Conservation Assessment for *Pinus albicaulis* (Whitebark Pine) on National Forest Lands in California with Management Considerations

Prepared by

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for the
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Cover Photo: Whitebark pine from the Thousand Lakes Wilderness, Lassen National Forest by Michael Kauffmann

Disclaimer: this Conservation Assessment with Management Considerations was compiled to synthesize the published and unpublished information on whitebark pine (*Pinus albicaulis),* a FWS Candidate species for listing under the Federal Endangered Species Act. It does not represent a management decision by the USDA Forest Service or any other federal agency. This document is based on information shared from all interested parties so the information is as complete as the data shared. Some information such as unpublished reports, data and publications in press were not available for this document. Although the best and most current scientific information available was used, it is expected that new information will arise.

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Whitebark Pine in California

EXECUTIVE SUMMARY

In the state of California, the habitat and ecology of whitebark pine (*Pinus albicaulis*) is unique due to the variety of ecological settings where this important tree species is found. The most extensive stands occur in high-elevation, open ridges and slopes of the central and southern portions of the Sierra Nevada mountain range. To the north, as the Sierra Nevada range transitions to the Cascade Range in Lassen County, whitebark pine occurs on volcanic summits from Lassen Volcanic National Park to Mount Shasta (the two largest stands in the Cascades) as well as on other summits of high elevation. Near the border of California to Nevada and Oregon, whitebark pine inhabits high elevations of the Great Basin into the Warner Mountains. Lastly, but importantly, are isolated stands of whitebark in the Klamath Mountains – these sky islands are scattered across the diverse geological landscape of northwest California. Because of this vast diversity in landscape and in scale, this status report explores the specific biology, ecology, distribution, of and threats to whitebark pine within the state of California.

In collaboration with US Forest Service, the California Native Plant Society Vegetation Program compiled existing ground-based datasets and references from agency staff, researchers, and others across California with a focus on the presence and impacts to whitebark pine. All current data are stored in a geodatabase for sharing with USFS and partners. We created GIS map displays of whitebark pine's range/extent and pest/pathogen occurrences (mountain pine beetle and white pine blister rust) across four regions and 12 national forests within California.

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Introduction

The purpose of this status report is to gather and summarize current published and unpublished information for whitebark pine (*Pinus albicaulis*) including, but not limited to: (1) general status, (2) species' biology and ecology, (3) population status and trends, (4) conservation status, and (5) management considerations. This project is funded by the USDA Forest Service's Pacific Southwest Region and, therefore, the scope of this assessment exclusively covers California lands. In collaboration with the USDOI Fish and Wildlife Service, USDOI National Park Service, the California Native Plant Society Vegetation Program, the California Department of Fish and Wildlife, and other partners, we include other information from California as much as possible.

Species Status

Pinus albicaulis is a candidate for federal listing but is precluded from full ESA recognition by higher priority listing activities (USFWS 2011). Whitebark pine was assigned a listing priority number (LPN) of 2, meaning the threats are of high magnitude and are imminent. The U.S. Forest Service listed whitebark pine on its Sensitive Species list in California in 2013 (Slaton et al. 2019b). Table 1 summarizes the various listing entities and current treatment and status of whitebark pine.

Table 1. Listing status of whitebark pine by entity.

State Listing	G-rank	S-rank	CRPR	R5 FSS	NFP SM	CA BLM
CA: Not listed NV: Not listed OR: Not listed	G3G4	CA: SNR NV: S3 OR: S3?	Not listed	Sensitive	Not listed	Not listed

SWAP: Not listed	**NNHP:** Track all extant and selected historical EOs	**NNPS:** Not listed	**ORBIC:** 4: Watch	**OCS:** Not listed	**IUCN:** Endangered (2011)

Note: Federally recognized Endangered, Threatened, Proposed, or Candidate species under the Endangered Species Act are omitted as they do not meet the definition of a Species of Conservation Concern (FSH 1909.12 § 12.52).

Expanded abbreviations and citations: State Listing=California Endangered Species Act Listing (CDFW 2018b), Nevada Division of Forestry Fully Protected Plant Species (NAC 527) (NDF 2012), Oregon Department of Agriculture Listed Plants (ODA 2014); G-rank=Global Conservation Status (CDFW 2018a; NatureServe 2018); S-rank=Subnational (state or province-level) Conservation Status (CDFW 2018a; NatureServe 2018; NNHP 2017; ORBIC 2016); CRPR=California Rare Plant Rank (CNPS 2018); R5 FSS=USDA Forest Service Region 5 Regional Forester Sensitive Plant Species List (USDA 2013); NFP SM=Forest Service and Bureau of Land Management Northwest Forest Plan Survey and Manage Species (USDA 2001); CA BLM=California Bureau of Land Management Designated Sensitive Species (BLM 2010); SWAP=California State Wildlife Action Plan Status (CDFW 2015); NNHP=Nevada Natural Heritage Program Status (NNHP 2017); NNPS=Nevada Native Plant Society Status (NNHP 2017); ORBIC=Oregon Biological Information Center Status (ORBIC 2016); OCS=Oregon Conservation Strategy Species (ODFW 2016); IUCN=International Union for Conservation of Nature Red List Status (IUCN 2017).

Biology & Ecology

Taxonomy

Five-needle white pines in the Family Pinaceae, Genus *Pinus*, Subgenus *Strobus* are foundational species from the lower montane belt to the upper subalpine and treeline forests of the Northern Hemisphere including California. This subgenus *Strobus,* also called white or soft pines, include about 45 species worldwide. In this subgenus, cone scales lack a sealing band, and the seed wing is articulate to strongly adnate. There is one leaf vascular bundle per needle and fascicles have 1-5 needles. Stomata are all or mostly on inner faces of the needle and resin ducts are medial or external ("Pinus (pine) Description - The Gymnosperm Database" n.d.). *Pinus* is one conifer genus that, despite its antiquity, shows evidence of ongoing speciation, making it a taxonomically complex group (Syring et al. 2005).

In California, six species in the Subgenus *Strobus* define a variety of habitats and vegetation types from the lower montane conifer belt to subalpine. Sugar pine (*Pinus lambertiana*) grow from 1,500-9,000 feet (300-2700m), western white pine (*P. monticola*) from 3,000'-9,000' (900-2700 m), limber pine (*P. flexilis*) from 4,000-11,500 feet (1200-3500 m), bristlecone pine (*P. longaeva*) from 7,500-11,500 feet (2200-3500 m), foxtail pine (*P. balfouriana*) 6,000-11,500 feet (1800-3500 m), and whitebark pine (*P. albicaulis*) from 6,000-13,800 feet (1800-4200 m). These species survive in a rough elevational progression, expressed in the dwindling size of morphological structures. On average, sugar pine prefers lower to middle elevations and have longer needles and cones, while western white pines live in the middle to upper elevations with cone and needle sizes intermediate in length. Whitebark and foxtail pine prefer the upper montane to subalpine and have small needles and cones. Limber and bristlecone pines survive in the more arid regions of southern and central California in the eastern part of the state (Kauffmann 2013).

From a distance, whitebark pine might be confused with lodgepole or western white pine. The bark is similar to that of lodgepole pine, but lodgepole has only two needles per bundle. The needles are similar to those of western white pine, but the whitebark form is bushier at the branch tips, cones are smaller and shorter, and the bark is less furrowed and blocky. Slaton et al. (2019) note that you can distinguish western white pine in the field with a hand lens by noting the fine serrations on its needle-like leaves; they also note that limber and whitebark pine are virtually indistinguishable, especially when young, before whitebark acquires its namesake color and develops mature cones.

Whitebark Pine Traits

Adapted from Jepson eFlora: http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=38254

Stem: generally prostrate to shrubby when exposed; trunks 1–many, < 26 m, < 1.5 m wide, much wider at base; mature bark gray-white, smooth, thin; mature crown often deformed by wind.

Leaf: 5 per bundle, 3–7 cm, ± curved, dark green, stiff; sheath deciduous.

Seed cone: sessile, erect, 3.5–9 cm, ovate, purple-brown, generally torn apart, seeds dispersed by animals; scale tip knobs angled, prickled.

Seed: wing persistent on scale, do not open at maturity.

Habitat: Upper red-fir forest to timberline, especially subalpine forest; 2000–3700 m. Klamath Ranges, High Cascade Range, High Sierra Nevada, Warner Mountains, East of Sierra Nevada; to British Columbia, Wyoming.

Similar Species: sugar pine (*Pinus lambertiana*), western white pine (*Pinus monticola*), limber pine (*Pinus flexilis*), foxtail pine (*Pinus balfouriana*), bristlecone pine (*Pinus longaeva*)

Distribution

Whitebark pine survives in the montane to timberline elevations in the Rocky Mountains (Alberta, British Columbia, Montana, Idaho and Wyoming), in the Coast Mountains of British Columbia, in the Cascade Mountains (California, Washington, and Oregon), the Klamath Mountains, the Sierra Nevada Mountains, and in a few isolated intermountain ranges of eastern California and Nevada (See Figure 1).

Within California, whitebark pine is found from 6,000-13,800 feet (1800-4200 m) in the Cascade, Warner, Klamath, and Sierra Nevada mountain ranges as outliers of the much broader range to the north. Figure 2 illustrates the predicted range of whitebark pine in California across four ecological regions.

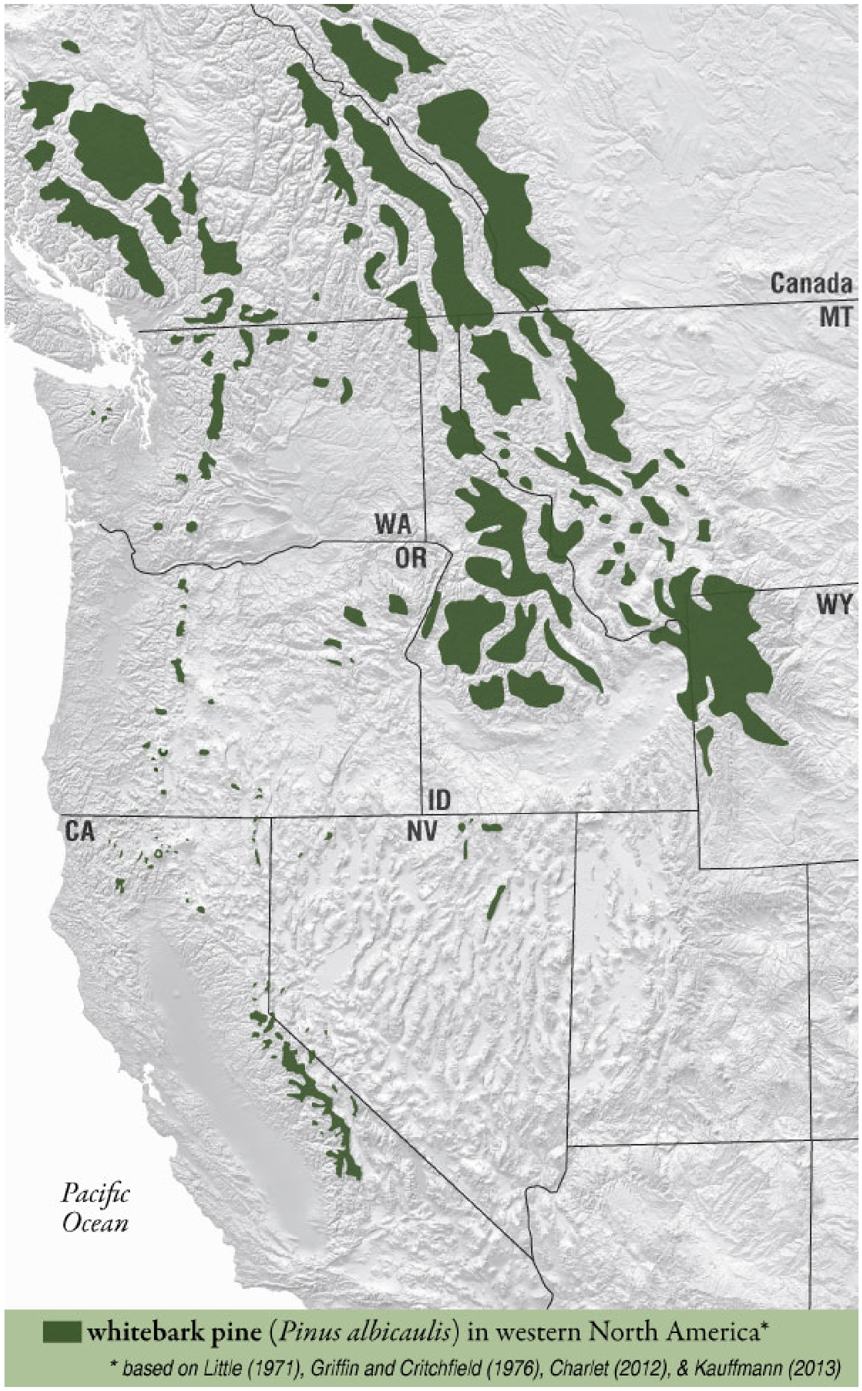


Figure 1. Western North American range map for whitebark pine (*Pinus albicaulis*).

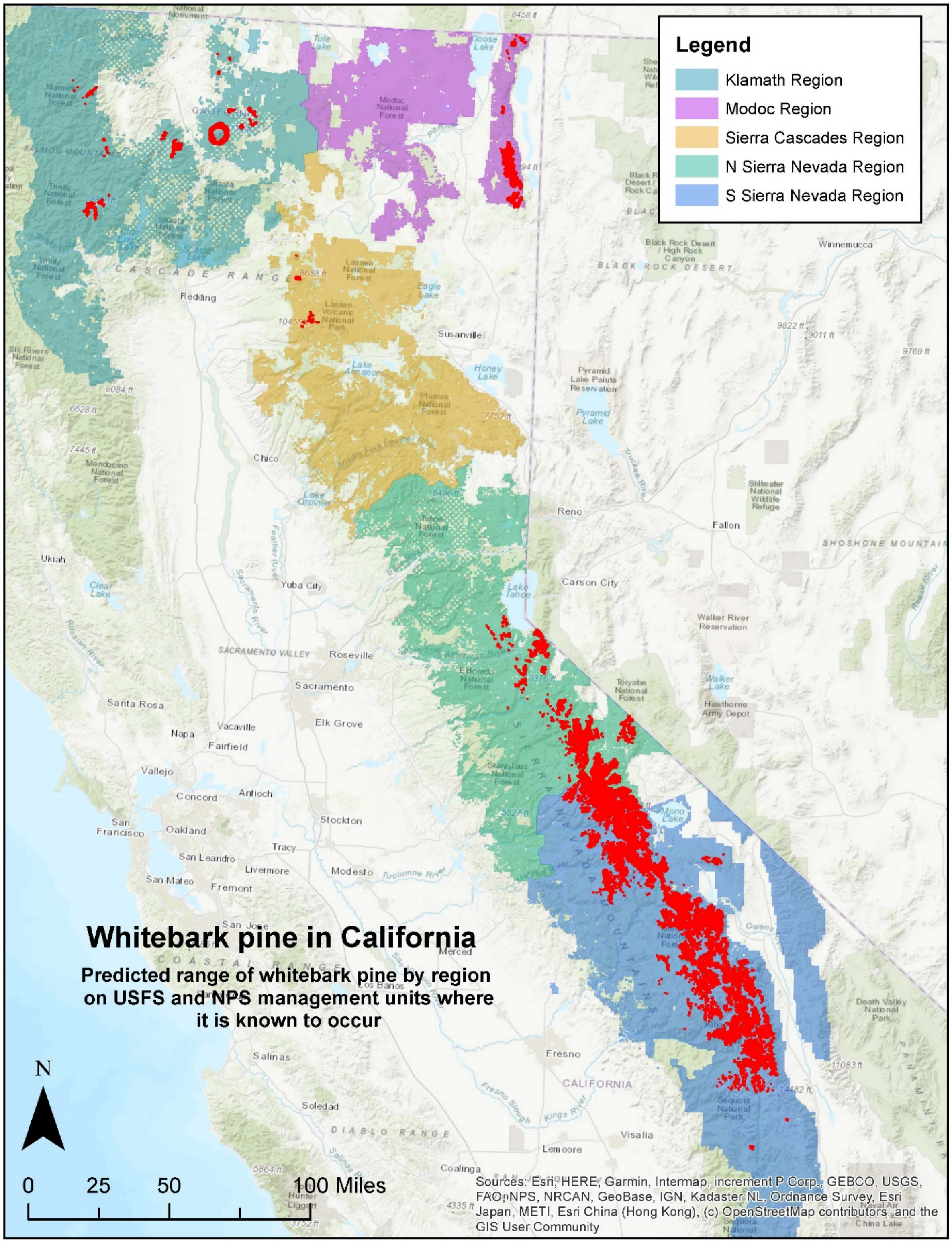


Figure 2. California predicted range map of whitebark pine (*Pinus albicaulis*) illustrated in red across four regions.

