (Figure 3.3). AQI showed the color in class 1-3 in the city and building areas. Moreover, this area was the central commercial area, markets, schools, hotels, hospitals and densely residential areas. So there may be, polluted air occurring in this area, especially during rush hour. The most polluted area, as indicated by AQI value, was found in Chiang Mai City moat. Very high pollution units were separated in urban and suburban areas with high anthropogenic effects such as commercial areas, schools, colleges, main roads etc. Very high to high was extended from urban to suburban area because of increasing development area. The residential area extended to outside the city, which may have caused the facilities also extending to suburban areas. High to moderate pollution mostly were found in moderately dense residential area, university area and military area in suburban area while in urban area, it was found in natural area like parks, gardens in the official area and river bank area. Moderate pollution was indicated in northeast, south and northwest of Chiang Mai City. This area was suburban with low density residential area and agricultural area occurred. Moderate to low pollution were found in the small area in northwest which had more open area and lower density residential area. Moderate and moderate to low pollution had lichen frequency in each site more than the other area that similar to Pinho *et al.* (2004).

Very high pollution was found in the city center along the roadside and in densely residential area corresponded with Saipunkeaw (1994), Subsri (2001) and

Pomphueak (2005). Most of the study area was determined as very high to high air pollution zone. This zone also extended to outer part of the city similar to the study of Subsri (2001). In this work, the areas of study site expanded more than the area where Subsri (2001) classified. Because the area had more developing area and construction occurs. That can cause high to moderate area extend into suburban area, while moderate area was scattered in the outside of the city and found in river bank area. The best air quality was determined in outer part of city where the volume of residential area was low.

Besides the land use type, the result of lichen mapping also corresponded with the atmospheric pollutants measured by passive sampling. The correlation test showed significant between the concentration of NO_2 and AQI ($r= -0.473$, $p< 0.05$). AQI value was significantly inverse with the concentration of NO_2 such as AQI in Class 1 was low while the concentration of NO_2 value was high. The atmospheric NO_2 appeared to be one of the most important factors affected lichen diversity and lichen abundance which corresponded with Van Dobben and Ter Braak (1998), Gombert *et al.* (2003), Frati *et al.* (2006) and Davies *et al.* (2007).

5.3 Lichens distribution map

Five lichen species were selected to produce lichens distribution maps. Each lichen species had different tolerant levels. *P* cf. *corticola* was found with high frequency in the city center where high traffic and anthropogenic impacts occurred (Figure 4.6). *H. adglutinata* distributed in many grid squares especially in densely residential area and in the main road areas with high frequency. Low frequency value was found in suburban area with less densely community or traffic (Figure 4.7). These result were similar to Subsri (2001), Chaithaswad, (2002), Saipunkeaw *et al.* (2005), Pruksakorn, (2007), Saipunkeaw *et al.* (2007), Kanjoem (2010) and Kheawsalab (2010). *P. cocoes* was widely distributed but occurred in lower frequency than *H. adglutinata*. *P. cooces* can be tolerant to pollutant in urban sites (Saipunkaew *et al.*, 2005). *P. cocoes* in this study had low frequency in the outer part of the city, showing that it had been decreased from previous studies of Subsri (2001) and Pimwong (2002). *Lecanora* spp. was found less than *P.* cf. *corticola*, *H. adglutinata* and *P. cocoes* in urban areas but it was widely distributed in suburban areas (Figure 4.9) (Subsri,2001; Kulapirak ,2006). But in urban area, it was found in low frequency value (Subsri, 2001; Chaithaswad, 2002; Pruksakorn, 2007). Lichen species of *D. picta* was found only in suburban areas and it had the narrowest distribution range than other selected lichens (Figure 4.10). Subsri (2001) and Pimwong (2002) found that *D. picta* was distributed in low frequency in the city while this study found this lichen in high frequency in suburban areas, the official place and village in outer part of the city.

The results from these lichen distribution maps showed that *H. adglutinata*, *P.* cf. *corticola* and *P. cocoes* were cosmopolitan species which can be tolerant to the air pollution in wide ranges, while *L.* spp. and *D. picta* were species with less tolerance to pollution. The distribution of *D. picta* showed that it can serve as the most sensitive species to air pollution and anthropogenic impacts among these four lichen species.

