Effect of Ambient Light Levels on Understory Composition in a Pine Barrens Ecosystem at Brookhaven National Laboratory's Proposed Solar Array; Establishing a Baseline for Future Studies

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EFFECT OF AMBIENT LIGHT LEVELS ON UNDERSTORY COMPOSITION IN A PINE BARRENS ECOSYSTEM AT BROOKHAVEN NATIONAL LABORATORY'S PROPOSED SOLAR ARRAY; ESTABLISHING A BASELINE FOR FUTURE STUDIES

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ABSTRACT

The increasing population of the human race and our escalating energy use forces us, as a nation and as a species, to adapt through the use of energy generation technologies that have less impact on our environment. To this end, Brookhaven National Laboratory has partnered with BP Solar to install a 200-acre, 35 MW, solar panel array on site at BNL. My research involved gathering a baseline survey of the existing understory vegetation as it relates to both the overstory type and the relative ambient light. This will allow my research team to draw immediate conclusions as to how the overstory habitat type affects the understory species composition, and will allow us to provide a baseline survey which can then be compared to the understory makeup post-solar-panel-installation, up to twenty years from now. In order to document the habitats, we laid twenty twenty-five meter transects, along which we placed six one meter square quadrats. In each of the quadrats, we identified, counted the number of, and measured the heights of each species. We also estimated percent ground cover of each species, and also overstory percent cover and species composition. I also put up 16 light meters in 12 different habitat types in order to better understand the relationship between light and the understory vegetation. Several variables are expected to be modified by removing the overstory and installing the solar panels, including increased light (all the trees will be removed), changes in water distribution (the solar panels are impervious and will direct rain that falls off their lower edge), and changes in herbivory levels (there will be a deer-proof fence erected around the entire solar array). These changes will have direct effects on the remaining plants, including changing water distribution patterns, easing herbivory stress, and possibly allowing other plant communities to establish due to the different light and moisture regimes. The data we have gathered indicate that the understory has a statistically significant correlation ($p<.0.8$ & 0.14) with overstory, with pine and oak forest associating with mixed *Gaylussacia spp.* and *Vaccinium spp.* understory, and open areas comprised mostly of grasses, *Asclepias spp.*, and other grassland plant species. Whether the removal of the overstory will give an advantage to invasive plants remains to be seen, but there is potential that the solar panels could provide enough shade to allow the existing plant communities to flourish.

INTRODUCTION

Energy generation technologies that have less impact on our environment are an important step in America's drive towards sustainable energy independence. To this end, Brookhaven National Laboratory has partnered with BP Solar to install a 200-acre, thirty-five megawatt, solar panel array on site at BNL. This solar panel array will be the most powerful array in the United States, surpassing the current leader at Nellis Air Force base in Nevada, which currently produces fifteen to eighteen megawatts.

The installation of this large an array gives us a unique opportunity to study how a solar array affects the existing vegetation. Several changes, including deer proof fencing around the entire array, changes in the light regime due to differences in light levels beneath solar panels and beneath the existing trees, as well as changes in water distribution due to the redirection of rainfall, which runs off of the solar panels, creating dry areas underneath them, and wetter areas at the lower ends of the panels are among the myriad changes which will occur.

Brookhaven National Laboratory is located in Upton, NY, on a 5,235-acre campus in the heart of the central Pine Barrens ecosystem on Long Island. The ecosystem consists of a mixed pitch pine (*Pinus rigida*) and oak (*Quercus alba*) forest with a mixed heath understory.[i] There are also some stands of Red Maple (*Acer rubrum*) in the wetter areas of the site, and some artificially introduced plantations of white pine (*Pinus stobus*), which were planted forty to fifty years ago.

The understory is mostly made up of the plant family Ericaceae (heath family).[ii] Ericaceae is mostly comprised of acid-loving plants, and contains both the genus Vaccinium and Gaylussacia, both of which are found prominently in the Long Island Pine Barrens ecosystem.[iii] The genus Vaccinium contains many edible berry plants, including the cranberry, blueberry, bilberry, lingonberry, whortleberry, and cowberry.