Of the approximately 378,693 acres (153,251 hectares) mapped by CNPS in 2019 where whitebark pine forms pure stands in California, >99% is on public land, often in remote wilderness settings of National Forest and National Park lands; however, the acreage of the whitebark pine's presence in mixed-stands across the state is much greater and has not been thoroughly mapped at this point. The majority of whitebark pine dominant stand occurrences are located within the National Forests in the Sierra Nevada Region (~83%). Less than 1% is found in the Sierra – Cascade Region, 8% in the Modoc Region, and 7% in the Klamath – Cascade Region (most of which is on Mount Shasta).

The majority of whitebark pines in California grow along the contiguous high-elevation crest of the Sierra Nevada, where they often form pure stands. Distribution in northern California is much more heterogeneous; sky islands supporting whitebark pine are relatively small in area and are broken up by vast river valleys. These islands in the sky include various volcanoes in the Cascades and isolated peaks in the geologically complex Klamath Mountains. The Warner Mountains offer homogeneous high elevation stands in the South Warner Wilderness, while whitebark pine stands in the northern Warners are more heterogeneously distributed across smaller, high elevation pockets.

Whitebark pine occurs in thin, rocky, cold, and weakly developed soils at or near the timberline. Soils often lack fine material. Historically, this species dominated much of the upper subalpine forests throughout the western United States. Krummholz (stunted windblown trees growing near the tree line on mountains) individuals' transition into alpine plant communities at the upper reaches of its elevation range and shift towards mixed-conifer forests lower in altitude. Much of whitebark pine's existing habitat was glaciated during the Pleistocene. Some of this habitat, range-wide, has been released from ice in the last 12,000 years (NatureServe 2018). Whitebark pine is an early colonizer of alpine and mountain meadow habitat, where it creates microsites for subalpine conifers and other understory vegetation (NRDC 2008).

Since the beginning of the Holocene (<10,000 years) the range of whitebark pine has been relatively static. However, a significant range expansion across the western landscape occurred in the late Pleistocene (Murray 2005). At that time, the species moved as climate changes cycled through periods of cooling and warming. In colder times, whitebark pines moved downslope from the Rockies and westward across the lower elevations of eastern Oregon, where they ultimately met the Cascades (Richardson 2002). As the climate warmed in the Holocene, pines moved upslope to where climatic extremes favored whitebark pine's cold-loving, shade-intolerant, and drought-tolerant traits. Now restricted to the highest mountaintops of the western cordilleras, the warming climate imposes geographic barriers to the expansion of this species.

Within California, whitebark pine prefers cold, windy, snowy, and generally moist zones. In the moist areas of the Klamath and Cascades, it is most abundant on the warmer and drier sites. In the more arid Warner Mountains and in the Sierra Nevada, the species prefers the cooler, more mesic north-facing slopes. However, some of these patterns are shifting. In the last 50 years, whitebark pines have been able to colonize novel habitat released by human-induced climatic changes including north-facing slopes that are now snow-free earlier in the year as well as lower elevations that have been subjected to browsing regimes by sheep—particularly in the Warner Mountains (Kauffmann et al. 2014).

White pines in general are experiencing declines across the West due to multiple factors including altered fire regimes, rapidly changing climate regimes, outbreaks of mountain pine beetle (*Dendroctonus ponderosae*), and the introduced pathogen *Cronartium ribicola* which causes white pine blister rust (Keane et al. 2017; van Mantgem et al. 2009). Whitebark pine has declined to such a severe extent in Canada that it is listed as endangered under the Canadian Species at Risk Act (Callison and Tindall 2017) and as a candidate species for protection under the U.S. Endangered Species Act (USFWS 2011).

Whitebark pine decline has been less severe in California for a variety of reasons, though limited research and monitoring has been systematically undertaken. High-elevation five-needle pines have been harbingers of climate change for millions of years and high-elevation ecosystems are often the first to register impacts of global climate change (Bunn et al. 2005). Thus, monitoring of high-elevation five-needle pine species is an important task in cataloging the leading edge of climatic shifts of vegetation.

Plant-Animal Interactions

Unlike other five-needle pines, the cone of whitebark pine does not open at maturity and its seed is "wingless" and rarely dispersed by wind. This is a characteristic of stone pines subsection (*Cembrae*) within the larger five-needle subgenus *Strobus* and whitebark pine is the only stone pine in North America. Whitebark pine relies on dispersion by squirrels or birds, primarily Clark's nutcrackers (*Nucifraga columbiana*) for seed distribution and future seedling recruitment (Arno and Hoff 1989, Tomback et al. 2001; See Figure 3). The birds open the cone, collect the seeds, and bury small caches in the soil; if not reclaimed, the seeds may germinate and grow. Because of this, regeneration is most often in clumps, a form which can be accentuated by the tendency of lower branches to become pressed horizontally against moist ground from snow and then grow upright. Stems that do reach tree size of greater than 3 inches (7.5 cm) in diameter at breast height are generally small compared to most other conifers, with height and diameter averaging 23 feet (7 m) and 8 inches (20 cm), respectively, in California (USFS, unpublished data).

Figure 3. Clark's nutcrackers and whitebark pine in the Trinity Alps Wilderness. Photo by Justin Garwood.

Over time, this relationship with Clark's nutcracker has developed into what is termed keystone mutualism (i.e., the two species are dependent on each other). Harry Hutchins estimated that individual nutcrackers in Wyoming made nearly 31,000 caches of three to four seeds per cache—ultimately burying close to 100,000 seeds per bird, per season (Lanner 1996). In Arizona, Stephen Vander Wall and Russell Balda estimated the combined caching ability for a flock of 150 jays to be several thousand seeds per acre, totaling nearly 4 million seeds per flock, with the combined nutritional value equivalent to 650 pounds of fat (Lanner 1996). Four pounds of fat per bird is significant nutrition for individuals weighing less than 5 ounces. Inevitably around 20% of the seed are unused or moved by other animals and, in the years following, clumps of whitebark pine saplings grow from these forgotten caches. During Kauffmann's 2013 surveys he found several unretrieved caches on mountain tops in the Trinity Alps (Packer's Peak, Seven

Up Peak). These young trees at maturity will extend the known range of this species in this region. Clearly, this mechanism of dispersal is important for both range expansion and genetic diversity across California.

Genetics

Given the decline of whitebark pine across much of its range, genetic diversity is of fundamental importance for conservation and restoration. Analyzing the whitebark pine genome allows for further study of population genetics, resistance genes, and other topics. California is the only region that does not currently have an active genetic restoration program for whitebark (Slaton et al. 2019b) so our local understanding is still quite limited.

Population genetics of whitebark pines is a significant area of research, given the wingless seeds are dispersed mainly via Clark's nutcracker caches. This mechanism promotes growth in clusters of closely related trees having progeny often inbred with heterozygote deficiencies (Jorgensen and Hamrick 1997, Krakowski et al. 2003). Jorgensen and Hamrick (2003) show, via allozyme loci, that whitebark pine populations in the Rocky and Sierra Nevada Mountains are more genetically diverse, or have a higher expected heterozygosity (H_e), than populations in the Cascade Range, possibly because populations in the Cascades are more isolated. Furthermore, between populations in the Rocky Mountains and Cascade Range, those in the south and east had greater observed heterozygosity than the north, which supports the theory that postglacial colonization occurred from the south to the north (Krakowski et al. 2003).

Krakowski (2003) also found that blister rust mortality was greater in the south, where there was less inbreeding and greater heterozygosity. Researchers stress that further study is needed to explore the correlation between inbreeding and blister rust resistance. Regarding conservation efforts in British Columbia, results suggest a focus on propagating blister rust-resistant individuals to spread resistance genotypes (Krakowski et al. 2003). Blister rust resistance and whitebark pine genetics research are also reviewed extensively by King et al. (2010). The body of research suggests that there are multiple means of spreading resistance, including hybridization. and breeding trees with partial or major gene resistance.

Two studies propose the use of single nucleotide polymorphisms (SNPs) and nuclear microsatellites (nSSRs), respectively, to study whitebark pine genetics. Liu et al. (2016) isolated the whitebark pine transcriptome and examined it for SNPs, of which they found 100,000. The researchers then focused in on 71 non-synonymous SNPs that provided information on genetic structure and phylogeny (Liu et al. 2016). The analysis of 371 individuals from British Columbia, Washington, and Oregon (close to California populations) found clear genetic differentiation among seed families and several genetic subgroups in whitebark pine breeding populations.

Interestingly, genetic components are associated with geographic variables including the homogeneity of the landscape and the scale with which this homogeneous landscape was pioneered at the end of the Pleistocene. Researchers also found that the mean heterozygosity in the genetic makeup was higher in western North American than in the inland West—probably due to the fact that, when compared to the inland West, western North American stands are smaller in scale due to the vast homogeneity of the high Rocky Mountains. These findings led to the hypothesis that, while more studies are needed, the differences could be due to isolation and adaptation to localized habitats and the southernmost, middle, and northernmost regions of the Cascades may be migrant fusion zones for post-glacial colonization events from glacial refugia. For California, this implies that genetic diversity, once analyzed, should be quite diverse, if not more diverse, than locations from the southern Oregon Cascades. This conclusion is based on the geographically isolated, complex, and varied landscapes whitebark pine inhabits across California.

In 2018, Lea et al. developed a method of genetic analysis by finding nSSRs for whitebark pines. 23 microsatellite loci were identified as polymorphic and useful to assess genetic diversity and were used to study two whitebark pine populations in the Greater Yellowstone Region. The researchers propose nSSRs to be a more efficient and less costly tool by which to analyze whitebark pine diversity, phylogeny, and identification of SNPs associated with specific traits.

At an eastern Sierra Nevada watershed level, Rogers et al. (1999) researched the fine-scale genetic structure of whitebark pine—again, of interest, because of their limited mobility and wind-pollinated fertilization mechanism. They found that whitebark pine had highly structured genetic variation especially within the natural groupings of both krummholz thickets and upright tree clumps. They also found only moderate differences in allele frequencies between growth forms. This suggests that nutcrackers may play a role in gene flow because gravity, wind, and phenological timing are not likely to support pollen or seed exchange between krummholz thickets and tree clumps.

Fire Ecology

Slaton et al. (2019) reiterates that fire plays an important role in the health and resilience of whitebark pine forests. Approximately every 70 to 90 years fires return in upright (non-krummholz) stands—although shorter fire return intervals have been documented in other high-elevation forest types (Murray and Siderius 2018, Meyer and North *in press*). With variability in both frequency and intensity, effects from fires are also variable. California's forests are experiencing shifts in fire severity, frequency, and extent due to warming temperatures, fire suppression, and human ignitions (Keeley and Syphard 2016). Again, more research and analysis are needed in California to understand the future of fire regimes in subalpine forests (Slaton et al 2019).

Fire suppression has encouraged the encroachment of shade-tolerant tree species into habitat originally occupied by whitebark pine. Fire exclusion at high elevations has led to successional replacement of whitebark pine with a variety of conifers in productive areas in some parts of its range. Burning eliminates competitive shade-tolerant trees, while encouraging open and complex habitat preferred for caching by Clark's nutcracker (Keane et al. 2012). In California, whitebark pine are encroached mainly by red fir and mountain hemlock in the northern part of the state. Other conifers less commonly encroaching whitebark pine habitat include white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*).

We are just beginning to learn about the extent of fire impacts on California's whitebark pine stands. Through sampling in 2013 and 2018, CNPS and Michael Kauffmann found evidence of fire, in the form of charred wood and burn scars, across the range of whitebark pine, though these impacts varied by region. The graph in Figure 4 shows that more than 50% of whitebark pine stands visited in the Modoc region showed evidence of fire impacts. This is significantly more than occurrences reported by Slaton et al. (2019), who indicate about 25% of 15 compiled plots sampled in the Warner mountains (part of the Modoc region) showed fire impacts with no impacts in the Cascade-Klamath range (n=26). Slaton et al. (2019) also compiled fire impact data across the Sierra Nevada (n= 189) with impacts as low as 1-2% in the central Sierra and up to 15% in the southern Sierras (Slaton et al. 2019b), thus there appears to be some variation based on sampling within the various regions. The 2014 Whites Fire occurred in high elevations of the Russian Wilderness in the western Klamath National Forest, burning small stands of whitebark pine in the subalpine forests along the ridge north of Russian Peak above Russian Creek (see Figure 5).

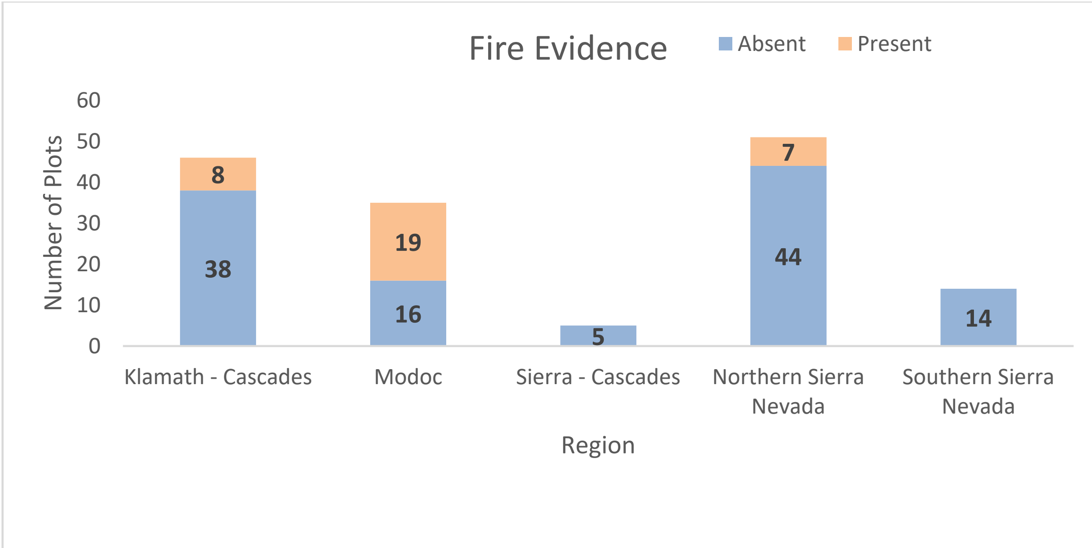


Figure 4. Fire evidence in whitebark pine stands across California by region, data was collected by CNPS and Michael Kauffmann in 2013 and 2018.

Figure 5. Burned whitebark pines in the 2014 Whites Fire, Russian Wilderness, Klamath National Forest. Photo by Melissa Desiervo.

Ethnobotany

Whitebark pines in the subalpine zones of the northern Rocky Mountains, Cascade Range, and Sierra Nevada Mountains have historically been used as a resource by the Native Americans and First Peoples in these regions (Fryer 2002). While the species was most commonly used as a food source other uses include materials and possibly medicine.

The cambium was eaten by Flathead, Shuswap, and Blackfoot peoples in Montana and British Columbia, but the most commonly consumed part of the tree were the seeds, or nuts (Kuhnlein and Turner 1991). The seeds were consumed by the Coeur d'Alene people of Idaho and the Nlaka'pamux (or Thompson), Spokane, Colville-Okanagan, Lillooet, Shuswap, Tsilhqot'in, Secwepemc, and Kootenay people of Washington and British Columbia (Kuhnlein and Turner 1991; Moerman 2010; Turner et al. 2011). Cones would be collected in late summer and fall, either by climbing or shaking trees. The cones were then either dried in the sun or roasted in a fire to allow for easy seed release and capture (Kuhnlein and Turner 1991).

The seeds were then eaten raw or roasted. Nlaka'pamux people also parched the seeds and ground them with a mortar and pestle to make flour, which was mixed with water or animal fat and eaten as a mush or porridge (Kuhnlein and Turner 1991, Moerman 2010). Roasted seeds, sometimes mixed with dried fruit, like Saskatoon berries or serviceberries, were often stored for later consumption in winter (Kuhnlein and Turner 1991, Moerman 2010). Some people believed eating too many raw seeds or eating seeds without added fat would cause constipation (Kuhnlein and Turner 1991, Moerman 2010). Seeds were also traded, as from the Upper to the Lower Nlaka'pamux people (Kuhnlein and Turner 1991).

Whitebark pine wood was used for fuel and its branches may have been used to line pits used to cook roots by the Tsilhqot'in people (Kuhnlein and Turner 1991, Moerman 1998). The pitch, seeds, and bark may have been used medicinally (Turner et al. 2011).

Regional and Vegetation Patterns

Various entities have attempted to map the distribution of whitebark pine across California. Table 2 displays the distribution of whitebark pine across various regions of California as mapped over time by different entities. Between 2018 and 2019, the USFS R5 Ecology program updated their CalVeg map product, after reviewing and incorporating edits from data collected by CNPS and USFS staff.

Table 2. Acreage of whitebark pine mapped in California by region through various entities. Brackets denote land ownership outside of National Forest lands.