5.4 Bark pH and the Direction of Lichens on Trees Trunk

The average pH value ranges from 4.36- 5.97. The results from ANOVA implied that there was significant difference between mean bark pH in each classes. The bark pH in class 5, suburban area, was higher than the other sites in urban areas (Table 4.8). This corresponded findings from with Pruksakorn (2007). As reports in previous studies (Saipunkeaw, 1994; Subsri, 2001), bark pH of Mango tree was lower in urban areas than in the suburban areas of Chiang Mai City.

Northern direction was where most lichens could be found. Next were northeast, northwest, west and east directions. Southeast, southwest and south directions had less lichens found (Figure 4.12). Saipunkeaw *et al.*(2007), Kanjoem (2010) and Kheawsalab (2010) also found lichens mostly in north direction while Subsri (2001) found lichens mostly in northeast. The wind direction may be one factor which determined the direction where lichens will grow the most (Figure 3.7). In 2011, wind mostly flowed from southwest direction. Southwesterly monsoon was occurred from May to September (wet season). Lichens were grown on the direction which located opposite or avoid to the point source or pollutant. It may be one factor that why lichens were mostly found in the north direction in this study because it avoided the pollutants from the wind.

5.5 Passive Sampling

The concentration of NO_2 was collected from 19 study sites, which were selected from city center, four directions outer part from city center, five sites in class 4 (Moderate) and one site in class 5 (Moderate to low) (Figure 4.14). The average concentration of NO_2 in each site during January to April was ranged between 0.21-13.09 ppbv which not exceeded the standard level of Pollution Control Department (170 ppbv/1 hr.). The highest concentration of NO_2 was found in February while lowest concentration was found in April. The highest concentration of NO_2 in each month was found in 36A (6.11, 13.09 and 9.41 ppbv) between January and March 2012, while 36B was a site with the highest value in April (4.08 ppbv). The lowest concentration of NO_2 was found in 3B in January and March 2012 (0.21 and 1.67 ppbv) while in February and April 2012 was found in 24B (1.70 and 0.24 ppbv). Site 36A was located in the city center. This site located on shortcut road to Jareon-prateah road where many schools were located and may cause high traffic during rush hour. Site 36B was located near Pa- dad road in front of a village entrance. This road is the main road to Tumbon Pa- dad, so there are many vehicles passing through this site. There was also some construction along the river bank that was ongoing during passive samplings were exposed. Both sites were affected by southwest wind flow directly. Southwest wind may have flown particle and pollutant from vehicles to the sampling sites. The lowest values in four months were found in 3B and 24B, Tree market for Welfare, 33rd Military circles, and residential area in Industrial Promotion Centre Region 1 Department of Industrial Promotion, respectively.

The NO_2 concentration in this study was lower than Thammapanya (2012) who also study in Chaing Mai City but samplinyed NO_2 in the different sites. This may cause from rain during the sampling time in January and February while in March and April, rain had arrived before and during shelters were exposure. Rain was one factor that causes decreasing of NO_2 concentration which corresponded with study of Bootdee (2009) and Thammapanya (2012). They found meteorological conditions in particular rainfall, temperature, relative humidity and water evaporation played an important role in ambient NO_2 concentrations. These made ambient NO_2 concentration was low in rainy season.

The result from this study corresponds with Pomphueak (2005) who found correlation between lichen data and concentration of NO_2 from passive sampling. Muangsuwun (2006) reported that Chiang Mai city had higher level of NO_2 and SO_2 than that of Chiang Mai University, as same as this study which the highest level of NO_2 was mostly found in A site, urban area, and the lowest level of NO_2 was found in B site (suburban area). Bootdee (2009) also had similar findings to this study. The author found that the highest NO_2 concentrations (28.1-45.1 ppbv) of each sampling month was found at Waroros market which located in urban area of Chiang Mai with high traffic density. The relationship between the concentration of NO_2 and lichen data was corresponded with Davies *et al.* (2007) who reported that NO_2 and NH_3 emitted by road traffic could influence lichen diversity, lichen vitality and the accumulation of nitrogen in lichen thallus. There was a significantly inverse relationship between diversity and NO_x (r = 0.80, p= < 0.01).

This result of this study showed that there were some lichen species which could be used as indicators for urban and suburban pollution in Thailand such as *Phyllopeltula* cf. *corticola, Hyperphyscia adglutinata, Pyxine cocoes, Rinodina* sp., *Lecanora* spp. and *Dirinaria picta.* Frequency of lichen could be used to produce air quality map. More pollutant measurement points should be required for comprehensive information. Moreover, determination of chlorophyll and phaeophytin content, and residual analysis in lichens may better support the result from air quality assessment.