

Expansion of herbaria data based on historically surveyed herbaceous plants in the Crested Butte area, Colorado

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Abstract

Climate change has been changing plant community systems worldwide. These observations can be seen over a broad range, when resurveyed. Recording these changes in plant community structure is necessary if future plant migration studies are to be done. Herbarium data was expanded using historically surveyed data as a basis for study. Elevation ranges for *Castilleja sulphurea* was expanded. Voucher specimens were collected in areas where data were lacking. Expansion of herbarium data can aid in future studies regarding the holistic biotic and abiotic components of ecosystems. *Geranium richardsonii* sex ratio data was also collected to help expand knowledge of whether elevation has an influence on number of female versus hermaphroditic flowers. Seven percent, on average, of *G. richardsonii* flowers within a single population are female. By mapping the elevations and ranges of the species I studied, others could use those herbarium records in the future to see the shifts in community structures, as well as understand plant species populations, based on area. These data points can be of use in other fields of study and could be added to, furthering understanding of population changes, dependent on temperature increase.

Introduction

Climate change has begun to alter plant biodiversity throughout the world. Specific plant migration has begun to arise as a result of climatic changes in a given area. Whether these changes are from biotic or abiotic factors has been a question of concern (Kennedy et al., 2012). Mapping these types of shifts is critical in monitoring climate change and its implications. When studying current models, historical data can be used in concurrence with other types of data to address questions relating to the spatial patterns of diversity and some of the reasoning behind these patterns (Graham et al., 2004).

Some studies have indicated that an increase in temperature causes many montane plant species to extend their range upward in elevation at an increasing rate (Chen et al., 2011). The rate of upward migration of these montane species is increasing threefold from previous decades (Chen et al., 2011). This could have many environmental implications, some of which have yet to be deduced. Climate change can result in dominance shifts of species within specific communities (Walther, 2010). Shifts in the range of plant species could also cause the reorganization of communities and impact species' interactions (Walther, 2010). These types of adaptations may be revealed by recent resurveying of historical research sites and revisiting herbarium records.

In some regions of the world 84% of species have expanded polewards as the global climate has warmed (Thomas, 2010). In high elevation communities, many studies have observed an increase in species richness. For example, in the Piz Linard study, the oldest plant monitoring site in the Alps, an increase in species richness has occurred over increasing elevation since 1835 (Wipf et al., 2013). These two studies suggest a positive correlation with temperature increase and upward plant migration in latitude and altitude. An increase of approximately 2° F has been observed in Gunnison County alone (Gunnison Climate Working Group, 2011) since 1900. Based on these studies, there is reason to believe similar changes have occurred within the areas that Langenheim surveyed as well as the Crested Butte area at large.

The research investigates possible correlations between changes in environmental conditions such as average temperature and precipitation and plant species shifts over a 70 year period.

Knowledge of plant range shifts can help expand the current understanding of plant community ranges, and whether range/area shifts are contingent on weather or other environmental factors is a question that can be proposed once a shift has been established. Using the past herbarium data recorded in this area (the East River Basin, Lake Irwin area, and 401 trail area) I recorded changes within past recorded herbarium specimens, based on historically surveyed areas. The herbarium records provided me with a starting point for where species have been observed in the past. With the availability of detailed historical data, scientists are able to return to the sites of past research and resurvey those areas to record changes over time (Smith et al., 2013). Using historical museum data to study current models is becoming increasingly common.

Another question posed is whether the ratio of hermaphroditic to female *Geranium richardsonii* flowers changes over an altitudinal range. *G. richardsonii* is a gynodioecious species in which populations have far fewer female flowers than hermaphroditic. Factors such as flower size of females (which is significantly smaller than hermaphroditic flower) has had an effect on the amount of visits made to individual plants by pollinators (Williams et al., 1999). Elevation could have an effect on the frequency of floral reproductive morphs.

Methods

One useful long-term study is the resurveying of Jean Langenheim's historical data, currently being analyzed by graduate student, Stephanie Zorio. Langenheim collected data on the herbaceous plants and major forest types in the East River Basin from 1948-1951 (Langenheim, 1962). Species abundance and distribution was plotted and recorded in detail within many different plant-community types specifically focusing on community composition and coincidence with environmental factors. For this study I focused on plants occurring in four of those communities (Sagebrush, Aspen, Spruce-Fir, and Upland-herbaceous) to determine if they were still present and if their range had expanded.