REGION	MANAGEMENT UNIT	Griffin and Critchfield Acres (1976)	CALVEG Acres (1997-2016)	USFS Whitebark pine range map Acres (2018)	CNPS/USFS Whitebark pine range map Acres (2019)
Klamath – Cascades Region		**281,133**	**3,806**	**6,741**	**30,749**
	Klamath National Forest	110,831	149	1,014	10,427
	Shasta Trinity National Forest	146,618	3,598	5,098	20,276
	[Other land ownership]	23,684	59	629	45
Modoc Region		**187,660**	**5,254**	**27,443**	**32,927**
	Modoc National Forest	138,973	5,254	27,142	32,886
	[Other land ownership]	48,686	0	300	42
Sierra Cascades Region		**88,403**	**15**	**838**	**1,486**

REGION	MANAGEMENT UNIT	Griffin and Critchfield Acres (1976)	CALVEG Acres (1997-2016)	USFS Whitebark pine range map Acres (2018)	CNPS/USFS Whitebark pine range map Acres (2019)
	[Lassen Volcanic National Park]	22,198	15	746	563
	Lassen National Forest	12,832	0	84	924
	Plumas National Forest	30,479	0	0	0
	[Other land ownership]	22,894	0	8	0
Sierra Nevada Region		**2,609,181**	**135,737**	**333,472**	**313,531**
	[Devil's Postpile National Monument]	806	0	0	0
	Eldorado National Forest	103,298	286	892	1,523
	Humboldt-Toiyabe National Forest, within CA	235,449	14,355	46,440	45,109
	Inyo National Forest	374,378	39,002	137,702	125,936
	[Kings Canyon National Park]	391,315	31,988	44,977	44,388
	Lake Tahoe Basin Management Unit, within CA	12,076	1,251	9,578	9,617
	Sequoia National Forest	18,228	1,838	2,068	269
	[Sequoia National Park]	84,935	1,405	7,671	1,505
	Sierra National Forest	528,406	13,609	23,262	24,388
	Tahoe National Forest	232,696	0	0	0
	Stanislaus National Forest	30,798	234	3,266	3,692
	[Yosemite National Park]	520,759	31,768	54,876	56,414
	[Other land ownership]	76,037	0	2,739	691
Total Acres (in California)		**3,166,377**	**144,812**	**368,494**	**378,693**

California's Klamath Mountains

Klamath and Shasta-Trinity National Forests

In California's Klamath Mountains, whitebark pines are true summit trees that survive in only the highest subalpine conditions where they define the limits of timber line between 7,000-9,000 feet (2,000-2,700 m) on localized mountain tops, or sky islands. Trees are often sparingly scattered across xeric serpentine savannahs or take purchase in meager soil deposits between granite outcrops where centuries of slow growth are in strict compliance with the rigorous demands of sun, soil, water, and wind. In the lower extent of the range, whitebark pines form complex vegetation communities in peripheral areas—including edges of lakes or meadows where they are less likely to be impacted by competition from other species. Oregon's Klamath Mountains hold only one small, scattered collection of fewer than 10 trees near the summit of Mount Ashland.

Klamath National Forest:

In the Klamath National Forest, Michael Kauffmann surveyed and mapped whitebark pine in the summer of 2013 and 2018 within the Scott River Ranger District. He found that whitebark pine is inhabiting a variety of ecological niches based on climate, geography, geology, and the synergistic effects of competition from other species. In the Klamath Mountains west of Interstate-5, the range of elevations the species is 1,825-2,743 m (6,000-9,000 ft). This distribution is limited by the available habitat with landmass at an average elevation high enough to support the species. The highest peak in the Klamath National Forest is Caesar Peak at 8,920 feet (2,719 m).

Table 3. Largest stands of Klamath NF whitebark pine by area.

Stand	Area (ha)	Comments
Boulder Peak Ridgeline	486	This area is in the northeast corner of the Marble Mountains on mafic and ultramafic rocks. Boulder Peak is the high point at 8,299 ft (2,530 m). Stands here are generally on the south facing slopes in the lower elevations with hemlocks and firs dominating the north slopes. At the highest elevation foxtail mixes with whitebark pine on ridgelines and south-facing slopes with intermittent growth on north slopes. Blister rust is occurring at a low rate of detection and bark beetles are causing mortality in the 5-15% range on both pine species.
Caribou Mountain region	412	Similar to the Mount Hilton-Thompson Peak polygon in the Shasta-Trinity National Forest table below.
China Mountain	220	This mountain is made of mafic and ultramafic outcrops with stands of whitebark pine co-occurring with foxtail pines on south slopes with firs and hemlocks on north slopes. Small-scale bark beetle outbreaks are occurring across the ridgelines around China Mountain.

Klamath Mountain portion of the Shasta-Trinity National Forest

In the Shasta-Trinity National Forest, Kauffmann surveyed for and mapped whitebark pine in the Big Bar Ranger District. In the Klamath Mountains (west of Interstate-5) the species survives between 6,000-9,025 feet (1,829-2,750 m). The highest points in the Klamath Mountain range includes both Thompson Peak and Mount Eddy with nearly identical elevations of just over 9,000 feet (2,750 m). Across the Shasta-Trinity NF, whitebark pine are found on a variety of substrates including granite, mafic, and ultramafic.

Table 4. Largest stands of Shasta-Trinity NF whitebark pine by area.

Stand	Area (ha)	Comments
Mount Eddy	2,198	This region holds the highest point in the Klamath Mountains at Mount Eddy at 9,025 feet (2,735 m). It is entirely ultramafic and mafic in origin, so trees are often well spaced with low density. Foxtail pines co-occur.
Mount Hilton to Thompson Peak	1,365	This region holds the second highest point in the Klamath Mountains at Thompson Peak at 9,023 feet (2,734 m). It is entirely granitic in origin with large slabs of rock creating spatially restricted microsites where whitebark and foxtail pine grow sparsely in the eroded cracks between boulders and bedrock. This area is extremely steep and difficult to navigate on foot.
Sawtooth Peak Ridgeline	516	Similar to the Mount Hilton-Thompson Peak polygon.

General vegetation patterns in the Klamath Mountains

Because of the average lower elevation of Klamath Mountain whitebark pine stands compared to the rest of California, there are unusual distribution patterns that emerge. Most whitebark pine grows on south-facing slopes due to competition from firs and hemlocks on north-slopes. Because of complex soils, vegetation associates are diverse and often include endemic species from between subregions.

Tree associates here, within one of the most species-rich temperate conifers forests in the world, include Klamath foxtail pine (*Pinus balfouriana* subsp. *balfouriana*), western white pine (*Pinus monticola*), white fir (*Abies concolor*), Shasta fir (*Abies magnifica* var. *shastensis*), mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*), Common juniper (*Juniperus communis*), and Douglas-fir (*Pseudotsuga menziesii*). Rarely Brewer spruce (*Picea breweriana*) or Pacific yew (*Taxus brevifolia*) are found with whitebark pine. Unlike in California's Cascades, lodgepole pine (*Pinus contorta* ssp. *murrayana)* are uncommon associates in the Klamath Mountains. When present, white and Shasta fir, along with mountain hemlock, are typically seedlings or saplings that appear to be pioneering (encroaching) whitebark pine habitat in the last 50-100 years due to a combination of decreased snowpack, fire suppression, and a lengthening growing season.

Shrub associates on granites of the Trinity Alps and Salmon Mountains (Klamath sub-ranges) include western moss heather (*Cassiope mertensiana*), mahala mats (*Ceanothus prostrates*), tobacco brush (*Ceanothus velutinus*), Sierra laurel (*Leucothoe davisiae*), and huckleberry oak (*Quercus vacciniifolia*). In the eastern Klamath on the ancient ultramafics, understory associates include curl leaf mountain mahogany (*Cercocarpus ledifolius* var. *ledifolius*), Shrubby cinquefoil (*Dasiphora fruticosa*) rabbitbrush species including *Ericameria greenei, Ericameria nauseosa* var. *speciosa*, and *Ericameria parryi* var. *latior*, Oregon boxwood (*Paxistima myrsinites*), and Dwarf bilberry (*Vaccinium cespitosum*).

California's Cascade Range

In the Cascade Range, whitebark pine occurs in a narrow belt from the north-central part of California from the California-Oregon border east of Interstate-5 southward in small, disjunct populations on the summit of volcanoes to Lassen Volcanic National Park. Across the Cascades they grow at elevations between 7,500-12,000 feet (2,300-3,700 m). In the lower elevations, trees become quite large (2-4 foot DBH [0.5-1.2 m]) and tall (60-80 feet [18-24 m]). At the upper elevational limits, krummholz individuals approach true alpine on Mount Shasta and extreme subalpine on Mount Lassen. The only true alpine in California is on the summit of Mount Shasta.

Cascades portion of Shasta-Trinity and Klamath National Forests

In California's Cascades, whitebark pines occur on both forests with the largest population on Mount Shasta. North of Mount Shasta the species occurs above 7,000 feet (2,133 m) on the summits of volcanoes and along ridgelines between certain summits. In the Cascades (east of I-5) whitebark occurs between 6,500-8,500 feet (1,980-2,590 m). The upper elevational limits are restricted by the height of the peaks, except for the flanks of Mount Shasta where the trees range from 7,000-10,000 feet (2,135-3,000 m) where the species may be expanding upslope. Whitebark pine is reported on Black Butte (a satellite cone of Mt. Shasta) at 6,300 feet (1,920 m) (Griffin and Critchfield 1976).

Lassen National Forest and Lassen National Volcanic Park

In the Lassen area, there are three separate populations of whitebark pine, isolated on the highest peaks and subalpine landscapes where they range from approximately 7,000-10,000 feet (2,133-3,000m). One of these populations is located around the Lassen Peak highlands within Lassen Volcanic National Park, managed by the National Park Service. Two other populations occur in the Lassen National Forest. One is within the Thousand Lakes Wilderness around Magee and Crater Peaks. This stand occurs along the rim of the ancient Thousand Lakes Volcano which has since eroded away. The other is a scattered stand of approximately 40 trees across 15 acres on the summit of Burney Mountain.

While white pine blister rust is present at varying degrees across the three population centers, mortality by mountain pine beetles (MPB) is generally absent. The lack of MPB infestation might be explained by lower cover of lodgepole pine within these populations of whitebark (compared to more arid regions of the West) which could mitigate the vectoring of beetles into the area; whitebark pine often inhabited xeric ridgelines on south slopes rather than the north slopes; MPB have not yet "found" these trees in large numbers.

General vegetation patterns in the Cascades

Whitebark pine occurs with other conifers including white fir (*Abies concolor*), Shasta fir (*Abies magnifica* var. *shastensis*), mountain hemlock (*Tsuga mertensiana*), lodgepole pine (*Pinus contorta* subsp. *murrayana*), and western white pine (*Pinus monticola*). Mountain hemlocks (*Tsuga mertensiana*) are commonly either pioneering or encroaching within, or adjacent to, stands of whitebark pine. This pattern is easily seen in Lassen Volcanic National Park along the Bumpass Hell Trail. In the swales carved out by erosion, decreased snowpack (and early season melting) has led to novel habitat in which hemlocks are rapidly pioneering. This is allowing encroachment into whitebark pine habitat on the ridges above these swales.

Another interesting pattern seen in the upper reaches of treeline on Mount Shasta is the ecological release whitebark pines are experiencing. Formerly krummholz trees are now sending out leaders skyward. This is most likely occurring due to decreased snowpack and early season melting. With the ability to explore a longer growing season, krummholz whitebark pine are becoming upright trees.

Common shrubs include Rocky Mountain maple (*Acer glabrum* var. *glabrum*), pine mat manzanita (*Arctostaphylos nevadensis*), greenleaf manzanita (*Arctostapylos patula*), mahala mats (*Ceanothus prostratus*), and tobacco brush (*Ceanothus velutinus*), Sierra chinquapin (*Chrysolepis sempervirens*), rubber rabbitbrush (*Ericameria nauseosa* var. *speciosa*), marum leaved buckwheat (*Eriogonum marifolium*), and Western blueberry (*Vaccinium uliginosum* ssp. *occidentale*)

California's Warner Mountains

Modoc National Forest

In northern California's Great Basin, whitebark pine only occurs in the Warner Mountains. This fault block range runs north to south for approximately 80 miles (180 km). The highest average elevation is in the south, mostly protected within the South Warner Wilderness. North of Highway 299, small stands of whitebark pine persist sporadically, with the largest stands near the Oregon border along Mount Bidwell's extensive ridgeline.

Northern Warner Mountains

This area, between Mount Vida (8,240 ft) north to Mount Bidwell (8,266 ft), hosts scattered stands of whitebark pine. Large swaths of conifers, including lodgepole, western white, and whitebark pine, were devastated by mountain pine beetles in the mid- to late-2000s. While many of the larger trees died, sapling and seedling regeneration is vigorous, and the short-term future of pines appears promising.

Central Warner Mountains

The small populations of whitebark pine in the central Warner Mountains exhibit excellent health on and around Bald Mountain (8,274 feet) and Cedar Mountain (8,152 feet). Stand size is small, and the trees are geographically isolated, thus, bark beetles were not present during the outbreaks between 2005-2009.

South Warner Wilderness

Large and extensive stands of whitebark pine exist in the southern Warner Mountains. Much of this is protected within the South Warner Wilderness highlighted by Eagle Peak (9,892 feet). Across this high elevation escarpment whitebark pine dominates the highest elevations and mixes with lodgepole pine in the mid- to upper elevations. Large pockets of lodgepole pine and smaller pockets of whitebark were killed by mountain pine beetles in the 2005-2009 outbreak. North-facing slopes of the highest elevations are being pioneered by young seedlings due to decreased snowpack. The seedlings began recruiting 20-40 years ago and are rapidly expanding in this novel environment.

A smaller, somewhat disjunct stand defines the southern limit of whitebark in the Warner Mountains around Emerson Peak (8,989 feet). Whitebark pine is common here on north-facing slopes where patterns of beetle mortality and recruitment are similar to that seen in the Northern Warner Mountains near Mount Bidwell. The species is expanding into the lower elevations in grazed areas most likely due to decreased competition from shrubs which are consumed by herds of grazing sheep.

General vegetation patterns in the Warner Mountains

Conifer associates include white fir (*Abies concolor*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta),* and the rare mountain hemlock *(Tsuga mertensiana).* Common shrubs include pine mat manzanita (*Arctostaphylos nevadensis*), low sagebrush (*Artemisia arbuscula* ssp. *arbuscula*), mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*), Rayless goldenbush (*Ericameria discoidea*), Greene's goldenbush (*Ericameria greenei*), Rock spiraea (*Holodiscus discolor* var. *glabrescens*), Tobacco brush (*Ceanothus velutinus*), antelope bush (*Purshia tridentata*), snowberry (*Symphoricarpos rotundifolius*), and others.

California's Sierra Nevada

Northern forests of the Sierra Nevada: Stanislaus, Eldorado and Tahoe National Forests including the Lake Tahoe Basin Management Unit

From the high country of Yosemite National Park and Humboldt-Toiyabe National Forest, whitebark pine extends northwards to Freel Peak with patchy occurrences north and west of Lake Tahoe, becoming more disjunct to the north and at lower elevations.

In the northern portion of the Sierra Nevada, whitebark pine is presumed present on approximately 47,000 acres across an elevation range of 7,200 to 11,400 feet (2,200 - 3,500 m) with an average elevation of 9,500 feet (2,900 m).

General vegetation patterns in the Northern Sierra Nevada

In Northern Sierra forests, whitebark pine is often found with lodgepole pine (*Pinus contorta* ssp. *murrayana*), mountain hemlock (*Tsuga mertensiana*), red fir (*Abies magnifica*), and western white pine (*Pinus monticola*). It occasionally co-occurs with Jeffrey pine (*P. jeffreyi*), Sierra juniper (*Juniperus grandis*), and quaking aspen (*Populus tremuloides*).

Common shrubs include sagebrush (*Artemisia tridentata*), ocean spray (*Holodiscus discolor*), wax currant (*Ribes cereum*) and mountain currant (*Ribes montigenum*), mountain snowberry (*Symphoricarpos rotundifolius*), low sagebrush (*Artemisia arbuscula*), and interior goldenbush (*Ericameria linearifolia*). Herbaceous species include native grasses such as subalpine fescue (*Festuca viridula*), squirreltail grass (*Elymus elymoides*), and Bolander's bluegrass (*Poa bolanderi*) that intermix with common perennial forbs like woolly mule's ears (*Wyethia mollis*), mountain monardella (*Monardella odoratissima*), spreading phlox (*Phlox diffusa*), and white stemmed lupine (*Lupinus albicaulis*).

Southern forests of the Sierra Nevada: Sequoia, Sierra, and Inyo National Forests

The southernmost known location of whitebark pine within California is found around Coyote Peaks of Sequoia National Park and Sequoia National Forest. Distribution of whitebark pine continues north in scattered patches on mountain tops. Around the Kings Kern Divide, whitebark pine occurs continuously across the peaks and ridges of the Sierra crest through Yosemite National Park.