Members of the genus Vaccinium prefer acidic soils and partial shade.[iv] The mixed pine/oak forest of the central Long Island pine barrens provides an excellent habitat for these species, with mixed heath, including plentiful members of the genus *Vaccinium* and *Gaylussacia*, comprising most of the understory.[v] The lowbush blueberry (*Vaccinium angustifolium et al. spp.)*, the highbush blueberry (*Vaccinium corymbosum*), and the huckleberry (*Gaylussacia spp.)* are the primary understory vegetation in much of the proposed solar array area[vi].

My research involved gathering a baseline survey of the existing understory vegetation and relating it to both the overstory type and the amount of relative ambient light. This has allowed my research team to come to the conclusion that the overstory habitat type affects the understory species composition through many factors, including light levels. This study will provide a baseline survey of the existing vegetation, which can then be compared, up to twenty years from now, to the understory species composition post-solar-panel-installation. From this comparison between the pre-installation understory plant community, and the post-installation ecosystem, future researchers will be able to track the changes that occur over time in the ecosystem due to the solar array installation.

Because of the long term nature of our research, and the short duration of the SULI internship, we have both a short term and long hypothesis. The short term hypothesis is that light levels affect the species composition of the understory, with less light being associated with fewer plants, moderate amounts of light being associated with a mixed heath understory, and full sun correlating strongly with grasses and other shade intolerant species.

The long-term hypothesis is an application of the short-term hypothesis. We believe that the removal of the overstory trees and the installation of the solar panels will cause enough disturbance to the understory to disrupt the current plant community, and that due to this, and the subsequent changes in light levels, the plant communities will change.

The amount of light in different areas (between the solar panels or underneath them) will create dramatic differences in light levels, with the areas under the panels receiving no direct sunlight at any point during the year, and the areas between the panels receiving no light during the winter months, and full sun during the summer. This is because the solar panels are positioned so that they can receive the maximum amount of sunlight during the longer winter, which energetically makes more sense to sacrifice some of the solar power during the summer while gaining the full effect during the much longer winter, even though the sun is much lower on the horizon.

Methods and Materials

In order to accurately sample the varying habitats in the proposed solar array area, we laid seventeen transects, twelve within the array, and five outside, as controls. We had two transects in each distinct habitat, distinguished mostly by overstory species. The habitats were divided by dominant overstory species; red maple, white oak, pitch pine, scarlet oak, and grasslands (none). Of course, these species frequently coexisted in the same area, so we further divided the habitats based on the dominant overstory. For example, white oak/pitch pine and pitch pine/white oak referred to two different communities that were made up of more than fifty percent white oak and less than fifty percent pitch pine, and *vice versa* for the latter. In addition to determining overstory species composition and percent cover, we also estimated percent ground cover of each understory species.

Additionally, I put up sixteen light meters in twelve different habitat types in order to better understand the relationship between light and the understory vegetation. Several variables are expected to be modified by removing the overstory and installing the solar panels, including increased or decreased light levels (All the trees will be removed, but light impervious solar panels will be installed), changes in water distribution (the solar panels are also impervious to water, and will direct rain that falls onto them off of their lower edge), and changes in herbivory levels (there will be a deer-proof fence erected around the entire solar array). [vii]

These changes will have direct effects on the remaining plants, including changing water distribution patterns, easing herbivory stress, and possibly allowing other plant communities to establish due to the different light and moisture regimes. The data we have gathered so far indicate that the understory correlates very strongly with overstory, with pitch pine and oak forest associating strongly with mixed huckleberry and low-bush blueberry understory, and open areas comprised mostly of grasses, milkweed, and other grassland plant species. Whether the removal of the overstory will give an advantage to grasses and other full sun species remains to be seen, but there is potential that the solar panels could provide enough shade to allow the existing plant communities to flourish.

In order to measure the light, I placed 16 Hoboware light meters at various places in the field on June 19, and collected the data off of them for analysis on July 21. (*Fig. 1.2*) Unfortunately, some of the light meters didn't function as expected, and several data points from of them had to be discarded due to large inconsistencies. I believe this is due to direct sunlight hitting the meter through the canopy, as the values were comparable to the full sun light meters. Fortunately, this was only true for less than five percent of the values.

