Spatiotemporal Analysis of Search and Rescue Incidents in Yosemite National Park

Introduction

Yosemite National Park is home to a wealth of natural wonders, including waterfalls, deep valleys, and giant sequoias. Yosemite regularly attracts 3.5 M to 4.5 M annual visitors (pre-COVID pandemic), who visit for sightseeing, hiking, backpacking, biking, fishing, paddling, horseback riding, rock climbing, skiing and snowshoeing (Sahagun 2017). While most visits are without incident, Yosemite Search and Rescue (YOSAR) responds to 200 to 250 emergency calls annually (NPS 2018).

YOSAR employs a diversity of rescue methods, including helicopter evacuation, litter carries, technical rope rescue, horseback, canine searches, snowmobile, and watercraft to conduct rescues 12 months of the year. YOSAR personnel include park rangers, helicopter pilots, incident management staff, and technical climbers (Theodore 2009). Many of the latter are volunteers who serve May to October (NPS 2018).

YOSAR began employing GIS in 2008 to support incident response efforts with field maps; search area assignments; and hazard, vegetation and terrain mapping (Theodore 2009). Applying GIS to long-term planning is a natural extension of this work. This project investigated the spatiotemporal patterning of YOSAR incidents to determine where and how incident frequency is changing over time.

Figure 0. Yosemite National Park location

Methods

Data sources

The primary dataset was 11 years of YOSAR incident data (2001-2011). The data included incident location (WGS84, lat./long.) and date, as well as victim type (injury, medical, or other), rescue method, and victim activity. In order to examine incident clustering by month across years, it was necessary to extract month from the existing date field. Rescue methods were reclassified to remove rare and redundant classes.

To aid in the interpretation of hot spot analysis results, OpenStreetMap trails (tagged "highway"="path") were extracted using Overpass Turbo.

Aggregation

Data was spatially aggregated into 1 km^2 hexagons. A hexagon grid is preferred over a square grid due to reduced edge effects (smaller perimeter to area ratio) and simplified neighborhood calculations (as all neighbors are an identical distance away, Strimas-Mackey 2016). Temporally, data was binned by years to create the space-time cube.

Results

Spatial aggregation

Spatial aggregation revealed areas of greater incident history (Figure 1). The highest incident area is concentrated over 5 km^2 along the **Merced River** with incident rates ranging from 4 - 22 incidents per year per km^2. 448 of 1 660 incidents within the 11 year study period (27%) occurred within this area. Many incidents occurred directly on the **John Muir Trail**, though a small number (12%) also occurred away (>50 m) from a trail. Two other high incident areas are the **Half Dome Trail / Cables**, as well as the **Upper Yosemite Falls Trail**.

Hot spot analysis

The Emerging Hot Spot Analysis tool (Getis-Ord Gi* statistic) was used to identify hot spots within bins across space and time (Figure 2). The core Yosemite Valley area shows intensifying hot spots through much of the eastern part of the valley and consecutive hot spots elsewhere. One new hot spot was found near Indian Rock. Other incidents scattered throughout the park show no pattern, which corresponds with the one-off nature of most of these incidents. Local Outlier Analysis showed these scattered incidents as largely not significant outlier types, or high-low outliers, meaning that those areas had a high incident count for one time slice within an otherwise low incident space-time neighborhood.

Trends and forecast

Recent Trend Analysis (Figure 3) of the space-time cube showed mostly up-trending areas (16) and some down-trending areas (5). Up-trend areas include **the Nose** area of El Capitan, and **Yosemite Creek** and the **Upper Yosemite Falls Trail**.

Curve Fit Forecast (Figure 4) provided additional insight on future incident rates, with forecasts for each cell (e.g. inset chart shows predicted doubling of incidents near Yosemite Creek from 2011 to 2014).

The forecasted uptick in incidents aligns with the general up-trend from 2001 to 2011 plots of incidents over time (Figure 5 and 6). Figure 5 shows an **intensification of summer incidents** (June to Aug) , as well as an **increase in spring and fall incidents** relative to the first half of the decade. Unprecedented spikes in incidents occurred in the final 3-month periods of 2011. Seasonal trends in rescue method are shown in Figure 7.