The largest stands of whitebark pine in California exist in the southern portion of the Sierra Nevada where average elevation is much higher than other parts of the state. Whitebark pine is estimated to be present on 266,400 acres. This acreage spans elevations ranging from 7,150 to 13,500 feet (2,200 - 4,120 m) with an average elevation of 10,430 feet (3,180 m).

General vegetation patterns in the Southern Sierra Nevada

In the Southern Sierra forests, whitebark pine commonly co-occurs with other pines and conifers such as lodgepole pine (*Pinus contorta* ssp. *murrayana*), mountain hemlock (*Tsuga mertensiana*) and foxtail pine (*P. balfouriana*), and occasionally with Jeffrey pine (*P. jeffreyi*), limber pine (*P. flexilis*), western white pine (*P. monticola*), or Sierra juniper (*Juniperus grandis*). In wetter areas, whitebark grows alongside broadleaf trees such as quaking aspen (*Populus tremuloides*).

Shrub cover can be variable but commonly found species include granite prickly phlox (*Linanthus pungens*), Brewer's mountain heather (*Phyllodoce breweri*), ocean spray (*Holodiscus discolor*), wax currant (*Ribes cereum*), dwarf bilberry (*Vaccinium cespitosum*), shrubby willows (*Salix* spp.), shrubby cinquefoil (*Dasiphora fruticosa*), and Sierra chinquapin (*Chrysolepis sempervirens*). Commonly found herbaceous species such as frosted buckwheat (*Eriogonum incanum*), rosy everlasting (*Antennaria rosea*), Sierra penstemon (*Penstemon heterodoxus*), and mountain pride (*P. newberryi*), are often intermixed with perennial graminoids like shorthair sedge (*Carex filifolia*), Parry's rush (*Juncus parryi*), western needlegrass (*Achnatherum occidentale*), and squirreltail grass (*Elymus elymoides*) in whitebark pine forests and woodlands.

Classification of whitebark pine vegetation

Using accessible floristic data on stands containing whitebark pine (n=400), CNPS developed a draft vegetation classification of whitebark pine communities. Stands dominated by whitebark pine have been categorized into at least seven associations under the *Pinus albicaulis* alliance (See Table 5). A selection of available species abundance and composition data with presence of whitebark pine were compiled comprising 404 California plots with 407 taxa. A general relativization of species cover by plot was performed (total cover in plot = 1) and taxa with 2 or fewer occurrences in the plot data were removed. A total of 23 plots were removed before cluster analysis because they were outliers based on their species composition and abundance. A cluster analysis was run on 381 plots with 204 total taxa, these were broken into 11 groups based on the number of significant indicator species and average p values. For more details about classification methods used by the CNPS Vegetation Program see Kauffman et al. (2017).

Whitebark pine also can be found as a minor component in aspen groves (*Populus tremuloides*) and in other conifer types including vegetation alliances of white and red fir (*Abies concolor, A. magnifica*), juniper (*Juniperus grandis*), numerous pines (*Pinus balfouriana, P. contorta* ssp. *murrayana*, P. flexilis, P. monticola) as well as mountain hemlock (*Tsuga mertensiana*). Scattered whitebark pine may emerge over high-elevation chaparral dominated by manzanita (*Arctostaphylos nevadensis*) or bush chinquapin (*Chrysolepis sempervirens*) and in shrubby wet areas characterized by purple mountain heath (*Phyllodoce breweri*), willows (*Salix petrophila, S. planifolia*) and dwarf bilberry (*Vaccinium cespitosum*). Whitebark pine also occurs intermittently over rocky and sparse herbaceous sedge stands (*Carex filifolia, C. helleri*), rush outcrops (*Juncus parryi*), and mountain sorrel patches (*Oxyria digyna*).

Table 5. Classification of vegetation containing whitebark pine at 1% absolute cover or greater (where whitebark pine canopy is estimated to cover at least 1% of the ground from a bird's eye view).

Life form	Alliance	Association	Klamath - Cascades	Modoc	Sierra - Cascades	Northern Sierra Nevada	Southern Sierra Nevada
Tree							
	Abies concolor	*Abies concolor alliance*	2				
	Abies magnifica	*Abies magnifica*			1		
		Abies magnifica – Pinus monticola				1	
		Abies magnifica – Pinus monticola / Arctostaphylos nevadensis	1				
		Abies magnifica – Tsuga mertensiana / Orthilia secunda	2				
		Abies magnifica / Arctostaphylos nevadensis	1				
		Abies magnifica alliance	1		1		
	Abies magnifica – Abies concolor	*Abies magnifica – Abies concolor alliance*	1				
	Juniperus grandis	*Juniperus grandis*					1
	Pinus albicaulis	*Pinus albicaulis – Tsuga mertensiana*	12		3	11	11
		Pinus albicaulis / Artemisia tridentata ssp. *vaseyana*	2	9		4	
		Pinus albicaulis / Carex filifolia					24
		Pinus albicaulis / Carex rossii					24
		Pinus albicaulis / Holodiscus discolor	8	1	3	5	12
		Pinus albicaulis / Penstemon davidsonii					6
		Pinus albicaulis alliance	5	13	3	48	19
		Pinus contorta ssp. *murrayana – Pinus albicaulis – Carex (filifolia, rossii)*	4	4		11	30
	Pinus balfouriana	*Pinus balfouriana*					1
		Pinus balfouriana – Pinus albicaulis	1				15
		Pinus balfouriana alliance					1
	Pinus contorta ssp. *murrayana*	*Pinus contorta* ssp. *murrayana*					1
		Pinus contorta ssp. *murrayana / Carex filifolia*					6
		Pinus contorta ssp. *murrayana / Carex rossii*					1

Life form	Alliance	Association	Klamath - Cascades	Modoc	Sierra - Cascades	Northern Sierra Nevada	Southern Sierra Nevada
		Pinus contorta ssp. *murrayana alliance*		1		1	
	Pinus flexilis	*Pinus flexilis – Pinus contorta* ssp. *murrayana*					1
		Pinus flexilis / Artemisia tridentata					1
	Pinus monticola	*Pinus monticola – Pinus contorta* ssp. *murrayana*		1			
		Pinus monticola / Angelica arguta		1			
		Pinus monticola alliance		2			
	Populus tremuloides	*Populus tremuloides – Pinus contorta / Artemisia tridentata / Poa pratensis*					1
		Populus tremuloides alliance		1			
	Tsuga mertensiana	*Tsuga mertensiana*			1		
		Tsuga mertensiana – Pinus contorta ssp. *murrayana*				2	2
		Tsuga mertensiana – Pinus monticola	1			1	
		Tsuga mertensiana / Arnica cordifolia	1				
		Tsuga mertensiana alliance	2			1	3
Shrub							
	Arctostaphylos patula – Arctostaphylos nevadensis	*Arctostaphylos nevadensis*	1		1		1
	Chrysolepis sempervirens	*Chrysolepis sempervirens* alliance			1		
	Phyllodoce breweri	*Phyllodoce breweri – Juncus parryi*					2
		Phyllodoce breweri – Vaccinium cespitosum					2
		Phyllodoce breweri alliance				1	
	Phyllodoce empetriformis	*Phyllodoce empetriformis* alliance	1				
	Salix petrophila	*Salix petrophila*					1
	Salix planifolia	*Salix planifolia*					1
	Vaccinium cespitosum	*Vaccinium cespitosum – Carex filifolia*					1

Life form	Alliance	Association	Klamath - Cascades	Modoc	Sierra - Cascades	Northern Sierra Nevada	Southern Sierra Nevada
Herb							
	Carex filifolia	*Carex filifolia – Erigeron algidus*					1
	Carex helleri	*Carex helleri – Eriogonum incanum – Raillardella argentea*					1
	Juncus parryi	*Juncus parryi – Eriogonum incanum*					1
		Juncus parryi alliance					1
	Oxyria digyna	*Oxyria digyna alliance*					1

Threats

The USFWS designated whitebark pine as a candidate for listing under the Endangered Species Act in 2011 due to a suite of factors, including altered fire regimes; the introduced pathogen, white pine blister rust (*Cronartium ribicola*); mountain pine beetle (*Dendroctonus ponderosae*); and climate change (Tomback and Achuff 2010, USFWS 2011, Slaton et al. 2019b). Decimation of populations in the northern Rocky Mountains led Canada's listing the species as an endangered species in 2010. The current and potential loss of this keystone species in the high mountains of California poses serious threats to biodiversity and losses of ecosystem services, because whitebark pine is one of only a few tree species in these unique settings.

Additionally, researchers are finding that incidence of mountain pine beetle is episodic over time, including an increase between 1994 and 2012 in the Warner Mountains (Figura 2014) and a decrease between 2014 and 2017 in Lassen Volcanic National Park (Smith 2017). However, factors causing mortality are variable but include beetle infestation and blister rust infection, respectively, in these two study areas. In monitoring between 2012 and 2017 in the Sierra Nevada at Yosemite, Sequoia, and Kings Canyon National Parks, researchers found very little mortality by either pine beetle infestation or blister rust infection (Nesmith et al. 2019). By continuing to monitor and evaluate trends, researchers and land managers will gain a better understanding of blister rust dynamics and infection through time, since impacts appear to have complex interaction over time, and monitoring will enable land managers to evaluate and ensure persistence of whitebark pine over time.

Mountain Pine Beetles (MPB)

The native mountain pine beetle (*Dendroctonus ponderosae*) has co-evolved with western pine forests for millennia. Infestations generally fluctuate through forests with mortality events followed by cleansing fire regime events. Mountain pine beetles are considered an important agent of disturbance in maintaining structural and compositional diversity of conifer forests (Weed et al. 2015). More recently, mass beetle infestations have been correlated with increased climatic warming (Mock et al. 2007). A warming climate is particularly impactful in the more xeric regions of the state where whitebark pine often grow near lodgepole pine (Cluck 2010). Mountain pine beetles require sufficient thermal input to complete their life cycle in one season, historically, high elevation ecosystems have not met these needs. However, due to recent warming trends, conditions are frequently adequate at high elevations to complete the beetle's life cycle, and infestations of whitebark pine are becoming increasingly common (Logan and Powell 2001). The preponderance of mass infestations at high elevations has been witnessed throughout California—especially in the arid Warner mountains and eastern Sierra Nevada mountains.

Forest Service data collection in 196 plots across the state from 2014 through 2018 indicate that mountain pine beetles are impacting 9% of whitebark pine trees (Slaton et al. 2019b) through induced crown mortality. Many trees with symptoms of past attack have survived, though the chance of survival varies by region. Upon compiling data from CNPS, NPS, Maloney et al. 2012 and other sources, data collection in 352 plots/samples across the state from 2013 through 2018 indicate that mountain pine beetles are impacting 54.5% of whitebark pine trees. Also, see Figure 6 which illustrates the incidence of mountain pine beetle across five geographic regions of California (Klamath – Cascades, Modoc, Sierra – Cascades, Northern Sierra Nevada, and Southern Sierra Nevada). This data compilation shows that the Sierra-Cascades and the Klamath-Cascades have fewer impacts from mountain pine beetle (14% and 29% respectively) than the Modoc and Sierra Nevada (60% or greater).

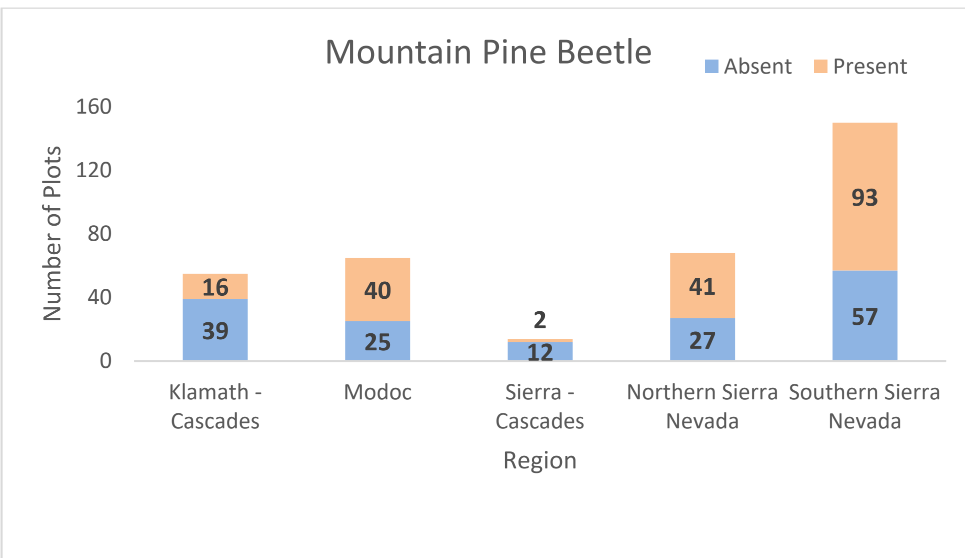


Figure 6. Detection of Mountain Pine Beetle in stands of whitebark pine across 5 regions of California, data was compiled from CNPS, NPS, Maloney et al. 2012 and other sources.

White Pine Blister Rust (WPBR)

In addition to native insects, a non-native fungal pathogen is affecting high elevation forests. In 1910, white pine blister rust (*Cronartium ribicola*) arrived in a British Columbia port and by 1930 had spread to southern Oregon, infecting western white pine (*Pinus monticola*) and sugar pine (*Pinus lambertiana*) along the way (Murray 2005). White pine blister rust requires a *Ribes* spp. as an alternate host with pines in order to complete its lifecycle. In late summer, spores from *Cronartium ribicola* are blown from the *Ribes* host and then enter 5-needle pines through stomata. Upon successful entry, hyphae grow, spread through the phloem, then ultimately swell and kill tissue above the site of infection.

Infected trees can survive for over 10 years, but infections tend to inhibit reproduction (Murray 2005). For species like whitebark pine, which live in fringe habitats and often delay reproductive events until conditions are optimal, infections that further inhibit cone production are extremely detrimental. White pine blister rust is found on foxtail and whitebark pines in northwest California (Maloy 2001) where variability in microsite infestation occurs (Ettl 2007). All five-needle native western pines have shown some heritable resistance in the past 100 years (Schoettle et al. 2007), but enduring an infection works against a long-lived pine's survival strategy.

White pine blister rust infection (and mortality from blister rust) is more prevalent in the cooler and wetter mountains of the Klamath and Cascades range and decreases in prevalence moving southward as the landscape becomes more xeric. Within the Sierra Nevada-Cascade Region, blister rust occurrence and severity generally decline from north to south. For example, in Lassen National Park, Jules et al. (2017) found an average infection rate of 54% on whitebark pine. Maloney et al. (2012) found that, on average, 35% of individual whitebark pine trees showed symptoms of infection in the Tahoe basin, while Nesmith et al. (2019) and Dudney et al. (unpublished data) estimate that less than 1% of individual trees in the southern Sierra Nevada are infected. This trend is likely due to a combination of factors, including the relatively recent arrival of blister rust in the southern part of California and the Sierra Nevada's relatively hot and dry climate. CNPS surveys in 2013 and 2018 detected white pine blister rust mortality in the Eldorado NF of the northern Sierra Nevada mountains and while blister rust was detected in scattered locations down to the southern extent of the Inyo National Forest, very little mortality was found.

The graphs in Figure 7 show that in 429 plots across the state from 2013 to 2018 indicate that white pine blister rust is impacting 45.2% of whitebark pine trees in the state, and more specifically that the southern Sierra Nevada region has much less incidence of this impact (18.7%) as compared to areas north such as the Sierra – Cascades (85%).