My group then spent several weeks out in the field, laying down twenty-five meter transects, and mapping their locations with a Trimble Geo XT Global Positioning System. We frequently had sub meter accuracy in our waypoints, which will allow future researchers to survey and compare the exact same locations after the clearing of the overstory, installation of the panels, up to twenty years from installation (the operating life of the solar panels), as the vegetation regrows and regenerates itself (*Fig. 1.2*). We then placed one meter square quadrats at six points along the twenty-five meter transect: at one meter, five, ten, fifteen, twenty, and twenty-five meters. We identified, counted, and measured the heights of all the plants contained within the quadrat (we did not include branches of plants which were growing outside of the quadrat), and recorded this information, which we then inputted into the computer. We did not end up putting down transects by five of the light meters, so ultimately we had comparable data for eleven different areas.

I then compiled the light meter data using excel, into an "average day", meaning that I averaged each of the same time of day points for a twenty-four hour period (*Fig 1.1*). I then compared these on the same graph, after converting them to degrees Celsius and Lux from Fahrenheit and Foot-candles, respectively (*Fig 2.1 & 2.2*). I then used the program Stata® to analyze the data.

RESULTS

The white pine areas had been artificially introduced by humans, and were extremely dense, with not much light available to the understory plants as shown by the average light intensity lines for plots two, three, and four (*Fig. 1.1*). The most light, and consequently the highest temperatures, were found in the open grassy areas, as shown in plots nine and ten, in comparison to the previously mentioned plots (*Fig. 1.1*). The white oak, pitch pine, and scarlet oak and red maple forests all had intermediate levels of light (*Fig. 2.1*). The lowest lying, and therefore the wettest areas, were primarily composed of Red Maple, a tree species that prefers bogs, swamps, and other habitats where the ground is saturated with water for much or part of the year. Though I did not measure moisture content of the soil or the air, from personal observation as well as other scientific research and literature, it seems that highbush blueberry prefer these wetter areas, which also have a medium amount of light.[viii,ix]

With the averaged light and temperature data and the number of identified *Vaccinium* in each plot, I ran regression analysis using Stata®, a statistical analysis program. This regression data show that temperature has no statistical significance at anytime during the day. (*Fig. 3.1,3.2*) It also shows that morning light levels have a small effect on *Vaccinium spp.*, with higher morning light being correlated with fewer *Vaccinium* plants. Midday light had no statistical significance while higher levels of afternoon light were positively correlated with *Vaccinium spp.* (*Fig. 3.1*). This latter statistic was the only variable which was statistically significant. I was able to determine through this regression analysis that there is a statistical difference between open areas and forested ones, and that light seems to play a small, although statistically significant role, though temperature does not. (*Fig. 3.2, 3.3*)

Though I only measured light and temperature, it is likely that many other factors, such as moisture levels, and pH affect the distribution of *Vaccinium*. From my data and analysis I found that at the ninety percent confidence interval, the hypothesis that morning light *negatively* affects the growth of *Vaccinium* plants is statistically significant. (*Fig. 3.1,3.2*) Slightly less significant (eighty-six percent confidence level) is the hypothesis that afternoon light *positively* affects *Vaccinium* populations. Midday light is not statistically significant.(*Fig. 3.2*) Temperature also is not statistically significant either, and therefore the data do not indicate a correlation between temperature and number of *Vaccinium* plants.(*Fig. 3.1*)

DISCUSSION AND CONCLUSIONS

The preference of *Vaccinium* for moderate to low light levels may indicate that they will not do as well once the solar panels are installed, primarily because of the extremes of light projected to occur in the array. The data gathered will be very important in providing a baseline survey of the solar array pre-installation. These transects can be referred back to years from now, as a quantitative baseline measurement of plant species distribution pre and post installation.

