UNTANGLING CLIMATE AND WILDFIRE INFLUENCES FROM SNOW WATER EQUIVALENT MEASUREMENTS ON THE DEER PARK, WA, SNOW COURSE

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ABSTRACT

In 1988, the Deer Park Fire burned 170 acres within Olympic National Park, WA. The wildfire burned up to the southern end of the NRCS/NPS Deer Park Snow Course. The burn eliminated a forest stand downwind and down-slope of the snow course; this study reports on a potential decline in snow water equivalent (SWE) measured by the course as a result of this adjacent change in forest cover. Regional climate trends based on Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO) were incorporated into the evaluation, allowing the wildfire's impacts to be isolated from climatic variability. A comparison of mean SWE values before (1949-1988) and after (1989-2007) the wildfire for every reporting month in every climate cycle showed a clear trend of a decline after the wildfire; these differences are statistically significant in April and May for all climate cycles except for positive PDO+negative ENSO. Overall, estimates of effect size of the difference between means were uniformly negative and as low as 2.9" for February 1 snowpack in warm, dry climate cycles and as high as 17.1" for May 1 snowpack in cool, wet climate cycles. The results of this work should be taken into consideration for any future evaluations or use of Deer Park Snow Course's long-term data set, whether for local streamflow forecasting or for regional climate change modeling.

INTRODUCTION

In the summer of 1988, the Deer Park Fire on Washington's Olympic Peninsula burned the southern slopes of Blue Mountain, removing much of the forest cover (Figures 1 and 2). The NRCS/NPS Deer Park Snow Course is located immediately adjacent to the northern burn perimeter. Because forest cover can affect snowpack characteristics, hydrologists using the course's data need to know if the wildfire impacted long-term snow measurement patterns. Long-term climate cycles important to the Pacific Northwest confound the ability to assess potential effects of the 1988 wildfire on snow water equivalent. We report on an analysis of changes in snow water equivalent values measured at Deer Park Snow Course for different long-term climate cycles.

METHODS

The NRCS-NPS Deer Park Snow Course was established in 1949 and consists of 9 permanent sampling points, which are normally sampled four times each year, for reporting dates of February 1, March 1, April 1, and May 1. Snow course data from 1950-1988 (pre-fire) was compared with data from 1988-2007 (post-fire). For this study, we focused only on average snow water equivalent (SWE); future work will include depth and point-by-point assessment. Data from 1949 were excluded as MEI data (see below) is not available for that year.

To isolate the effect of the burn from long term climate cycles, we used Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO) index data to assign each reporting date in each year to a particular climate cycle. The PDO index is the leading principal component of North Pacific monthly sea surface temperature variability (Mantua and Hare 2002); data were obtained from Mantua (2008). We used the Multivariate ENSO Index (MEI) for the ENSO cycle, defined as the first unrotated principal component of six climate variables (sea-level pressure, zonal and meridional surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky), standardized with respect to each season and to the 1950-93 reference period (Wolter 1987; Wolter and Timlin 1993); data were obtained from Wolter (2008). Both PDO and MEI are defined as either positive or negative, based on the sign of the average standard deviation; positive years are warmer/dryer and negative years are cooler/wetter. Overlaying PDO phase with MEI phase classifies each winter into one of four climate cycles: Negative PDO+Negative MEI (Neg. MEI=La Niña), Negative PDO+Positive MEI (Pos. MEI=El Niño), Positive PDO+Negative MEI, and Positive PDO+Positive MEI.

