National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

# A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks

## *Appendix 14 – Plants of Conservation Concern*

Natural Resource Report NPS/SEKI/ NRR—2013/665.14

In Memory of Rebecca Ciresa Wenk, Botaness

**ON THE COVER**
Giant Forest, Sequoia National Park
Photography by: Brent Paull

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Natural Resource Report NPS/SEKI/ NRR—2013/665.14

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# Scope of analysis

Sequoia and Kings Canyon National Parks are located in the California Floristic Province, which has been named one of world's hotspots of endemic biodiversity (Myers et al. 2000). The California Floristic Province is the largest and most important geographic floristic unit in California and extends from the Klamath Mountains of southwestern Oregon to the northwestern portion of Baja California (Hickman 1993). The Sierra Nevada, one of six regions that make up the California Floristic Province, covers nearly 20% of the land in California yet contains over 50% of its flora. Within the Sierra Nevada, the southern Sierra supports more Sierran endemic and rare plant taxa than the central and northern portions of the region (Shevock 1996). Sequoia and Kings Canyon National Parks (SEKI) encompass roughly 20% of the southern Sierra Nevada region[1]. The parks overlap three floristic subregions (central Sierra Nevada High, southern Sierra Nevada High, and southern Sierra Nevada Foothills), and border the Great Basin Floristic Province[2].

The parks support a rich and diverse vascular flora composed of over 1,560 taxa. Of these, 150 taxa are identified as having special status. The term special status is applied here to include taxa[3] that are state or federally listed, rare in California, or at risk because they have a limited distribution. Only one species from these parks is listed under the state or federal Endangered Species Acts (*Carex tompkinsii*, Tompkins' sedge, is listed as a rare species under the California Endangered Species Act), and one species is under review for federal endangered listing (*Pinus albicaulis*, whitebark pine). However, an absence of threatened and endangered species recognized by Endangered Species Acts is not equivalent to an absence of species at risk. There are 83 plant taxa documented as occurring in SEKI that are considered imperiled or vulnerable in the state by the California Department of Fish and Game's California Natural Diversity Database (CNDDB 2010a).[4] There are an additional 66 taxa not formally listed by CNDDB that are recognized as having special status because their distribution is restricted to the Sierra Nevada. Special status plants are distributed throughout the two parks and inhabit a wide range of environments along the length of the elevation gradient that characterizes these parks.

Ideally, we would assess the condition (status and trends) of each of the taxa on the SEKI special status plant list, documenting current population sizes, demographic rates and demographic trends. We would also hope to quantify the effects of individual stressors on each species based on existing monitoring and research. However, no data are available for most of the species on the special status plant list. For those few species (12 herbaceous species and two tree species) for which we possess some change over time information, the data are not adequate to make a

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[1] Calculated in ArcGIS using boundaries of Sequoia and Kings Canyon National Parks and approximate boundaries of The Jepson Manual geographic subdivisions (23).

[2] Floristic Provinces and the regions and subregions within them are delineated on the basis of topographic, climatic, and plant communities, with Provinces having the broadest physiographic and biologic groupings. See The Jepson Manual (Hickman 1993) for a description and map of these geographic units.

[3] The terms taxa, plants, and species are used interchangeably in this report for easier reading.

[4] These taxa are also included in the California Native Plant Society's Inventory of Rare and Endangered Plants in California (CNPS 2010).

competent assessment. Note that we have not explored the tree demographic information in any detail, as is covered in the NRCA Intact Forest/Five Needle Pines and Sequoia chapters. In general, we are unable to present an 'integrity' metric for special status species in the parks, since the data to quantify the condition of each species in such a manner is not available.

In contrast, the park does possess substantial data describing biodiversity in the parks. Therefore, our analysis focuses on describing the distribution and rarity of special status plants within the parks, with a particular focus on assessing the spatial distribution of species richness. We hope that such information will prove useful to park managers in determining which areas in the parks merit the most attention (for example in developing monitoring protocols). We also assess potential vulnerability of special status species to the stressors chosen by the NRCA working group, using both park data and available literature.

As a first step, we spent considerable effort updating and refining the criteria for the special status plant list, as this list defines which taxa are considered in our assessment. Observation data of these species was then compiled from all known sources in order to provide a comprehensive view of where special status plants have been documented and, ultimately, to enable the most informed determinations of areas in the parks that potentially support the highest number of rare and endemic taxa. These 'hot spot' analyses are presented by geographic region, vegetation type and elevation.

For these and other analyses presented in this report, we place more focus on summarizing findings for the herbaceous and shrub special status taxa than on special status trees. The trees which qualify as special status are the focus of other NRCA chapters, including Giant Sequoia and Intact Forests/Five-needle Pines. We do, however, present their mapped distributions and provide overviews of research related to the special status tree taxa in the Stressors section of this report.

# Critical questions

1. What are the special status plants known to occur in SEKI?

2. What is the known distribution of special status plants within SEKI?

3. What is known about their condition?

4. What is known about the effects of the six stressors identified by the NRCA working group on special status plants in SEKI?

1. Air quality
2. Land use/fragmentation
    - Proximity to trails, roads and other infrastructure
    - Stock use in meadows
3. Climate change
4. Invasive species
5. Altered fire regimes
    - Fire return interval departure analysis
    - Fire effects literature review
6. Disease paradigms

# Data sources and types used in analysis

### Data sources used to determine the special status plants in SEKI

Evaluation of the condition of special status plants begins with development of the list of taxa[1] of interest. The criteria for this analysis include taxa known to occur in the parks that meet at least one of the following categories:

1. Rare or threatened plants
    - Listed, candidate, or proposed species for threatened, endangered or rare status under the California or federal Endangered Species Acts
    - Species included in the California Native Plant Society's Inventory of Rare and Endangered Plants (CNPS Inventory)
    - U.S. Forest Service Sensitive plants or plants otherwise listed as special status by Forests adjacent to SEKI (Inyo, Sequoia and Sierra National Forests and Giant Sequoia National Monument)
    - Species ranked as critically imperiled, imperiled or vulnerable in the state by the California Department of Fish and Game's California Natural Diversity Database (CNDDB) list of Special Plants
    - Bryophytes meeting any of the above criteria
2. Regionally endemic plants

- Sierra Nevada endemics
- Southern Sierra Nevada endemics
- Local endemics (geographic range restricted to within 8 kilometers of SEKI)

Please refer to Appendix A for the special status plant list; Appendix B for additional information regarding the revision process; and Appendices C and D for descriptions of CNPS and CNDDB rarity and threat rankings.

***SEKI flora***

The SEKI Vascular Plant Checklist (1) was the primary resource used to identify vascular plant taxa known to occur in Sequoia and Kings Canyon National Parks. Following NPS convention (NPS 2011), only taxa with specimens collected in the parks and vouchered in the SEKI Herbarium or a research herbarium (e.g., the University and Jepson Herbaria at the University of California at Berkeley or other recognized institution) were retained on the checklist. As SEKI has not identified taxa on the checklist that are known only from historic data, plants that lack recent documented occurrences are also included.

It is worth noting that in 1995, the nomenclature of the checklist was updated from Munz and Keck (1959, 1968) to follow The Jepson Manual (Hickman 1993). The translation was conducted using taxonomic update data provided by the University and Jepson Herbaria at the University of California, Berkeley. Because the update was not conducted by re-examining the actual plant specimens, the checklist could be considered a "most likely" translation from Munz and Keck (2).

***Rare or threatened plants***

This category includes plants in SEKI that are formally recognized by a state or federal organization as rare or threatened. The only non-governmental organization included in this category is the California Native Plant Society (CNPS). CNPS rare and endangered plant listings are regularly reviewed by Rare Plant Review groups, which include botanical experts from government, academia, non-governmental organizations and publications.

CNPS Lists: CNPS designations were obtained from the California Native Plant Society's Inventory of Rare and Endangered Plants (CNPS 2010). Please see Appendix C for a description of the California Native Plant Society's Inventory of Rare and Endangered Plant lists and ranking criteria.

CNDDB State and Global Rankings: We referred to the California Department of Fish and Game's Natural Diversity Database's quarterly publication, "Special Vascular Plants, Bryophytes, and Lichens List" (CNDDB 2010a) to identify taxa on the SEKI Vascular Plant Checklist that are tracked as vulnerable or imperiled by the CNDDB. These species are referred by the CNDDB as 'special plants'. The CNDDB gives 1) global and state rankings; 2) federal

[1]1Note, the list of plants in SEKI that are recognized by the CNPS Inventory of Rare and Endangered Plants (2010) is identical to those recognized as 'special plants' by the CNDDB (2010a). In addition, both sources are comprehensive with regard to inclusion of bryophyte and vascular taxa in SEKI listed as special status by the U.S. Forest Service Region 5 Sensitive Species List or listed under state or federal Endangered Species Acts.

and state designations, including information on whether a given species is federally or state listed as threatened, endangered or candidate under state or federal Endangered Species Acts or other agency-determined status (USFS Sensitive or BLM Sensitive); and 3) CNPS List status. Please refer to Appendix D for a description of the California Natural Diversity Database including criteria for global and state rankings.

Other Federal Status: We used the U.S. Fish and Wildlife Service's (USFWS) Species Reports website to confirm federal status as recorded by the CNDDB and to annotate species with other federal designations not tracked by the CNDDB, including USFWS Species of Concern and Species of Local Concern (USFWS 2010). We acquired the sensitive plant lists from National Forest lands adjacent to SEKI (Sequoia, Inyo and Sierra National Forests and Giant Sequoia National Monument) to seek additional USFS Sensitive taxa known to occur in the parks that might not be tracked by the CNDDB.

Rare Bryophytes: Bryophytes consist of three groups of non-vascular plants: mosses (Bryophyta), hornworts (Anthocerotophyta), and liverworts (Marchantiophyta). They were once grouped as three classes of the division Bryophyta, but because the groups are not monophyletic they are now placed into three separate divisions (Glime 2007). Before the publication of the sixth edition of the California Native Plant Society's Inventory of Rare and Endangered Plants of California in 2001, not enough was known about the distribution of California bryophytes to assess species rarity. Bryophytes are thought to be highly important in the function of ecosystems. They generally have much wider geographic ranges than vascular plants but are also typically restricted to specific microhabitats, a pattern that can lead to patchy distributions and vulnerability to local extirpation. Bryophytes are sensitive to environmental changes, such as air and water pollution and changes in the frequency of rain events, making them useful as indicators for environmental change in pollution and climate change studies (CNPS 2001).

Relative to the vascular flora, much less is known about the presence, distribution, and abundance of bryophytes in SEKI. Three datasets served as the primary source of information about bryophytes in the two parks: the NPS Inventory and Monitoring Wetland Ecological Integrity Surveys (20); James Shevock's personal dataset which includes records of specimens collected by him and others (6); CNDDB (2010b); and the SEKI Herbarium holdings (1). All of the bryophyte records from these sources were compiled into a single database and attributed with CNPS, state, federal, USFS and CNDDB global and state rankings.

### *Regionally endemic plants*

Endemism is commonly viewed as an important criterion for assessments of the conservation value of an area (Tchouto et al. 2006, Shevock 1996). Inclusion of Sierra Nevada and southern Sierra Nevada endemics adds taxa to the special status plant list that may not necessarily be rare on a statewide basis but because of their limited geographic distribution may be more vulnerable than widespread species. The long-term viability of an endemic species relies greatly upon the conditions and management of the geographic area to which they are restricted (Shevock 1996).

The known distribution of a species is usually determined by two main methods, with vouchered herbarium specimen records or the published expert opinion of a botanical specialist or biogeographer (Thorne et al. 2009). The website CalFlora (2011) considers a wide variety of data sources to map species extent by county, including herbarium records, non-vouchered

documented records confirmed by an expert, reported records (not confirmed by an expert), and indirect records such as botanical literature. Some studies narrow the frame of reference much more by relying solely on georeferenced herbarium specimens (e.g. Loarie et al. 2008). Herbarium records provide the highest degree of confidence for identification and spatial precision (Thorne et al. 2009). However, plant ranges determined by botanical experts are thought to more accurately describe the geographic range of a species than herbarium records alone (Gaston 1991, Gaston 2003).

We used geographic range data from The Jepson Manual 2nd edition (Baldwin et al. *in press*) to identify Sierra Nevada and southern Sierra Nevada endemics. These data were acquired for all plants on the SEKI Vascular Plant Checklist on October 19, 2010 from Richard Moe, Manager of Collections Data at the University and Jepson Herbaria, University of California, Berkeley. These range assessments represent the expert opinion of authors in The Jepson Manual 2nd edition, and rely more heavily on knowledge of vouchered specimens than in the first edition (University of California Berkeley, Richard Moe Manager of Collections Data at the University and Jepson Herbaria, personal communication, 23 June 2010). The geographic range units, or bioregions, are described and mapped in The Jepson Manual (Hickman 1993).

Sierra Nevada endemics, as defined in this study, are plants with native distributions that are thought to be restricted to the Sierra Nevada bioregion. Southern Sierra Nevada endemics are those that are thought to be restricted to the southern Sierra Nevada foothills and/or southern High Sierra Nevada bioregions. We recorded possible range extensions beyond the Sierra Nevada or southern Sierra Nevada bioregions. These are specimens catalogued in the Consortium of California Herbaria (CCH 2011) database that were collected outside of the species' reported range and have not yet been verified by authors of The Jepson Manual 2nd edition. Thus, possible range extension data can be used to provide a measure of uncertainty for endemism assignments (see Uncertainty in Analysis section).

We defined locally endemic as plants with geographic ranges thought to be restricted to within eight kilometers of the parks. We initially intended to include only SEKI endemics, but based on our research none in the SEKI flora have ranges solely limited to the parks. We chose an eight kilometer (five mile) buffer around the parks because this distance best fit the extent of the range of plants that are nearly endemic to Sequoia and Kings Canyon National Parks.

The process of determining which plants are locally endemic was iterative. Since the northern tip of Kings Canyon National Park extends into the central Sierra Nevada high bioregion, we needed to expand the search for local endemics to plants restricted to either the southern or central Sierra Nevada bioregions or both. First, we narrowed this list of plants by eliminating any taxa that are recorded as occurring in Yosemite National Park according to the Yosemite Vascular Plant Checklist (7). From this subset, we removed taxa with vouchered specimens in CCH collected from counties farther than eight kilometers from the parks (e.g., Madera, Kern, Tuolumne, and Mariposa Counties). For the remaining taxa, we investigated specimen collection locations with paper and digital maps (Google Earth (2010), USGS topographic map (26), Sierra National Forest (2003), Inyo National Forest (2002), Sequoia National Forest (2001), and Sequoia and Kings Canyon National Parks and Vicinity (1996)) and measured the approximate distance from the parks' boundaries.

The locally endemic list could be considered conservative. Some of the older vouchered specimens farther than eight kilometers from SEKI may no longer represent extant populations. Almost all specimens in this final subset that were located farther than eight kilometers from the parks had been collected after 1960, with one exception. *Ivesia campestris* was most recently collected in 1916 at Mojave Lake in Inyo County. Since this collection is so old and since we could not find a more recent observation for this locality, we decided to retain this species on the list of locally endemic taxa. Notes from the endemic research are recorded in the SEKI NRCA special status plants database (21).

### *Taxonomic and nomenclatural changes*

This study took place in the midst of great change in California vascular plant taxonomy with the impending publication of the second edition of The Jepson Manual. We checked for taxonomic and nomenclatural changes to taxa in the SEKI flora (1) using the latest available dataset to be published in The Jepson Manual 2nd edition, provided by Richard Moe, Manager of Collections Data at the University and Jepson Herbaria at University of California, Berkeley (most recently provided on October 18, 2010). In some cases we also contacted the author for the treatment of the species in question. We used several online sources including the Jepson Interchange (2010), the USDA PLANTS database (2010), and the Integrated Taxonomic Information System (ITIS) (2011) to record synonyms in whole in order to perform complete comparisons with other datasets (USFS species lists, the CNDDB, and CNPS Inventory). This step was also important to look for taxa that lost or gained listing status because of revised taxonomic treatments, i.e., newly recognized taxa or those that were previously listed as rare or endangered that have been subsumed into non-listed taxa. Plant names in this report follow ITIS, as required by the NRCA program.

## Data sources used to determine the distribution of special status plants

Knowledge of the distribution and abundance of plants within SEKI is derived from a number of NPS datasets reflecting investigations conducted between 1980 and 2009. Observation data of special status plants in the parks included park and non-park data (Table 1). To describe the spatial distribution of special status trees in the parks, we used the SEKI Vegetation Map (24). The vegetation map provides a more complete picture of tree distribution than the plot and single species observations shown in Table 1.

Data sources in Table 1 are classified by survey type. Comprehensive surveys are survey types with full species composition data, recorded either for the entire sample plot or a subsample of the plot. Rapid assessment surveys are those that recorded a subset of species only, such as dominant species or a particular set of species specific to the purpose of the study. Single species observations are herbarium specimen coordinates or locations of singular special status plant populations. The Natural Resource Inventory plots contribute the highest number of rare and endemic species observations (930) of any single data source. In total, comprehensive data sources contribute more special status species observations (1824 total observations) than single species sources (1158 total observations).

In addition to data sources identified in Table 1, the Sequoia and Kings Canyon National Parks digital elevation map (DEM) was used to obtain elevation data. This dataset was developed in 2010 for the SEKI NRCA project (28). All files and datasets used in this report are included in the Literature Cited section.

**Table 1.** Data available for analysis of the distribution of special status plants in SEKI. SS=Single Species; Comp=Comprehensive; RA=Rapid Assessment.

| Data Source | Survey Type | Plots, Transects, or Specimens | | Number of Special Status Plant Observations |
|---|---|---|---|---|
| | | *Total* | *Number with Special Status Plants* | |
| SEKI Vascular Plant Observation Database | | | | |
| Fire Effects Monitoring | Comp | 131 | 86 | 150 |
| Stephenson Gradient Analysis | Comp | 222 | 170 | 310 |
| Natural Resource Inventory | Comp | 625 | 469 | 930 |
| Wetland Ecological Integrity Monitoring | Comp | 95 | 48 | 85 |
| Paired Meadow Species Composition | Comp | 10 | 10 | 26 |
| Vegetation Mapping Full Plots | Comp | 423 | 213 | 323 |
| Vegetation Mapping Accuracy Assessment | RA | 2705 | 473 | 493 |
| Vegetation Mapping Rapid Assessment | RA | 122 | 3 | 3 |
| Vankat/Roy Vegetation Change Study | RA | 76 | 15 | 15 |
| White Pine Blister Rust Study | RA | 140 | 3 | 3 |
| Inventory and Monitoring Special Status Plant Surveys | SS | 93 | 93 | 93 |
| Norris and Brennan Special Status Plant Surveys | SS | 243 | 243 | 243 |
| SEKI Herbarium Holdings | SS | 494 | 494 | 494 |
| California Natural Diversity Database | SS | 108 | 108 | 108 |
| Consortium of California Herbaria | SS | 92 | 92 | 92 |
| NPSpecies | SS | 118 | 118 | 117 |
| Shevock's Bryophyte Collections* | SS | 11 | 11 | 11 |
| | | 5709 | 2648 | 3496 |

Notes regarding Table 1: Table 1 lists only those data used in analysis. *There are also bryophyte observations in the CNDDB database and the Wetland Ecological Integrity Monitoring plots. However, the Wetland Ecological Inventory Monitoring plots did not include observations of any special status bryophytes. CNDDB records of special status bryophytes are contained in Shevock's Bryophyte Collections.

The numbers of special status plant observations shown in the last column of Table 1 are the number of observations used in this analysis, and not necessarily the total number of special status plant observations available from these datasets. Records removed from consideration include observations outside the parks, inaccurate records, some duplicate records and specimen records with a distance error of more than 400 meters in order to more accurately portray species distributions.

Duplicate records (observations of the same species in the same place and recorded on the same date) exist between datasets, especially among the single species datasets. Records in the SEKI Herbarium Holdings that were duplicated in NPSpecies were removed. Bryophyte coordinates in CNDDB that were duplicated in Shevock's dataset were also removed. Due to time constraints no other duplicate records were removed. We have not quantified the extent of duplication for species among datasets, but our work with a subset of twelve special status taxa indicate that it could be a substantial. Therefore, we believe it would be inaccurate to report number of occurrences by simply counting the number of observations for each species. Estimates of number of occurrences or populations can be attained with a careful examination of the spatial data associated with each species. Due to unknown (not reported) and known distance errors associated with specimen data, it cannot be accurately calculated with a simple distance function between observation points in GIS.

Inaccurate records included several specimen records in CCH with no distance error value but were clearly given generic coordinates for the parks (all records had the exact same coordinates) with vague localities such as "from Sequoia National Park" but collected by different people and different times, but generally before 1930. A small number of records from CCH were also removed when the derived coordinates for CCH records were found to be less accurate than duplicate observations captured more accurately in park datasets (e.g. Norris and Brennan surveys). These records are documented in Appendix E. All CNDDB records in the parks were labeled by CNDDB as "presumed extant", so none were filtered due to "extirpated" or "likely extirpated" status.

No records were removed because they were historic. Therefore, the distribution of special status plants presented in this report represents a best case scenario, as some of the older observations may no longer be extant.

For special status species without coordinates documented in any of the data sources shown in Table 1, derived coordinates were assigned by park staff where there was enough information to do so.

Sample points of all datasets for all plants (not just special status plant observations) are shown in Figure 1. Plot locations and other sample points from these datasets are widely distributed across the two parks, although large areas in Kings Canyon National Park that are not near roads or trails have not been surveyed.

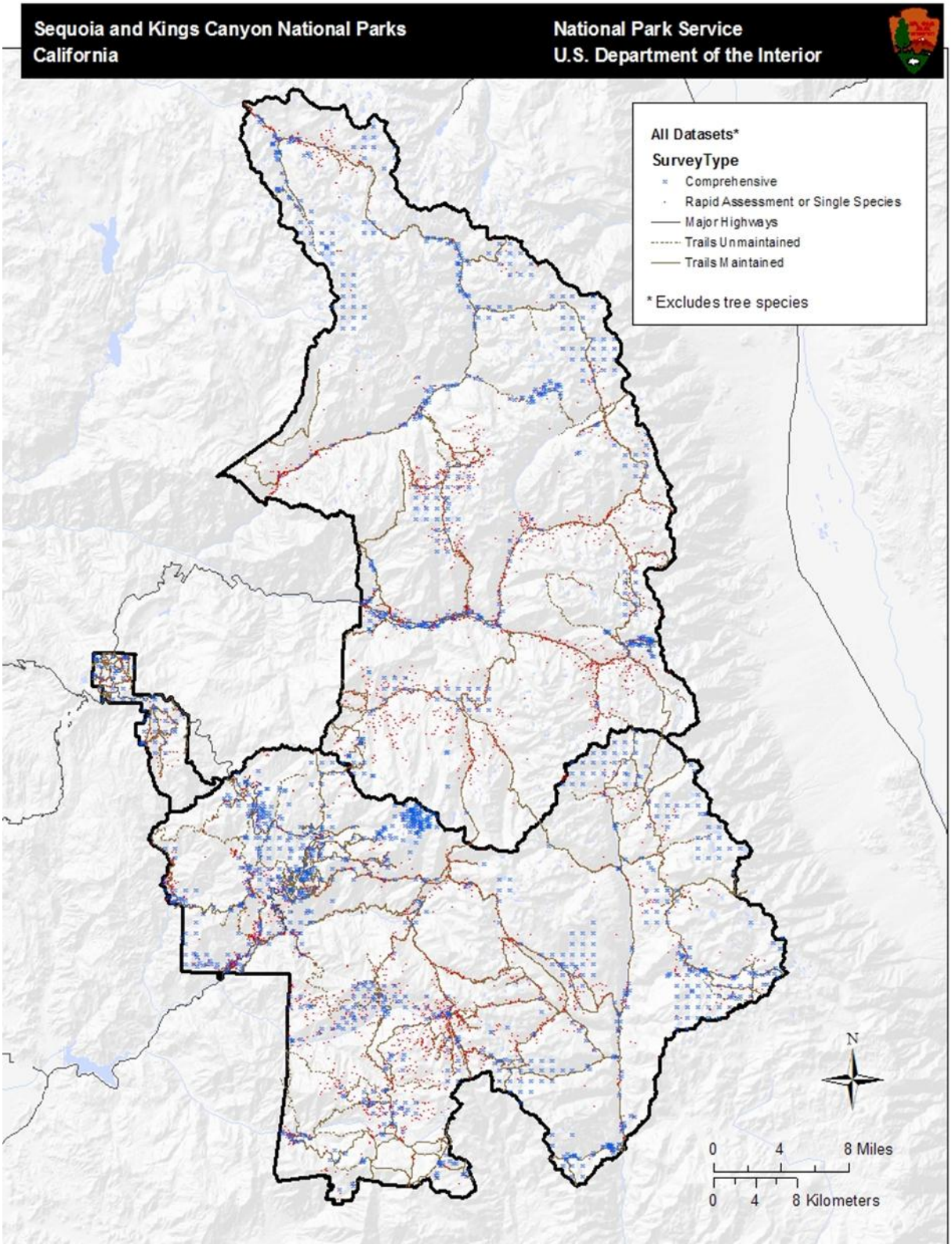


**Fig.1** Datasets available for analysis. Blue x = comprehensive survey type plot locations; small orange points = non-comprehensive plot locations (rapid assessment and single species observations).

***Descriptions of data sources***

Comprehensive Survey Types: Systematic surveys have been undertaken since the 1980s to describe the distribution of vascular plants in Sequoia and Kings Canyon. The most wide-ranging surveys, in terms of both geographic and floristic coverage, include the Natural Resource Inventory (NRI), the Stephenson Gradient Analysis study and the Vegetation Mapping project.

The goal of the Natural Resource Inventory was to inventory the vascular plants in the parks and to test the adequacy of the vegetation classification used by the parks at the time (Graber et al. 1993). NRI plots were sampled between 1985 and 1998 (13). Plot locations were chosen with a stratified random sampling scheme designed to maximize sampling efficiency and cover a broad geographic range of slope, elevation, and aspect classes in the parks (15). One–tenth hectare circular plots were located at one kilometer Universal Transverse Mercator (UTM) grid intersections, with plot center randomly placed within a 100 meter radius of the intersection. Clusters of sample points were sampled throughout the parks in order to maximize field effort and efficiency. Unlike traditional approaches to vegetation sampling, plots were not placed in either homogeneous vegetation or environment. The resulting dataset is thus well suited for describing the actual distribution of vascular plants within the two parks. The surveys recorded cover and vascular species composition data for 628 plots, capturing 860 plant species in the parks, or 68% of the known flora (Graber et al. 1993).

Stephenson Gradient Analysis data were collected from 1982 to 1984 to describe the distribution of forest trees along environmental gradients in Sequoia National Park. Plots were located to sample a wide range of environmental gradients including elevation, slope steepness, slope aspect and soil depth, and also to cover a wide geographic range of the park. Plot locations were not chosen with regard to vegetation type. Vascular species composition (including both woody and herbaceous taxa), cover, tree diameter at breast height, tree canopy cover and abiotic plot attribute data were taken on 228 rectangular plots that were 0.1 hectare in area (16, 17).

Vegetation Mapping Plots include full plots, Rapid Assessment plots and Accuracy Assessment plots. (Full plots are comprehensive type surveys; Rapid Assessment and Accuracy Assessment plots are rapid assessment type surveys.) These plots are associated with data collected from 2000 to 2007 to produce a vegetation map of the parks consistent with the National Vegetation Classification Standard (FGDC 1997). The minimum mapping unit was 0.5 hectares, resulting in over 80,000 individual vegetation polygons mapped to alliance and association classes, and crosswalks to CALVEG and CWHR (California Wildlife Habitat Relationships System) vegetation classifications. Vegetation polygons were delineated and photo interpreted based on color infrared photography taken in 2000 and 2001 (24). On the ground vegetation classification and mapping accuracy plots varied in size and shape depending on vegetation type. For example, vegetation map full plots, which recorded vascular species composition and other data were approximately 1000 $m^2$ in area in forests, 400 $m^2$ in shrubland, 100 $m^2$ in grassland, and 100 $m^2$ in dwarf-shrub heath communities. Accuracy Assessment plots mirrored the minimum mapping unit with an area of 0.5 hectares (12). Rapid Assessment and Accuracy Assessment survey plots were sampled to train and test the accuracy of the photo interpretation work for the vegetation map of the parks. Only dominant and characteristic species were recorded to classify the vegetation to alliance and association levels of the vegetation classification (12).