More transects are needed in order to further strengthen our results, but with the limited time and resources available to our research team, we were able to prove that there is a statistically significant negative correlation between morning light and a positive correlation between afternoon light and *Vaccinium spp.* Most importantly, we provided a baseline survey of the ecosystem before it is significantly altered by human activity. Though it is hard to predict what will happen to the understory in the wake of the overstory removal and the solar panel installation, because of our data collection and research, future researchers will be able to monitor the changes to the habitat for years to come. This vegetation survey is not nearly as important for what we have discovered, but instead for what it will allow us to monitor, analyze, and discover in the years to come.

Aknowlegements

I would like to thank the Department of Energy, The National Science Foundation, and Brookhaven National Laboratory for allowing me to participate in this wonderful opportunity. I would also like to thank my two mentors, Dr. Tim Green and Jennifer Higbie, whose support and guidance were invaluable. I would also like to thank the Office of Education, and Mel Morris for finding time to meet with me and address my concerns. Finally I would like to thank the numerous scientists, staff members and researchers who willingly shared their time, expertise, and passion by sharing their knowledge and research with me.

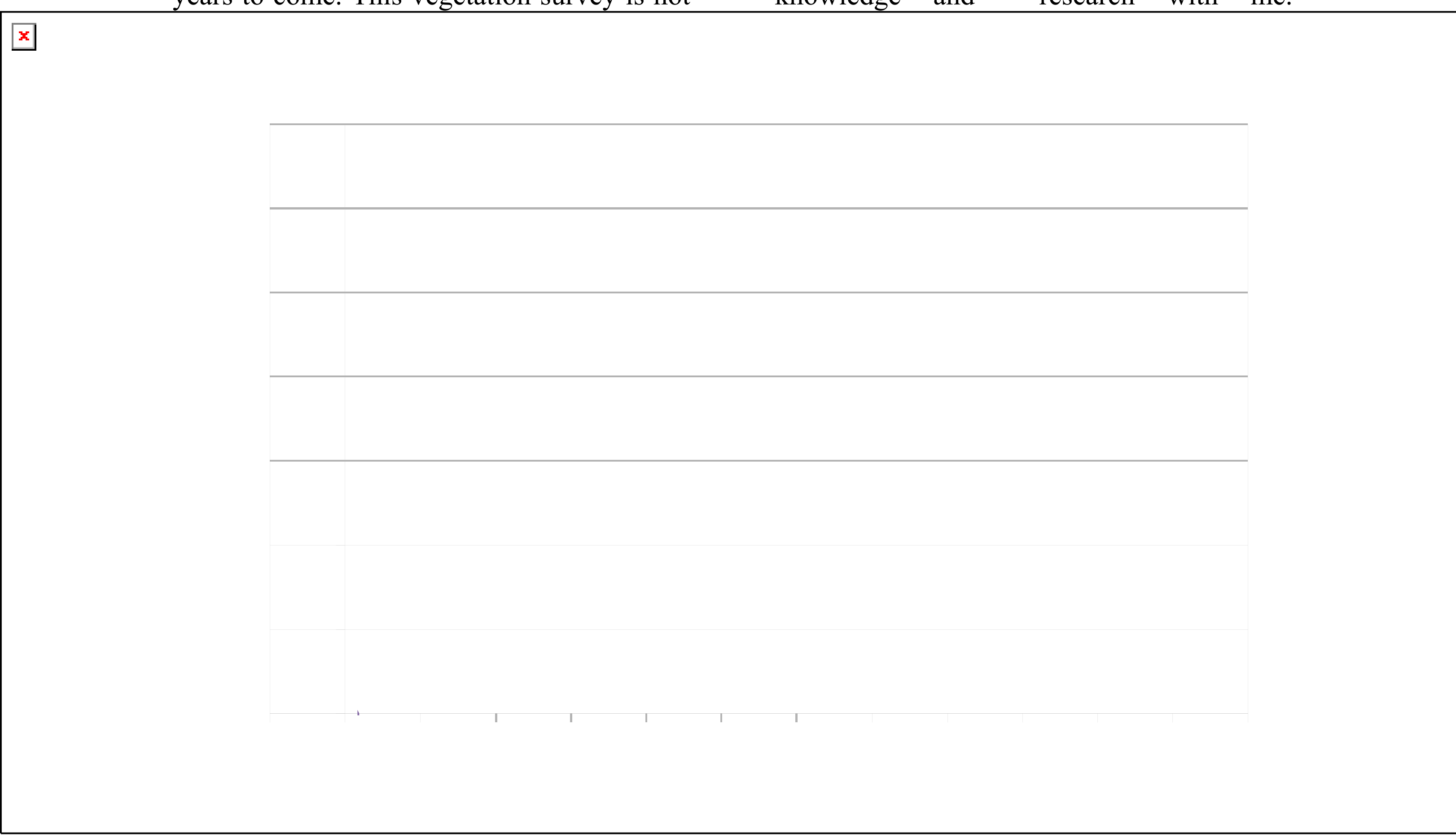

Fig. 1.1 - Comparison of high light intensities (open fields) and low light intensities (white pine plantations)

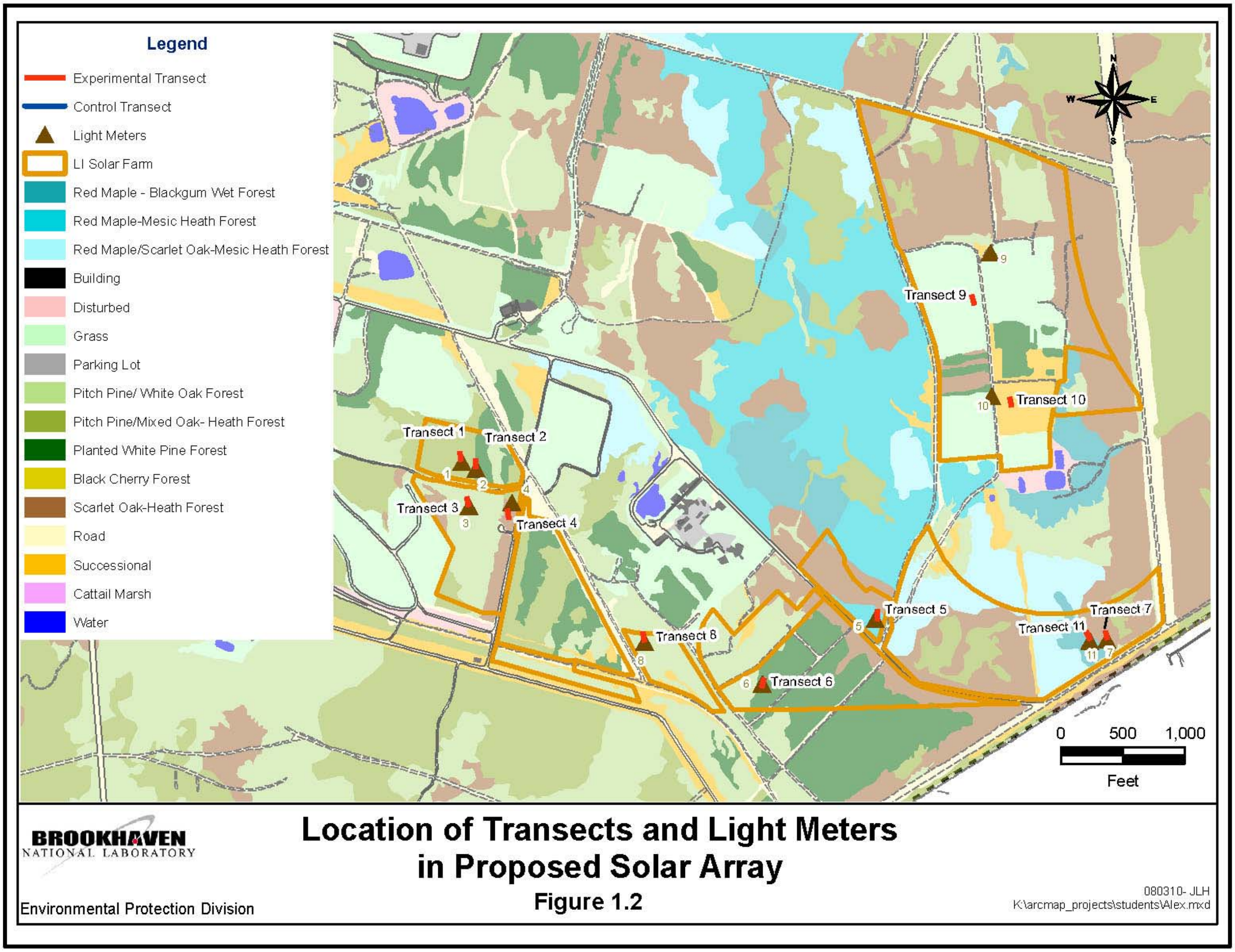

Fig 1.2 – Map of proposed solar array with transects/light meter locations marked.

