

**Influence of Tree Size and Species on Lichen Abundance, Diversity, and Richness in a
Northern Hardwoods Forest**

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Ashley Logsdon

Advisor: Dr. Walt Carson

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ABSTRACT

Lichens play an important role in a number of forest ecosystem processes, and their sensitivity to air pollution and disturbance makes them ideal candidates for long-term monitoring of forest health. Lichen abundance and diversity have been correlated to a number of substrate and environmental characteristics, particularly tree size, tree age, bark acidity, and light availability. My study is a preliminary investigation of lichen distributions at the University of Notre Dame Environmental Research Center (UNDERC). I identified lichen species and estimated their cover on 20 quaking aspen (*Populus tremuloides*), 20 sugar maple (*Acer saccharum*), and 20 paper birch (*Betula papyrifera*) trees throughout the UNDERC property. I observed no correlation between trunk diameter and lichen diversity, species richness, or cover. Sugar maples supported significantly higher lichen diversity than either aspen or birch trees, and there was a marginally significant difference in lichen diversity on birch and aspen trees. These results suggest that tree size is not the main factor controlling lichen distributions at UNDERC, and further investigation will be required to reveal what other variables might be playing a larger role.

INTRODUCTION

Lichens consist of a symbiotic association between a photosynthetic microorganism (photobiont), often a cyanobacterium or green alga, and a fungus (mycobiont), usually an ascomycete but occasionally a basidiomycete (Galloway 1992). This highly successful symbiosis permits lichens to colonize a variety of harsh environments and even thrive in recently

disturbed habitats (Medlin 1996; Galloway 1992). In addition to their role as pioneers, lichens have important ecological functions in food webs (Hale and Cole 1988), mineral and nutrient cycling (Nieboer et al. 1978), carbon fixation (Galloway 1992), and nitrogen fixation (Forman 1975).

Lichens have a number of characteristics which make them suitable as indicators of ecosystem health. Because lichens derive water and nutrients primarily from the air, they are highly sensitive to air pollution, for pollutants accumulate in the lichen body and cannot be efficiently excreted (Hale and Cole 1988). Thus, scientists have long regarded lichen diversity as an indicator of air quality (Hawksworth 1990). Lichens can adjust their metabolic processes to accommodate changing environmental conditions, making them relatively resilient to climate change (Galloway 1992). It may be possible to monitor variations in lichen metabolic activity as a measure of increasing UV radiation due to ozone thinning (Galloway 1992). Lichens are long-lived, slow-growing organisms sensitive to habitat disturbances (Hawksworth 1990); they have been put forward as ideal candidates for monitoring forest health both in the United States and in Europe (McCune 2000).

Efforts to use lichens to assess forest health are already underway. Selva (1994) identified several lichen species which may be used as indicators of forest continuity. In Thailand, Wolseley et al. (1994) have established permanent plots in which lichen biodiversity will be monitored to evaluate long-term changes in forest type. McCune (2000) reported on the inclusion of lichens in the Forest Health Monitoring Program developed by the U.S.D.A. Forest Service and U.S. Environmental Protection Agency, among other federal and state agencies. However, even with the development of standardized protocols for such monitoring, researchers

must be careful not to generalize, for the relationships between many environmental variables and the health of lichen communities are highly context-dependent (Will-Wolf et al. 2006).

Those interested in the use of lichens for evaluating forest health have sought to correlate lichen occurrence with an array of substrate characteristics and environmental conditions. A number of European studies have been conducted to this effect; for example, Esseen et al. (1996) found that lichen biomass strongly correlated to the mass, diameter, and age of Norway spruce branches in northern Sweden. Johansson et al. (2007) likewise observed a positive relationship between tree age and lichen cover in their investigation of ash trees in southern Sweden, though the composition of lichen communities changed throughout a tree's lifetime. In a study of floodplain forest stands in Estonia, Jüriado et al. (2009) observed that lichen cover and species richness depended upon a host of factors including tree species, bark acidity, light availability, latitude, tree age, and trunk circumference. Nascimbene et al. (2009) noted the difficulty in distinguishing between tree size and age effects on lichen diversity in an Italian spruce forest.