Wetland Ecological Integrity surveys sampled wet meadows and fens excluded from grazing by pack animals. These surveys recorded total species composition and tree tally in 100 $m^2$ macroplots. Cover of vascular plants and bryophytes and bryophyte richness were sampled in smaller plots nested in the macroplot (20). These plots were established in SEKI in 2009 and 2010 by the Sierra Nevada Network Inventory & Monitoring program as part of a pilot long term monitoring program being developed for park wetlands.

The Paired Meadow Species Composition dataset includes species composition recorded every five years from five pairs of subjectively selected grazed and ungrazed meadows within close proximity to one another. Species frequency and other data related to grazing is recorded in meadows open to pack stock use and reference meadows or areas within the same meadow that are closed to pack stock use. This dataset includes vascular plant species composition found within 100 to 200 small quadrats (0.0625 $m^2$ in area) per plot (one plot per grazed or reference meadow) per visit. Data have been collected from these plots since 1985 (25).

The NPS Fire Effects Monitoring program establishes permanent plots in the parks to track the response of vegetation to fire management activities (Webster and Halpern 2010). Fuels, vegetation and fire related data are recorded pre and post fire and in control plots placed in shrub and forest vegetation communities. Plot sizes and sampling area of herbaceous vascular plant species composition vary by vegetation type and by year as the sampling protocol changed over time (Sequoia and Kings Canyon National Parks, Tony Caprio, Fire Ecologist, personal communication, 17 February 2011). Although species composition is taken in belt transects within the plots, the data used in this report only includes the species composition data that was recorded along the point-intercept transect placed in the middle of the belt transect due to the availability of the data at the time of this report.

Rapid Assessment Survey Types: The Vegetation Map Rapid Assessment and Accuracy Assessment survey plots, which are part of the Vegetation Mapping Plots, are described above.

White Pine Blister Rust Study plots were established to document the distribution of white pine blister rust in the parks. Vegetation sampling in these plots included trees associated with white pine blister rust and shrub species in the genus *Ribes*, which serves as the alternate host for white pine blister rust (Duriscoe and Duriscoe 2002).

Vankat/Roy Vegetation Change Study plots were established by John Vankat in the 1960s. Many of the plots were revisited in the 1990s by Graham Roy who evaluated change in vegetation between the two sampling periods. Vegetation observations from these plots are limited to woody species only (Roy and Vankat 1999).

Single Species Surveys: The remaining data sources shown in Table 1 are datasets that describe the collection of plant specimens or surveys that recorded individual special status plant populations (Norris and Brennan and Inventory and Monitoring (I&M) Special Status Plant Surveys). A description of the Norris and Brennan and I&M Special Status Plant Surveys is included in the Reference Condition section of this report.

A description of the California Natural Diversity Database (CNDDB) is included in Appendix D. The Consortium of California Herbaria (CCH or Consortium) is an online database of vascular plant specimen collections from 17 academic and research herbaria in California. Please see the CCH website at ucjeps.berkeley.edu/consortium for the full list of participating herbaria. Bryophyte specimen collections were obtained from several sources (shown in Table 1). The largest contribution of bryophyte observations came from James Shevock's (California Academy of Sciences and University of California at Berkeley) personal database. The Shevock bryophyte dataset is a compilation of specimen records collected by Shevock and others.

## Data sources used to assess the condition of special status plants

### *Imperilment rankings and endemism: Data available for analysis*

We referred to the California Department of Fish and Game Natural Diversity Database's (CNDDB) quarterly publication, "Special Vascular Plants, Bryophytes, and Lichens List" (October 2010) to assign global(G-rank) and state (S-rank) imperilment designations (described in Appendix D) for all taxa on the SEKI Vascular Plant Checklist that are tracked by the CNDDB. We obtained CNPS list designations (described in Appendix C) from the California Native Plant Society's Inventory of Rare and Endangered Plants (CNPS 2010).

Please refer to the section "Data sources used to determine the special status plants in SEKI" for a description of the data sources used to assign endemism.

### *Trend assessment: Data available for analysis*

Existing data is insufficient to perform a temporal analysis of change in the special status plant resource as a whole over time. Although extensive comprehensive plant surveys have been conducted in the parks in each decade since 1980, these studies were not designed to track changes in the status of special status plants. Plot locations and survey protocols were not identical among studies (i.e., plots were not re-visited from one study to the next), making any inference about changes through time suspect. A broad scale analysis of the change in special status plants through time using these various datasets would likely be more misleading than informative.

Two park datasets and their accompanying reports comprise the data available for a trend assessment of special status plant populations in SEKI: the Norris and Brennan Surveys conducted in the 1980s and the Inventory and Monitoring (I&M) Special Status Plant Surveys conducted in 2003-2004. These are the only surveys conducted in the parks to date that specifically targeted special status plants. Please refer to the Reference condition section of this report for a description of the surveys. There are twelve special status species that were visited during both time periods that are included in this assessment (Table 2). Limitations of these data for application to an assessment of "trends" are described in the Temporal analysis section of this report.

**Table 2.** Special status plant taxa surveyed by both the Norris and Brennan Surveys (1980s) and the I&M Special Status Plant Surveys (2003-2004).

| Scientific Name | Common Name | Federal or State | CNPS List | State Rank | Global Rank | Endemic Region |
|---|---|---|---|---|---|---|
| *Astragalus ravenii* | Raven's milkvetch | -/- | 1B.3 | S1.2 | G1Q | Southern Sierra |
| *Carex tompkinsii* | Tompkins' sedge | -/Rare | 4.3 | S3.3 | G3 | Sierra Nevada |
| *Draba cruciata* | Mineral King draba | -/- | 1B.3 | S2.3 | G2 | Southern Sierra |
| *Erigeron aequifolius* | Hall's daisy | -/- | 1B.3 | S2.3 | G2 | Southern Sierra |
| *Erigeron nudum* var. *murinum* | mouse buckwheat | -/- | 1B.2 | S2.3 | G5T2 | Locally Endemic |
| *Erythronium pusaterii* | Kaweah fawn lilly | -/- | 1B.3 | S2.3 | G2 | Southern Sierra |
| *Lupinus culbertsonii* ssp. *culbertsonii* | Hockett Meadows lupine | -/- | 1B.3 | S1.4 | G3?T1 | Southern Sierra |
| *Mimulus norrisii* | Kaweah monkey flower | -/- | 1B.3 | S2.3 | G2 | Southern Sierra |
| *Oreonana purpurascens* | Purple mountain-parsley | -/- | 1B.3 | S3.2 | G3 | Southern Sierra |
| *Carlquistia muirii* | Muir's raillardiopsis | -/- | 1B.3 | S2.3 | G2 | -- |
| *Streptanthus fenestratus* | Tehipite Valley jewelflower | -/- | 1B.3 | S2.3 | G2 | Locally Endemic |
| *Streptanthus gracilis* | Alpine jewelflower | -/- | 1B.3 | S3.3 | G3 | Locally Endemic |

The I&M Special Status Plant Surveys draft species accounts provide comprehensive accounts of the plants that are included in this assessment of change (Haultain et al. 2004). These accounts include taxonomic description, distribution, habitat, associated plant species, associated vegetation communities, and condition of the populations that were visited (number of plants, phenological stage, appearance, and apparent threats to the populations, if any). Accounts also include recommendations for locations of future surveys and photographs of the plants taken in the field. The Norris and Brennan reports (Norris and Brennan 1982, Norris 1984) are similarly comprehensive species accounts of the plants included in their surveys. The habitat and distribution information presented in Appendix A come from these and other sources (CNDDB, CCH, CalFlora, Jepson Interchange, and CNPS Inventory) and provide current conservation status and knowledge of the species' geographic distribution in the state. A description of notable CNDDB and CCH specimen records was also added.

### *Rarity in the parks: Data available for analysis*

The number of occurrences for the 12 taxa that were surveyed by both the Norris and Brennan and I&M Special Status Plant Surveys were counted using the georeferenced location data for each species shown in Table 2, and also GIS data of population extents from the I&M Special Status Plant Surveys. We followed the CNDDB's approach to define an occurrence as "any population or group of nearby populations located more than 0.25 miles [402 meters] from any other population" (CNDDB 2010a).

For all other special status herbaceous plants, we estimated the relative rarity for each species in the parks by overlaying a grid of equal-area hexagonal cells 805 meters (0.5 miles) in diameter and counting the number of hexagons in which the species has been observed. The data sources

used in this analysis are described Table 1. Please see the Spatial analysis section for more information about methods.

### Data sources used to determine what is known about the NRCA-Identified stressors on special status plants

We combined literature searches with data from Sequoia and Kings Canyon National Parks to describe the potential effect of each of the stressors. A list of plants affected by poor air quality was obtained from the SEKI Air Quality Specialist, Annie Esperanza. For land use, we focused on proximity to roads, trails and park operations as well as stock use in meadows. We referred to earlier survey reports (I&M and Norris and Brennan Special Status Plant Surveys) as well as available spatial information. For stock use, we examined the Paired Meadow Species Composition data and consulted with the Meadows team of the SEKI NRCA project. For invasive species, we referred to the Invasive Species focal resource chapter of the SEKI NRCA. For fire, we referred to the available literature and the SEKI Fire Return Interval Departure (FRID) layer. For the Disease Paradigms stressor, we consulted the limited literature available for a few of the species on our list as well as data taken within the parks to track diseases such as *Cronartium ribicola* (White Pine Blister Rust).

# Reference conditions

## Existing knowledge: Special status plant list

### *Jones & Stokes special status plant list - 2003*

The current SEKI special status plants list was largely compiled in 2003 by Jones & Stokes, an environmental consulting company. Under contract with the NPS Inventory and Monitoring Program (I&M), the company was tasked to develop a list of special status plants and a survey strategy for SEKI as well as the other units of the Sierra Nevada Network (Yosemite National Park and Devils Postpile National Monument). This effort was part of the I&M program's initiative to develop 12 essential datasets for all national park units. The definition of special status included state or federally listed species, USFS listed sensitive species, CNPS listed plants (CNPS Lists 1 to 4), and plants with limited distribution in California. Jones & Stokes also developed a habitat model to predict special species locations and help prioritize future survey locations.

As now, there were no federally or state listed threatened or endangered plants known to occur in Sequoia and Kings Canyon National Parks in 2003. The list that Jones & Stokes compiled included 185 species, of which 136 were documented as occurring in the parks and 49 were identified as potentially occurring.

### *SEKI modifications to the special status plant list since 2003*

The list of special status plants that was provided to the NRCA in 2010 for this report (SEKI Special Status Plants.mdb) included two additional species that were not on the original Jones and Stokes list, *Brodiaea coronaria* and *Eschscholzia hypecoides.* However, we removed these taxa from the special status plant list as we could not find evidence of these taxa in the parks. Sources searched included the Sequoia and Kings Canyon National Parks herbarium, Consortium of California Herbaria (CCH 2011), Sequoia and Kings Canyon vegetation datasets (see Data sources used to determine the special status plants in SEKI section of report), the California Natural Diversity Database Rarefind program (CNDDB 2010b) or CalFlora (2010). Appendix B gives additional information about the special status plant list revision process.

### *SEKI flora*

The basis for determining the list of special status plants is dependent upon knowledge of the Sequoia and Kings Canyon National Parks' flora. Based on expert opinion, the Sierra Nevada Network Working Group (2001) estimated that 90% of the vascular flora in SEKI has been documented. Please see the Data sources section for information on the extent and limitations of knowledge of the flora in the parks.

## Existing knowledge in SEKI: Special status plant surveys

### *Norris and Brennan special status surveys - 1980s*

Larry L. Norris and David A. Brennan led the first surveys targeting special status plant species in the parks during the early 1980s (Norris and Brennan 1982, Norris 1984). They set out to inventory all known populations of special status plants in the parks and to find additional populations. Surveys for the 1982 report were conducted from April-September 1980 and May-September 1981. Search areas included both parks but their efforts were largely limited to trail

corridors. Large portions of the northern and central Kings Canyon, where trail access is limited, remained unsurveyed (4).

Their 1982 report is a detailed two-volume report containing locations, habitat descriptions, professional line drawings, population endangerment factors, and management recommendations for 30 special status species. Fourteen were candidates for listing as federally threatened; ten were unlisted but considered unique or rare in the parks; and six species were not known to occur in the parks but were considered rare, unique, or federally listed candidate species that were expected to occur in SEKI (Norris and Brennan 1982).

In an update given in 1984, Norris reported that the number of special status plants in SEKI had shrunk from 30 to 14, due to a significant reduction in the number of USFWS-listed candidate threatened species. Only six species were still candidates for federal threatened listing. Many of the taxa that had lost candidate status were removed because of the additional populations that Norris and Brennan had reported in their 1982 report and soon after (Norris 1984). Between July 1982 and March 1984 Norris and others found an additional 40 sensitive plant populations. From these surveys, two new rare plant species were found, a newly described species *Mimulus norrisii* (Kaweah monkeyflower), and a desert fern limestone lithospecific species *Notholaena jonesii* (Jones' false Cloak fern, current name *Argyrochosma jonesii*).

At the time of these reports, there were no federally listed threatened or endangered species known or expected to occur within the parks. Based on their evaluations, the authors concluded that none of the sensitive plant species faced serious threats in the parks.

#### *NPS Inventory and Monitoring program rare plant surveys – 2003 to 2004*

The Inventory and Monitoring (I&M) program funded field surveys in 2003 and 2004 to revisit and document known populations of CNPS List 1B plants in SEKI, since 1B plants are considered rare throughout their range and represent the highest level of rarity represented in the SEKI flora (see Appendix C for details). Field botanists revisited a majority of the populations documented by the Norris and Brennan surveys and also explored new ground that had not been previously systematically searched. These searches resulted in newly discovered special status plant populations. Like the Norris and Brennan surveys, the I&M special status plant surveys documented for each population its location, estimated number of plants, total area, percent in flower or in fruit, general appearance and any potential or immediate threats (such as trampling by hikers, trail, or road work). Unlike the Norris and Brennan surveys, the I&M surveys also documented their search areas and population extents using GPS technology.

These two sets of surveys comprise the bulk of SEKI's data directed at special status plant populations. The technical reports from the Norris and Brennan surveys summarize results of their surveys for 24 of the 147 plants on the NRCA special status plants list (Norris and Brennan 1982 and Norris 1984). The summary report for the I&M Special Status Plant Surveys has not yet been finalized, but draft species accounts have been prepared for all 15 taxa targeted for survey, all of which are on the NRCA special status plants list (Haultain et al. 2004). Twelve of these species were also surveyed by Norris and Brennan (see Table 2). In general, the same population was not revisited more than once between these two datasets. These data provide a glimpse of the condition of twelve special status plants between the two time periods.

## Existing knowledge in SEKI: Geographic and ecologic coverage of surveys

Jones and Stokes analyzed the geographic and ecologic coverage completeness of vascular plant inventories conducted in the parks from the 1980s to 2003, and summarized their findings in a 2003 report to the National Park Service.

To assess geographic coverage, Jones and Stokes mapped the locations of surveys that comprehensively sampled vascular species: Natural Resource Inventory plots, Stephenson Gradient Analysis plots, and Vegetation Map plots. They also produced a map of special status plant locations, using the comprehensive surveys and other sources including CalFlora, databases from Dana York's thesis on the Kings River Flora, the SEKI Herbarium database and the Norris and Brennan surveys. Their report concluded from the two maps that while large portions of the parks had been sampled that a great deal of the parks still remained unsurveyed.

To assess ecologic coverage, they first compared the relative area of each vegetation type in the parks with the distribution of sample plots among vegetation types. For this analysis, each plot was attributed with vegetation type based on the plot data, not by a spatial join in GIS with the parks' vegetation map. For this reason, they only used plot locations from the Natural Resource Inventory and Vegetation Mapping surveys because vegetation types had not been described for the Stephenson Gradient Analysis plots. They found that sampling effort (measured by number of plots of each vegetation type) broadly corresponded with relative area that each vegetation type covered in the parks. Thus, they concluded that the sampling was representative for vegetation types in the parks.

Two exceptions were meadows and lodgepole pine vegetation types. Meadows, wetlands, and riparian habitats were sampled disproportionately more than their relative coverage in the parks and lodgepole pine and montane chaparral habitats were sampled relatively less. However, they found this to be reasonable ecologically, arguing that wetlands potentially support disproportionately more special status species while lodgepole pine and chaparral support fewer than their relative areas in the parks might suggest.

They then compared the number of special status species associated with each vegetation type with the number of sample plots for each vegetation type. They found that the most widespread habitats support the greatest number of special status plants (with the exception of meadows which support more special status plants relative to their coverage in the parks) and that the distribution of special status species occurrences closely parallels that of the sample plots.

Based on these findings, Jones and Stokes concluded that the results of previous surveys are representative of the park and, on the whole, provide an adequate baseline for landscape-level planning efforts. They noted however that "additional surveys are warranted to inventory the existing populations, determine species distributions in the parks, and locate additional undocumented populations".

It is worth noting that vegetation types attributed to each special status species were not based on vegetation types attributed to the sample plots in which species were found, nor a link made between observations and the SEKI vegetation map. Vegetation types for each species were based on habitat matrices that were developed from narrative habitat descriptions for each

species from The Jepson Manual (Hickman 1993), the CNPS Inventory (2001), and CNDDB (1999).

As part of the management strategy provided to the parks, Jones and Stokes suggested that predictive habitat models be developed for special status plant species in order to prioritize survey efforts. As a demonstration, they developed habitat models for five species: Ramshaw Meadows abronia (*Abronia alpina)*, Kaweah brodiaea (*Brodiaea insignis)*, Tompkin's sedge (*Carex tompkinsii*), Springville clarkia (*Clarkia springvillensis*), and Tulare County bleeding Heart (*Dicentra nevadensis*). Two of these taxa (Kaweah brodiaea and Springville clarkia) are not known to occur in the parks, but were chosen as likely candidates for focused surveys. They note several limitations of such an approach: lack of adequate habitat information for a given species, potentially inadequate resolution of the park's vegetation map, and lack of spatial data for certain habitat attributes (e.g., the parks currently lack a soils map). Nonetheless, they felt that such modeling would be valuable given limited resources and suggested improvements through "an iterative process of data collection and model revision" (Jones and Stokes 2003).

# Spatial and condition analyses

## Spatial analyses: Distribution of special status plants in SEKI

### *Special status plant observation and tree distribution maps*

Special status plants have been observed throughout the park and across the range of sampling locations (Fig. 2a). Figures 2b-d show the mapped distributions of the special status tree species in the parks. *Abies magnifica* var. *critchfieldii* (Critchfield red fir) is not shown because this is a newly described variety of red fir (Lanner 2010), and the precise locations of these trees are not known.

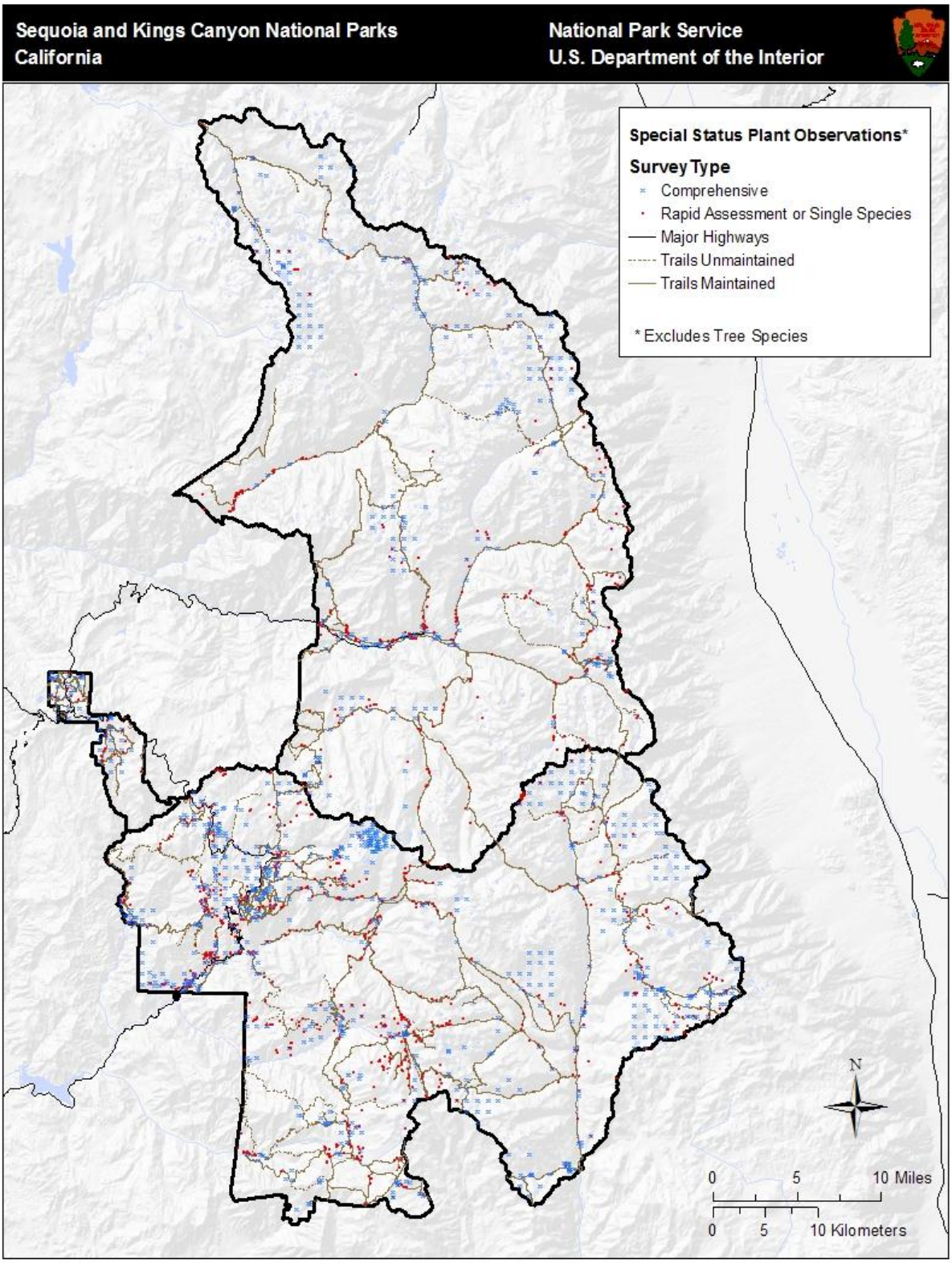


**Figure 2a.** Special status plant observations (excludes tree species). Blue x = comprehensive survey type plot locations; small orange points = non-comprehensive plot locations (rapid assessment and single species observations).

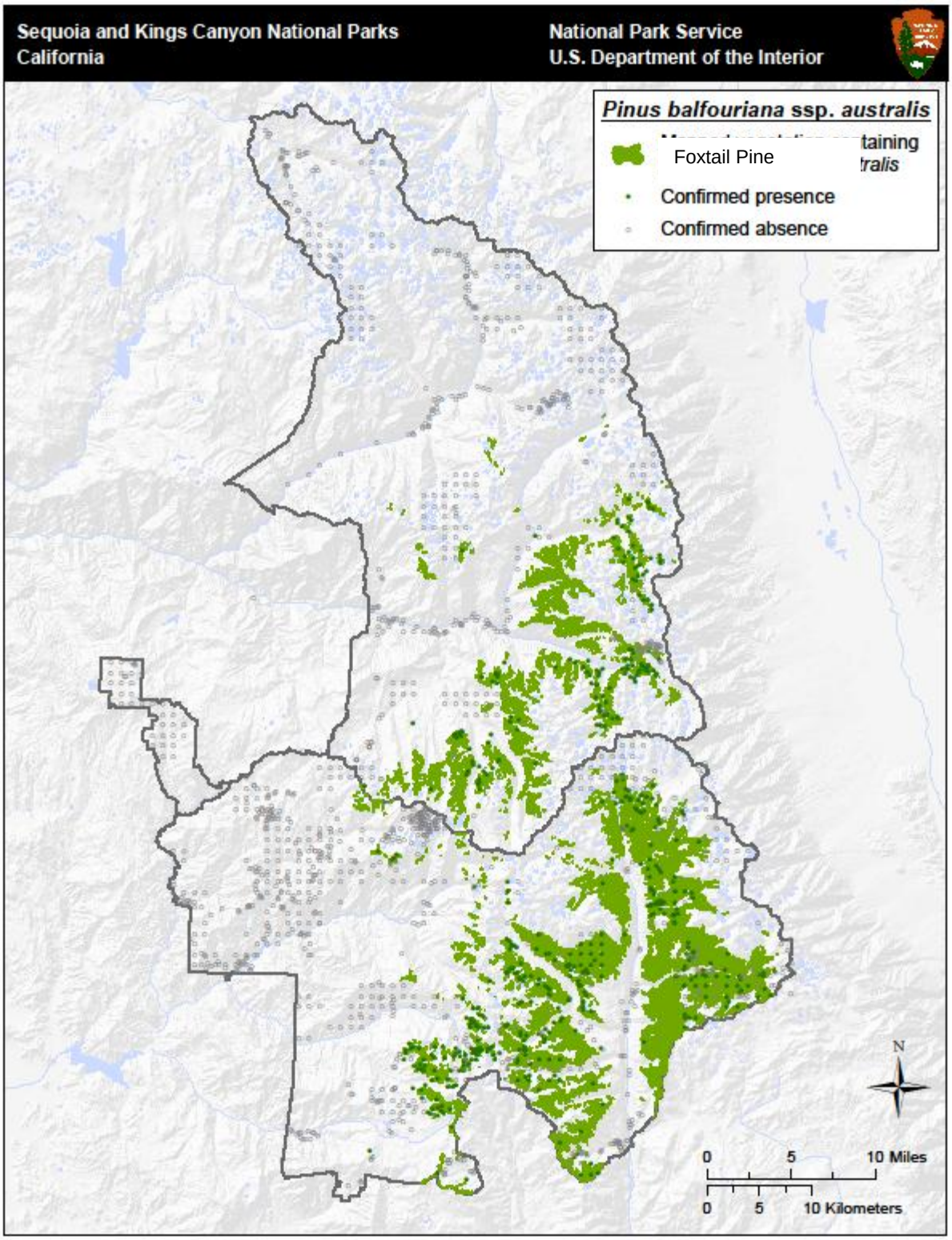


**Figure 2b.** Distribution of foxtail pine (*Pinus balfouriana* ssp. *australis*) in SEKI. Polygons of vegetation types containing *P. balfouriana* ssp. *australis* derived from 2007 SEKI vegetation map. Confirmed presence and absence reflect SEKI plot-based vegetation survey data.