With Langenheim's original transect data, I was able to select species that are common in lower elevation sites (Sagebrush/Aspen) but not in mid-elevation sites (Spruce-Fir/Upland-Herb), species common in mid-elevation sites (Spruce-Fir/Upland-Herb) or species common throughout many communities (to monitor changes throughout communities as a whole).

Species (Weber and Whitman, 2012)	Plant community predominately found in
<i>Lupinus argenteus</i>	spruce-fir and upland-herb
<i>Pedicularis racemosa</i>	spruce-fir
<i>Vaccinium scoparium</i>	all plant communities, excluding sagebrush
<i>Geranium richardsonii</i>	spruce-fir and upland-herb
<i>Pachystima myrsinites</i>	sagebrush and spruce-fir
<i>Castilleja sulphurea</i>	spruce-fir and upland-herb

I used Langenheim's original plant-community surveys as the foundation for my data collection. I accompanied Stephanie Zorio as she resurveyed Langenheim's original sites throughout the East River Basin, where I recorded the number of species I saw from my species list, GPS coordinates for those plants, and in some cases collected voucher specimens to add to the RMBL herbarium collection.

For locating additional historical and contemporary data on the selected species regarding elevation, location, and collection date, I referenced the Rocky Mountain Biological Laboratory's herbarium records on the herbarium database, Intermountain Herbarium Consortium (<http://intermountainbiota.org/portal/index.php>). I georeferenced the historical sites, attempting to narrow the margin of error that can occasionally accompany historical GPS data, referencing the methods developed by the Mapstedi system (Murphey et al., 2004). For two of the species, *G. richardsonii* and *C. sulphurea*, I used the GPS points from the georeferenced historical data, returned to those sites, and recorded the species' information to map changes and shifts within those plant species. Voucher specimens were pressed and added to the Rocky Mountain Biological Laboratory's Herbarium collection and added to the Intermountain Herbarium Consortium's online database. When observing *G. richardsonii* populations, I counted 100 flowers at three different locations, each at different elevations and recorded how many flowers were hermaphroditic or female.

Data analysis was predominantly preformed in Excel (Microsoft, Redmond, WA). Latitude, longitude, and elevation were recorded for each species and compiled into an Excel table. ArcGIS was used for map generation of the areas visited as well as the georeferenced locations of the voucher specimens. Maps were generated comparing the historical and contemporary ranges of species of interest. I also used Excel to analyze averages of hermaphroditic vs. female ratio of *G. richardsonii* flowers.

Results

After collecting data in the field, I found that certain species were also located in other plant communities that they had not been typically abundant in, based on previous research done by Langenheim and other collectors and specimens collected. The voucher specimens collected expanded the Rocky Mountain Biological Laboratory's herbarium collection as well as the

Intermountain Herbarium Consortium online reference list. Not only were specimens added to the collection, expanding current knowledge of plant community lists, but the maximum elevation of collected specimens for one of the study plants, *Castilleja sulphurea*, was increased from 11,607 feet to 11,691 feet (Figure 3). Some of the *C. sulphurea* were not present when I went back to ground-truth the georeferenced lower elevation sites (Figure 5). *C. sulphurea* was confused in my study with *Castilleja occidentalis*, the alpine sulphur paintbrush. Four of the six species' mean elevations rose in my collected data as compared to their historical elevations (Figure 5).

Table 1: Mean Elevations (in ft)

Species	Historical	2014
<i>C. sulphurea</i>	10603.5	10407
<i>G. richardsonii</i>	10205.75	10826.5
<i>L. argenteus</i>	10456.7	10563
<i>P. mysinites</i>	no record	10325.86
<i>P. racemosa</i>	10978.17	10531.71
<i>V. scoparium</i>	10575	10665.83

Table 2: *G. richardsonii* sex ratio

Male	Female	Elevation
90	10	10726'
92	8	10679'
97	3	11499'

G. richardsonii, *L. argenteus*, *P. mysinites*, and *V. scoparium* all had a mean higher elevation than previous records had implied (Table 1).

In the three sites where I recorded sex of *G. richardsonii*, the number of female verses hermaphroditic *G. richardsonii* was expectedly fewer in number. Out of the 100 flowers counted, seven percent, on average, of observed populations were female (Table 2).