Figure 1. YOSAR Incidents per km^2 2001 - 2011

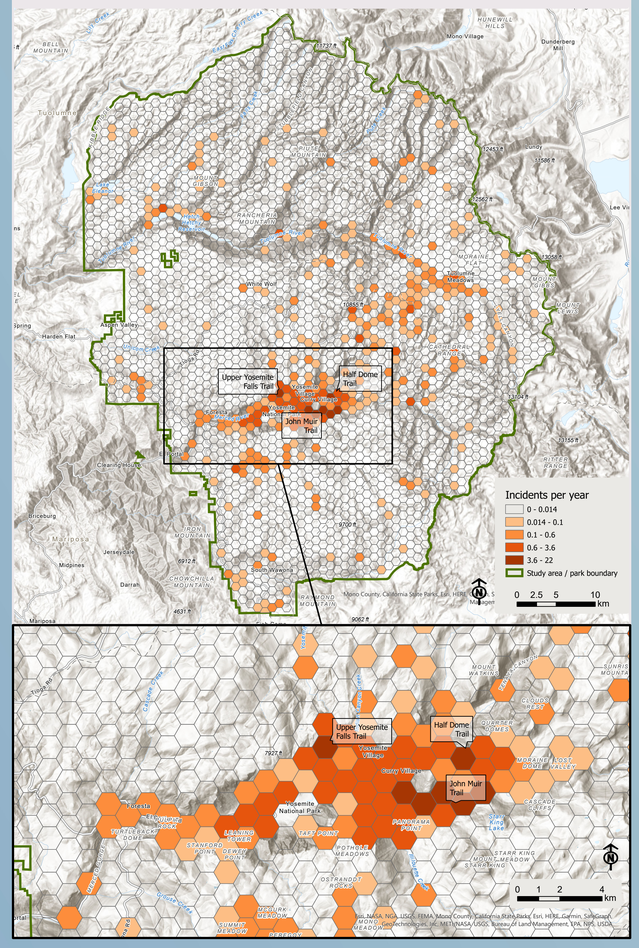


Figure 2. Space-time Hot Spot Analysis

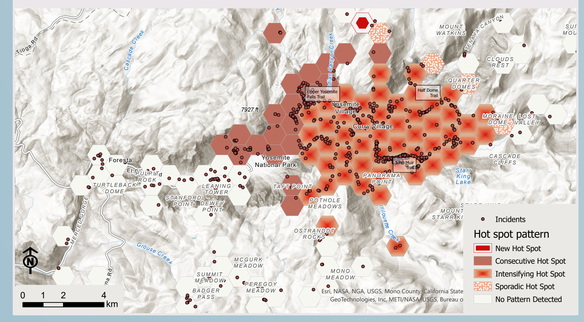


Figure 3. Recent Trend Analysis

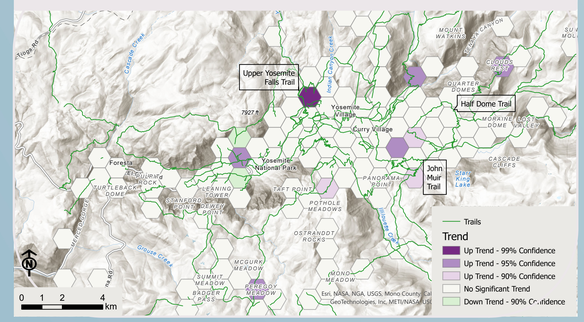


Figure 4. Curve Fit Forecast for 2014

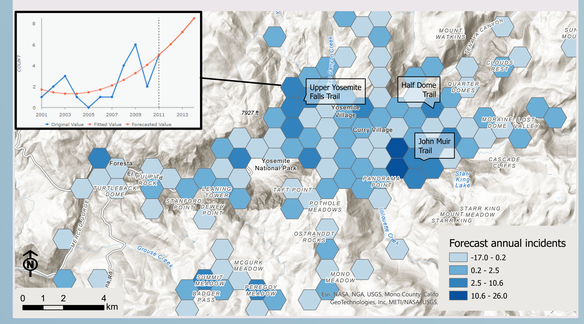


Figure 5. Incident Heat Matrix (month/year)

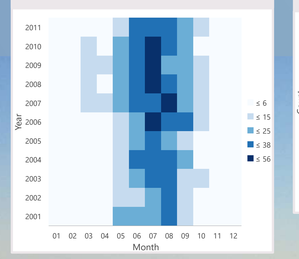
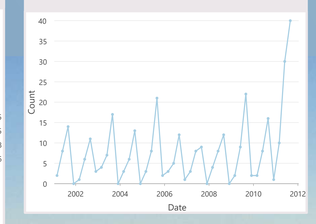


Figure 6. Incidents Over Time (3-month time interval)

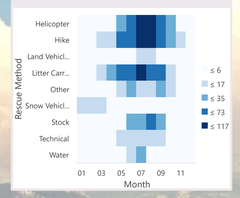


Limitations

Coarse spatial scale: This analysis was performed at a moderate spatial scale (1 km^2 units) to cover the entire park area. A more granular investigation of incident patterns within Yosemite Valley and other high-incident areas, such as Tuolumne Meadows, is warranted to accurately identify specific hazard zones.

Old data: The most recent data used in this study date back over a decade to 2011. More current data should be examined to ensure results and recommendations are relevant.

Figure 7. Rescue Method Heat Matrix (by Month)



References

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Map projections: California (Teale) Albers

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Advanced Topics in GIS, April 8, 2022