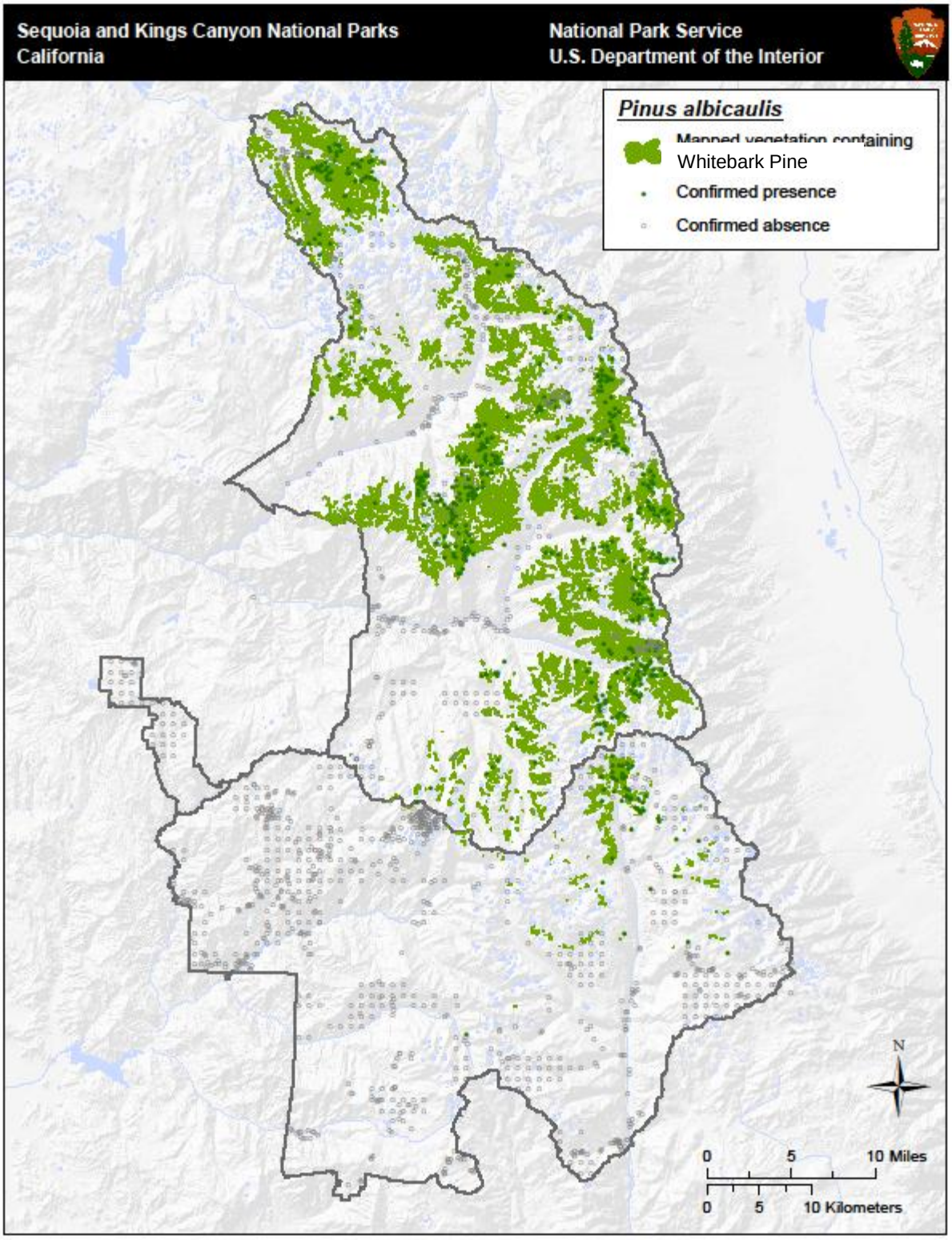


**Figure 2c.** Distribution of whitebark pine (*Pinus albicaulis*) in SEKI. Polygons of vegetation types containing *P. albicaulis* derived from 2007 SEKI vegetation map. Confirmed presence and absence reflect SEKI plot-based vegetation survey data

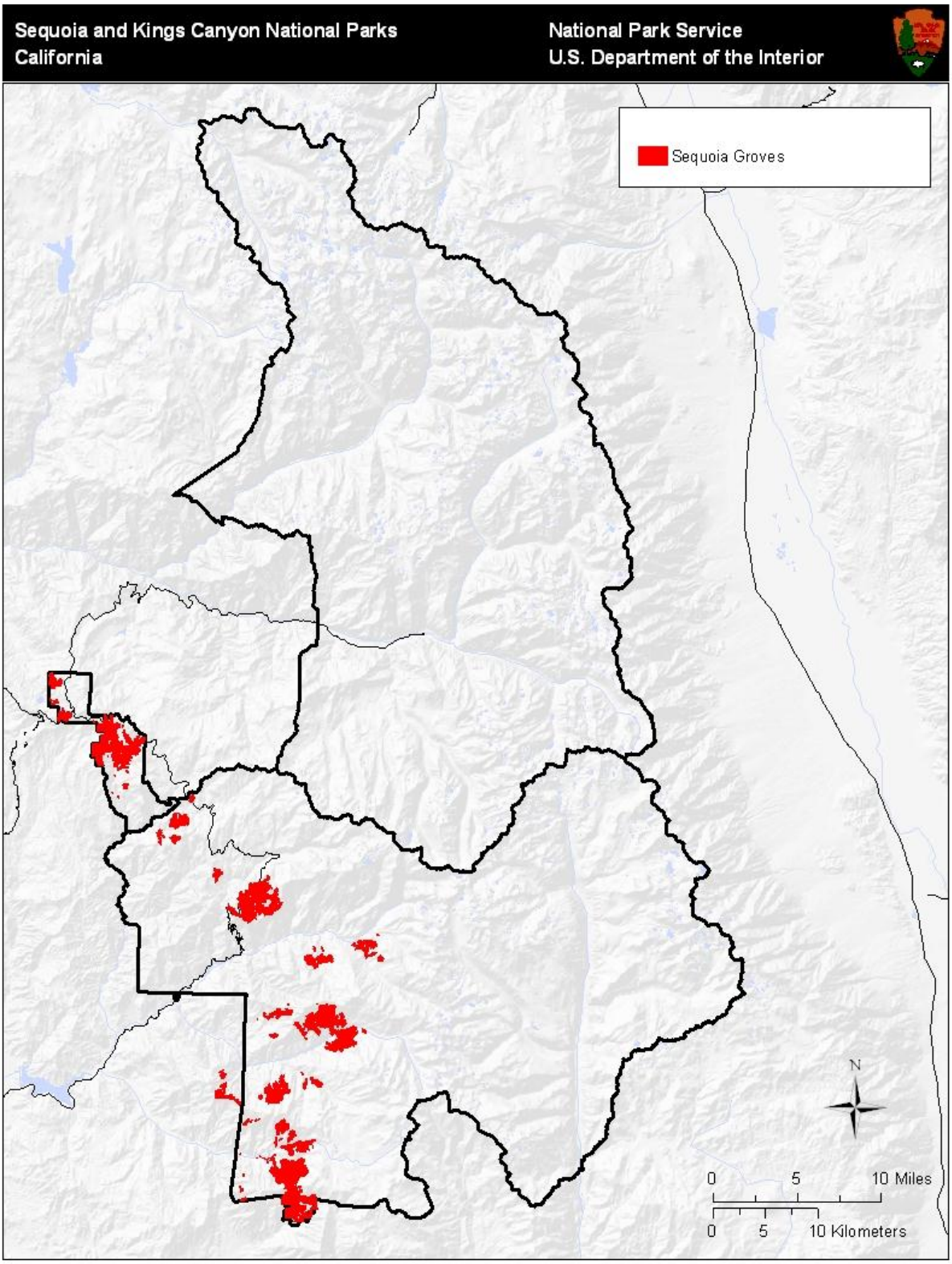


**Figure 2d.** Distribution of *Sequoiadendron giganteum* (giant sequoia) groves

### *Unweighted spatial patterns of richness*

Rationale for analytic approach

One of the primary limitations in the data available for special status plants is the lack of population demographic information for individual species (see Gaps in understanding section). For example, we are unable to confidently identify which species are most at risk due to small or rapidly declining populations — and then use the locations of those species to help prioritize which areas in the park require the most management attention. Instead, we primarily have information about documented locations of special status species without accompanying population information for those species.

Therefore, we focus the spatial analyses on identifying areas in the parks that are known to support special status plants, and from that data identify special status plant 'hot spots'; i.e., areas that appear to have the highest concentrations of those taxa. While certainly limited, this approach is not without merit or precedent.

For example, the identification of biodiversity hot spots often focuses on areas with the greatest total diversity of species or the greatest number of species at risk (Williams 1996). The idea of biodiversity hotspots for conservation planning was developed with the goal of protecting as many species as possible with limited funding, as it is often not practical or possible to protect all species (Myers 1988, Myers et al. 2000, Myers 2003). Indeed, the use of high biodiversity and endemism levels is one commonly applied method to prioritize regions for conservation since first published by Myers in 1988 (e.g., Mettermeier et al. 2004, Hou et al. 2010, Medail and Quezel 1999). More specific to our task here, richness of endemic species (Myers et al. 2000), rare species (Williams 1996), or a combination of these (Tchouto et al. 2006) have been used to prioritize regions high in sensitive species biodiversity for conservation.

Here we provide an array of spatial examinations of special status plants in SEKI-- examining the distribution of special status from a variety of viewpoints-- with the intention that these analyses will serve as useful tools to better understand the distribution patterns of special status plants, and use this information for management and conservation efforts.

Methods

In order to analyze the spatial distribution of special status plant richness, we subdivided the parks into discrete, equal area hexagonal sampling units and counted the number of special status species within each cell. The hexagonal approach was chosen because the approach gives a straightforward spatial representation of the distribution of special status plants across the parks by applying a defined unit of area as the sampling unit (as in Stein et al. 2000 and Parisi 2003). It also combines closely spaced sampling points into single spatial units and corrects for the problem of duplicate observations within and among the plant observation datasets (see Data sources section).

The hexagonal approach also considerably simplifies the analysis when compared to the CNDDB method for determining individual occurrences, which treats all observations of the same species within 0.25 miles of one another as a single occurrence. This requires that

occurrence extents are defined over a variable area depending on how many observation points of the same species are 'chained' (e.g., four plots on a line spaced 0.25 miles apart would be counted as the same occurrence although the farthest points would be one mile apart). The CNDDB approach probably offers a more accurate representation of the extent of a given population or set of clustered subpopulations, but this representation becomes less relevant when one is simply interested in estimating richness for a given location. Also, for practical reasons, with over 100 taxa and nearly 6,000 observations, implementing the CNDDB approach for Sequoia and Kings Canyon National Parks would have been prohibitively time consuming. We could not simply use existing CNDDB occurrence data since the CNDDB does not contain a substantial amount of the parks' data.

We chose an 805 meter (0.5 mile) diameter hexagon size (42 hectares or 0.4 kilometers$^2$ in area) after some experimentation with larger and smaller sized hexagons. This size was large enough to smooth patterns of the distribution of special status plants to an interpretable scale while small enough to retain a level of biological relevance to the locations in which they are found. Furthermore, an 805 meter hexagon roughly approximates the CNDDB approach by allowing a plant observation in the center of the hexagon to be grouped together with any observation of the same species within about 402 meters (0.25 miles). However, the hexagonal approach does not give the same results as the CNDDB approach, given the lack of chaining and the influence of where the hexagon boundaries are drawn.

All of the hexagon maps presented here should be considered in light of the spatial distribution of sampling effort, since sampling intensity varies considerably by hexagon (Figs. 3a, b). Although intensely sampled hexagons are distributed widely throughout the parks (Fig. 3a), when only comprehensive survey type plots are considered, some areas stand out as more intensely sampled (Fig. 3b). These areas include the South Fork of the Kings River and the Marble and Middle Fork drainages of the Kaweah River (including the Tablelands area). Note that in the analyses that follow these areas frequently stand out as having relatively high richness.

Areas with more sampling should have closer estimates of actual richness than those that are sparsely sampled, and in turn, richness estimates for sparsely sampled areas are more likely to be underestimated. Consequently, an attempt to identify which areas in SEKI have relatively high richness could be affected by uneven sampling effort. At worst, sparsely sampled areas with apparently low richness might in actuality have a high richness. Using only comprehensive survey type plots (a necessity for evaluating sampling effort - see discussion of methods for Rarity Weighted Richness map), we find a correlation between the reported richness in each hexagon and the sampling effort ($r$=0.36). This indicates that at least some hexagons are likely under sampled. In addition, when we estimate the average richness per plot and per hexagon we find that, for areas with intense sampling effort, richness would likely be underestimated if we only had one plot in each hexagon in those areas (results not shown). This suggests that in the numerous locations in the park with only one or a few plots per hexagon that our estimates of richness are likely underestimated. In short, all estimates of richness in this report should be considered minimum richness.

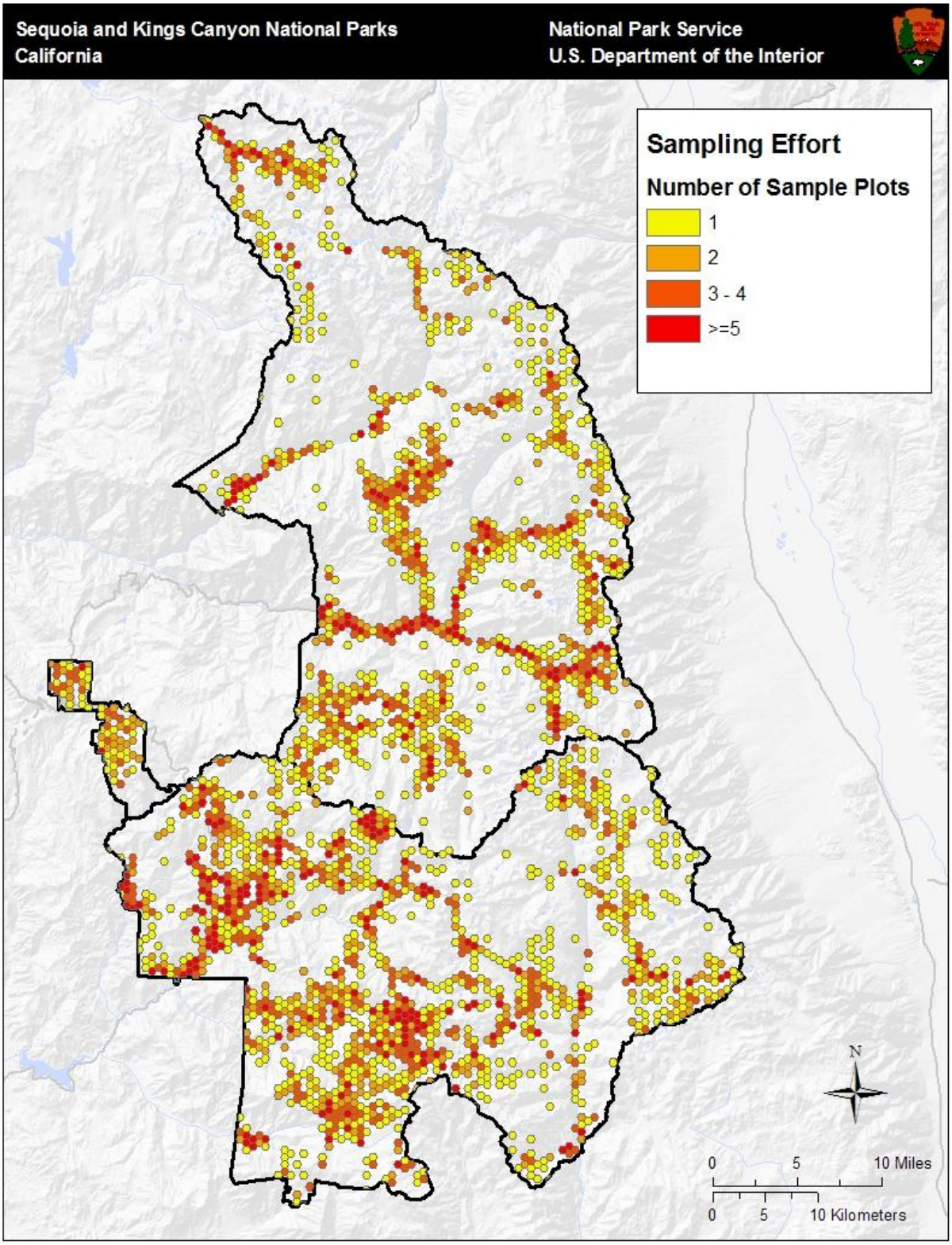


**Figure 3a.** Sampling effort including all data sources. Sampling effort measured by total number of sample plots per sampled hexagon. Areas with no hexagons indicate no data.

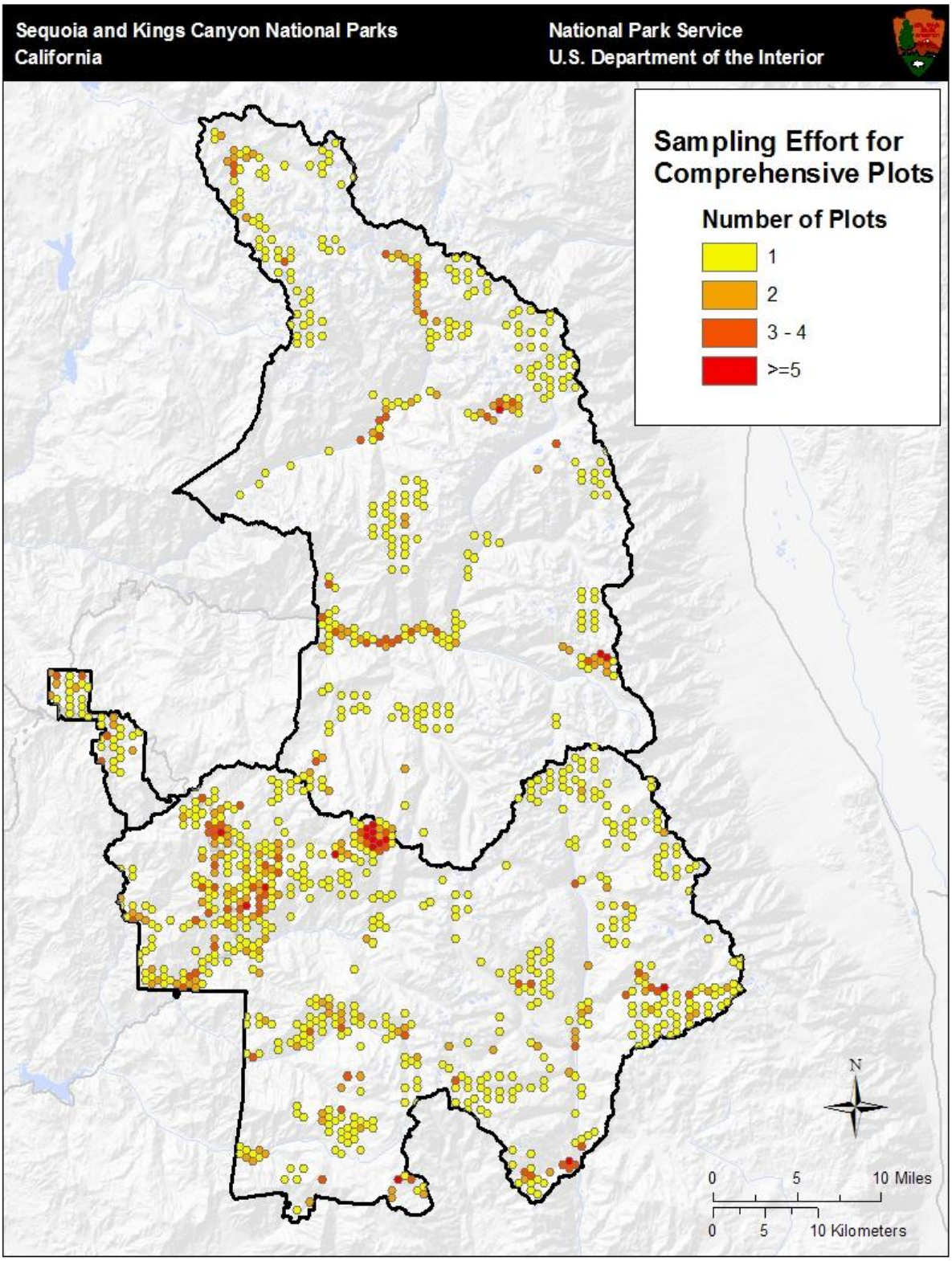


**Figure 3b.** Sampling effort including comprehensive plots only. Sampling effort measured by total number of comprehensive-type sample plots per sampled hexagon. Areas with no hexagons indicate no data.

Despite the limitations, these datasets represent our best estimate of the spatial distribution of special status species richness in the parks, and it almost certainly has more than a passing relationship to the actual conditions on the ground (i.e., the correlation with sampling effort is only modest). However, in interpreting the maps that follow, it is best to keep in mind that absence of evidence is not evidence of absence.

Results

*All special status plants:* Overall, special status plants occur in 1,224 out of a total of 2,489 sampled hexagons (excluding the four special status tree species which, due to their wide distributions in the parks, would skew the results) (Fig. 4). The number of hexagons in which each special status species was found is given in Appendix F. In general, species that are listed as rare or threatened (listed as rare by CNPS, CNDDB, or a federal or state agency) appear to be less common in the parks than special status species without a rare listing. Unlisted taxa occur on average in at least three times more hexagons than rare listed plants. Locations with relatively high special status plant richness (i.e., a richness of five or more species) are located throughout the park in every major basin, across the full elevation range of the parks, and across a wide variety of vegetation types (vegetation and elevation data not shown in Fig.4). The Marble Fork drainage of the Kaweah River provides an excellent representation of the wide distribution of special status plants. Hexagons with high richness are located as high as 3,352 meters (11,000 feet) in elevation and as low as 425 meters (1,400 feet). Vegetation types within such hexagons vary from the blue oak woodland found in the foothills at Ash Mountain, the mixed conifer forest in Giant Forest, and sparsely vegetated alpine habitat found in the Tablelands.

A similar variety of habitat types are represented in areas with the highest values of special status plant richness (eight or more species represented by dark red hexagons in Fig. 4). In Kings Canyon, hexagons with the highest richness (dark red) are located in the Goddard Creek and Hotel Creek areas. In Sequoia National Park, they are found in the Siberian Outpost area, Ash Mountain Headquarters area, and three areas in the Marble Fork of the Kaweah drainage including the Crescent Meadow, Emerald Lake, and Tablelands areas.

Special status species documented in hexagons with the highest values of richness (dark red) occur in a variety of vegetation types (eight types classified by the California Wildlife Habitat Relationships System or CWHR). Three of the seven hexagons contain meadows with special status plants. It is important to note that vegetation type minimum mapping units can be larger than the habitats that some of these species are closely associated with, so using the vegetation type polygons alone can miss important correlations with species that have narrow habitat requirements. Thus, we checked to see if any special status plants in the highest richness areas had narrow habitat requirements. We found that nearly half of the taxa in the highest richness hexagons are restricted to wet or moist habitats or subalpine to alpine elevations (13 and 10, respectively, out of a total of 50 taxa occurring in the highest richness hexagons).

Hexagons with the highest richness occur at a wide range of elevations (542-3,465 meters or 1,780-11,370 feet), although four of the seven very high richness hexagons are above 3,000 meters (9,842 feet) in elevation. Half of the hexagons contain several different vegetation types that support special status plants and the remaining have only one or two vegetation types. With regard to sampling effort, some of the species rich hexagons contain a high number of sampling

points (>15) and others only a very few. Only one of the seven highest richness hexagons, in the Ash Mountain Headquarters area, has special status species that are associated with uncommon rock or soil types (*Mimulus norrisii* and *Eriogonum nudum* var. *murinum*, which are found on marble or limestone derived soils). In short, there does not appear to be a simple set of factors that can easily categorize where the highest numbers of special status plant species are found, although it suggests that wetland associated species and subalpine or alpine environments might be important.

*Rare or threatened special status plants:* In terms of rare or threatened listed plants alone, the spatial distribution of occurrences is still also very wide, although considerably less dense (Fig. 5). As defined in the Data sources section of this report, rare species included in this assessment are those that have been listed as rare by CNPS or a federal or state agency (see Critera 1 on page 5). Rare plants have been documented in 689 of the total 2,489 sampled hexagons. They occur in a wide variety of vegetation types and across a wide range of elevations. Areas with the highest rare plant richness (four or more rare species) include many of the same areas that stand out in Figure 4: Siberian Outpost, Emerald Lake area, and areas in the Marble Fork drainage (near Potwisha Campground and east of Admiration Point). An additional high rare richness hexagon is found in the Hockett Meadow Plateau, which also supports a relatively high number of both rare and endemic species (Fig. 4).

An examination of the five areas with the highest number of rare listed taxa in the parks shows that the majority of the rare species in four of the five hexagons are restricted to alpine or subalpine environments, wetlands, or associated with uncommon rock or soil types (marble or limestone). This is in keeping with our findings for special status plants as a whole that alpine and wet environments may be important habitats.

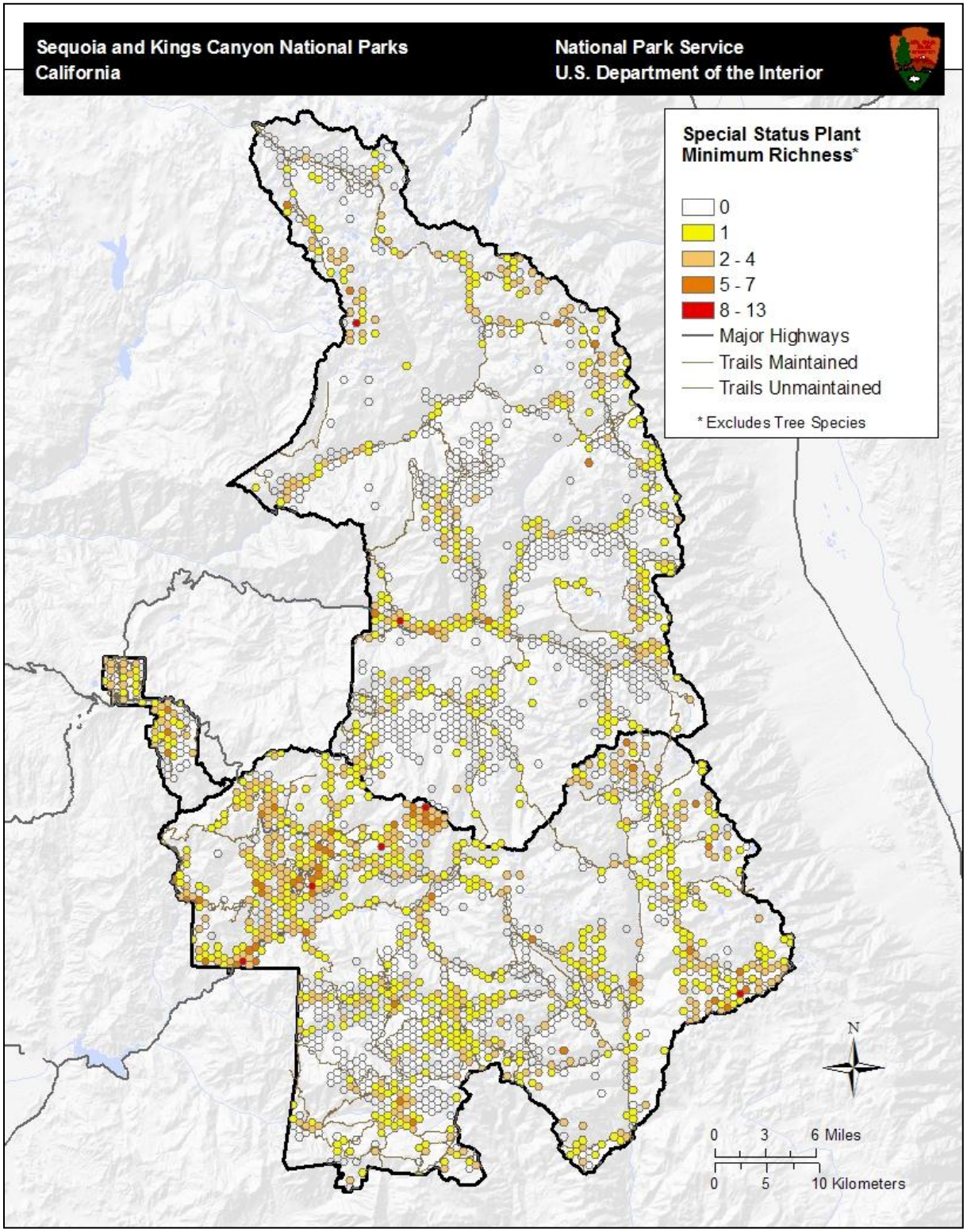


**Figure 4.** Minimum richness map of special status plants (excludes special status tree species). Empty hexagons have at least one sample plot with no special status species. Areas with no hexagons indicate no data.