Similar studies of lichen occurrence have been performed in North America. Lang et al. (1980) observed an increase in lichen cover with increasing tree height in New Hampshire balsam fir forests. A survey of lichens in Yellowstone National Park found that lichen diversity was highest in moist sites and those that had gone a relatively long time without being disturbed by fire (Eversman et al. 2002). Bennett and Wetmore (2005) compiled a database of lichen species based on records from 144 U.S. national parks. With an estimated 696 lichen species, Michigan, the location of the present study, is second only to California in terms of lichen diversity (Bennett and Wetmore 2005).

My study is intended to provide a preliminary survey of lichen species at the University of Notre Dame Environmental Research Center (UNDERC) while also testing to see if lichen

occurrence can be correlated to tree size or species. I surveyed foliose and fruticose lichen communities on quaking aspen (*Populus tremuloides*), sugar maple (*Acer saccharum*), and paper birch (*Betula papyrifera*) trees throughout the UNDERC property. Since larger trees have more surface area available for lichen colonization, I hypothesized that lichen diversity, species richness, and cover would increase with increasing trunk diameter. In addition, I expected to find differences in lichen diversity among tree species, for different tree species may have unique bark characteristics which favor the growth of some lichen species over others (Jüriado et al 2009; Sillett et al. 2000).

MATERIALS AND METHODS

Tree selection

I sampled a total of 60 trees, 20 each of quaking aspen (*Populus tremuloides*), sugar maple (*Acer saccharum*), and paper birch (*Betula papyrifera*) trees throughout UNDERC. Only trees that were alive, beneath closed canopy, not adjacent to a bog, at least 15.9 cm in diameter at breast height (DBH, 1.3 m above the ground), and at least 10 m from a road were used.

Beginning at a randomly-selected starting point, I drove in a predetermined pattern along the UNDERC roads, stopping every 1.6 km to sample. If a site was for some reason unsuitable (for example, if not all three study species were present), I drove an additional 0.2 km and attempted to sample again. I stopped up to three times per site, after which I drove 1.6 km and began anew at the next site. A map of my sampling locations is found in Appendix 1.

At each site, I randomly selected one side of the road on which to sample, walked 30 m directly into the forest, and sampled the first eligible individual I saw of each of the three study species. If I did not immediately encounter an individual of each species, I randomly selected a

cardinal direction and walked in that general direction, more or less maintaining a distance of 30 m from the road. I proceeded in this manner until I encountered an individual of each study species or until 15 minutes had passed. If after this time I had still been unsuccessful, I returned to the point at which I entered the forest and resumed my search in the opposite direction before driving 0.2 km to try again.

Sampling strategy

For each tree, DBH and Universal Transverse Mercator (UTM) coordinates (Appendix 2) were recorded. I surveyed lichen cover using a modified version of the Stofer et al. (2003) protocol, which is considered standard technique for environmental monitoring of International Co-Operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP) forests throughout Europe. A 10 x 54 cm frame subdivided into five 10 x 10 cm quadrats (each separated by 1 cm) was attached to the tree at each of the four cardinal points consecutively with the top (shorter edge) of the frame at 1.5 m above the ground. I estimated the cover of all foliose (leaflike) and fruticose (bushy) lichens found within each quadrat; thus, a total area of 2000 cm² was surveyed per tree. I removed a small sample of each lichen species for identification in the lab.

Lichen identifications

Lichen specimens were stored in paper bags at room temperature while they awaited identification. I used the keys devised by Hale and Cole (1988) to identify lichens to genus; when possible, I identified lichens to species with the aid of the *Lichens of Wisconsin* online database provided by the Consortium of North American Lichen Herbaria (Bennett). Lichens

were identified based on visual characteristics and chemical spot tests using 10% NaOH and common household bleach (Hale and Cole 1988; Medlin 1996). Voucher specimens were stored in the UNDERC herbarium.

Analysis

Pearson correlation coefficients for lichen diversity, species richness (number of lichen species per tree), and cover were calculated, both overall and by tree species. Lichen cover is defined as the sum of the total lichen cover (in cm²) among all 20 quadrats per tree. Diversity was quantified by the Simpson-Yule diversity index, D (Southwood 1966), using the following formula:

$$C = \sum_i^{s_r} p_i^2 \quad D = 1 / C$$

Nonparametric Dwass-Steel-Christchlow-Fligner pairwise comparisons were performed to test whether lichen diversity varies among tree species. Trees lacking lichens were omitted from all analyses of lichen diversity. In addition, a frequency distribution by lichen genus was plotted. All statistical analyses were performed using SYSTAT 13.