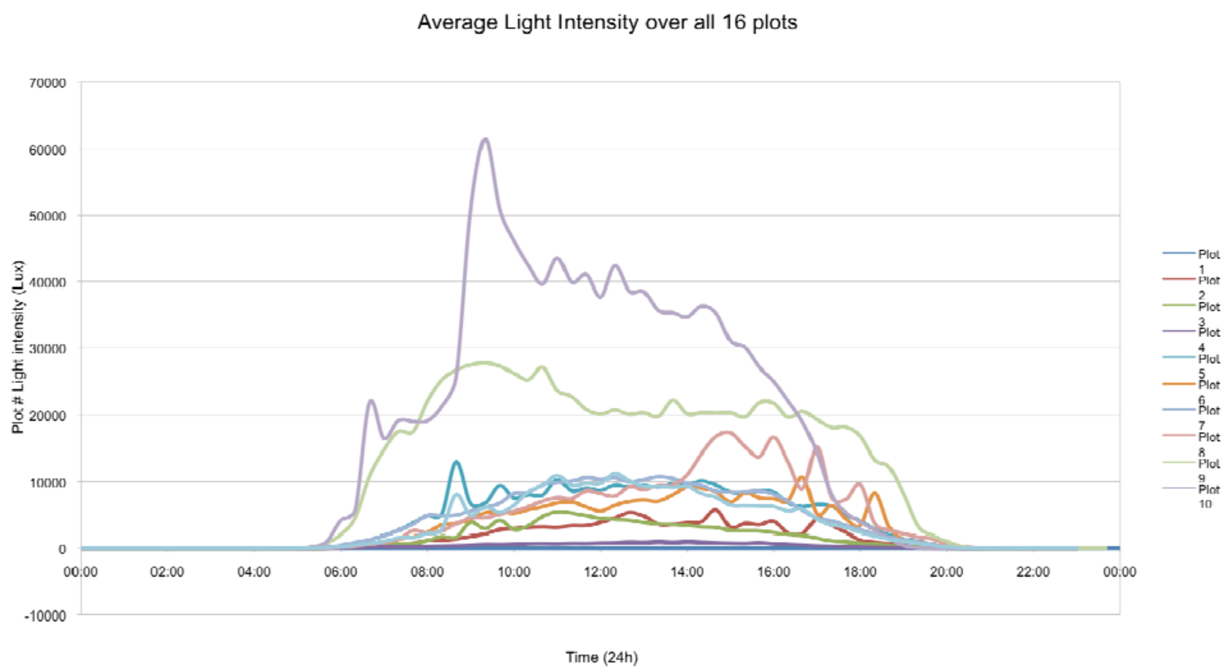

Fig. 2.1 – Line graph of average light intensity (Lux) at 20 minute intervals throughout an average day.