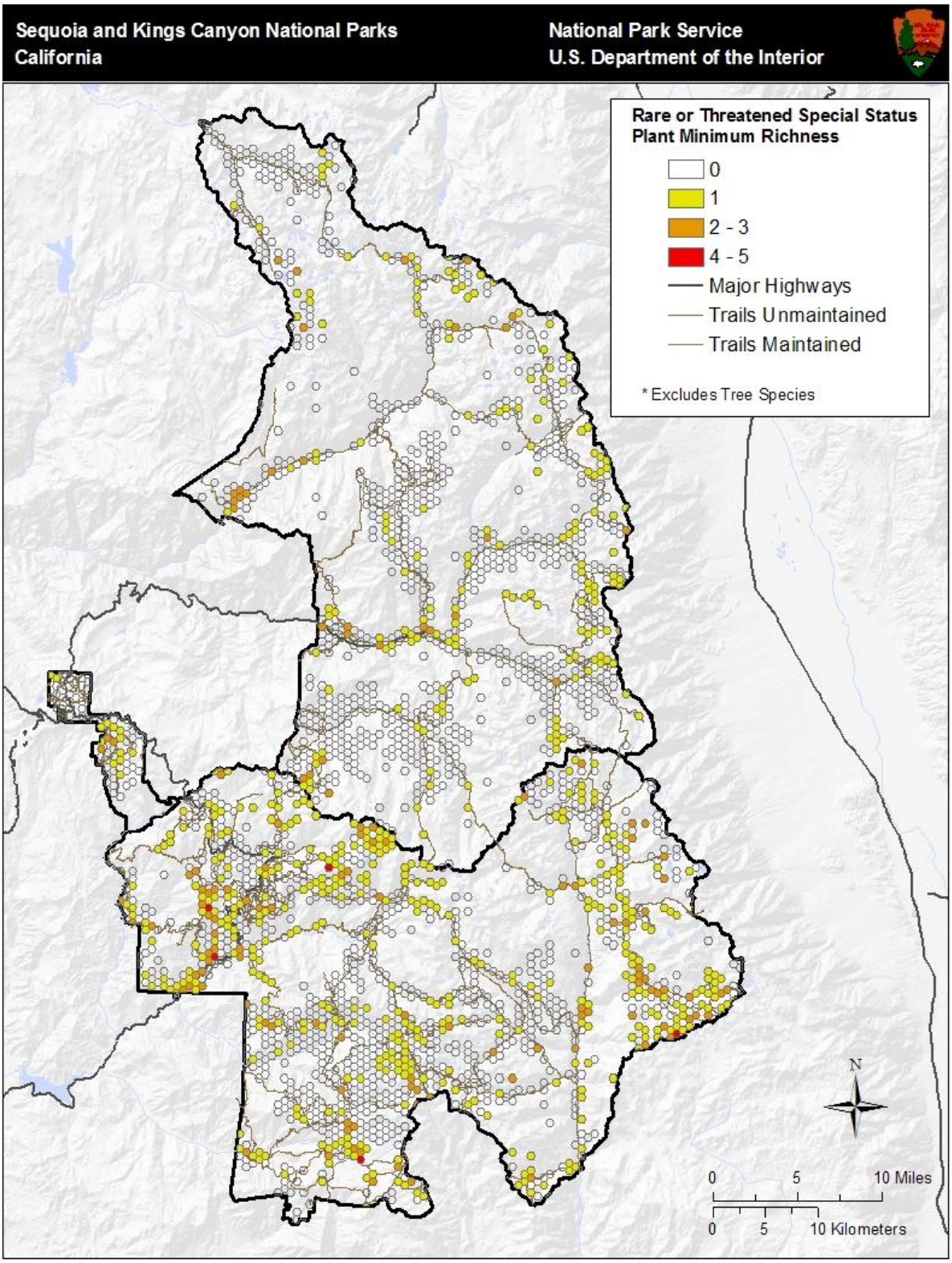


**Figure 5.** Minimum richness map of rare or threatened plants (taxa listed as rare or threatened by state or federal organizations, excludes non-listed special status endemics and trees). Empty hexagons have at least one sample point with no rare species. Areas with no hexagons indicate no data.

### *Weighted spatial patterns of richness*

Unweighted richness (Figs. 4 and 5) is only one dimension in which the spatial distribution of special status plants can be examined and applied to identify areas with high concentrations of rare and endemic plant species. For example, there is reason not to treat all special status taxa equally, since some are more uncommon or imperiled and perhaps more vulnerable to extirpation than others.

Weighted by class

One straightforward approach is to distinguish special status taxa by whether or not they are listed as rare (about half of which are endemic to the Sierra Nevada), or not listed as rare but are endemic, either to the Sierra Nevada or more narrowly, to the southern Sierra Nevada (all locally endemic species are listed rare taxa). See pages 5-6 for a description of rare species as defined in this report. For this analysis, we also consider species which have been documented in three or fewer hexagons as being 'locally rare'— here meaning rarely documented in the parks (Appendix F).

*Methods:* Figure 6 color codes hexagons by presence or absence of rare and non-rare endemic taxa. As in previous maps, blank areas have not been sampled. Green hexagons have a comprehensive plot located within them but have no reported occurrence of a special status species. Yellow hexagons have documented presence of at least one special status endemic species but no rare species. Red hexagons have documented presence of at least one rare species or locally rare species (documented in three or less hexagons). Note that lack of a reported species in a hexagon does not preclude its presence, and therefore caution should be taken in classifying yellow or green areas as of definitively less importance. At the very least, sampling effort should be examined to assess confidence in the assessment of a given hexagon (Fig. 3).

*Results:* Several large portions of the parks stand out as supporting relatively high and consistent coverage of rare and endemic species: Kern Canyon, the Middle and Marble Forks of the Kaweah River, and the South Fork of the Kings River. Other sampled areas are notable for the relative lack of special status plants, including the northern tip of Kings Canyon National Park (Evolution Valley), Dougherty Creek basin, Woods Creek, and the arc made by Sugarloaf Creek and Roaring River basin. Note that special status species are found in these areas, but taken as a whole they have been reported less frequently than other areas in the parks.

Weighted using rarity weighted richness index

Another approach is to use the rarity-weighted richness index.

*Methods:* Figures 7a and 7b show an alternative approach to identifying special status plants hotspots in the parks. Rather than overall richness, we applied a rarity-weighted richness index (RWRI) using methods described by Chaplin et al. (2000). RWRI takes into account the relative rarity of a species in a given area (in this case, Sequoia and Kings Canyon National Parks) as well as the overall special status richness within a hexagon. Each special status taxon in a hexagon is assigned a weight based on the inverse of the number of hexagons in which it has been documented. Each taxon is only counted once in each hexagon, no matter how many observations of that species are in a hexagon. Thus, it gives more weight to species that are locally rare in terms of distribution (limited range species). The equation is shown below:

$$RWRI = \sum_{i=1}^{n} \frac{1}{h_i}$$

where $h_i$ = the number of hexagons that species *i* occupies, and *n* = the number of species found within a hexagon.

The RWRI approach has been applied by NatureServe in its analysis of biodiversity patterns of imperiled species on the national scale (Stein et al. 2000), and on a state scale by the California Department of Fish and Game in its Atlas of the Biodiversity of California (Parisi 2003). NatureServe characterizes the index as an indicator of the "irreplaceability" of an area, because hexagons with the highest values harbor more species that are not found in many other places (relative to the other species included in the index) (Stein et al. 2000).

The biases and assumptions in this approach are described in Parisi 2003 and by Hunting 2003. The accuracy of the index is dependent upon how completely species distributions have been characterized. Although SEKI and non-park sources contribute thousands of sampling points for special status flora in the parks, only a subset of special status taxa have been systematically surveyed (see Reference condition section) and there are large areas in the parks that have not been sampled (Fig. 1).

An advantage of RWRI is that it can give weight to species that are rare in the parks but have not achieved a listing status (either due to the presence of populations outside the parks or to a lack of data). Conversely, it downweights species that might be relatively uncommon statewide but are locally common within the parks. A disadvantage of the approach is that it is highly dependent on the implicit assumption that sampling effort has been relatively equal among species (i.e., each species' potential habitat has been searched with an effort proportional to its true distribution in the parks). This is unlikely to be true, and the assumption is difficult to test given lack of information about each species specific habitat requirements (as described above). Nonetheless, in combination with other metrics, RWRI can be a valuable tool for visualizing overall richness while taking into account local rarity. It is also worth noting that rare species have been found in far fewer hexagons on average than endemic species that are not ranked as rare (Appendices A, F), lending some credence to our estimates of rarity. That said, due to the large areas of the park remaining unsampled, any estimates of local rarity will contain a relatively high degree of uncertainty.

To calculate the number of hexagons in which each species occurs ($h_i$ term in the RWRI equation), we used only the comprehensive plots in order to minimize the bias of unequal sampling effort among species. While the full set of observations provides our best estimate of raw richness, the full dataset is problematic when performing analyses that make some assumption of unbiased sampling. Most importantly, rapid assessment and single species survey types are targeted at specific species or sets of species. They do not reveal information on negative findings. They tell us only that target species were found, not that other species were absent. In addition, some surveys are targeted at specific species and therefore give a more thorough sampling of the habitat of those species (e.g., species surveyed by the Norris and Brennan and I&M Special Status Surveys). For calculating the RWRI, both of these biases can lead to species that are rare appearing less so (e.g., a very rare species for which every population

has been sampled in targeted surveys may appear less rare than a relatively more common species which has not been the target of such surveys). Differences among comprehensive plots, such as differences in sampling area could potentially produce other biases. However, these biases are likely to be far less influential than the inclusion of targeted surveys, and, given the already geographically limited sampling data, we chose to include all comprehensive plots in our analysis.

*Results:* Figures 7a and 7b present the RWRI results for the comprehensive plots and for the full set of plots respectively. In both cases $h_i$ (number of hexagons in which each species occurs) was calculated using only the comprehensive plots. Figure 7a is less subject to relative sampling biases by plot type (e.g., a hexagon with comprehensive plots may have a better estimate of richness than one with only targeted sampling), while Figure 7b provides a better overall estimate of richness for hexagons in which targeted sampling locations are present (e.g., using only comprehensive plots may miss species known to occur in a given hexagon from non-comprehensive plots). Note, however, that in Figure 7b we do not include hexagons without reported special status species unless that hexagon contains at least one comprehensive plot to ensure that special status species were actually sought in the hexagon.

Figures 7a and 7b indicate that many of the same areas within the parks that appear to have high overall special status plant richness (Figs. 4, 5) also stand out in the RWRI map (e.g., Middle and Marble Fork drainages of the Kaweah River, Hockett Plateau, Siberian Outpost, South Fork Kings – Cedar Grove area). In addition, a few new areas are highlighted, including the Palisade Creek area and sections along the East Fork of the Kaweah River. Several more isolated hexagons also stand out (e.g., Volcanic Lakes and Paradise Valley in Kings Canyon, Windy Ridge and Rattlesnake Creek in Sequoia). Overall, placing extra emphasis on species that appear to be locally rare does not paint a radically different spatial picture than our other analyses. It does however help to point out those locations which contain species that may be rare in the parks (or at least have been infrequently reported).

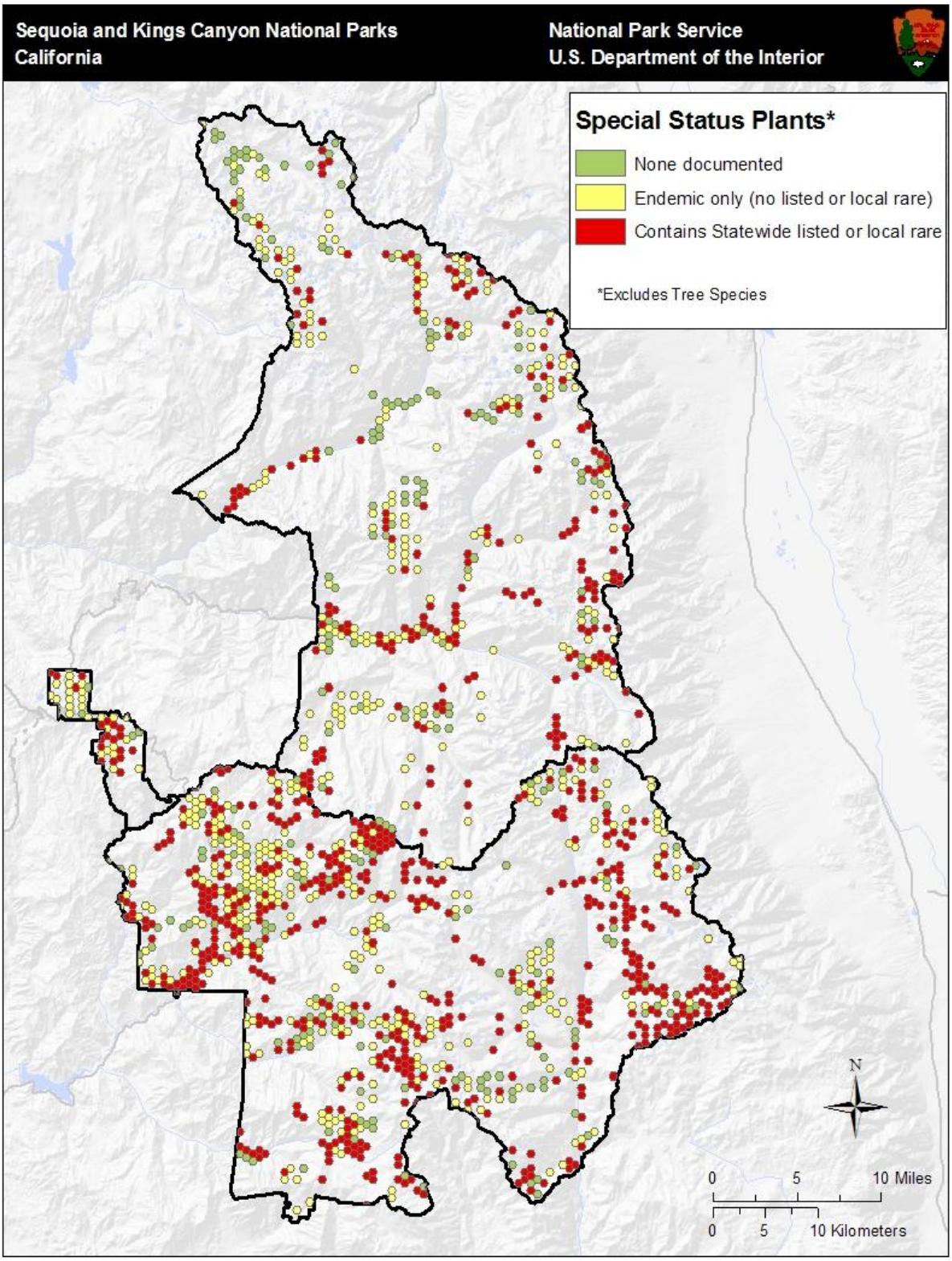


**Figure 6.** Special status plant observations by class (excluding tree species). Green = no special status species documented; yellow = endemic species but no rare or locally rare species documented; red = rare species documented or potentially locally rare endemic species (found in 3 or fewer hexagons).

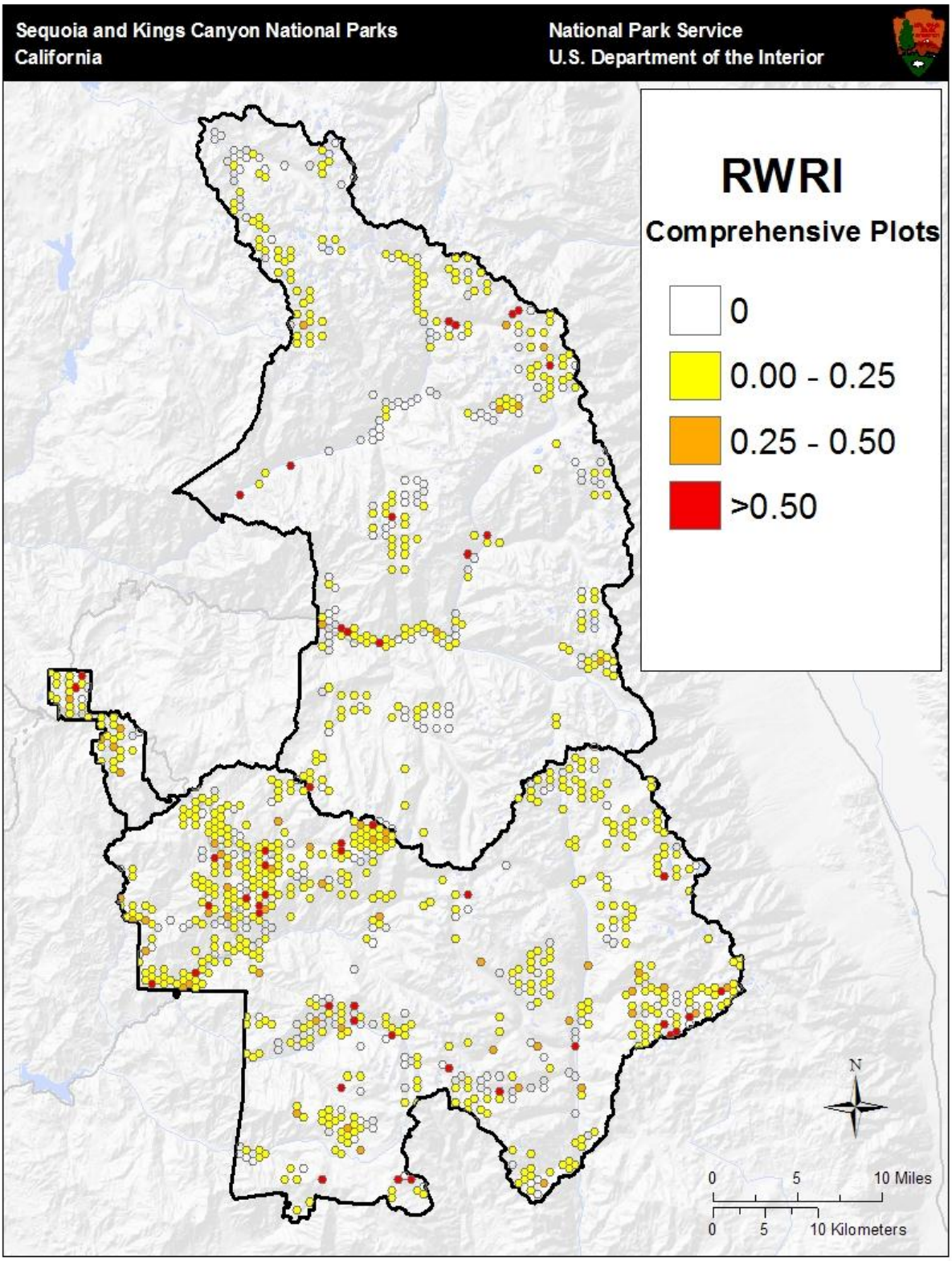


**Figure 7a.** Rarity-weighted richness index map using comprehensive data sources only. Excludes special status tree species.

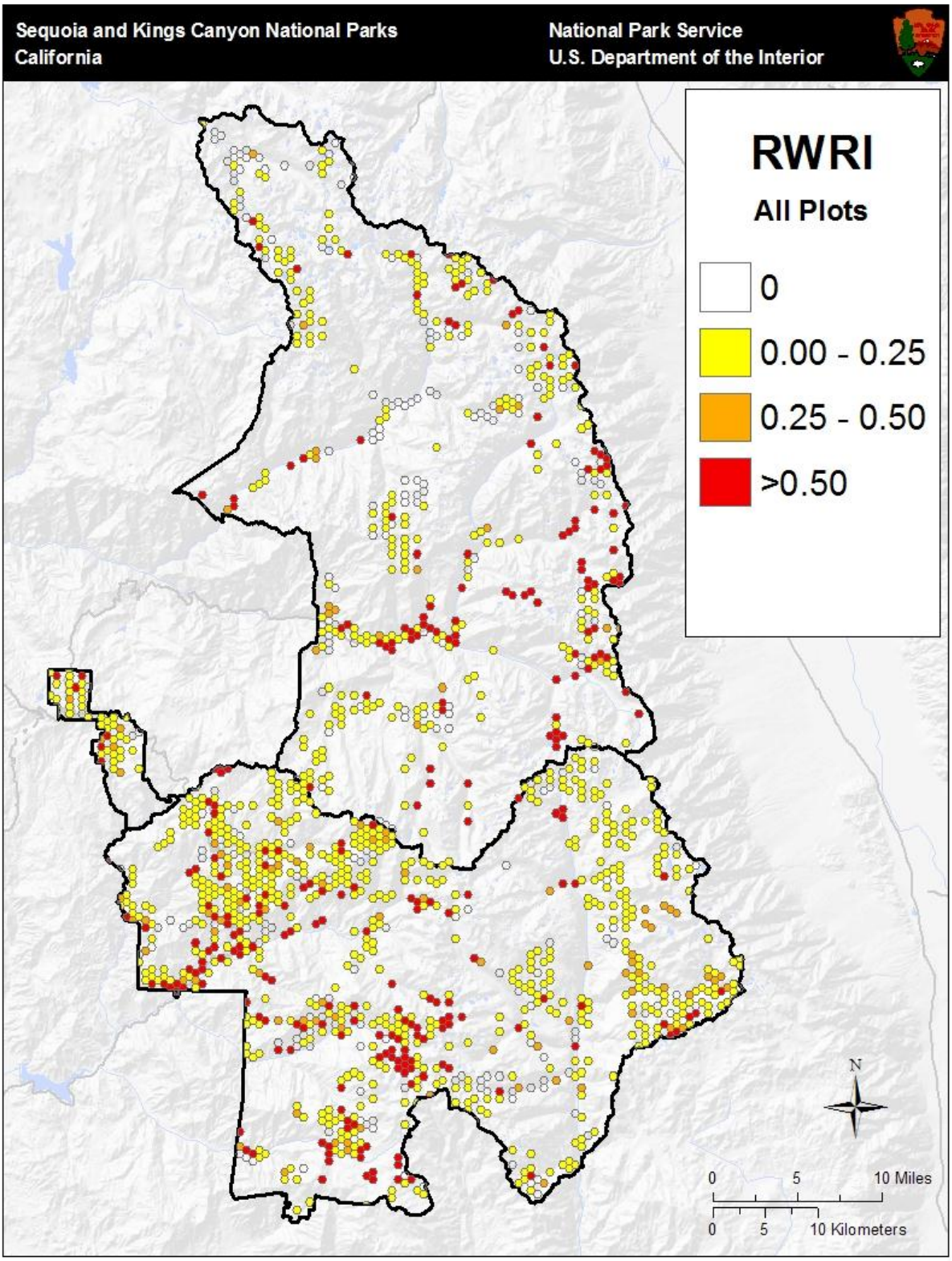


**Figure 7b.** Rarity-weighted richness index map using all data sources but weighting with comprehensive data. Excludes special status tree species.

### *Analysis of richness by vegetation type and elevation*

Methods

For both vegetation type and elevation analyses, we calculated richness with point data associated with special status plant observations rather than richness calculations aggregated by hexagon. This was necessary for the vegetation type analysis because each hexagon contained multiple vegetation types, while most sample points could be assigned to a specific vegetation type. We removed sampling points with a documented location error of over 25 meters and points that were mapped to water. This resulted in a dataset with 5,574 total sampling points, of which 2,541 contained special status species observations. For the elevation analysis, we removed sampling points with a documented distance error of over 100 meters. We allowed a less stringent requirement for elevation since our elevation bands encompass broad contiguous areas. This resulted in a dataset with 5,655 sampling points, of which 2,594 contained special status plant observations.

The area covered by each vegetation type in the park was derived from the SEKI Vegetation Map (24). To estimate total area in each elevation band, we first used the park DEM layer to assign each of the 805 meter wide hexagons an elevation based on its center using ArcGIS. We then summed the areas of all the hexagons that fell within each 500 meter wide elevation band.

Note that we have chosen to use vegetation types classified by the California Wildlife Habitat Relationships System (CWHR), which groups plant communities more broadly than the alliances described by Sawyer et al. 2009, for three reasons. First, CWHR types are more easily interpretable than the more finely divided alliances. Secondly, since the vegetation mapping polygons are mapped on a coarser spatial scale than the special status plant sample points, using alliance would imply more precision in our spatial data than we possess. Finally, using CWHR allows our results to be compared to other NRCA chapters (Invasive Plants and Biodiversity/Landscape), which have also chosen to use the CWHR classification.

However, some caution should be taken in interpreting our analysis by vegetation types. As noted previously, the habitat associated with special status species may occur on a much smaller scale than the minimum mapping unit for the SEKI vegetation map (0.5 hectares). When alliances are translated to the CWHR types, additional resolution is lost. For example, a species might commonly occur in the Sierra Mixed Conifer vegetation type but only in very moist habitats within the type. Our analysis would not capture that ecological relationship and, if interpreted too broadly, might lead one to conclude that such a species has a wide available habitat when it clearly does not. Rather, the intention of our analysis is to investigate the geographic relationship between special status plants and the broadly classified vegetation communities in which they are found in the parks.

As with our hexagon analysis, it is important to recognize that all richness values in this report are best described as ‘minimum richness’. For example, at any given time, a given vegetation type supports a certain number of special status plants. The more intensively a vegetation type is sampled the better our estimate of actual richness. At some point, richness will no longer increase with increased sampling as sampling reaches the saturation point (actual richness). Therefore, recording the number of sampling points within a given vegetation type alone does not necessarily indicate actual richness, and a direct comparison of sampling effort between

vegetation types may or may not be informative. The SEKI NRCA Biodiversity focal group has estimated sampling efficiency for each vegetation type. However, it is again important to remember that the specific habitat requirements of a given species—particularly a rare plant with narrow habitat requirements— is finer than the level of detail provided by the park vegetation map polygons (e.g., a plant may only occupy a very particular habitat within a given vegetation type). Given this, even though a given vegetation type may be adequately sampled on the whole does not demonstrate that it is adequately sampled for a particular subset of species (i.e., special status plants). So, while we consistently report sampling effort throughout this report, care should be taken in its interpretation.

Results

*By vegetation type:* A broader look at the relationship between the distribution of special status plants and vegetation types shows that in general, vegetation types that cover more area in the parks appear to support higher numbers of rare and endemic species (Fig. 8). There are several exceptions -- including meadows, mixed chaparral, perennial grassland, montane riparian (modified), alpine dwarf shrub, and blue oak woodland -- which have disproportionately high richness for their coverage in the parks. Similar patterns in richness are apparent for the subset of species that are listed as statewide rare.

Sampling effort also generally corresponds to relative area of vegetation types (Figs. 8, 9). There are some exceptions: Sierra mixed conifer, lodgepole pine and wet meadows appear to be sampled more heavily than indicated by their extent in the park, while the barren type (which includes much of the alpine) is substantially less sampled relative to its area. (Note that Jones and Stokes (2003) reported that lodgepole pine was relatively undersampled compared to its area in the parks, but their analysis only included the NRI, Gradient Analysis and Vegetation Mapping plot datasets.) Nonetheless, for the most part, these results suggest that sampling effort is not grossly skewed by vegetation type in the park and that patterns of richness are not wholly driven by sampling bias. Figure 7 shows the proportion of sampling types in each vegetation type.

The finding that meadows have disproportionately high special status plant richness is most likely not simply a function of relatively high sampling effort. Meadows are generally expected to have relatively high plant biodiversity (Ratliff 1982), thus additional sampling in meadows makes sense ecologically for many study purposes. So, while meadows are disproportionately sampled relative to their area in the park, they are likely appropriately sampled given their relatively high biodiversity.