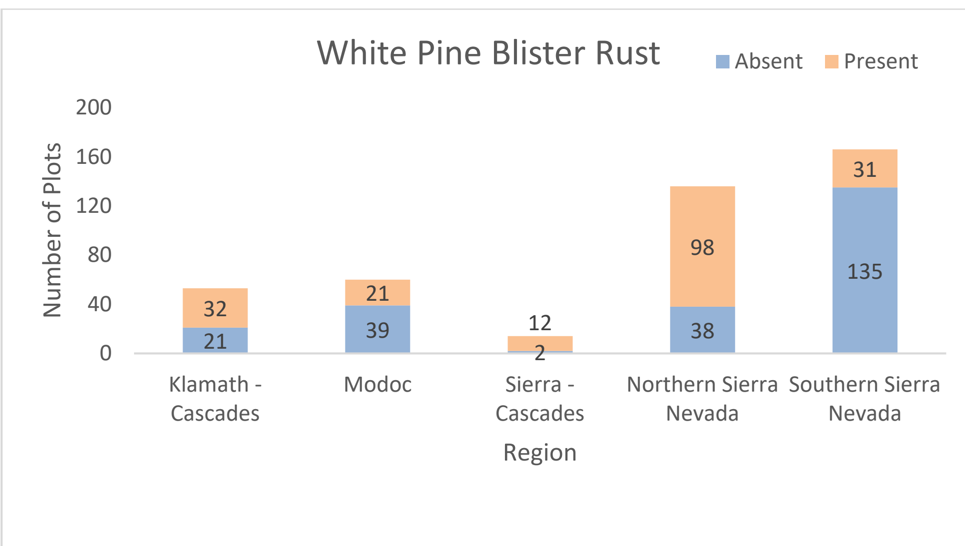
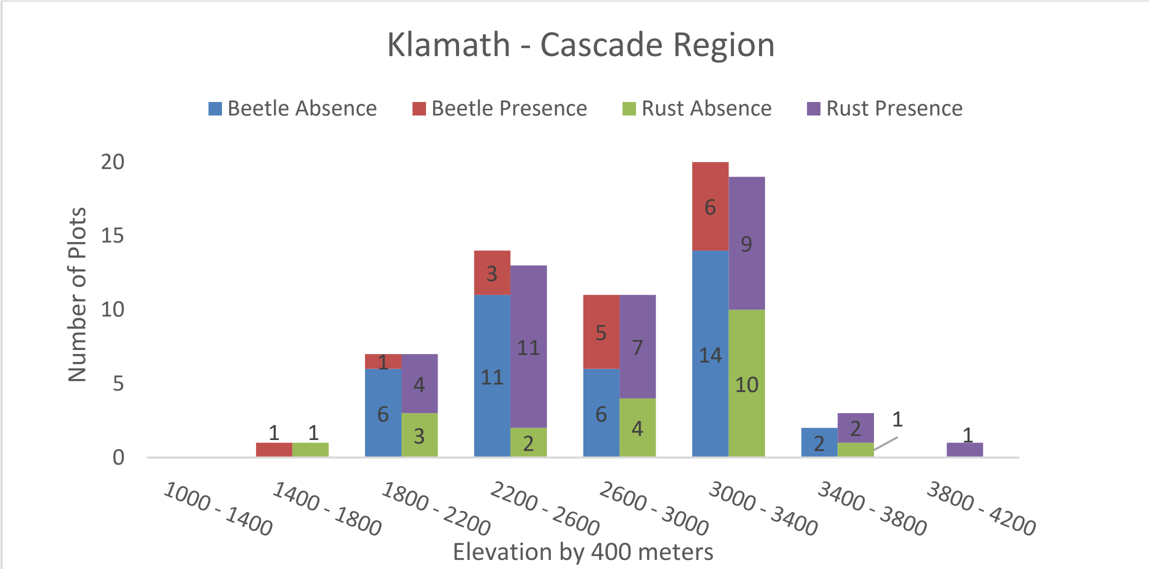
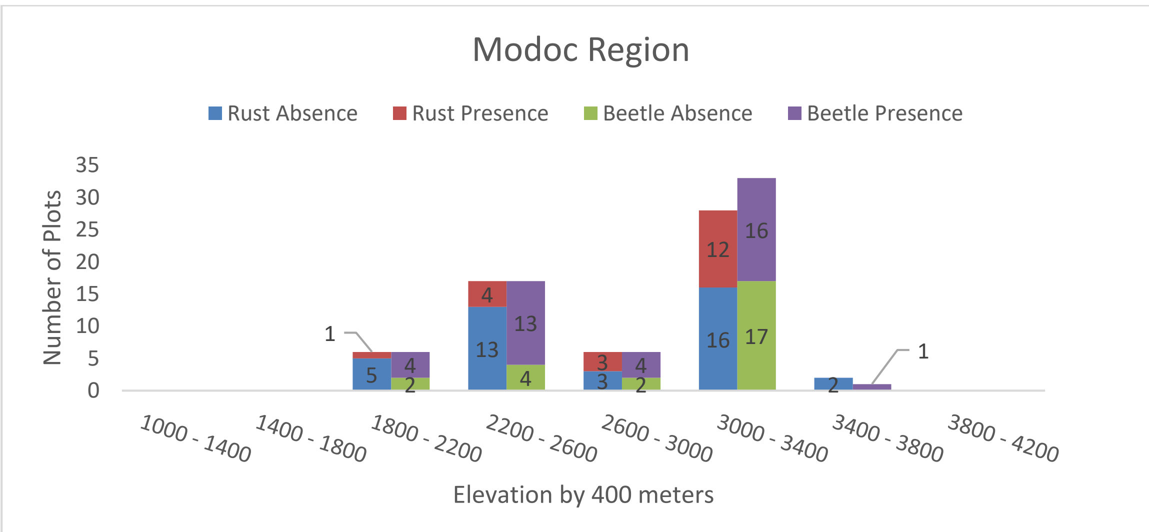


Figure 7. Detection of White Pine Blister Rust in stands of whitebark pine across 5 regions of California, data was compiled from CNPS, NPS, Maloney, et al. 2012 and other sources.

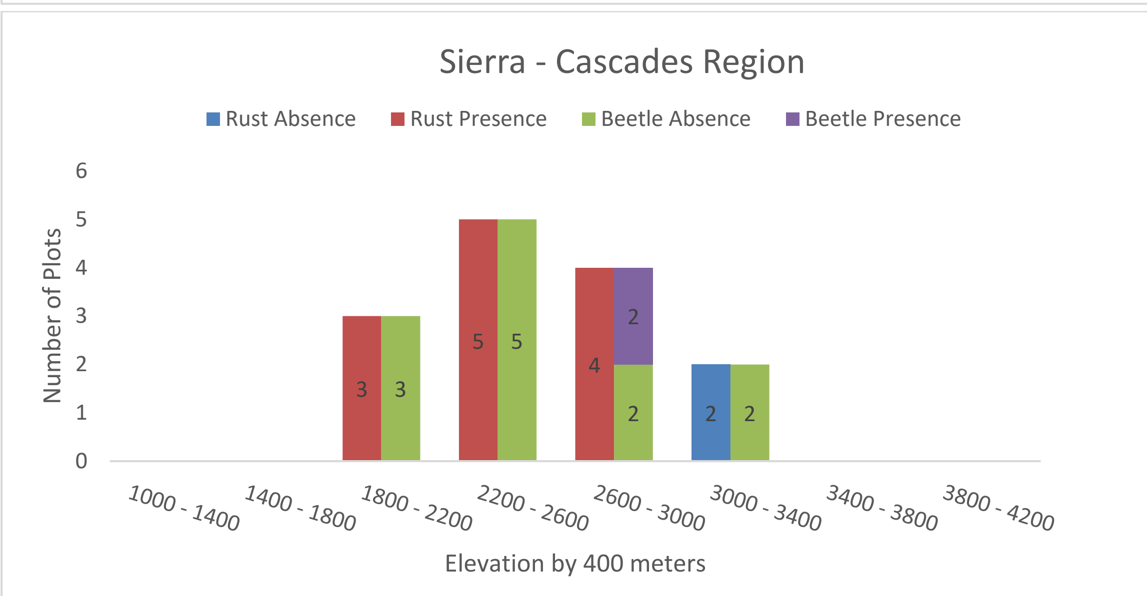
Additionally, see graphs in Figure 8 that show more specific field-observed presence of health impacts on whitebark pine trees in the five geographic regions across California. Health impacts (presence/absence of whitebark pine rust and mountain pine beetle) were summed across 400-meter elevation bands and marked as present or absent. There is some variation by region, but broadly each region tends to have higher incidences of disturbance presence at the middle of the elevation range (3000 – 3400 m), and lower at the leading and tailing edge of the elevation range. The regions were not evenly sampled with the Sierra – Cascades region having the lowest number of surveys overall (28), and the Northern Sierra Nevada region (316) having the highest number of surveys.



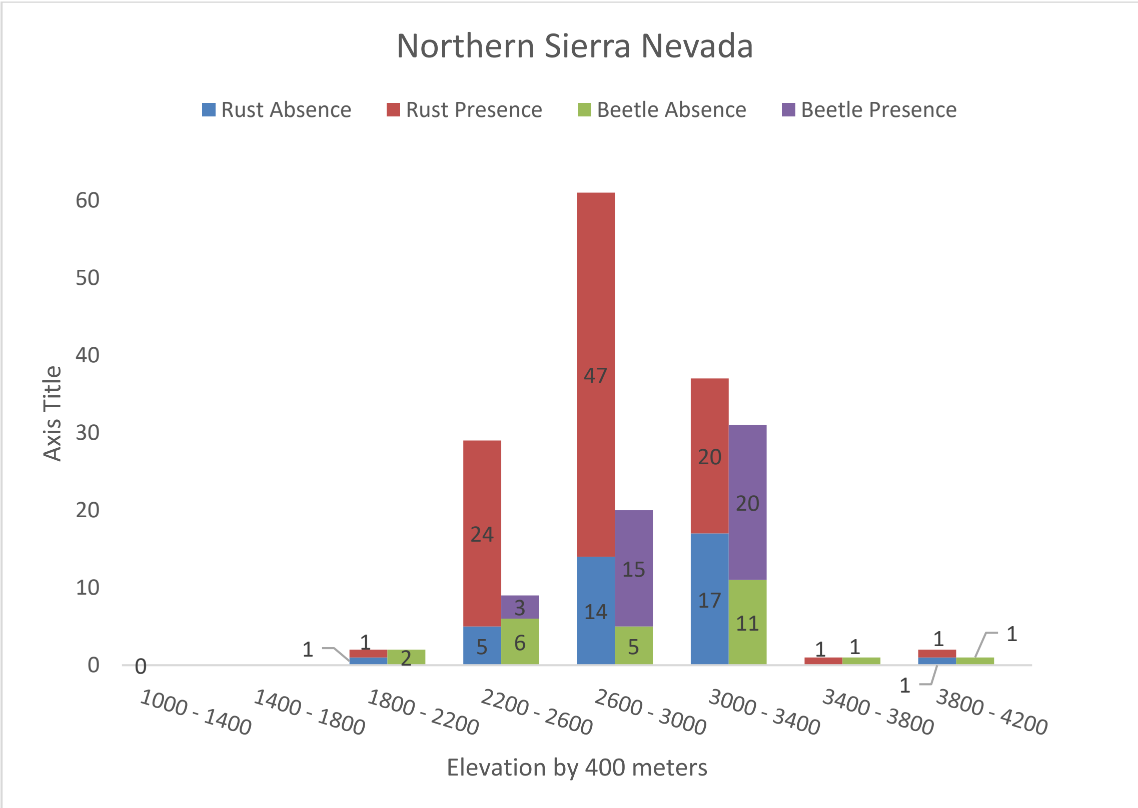
Klamath - Cascade Region
Beetle Absence
Beetle Presence
Rust Absence
Rust Presence
Number of Plots
20
15
10
5
0
1000 - 1400
1400 - 1800
1800 - 2200
2200 - 2600
2600 - 3000
3000 - 3400
3400 - 3800
3800 - 4200
Elevation by 400 meters



Modoc Region
Rust Absence
Rust Presence
Beetle Absence
Beetle Presence
Number of Plots
35
30
25
20
15
10
5
0
1000 - 1400
1400 - 1800
1800 - 2200
2200 - 2600
2600 - 3000
3000 - 3400
3400 - 3800
3800 - 4200
Elevation by 400 meters



Sierra - Cascades Region
Rust Absence
Rust Presence
Beetle Absence
Beetle Presence
Number of Plots
6
5
4
3
2
1
0
1000 - 1400
1400 - 1800
1800 - 2200
2200 - 2600
2600 - 3000
3000 - 3400
3400 - 3800
3800 - 4200
Elevation by 400 meters



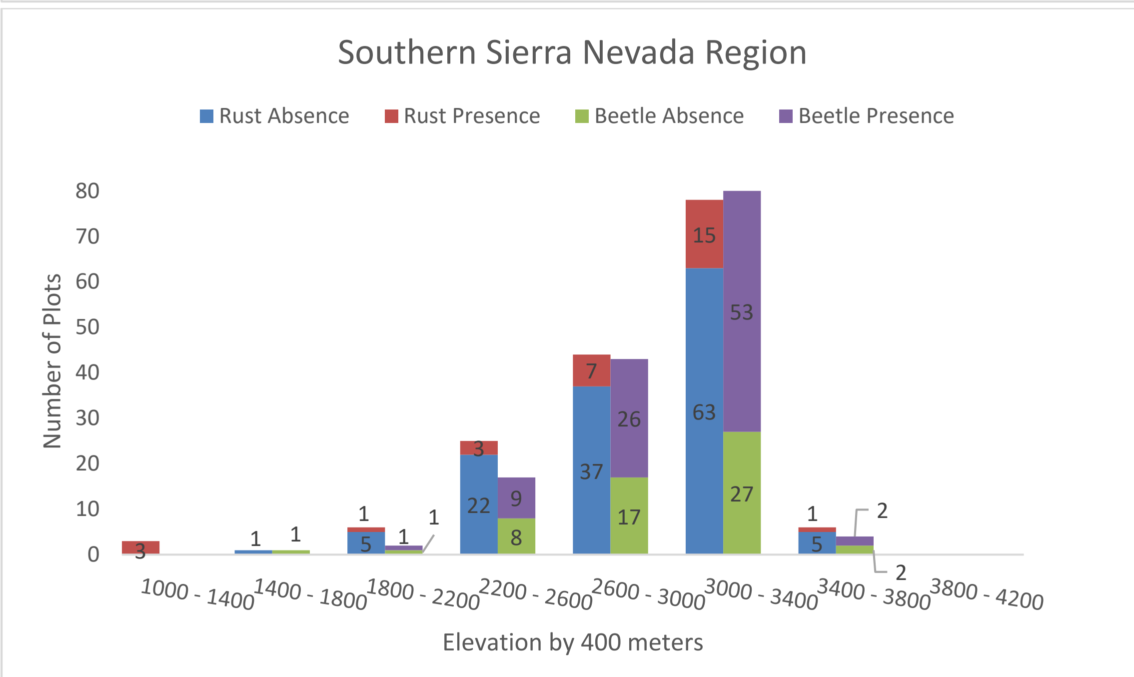


Figure 8. Health impacts by elevation in stands of whitebark pine across 5 regions of California, data was compiled from CNPS, NPS, Maloney, et al. 2012 and other sources.

Climate Change

Studies are currently underway to understand the impacts of warming temperatures, drought, and climatic water deficits on whitebark growth and survival in the Sierra Nevada. Dolanc et al. (2013) has presented evidence that warming temperatures may increase recruitment and promote survival of small trees, leading to a shifting stand structure weighted toward smaller, younger trees. However, temperature induced increases in aridity may exacerbate physiological stress and susceptibility to mountain pine beetles (Logan et al. 2010, Millar et al. 2012, Moore et al. 2017). In addition, low minimum temperatures are known to control both mountain pine beetle and white pine blister rust spread (Weed et al. 2013). Thus, rising temperatures may facilitate an upward expansion of both blister rust and beetles to higher elevations, creating concern for the long-term outlook of whitebark pine (Slaton et al. 2019b).

Research Needs and Recommendations

- Continued research on evaluating the risk of higher and lower elevation stands of whitebark pine to pests and pathogens
- Revisit previously sampled stands to evaluate if blister rust has spread
- Develop forestry best practices to reduce interspecific competition
- Understand general patterns in regional population genetics across the state
- Study patterns of genetic resistance to white pine blister rust
- Map patterns of vulnerability and resistance to mountain pine beetle

Klamath Mountains

- Conduct a range-wide genetic survey of whitebark pine populations, emphasizing disjunct, potentially unique stands along the range margins and at lower elevations.
- Monitor fire impacts and regeneration after the 2014 Whites Fire in the Russian Wilderness.

Cascade Range

- Conduct a range-wide genetic survey of whitebark pine populations, emphasizing disjunct, potentially unique stands along the range margins and at lower elevations.
- Study genetics and phytogeography of whitebark pine in the southern Cascades.
- Understand competitive relationships between whitebark pine and Tsuga mertensiana and other trees growing in high alpine environments
- Monitor recruitment and regeneration in previously logged sites like the Whaleback or around Haight Mountain.

Warner Mountains

- Monitor grazing impacts in the South Warner Wilderness.
- Collaborate with the Fremont National Forest to survey Oregon’s Warner Mountains.

Sierra Nevada

- Understand degree and distribution of resistance to white pine blister rust within populations of whitebark pine in the Sierra Nevada.

Management Considerations

Managers face multiple challenges related to conservation of white pines including climate change, degradation of white pine ecosystems, and conflicts between restoration activities and wilderness policy. Efforts to monitor whitebark populations rely on field studies of the ecological, pest, and disease conditions

(Maloney et al. 2012). These baseline assessments help land managers identify individuals and populations that require intervention and restoration (Maloney et al. 2012). Given the broad suite of threats, efforts to conserve whitebark pine will need to acknowledge complex dynamics when developing conservation and restoration plans within National Forests, National Parks, Wilderness Area, and across California. Ultimately, mitigation of the effects of these threats occurs at the local level, and therefore, forest management strategies will best serve populations of whitebark pine when local stressors are acknowledged (Diggins et al. 2010). The presence and severity of these threats varies with the differences in climate and topography across the subregions represented here, however, there are general trends found in California that are reflective of trends found range wide.