RESULTS

Lichen collection

Lichens were found on 13 quaking aspen, 20 sugar maple, and 15 paper birch trees. Quaking aspen trees ranged from 15.9 to 47.4 cm in DBH, sugar maples ranged from 18.9 to 44.7 cm in DBH, and paper birch trees ranged from 17.0 to 42.7 cm in DBH.

I collected a total of 99 lichen specimens, representing 24 species distributed among 10 genera (Table 1). Eight foliose (*Candelaria*, *Flavoparmelia*, *Parmelia*, *Parmotrema*, *Phaeophyscia*, *Physconia*, *Punctelia*, and *Tuckermannopsis*) and two fruticose (*Cladonia* and *Stereocaulon*) genera were represented.

Lichen diversity, species richness, and cover

For all three tree species combined, there were no significant correlations between DBH and lichen diversity ($R^2 = 0.007$, $p = 0.580$), DBH and species richness ($R^2 = 0.036$, $p = 0.148$), or DBH and cover ($R^2 = 0.018$, $p = 0.305$).

Similar results were obtained when these correlations were repeated separately for each tree species. No significant relationships emerged when DBH was correlated to lichen diversity ($R^2 = 0.092$, $p = 0.315$), species richness ($R^2 = 0.126$, $p = 0.125$), and cover ($R^2 = 0.138$, $p = 0.108$) for quaking aspen trees. Likewise, sugar maple trees did not show the expected increase in lichen diversity ($R^2 = 0.113$, $p = 0.147$), species richness ($R^2 = 0.179$, $p = 0.063$), or cover ($R^2 = 0.105$, $p = 0.163$) as DBH increased. Neither were these relationships significant when DBH was correlated to lichen diversity ($R^2 = 0.129$, $p = 0.189$), species richness ($R^2 = 0.063$, $p = 0.286$), and cover ($R^2 = 0.008$, $p = 0.710$) of paper birch trees.

Nonparametric pairwise comparisons were performed to identify differences in lichen diversity among tree species (Figure 1). Sugar maples supported significantly greater lichen diversity than did quaking aspen ($p < 0.001$) or paper birch ($p = 0.002$) trees. The difference in lichen diversity between quaking aspen and paper birch trees attained marginal significance ($p = 0.055$), with diversity on birches being intermediate between that on aspens and maples.

Distribution by lichen species

To see whether some lichens were more commonly found on one tree species over others, I used a frequency distribution to compare the occurrence of lichen genera among tree species (Figure 2). *Phaeophyscia*, *Flavoparmelia*, and *Parmelia* were by far the most widely distributed lichen genera. *Phaeophyscia*, *Parmelia*, and *Candelaria* were most often found on sugar maples while *Punctelia* was found almost exclusively on paper birch trees.

DISCUSSION

Tree size is expected to positively correlate with lichen diversity and richness for two main reasons. First, larger trees have a higher probability of being colonized by lichens simply because they serve as a larger “target” for airborne spores. Aerial dispersal of asexual reproductive structures called soredia is a dominant means of lichen reproduction (Marshall 1996), though the mycobiont will often also produce sexual spores (Medlin 1996). Lichen colonization is therefore limited by the dispersal range of the spores and the conditions at the landing site (Sillett et al. 2000). Second, in accord with the predictions of island biogeography theory, larger trees may be more likely to support a greater variety of microhabitats, thus promoting increased diversity of lichen communities (Botkin and Keller 2003).

Tree diameter did not correlate with lichen diversity, species richness, and cover among the three tree species surveyed at UNDERC. These results are inconsistent with the findings of Johansson et al. (2007) and Nascimbene et al. (2009), among others, who have observed a positive correlation between tree size and lichen species richness. This suggests that tree size is *not* the major driver of lichen community composition at UNDERC.

Many alternative explanations for lichen distributions have been proposed including tree age (Esseen et al. 1996; Nascimbene et al. 2009), bark acidity (Jüriado et al. 2009), light availability (Johansson et al. 2007; Nascimbene et al. 2009), latitude (Jüriado et al. 2009), branch availability (Esseen et al. 1996), disturbance history (Eversman et al. 2002; Wolseley et al. 1994), strand identity (Esseen et al. 1996; Johansson et al. 2007; Lang et al. 1980; Selva 1994; Wolseley et al. 1994), bryophyte cover (Jüriado et al. 2009), and tree height (Lang et al. 1980). Unfortunately, my study does not address any of these factors, so further research will be required to discern which of these variables, if any, is most strongly affecting UNDERC lichen populations.