*By elevation:* With regard to an analysis by elevation only, the number of rare and endemic taxa generally increases with elevation from 4,00 to 2,500 meters (1,312 to 8,202 feet), above which richness declines gradually with increasing elevation, and then drops precipitously above 3,500 meters (11,483 feet) (Fig. 10). This does not appear to be wholly a function of the area represented by a given elevation band in the parks, since richness reaches a maximum in the 2,000 to 2,500 meter (6,562 to 8,202 feet) band, while area by elevation is greatest between 3,000 to 3,500 meters (9,843 to 11,483 feet). The pattern also does not appear to reflect a function of sampling bias, since the area sampled within most bands roughly corresponds to the proportion of the area in the parks contained in those bands (Fig. 10; types of survey given in

Fig. 11). It does appear that the highest elevations are relatively under sampled, however, that the sparseness of sampling  quite likely corresponds to the sparseness of vegetation—a factor that likely explains the drop in the richness of special status plant species as well.

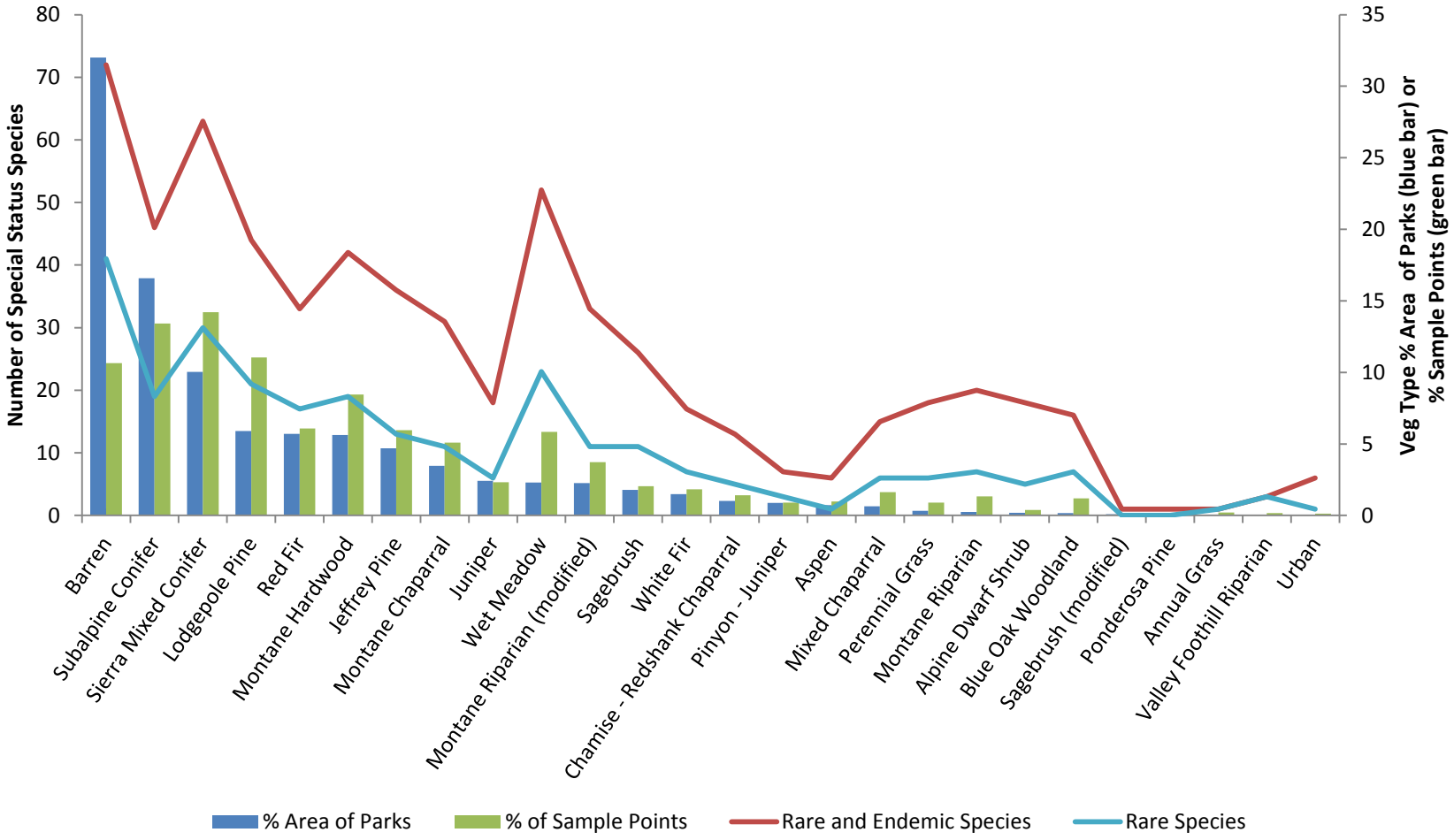


**Figure 8.** Number of special status plants by CWHR vegetation type.

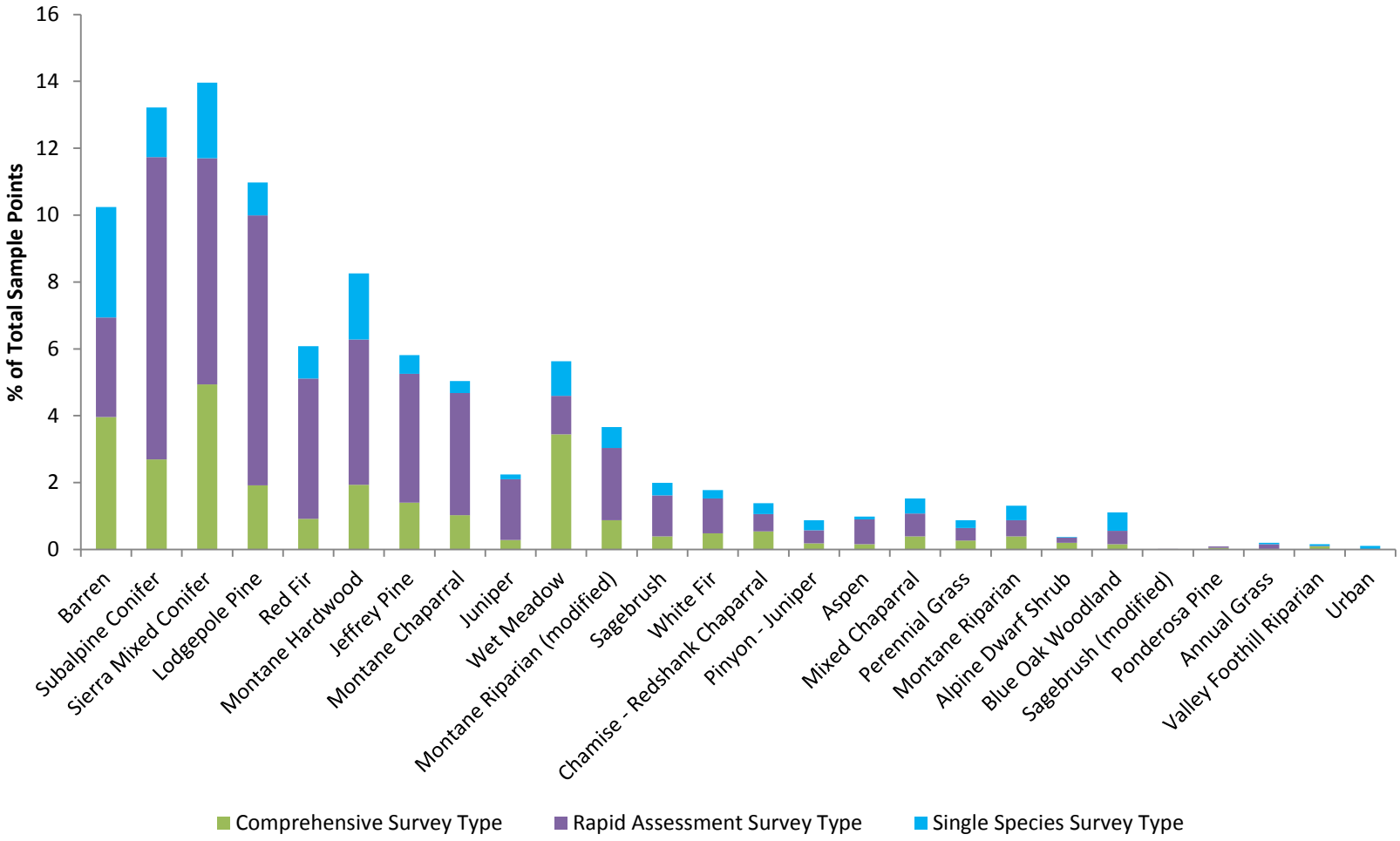


**Figure 9.** Proportion of survey types for all sample points by CWHR vegetation type.

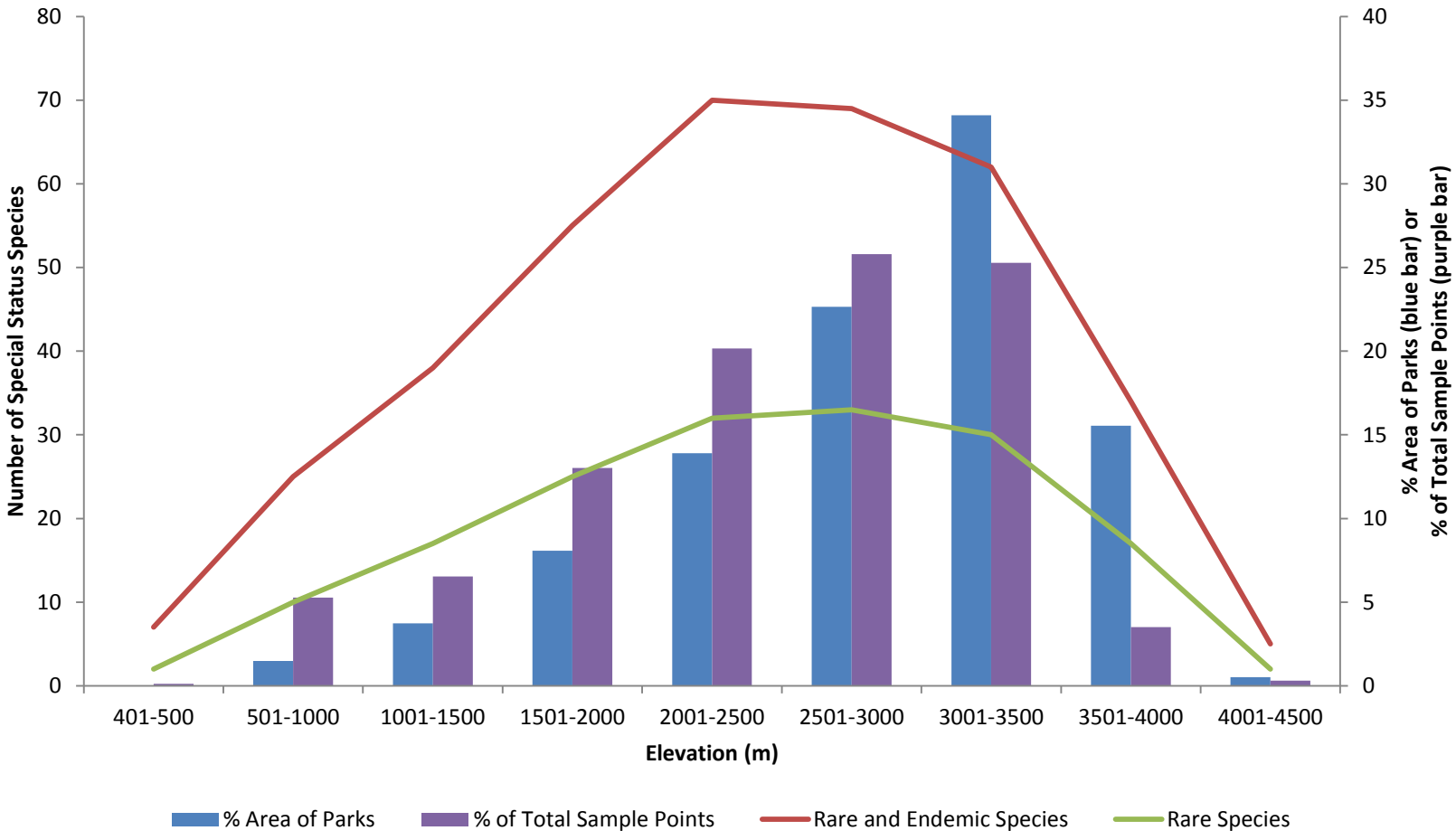


**Figure 10.** Number of special status plants by elevation.

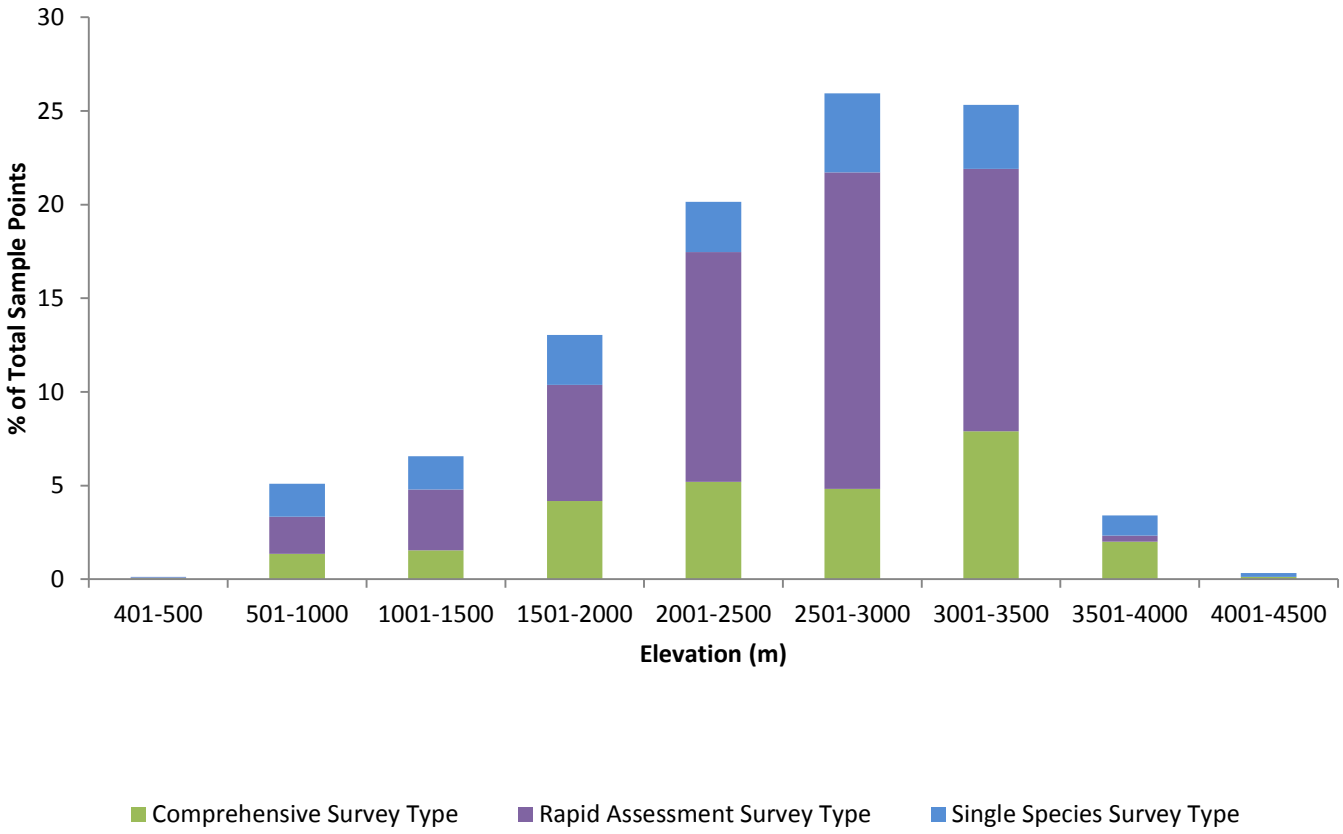


**Figure 11.** Proportion of survey types for all sample points by elevation.

## Condition analyses

### *Imperilment rankings and endemism*

Please see the Assessment section, "What are the special status plants known to occur in SEKI" on page 79 for a summary of imperilment and endemism assignments.

### *Temporal analysis: Trend assessment*

There are 12 special status herbaceous plant taxa for which spatial and population data are sufficient to allow a qualitative assessment of potential trends. This information is available from surveys conducted in the early 1980s (Norris and Brennan Surveys) and then again in 2003 and 2004 (I&M Special Status Plant Surveys). Please refer to Appendix E for information about species descriptions, survey methods, survey results and estimated change calculations.

Because of the limitations of the data, the summary of results provided here should be considered as a glimpse of potential trends rather than conclusive findings. Nearly all plant populations were only visited twice, so it is not possible to adequately quantify short or long-term trends for these species as we cannot take into account year-to-year variability (i.e., we cannot assess whether an apparent decline in population size is outside the normal year to year changes in populations sizes or whether it represents a consistent decline over time). In addition, winter and spring precipitation differed greatly between the two sampling periods. Typical year to year fluctuations for these species have not been described in the scientific literature, and relatively large differences in winter and spring weather conditions likely have a substantial influence on the size of herbaceous populations, irrespective of long-term trends. Differences in weather conditions may also affect the accuracy of the survey. For example, for *Oreonana purpurascens* (purple-mountain parsley) the resampling for some of its populations was not conducted at the same stage in phenology as the initial visit. These small plants are difficult to see during the later stage in phenology; after flowering the above-ground structures become dry and brittle and eventually disappear. The plants during the resample year flowered earlier in the year than the original visit, so although the revisit occurred during the same time of year, the plants were difficult to detect. The main goal in examining these data is to flag species or sites for which the data suggest that substantial declines may have occurred or are occurring, meriting high priority for monitoring. At the same time, given the limitations in the data, lack of an apparent decline does not convincingly demonstrate that a species population trend is stable in the parks.

Table 3 provides a summary of the overall change in the number of plants for populations that were resurveyed. Eight of the twelve species have populations that should be given priority for future monitoring (species with asterisks), either due to very small population sizes, substantial apparent decline in number of plants, or because surveyors noted that the population was possibly at significant risk due to trampling.

**Table 3.** Special status plant taxa surveyed by both the Norris and Brennan Surveys (early 1980s) and the I&M special status plant surveys (2003 to 2004). *One or more populations of this species are a high priority for monitoring. *NA*=data is inadequate to estimate change.

| Scientific Name | Lifeform | Common Name | CNPS List | Estimated Change in Population Size of Resurveyed Populations | Total number of plants estimated in Initial Survey |
|---|---|---|---|---|---|
| *Astragalus ravenii* | Perennial | Raven's milkvetch | 1B.3 | *NA* | "thousands" |
| *Carex tompkinsii* | Perennial | Tompkins' sedge | 4.3 | +706% | 96 |
| *Carlquistia muirii** | Perennial | Muir's raillardiopsis | 1B.3 | -54% | 1,153 |
| *Draba cruciata** | Perennial | Mineral King draba | 1B.3 | +11% | 2,190 |
| *Erigeron aequifolius** | Perennial | Hall's daisy | 1B.3 | -24% | 33 |
| *Erigeron nudum* var. *murinum** | Perennial | Mouse buckwheat | 1B.2 | -31% | 5,222 |
| *Erythronium pusaterii* | Perennial | Kaweah fawn lilly | 1B.3 | +50% | 20,000 |
| *Lupinus culbertsonii* ssp.. *culbertsonii* | Perennial | Hockett Meadows lupine | 1B.3 | *NA* | 5,000 |
| *Mimulus norrisii** | Annual | Kaweah monkey flower | 1B.3 | -64% | 5,450 |
| *Oreonana purpurascens** | Perennial | Purple mountain-parsley | 1B.3 | *NA* | *NA* |
| *Streptanthus fenestratus** | Annual | Tehipite Valley jewelflower | 1B.3 | *NA* | *NA* |
| *Streptanthus gracilis** | Annual | Alpine jewelflower | 1B.3 | +83% | 165 |

Table 3 notes: Change in population size is the percent change in the total number of plants for all resurveyed populations between surveys. For species with population estimates given as a range, estimated change was assessed using the midpoint of the range. Total number of estimated plants from initial surveys is shown to provide context for the percent change value.

While a useful reference, this summary could be misleading for a number of reasons, in addition to those already mentioned above. Overall changes may be driven by one or a few populations for a given species (e.g., one population may have changed substantially while most of the others did not). Population size is highly variable, making the percent changes not directly comparable. A substantial decline in one population for a given species might be masked by increases in another population (hence, some species are asterisked even though the overall change was positive). In short, this summary alone should not be relied upon for assessing the status of a given species.

### *Rarity in the parks*

As stated in the Data sources section, the number of occurrences for the 12 taxa that were surveyed by both the Norris and Brennan and I&M Special Status Plant Surveys were counted using the georeferenced location data for each species. We followed CNDDB's approach to define an occurrence as "any population or group of nearby populations located more than 0.25 miles [402 meters] from any other population" (CNDDB 2010a).

To obtain an estimate of relative rarity of herbaceous and shrub special status taxa in the parks, we counted the number of hexagons (42 hectares in area, 805 meters in diameter) in which they have been found. This also gives an estimate of area of occupancy for each species. We classify taxa found in three or fewer hexagons as potentially locally uncommon in the parks. These

calculations are qualified as “potential” and “estimates” because it is unknown whether the entire distribution for these taxa has been documented. These results are shown in Appendix F. We did not report special status tree area of occupancy, because their coverage in the parks is relatively widespread and are more accurately visualized by the maps shown in Figures 2b-d.

Note that we do not report the number of occurrences for any other species-- beyond the 12 taxa mentioned above-- because of the potentially substantial duplication among observation datasets (shown in Table 1, see Data sources section).

## Analysis uncertainty

We have identified the uncertainties in a given analysis within the corresponding section describing that analysis. For example, we have quantified distribution of sampling effort for all our spatial analyses and have provided breakdowns of sampling both by vegetation type and elevation band. For our trend analysis, we discussed the difficulties with attempting to quantify trends when given only two time periods and provide more detail regarding the uncertainties for each species in the trend analysis in Appendix E. Therefore, we refer the reader to the description of the particular analysis for a discussion of its uncertainty.

We do here provide some additional information about uncertainties in the updated special status plant list.

### Number of special status plant taxa

There are nine special status taxa for which there is some uncertainty about whether they actually occur in the parks and merit further investigation. Eight of these are listed by CNPS and the CNDDB, half of which are CNPS List 1B taxa that are ranked by the CNDDB as critically imperiled or imperiled in California. Seven of the nine have observations that were included in making the maps in the spatial analyses section, but the removal of these taxa would not noticeably change the results of these maps.

Two species are questionable because they have only been reported in the parks from historic records (*Jensia yosemitana*, collected in 1900 and *Eriogonum spergulinum* var. *pratense*, collected in 1897). The remaining seven are questionable due to uncertainties associated with their identification, either because the vouchered specimen of the special status taxon was later determined to be a different taxon but its evidence in the parks also includes observations from survey plots, or because SEKI is far beyond the taxon's described range as reported in The Jepson Manual 2nd edition (Baldwin et al. *in press*). The taxa that fall into the first category are: *Plagiobothrys torreyi* var. *torreyi*, *Allium tribractatum* (SEKI is also outside its described range), *Arabis bodiensis*, and *Silene occidentalis*. Taxa in the second category are: *Arabis microphylla* var. *microphylla* and *Carex geyeri*.

### Endemism assignments

Of the 102 Sierra Nevada endemics identified as occurring in the parks, 34 taxa are reported to have vouchered specimens that, if verified, would represent range extensions outside the Sierra Nevada. Of the 39 southern Sierra Nevada endemics in the parks, eight taxa are reported to have unverified specimens that are considered possible range extensions outside the southern Sierra Nevada (Baldwin et al. *in press*). We did not find evidence of occurrence (records of vouchered specimens in CCH) beyond eight kilometers of the parks for the nine locally endemic taxa.

## Interactions with other focal resources

Special status plants interact with the various other focal resources (foothills, meadows, Sequoia forests, alpine) in the sense that they form a part of and may be dependent upon the ecosystem in which they occur. For example, special status species that occur only in meadows are clearly dependent on the integrity of meadow ecosystems. The same is presumably true of other ecosystems, though interactions might not be straightforward depending on the particular properties of the given species. For example, an understory species that prefers shade would probably be adversely affected by the tree overstory mortality due to a virulent pathogen, but some shrub species might thrive when that same overstory is destroyed by fire. At best we can make the tentative assumption that these species are historically adapted to the ecosystem in which they occur and that proper management of that ecosystem would, overall, be beneficial to the special status species within them. Such an approach seems more feasible than attempting to manage for the particular properties of a given species, except perhaps in cases of severe endangerment.

Special status species also interact with biodiversity. Loss of special status plants would necessarily reduce biodiversity, and biodiversity management efforts might well focus on species that are most likely to be lost (i.e., special status species).

Interactions with the other focal resources topics (e.g., air quality, altered fire regimes) are described in the stressors section of this report.

## Stressors

### Air quality

The most substantial air quality risk to special status plants in the parks is high ozone concentrations, since areas within the parks regularly exceed state limits of acceptable ozone levels during the summer and a number of plant species have been shown to be sensitive to ozone damage. However, none of the species listed on the special status plant list have been found to be sensitive to ozone damage. In part, this may be due to lack of research. Therefore, monitoring for special status plants that occur in areas of high ozone concentrations should give at least some attention to seeking the typical signs of ozone damage.

### Land use/fragmentation

#### *Proximity to trails, roads and other infrastructure*

Many special status plant populations have been documented along roads, trails, and next to other infrastructure in the parks (buildings, campgrounds, weather stations, parking lots, etc.). Any population near a trail, road, or other infrastructure is potentially at risk from human-related use (trampling, collection, etc.) or from maintenance activities, such as trail or road work. The special status plant observation dataset that was used to make Figure 1 can be applied by SEKI managers in conjunction with planned trail, road and other management activities to avoid impacts to known locations of special status plants.

Interestingly, some special status species appear to thrive in these disturbed environments and in some cases the road or trail itself has created new colonization sites. Perhaps the most well known example is *Eriogonum nudum* var. *murinum* (mouse buckwheat). Plants growing in naturally or man-made disturbed areas, including on curbs along Generals Highway, were noted as thriving and appearing larger than those growing in less disturbed sites. Plants in one of two known populations of *Hulsea brevifolia* (short-leaved hulsea) in the parks appeared to be thriving on the shoulder of Generals Highway near Dorst Campground. *Carlquistia muirii* (Muir's raillardella) colonized a rock cut created by trail construction (the eastern High Sierra Trail population) (Haultain et al. 2004). Norris and Brennan (1982) noted that *Streptanthus fenestratus* (Tehipite Valley jewelflower) invades disturbed sandy soils and was found colonizing trailbeds. Their report stated that trampling did not constitute a threat to this annual species.

Even with species that appear to thrive in disturbed sites, it is of course still important that special status populations in close proximity to roads and along heavily trafficked trails are monitored and that trail and road crews are aware of these populations to avoid any management-related impact. Disturbance might well open up habitat opportunities for some species, but that same type of disturbance can damage existing populations.

Norris and Brennan (Norris and Brennan 1982, Norris 1984) and the I&M special status plant surveys (2003) documented special status populations that they found near infrastructure (usually trails or roads) and also noted if there was any associated evidence of damage or threat of damage to plants (usually trampling from hikers).

Specific populations noted in those reports as being potentially at risk include:

- *Carex tompkinsii*. The Lower Hotel Creek sub-population may have been impacted by trails cutting switchbacks through the population. In general, the Hotel Creek, Lewis Creek and Copper Creek populations are all located near heavily used trails.
- *Carlquistia muirii*. Three populations along the High Sierra trail were listed as potentially at risk from trampling by hikers or trail maintenance.
- *Dicentra nevadensis.* Middle Fork Buck Creek population was listed as significantly trampled by hikers in the Norris and Brennan 1982 report (not surveyed in 2003-2004).
- *Eriogonum nudum* var. *murinum*. Populations growing along Generals Highway near Ash Mountain Visitor Center are potentially at risk from road maintenance.
- *Hulsea brevifolia*. Population growing along Generals Highway near Dorst Campground are potentially at risk from road maintenance.
- *Iris munzii*. Populations growing in the Ash Mountain Administrative Pasture are potentially at risk from mule traffic.
- *Oreonana purpurascens*. Significant impact of trail cuts and trampled plants were observed at South Fork Crossing at Hockett Plateau, especially along the stream bank. There is also potential impact of trampling of population near snow survey station at Hockett Meadow.
- *Petrophyton caespitosum* ssp. *acuminatum.* The South Wall population is potentially at risk from the establishment of climbing routes.
- *Ribes tularense*. Crystal Cave Road populations potentially threatened by heavy dust accumulation from road sweeping (Norris and Brennan 1982, not surveyed in 2003-2004).