Local conservation strategies have the best chance of mitigating the loss of key individuals and populations which may be integral to conservation efforts at the range wide scale. Local strategies may include: identifying rust resistant trees and seed collection for propagation (Sniezko et al. 2011) and out-planting (Sniezko and Kegley 2012); treating stands with Verbenone (Bentz et al. 2005; Kegley and Gibson 2004) to deter mountain pine beetle attack (especially for cone bearing, blister rust resistant individuals); prescribed fire or thinning to reduce interspecific competition (Arno 2001; Keene et al. 2012); and identifying and targeting areas that may support whitebark pine in the future as the climate continues to change (Shanahan et al 2016; Chang et al 2014).

Forest	**Management Recommendation**
Sierra	**Bass Lake Ranger District** Ground truth predicted polygons in the Ansel Adams Wilderness Area. Survey CDFW whitebark pine observation outside near Jackass Creek. **High Sierra Ranger District** Ground truth whitebark pine observation in the Kaiser Wilderness Area. Survey CDFW whitebark pine observation near Pine Ridge and western populations along the lower edge of the whitebark elevation range.
Eldorado	1) northern Sequoia NF in the Monarch and Jennie Lakes Wilderness areas near 3,000 m (10,000 ft) 2) southern Sierra NF in the Monarch Wilderness and CALVEG polygons near Florence and Edison Lakes 3) Lake Tahoe Basin near Relay and Freel Peaks 4) southern Inyo NF CALVEG polygons in the Golden Trout Wilderness 5) northern Inyo NF Research Natural Areas, Sentinel Meadow and Harvey Monroe Hall, based on ecological surveys (Keeler-Wolf 1990) and 6) Stanislaus NF peaks above 2,700 m (9,000 ft) in Carson-Iceberg and Emigrant Wilderness areas.
Sequoia	1) northern Eldorado NF in the Desolation Wilderness near McConnel Peak and Mount Price and southern Eldorado NF in the Mokelumne Wilderness near Deadwood Peak 2) southern Sierra NF in the Monarch Wilderness and CALVEG polygons near Florence and Edison Lakes 3) Lake Tahoe Basin near Relay and Freel Peaks 4) southern Inyo NF CALVEG polygons in the Golden Trout Wilderness 5) northern Inyo NF Research Natural Areas, Sentinel Meadow and Harvey Monroe Hall, based on ecological surveys (Keeler-Wolf 1990) 6) Stanislaus NF peaks above 2,700 m (9,000 ft) in Carson-Iceberg and Emigrant Wilderness areas.
Stanislaus	**Calaveras Ranger District** • Survey and ground truth predicted polygons around Highland Lakes to assess the health and extent of potential whitebark pine populations.

	• Survey observations on high ridges north of Hwy 4 and east of Lake Alpine. **Summit Ranger District** • Survey observations around the Three Chimneys (9846') to assess the health and extent of whitebark pine populations - new populations of whitebark pine were found west of Three Chimneys near Castle Rock and additional populations may extend north and also west along the ridge above the Emigrant Wilderness. • Ground truth scattered predicted polygons around Emigrant Lake and near the north and east forks of Cherry Creek
Klamath	•Goosenest Ranger District 1. Survey Garner Mountain 2. Look closer at the West Haight Mountain stands (particularly along the east ridge) and possibly pursue the designation of a botanical area. • Scott River 1. Survey and map the "Big Ridge" between Black Marble Mountain and King's Castle in the Marble Mountain Wilderness. 2. Set up long term monitoring plots in the Boulder Peak Region. This is one of the most extensive stands of whitebark pine in the Klamath Mountains and most likely serves as a "feeder" population for the smaller mountain-top stands nearby. This area is critical to the future of whitebark in the Klamath Mountains. 3. Ground truth the higher peaks around Upper Albert and Big Blue lakes. 4. Set up a permanent plot on South China Mountain. 5. Work with Shasta-Trinity to ground-truth the Cory Peak Botanical and Geological area to verify or nullify species occurrence. • Salmon River Ranger District 1. Work with the Weaverville and Big Bar RDs on the Shasta-Trinity to map and ground-truth the extent of WBP along the Stuarts Fork-Salmon Divide (this is some steep country!). 2. I believe that WBP could occur in the Dorleska Mine region in the Big Flat Region. This area should be ground-truthed and mapped •Across the Klamath National Forest 1. Create a map to target areas where encroachment from firs and hemlocks is an issue and consider managing for this problem
Shasta-Trinity	• McCloud Ranger District 1. Work with Goosenest Ranger district to monitor the regions on the border of the two forests like Ash Creek Butte and ridgelines near the Antelope Creek RNA. 2. Set up long term monitoring in the Antelope Creek Research Natural Area because it is one of the most susceptible to decline due to narrow, site-specific, ecological amplitude. • Mount Shasta Ranger District 1. Set up plots on Mount Shasta, create a more thorough range map for the mountain, monitor for the omnipresent leader dessication observed in the Brewer Creek region, and monitor the range overlap of whitebark with western white and lodgepole pines for the spread of blister rust and mountain pine beetle. 2. Continue to pursue long term monitoring of the Mount Eddy populations of whitebark pine, which are some of the most extensive in the Klamath Mountains. Create a map for WBP regional dominance around Mount Eddy. Wilderness designation for this region should be explored to preserve habitat for WBP, foxtail pine, and other rare biota. 3. Locate, document, and assess the isolated population of WBP on Black Butte - what is their health, how many trees, etc. • Weaverville Ranger District 1. Ground truth the extent of WBP along the Stuarts Fork-Canyon Creek divide as well as the Stuarts Fork-Salmon Divide (this is some steep country!)

	• Big Bar Ranger District 1. More thoroughly map locations of trees throughout the Trinity Alps high country, particularly the highest granite peaks including Mount Hilton northward to Caribou Peak. Create polygons for regional dominance. 2. Long term monitoring for some of the larger and more contiguous populations in the White Alps including the south-facing ridgeline south of Papoose Lake and the south-facing ridgelines of Thompson Peak and Caribou Mountain. •Across the Shasta-Trinity National Forest 1. Create a map to target areas where encroachment from firs and hemlocks is an issue and consider managing for this problem. 2. Monitor mortality in populations of of lodgepole pine, western white pine and foxtail pine in relation to whitebark pine. These species often associate here and this my to lead to synergistic epidemic outbreaks of WPBR and MPB.
Modoc	• South Warner Mountains - Buck Mountain region 1. With some of the highest mortality rates seen while ground-truthing the Warner Mountains, it would be advisable to set up several long-term monitoring plots on both Buck and Hat mountains. 2. Are there whitebark pine on Little Hat Mountain? Elevation suggests they could be there. • South Warner Wilderness 1. Assimilate all data for the wilderness and create a comprehensive range map for whitebark pine. 2. Monitor the expansion of the species onto north-facing slopes at high elevations and downslope into meadows at the lower extent of the species range within the wilderness. • Middle Warners - Bald Mountain region 1. Continue to monitor these isolated and small populations of whitebark on both Bald and Cedar mountains. Explore the idea of designating these two peaks and the ridgeline between them as a botanical and geological area. 2. Ground truth Payne Peak, south of 299, to assess if WBP are present and the extent of the populations.

Genetics

Conservation biology emphasizes the maintenance of native gene pools as an important function in maintaining ecosystem and species integrity. Because of the diversity of whitebark pine populations in California, especially disjunct stands in the Klamath and Cascade ranges, we recommend managers conduct a range-wide genetic survey of whitebark pine populations, emphasizing potentially unique stands along the range margins and at lower elevations. The USFS National Forest Genetics Laboratory in Placerville, California, would be an ideal cooperator because of its extensive experience in this field. A genetic survey could identify unique populations that may require priority restoration efforts and would provide the basis for developing refined Species Distribution Models for different genotypes.

The development of genomic techniques to rapidly test trees for genetic resistance to blister rust would save years of greenhouse work and would make proactive restoration planning easier and less costly. Research should improve the restoration process by providing vital information on state-of-the-art techniques and protocols that will hopefully make restoration efforts more effective and economical.

Livestock Grazing

While grazing whitebark pine stands is uncommon in California it is nevertheless occurring. Many areas in whitebark pine ecosystems were grazed by huge herds of sheep and cattle in the late 1800s and early 1900s—particularly in the Warner Mountains. Domestic livestock grazing continues in many areas and the effects on whitebark pine are largely unstudied.

Logging

While logging in whitebark pine stands is uncommon in California, it is happening. The highest rates of peripheral whitebark pine logging are occurring in areas with other target species such as lodgepole pine and mountain hemlock. The highest impacts by logging is occurring on the patchwork of public and private lands of the Klamath National Forest in the Cascade Range—generally north of Mount Shasta.

Climate Change

Managers need to understand how climate change influences the life cycle of whitebark pine, associated species, and pests and pathogens that impact the species. Fire frequency and intensity will also affect stands in California, particularly in the Klamath Mountains in the short term. This work is ongoing, and further work is encouraged.

Education and Outreach

- Develop a Sierra Nevada specific 6th-12th curriculum, built around whitebark pine ecology, ecosystem services and disturbances related to ski areas and/or other recreational sites near the human/wildland interface
- Coordinate with the
- Partner with the Pacific Crest Trail Association to develop education and outreach resources
- Use a model such as a Sierra Nevada Network Publication Brief summarizing Nesmith et al 2019 that would be applicable and shared with the general public with respect to whitebark pine in California
- Develop a book focused on whitebark pine in California – or include all five-needle pines

Path Forward

Various efforts to map, inventory, monitor, and manage whitebark pine are in their initial stages of development including through the USFS (including the R5 Ecology program) and National Park Service (including their Network Inventory & Monitoring programs). Through these and other restoration efforts, more coordination and communication will be beneficial towards evaluating the long-term trends and continued management of whitebark pine. Below are a set of recommend objectives to chart a path forward in California.

- Map, Inventory and Monitoring:
    - Continue to document range, extent and condition in California
    - Review areas that haven't been sampled to expand inventory and assessment efforts since each region of California appears to be exhibiting different trends
    - Revisit stands sampled to determine if blister rust has spread to stands that did not previously detect it
    - Co-analyze data across different datasets

        - To further evaluate condition of stands and to help direct management activities in California
        - To further understand the classification of different associations of whitebark pine across California and to develop a rarity rank for each vegetation type.
        - Develop a floristic key to whitebark pine vegetation with associated descriptions, including summary stand tables.
    - Support an interactive GIS database of California based research, mapping, and monitoring efforts
- Research for Science/Data-Based Work: find ways to share information on current efforts; identify management needs and data gaps; make a list of projects to fund
- Coordinate and Communicate between interest groups
- Coordinate with the Whitebark Pine Ecosystem Foundation to provide California-specific research and resources
- Explore the protection of additional areas such as through RNAs, forest plans, etc.
- Synthesize existing cone collection information for: 1) gene conservation, 2) rust screening, 3) other management needs.
- Develop a cone collection plan for gene conservation
- Protect whitebark pine cones/seeds as needed
- Better understand genetic considerations/seed zones for the species
- Develop a rust screening plan and suggested timeline
- Better understand the effectiveness of seeding, thinning, and planting; learn from case studies in California and other areas outside of California
- Education and outreach efforts: find ways to share information, identify needs and gaps; make a list of projects to fund
- At a statewide level, convene an Interagency California Whitebark Pine Working Group of Experts
- At the local level, develop sub-regional working groups to coordinate and share information *and* develop simple action plans (2-3 items) to work on (and seek funding for) every year

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Appendix 1: National Forest surveys, range, and extent

Methods

Inventorying Statewide Whitebark Pine Data (2013-2019)

Beginning 2013, the California Native Plant Society (CNPS) initiated a mapping and inventory project in conjunction with Region 5 and Diane Ikeda, Botanist. This began through obtaining existing GIS data from various sources including the USFS Pacific Southwest - Region Remote Sensing Lab's CALVEG maps (CALVEG 2008-2013), USFS Forest Health Technology Enterprise Team's National Insect and Disease Risk Model (USFS 2014) Host species layers, USFS Pacific Southwest Regional Forest Health and Monitoring Aerial Detection Survey Data (USFS 2018), USFS Forest Health Protection Margins dataset (Bokach 2013), USFS Forest and Inventory Analysis database (USFS 2019), The Consortium of California Herbaria (UC Berkeley 2019), USFS Central Sierra Province Ecologist-Becky Estes, USFS Southern Sierra Nevada Province Ecologist - Marc Meyer, National Park Service (NPS) Sierra Nevada Network Inventory and Monitoring Program Ecologist - Jonathan Nesmith, US Geological Survey (USGS) Western Ecological Research Center Ecologist - Nathan Stephenson, California Department of Fish and Wildlife (CDFW) Wildlife Biologist - Pete Figura and USFS Northern California Shared Service Center Entomologist - Cynthia Snyder.

In addition, we used older sources of whitebark pine distribution in the state for context (Griffin and Critchfield 1972) and for lone populations or individuals not delineated or attributed by CALVEG (CCH 2019). CNPS also reviewed existing protocols for evaluating whitebark pine vegetation and insect/disease impacts. These protocols included the NPS Standard Operating Procedures for monitoring Whitebark Pine (McKinney et al. 2012), Whitebark Pine Ecosystem Foundation (Tomback et al. 2005), Whitebark Pine Inventory and Monitoring Plot protocol (Meyer et al. 2019) and several government research and staff reports (i.e., Millar et al. 2012, Simons and Cluck 2010, Figura 1997, McKinney et al. 2011, and Maloney et al. 2012). We also discussed the existing protocols for assessing whitebark pine vegetation with USFS staff, including Marc Meyer and Shana Gross. Upon evaluating existing datasets and obtaining input from local National Forest staff, we identified areas to further ground-truth to better determine the distribution and health/status of whitebark pine on the National Forest lands.

Priorities included sampling within wilderness lands and identifying areas with low-levels of insect/disease impact.

With our new predicted distribution layers, we strategically initiated ground-truthing surveys using a modified CNPS/CDFW Vegetation Rapid Assessment protocol to gather information on occurrence, habitat, and impacts of stands with whitebark pine. We modified this protocol to include signs of Mountain Pine Beetle (MPB) and White Pine Blister Rust (WPBR), and overall whitebark pine status/health. The modified rapid assessment aimed to gather as much information on whitebark pine health without spending a significant amount of time establishing plots or collecting data on individual trees. Therefore, the survey technique was a stand-based assessment of health and extent. This data, along with new field surveys collected in 2018, has been incorporated into these reports.

In 2019, the California Native Plant Society was tasked with assimilation of all data relating to whitebark pine in California. We reached out to partners across the state to learn where they have collected data and what that data includes. Partners who provided updated data since 2014 include:

- Michele Slaton - USDA Forest Service, Pacific Southwest Region, Remote Sensing Laboratory

- FIA Plot Data
- The National Park Service
    - Sierra Nevada Network (SIEN)
    - Klamath Network (KLMN)
    - SEKI and YOSE veg points
    - Lassen National Park veg map data
- CDFW high elevation study
- Consortium of California Herbaria (CCH)
- CNPS Eldorado 2018 crew observations
- CNPS Kauffmann 2018 field surveys in Klamath and Modoc

This new information was then used in conjunction with the 2014-2018 CNPS survey data to create aggregated ArcGIS maps. These maps include overall distribution across California as well as the impacts of insects and disease, at various scales. Draft maps were then sent to regional partners who were asked for feedback. Across the state, over 20 individuals replied with comments and suggestions to both the Distribution maps and Insect and Disease maps. All feedback has been incorporated into this report (Table 1-1).