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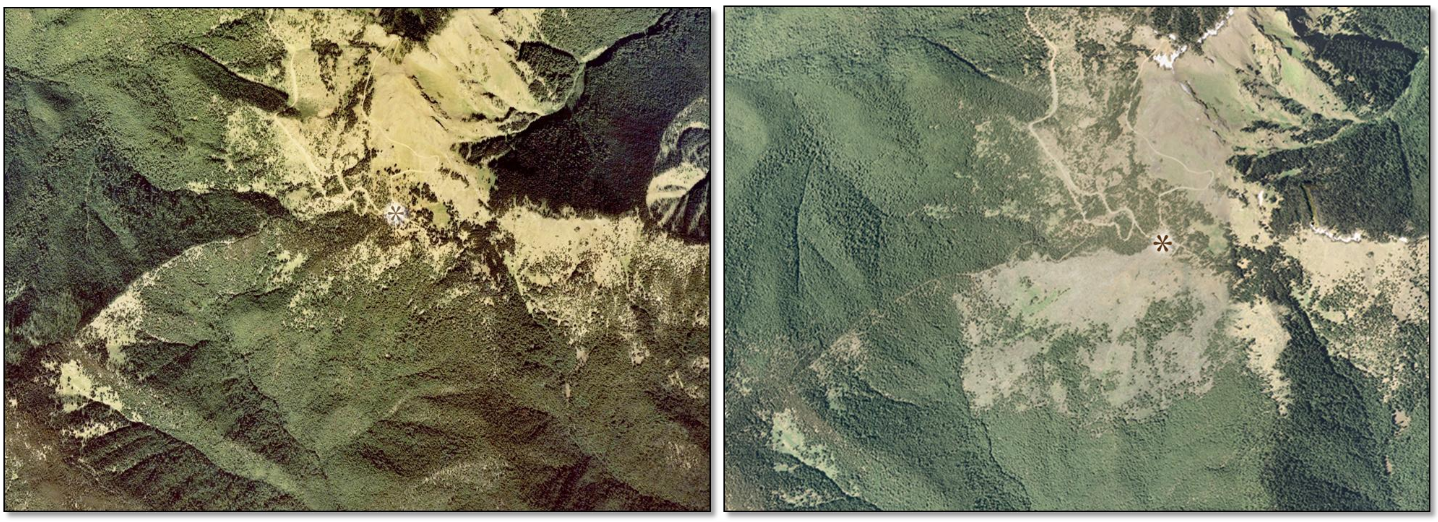
In 1988, the Deer Park fire burned 170 acres (69 hectares) within Olympic National Park, WA. The fire burned up to the southern end of the Deer Park Snow Course, located in the Dungeness River drainage at an elevation of 5,200 ft. (1,585 m).

Data courtesy: ESRI, Olympic National Park, USDA Natural Resource Conservation Service

Figure 1. Location and boundary of the Deer Park Snow Course and the 1988 wildfire.



1976 2006

Figure 2. Comparison of Deer Park before and after the 1988 fire; snow course indicated by asterisk.

Means and 95% confidence intervals were calculated for each reporting date, separated by climate cycle and whether it was before or after the burn. Mean differences (with 95% CIs) for each reporting date were used as the effect size scores. These differences were also assessed for statistical significance by randomization tests based on 10,000 Monte Carlo samples per contrast, using NCSS software; p-values are reported with the effect size graphs.

RESULTS

A comparison of mean SWE values before and after the fire for every reporting month in every climate cycle shows a clear trend of a decline after the Deer Park Fire (Figures 3-6), with differences becoming larger as winter progresses. The magnitude of this trend is greater in high snow years than in low snow years, and holds for most climate cycles. However, an evaluation of the 95% confidence intervals for each mean shows that in many cases the estimates of those means are not very precise or have considerable overlap. Confidence intervals are wide in many cases because of the small sample size and normal climatic variability.

An examination of mean differences in SWE shows the magnitude and direction of the trends (Figures 7-10). These differences are statistically significant in April and May for all climate cycles except for positive PDO+negative ENSO; the decline was as much as 17.1 inches of SWE (95% CI=4.7-29.4; p=0.02) in May for negative PDO+negative ENSO and as much as 9.2 inches (95% CI=1.7-16.7; p=0.02) in May for positive PDO + positive ENSO.

Figure 3. Differences in snow water equivalent before and after the 1988 wildfire by month in negative PDO + negative ENSO years (with 95% confidence intervals on means).

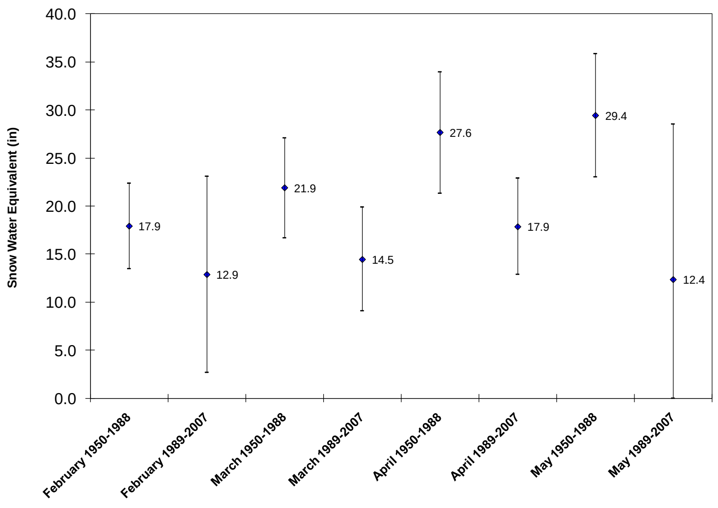


Figure 4. Differences in snow water equivalent before and after the 1988 wildfire by month in negative PDO + positive ENSO years (with 95% confidence intervals on means).