Discussion

Plants were found and collected in areas, as well as elevations, they had not been previously found. This expands the current knowledge possessed within the herbaria collections they were added to. This will allow further research to be done potentially using the herbaria collections as a reference or guide of where plants have been found or should be found typically, based on plant community.

C. sulphurea and *Castilleja occidentalis* can be easily confused. Height of the plant was critical to take into account for identification. Future research could be done, mapping the overlap, if any, of the two species and seeing if environment plays a role in the distinction of location.

For *G. richardsonii* flower type ratio, based on elevation, was inconclusive. Due to small numbers of females within populations, a larger sample size would be needed to analyze elevation implications based on this phenomena.

Using museum collections for research can and should be used more often throughout research, especially when considering plant community shifts. If future research is done, concerning one, some, or all of the study plants, herbaria collections can be cross-referenced with other area data to pull results from. The voucher specimens I collected can be used as a reference within future studies. The vouchers collected help determine specific areas the plants are found in, including elevations. This could expand understanding and further analysis capabilities of entire systems, as a whole, rather than just piece-wise understandings or projections (Graham et al., 2004). This could change the way museum specimens are viewed in large ways.

Range shifts in species are a growing topic of concern. The more plant communities shift, the further entire systems could be skewed, changing ecosystem structure. Having more species of interest, over a broader range such as whole community types, would further the understanding of shifts as a whole. More experimental design would be required to understand whether some species would be able to survive in a different plant-community type then they are commonly found. Another experiment that could suggest the impacts of climate change could be temperature increase studies for a number of different species.