I observed highly significant differences in lichen diversity among tree species, most notably the high lichen diversity found on sugar maples. In addition, several lichen genera were commonly found more frequently on one tree species than on others. These results are not unexpected, for different lichen species perform best on different substrate types (Hale and Cole 1988). For example, Selva (1994) observed that different lichen assemblages are found preferentially on angiosperms over gymnosperms, and vice versa. Jüriado et al. (2009) found significant differences in lichen richness among tree species and attributed these results primarily to differences in bark acidity among species. Sillett et al. (2000) investigated the relationship between bark texture and lichen establishment, noting that the smooth bark of *Populus tremuloides* and *Betula papyrifera* poses a significant obstacle to lichen colonization. This observation would seem to account for lower lichen diversity I observed on aspens and birches relative to sugar maples. However, without additional investigation, I am unable to conjecture about which species-specific characteristics, such as bark acidity or texture, might best account for the differences I observed in lichen diversity.

My work is limited by the narrow scope of my study, for time constraints compelled me to restrict my investigation to only two main variables (tree size and species). Without additional data about other possible contributing factors – such as tree age, light conditions, bark acidity, etc. – I am unable to account for the lichen distributions I observed. However, my work may still have value as the preliminary investigation of lichen communities in this area, serving as a baseline for future studies of lichens as indicators of forest health.

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TABLES

Table 1: Lichen species and distributions

Lichen species	Number of trees	Total cover (cm²)
<i>Candelaria concolor</i>	11	131
<i>Cladonia fimbriata</i>	1	14
<i>Cladonia</i> sp.	2	21
<i>Flavoparmelia caperata</i>	20	2824
<i>Parmelia saxatilis</i>	10	1383
<i>Parmelia sulcata</i>	7	1397
<i>Parmotrema</i> sp. 1	1	10
<i>Parmotrema</i> sp. 2	2	21
<i>Phaeophyscia orbicularis</i>	1	226
<i>Phaeophyscia</i> sp. 1	18	1925
<i>Phaeophyscia</i> sp. 2	1	22
<i>Phaeophyscia</i> sp. 3	1	2
<i>Physconia</i> sp. 1	4	65
<i>Physconia</i> sp. 2	1	55
<i>Physconia</i> sp. 3	1	183
<i>Physconia</i> sp. 4	1	128
<i>Physconia</i> sp. 5	1	3
<i>Physconia</i> sp. 6	1	20
<i>Physconia</i> sp. 7	1	19
<i>Punctelia bolliana</i>	3	313
<i>Punctelia rudecta</i>	3	491
<i>Punctelia subrudecta</i>	3	154
<i>Stereocaulon</i> sp.	4	26
<i>Tuckermannopsis</i> sp.	1	49

