Thermal Photography Indicates Differences in Temperature of Wild Lupine (*Lupinus perennis*) Compared to Ambient Environments in Indiana Dunes National Lakeshore

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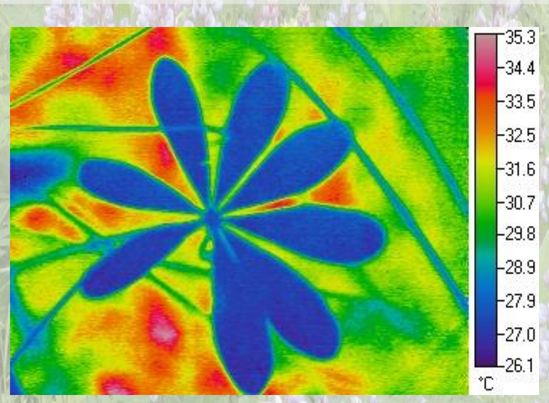
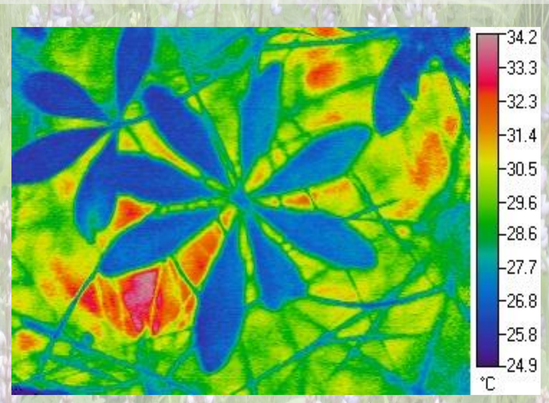
Objectives:
Indiana Dunes National Lakeshore is the southernmost home to the endangered Karner Blue Butterfly. However, predicted increases in temperature and changes in precipitation as a result of anthropogenic climate change is further threatening this species (IPCC 2007). Conserving the Karner blue's habitat and prolonging its existence in the Indiana Dunes is a priority. To this end, understanding the butterflies' main host plant, wild lupine (*Lupinus perennis*, Sundial lupine at USDA Plants database) in the face of climate change is a necessary step. Thermal imagery of lupine exhibited a general trend toward lower vegetative temperatures compared to the plant's surroundings. The goal was then, to evaluate the relevance of this difference in temperature across the landscape of the Indiana Dunes National Lakeshore, and to consider factors that may influence lupine temperature relative to it's environment, to gauge the risk of losing lupine and in turn, Karner Blue Butterflies, here at the Indiana Dunes due to a warming climate.

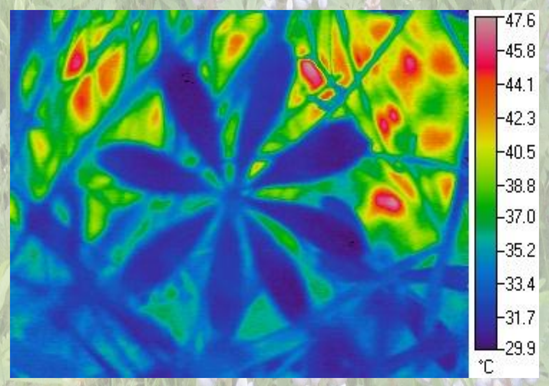
Methods:
Thermal images of 64 wild lupine leaves from five areas including Miller Woods -- North and South of the Harbor Belt, Inland Marsh, West Beach, and Cowles Bog units of the lakeshore, were obtained using a Mikron M7815 thermal imager. Mikron's software application, MikroSpec, was used to find differences in average temperatures for the lupine and the background image. Other values corresponding to ambient temperature were obtained from weather data collected from the Bailly MesoWest weather station in Porter, Indiana. The differences between lupine temperature and the various values of ambient temperature (lupine temperature – ambient temperature) were major factors in the statistical comparisons of lupine thermal behavior between sites, aspects, and dates. These statistical comparisons were conducted as ANOVA tests in the IBM SPSS 20 Statistics software package, as well as regressions in the R 2.15.0 and HyperNiche 2 statistical packages.



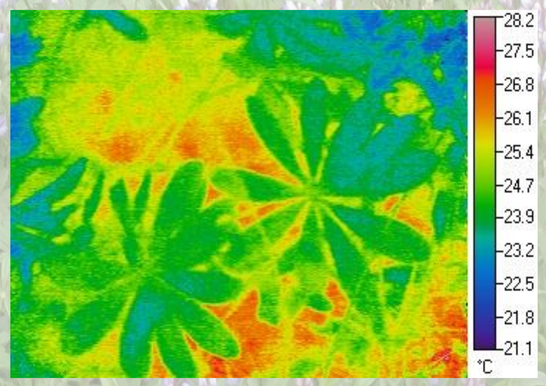
Thermal image of lupine taken at Inland Marsh, Indiana Dunes National Lakeshore