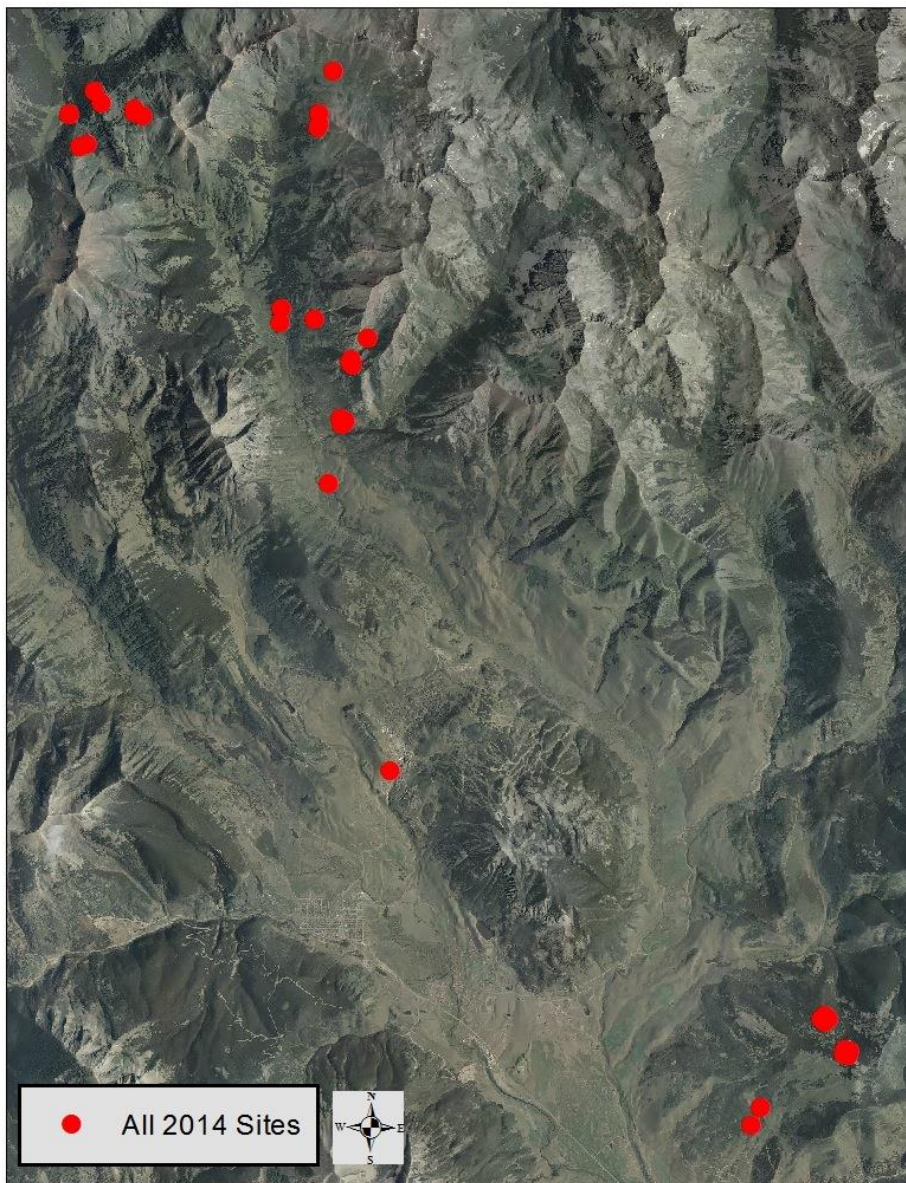


Figure 1: All Sites Map

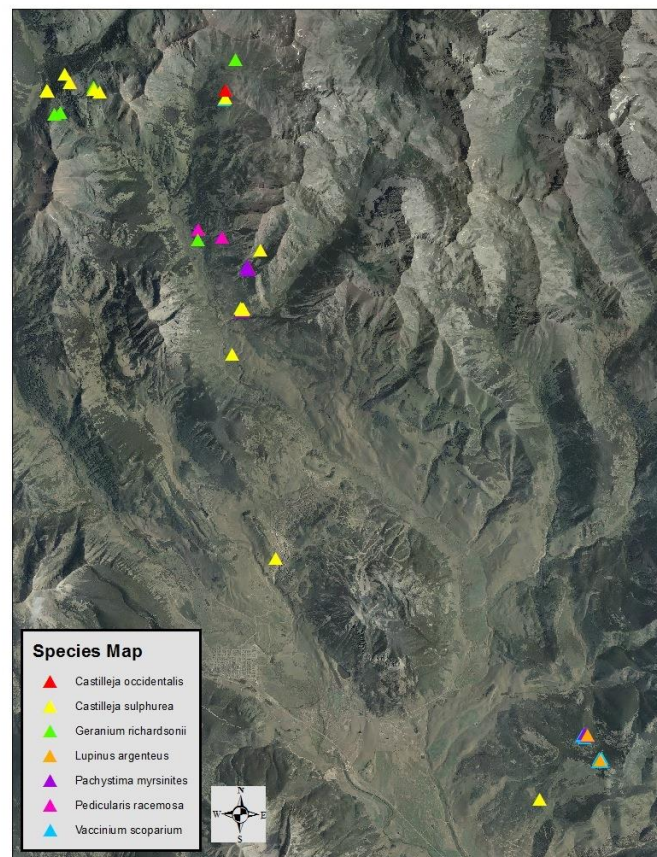


Figure 2: Species Map

