

May 2016

Estimated Effects of Climate Change on the Reproductive Fitness of the Northern Spotted Owl, *Strix occidentalis caurina*

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Recommended Citation

Swit, Nadia. "Estimated Effects of Climate Change on the Reproductive Fitness of the Northern Spotted Owl, *Strix occidentalis caurina*." *The Downtown Review*. Vol. 2. Iss. 2 (2016) .
Available at: <https://engagedscholarship.csuohio.edu/tdr/vol2/iss2/5>

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Introduction

The Spotted Owl (*Strix occidentalis*) is often considered an indicator species of forest health due to its particular habitat preferences and temperature tolerance. Spotted Owls have an affinity for old-growth conifer forests, inhabiting older trees that allow the owls to use the hollows for nesting and refuge, canopy cover and shade, and roosting perches. In particular, the Northern Spotted Owl subspecies (*S. o. caurina*) inhabits the conifers of the Pacific Northwest, including northwestern California, southwestern British Columbia, and western Washington and Oregon (Franklin et al. 2000). This owl is characterized by its medium size, dark brown plumage with white spots on the head and breast, as well as dark brown eyes framed by prominent facial disks (U.S. Fish and Wildlife Service, 2014).



Figure 1. Northern Spotted Owl, *Strix occidentalis caurina* © Larry Meade

The habitat ranges of both Northern and California Spotted Owls overlap in California. Spotted Owls are further limited and made vulnerable by certain elements in their life history, including late maturity in their reproductive cycle, low reproductive output, and their inability to disperse readily due to their specialized habitat requirements (Weathers et al. 2001). Additionally, Spotted Owl populations are under stress primarily due to deforestation caused by logging industries. Mature and old-growth forests that are the most suitable for the owl and its subspecies in the Pacific Northwest have reportedly declined by 88% since

the 18th century because of logging (Groc, 2014). The quality of their available environment has also become varied, as previously homogenous old-growth forests are now a mosaic of younger and older trees and various vegetation (Franklin et al. 2000). The invasion of the Barred Owl (*S. varia*) has also created competition and further limited the Spotted Owl's home range and reproductive success (U.S. Fish and Wildlife Service, 2014).

Consequently, increasingly lower habitat quality and availability are causing the Northern Spotted Owl to decline rapidly. As habitat ranges become increasingly scarce, genetic variation decreases, reducing demographic stochasticity in small populations (Franklin et al., 2000; Lande, 1988). In a further complication, Spotted Owls are not tolerant of heat stress, utilizing adaptive behaviors and roost selection to avoid increasing heat: this also explains their preference for old-growth forests, which provide the optimal temperature for the owls' survival while also supporting a wide range of prey (Barrows 1981, Weathers et al. 2001). Additionally, as owls are generally more affected during the spring rather than winter because of their breeding season and the necessary increase in energetic output, climate conditions have also shown to exacerbate energetic stress conditions, causing further population decline (Franklin et al. 2000).

With the growing concerns of climate change and rising temperatures, there has been speculation of how organisms such as Spotted Owls will be able to withstand altered habitats. The following study examines the potential implications increasing temperatures can have on the reproductive success of the Northern Spotted Owls in Marin County, located in the northern San Francisco Bay area in the state of California. The area is recognized as a biodiversity hotspot that is able to support several different ecosystems, and therefore, potential changes in its climate often have negative consequences towards native biota. A previous study performed by Weathers et al. (2001) analyzing the

thermal ecology and ecological energetics of a spotted owl subspecies was adapted to the present study in order to determine effects that changing climate would have on the thermal requirements of the Northern Spotted Owl.

Methods

Marin County, California was selected as an area within the Northern Spotted Owl's range. The county contains three National Park lands and is included in the southernmost range of the owl (U.S. Forest Service, n.d.). The separate park areas that the Northern Owl inhabits within Marin County suggests range expansion and the forests' suitability for the owls' nesting. Additionally, Muir Woods, one of the National Park sites within the county, has been claimed to possibly contain the densest population of Spotted Owls on public land (National Park Service, 2014). While these owls prefer old-growth coniferous forests, according to the studies being conducted within the park, the evergreen forests that are also within the area are meeting ecological conditions for the owl, especially in the mild coastal California climate (National Park Service 2014). It can also be conjectured that competition from the Barred Owl and deforestation from logging creates a need to seek different habitats.