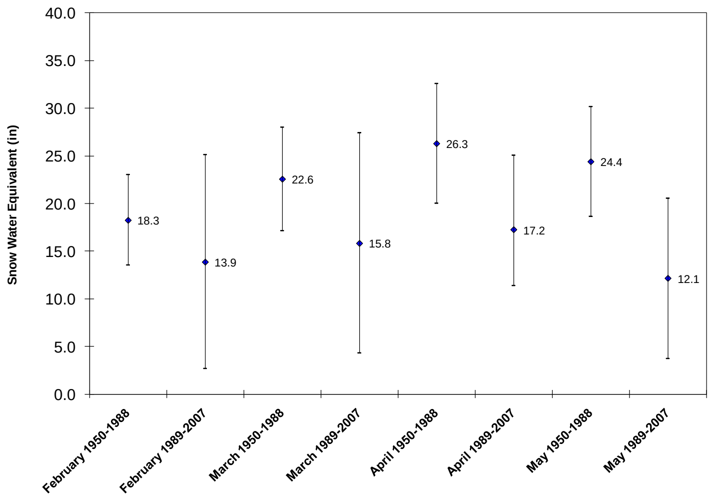


Figure 5. Differences in snow water equivalent before and after the 1988 wildfire by month in positive PDO + negative ENSO years (with 95% confidence intervals on means).

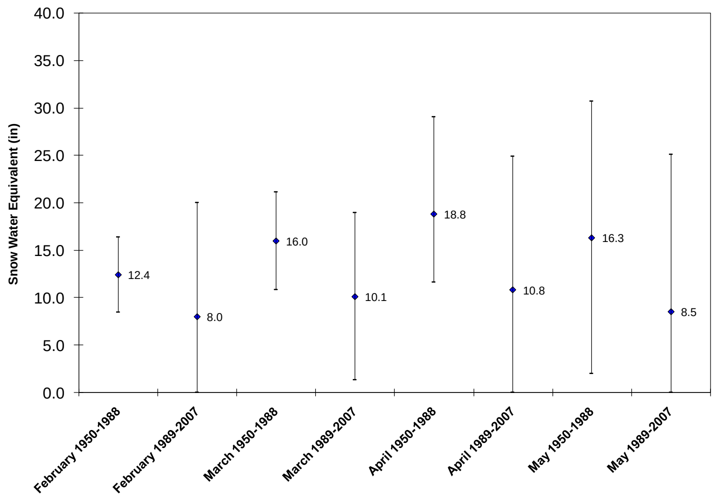


Figure 6. Differences in snow water equivalent before and after the 1988 wildfire by month in positive PDO + positive ENSO years (with 95% confidence intervals on means).

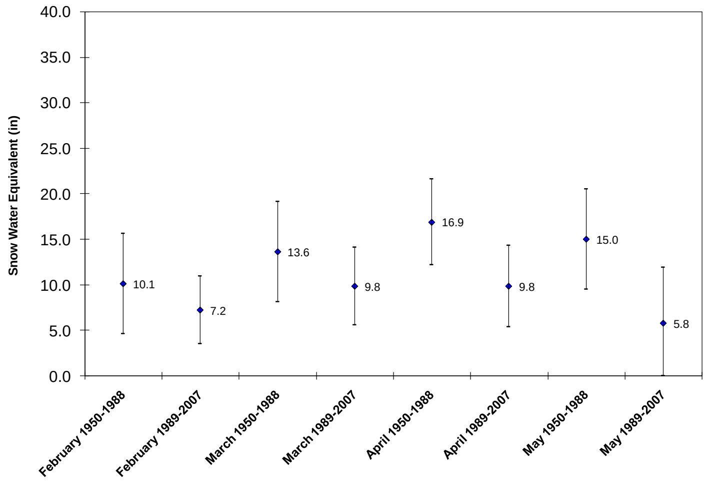


Figure 7. Mean differences in snow water equivalent by month for negative PDO + negative ENSO years (with 95% confidence intervals on effect size and p-value from Monte Carlo simulation).

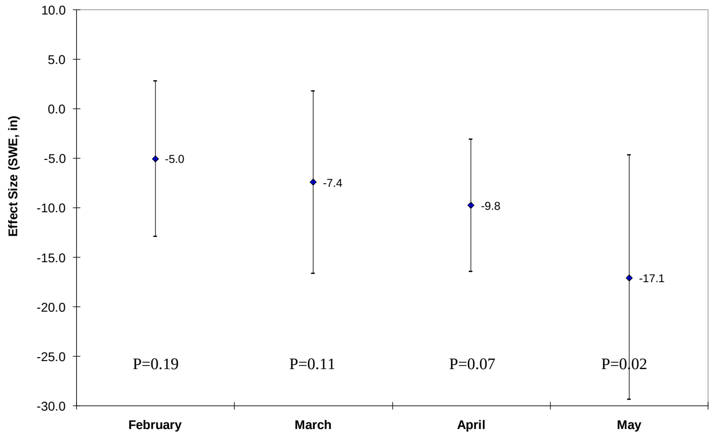


Figure 8. Mean differences in snow water equivalent by month for negative PDO + positive ENSO years (with 95% confidence intervals on effect size and p-value from Monte Carlo simulation).