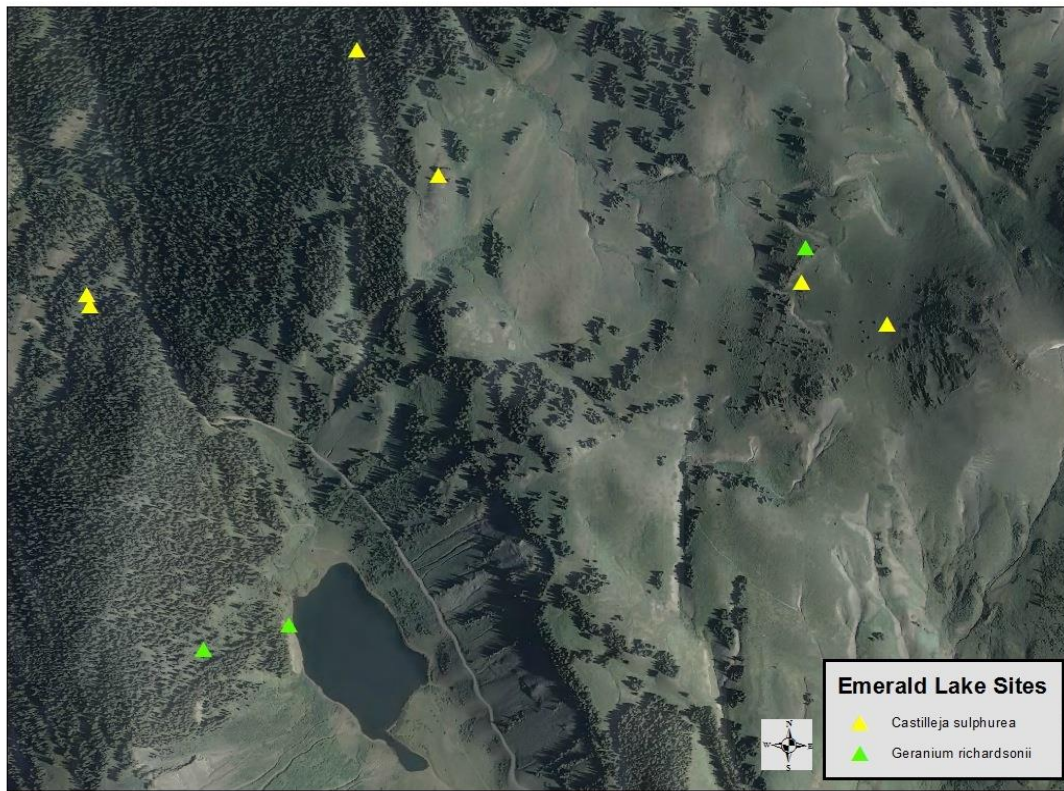


Figure 3: Emerald Lake Map

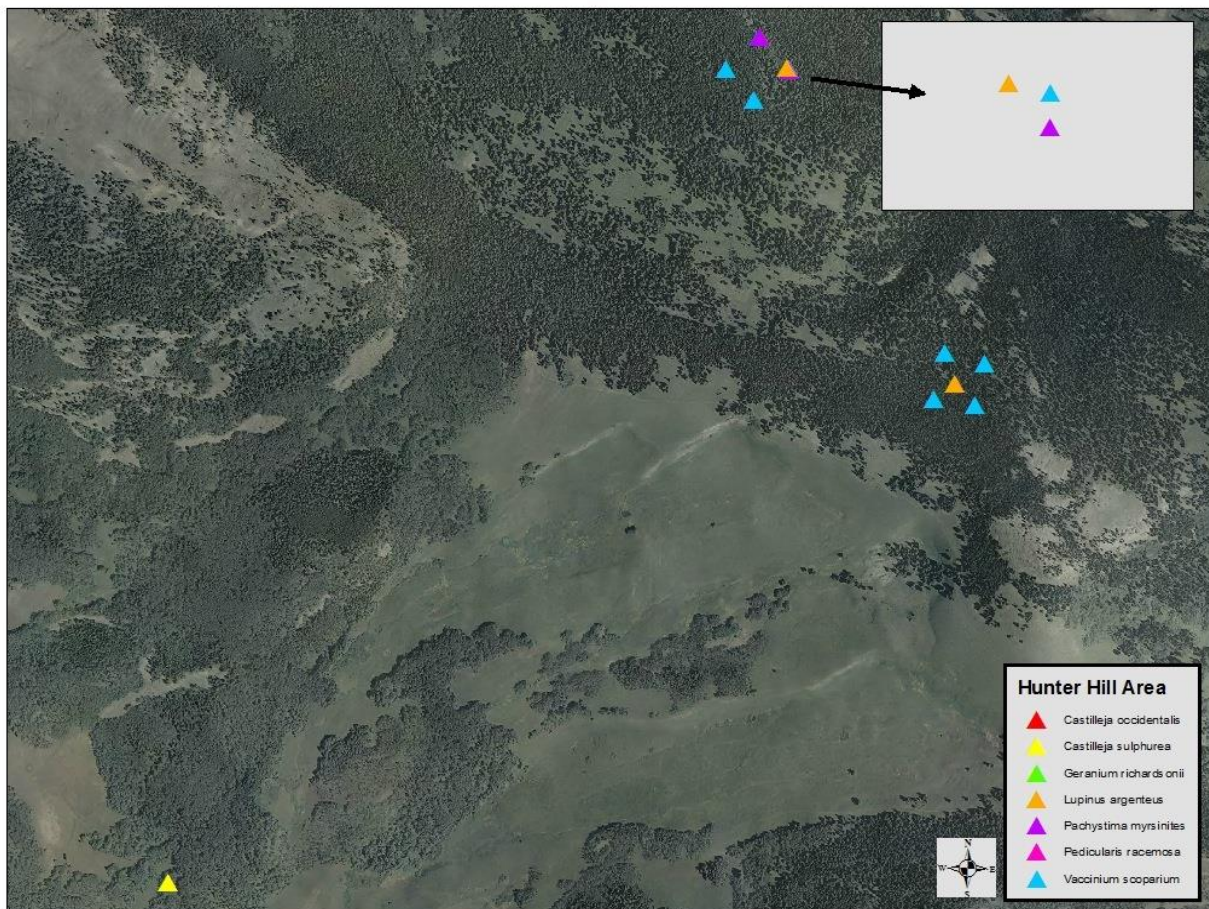


Figure 4: Hunter Hill Map