To create a baseline of temperatures to analyze for the Northern Spotted Owl in this area, data was obtained from the U.S. Geological Survey (USGS) site, using the National Climate Change Viewer. As spring months are more exhaustive for the owl due to rearing and providing for their young, a five month period from January to June was selected to test effects of climate change on metabolic rate as mating behavior can occur in early spring, and laying and hatching can occur in late spring to early summer depending on location (U.S. Forest Service, 2014a, 2014b).

First, a baseline was created using the USGS data to estimate the climate trends. These were then compared to the known thermal temperature maximum

and minimum values, as well as basal metabolic rate and thermal neutral zone which was calculated in a previous study (Weathers et al. 2001). While the aforementioned study focused on the California Owl (*S. o. occidentalis*), its results could here applied here because the subspecies of the Spotted Owl are similar in size and the territories of all three owls exhibit some overlap.

The basal metabolic rate (BMR) was calculated as the mean of the thermal neutral zone, averaging 10.13 ± 0.46 J/g/hr. The lower critical temperature (T_{lc}) was estimated to be 18.2°C , and the upper critical temperature (T_{uc}) was 35.2°C . (Weathers et al., 2001). The thermal neutral zone extended from these two temperatures. Additionally, metabolic rate equations were also calculated in order to determine the rate when temperature dropped below T_{lc} or increased above T_{uc} . The metabolic rate increased linearly with declining temperature as described by the following equation:

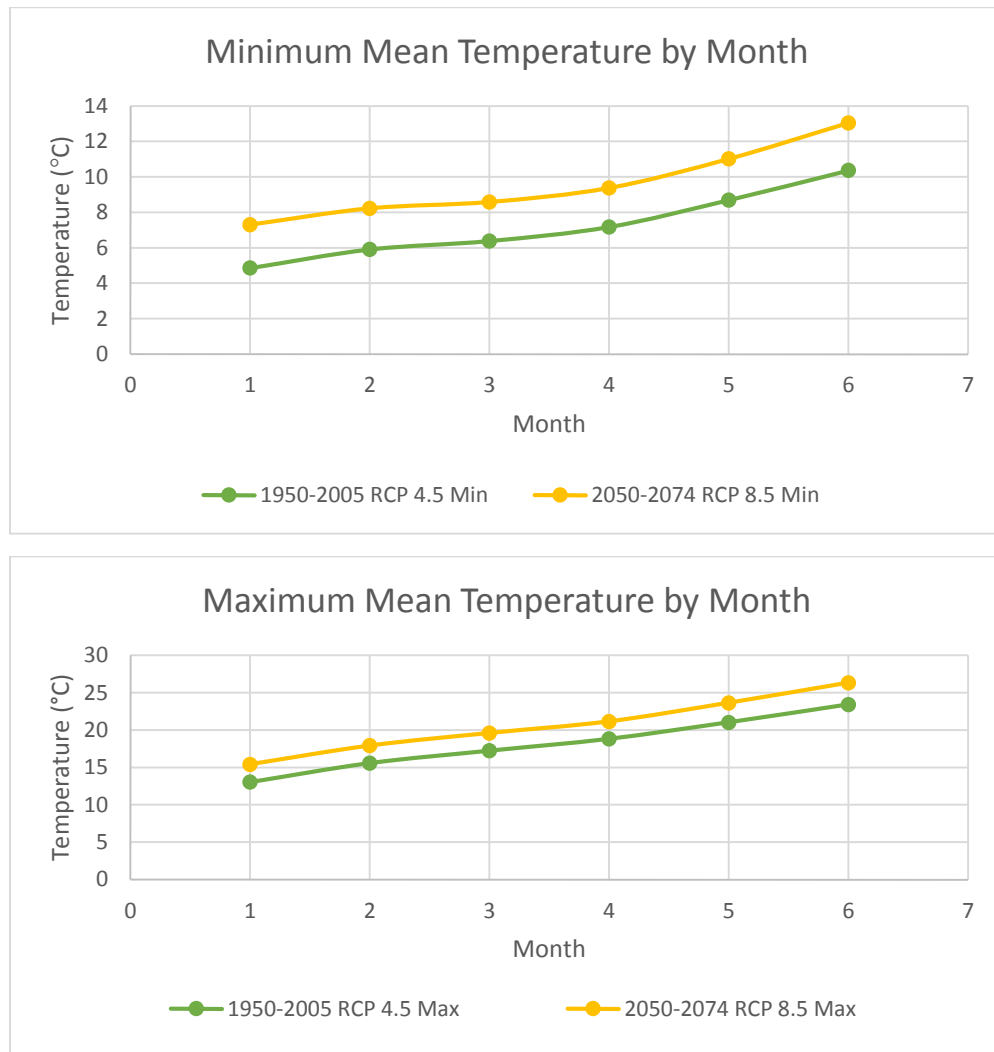
$$y = 18.1 - 0.436x \quad (1)$$

Likewise, as temperatures increased above the upper critical temperature, it was also described by the following equation:

$$y = -23.0 + 0.941x \quad (2)$$

These equations were then used with the climate data to determine how the metabolic rate would be affected. Temperature was inserted for x, which was in $^{\circ}\text{C}$ and y was resting metabolic rate (RMR).

Results and Discussion



Figures 2 & 3. Relationship between the current and future climate trends for minimum and maximum monthly temperature for months January to June (1 to 6) in Marin County, CA. Representative Concentration Pathway (RCP) values designate different reports simulating effects of increasing temperatures based on greenhouse gas emission trajectories.

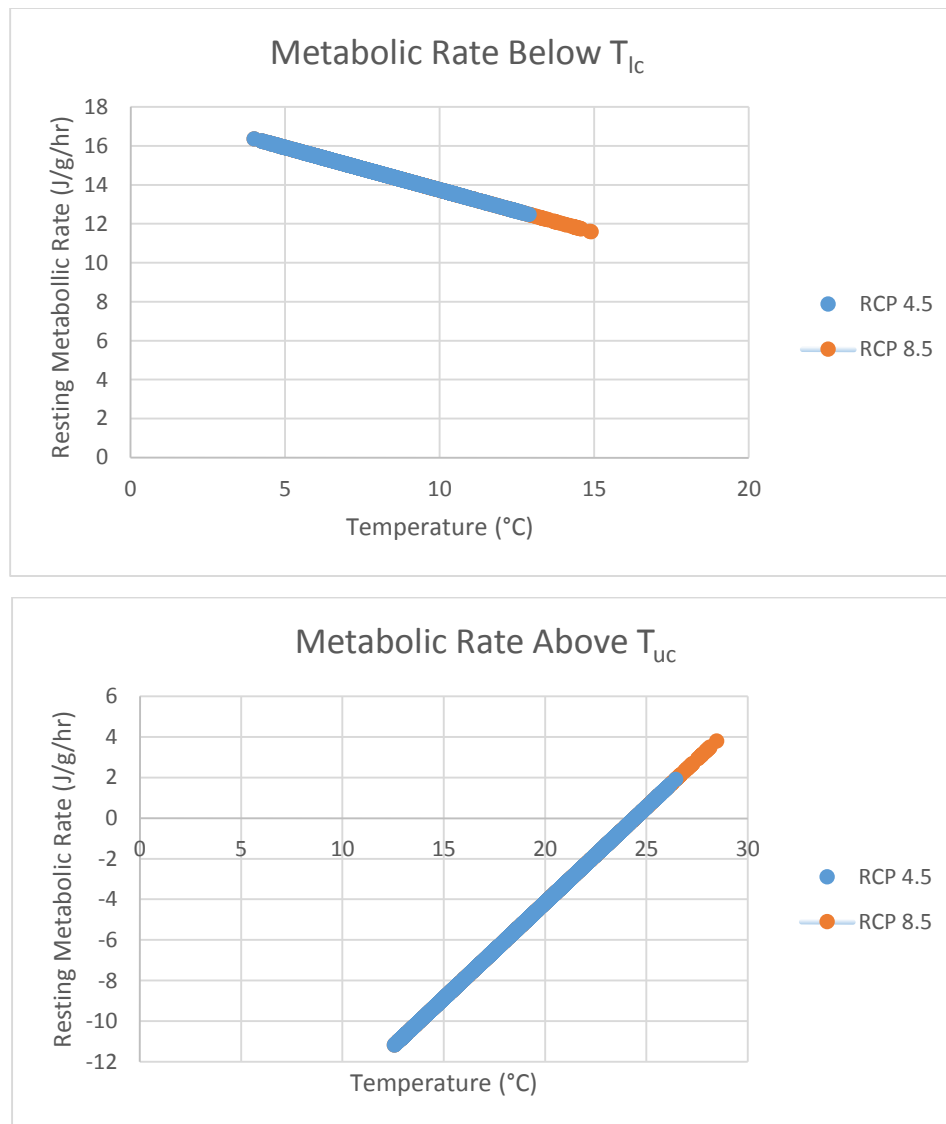


Figure 3 & 4. Relationship between RMR of the Spotted Owl with temperatures that are below its T_{lc} (lower critical temperature) and T_{uc} (upper critical temperature). The BMR was averaged to be 10.13 ± 0.46 J/g/hr. The lower critical temperature (T_{lc}) was estimated to be 18.2°C , and the upper critical temperature (T_{uc}) was 35.2°C .