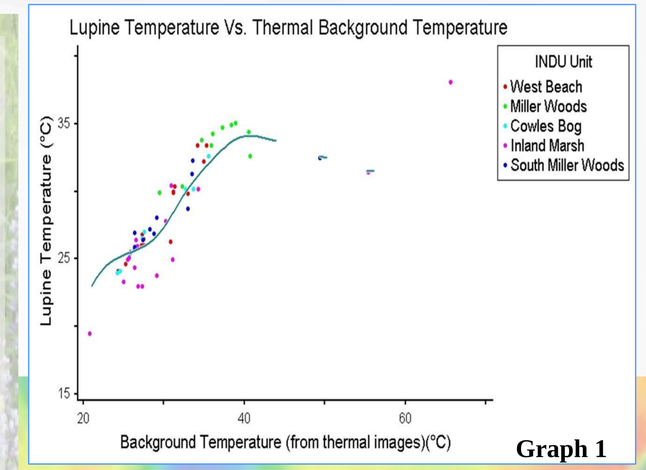
Thermal image of lupine taken at South Miller Woods, Indiana Dunes National Lakeshore



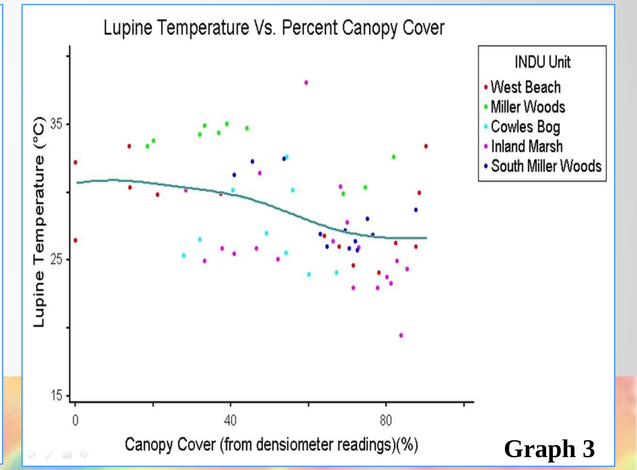
Thermal image of lupine taken at West Beach, Indiana Dunes National Lakeshore



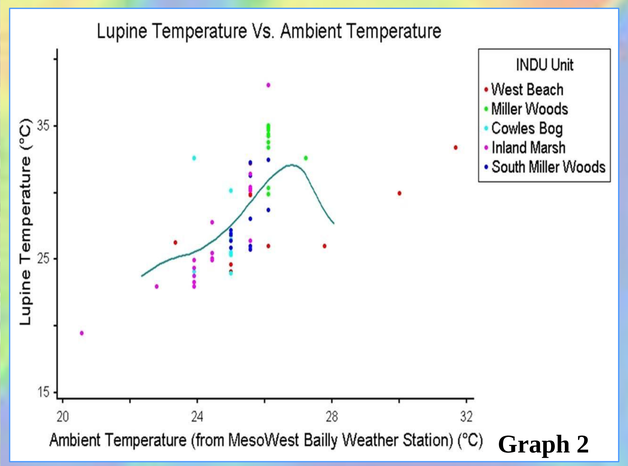
Thermal image of lupine taken a Cowles Bog, Indiana Dunes National Lakeshore



Graph 1



Graph 3



Graph 2

ANOVA: Lupine Temperature Vs. Year	**$F_{1,62} = 1.281$**	**p = 0.262**
ANOVA: Lupine Temperature Vs. INDU Unit	**$F_{4,59} = 8.223$**	**p < .0001**
ANOVA: Lupine Temperature Vs. Aspect (Southerly/flat vs. non-Southerly/flat)	**$F_{1,62} = 2.289$**	**p = 0.135**
Regression: Lupine Temperature Vs. Percent Canopy Cover	**t = -3.711**	**p < .0001**

Results:
While thermal images suggest that lupine plants exist at significantly lower temperatures compared to their surroundings—average lupine temperature was 2.96°C lower than the average temperature of the background in the thermal images (graph 1), this response was not observed when lupine temperature was compared to the weather station ambient air temperature –average lupine temperature is 2.92°C higher than the average ambient MesoWest temperature (graph 2). When assessing lupine temperatures across the landscape, the average lupine temperature was significantly different among the various units of the Indiana Dunes National Lakeshore. Miller Woods revealed a much higher lupine temperature than the four other units sampled. However, there was no significant difference between sample years (2011 vs. 2012) or between slope aspects (southerly vs. non-southerly). Further, the regression analysis confirmed that shaded lupine plants tend to exhibit lower temperatures than plants in full or direct sunlight (graph 3).

Conclusions:
The data suggests that lupine warms at a faster rate than ambient (MesoWest) temperature, but due to the parabolic shape of the curve in Graph 1, it appears that there is a temperature threshold at which the lupine plants begin to decrease their rate of temperature increase, likely due to thermal regulation processes. However, due to the lack of data at high ambient temperature extremes, this trend cannot be confirmed. At this time, data does not support the theory that lupine undergoes any different thermoregulation processes as compared to its surroundings and further investigation is necessary to determine if changes to lupine or Karner Blue Butterfly management strategies are warranted.