FIGURES

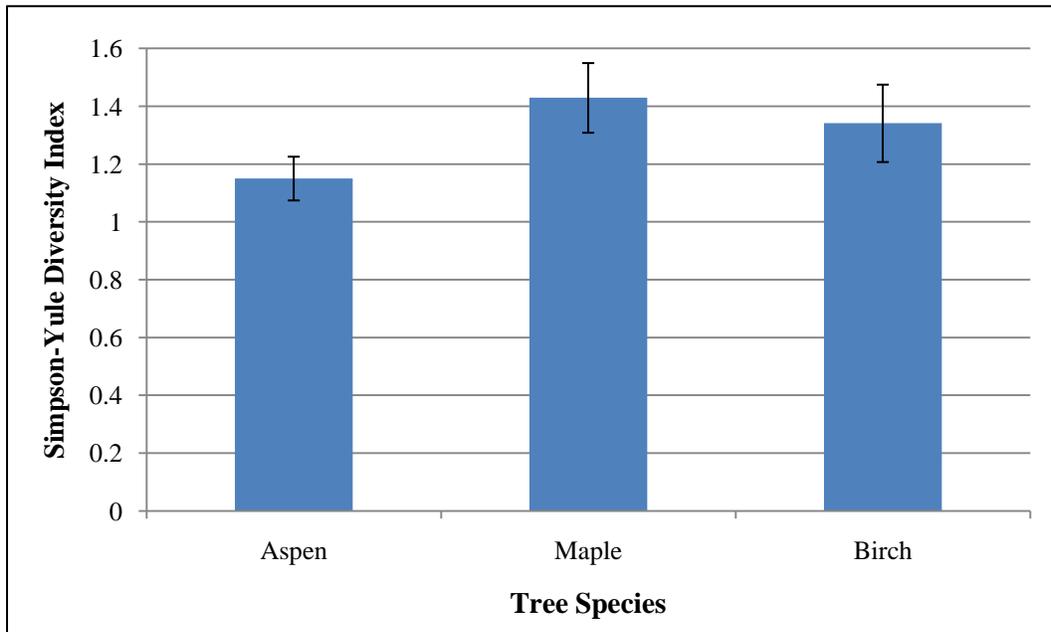


Figure 1: Differences in lichen diversity among tree species. Lichen diversity on sugar maple trees is significantly higher than on quaking aspen ($p < 0.001$) or paper birch ($p = 0.002$) trees. The difference in lichen diversity between quaking aspen and paper birch trees is marginally significant ($p = 0.055$).

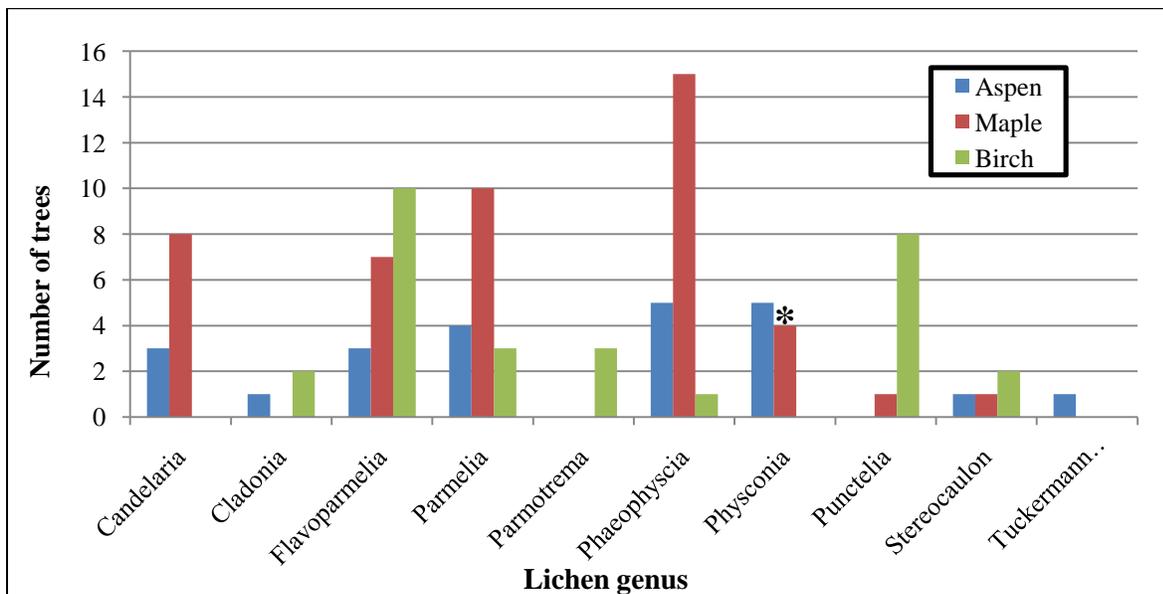
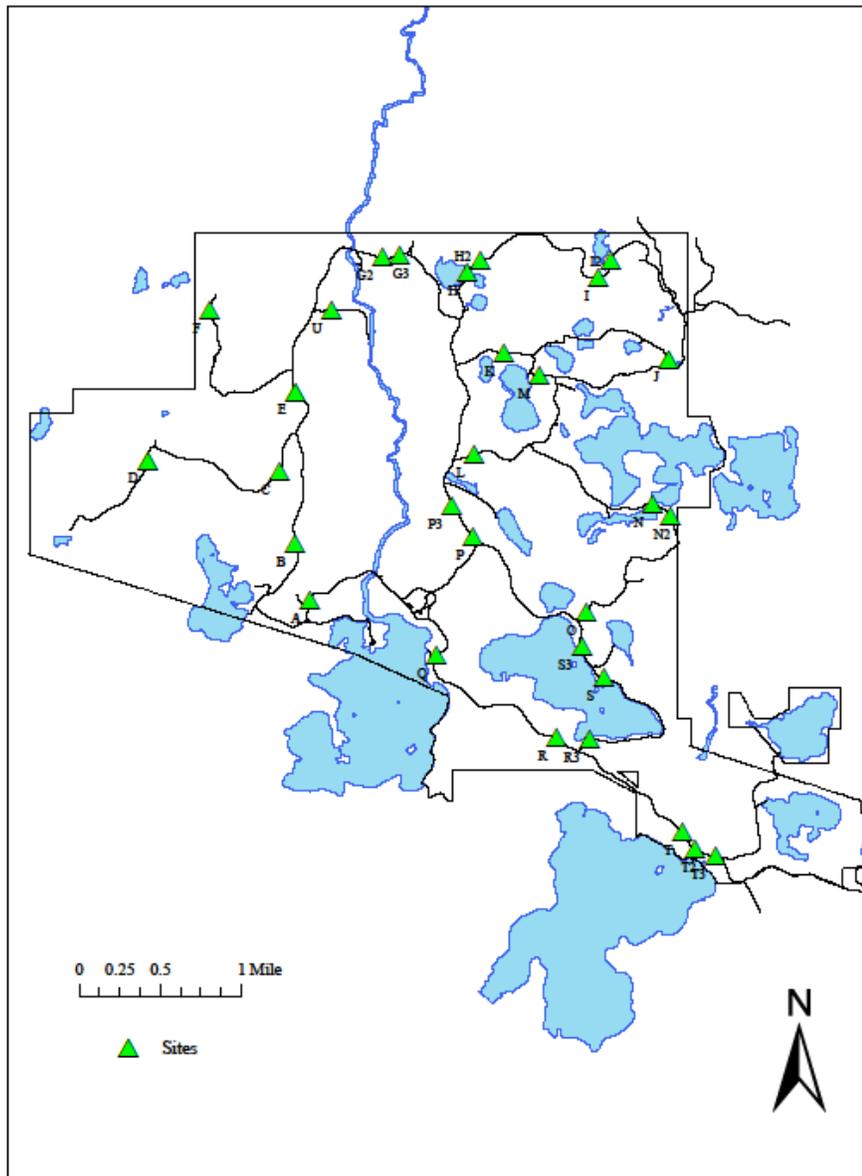