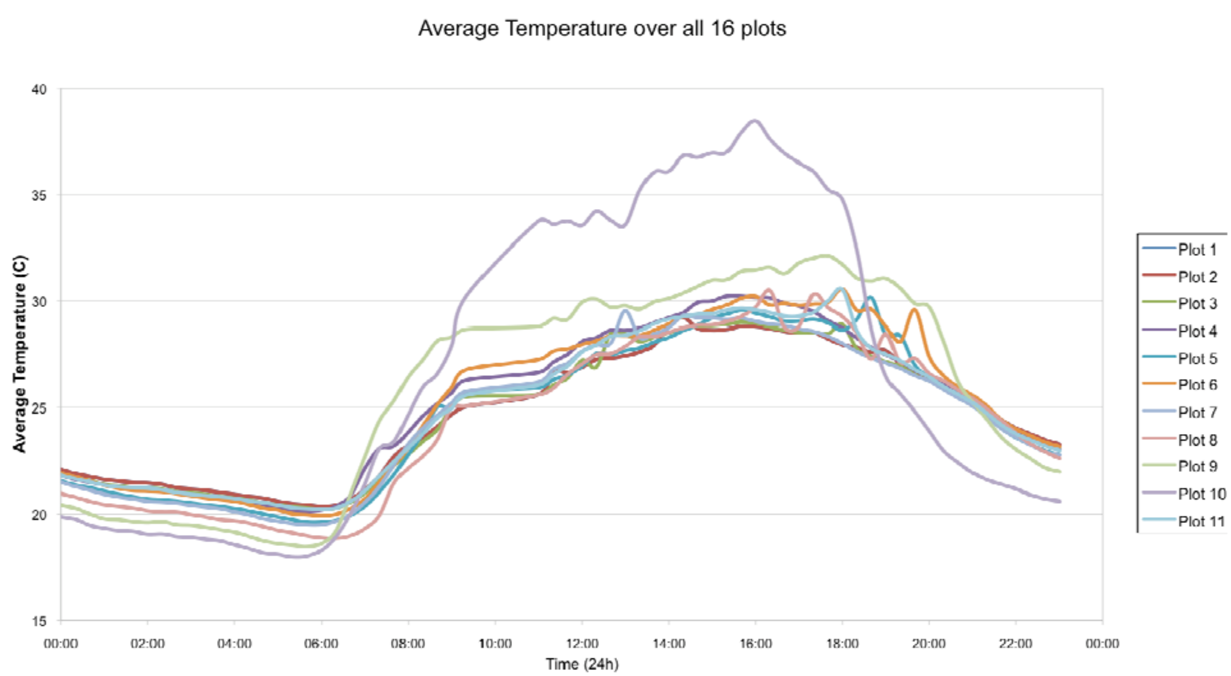

Fig. 2.2 - Line graph of average temperature (ºCelsius) at 20 minute intervals throughout a twenty four hour period.

. reg Vaccinium Morning Midday Afternoon

Source	SS	df	MS
Model	108504.041	3	36168.0136
Residual	102704.687	7	14672.0981
Total	211208.727	10	21120.8727

Number of obs =	11
F(3, 7) =	2.47
Prob > F =	0.1469
R-squared =	0.5137
Adj R-squared =	0.3053
Root MSE =	121.13

Vaccinium	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Morning	-.0405838	.019384	-2.09	0.075	-.0864197	.005252
Midday	-.0208052	.0205669	-1.01	0.345	-.0694383	.0278279
Afternoon	.0716622	.0430533	1.66	0.140	-.0301426	.173467
_cons	217.0787	57.9088	3.75	0.007	80.14618	354.0113

Fig 3.1 – Stata® regression analysis of average morning (5:40-10:20), midday (10:40-15:20), and Afternoon (15:40- 20:20) light intensity in relation to number of *Vaccinium* per plot.

reg Vaccinium TempMorning TempMidday TempAfternoon

Source	SS	df	MS
Model	80469.7666	3	26823.2555
Residual	130738.961	7	18676.9944
Total	211208.727	10	21120.8727

Number of obs =	11
F(3, 7) =	1.44
Prob > F =	0.3112
R-squared =	0.3810
Adj R-squared =	0.1157
Root MSE =	136.66

Vaccinium	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
TempMorning	-63.87159	72.50221	-0.88	0.408	-235.3121	107.5689
TempMidday	-80.95458	54.63055	-1.48	0.182	-210.1353	48.22614
TempAftern~n	49.16561	51.16913	0.96	0.369	-71.83016	170.1614
_cons	2667.002	1715.161	1.55	0.164	-1388.71	6722.713

Fig 3.2 - Stata® regression analysis of average morning (5:40-10:20), midday (10:40-15:20), and Afternoon (15:40- 20:20) temperature in relation to number of *Vaccinium* per plot.