We could find only one recorded instance of a special status plant population that may have disappeared due to its proximity to a road. The I&M special status plant surveys were unable to relocate a small population of *Eriogonum nudum* var. *murinum* that Norris and Brennan had recorded as growing in the roadside gutter directly across from Ash Mountain Visitor Center. Norris and Brennan had noted that the plants' roots were exposed from erosion. The cause of their disappearance from this site is not known.

### *Stock use in meadows*

There are potentially 132 meadows in the parks that contain special status plants. Of these, 41 meadows are open to grazing and have had at least some recorded use by stock (Table 4, Figure 12). Forty-five special status plant taxa have been documented in meadows (Table 5).

The definition of 'meadow' in this analysis is vegetation characterized as such in the SEKI meadow layer (22; see also the SEKI NRCA Meadow Chapter). These include a range of wet to dry meadows, including *Carex filifolia* (shorthair sedge) dominated meadows that occur on dry uplands. The numbers of meadows in Table 4 are counts of meadow identification numbers (MID). Each MID represents a meadow that is distinctly mapped in the SEKI meadow layer; not all are hydrologically disconnected. These counts would be greatly reduced if observations were counted by meadow name or meadow complex; however, not all meadows are named nor grouped by complex.

Counts of meadows with special status plants were obtained by plotting special status observations from all data sources (Table 1) on the SEKI meadow layer. Specimen observations with a reported distance error of more than 100 meters were not included, as these distance errors introduce substantial uncertainty as to whether a given specimen was actually collected in a meadow. Upland species observations were individually researched to determine our confidence that the plot or specimen associated with the observation was actually located in a meadow. Meadows with only upland special status species were included when there was some evidence that the observation was made in a meadow (i.e., plot data or specimen locality information).

The Paired Meadow Species Composition data, part of the SEKI Meadow Monitoring Program, is the only data available that has repeated measurements of plants in grazed and ungrazed reference meadows in SEKI. Four special status species have been recorded in the Paired Meadow Species Composition dataset: *Ivesia campestris* (field ivesia), *Ivesia lycopodioides* ssp. *megalopetala* (club-moss ivesia), *Luzula orestera* (mountain woodrush), and *Ptilagrostis kingii* (King's ricegrass). Of these, only *Luzula orestera* (mountain woodrush) and *Ivesia lycopodioides* ssp. *megalopetala* (club-moss ivesia) appear with any consistency.

We do not here attempt to analyze the effect of grazing on these species using the Paired Meadow Species Composition data (see SEKI NRCA Meadows chapter for details). Nonetheless, there is certainly utility in these data for assessing year to year variability in population size of these few special status species. In particular, they could be used to inform the sampling design of a potential special status plant monitoring program (i.e., they could inform power analyses to determine necessary sampling effort for these species).

**Table 4.** Number of meadows with special status plant observations according to spatial data.

| Meadow Stock Use Regulation Status | Number of Meadows |
|---|---|
| Closed to all stock use | 35 |
| Open to grazing and grazed by stock | 41 |
| Open to grazing yet ungrazed by stock | 56 |
| *total* | 132 |

**Table 5.** Special status plant species found in meadows according to spatial data.

| Scientific Name (Common Name) | CNPS Ranking | In Meadows Open to Stock yet Ungrazed | In Meadows Open to Stock and Grazed |
|---|---|---|---|
| *Arabis pygmaea* (Tulare County rock cress) | 4.3 | Yes | |
| *Astragalus ravenii* (Raven's milkvetch) | 1B.3 | | Yes |
| *Botrychium minganense* (Mingan moonwort) | 2.2 | | |
| *Bruchia bolanderi* (Bolander's bruchia) | -- | | |
| *Calamagrostis muiriana* (no common name) | -- | | Yes |
| *Calochortus minimus* (lesser star tulip) | -- | | Yes |
| *Carex congdonii* (Congdon's sedge) | 4.3 | | |
| *Claytonia palustris* (marsh claytonia) | 4.3 | | Yes |
| *Delphinium gracilentum* (slender larkspur) | -- | | |
| *Dicentra nevadensis* (Tulare County bleeding heart) | 4.3 | | Yes |
| *Draba lemmonii* (Lemmon's draba) | -- | | Yes |
| *Draba sharsmithii* (Mount Whitney draba) | 1B.3 | Yes | |
| *Epilobium oreganum* (Oregon fireweed) | 1B.2 | | Yes |
| *Eriogonum nudum* var. *scapigerum* (tibinagua) | -- | Yes | |
| *Frasera tubulosa* (Kern swertia) | -- | | Yes |
| *Helodium blandowii* (Blandow's bog moss) | -- | Yes | |
| *Ivesia campestris* (field ivesia) | 1B.2 | Yes | Yes |
| *Ivesia lycopodioides* ssp. *megalopetala* (club-moss ivesia) | -- | Yes | Yes |
| *Ivesia muirii* (Muir's ivesia) | -- | Yes | |
| *Ivesia pygmaea* (dwarf ivesia) | -- | Yes | Yes |
| *Lilium kelleyanum* (Kelley's lily) | -- | | Yes |
| *Lilium parvum* (alpine lily) | -- | | Yes |
| *Linanthus oblanceolatus* (Sierra Nevada linanthus) | 4.3 | Yes | |
| *Lomatium torreyi* (Torrey's lomatium) | -- | | |
| *Lupinus covillei* (Covill's lupine) | -- | | Yes |
| *Lupinus culbersonii* ssp. *culbertsonii* (Hockett Meadows lupine) | 1B.3 | Yes | |
| *Luzula orestera* (mountain woodrush) | -- | Yes | Yes |
| *Mimulus whitneyi* (varicolored monkeyflower) | -- | | Yes |
| *Oreonana clementis* (Clement's mountain parsley) | -- | Yes | Yes |
| *Oreonana purpurascens* (purple mountain-parsley) | 1B.2 | Yes | |
| *Oreostemma peirsonii* (Peirson's aster) | -- | Yes | |
| *Penstemon heterodoxus* var. *cephalophorus* (Sierra beard-tongue) | -- | Yes | Yes |
| *Phacelia eisenii* (Eisin's phacelia) | | | Yes |
| *Phalacroseris bolanderi* (Bolander's dandelion) | -- | | Yes |
| *Pinus balfouriana* ssp. *austrina* (foxtail pine) | -- | Yes | Yes |
| *Poa stebbinsii* (Stebbin's bluegrass) | -- | Yes | Yes |
| *Podagrostis humilis* (mountain bent grass) | 2.3 | Yes | Yes |
| *Potentilla grayi* (Gray's cinquefoil) | -- | Yes | |
| *Ptilagrostis kingii* (King's ricegrass) | -- | Yes | Yes |
| *Senecio clarkianus* (Clark's ragwort) | -- | | Yes |
| *Sidalcea ranunculacea* (marsh checkerbloom) | -- | Yes | Yes |
| *Sidalcea reptans* (creeping checker) | -- | | Yes |
| *Streptanthus gracilis* (alpine jewelflower) | 1B.3 | Yes | |
| *Trichophorum clementis* (Yosemite bulrush) | -- | Yes | Yes |
| *Triglochin palustre* (marsh arrow-grass) | 2.3 | Yes | |

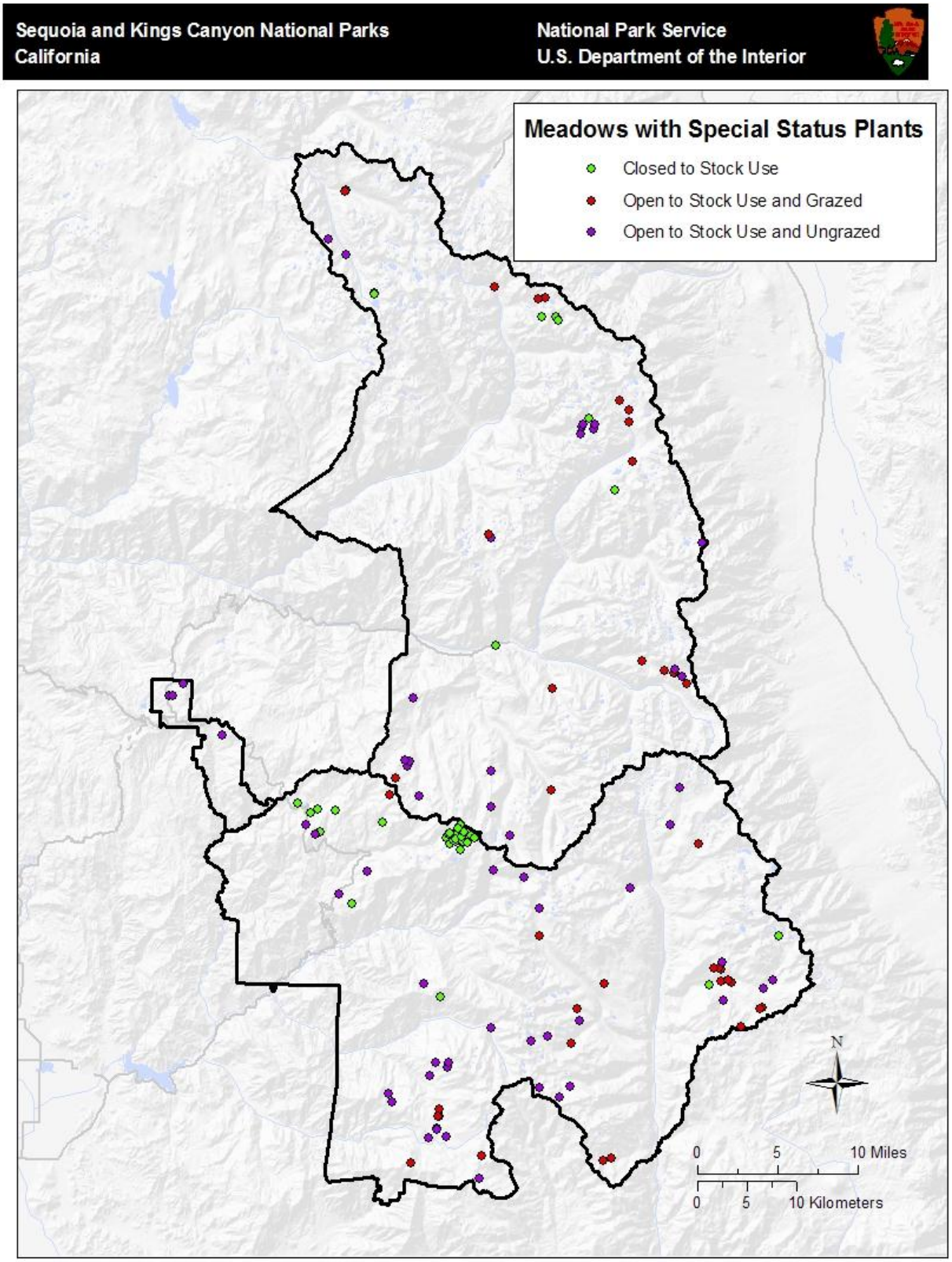


**Fig. 12.** Map of regulatory status of meadows with special status plant populations.

## Climate change

Due to its pervasive nature, climate change will almost certainly have an impact on special status plants in Sequoia and Kings Canyon National Parks. Some of those effects may well already be occurring. Over the past century, temperatures have increased, temperature extremes have changed, snow pack has been reduced in many areas and snowmelt has been occurring earlier (Cayan et al. 2009). Projections of future climate suggest a continuation of these trends, with California generally becoming hotter and drier (Moser et al. 2009).

One would expect these climatic alterations to result in changes in the locations of ideal habitat for plant species. Such changes in ideal habitat could result in increased mortality in current habitats, and, due to a variety of factors (e.g., dispersal limitations, lack of suitable microhabitat, competition from existing species), dispersal to newer habitats might be hampered. It is also possible that due to particular traits and circumstances, a given species might thrive in a changing climate.

Of those species that may suffer deleterious effects, special status plants are likely to be particularly susceptible due to their already vulnerable condition. Accurately predicting the effects of climate change upon specific species or for special status plants as a whole is difficult at the current time due to a variety of uncertainties, both in climate change projections and in the specific habitat requirements for a given plant. The task is further hampered by potential interactions with herbivores, pollinators, competitors, facilitators, soil conditions and microhabitats. The non-profit organization NatureServe has developed a Climate Change Vulnerability Index tool (NatureServe 2010) to try to predict whether a species will suffer a range contraction or population reduction in response to climate change. The index is based on species' dispersal abilities, sensitivity to temperature and moisture changes, hydrology regimes, reaction to disturbance, interspecific interactions such as with pollinators, and genetic variation. Information at this detailed level is simply not available for the majority of plant species in California, particularly those that have narrow distributions.

Here, we present a general overview of the potential risks to SEKI special status plants in a changing climate and we identify species on the list that are particularly vulnerable. Lists of species by vulnerability group are placed at the end of the climate change section.

### *Direct effects*

Changes in habitat**:** Species that are most likely to suffer from changing climatic conditions in the places where they occur are those with narrow habitat restrictions, including moisture regime, narrow elevation range, uncommon or vulnerable vegetation types, and uncommon rock type or substrate specificity. Because of Sequoia and Kings Canyon National Parks location near the southern end of a major California bioregion (Sierra Nevada) (Hickman 1993), many species reach the extent of their geographic range in or near the parks (within 8 kilometers).

*Soil moisture regime:* A list of species that are most likely to be sensitive to changes in soil moisture regime are given at the end of this section. They occur in habitats associated with stream banks, wet meadows, marshes, bogs, or other moist areas. While specific numbers are not known, climate change will almost certainly affect the water cycle on the western slope of the Sierra Nevada. In the past century we have already seen some of these changes: more precipitation is falling as rain and less as snow, and snowmelt is occurring earlier in spring,

leading to earlier dates of low stream flow conditions. While lower elevation areas are receiving less snow, some southern Sierra high elevation areas have had an increase in snow pack, however spring snowmelt is occurring at an earlier date, so summer water shortages will still occur (Moser et al. 2009).

*Alpine environments:* Loarie et al. (2008) tested multiple climate change scenario models and found that plants are likely to move up in elevation and north in latitude. In particular, this will be a problem for plants restricted to high elevations, as they will be pushed out of their current climate zone. Lenihan et al. (2008) used dynamic global vegetation modeling to show that high elevation areas will have longer and warmer growing seasons, leading to replacement of alpine and subalpine vegetation by other vegetation types. A list of special status plants we have defined as alpine are given at the end of this section. These species are found above 3,000 m (approximate timberline), but not below 2,500 m (elevations based on those given in Baldwin et al. *in press*), or have been documented as occurring primarily in alpine habitats in SEKI. Plants with distributions large enough to range below 2,500 m were considered generalists and are probably not restricted to alpine habitats. We also removed plants whose descriptions listed coniferous forest as their only habitat and those that are known to also occur in upper montane areas in SEKI or other places.

*Oak woodlands:* Vegetation change models predict that California's "mixed evergreen woodlands" (consisting mainly of oak woodland) will undergo a major shift in distribution to the north and a decrease in percent cover, where some of the current distribution will be replaced by grassland (Lenihan et al. 2008). The blue oak woodland belt in California faces a major decline, with statewide habitat for this species modeled to shrink to between 59% and 81% of its current range (Kueppers et al. 2005). In this study, blue oak ranges were also found to move northward, and are predicted to become largely absent from the southernmost Sierra foothills, including the region of Sequoia and Kings Canyon National Parks. Because of this drastic decline, special status plants occurring in oak woodland habitats in the southern Sierra may be especially vulnerable. A list of special status plants that occur in oak woodlands are given at the end of this section. Those with an asterisk denote plants restricted primarily to blue oak woodland. The list is based on a combination of elevation range and habitat descriptions from The Jepson Manual 2$^{nd}$ edition (Baldwin et al. *in press*), A Sierra Nevada Flora (Weeden 1996), A Kern County Flora (Twisselmann 1967), and unpublished NPS plot data. The Jepson Manual 2$^{nd}$ edition data were provided by Richard Moe, Manager of Collections Data at The University and Jepson Herbaria, University of California, Berkeley.

*Substrate specificity:* Plants restricted to a specific soil type face a high risk from climate change because their narrow ranges limit their possibilities to adapt through migration (Harrison et al. 2009). Most of the current research is focused on serpentine-adapted plants, but the same limitations apply to other edaphically-restricted species as well. Three species of special status plants are associated with marble and limestone derived soils: *Eriogonum nudum* var. *murinum* (mouse buckwheat), *Mimulus norrisii* (Kaweah monkeyflower), and *Petrophyton acuminatum* (marble rockmat). Although *Streptanthus fenestratus* (Tehipite Valley jewelflower) is also found on granitic soils, York (2001) found that the rare species thrives on limestone outcrops. In combination with a very narrow geographic range ((endemic to the Kings River canyon between 1,050–1,800 m (Baldwin et al. *in press*)), a change in climate could disproportionately impact

this species, which may not be adapted to compete as well on common soil types. As climate changes these species, especially those that are restricted to uncommon soil types, may not survive migration to new habitats if they require the nutrients specific to this soil type (in this case, high calcium) or are limited to these soil types for another reason (e.g., they are relatively poor competitors). They will also likely be poor competitors with other species that are adapted to living in a wider range of soil types.

*Plants at the edge of their geographic range (peripheral taxa):* Sequoia and Kings Canyon National Parks lie near the southern end of a major California bioregion, the Sierra Nevada mountain range. South of Sequoia National Park the rugged peaks of the crest make a dramatic transition to the weathered terrain of the Kern Plateau. Because of this geographic location, there are many species that reach the periphery of their range within the park, particularly their southern and eastern range extents. As plants are predicted to migrate north to follow shifts in temperature and precipitation, the biodiversity of the parks might experience a net decrease because so many plants reach the edge of their range within the parks. Peripheral populations may also be better adapted to extreme environments and have the genetic capability of adapting to changes in climate (Hardie & Hutchings 2010). A list of all the taxa that reach the north, south, east or west limits of their range within Sequoia and Kings Canyon National Parks or within eight kilometers of the parks is given at the end of this section.

Seed dispersal and germination: Seed dispersal is a necessary agent in a plant's ability to expand into new environments. This will be especially important as climate changes and plant populations must migrate to places with more favorable climatic conditions. Most studies looking at the ability of plants to migrate under changing climate conditions use simplified models that include only the two migration extremes: no dispersal and unlimited dispersal (Midgley et al. 2007). In reality, dispersal will occur somewhere between these two extremes. A lack of species and genus-level information about the dispersal methods of plants makes it difficult to predict how an individual species will react to climate change (Thuiller et al. 2008). However, even those species that are thought to be poor long-distance dispersers (those with seeds that are dispersed by ants or gravity) are often found attached to animal feathers or fur, which serves as an effective way to transport them long distances (Higgins et al. 2003). Some seeds also require specific processes to germinate once they have been dispersed, such as fire, scarification, stratification, or long periods spent in water. All of these factors are likely to be affected by climate change and plants with less specific requirements will probably be more likely to succeed in new environments.

Little is known about the dispersal agents of the special status plants at SEKI. Information that does exist is at a genus level and may not specifically apply to the special status species. Keeley (1991) found that while *Ceanothus* has seeds that are ejected from their capsules and *Arctostaphylos* fruits are often eaten by mammals, in both cases their seeds are not dispersed very far from where they originate. Many herbaceous plants with small seeds are wind dispersed, but most seeds do not contain any special structures that allow them to be carried very far, and are dispersed only locally.

Competition: Although there are no competition studies specifically looking at SEKI special status plant species, a study by Levine et al. (2010) on the Channel Islands of California found

that native and nonnative annual species (example: *Gilia* and *Bromus*) often reacted similarly to changes in precipitation, such that competition between the species did not change. However, they also found that different species were highly variable in terms of whether total precipitation influenced population size and whether the exact timing of drought and precipitation events influenced population size. There are currently not enough data on SEKI special status plants to predict whether competition will cause changes to population sizes under various climate change scenarios.

#### *Indirect effects*

Changes in fire regime: Future climate change models predict more frequent and intense fires and a longer fire season as a result of warming temperatures (California Natural Resources Agency 2009). Using three different models of climate change, Lenihan et al. (2008) predicts that total annual area burned in California will increase 9% to 15% by 2100, with some areas (including the southern Sierra foothills) up to 50% more than current levels. While some type of fire-adapted plants may thrive under these conditions, it will undoubtedly be detrimental to others. See Altered fire regimes section for more information.

Insect herbivory: While the specific effects of herbivores to plants of Sequoia and Kings Canyon are unknown, there are several scenarios that may lead to increased damage from insect populations. As climate warms, insects will have the ability to move to new environments faster than their host plants. In one study looking at butterfly larvae that feed on oak trees in Northern California and Oregon, the authors hypothesized that the butterflies will likely move north in advance of the oak trees and choose to feed on species of oak trees less suited to their adaptations to the chemical defenses in the oak leaves, reducing the fitness of the herbivore (Pelini et al. 2010). In this example, herbivores shift from one species to another, interrupting the current herbivore-host interactions. Other studies focus on herbivores whose populations are usually kept in check by winter cold-induced mortality. As global temperatures rise, bark beetle (Coleoptera: Curculionidae, Scolytinae) outbreaks are already increasing across the western United States due to a decrease in cold-induced mortality as well as host-tree stands that are more homogenous with regard to age and species, making it easier for bark beetles to spread rapidly (Bentz et al. 2010). Research done on crop pests shows that an increase in temperature allows for range expansions of current pests, an increase in the arrival of new species of pests, and current species to increase their population levels (Trumble and Casey 2009).

Pollination: Cross pollination plays a vital role in the genetic variation in plants. Pollination syndromes range widely across the SEKI special status plants. Some species such as pines, firs, grass, and sedges rely on wind pollination and will be less affected, while most others on the list rely on insect pollination. In the latter case, not only must a plant be able to cope with changes in its own habitat, but its pollinator must also continue to have a sustainable food source and habitat and must migrate together with the plant. This is especially important for plants with very specific plant-pollinator interactions.

#### *Conclusions and future research needs*

In order to make decisions about the best way to protect special status plants, we require more information about their habitat requirements, confidence that their distributions are known, moisture and temperature requirements, interactions with pollinators, dispersal abilities and the effects of increased fires. Until we know more about the complex biology of these plants, we can

only speculate how they might be affected using climate change models. Furthermore, these models are often very general and the projection scenarios may not accurately portray changes to the microhabitats of these plants.

Hydrologically-influenced species (42 taxa): These species contained habitat descriptions that included words such as: stream bank, wet meadow, marsh, bog, or moist area or have been documented in wetland habitats in SEKI. Habitat descriptions came from The Jepson Manual 2nd edition (Baldwin et al. *in press*), A Sierra Nevada Flora (Weeden 1996), and A Kern County Flora (Twisselmann 1967). The list of hydrologically-influenced species is below:

*Angelica callii* (Call's angelica)
*Botrychium minganense* (Mingan moonwort)
*Carex praticola* (meadow sedge)
*Cinna bolanderi* (Bolander's woodreed)
*Claytonia palustris* (marsh claytonia)
*Claytonia parviflora* ssp. *grandiflora* (streambank springbeauty)
*Cryptantha glomeriflora* (Truckee cryptantha)
*Delphinium gracilentum* (slender larkspur)
*Dicentra nevadensis* (Tulare County bleeding heart)
*Dodecatheon subalpinum* (subalpine shooting star)
*Draba monoensis* (White Mountains draba)
*Draba sharsmithii* (Mount Whitney draba)
*Epilobium oreganum* (Oregon fireweed)
*Erigeron multiceps* (Kern River daisy)
*Eryngium spinosepalum* (spiny-sepaled button-celery)
*Hosackia oblongifolia* var. *cuprea* (copper-flowered bird's foot trefoil)
*Iris munzii* (Munz's iris)
*Ivesia lycopodioides* ssp. *megalopetala* (club-moss ivesia)
*Jensia yosemitana* (Yosemite tarweed)
*Juncus hemiendytus* var. *abjectus* (Center Basin rush)
*Lilium kelleyanum* (Kelley's lily)
*Lilium parvum* (alpine lily)
*Limnanthes montana* (mountain meadowfoam)
*Lupinus covillei* (Covill's lupine)
*Luzula orestera* (mountain woodrush)
*Mimulus inconspicuus* (small-flowered monkeyflower)
*Mimulus laciniatus* (cut-leaved monkeyflower)
*Mimulus whitneyi* (varicolored monkeyflower)
*Minuartia stricta* (bog stitchwort)
*Packera indecora* (rayless mountain butterweed)
*Penstemon heterodoxus* var. *cephalophorus* (Sierra beard-tongue)
*Phalacroseris bolanderi* (Bolander's dandelion)
*Potentilla grayi* (Gray's cinquefoil)
*Ptilagrostis kingii* (King's ricegrass)
*Ranunculus hystriculus* (waterfall buttercup)
*Senecio clarkianus* (Clark's ragwort)
*Sequoiadendron giganteum* (giant sequoia)

*Sidalcea ranunculacea* (marsh checkerbloom)
*Sidalcea reptans* (creeping checker)
*Trichophorum clementis* (Yosemite bulrush)
*Triglochin palustre* (marsh arrow-grass)
*Utricularia intermedia* (flat-leaved bladderwort)

Alpine plant species (32 taxa): These species occur above 10,000 feet, but are not found below 8,000 feet (based on elevation ranges given in The Jepson Manual 2nd edition (Baldwin et al. *in press*)) or have been documented as occurring primarily in alpine habitats in SEKI. Alpine plants are shown below:

*Antennaria pulchella* (beautiful pussy-toes)
*Aquilegia pubescens* (Sierra columbine)
*Arabis bodiensis* (Bodie Hills rock cress)
*Arabis microphylla* var. *microphylla* (small-leaved rock cress)
*Astragalus kentrophyta* var. *danaus* (Sweetwater Mountains milkvetch)
*Astragalus ravenii* (Raven's milkvetch)
*Calamagrostis muiriana* (Muir's reed grass)
*Carex congdonii* (Congdon's sedge)
*Carex incurviformis* (coastal sand sedge)
*Carex tahoensis* (Tahoe sedge)
*Draba cruciata* (Mineral King draba)
*Draba lemmonii* (Lemmon's draba)
*Draba monoensis* (White Mountains draba)
*Draba praealta* (tall draba)
*Draba sharsmithii* (Mount Whitney draba)
*Elymus scribneri* (Scribner's wheatgrass)
*Eriogonum nudum* var. *scapigerum* (tibinagua)
*Eriogonum spergulinum* var. *pratense* (spurry buckwheat)
*Galium hypotrichium* ssp. *subalpinum* (alpine bedstraw)
*Hackelia sharsmithii* (Sharsmith's stickseed)
*Ivesia muirii* (Muir's ivesia)
*Ivesia pygmaea* (dwarf ivesia)
*Luzula orestera* (mountain woodrush)
*Minuartia stricta* (bog stitchwort)
*Oreostemma peirsonii* (Peirson's aster)
*Oxytropis parryi* (Parry's oxytrope)
*Phlox dispersa* (High Sierra phlox)
*Poa lettermanii* (Letterman's bluegrass)
*Poa stebbinsii* (Stebbin's bluegrass)
*Polemonium eximium* (sky pilot)
*Streptanthus gracilis* (alpine jewelflower)
*Tonestus peirsonii* (Peirson's serpentweed)

Species found in oak woodlands (15 taxa): Denotes plants restricted primarily to blue oak woodland. These were chosen based on a combination of elevation range and habitat descriptions from The Jepson Manual 2nd edition (Baldwin et al. *in press*), A Sierra Nevada Flora (Weeden

1996), and A Flora of Kern County (Twisselmann 1967) and includes those species that have been documented as occurring in oak woodlands in SEKI. These taxa are as follows:

*Astragalus congdonii* (Congdon's rattleweed)
*Calochortus amoenus* (rosy fairy lantern)
*Eriogonum nudum* var. *murinum* (mouse buckwheat)
*Eryngium spinosepalum* (spiny-sepaled button-celery)*
*Iris munzii* (Munz's iris)
*Linanthus montanus* (mustang clover)*
*Mimulus inconspicuus* (small-flowered monkeyflower)
*Mimulus norrisii* (Kaweah monkeyflower)
*Phacelia cicutaria* var. *cicutaria* (caterpillar phacelia)*
*Pityopus californicus* (California pinefoot)
*Ribes menziesii* var. *ixoderme* (canyon gooseberry)
*Streptanthus diversifolius* (varied-leaved jewelflower)
*Streptanthus farnsworthianus* (Farnsworth's jewelflower)*
*Streptanthus fenestratus* (Tehipite Valley jewelflower)

Special status taxa that reach the edge of their geographic range in SEKI (peripheral species): Each taxon was classified as to whether or not it reached its north, south, east, or west range limits in Sequoia and Kings Canyon National Parks using a combination of data from the California Natural Diversity Database (CNDDB) range maps, The Jepson Manual bioregions, California Consortium of Herbaria (CCH) specimen records, SEKI herbarium specimen records, and the SEKI Vascular Plant Checklist. Following the lists are notes on the extents of each species, including citations to herbarium specimens for each extent. A plant was considered to be at the extent of its range within the parks if the extent was within eight kilometers of the border of the parks. North, south, east, and west extents are based solely on longitude and latitude of the collection location. If a taxon reaches its eastern (or other) extent in California, but also occurs farther east in another state, this is denoted by an asterisk on the list and explained in the notes for that species.