Based on the two RCP reports, the resulting estimated maximum and minimum temperature give the range in which the Spotted Owl will be living. The minimum temperature range for RCP 4.5 was estimated to be 4.8°C to 10.4°C, whereas RCP 8.5 projected it to be 7.3°C to 13.04°C. As for the average maximum temperature, RCP 4.5 predicted its range from 13.04°C to 23.4°C, whereas RCP 8.5 estimated it to be 15.4°C to 26.3°C. Interestingly, the average minimum temperatures show that the owl will be living in conditions that would be below its lower thermal minimum (18.2°C), especially in the early spring (Figure 2). Thus, metabolically, the owl will need to exert more energy in order to retain body heat. Additionally, the average maximum temperatures shown in Figure 2 are also indicative of the owl living below its thermal minimum, and it is not until about April (mid-spring) that the owl will experience maximum temperatures from the RCP 4.5 estimate in which it can comfortably reside.

The data does not indicate whether the minimum temperatures were only experienced at a certain time of day, such as at night, where these temperatures would be the lowest for a limited amount of time. Reproductive success could then be negatively affected due to the additional energy required by the parent in order to maintain its own body heat. As more energy is exerted for its own survival, rearing young could be a potentially fatal challenge for the owl. With lower temperatures, owl hatchlings will also have to face demanding metabolic needs, which could be difficult to fulfill. In fact, the RCP 8.5 estimates are looking more favorable as temperatures would increase, therefore also increasing the amount of time the owl would reside in its thermal neutral zone. The temperature increase, however, can negatively affect other aspects of the Spotted Owl's ecosystem, therefore making the change not entirely beneficial. As mentioned before, the Spotted Owl is relatively intolerant of high temperatures (Weathers et al., 2001). Therefore while this study only examines a small portion

of the data from five months out of the year, the increasing temperature change may instead be unsuitable as the summer months continue to get warmer.

Figures 3 and 4 describe the metabolic exertion made by the owl due to temperatures below its thermal neutral metabolic rate. Basal metabolic rate was determined to be 10.13 J/g/hr (Weathers et al 2001). Metabolic rate was estimated to be approximately 16 J/g/hr when temperatures dropped to below 5°C, which is much higher than its resting rate. When temperatures were at its thermal neutral zone, metabolic activity decreased, as evidenced by the negative values on Figure 4. The overlap between the RCP 4.5 and RCP 8.5 projections suggests similar metabolic activity to occur in concurrent temperature predictions, however RCP 8.5 provides evidence that increasing temperatures have higher energy requirements.

Conclusion

As previously mentioned, the data analyzed in this paper is limited to only a small portion of the year. While these months are important to the life history of the Northern Spotted Owl in terms of reproductive success, the temperature and weather fluctuations caused by climate change can be much more significant as both RCP reports are projecting lower temperatures below its thermal minimum. Increasing metabolic activity in response to too cold or too warm weather would be detrimental to the reproductive capabilities of the owl, and the relative survival of the offspring. Population decline can result as fewer individuals are able to survive and maintain a viable population.

Similarly, climate change can negatively impact animals of lesser trophic levels in Marin County, providing additional consequences to predatory species, including the Spotted Owl. Further research would be needed in order to fully evaluate the implications of climate change as it would affect the owl's entire ecosystem. As for the Spotted Owls living in Marin County, the prospects for

survival seem to be adequate for the time being, besides the influx of Barred Owls and the habitat loss caused by logging companies. However, it should be noted that continuous destruction of old-growth forests and interspecific competition would exacerbate the challenges of increased metabolic demand already resulting from unusual temperature extremes. Alterations in the environment brought on by climate change, specifically the potentially low temperatures proposed by the RCP 4.5 and RCP 8.5 reports, must motivate policies and environmentally-minded actions in order to support the longevity of the species.

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