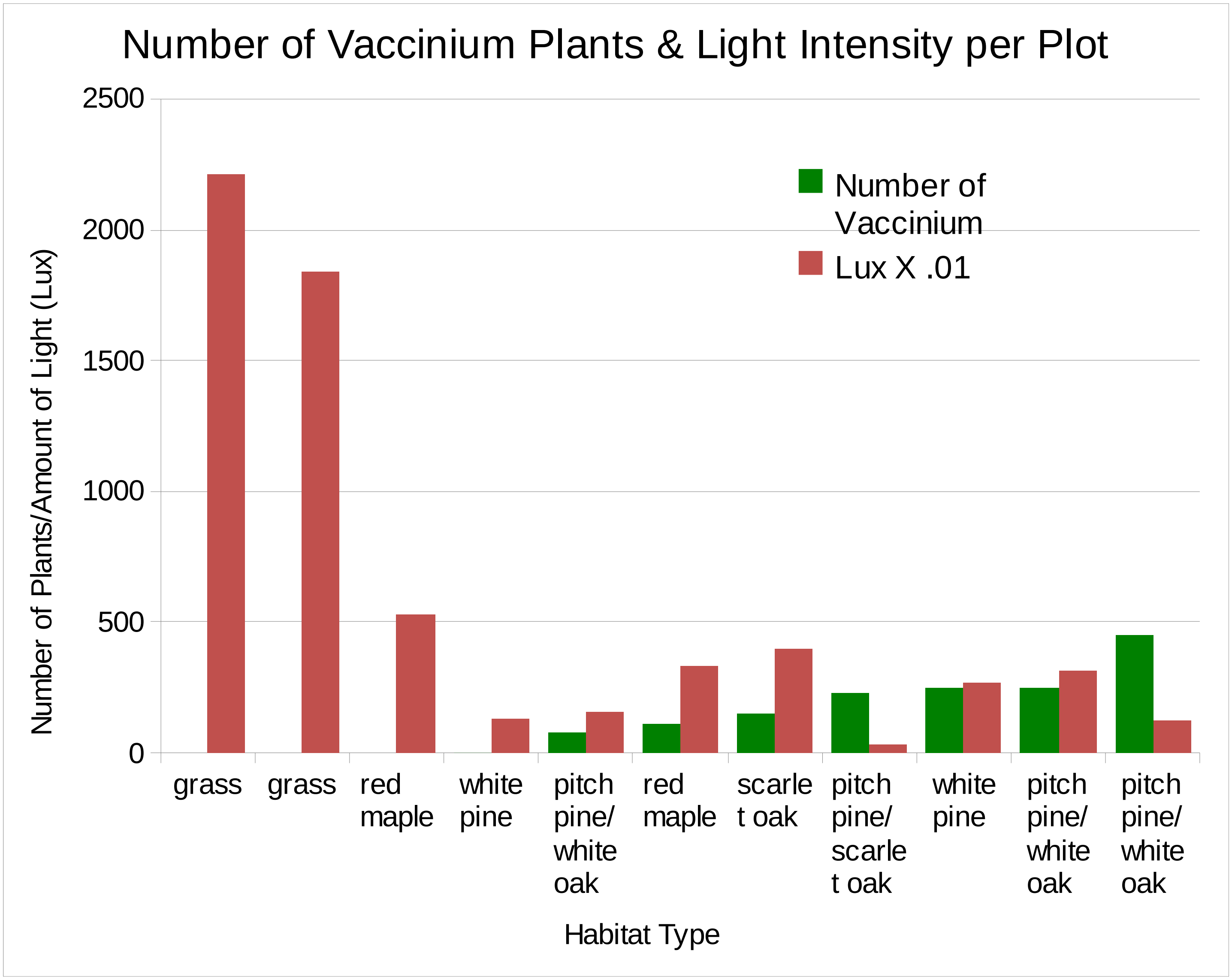

Fig. 3.3 - Number of *Vaccinium* plants versus the light intensity of each habitat, arranged by increasing numbers of Vaccinium. Note that the higher light intensities (> 5000 Lux) have no *Vaccinium* plants, while the transects with lower light levels are much more inconsistent.

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