*Taxa that reach the northern limit of their range within the parks (30):*

*Agnorhiza invenusta* (mule-ears)
*Angelica callii* (Call's angelica)
*Arabis pygmaea* (Tulare County rock cress)
*Dicentra nevadensis* (Tulare County bleeding heart)
*Draba cruciata* (Mineral King draba)
*Erigeron aequifolius* (Hall's daisy) (reaches northern limit at Boyden Cave which is within 8 kilometers of Kings Canyon National Park border)
*Erigeron inornatus* var. *keilii* (Keil's erigeron)
*Erigeron multiceps* (Kern River daisy)
*Eriogonum nudum* var. *murinum* (mouse buckwheat)
*Eriogonum polypodum* (Tulare County buckwheat)
*Eriogonum spergulinum* var. *pratense* (spurry buckwheat)
*Eriophyllum lanatum* var. *obovatum* (woolly sunflower)
*Erythronium pusaterii* (Kaweah Lakes fawn lily)
*Frasera tubulosa* (Kern swertia)

*Fritillaria pinetorum* (pinewoods fritillary)
*Hackelia sharsmithii* (Sharsmith's stickseed)
*Iris munzii* (Munz's iris)
*Ivesia campestris* (field ivesia)
*Ivesia pygmaea* (dwarf ivesia)
*Mimulus norrisii* (Kaweah monkeyflower)
*Oreonana purpurascens* (purple mountain-parsley)
*Orochaenactis thysanocarpha* (California mountainpincushion)
*Petrophyton acuminatum* (marble rockmat) (reaches northern limit at Boyden Cave which is within 8 kilometers of Kings Canyon National Park border)
*Phacelia orogenes* (mountain phacelia)
*Phlox dispersa* (High Sierra phlox)
*Pinus balfouriana* ssp. *austrina* (foxtail pine)
*Ribes tularense* (Sequoia gooseberry)
*Sidalcea ranunculacea* (marsh checkerbloom)
*Silene aperta* (naked campion)
*Streptanthus fenestratus* (Tehipite Valley jewelflower)

*Taxa that reach the southern limit of their range within the parks (58):*
*Allium tribracteatum* (three-bracted onion)
*Antennaria pulchella* (beautiful pussy-toes)*
*Arabis bodiensis* (Bodie Hills rock cress)*
*Arabis microphylla* var. *microphylla* (small-leaved rock cress)
*Asplenium septentrionale* (northern spleenwort)
*Astragalus kentrophyta* var. *danaus* (Sweetwater Mountains milkvetch)
*Astragalus ravenii* (Raven's milkvetch)
*Calamagrostis muiriana* (Muir’s reed grass)
*Carex congdonii* (Congdon's sedge)
*Carex geyeri* (Geyer's or elk sedge)*
*Carex incurviformis* (coastal sand sedge)*
*Carex praticola* (meadow sedge)
*Carex tahoensis* (Tahoe sedge)
*Carex tompkinsii* (Tomkins' sedge)
*Cinna bolanderi* (Bolander's woodreed)
*Dicentra nevadensis* (Tulare County bleeding heart)
*Dodecatheon subalpinum* (subalpine shooting star)
*Draba lemmonii* (Lemmon's draba)
*Draba monoensis* (White Mountains draba)
*Draba praealta* (tall draba)
*Elymus scribneri* (Scribner's wheatgrass)
*Epilobium oreganum* (Oregon fireweed)
*Erigeron elmeri* (Elmer's daisy)
*Erigeron inornatus* var. *keilii* (Keil's erigeron)
*Eriogonum nudum* var. *murinum* (mouse buckwheat)
*Eriogonum nudum* var. *scapigerum* (tibinagua)
*Eriogonum prattenianum* var. *avium* (kettle dome buckwheat)

*Fritillaria micrantha* (brown bells)
*Galium sparsiflorum* ssp. *sparsiflorum* (Sequoia bedstraw)
*Hackelia sharsmithii* (Sharsmith's stickseed)
*Hulsea brevifolia* (short-leaved hulsea)
*Ivesia muirii* (Muir's ivesia)
*Juncus hemiendytus* var. *abjectus* (Center Basin rush)*
*Lilium parvum* (alpine lily)
*Lupinus covillei* (Covill's lupine)
*Lupinus culbertsonii* ssp. *culbertsonii* (Hockett Meadows lupine)
*Lupinus fulcratus* (greenstipule lupine)
*Luzula orestera* (mountain woodrush)*
*Mentzelia crocea* (Sierra blazingstar)
*Mimulus laciniatus* (cut-leaved monkeyflower)
*Mimulus norrisii* (Kaweah monkeyflower)
*Minuartia stricta* (bog stitchwort)
*Oreostemma peirsonii* (Peirson's aster)
*Packera indecora* (rayless mountain butterweed)
*Petrophyton acuminatum* (marble rockmat)
*Phalacroseris bolanderi* (Bolander's dandelion)
*Poa lettermanii* (Letterman's bluegrass)
*Poa stebbinsii* (Stebbin's bluegrass)
*Polemonium eximium* (sky pilot)
*Potentilla grayi* (Gray's cinquefoil)
*Ptilagrostis kingii* (King's ricegrass)
*Ranunculus hystriculus* (waterfall buttercup)
*Ribes tularense* (Sequoia gooseberry)
*Streptanthus fenestratus* (Tehipite Valley jewelflower)
*Streptanthus gracilis* (alpine jewelflower)
*Trichophorum clementis* (Yosemite bulrush)
*Triglochin palustre* (marsh arrow-grass)*
*Utricularia intermedia* (flat-leaved bladderwort)*

*Taxa that reach the eastern limit of their range within the parks (55):*
*Allium tribracteatum* (three-bracted onion)
*Asplenium septentrionale* (northern spleenwort)
*Astragalus ravenii* (Raven's milkvetch)
*Calamagrostis muiriana* (Muir’s reed grass)
*Carex congdonii* (Congdon's sedge)
*Carex geyeri* (Geyer's or elk sedge)
*Carex incurviformis* (coastal sand sedge)
*Carex praticola* (meadow sedge)
*Carex tahoensis* (Tahoe sedge)
*Carex tompkinsii* (Tomkins' sedge)
*Cinna bolanderi* (Bolander's woodreed)
*Dicentra nevadensis* (Tulare County bleeding heart)
*Dodecatheon subalpinum* (subalpine shooting star)

*Draba cruciata* (Mineral King draba)
*Draba lemmonii* (Lemmon's draba)
*Epilobium oreganum* (Oregon fireweed)
*Erigeron aequifolius* (Hall's daisy)
*Erigeron elmeri* (Elmer's daisy)
*Erigeron inornatus* var. *keilii* (Keil's erigeron)
*Eriogonum nudum* var. *murinum* (mouse buckwheat)
*Eriogonum nudum* var. *scapigerum* (tibinagua)
*Eriogonum prattenianum* var. *avium* (kettle dome buckwheat)
*Galium sparsiflorum* ssp. *sparsiflorum* (Sequoia bedstraw)
*Hackelia sharsmithii* (Sharsmith's stickseed)
*Hulsea brevifolia* (short-leaved hulsea)
*Ivesia campestris* (field ivesia)
*Ivesia muirii* (Muir's ivesia)
*Ivesia pygmaea* (dwarf ivesia)
*Juncus hemiendytus* var. *abjectus* (Center Basin rush)*
*Linanthus montanus* (mustang clover)
*Linanthus oblanceolatus* (Sierra Nevada linanthus)
*Lorandersonia peirsonii* (Peirson's serpentweed)
*Lupinus covillei* (Covill's lupine)
*Lupinus culbertsonii* ssp. *culbertsonii* (Hockett Meadows lupine)
*Lupinus fulcratus* (greenstipule lupine)
*Luzula orestera* (mountain woodrush)*
*Mentzelia crocea* (Sierra blazingstar)
*Mimulus laciniatus* (cut-leaved monkeyflower)
*Mimulus norrisii* (Kaweah monkeyflower)
*Minuartia stricta* (bog stitchwort)*
*Oreonana clementis* (Clement's mountain parsley)
*Petrophyton acuminatum* (marble rockmat)
*Pityopus californicus* (California pinefoot)
*Poa stebbinsii* (Stebbin's bluegrass)
*Podagrostis humilis* (mountain bent grass)*
*Polemonium eximium* (sky pilot)
*Ptilagrostis kingii* (King's ricegrass)
*Ribes menziesii* var. *ixoderme* (canyon gooseberry)
*Ribes tularense* (Sequoia gooseberry)
*Rosa pinetorum* (pine rose)
*Ranunculus hystriculus* (waterfall buttercup)
*Streptanthus diversifolius* (varied-leaved jewelflower)
*Streptanthus fenestratus* (Tehipite Valley jewelflower)
*Trichophorum clementis* (Yosemite bulrush)
*Utricularia intermedia* (flat-leaved bladderwort)*

*Taxa that reach the western limit of their range within the parks (23):*
*Angelica callii* (Call's angelica)
*Dicentra nevadensis* (Tulare County bleeding heart)

*Draba monoensis* (White Mountains draba)
*Draba sharsmithii* (Mount Whitney draba)
*Erigeron inornatus* var. *keilii* (Keil's erigeron)
*Eriogonum nudum* var. *murinum* (mouse buckwheat)
*Eriogonum spergulinum* var. *pratense* (spurry buckwheat)
*Erythronium pusaterii* (Kaweah Lakes fawn lily)
*Frasera tubulosa* (Kern swertia)
*Hackelia sharsmithii* (Sharsmith's stickseed)
*Ivesia campestris* (field ivesia)
*Ivesia pygmaea* (dwarf ivesia)
*Oreonana purpurascens* (purple mountain-parsley)
*Oreostemma peirsonii* (Peirson's aster)
*Petrophyton acuminatum* (marble rockmat) (reaches western limit at Boyden Cave which is within 8 kilometers of Kings Canyon National Park border)
*Phacelia orogenes* (mountain phacelia)
*Phlox dispersa* (High Sierra phlox)
*Pinus balfouriana* ssp. *austrina* (foxtail pine)
*Poa lettermanii* (Letterman's bluegrass)
*Ribes tularense* (Sequoia gooseberry)
*Sidalcea ranunculacea* (marsh checkerbloom)
*Silene aperta* (naked campion)
*Streptanthus fenestratus* (Tehipite Valley jewelflower) (reaches western limit at Boyden Cave which is within 8 kilometers of Kings Canyon National Park border)

Notes on species extents with specimen citations are included in Appendix G.

### Invasive species

Invasive species could pose a threat to special status plants in areas where invasions are particularly prevalent. Invasive species are known to displace native plant populations, and, given the limited distribution of many special status plant species, special status plants might be particularly susceptible to such invasions.

No directed research has been done in the parks to track the effect of invasive species on special status plant species. However, the park does spend considerable effort tracking invasive species populations as part of their invasive species removal program. Therefore, it would be worthwhile to summarize where substantial populations of invasive species occur in conjunction with special status plants. At the time of this writing, however, lack of availability of finalized spatial data for the invasive plant species precluded its inclusion in this analysis.

The Invasive Species SEKI NRCA chapter states:

> "the strongest factors that appear to determine where invasive plants are located within the park are elevation, current or past disturbances such as roads, trails, fire fighting activities, helicopter landing sites, camps, and riparian sites. Where disturbances intersect with high resource availability, such as in meadows/streams/seeps/moist areas, sites with recent fires where there is much available light and nutrients, past grazing activity (pack stations with

manure), and sewage spray fields, etc. are all determinants of where invasive plants might be located."

This summary suggests that many of the same populations noted in the Land use/fragmentation section above may also be most at risk from competition with invasive species.

The Invasive Species NRCA chapter notes that the presence of invasives appears to be highest at lower elevations and that the five most invaded CWHR vegetation types are Blue Oak Woodland, Ponderosa Pine, Montane Hardwood, Chamise-Redshank Chaparral, and Valley Foothill Riparian. With regard to elevation, special status plant species, in contrast to invasive species, tend to increase in number with elevation (Fig. 8), making many of the species on the special status list presumably above the most heavily invaded areas. Nonetheless, three of the most invaded vegetation types have at least ten special status species occurring in them, including Blue Oak Woodland, Montane Hardwood, and Chamise-Redshank Chaparral.

## Altered fire regimes

Historically, many of the ecosystems in the park were adapted to frequent fire. With the advent of European colonization in the 19$^{th}$ century, fires were systematically suppressed, leaving many areas in the parks well outside their historical fire regime. This undoubtedly has had substantial impacts on the plants within these ecosystems, and much research has been devoted to studying these impacts with regard to tree species. Four tree species are on the special status list of plants (*Sequoiadendron giganteum* (giant Sequoia), *Pinus balfouriana* ssp. *austrina* (foxtail pine), *Pinus albicaulis* (whitebark pine), and a newly described variety of red fir (*Abies magnifica* var. *critchfieldii*). These tree species are treated in other NRCA chapters (Giant Sequoia and Intact Forests/Five-needle Pines), so in this section we focus on shrub and herbaceous special status species.

Much less research has been devoted to the effects of altered fire regimes on understory species, which comprise the vast majority of species on the special status plant list. Fire suppression in the past century has undoubtedly affected these species, but we cannot say for certain whether that effect has been positive or negative for most species. It is likely that less frequent fire has benefited some species (as is the case, for example, with *Abies concolor* (white fir) (Vankat and Major 1978, Minnich et al. 1995) and been detrimental for others (as with many pine species).

We take a two-pronged approach to assess the likely interaction of altered fire regimes with special status plants. First, we note species that have been found in areas of the parks in which the fire regimes are most altered from their historical norms. While data are lacking to draw conclusions about whether the effect of fire suppression has been positive or negative on a given species or whether the re-introduction of fire would have a positive effect, the procedure identifies special status species that are most likely to be affected by altered fire regimes. Such information will hopefully inform managers in their approach to monitoring the effects of fire, by, for example, directing attention to special status species in post-fire monitoring plots. Secondly, we provide a summary of the fire ecology literature available for species on the special status plant list. We categorize these species by the presumed positive or negative effect of fire.

### *Fire return interval departure analysis*

Many locations in the parks known to contain special status species are in areas with a high or extreme fire return interval departure, and some of those areas (e.g., Marble Fork drainage) also

have relatively high reported special status plant species richness (Fig. 13). Therefore it is reasonable to expect that fire-- including both its reintroduction and suppression-- has had and will have impacts on special status species in SEKI.

Figure 13 overlays special status plant observations with the parks' fire return interval departure (FRID) map. We selected areas in the parks with FRID values equivalent to a high or extreme return interval departure (Class 1 or 2). FRID values are calculated using the time since last fire and the average maximum number of fire return intervals that have been missed for particular vegetation types. These values are placed into classes from 1 to 5, with 1 having the highest departure values. The FRID map categorizes Class 1 as extreme, with 5 or more maximum return intervals surpassed, and Class 2 as high, with between 2 and 5 maximum intervals surpassed (Tony Caprio, Fire Ecologist Sequoia and Kings Canyon National Parks, personal communication, 1 April 2011).

Of the species on the special status plant list, seven have been documented to occur solely within areas with a high or extreme fire return interval departure, including *Carex geyeri* (elk sedge), *Horkeliella purpurascens* (purple false horkelia), *Limnanthes montana* (mountain meadowfoam), *Mentzelia crocea* (Sierra blazingstar), and three moss species: *Meesia triquetra* (three-ranked hump moss), *Meesia uliginosa* (broad-nerved hump moss) and *Porotrichum bigelovii* (Bigelow's porotrichum).

Eight other species are reported to occur more frequently in areas of high or extreme departure areas than in other FRID categories, which range from moderate to low. These are: *Agnorhiza invenusta* (mule-ears), *Claytonia parviflora* ssp. *grandiflora* (streambank springbeauty), *Eriophyllum lanatum* var. *croceum* (common woolly sunflower), *Hulsea brevifolia* (short-leaved hulsea), *Iris munzii* (Munz's iris), *Streptanthus farnsworthianus* (Farnsworth's jewelflower), *Meesia triquetra* (three-ranked hump moss) and *Mielichhoferia mielichhoferiana* var. *elongata* (elongate copper moss).

In areas where prescribed fire is planned, some extra attention may be merited for these species, including both pre and post fire monitoring.

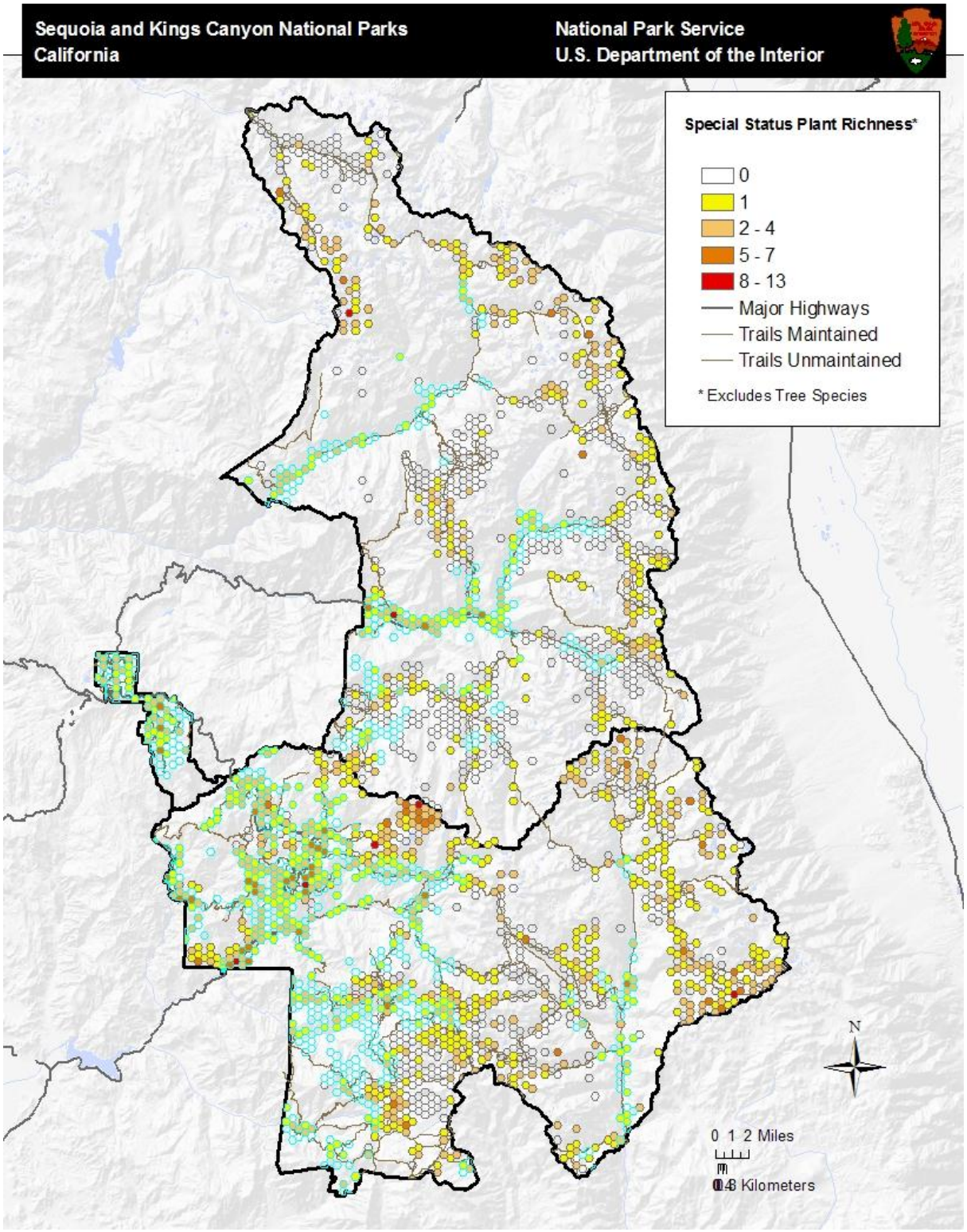


**Figure 13.** Minimum richness map of special status plants (all rare and endemic species, excludes special status tree species); hexagons which fall within areas categorized has having a high or extreme fire return interval departure (FRID categories 1 and 2) are highlighted in blue. Empty hexagons have at least one sample point with no special status species. Areas with no hexagons indicate no data.

### *Fire effects literature review*

A great deal of research has been done in the Sierra Nevada studying the effect of fire and fire suppression on vegetation. A summary of that research is beyond the scope of this report and is covered in the Altered Fire Regimes SEKI NRCA chapter. Perhaps of most relevance to special status species is research that suggests that spatial heterogeneity in fire may be important for maintaining understory communities in fire adapted forests (Webster and Halpern 2010, Harvey et al. 1980, Rocca 2009). In mixed-conifer forests of the Sierra Nevada, decades of fire suppression can lead to higher fire intensities and lower spatial heterogeneity in burn severity than these forests have experienced historically (Miller and Urban 2000).

A summary of the known or presumed fire ecology of special status species is below, based on information available in the literature. Again, we do not include special status tree species in this review, as these species will be reviewed in other SEKI NRCA chapters. We place each species into the following categories: fire enhanced, possibly fire enhanced, fire tolerant, fire sensitive, and possibly fire sensitive.

Fire enhanced special status plant species:
*Arctostaphylos viscida* ssp. *mariposa* (Mariposa manzanita): Fire ecology specific to this subspecies was not found, but *A. viscida (*whiteleaf Manzanita), as well as other species in the genus *Arctostaphylos*, recolonizes after fire by fire-stimulated germination of dormant seeds in the soil (Eastwood 1934, Hanes 1977). The subspecies *mariposa* is found in openings in chaparral, oak woodland, and coniferous forest up to 2,200 meters in elevation (approximately 7,200 feet).

*Ceanothus parvifolius* (littleleaf ceanothus): Seed germination of all *Ceanothus* species is stimulated by heat (Keeley and Davis 2007). Studies have indicated that *C. parvifolius* increases in abundance after fire (Harvey et al. 1980, Webster and Halpern 2010, and Rocca 2009).

*Ceanothus pinetorum* (Kern ceanothus): Seed germination of all *Ceanothus* species is stimulated by heat (Keeley and Davis 2007).

*Gayophytum eriospermum* (Coville's groundsmoke): Rocca (2009) reported this species as fire stimulated; its seeds germinated and seedlings established after fire in both light and heavy fuel experimental plots.

*Ribes tularense* (Sequoia gooseberry): Germination of seedbanked seeds is stimulated by fire. Seedling establishment was higher in light versus heavy fuel load experimental burn plots (Rocca 2009). This species prefers openings in the mixed coniferous forest (Norris and Brennan 1982). Norris and Brennan speculated (1982) that dense forest conditions resulting from fire suppression may have reduced population sizes of this species.

Possibly fire enhanced special status plant species:
*Carex tompkinsii* (Tompkins' sedge): Fire ecology specific to this species was not found, but Norris and Brennan (1982) noted that the perennial prefers rocky openings in the forest or forest edges. This species is found in chaparral, cismontane woodland, lower and upper montane coniferous forest (Baldwin et al. *in press*).

*Hosackia oblongifolia* var. *cuprea* (copper-flowered bird's-foot trefoil): Fire ecology specific to this variety was not found, but Webster and Halpern (2010) reported that *Lotus oblongifolius* (synonym of *Hosackia oblongifolia*) plants in SEKI Fire Effects Monitoring plots were only found in burned plots, and referred to this species as fire-enhanced. SEKI supports two varieties of *Hosackia oblongifolia* – var. *cuprea* and var. *oblongifolius*, which are found in similar habitats (meadows, streambanks, and open, moist places in pine forest). Plants of the variety *cuprea* are more restricted in distribution and in elevation (2,400-2,800 meters) than *H. oblongifolia* var. *oblongifolia* (200-2,400 meters in elevation) (Baldwin et al. *in press*).

*Phacelia cicutaria* var. *cicutaria* (caterpillar phacelia): Fire ecology specific to this variety was not found, however Keeley and Davis (2007) reports *Phacelia cicutaria* as a post fire specialist and that its germination is triggered by fire. *P. cicutaria* is split between two varieties (also var. *hispida*) that are found in similar habitats (rocky slopes, oak/pine woodland, grassland) but are separated by geographic range and by flower color (Baldwin et al. *in press*).

*Strepanthus fenestratus* (Tehipite Valley jewelflower): Norris and Brennan (1982) observed that Tehipite Valley jewelflower may benefit from fire-created openings as the species appears to require openings in forest and brush in mixed coniferous forest and oak woodlands. They recommended research on the fire ecology of this species.

Fire tolerant special status plant species:
*Carex geyeri* (elk sedge): Elk sedge is able to resprout from underground rhizomes or recolonize from its seed bank after fire and is often one of the first species to recolonize or grow back after a fire (Brown and Smith 2000). SEKI is outside this species reported range in California (southernmost populations in California are found in northern Sierra Nevada bioregion) (Baldwin et al. *in press*), and it is known in SEKI from only one observation, in the Middle Fork Kaweah River basin. The identification of the vouchered specimen collected in SEKI was verified in 2004 (1).

Possibly fire sensitive special status plant species:
*Pityopus californicus* (California pinefoot): This species prefers shady places in broad-leaf and coniferous forest. Norris and Brennan (1982) recommended this species for fire research; they found plants in the parks to grow in thick duff and never in full sun.

*Galium sparsiflorum* ssp. *sparsiflorum* (Sequoia bedstraw): Webster and Halpern (2010) described *G. sparsiflorum* as more fire sensitive than some other understory species and typically grows in more shaded habitats with deeper duff levels. (Note that, although Webster and Halpern do not list the subspecies, Sierran plants are ssp. *sparsiflorum* (Baldwin et al. *in press*)). However, their analysis also found that while *G. sparsiflorum* frequency was reduced immediately following first entry burns that ten years following fire the species actually occurred more frequently in burned than unburned plots. Results from plots that had been burned twice were more equivocal, with the species recovering after ten years but not to pre-fire levels--perhaps suggesting that frequent burning could have more detrimental effects (Webster and Halpern 2010).

Note that although the plants of the "possibly fire sensitive" taxa have been found to be sensitive to fire in these studies, these taxa are associated with vegetation types in which fire is a naturally occurring process in the ecosystem. Thus it is unlikely that the persistence of these species is threatened by fire in general, especially when fire occurs with the frequency and conditions under which these taxa have experienced historically.