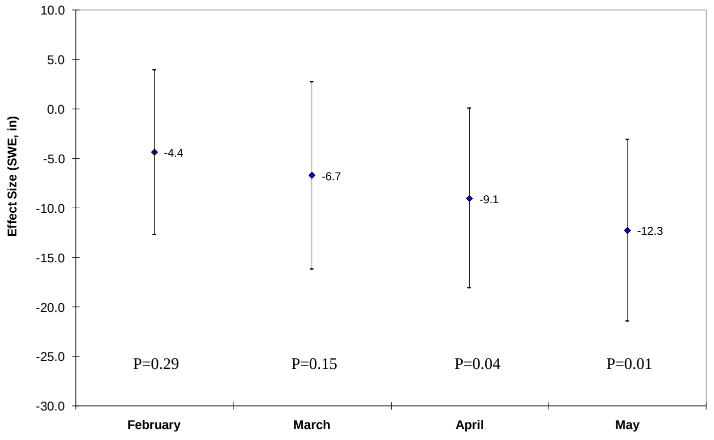


Figure 9. Mean differences in snow water equivalent by month for positive PDO + negative ENSO years (with 95% confidence intervals on effect size and p-value from Monte Carlo simulation).

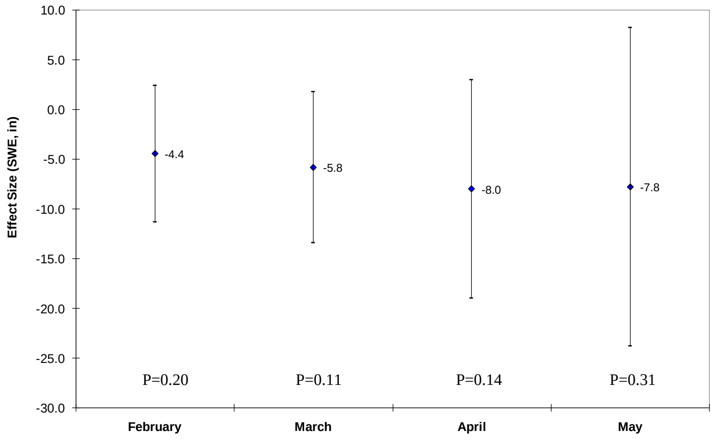
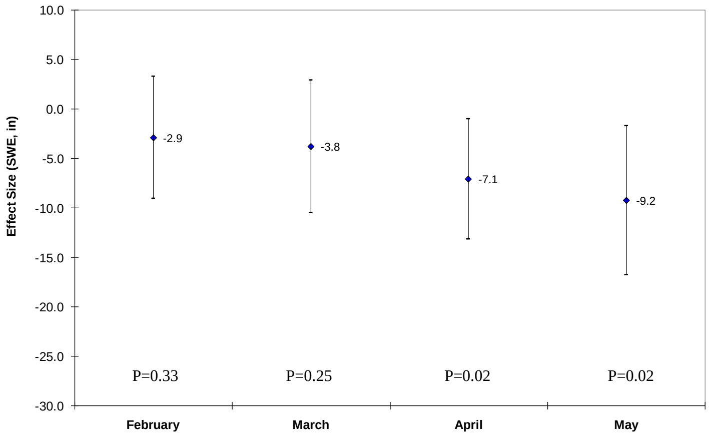


Figure 10. Mean differences in snow water equivalent by month for positive PDO + positive ENSO years (with 95% confidence intervals on effect size and p-value from Monte Carlo simulation).



CONCLUSIONS

The estimates of difference in mean SWE values for April and May reporting dates are large and usually statistically significant. While the confidence intervals were large in some cases, the estimates of the effect size of the difference between means suggest that the trend in lower SWE values after the burn is likely a real effect of the burn for the reporting dates of April 1 and May 1 for most climate cycle combinations. The estimated decline of mean SWE values post-fire for April 1 in cool, wet years (9.8") as well as in warm, dry years (7.1") is quite large, and has implications for long-term stream flow forecasting and water management. Because the April 1 snowpack is the most ecologically and hydrologically important date for predicting summer streamflow conditions on the north Olympic Peninsula, this is a significant finding of this analysis. Further research should incorporate regional estimates of long-term temperature and precipitation to determine whether there is also an effect due to climate change, and whether that impacts the results of this assessment. Regardless, the results of this work should be taken into consideration for any future evaluations or use of Deer Park Snow Course's long-term data set, whether for local streamflow forecasting or for regional climate change modeling.

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