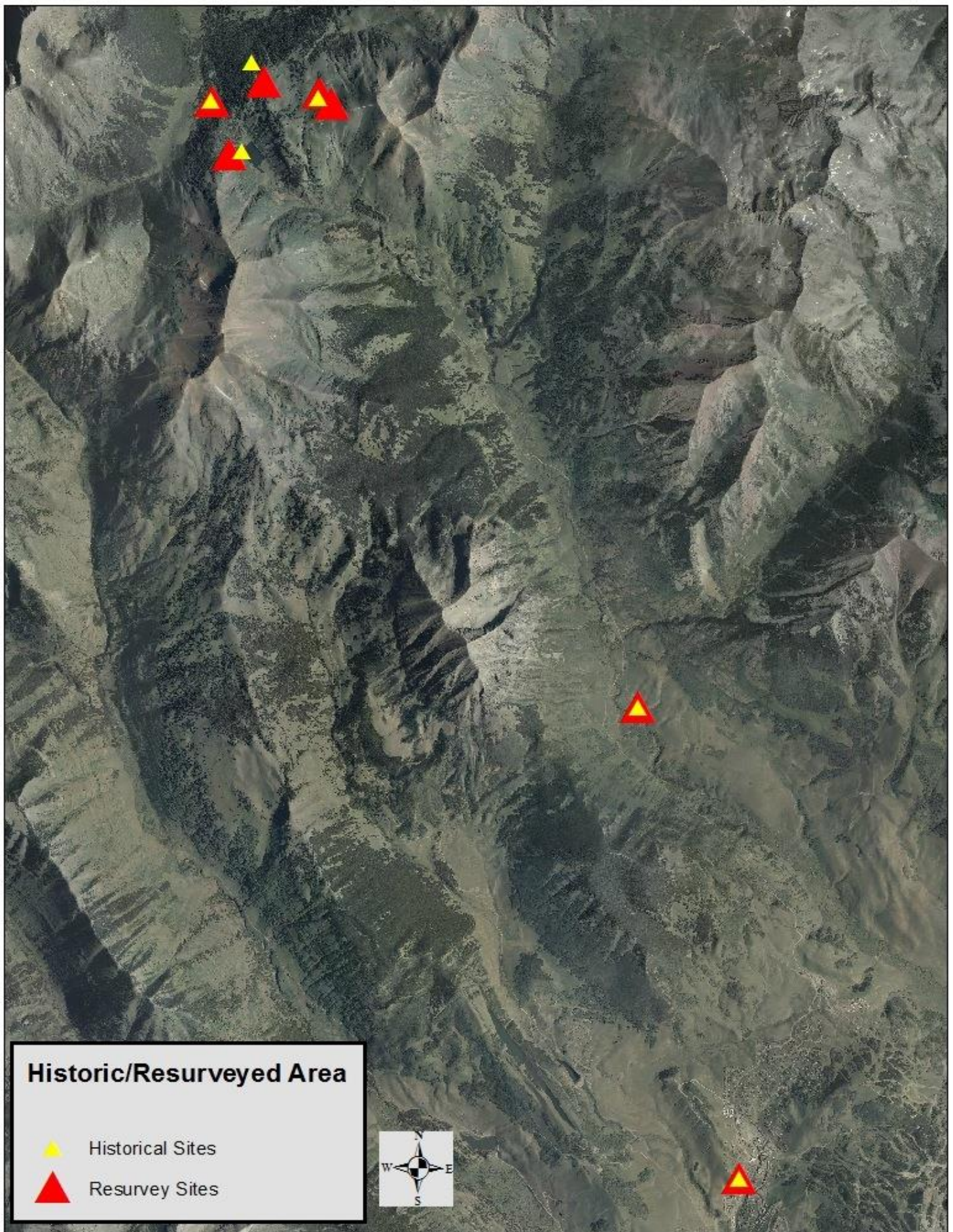


Figure 5: Historical and Resurveyed Area Map

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