### Disease paradigms

Knowledge about the effects of insects and pathogens on special status plants is limited to three of the four tree species that are on the list: *Sequoiadendron giganteum* (giant sequoia), *Pinus albicaulis* (whitebark pine), and *Pinus balfouriana* ssp. *austrina* (foxtail pine). The parks contain some datasets that track mortality for these species, and some surveys have been conducted for exotic pathogens.

Both pine species are known to be susceptible to the exotic pathogen *Cronartium ribicola* (white pine blister rust) and to the native bark beetle *Dendroctonus ponderosae* (mountain pine beetle). Whitebark pine in particular has suffered very heavy mortality in parts of the Rockies and Cascades (Tomback et al. 2001) from these agents. Because of these declines, and the threat of continuing declines from the interaction of white pine blister rust, mountain pine beetle and climate change, the US Fish and Wildlife Service has recently recognized whitebark pine as warranting protection under the Endangered Species Act. Lack of resources, however, precludes listing at this time and it has been designated as a candidate species subject to annual review (USFWS 2011).

Both blister rust and mountain pine beetle are present in the parks, however, no instances of blister rust or mountain pine beetle caused mortality for either pine species has been documented in SEKI (McKinney 2010). Blister rust has been observed on one foxtail pine in the parks during a blister rust survey (Duriscoe and Duriscoe 2002). The variety of foxtail found in the Klamath Ranges, *Pinus balfouriana* ssp. *balfouriana*, has infection levels over 20%. Although blister rust has been detected infrequently in the Sierra for both foxtail and whitebark pine, these trees are believed to be vulnerable (NPS, Shawn McKinney, Inventory and Monitoring Sierra Nevada Network, personal communication, 7 April 2011).

Note, however, that these datasets are relatively small (particularly for mortality) and cannot be considered a comprehensive sampling. Furthermore, given the damage that blister rust and mountain pine beetles have caused in other regions, these threats should not be discounted in the parks. Blister rust was recently discovered on whitebark pine in Yosemite National Park (McKinney 2010). With a changing climate and potentially increased stress on tree species in these forests (van Mantgem et al. 2009), these white pines might face a dramatically increased risk in the future.

Although giant sequoias are generally considered resistant to insects and pathogens, they are sometimes infected by root pathogens, including *Armillarea mellea* and *Heterobasdion annosum* (Burns and Honkala 1990). Nonetheless, mortality from these agents appears to be very limited, and USGS forest demography plots in SEKI indicate a very low mortality rate for giant sequoia, although the dataset is too small for this species to make definitive statements. Once again, caution should be taken in making strong inferences about future mortality risk based on past

evidence, especially given a changing climate. This is particularly relevant in light of the finding that mortality rates have increased in old growth forests across the west in the past few decades (van Mantgem et al. 2009).

For more detailed treatments and vulnerability assessments of the tree species, please refer to the Giant Sequoia and Intact Forests/Five-needle Pines NRCA chapters.

# Assessment

## Overview

As we noted in the Scope of analysis, available data are inadequate to apply an integrity metric to assess the overall condition of special status species in SEKI. In short, we lack demographic information on most of the species on the list (population sizes, mortality rates, recruitment rates, and trends). Therefore we have not provided a table with integrity indices. We do, however, have considerable distribution data for special status species in the parks, and we have attempted to describe those in detail in the preceding sections—in particular by identifying zones in the park that appear to have relatively high special status plant richness. There is a temptation to take the number of observed occurrences for each species (such as number of hexagons in which a given species occurs) and attempt to develop an integrity index from that. But due to problems of sampling effort (described above) such an index could be very misleading. Nonetheless, we have provided that raw information (Appendix F) should managers wish to use it.

On the other hand, if we can define condition as a measure of vulnerability (those areas with species that may be especially vulnerable), we would recommend Figure 6 as a guide for identifying which areas in the parks have a high prevalence of vulnerable species. The analysis for that figure contains both a statewide measure of species vulnerability (CNPS and CNDDB rankings) as well as a local measure (rarity with which a given species has been observed in the parks).

### *Regional context*

The approximately 350,254 hectares of land that currently comprise the parks are predominately in the southern portion of the Sierra Nevada. As reported in the Scope of analysis, the southern Sierra Nevada supports more Sierra Nevada endemic and rare plant taxa than the central and northern portions of the region (Shevock 1996). To determine rare plant taxa, Shevock's 1996 analysis referred to similar sources as we do in this report-- the CNPS Inventory (Skinner and Pavlik 1994) and the rare plant component of CNDDB (1995). Although it is probable that the large-scale patterns that Shevock reported hold true today, a similarly detailed and updated analysis would be of great value, especially given taxonomic changes that have since occurred (Baldwin et al. *in press*) and the greater availability of floristic data online (e.g. CCH).

The factors that have been identified as contributing to the high diversity of the southern Sierra Nevada include the wide range in elevation (from low-elevation foothills to Mount Whitney at the highest point); steepness of the elevation range (southern Sierra is narrower than central or northern sections); extensive alpine and subalpine habitat that supports many Sierran endemic and rare taxa (Stebbins 1982); and aridity of the southern portion of the Southern Sierra. Within the southern Sierra Nevada, three river basins are reported to have the highest number of Sierran endemics: the Kern, Kaweah, and Kings (Shevock 1996). The headwaters of all three are located in SEKI. Of the seven major river basins in the southern Sierra Nevada, the Kern River Basin is exceptionally high in total plant diversity, Sierran endemics, rare plants, and number of taxa endemic to a single river basin. Shevock also compiled data on rare plants by topographic quadrangle in the Sierra Nevada and found that the sandy granitic meadow borders of the Kern Plateau in Tulare County were among the areas in the Sierra that supported the highest number of rare species (based on data obtained from Skinner and Pavlik 1994).

Based on Shevock's analysis of the southern Sierra Nevada, Sequoia and Kings Canyon National Parks do not stand out as disproportionately higher in rare species than the area to the south that encompasses Sequoia National Forest, which includes the Kern Plateau (based on Figure 24.3 in Shevock 1996 which depicts rare plant richness by 7.5-minute topographic quadrangles). Sequoia National Forest reports 49 vascular and non-vascular taxa on their list of threatened, endangered, or sensitive plants (USFS-sensitive plants), all of which are also listed by the CNPS Inventory or CNDDB as rare or threatened. SEKI has considerably more taxa recognized as rare in the state by CNPS Inventory and CNDDB (83 taxa), but the US Forest Service appears to have a stricter criteria than these organizations for rare or threatened status. There are only 18 taxa in SEKI that are listed as USFS-Sensitive.

For a broader view, we calculated the number of rare taxa (listed by the CNPS Inventory) in each Jepson bioregion that fall mostly within the PACE (Protected Area Centered Ecosystem) boundaries and also overlap with SEKI (Fig. 14): southern Sierra Nevada Foothills (s SNF), southern High Sierra Nevada, and central High Sierra Nevada. These bioregions support, respectively, 71, 153, and 132 rare taxa (Baldwin et al. *in press*, data provided by Richard Moe, University and Jepson Herbaria at University of California, Berkeley on 27 March 2011). Based on our findings, the parks support 83 rare taxa. The parks contain 22% (29 of 132) of the rare taxa in c SNH; 13% (9 of 71) of the rare taxa in s SNF; and 37% (56 of 153) of the rare taxa in the s SNH. In general, the richness of rare taxa in SEKI as a whole, relative to its size in the PACE, is comparable to the richness of these bioregions. It does not appear to have especially high or low rare plant richness.

Compared to Yosemite National Park, SEKI appears to support more rare vascular taxa (using CNPS Inventory listed plants as the reference for designating rarity status), though not substantially more when corrected for the difference in the size between Yosemite and Sequoia and Kings Canyon National Parks. Yosemite National Park's Special Status Vascular Plant Species List (2005) reports 61 taxa with a CNPS listing status compared to SEKI's 76 CNPS listed rare vascular taxa. SEKI, however, is approximately 1.16 times larger in area than Yosemite National Park. Rare plant richness per unit area is 0.000217 taxa per hectare in SEKI versus 0.000202 taxa per hectare in Yosemite. These comparisons between the parks do not take into account relative differences in sampling effort nor estimates of coverage or frequency of rare plant taxa in the parks. Comparisons between the number of Sierra Nevada endemics were not made because identification of all Sierra Nevada endemics in Yosemite National Park's Special Status Vascular Plant Species List (2005) was not completed in this version of the list (Peggy Moore, Plant Ecologist, USGS Western Ecological Research Center Yosemite Field Station, personal communication 14 June 2011).

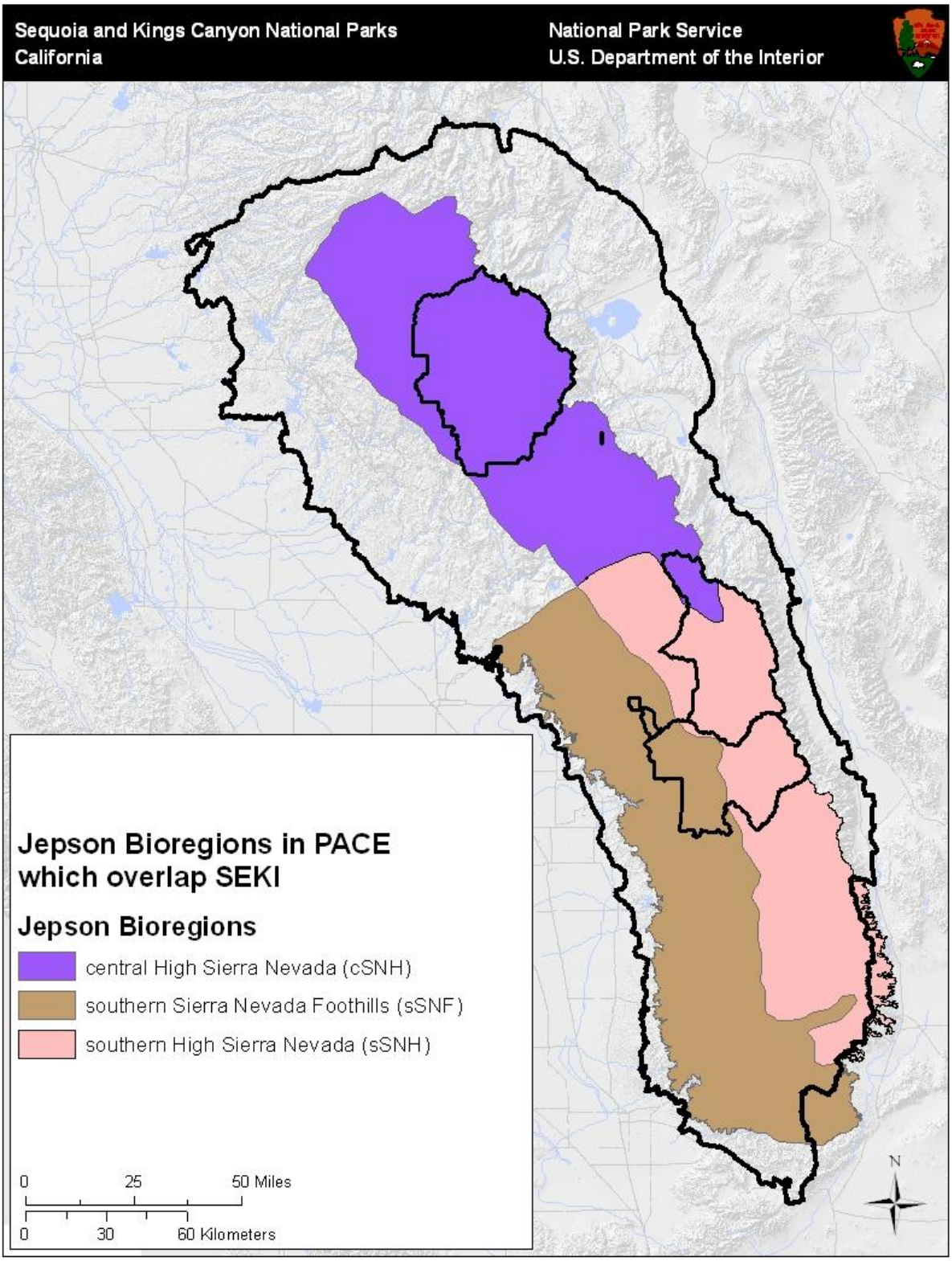


**Figure 14.** Jepson Bioregions within the PACE that overlap SEKI.

## 1. What are the special status plants known to occur in SEKI?

There are no federal or state listed threatened, endangered, or candidate for threatened or endangered listing plant species known to occur in Sequoia and Kings Canyon National Parks. *Pinus albicaulis* (whitebark pine*)* is warranted for listing by the US Fish and Wildlife Service under the federal Endangered Species Act, but has been precluded due to a lack of resources. It has been placed in candidate status until further notice. There are a number of previously candidate status species for state or federal threatened or endangered listing that have since been removed from consideration, in large part due to the discovery of additional populations in the parks during the early 1980s (Norris 1984). The parks support one species listed as rare under the California Endangered Species Act (CESA), *Carex tomkinsii* (Tompkins' sedge).

*Carex tompkinsii* is a California endemic that was listed as a rare species under CESA in 1979 (CDFG 2004). Although it is the only species with a state "rare" designation in the parks, it is not necessarily the most vulnerable species that is found in the parks. NatureServe last reviewed its ranking status in 2000. Tompkins' sedge has a state and global rank of G3, meaning it is considered vulnerable, with a moderate risk of extinction (NatureServe Explorer website 2010). In 2001, CNPS downgraded the vulnerability status of this species, changing its listing status from List 1B to List 4 (see Appendix C for a description of the CNPS lists) upon the publication of the sixth edition of the CNPS Inventory of Rare and Endangered Plants in California (CNPS 2001). There are 45 other taxa in the parks with greater state vulnerability rankings of critically imperiled or imperiled (S1 or S2) and greater vulnerability CNPS rankings, some of which have narrower geographic ranges, fewer known occurrences, and narrower habitat requirements than Tompkins' sedge.

Seventy-six vascular plants (including *Carex tompkinsii* ) and seven bryophyte taxa recognized as rare or threatened by CNDDB or CNPS have been documented in the parks. An additional 66 taxa that are not listed by CNPS or CNDDB are endemic to the Sierra Nevada. With the addition of *Pinus albicaulis*, the total number of special status taxa is 150.

Based on geographic range data for the 1,561 plant species in the SEKI flora, 102 taxa are thought to be endemic to the Sierra Nevada. Of these, 35 species have possible range extensions outside the Sierra Nevada bioregion. Of the Sierra Nevada endemics, 39 are thought to be restricted to the southern Sierra Nevada, including nine taxa that have possible range extensions beyond the southern Sierra Nevada. We identified 12 'locally endemic' taxa, or plants with geographic ranges that are restricted to within eight kilometers of the parks since 1912. (*Ivesia campestris* is included on the list of local endemics but was most recently collected from Mono County in 1911.)

We report a summary of findings in patterns of distribution in the parks in the next section, but we also used several botanical literature sources, combined with observation data of special status plants in the parks to attribute each taxon on the special status list with the following memberships: alpine restricted, alpine and subalpine restricted, hydrologically influenced (usually associated with wet meadows, seeps, riparian, or other wet or moist habitats), restricted to uncommon substrates (carbonate or carbonate-derived substrates like mable or limestone), or restricted to oak woodlands (see Climate Change Stressor section for methods and sources). Based on this work, we can report that 73% (61 of 83 taxa) of the rare or threatened taxa in SEKI

fall into at least one of these categories. Of the total 83 rare taxa, 30 are restricted to alpine and/or subalpine environments, 27 are hydrologically influenced, 12 restricted to oak woodlands, and three to uncommon substrates. (Overlap exists among attributes for some taxa so these numbers combined add up to more than 61.) Together, alpine and subalpine restricted taxa contribute the most (62%, 52 of the 83 taxa) than the other categories. These findings are consistent with those reported in the Spatial analysis section of this report: sparsely vegetated barren vegetation types and meadows and other wetland habitats are especially important for special status rare plants in the parks.

### 2. What is the known distribution of special status plants within SEKI?

Broadly, it can be said that special status species are found throughout the park, at all elevations, and in every vegetation type (Figs. 4, 5). Please refer to the Spatial and temporal analysis sections for details. In general, vegetation types that cover more area in the parks appear to support higher numbers of rare and endemic species (Fig. 8). There are several exceptions -- including meadows, mixed chaparral, perennial grass, montane riparian (modified), alpine dwarf shrub, and blue oak woodland -- which have disproportionately high richness for their coverage in the parks. In addition, the number of rare and endemic taxa generally increases with elevation from 400 to 2,500 meters (1,312 to 8,202 feet), above which richness declines gradually with increasing elevation, and then drops precipitously above 3,500 meters (11,483 feet) (Fig. 10). All of these patterns appear to hold both for special status taxa as a whole and also for taxa that are listed as rare (recognized by the CNDDB or CNPS Inventory as rare or threatened).

We also used several botanical literature sources, combined with observation data of special status plants in the parks to attribute each taxon on the special status list with the following memberships: alpine restricted, alpine and subalpine restricted, hydrologically influenced (usually associated with wet meadows, seeps, riparian, or other wet or moist habitats), restricted to uncommon substrates (carbonate or carbonate-derived substrates like mable or limestone), or restricted to oak woodlands (see Climate Change Stressor section for methods and sources). Based on this work, we can report that 73% (61 of 83 taxa) of the rare or threatened taxa in SEKI fall into at least one of these categories. Of the total 83 rare taxa, 30 are restricted to alpine and/or subalpine environments, 27 are hydrologically influenced, 12 restricted to oak woodlands, and three to uncommon substrates. (Overlap exists among attributes for some taxa so these numbers combined add up to more than 61.) Together, alpine and subalpine restricted taxa contribute the most (62%, 52 of the 83 taxa) compared to the other categories. These findings are consistent with those reported in the Spatial analysis section of this report: sparsely vegetated barren vegetation types and meadows and other wetland habitats are especially important for special status rare plants in the parks.

### 3. What is known about their condition?

Five percent of the vascular plants (76 out of 1561 taxa) known to occur in SEKI are vulnerable to extinction (have a state rank of S1 ‘critically imperiled’ to S3 ‘vulnerable’—see Appendix A for species list), taking into account the CNDDB imperilment rankings which give an assessment of overall condition throughout the species’ range in the state. Figure 5 shows the distribution of these taxa in the parks. All of these taxa are also listed as rare or endangered by CNPS (all are on CNPS Lists 1 to 4). SEKI also supports at least seven rare bryophyte taxa. About half (41) of the

83 statewide listed rare vascular plants have a high to very high risk of extinction (S1, critically imperiled and S2 or S2S3, imperiled ranking).

Data are lacking to make an assessment of short or long term population trends for these species' condition in SEKI. Data from one survey (I&M Special Status Plant Surveys) which revisited a subset of the number of rare plant populations in the parks that had been surveyed in the early 1980s (Norris and Brennan Surveys) suggest potential, substantial declines (at least 25%) in the total number of plants in revisited populations for at least four of the 12 rare plants that were revisited. Eight of the 12 taxa have one or more populations that have apparently decreased by at least 25%. However, since these data represent only two sampling points in time and lack any quantification of year to year variability, they cannot be used as a reliable assessment of condition. At best, they represent a starting point for evaluating these species in a future monitoring program.

### 4. What is known about the effects of the six stressors identified by the NRCA working group on special status plants in SEKI?

In general, additional research is needed to assess the effect of stressors on the special status plants in Sequoia and Kings Canyon. Please refer to the stressors section above for details. Air quality is not known to have a negative effect on any of these species, but few have been examined directly. Stock use might have an effect on special status species that occur in meadows, but direct species-specific evidence is lacking. Climate change will almost certainly affect many of these species, presumably by altering the location of the niches in which they occur, and special status plants might be particularly vulnerable given their already limited distribution. Without detailed soils information, well-known current distribution and knowledge of habitat requirements of these species, making predictions about the effect of climate change will be difficult. Furthermore, simply understanding the habitat requirements may fail to capture unexpected changes in biological interactions—such as relationships with competitors, pathogens, and herbivores. We expect that invasive species may have a deleterious effect on special status species in those regions that are most heavily invaded, but monitoring is necessary to quantify how severe a threat invasives actually pose. Changes in fire regimes probably have and will continue to impact special status plant populations, although whether that effect is positive or negative likely varies with the species. We have documented those species for which fire research is available and listed those which merit the most attention due to their presence in areas with a high fire return departure interval. Finally, the effect of diseases and pathogens on special status species is almost completely unknown, except for the tree species on the list. All of the tree species deserve attention with regard to the effect of not only exotic but also native diseases, particularly as the climate continues to change.

## Level of confidence in assessment

As we have stated previously, we are unable to quantify the overall condition (good or poor) of any of the particular species on the special status plant list due to a lack of data. Instead we have focused on providing the best available list of plants, describing the known spatial distribution of special status species richness throughout the parks, and providing an overview of the possible trends for those few species for which we had some limited demographic data. The uncertainties in each of these analyses are described in the pertinent section and in the Analysis Uncertainty section.

We can say with a high degree of confidence that special status plants in SEKI are distributed throughout the parks, across a wide elevation range and in a wide variety of vegetation types. In addition, SEKI provides important habitat for many of the species on the list. In short, we have a high degree of confidence that special status plants should be considered an important resource in the parks and that they likely merit more monitoring than they are currently receiving.

## Gaps in understanding

The single largest gap in data for special status plants in SEKI is the lack of demographic data for almost all of the species (population sizes, mortality rates, recruitment rates, year to year variability and trends in these factors). Even for the 12 non-tree species for which we have some population data, we have data from only two points in time, making assessments of trends unreliable. In essence, the park lacks the data to make any meaningful assessment of the condition for the vast majority of species on the special status plant list. The potential exceptions are the tree species, for which limited demographic data is available.

Of course collection of such data presents substantial challenges, given the large geographical area of the park, the relative inaccessibility of many regions, and the potential costs of a regular monitoring program. Nonetheless, it would be highly beneficial to implement a regular program that monitors a meaningful subsample of the populations of at least the most at risk species.

The knowledge of species distributions and special status plant richness in the parks is stronger due to the relatively large number of plots. However, there is still a very uneven sampling effort, particularly for the most informative data collection types (comprehensive plots). In addition, large areas of the parks remain unsurveyed due to remoteness. Finally, while the distribution of sampling effort among broad vegetation classifications is fairly consistent with their representation in the parks, those classifications are too broad to be confident that the specific habitat type of a given species has been adequately sampled. All of these considerations make our confidence in richness estimates highly variable spatially across the parks, and, further, the differences in sampling effort make our assessments of which areas contain relatively high special status species richness (hotspots) potentially unreliable. A more even and dense distribution of non-targeted surveys would be highly beneficial, though we understand that practical considerations make the implementation of such a program challenging.

We also lack adequate understanding of both the autecology and ecological interactions of most species on the list. For example, while we generally know the broad vegetation types a given species is found in, we rarely know their specific habitat requirements. Nor do we have an understanding of the particular herbivores and pathogens that attack them or how each species responds to its local competitors. Put another way, we lack an understanding of what factors define a given species' fundamental niche (where a species could potentially occur) versus its realized niche (where it actually occurs due to factors such as competition, herbivores, pathogens and dispersal). Without that basic understanding, we will not with any confidence be able to judge how factors such as climate change will affect each special status plant species. In general, we are short on studies that define relationship between a given stressor and a given species.

On a related note, even should we obtain such biological information about each species—enough perhaps to do more robust habitat modeling—certain geographic knowledge gaps may be a hindrance. For example, the lack of a detailed soils map makes it very difficult to define potential habitat for any given species. The resolution of the vegetation map may also be a barrier for some species in which the habitat requirements are finer than the scale of the map.

## Recommendations for future study/research

First, it is important to recognize that SEKI possesses a remarkable collection of vegetation datasets. They are spread throughout the parks, across the full range of elevations, and in all of the parks' vegetation types. Our observation that these datasets are not always ideal for assessing the condition of special status plants should not detract from the utility of these resources.

Nonetheless, for the purpose of evaluating special status plants, there are several areas in which data collection could be enhanced and improved.

1) *Establish a special status plant monitoring program*. In order to track the condition of special status species, populations of special status species should be periodically monitored in order to establish estimates of demographic rates by, at the minimum, estimating the number of individuals in each population. Particularly for herbaceous species (both annuals and perennials) monitoring needs to be fairly frequent in order to distinguish typical inter-annual variability from actual trends (whether the population is actually increasing or decreasing over time). The number of years of repeated sampling in order to report at least a short term trend will depend on the sensitivity of the species to inter-annual fluctuations (generally much higher for annual species) but conceivably could include a minimum of three years of sampling within a ten year time frame. NatureServe's Conservation Status Assessments: Factors for Assessing Extinction Risk provides general guidelines for methods and rating values for short and long term changes (Master et al. 2009). As resources are unlikely to be available to track all special status species, a subset of the highest priority taxa would need to be identified for monitoring. Selection criteria for highest priority could be based on vulnerability rankings (CNPS Inventory or CNDDB rankings), rarity in the parks, or other social or ecological values. As a suggestion, a monitoring program that focused on the 30 CNPS 1B List taxa in the parks would be a good starting point. Focusing on CNPS 1B taxa has several advantages:

    1) Builds on existing data of special status plant population level monitoring (Norris and Brennan and Inventory and Monitoring Special Status Plant Surveys);
    2) Focuses monitoring on taxa that have highest vulnerability rankings (List 1B is the highest CNPS rarity ranking and the majority of List 1B taxa in SEKI are ranked by CNDDB's highest vulnerability rankings in the state of S1, critically imperiled or S2, imperiled);
    3) Includes nine of the 12 locally endemic taxa found in the parks. These taxa should be considered as high priority for monitoring as well, as they are extremely narrow in geographic range, highly vulnerable throughout their range (CNPS 1B, S1 to S2), and the parks provide a major refuge for these rare plant species.

2) *Increase comprehensive sampling in the parks to fill in data gaps for special status plant distribution.* We would suggest that the Natural Resource Inventory (NRI) plots provide the best template for this additional sampling. Gaps in the vegetation sampling include both a) broad areas without sampling visible in Figure 3b; and b) also smaller scale habitats that might be important for species on the list. Note, however, that there will be practical limitations to this effort. The large unsampled areas shown in Figure 3b are

difficult to access due to steep terrain and lack of trails and roads. As such, filling in some gaps may prove prohibitively expensive. Therefore, efforts would best be targeted, perhaps through the use of habitat modeling for species of interest.

3) *Establish a program to revisit comprehensive plots to track changes in vegetation through time.* This has broader applicability than special status plants, but such a program would certainly also be useful for establishing changes in special status plant richness and distribution throughout the parks. As with expanding the comprehensive sampling, we suggest that the NRI plots are the best target for re-sampling.

4) *Coordinate with the CNDDB.* It is important that SEKI, as well as Yosemite National Park and the surrounding US National Forests, consistently report special status plants observations to the CNDDB. In the long run, this will allow for better regional assessments as well as CNPS Inventory and the CNDDB imperilment rankings for rare species. National Forests in California have entered into a memorandum of understanding agreement with the CA Department of Fish and Game that formalizes a protocol for sharing USFS rare plant observations with the CNDDB. This level of coordination between the CNDDB and SEKI (as well as other NPS units in the region) could greatly benefit regional and species specific assessments that are conducted with CNDDB data.

5) *Conduct species specific research:* For those species identified as being of high priority, we recommend performing research to establish habitat requirements, the most important stressors, and the likely effects of climate change. Establishing the effect of grazing on sensitive plants that occur in meadows might be of particular interest. Also, information on non-vascular species, including both bryophytes and lichens, is very limited in the parks and a systematic survey targeting rare taxa is needed.

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### Datasets and files

1. SEKI Flora.mdb, includes the SEKI Vascular Plant Checklist and the SEKI Herbarium Holdings tables
2. SEKI Flora_metadata.doc
3. SEKI Special Status Plants.mdb
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6. SEKI bryophytes.xls (James Shevock's bryophyte collection records, provided by James Shevock, California Academy of Sciences Department of Biology, on July 7, 2010.
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8. Special Status Plant Species List-Yosemite 2005.mdb
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