Figure 2: Frequency distribution of lichen genera among tree species. *One maple tree supported two species of the genus *Physconia*.

APPENDICES

Appendix 1 – Map of sampling locations



Appendix 2 – UTM coordinates of sampled trees

Quaking Aspen <i>Populus tremuloides</i>	Sugar Maple <i>Acer saccharum</i>	Paper Birch <i>Betula papyrifera</i>
16T 0304340, 5122300	16T 0304337, 5122259	16T 0304327, 5122214
16T 0304181, 5122841	16T 0304188, 5122872	16T 0304166, 5122968
16T 0304048, 5123533	16T 0304039, 5123535	16T 0303983, 5123520
16T 0302726, 5123660	16T 0302717, 5123655	16T 0302712, 5123654
16T 0304133, 5124335	16T 0304146, 5124298	16T 0303334, 5125116
16T 0303350, 5125215	16T 0303344, 5125151	16T 0305031, 5125707
16T 0305212, 5125690	16T 0305987, 5125616	16T 0305912, 5125563
16T 0305873, 5125523	16T 0307301, 5125645	16T 0307202, 5125456
16T 0307193, 5125455	16T 0307875, 5124674	16T 0307816, 5124661
16T 0307821, 5124660	16T 0306259, 5124694	16T 0306228, 5124681
16T 0306195, 5124704	16T 0305928, 5123750	16T 0305859, 5123737
16T 0305942, 5123736	16T 0306568, 5124482	16T 0306561, 5124471
16T 0306574, 5124475	16T 0307699, 5123199	16T 0307694, 5123216
16T 0307850, 5123109	16T 0307064, 5122122	16T 0307086, 5122159
16T 0307049, 5122141	16T 0305687, 5123216	16T 0305894, 5122889
16T 0305908, 5122886	16T 0305558, 5121718	16T 0305596, 5121737
16T 0305614, 5121730	16T 0306729, 5120883	16T 0306774, 5120866
16T 0307202, 5121590	16T 0307222, 5121523	16T 0307017, 5121810
16T 0308374, 5119684	16T 0307997, 5119905	16T 0308151, 5119757
16T 0304520, 5125138	16T 0304501, 5125107	16T 0304506, 5125112