Table 1-1. Summary of California Data Collection

Partner	Year Data Received			
	Klamath Mountains	**Southern Cascades**	**Warner Mountains**	**Sierra Nevada**
California Native Plant Society	2013, 2018	2013	2013, 2018	2013, 2018
USDA Forest Service, Pacific Southwest Region, Remote Sensing Laboratory	2013, 2019	2013, 2019	2013, 2019	2013, 2019
FIA Plot Data	2019	2019	2019	2019
CDFW high elevation study		2018		2018
Consortium of California Herbaria	2012-2019	2012-2019	2012-2019	2012-2019
Pete Figura, DFW			2019	

Table 1-2-1. Statewide datasets

Dataset	Agency or Organization	Citation	Year Collected	n	positional accuracy	Health / Mortality (WPBR/MPB)	Species Composition / Cover	Notes	Units NOT included
CNPS Rapid Assessments	CNPS	Buck-Diaz et al. 2018, Kauffmann et al. 2014, Taylor et al. 2014	2013 to 2018	152	GPS	X	X		Inyo NF, Sequoia NF, Tahoe NF
CNPS Recon-naissance Data	CNPS	Buck-Diaz et al. 2018, Taylor et al. 2014	2013 to 2018	54	GPS	X	minimal		Klamath Mtns, Southern Cascades, Warner Mtns
Consortium of California Herbaria	Participants of CCH (UC Berkeley)	CCH 2019	1862-2016	323	The majority of geocoordinates have been assigned from the location description and not using GPS	no	no		none
Forest Inventory Analysis (FIA) plots - forest type	USFS	USFS 2019	1994-2017	54	Note that coordinates for these locations may be fuzzed up to a mile from their precise location. In addition, some locations are swapped with other plots with similar characteristics in the same county	no	X		Lassen NF, Sequoia NF, Tahoe NF

Dataset	Agency or Organization	Citation	Year Collected	n	positional accuracy	Health / Mortality (WPBR/MPB)	Species Composition / Cover	Notes	Units NOT included
Forest Inventory Analysis (FIA) plots - presence of PIAL	USFS	USFS 2019	1994-2017	34	Note that coordinates for these locations may be fuzzed up to a mile from their precise location. In addition, some locations are swapped with other plots with similar characteristics in the same county	no	X	Additional plots not assigned to PIAL forest type	Lassen NF, Sequoia NF, Tahoe NF
Margins Data	USFS	M. Bokach 2013	1954-2011	334	Some locations are pre-GPS	X (presence only)	no	Compila-tion of georefer-enced locations	Tahoe NF
USFS Long-term Monitoring & Trend analysis	USFS Ecology Program	Meyer et al. 2019	2012-2019	163	GPS	yes, but not presented here	X		Sequoia NF, Stanislaus NF, Tahoe NF
WPBR incidence in CA high elevation	UCD & USFS	P. Maloney 2011	2004-2006	49	GPS	X	no		Lassen NF, Sequoia NF, Tahoe NF

Table 1-2-2. Statewide datasets by region

Dataset	Agency or Organization	Citation	Year Collected	Surveys from all regions	Klamath	Modoc	Sierra - Cascades	Northern Sierra Nevada	Southern Sierra Nevada
CNPS Rapid Assessments	CNPS	Buck-Diaz et al. 2018, Kauffmann et al. 2014, Taylor et al. 2014	2013-2018	152	46	34	5	54	13
CNPS Recon-naissance Data	CNPS	Buck-Diaz et al. 2018, Taylor et al. 2014	2013-2018	54				51	3
Consortium of California Herbaria	Participants of CCH (UC Berkeley)	CCH 2019	1862- 2016	323	57	22	15	49	180
Forest Inventory Analysis (FIA) plots - forest type	USFS	USFS 2019	1994-2017	54	2	2		9	41
Forest Inventory Analysis (FIA) plots - presence of PIAL	USFS	USFS 2019	1994-2017	34	2	2		6	24
Margins Data	USFS	M. Bokach 2013	1954-2011	334	57	47	14	81	135
USFS Long-term Monitoring & Trend analysis	USFS Ecology Program	Meyer et al. 2019	2012-2019	163	20	15	6	52	70
WPBR incidence in CA high elevation	UCD & USFS	P. Maloney 2011	2004- 2006	49	4	2	2	19	22

Table 1-3. Other datasets

Dataset	Agency or Organization	Citation	Year Collected	Klamath Mtns	Southern Cascades	Warner Mtns	Sierra Nevada	n	Health / Mortality (WPBR/MPB)	Species Composition / Cover	Notes
High Elevation Species and Natural Communities of the Northern Sierra	CDFW	J. Stewart et al. 2017	2015-2016		X		X	110	For 43 assessed plots		Additional points (67) were not assessed
Sierra Monitoring Project/Ecoregional Biodiversity Monitoring project	CDFW	D. Wright et al. 2016	2013-2018				X	6			
Structure and dynamics of whitebark pine forests in the Warner Mountains	Humboldt State, CDFW	P. Figura et al. 2012	2006, 2012			X		44	X (combined in 1 macroplot)	Yes, but not currently available	Plots are close together, all within 3 km of each other
Lassen Volcanic National Park mapping gdb	NPS	NPS 2012	2006-2009		X			53		X	Includes releves, transects, and AAs
Sequoia & Kings Canyon (SEKI) Vegetation Mapping Inventory Project	NPS	NPS 2009	2000-2003				X	62		X	31 Accuracy Assessments, 32 Surveys

Dataset	Agency or Organization	Citation	Year Collected	Klamath Mtns	Southern Cascades	Warner Mtns	Sierra Nevada	n	Health / Mortality (WPBR/MPB)	Species Composition / Cover	Notes
Yosemite (YOSE) Vegetation Inventory and Type Mapping Project	NPS	NPS 2003	1991-1999				X	55		X	33 NRI surveys (1991-93). 22 releves (1998-99)
NPS Inventory and Monitoring Long-term monitoring, Lassen Volcanic National Park	NPS I&M - Klamath Network	S. Smith 2018	2016-2018	X				30	X	only tree census data	Data collected every 3 years since 2012
NPS Inventory and Monitoring Long-term monitoring, Yosemite and Sequoia-Kings Canyon	NPS I&M - Sierra Network	J. Nesmith et al. 2019	2015-2017				X	79	X	only tree census data	Data collected every 3 years since 2011
Ecology of WBP in relation to WPBR, Lake Tahoe Basin	UCD & USFS	P. Maloney et al. 2012	2009				X	29	X		
Eldorado NF crew observations	USFS	USFS 2018	2018				X	25	Anecdotal only		2004 Wilderness Ranger observations (34) are included in Bokach 2013

Dataset	Agency or Organization	Citation	Year Collected	Klamath Mtns	Southern Cascades	Warner Mtns	Sierra Nevada	n	Health / Mortality (WPBR/MPB)	Species Composition / Cover	Notes
WBP Long-term monitoring, Klamath & Shasta-Trinity NF	USFS	C. Snyder 2019	2018	X				6	X		Data collected annually since 2010
WBP Long-term monitoring, Modoc NF	USFS	D. Cluck 2019	2010			X		18	X		Plots established in 2006
Inyo National Forest	USFS Ecology Program	M. Meyer et al. 2012	2012				X	64	X (mortality MPB-related)	X	
USFS eastern CA ecology plots	USFS Ecology Program	M. Slaton 2018	2004-2018			X	X	75		X	
Yosemite National Park, Long Term Forest Reference Stand	USGS/Western Ecological Research Center	N. Stephenson 2018	2018				X	1	X		Data collected annually since 1997

Table 1-4. Spring 2019 Survey Results Summary.

Forest Region	Number of survey responses	General survey summary	What are the top three outstanding research needs for whitebark pine?
Klamath – Shasta Trinity	4	• Maps look great • General questions about specific polygons (addressed) • Questions about survey locations by a variety of agencies (addressed)	- Climate change and genetic screening of our low elevation populations for novel genes
Modoc – Lassen	5	• General questions about symbology (addressed) • General questions about specific polygons (addressed) • Questions about survey locations by a variety of agencies	- BR resistance, Identifying areas (microclimates) where WBP are most likely to persist under the current climate change scenario, Best practices to reduce interspecific competition. - What are current trends in regeneration and growth across the area? What conditions, if any, favor stand resilience? Are there practical habitat modifications that can improve regeneration and/or resilience? - Genetics and phytogeography of WBP in the southern Cascades; competitive relationships between WBP and *Tsuga mertensiana* and other trees growing in high alpine environments.
Northern Sierra	4	• General questions about specific polygons (addressed)	- Epidemiology, population genetics, and eco-evolutionary studies
Southern Sierra	2	• Initial impression is that the map overestimates presence in the southern Sierra. • How does this differ from the 1 km scale distribution map just published by the whitebark pine ecosystem foundation?	- Patterns of genetic resistance to white pine blister rust. Patterns of vulnerability and resistance to mountain pine beetle. - Degree and distribution of resistance to WPBR within populations of whitebark in the Sierra Nevada.

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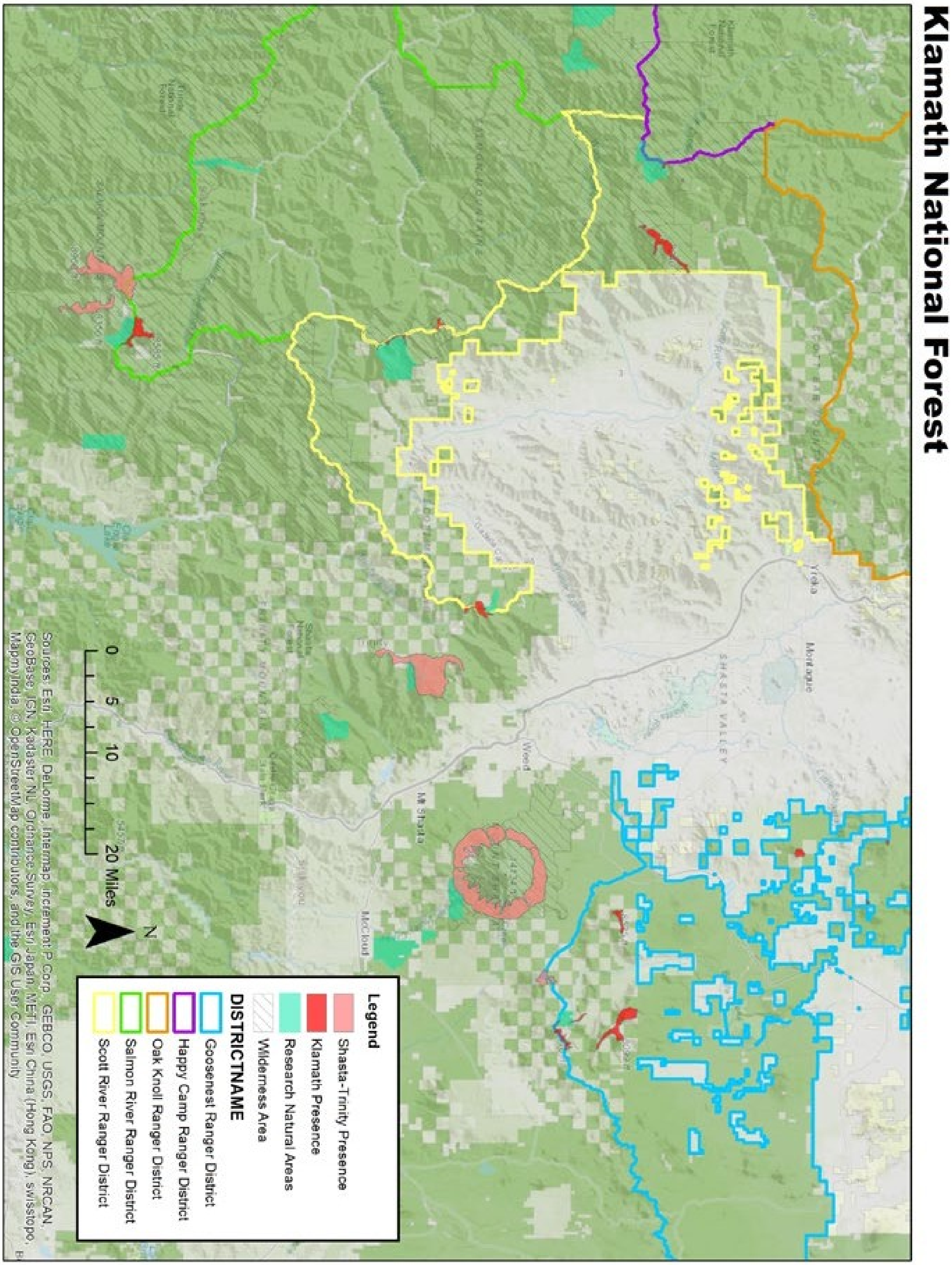
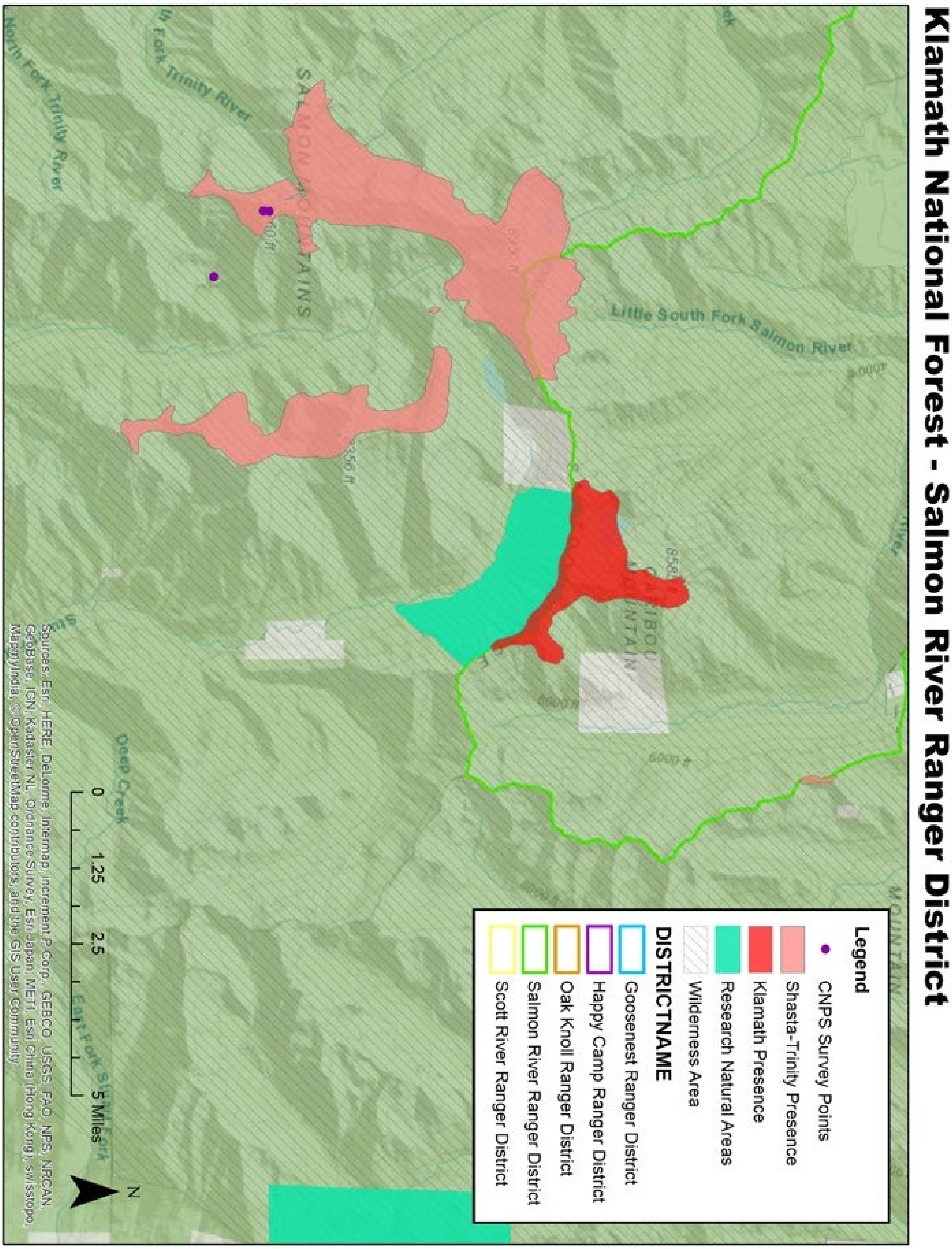
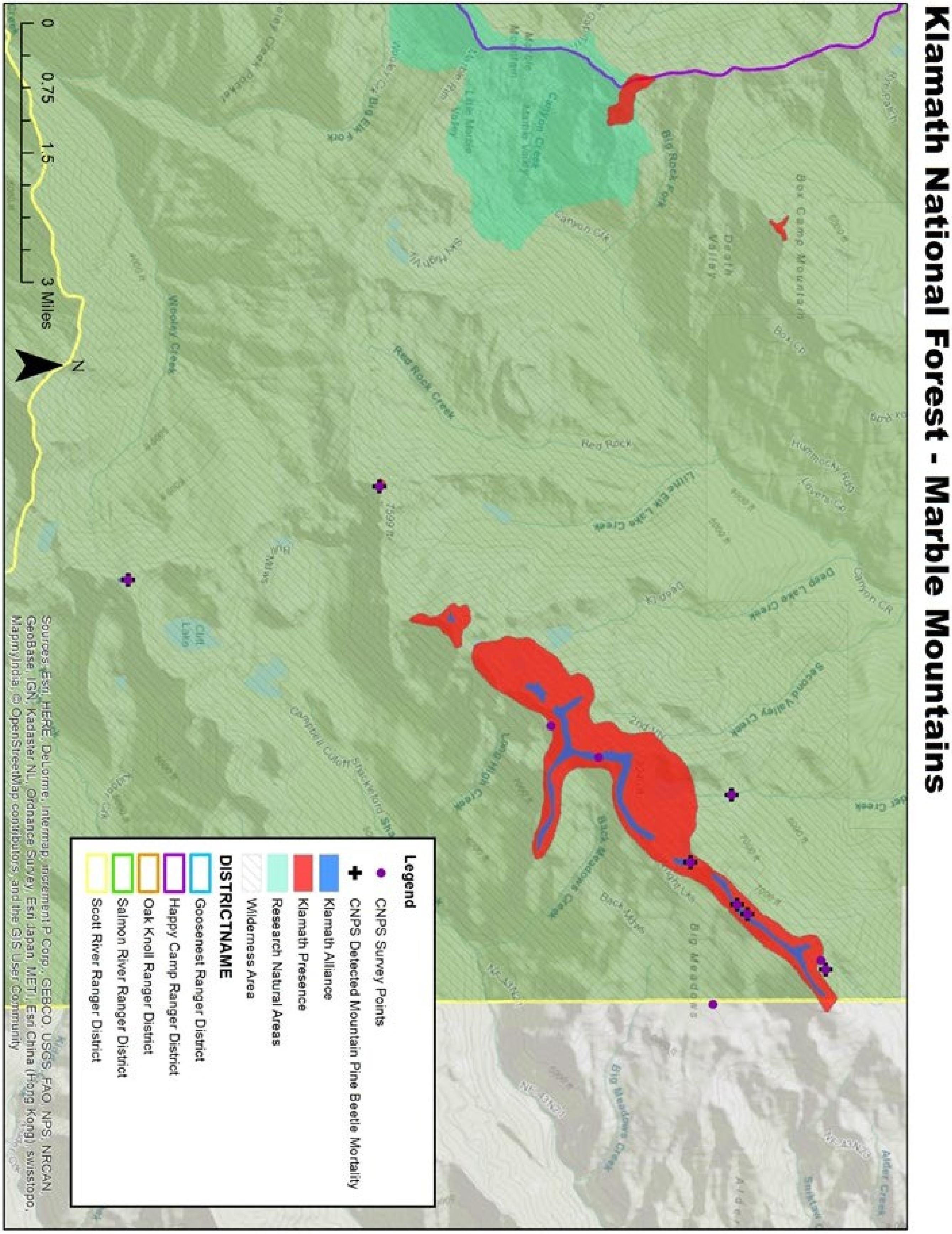


Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent

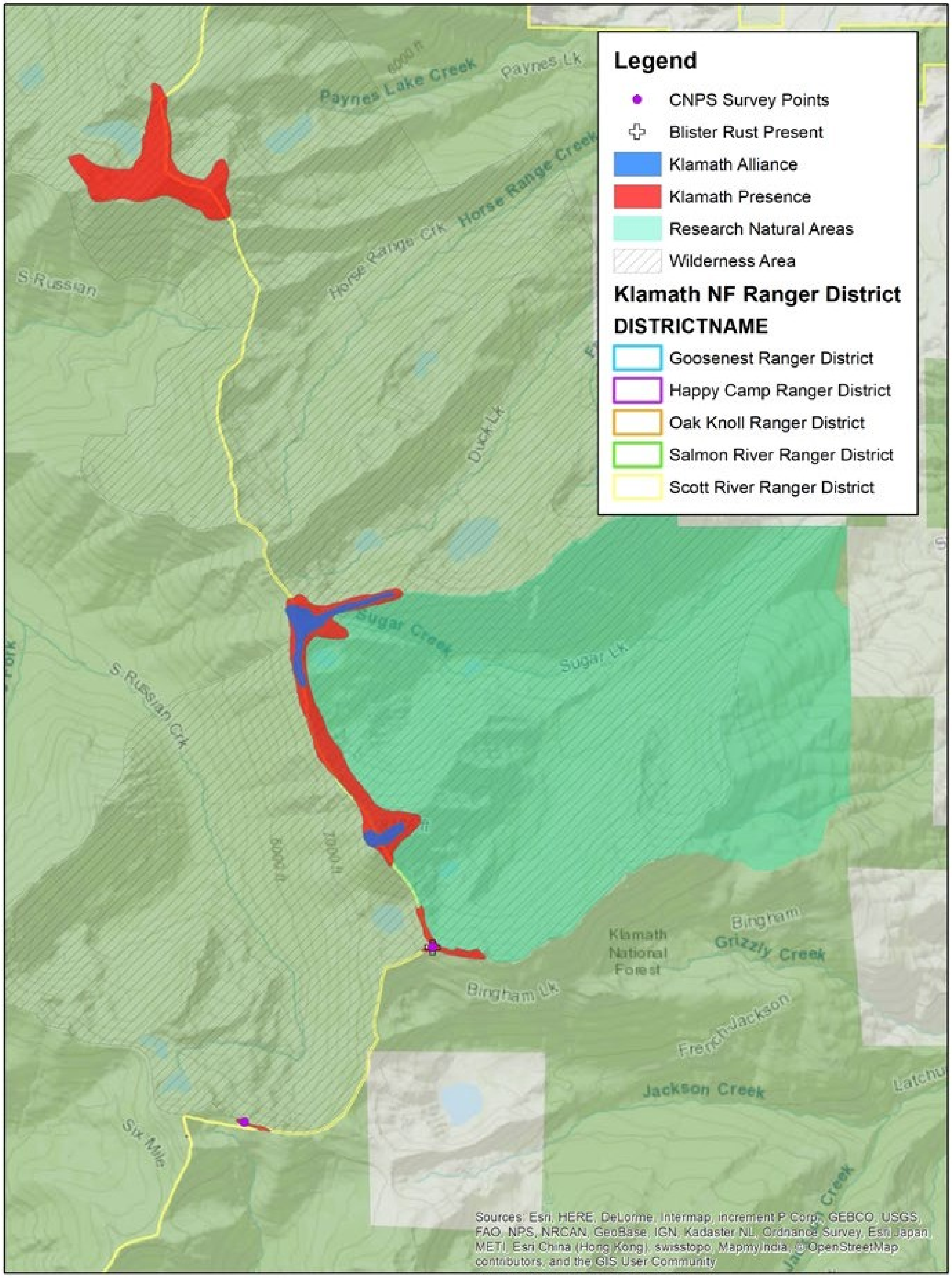


Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)



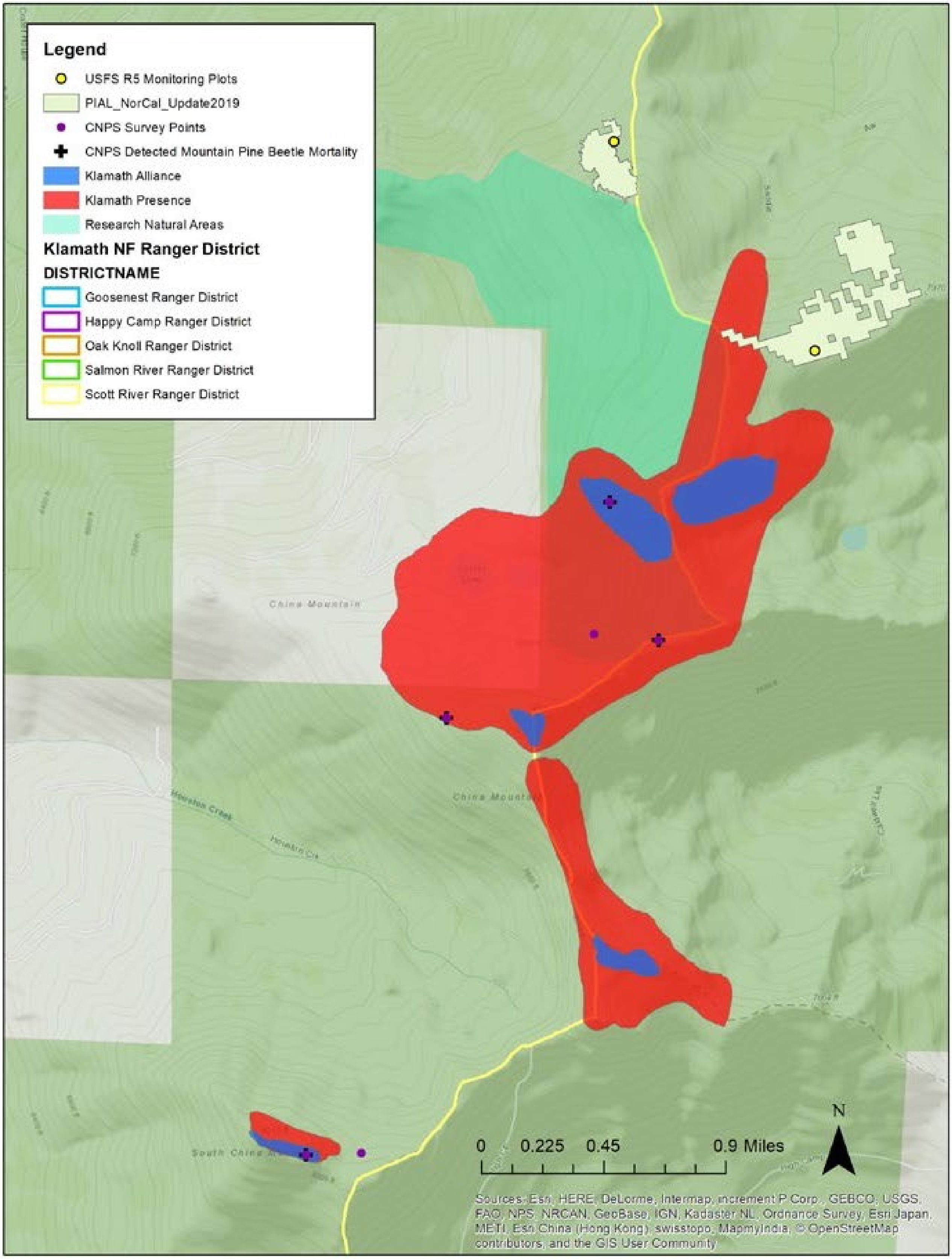
Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)

Klamath National Forest - Russian Wilderness

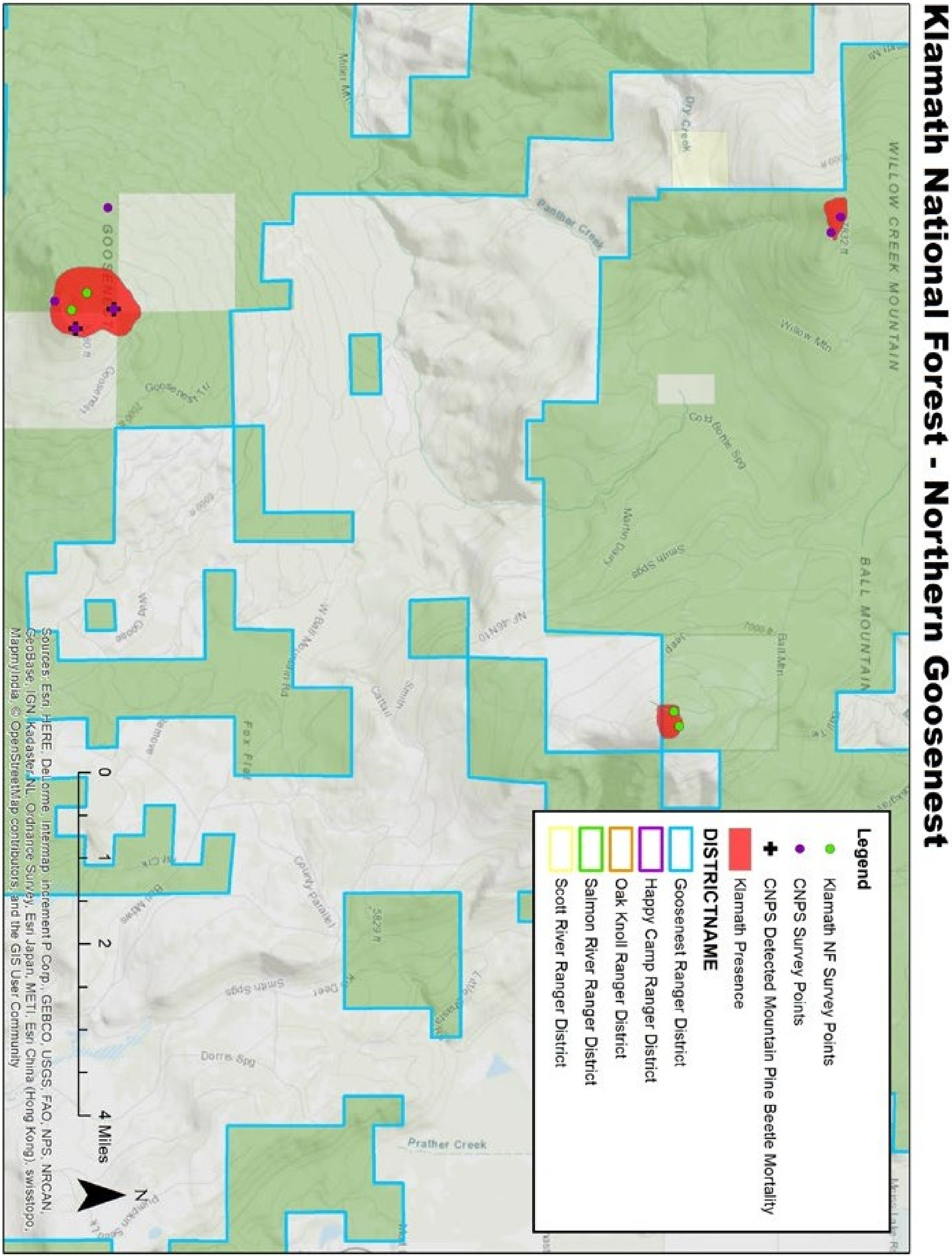


Appendix1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)

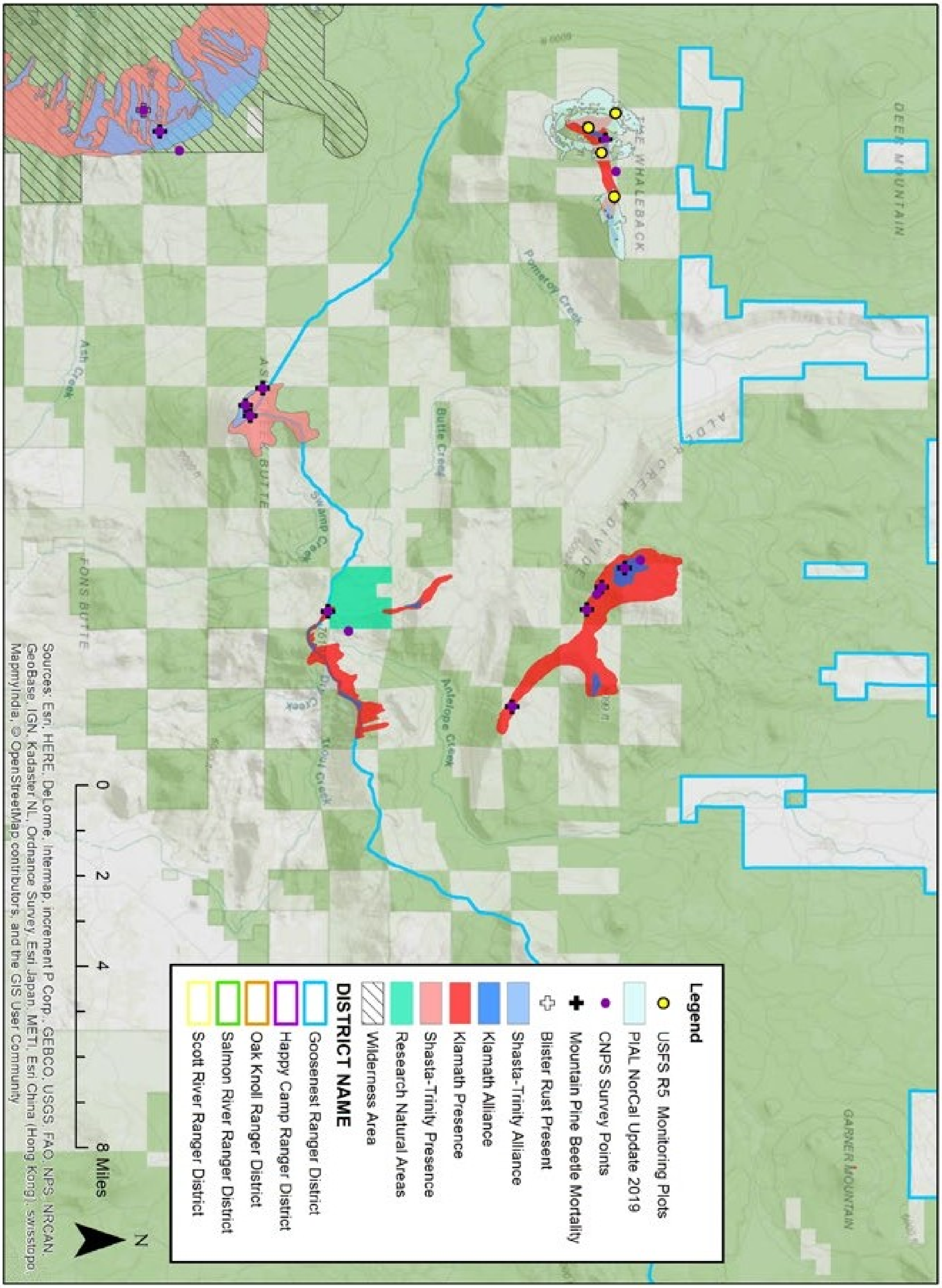
Klamath National Forest - China Mountain Region



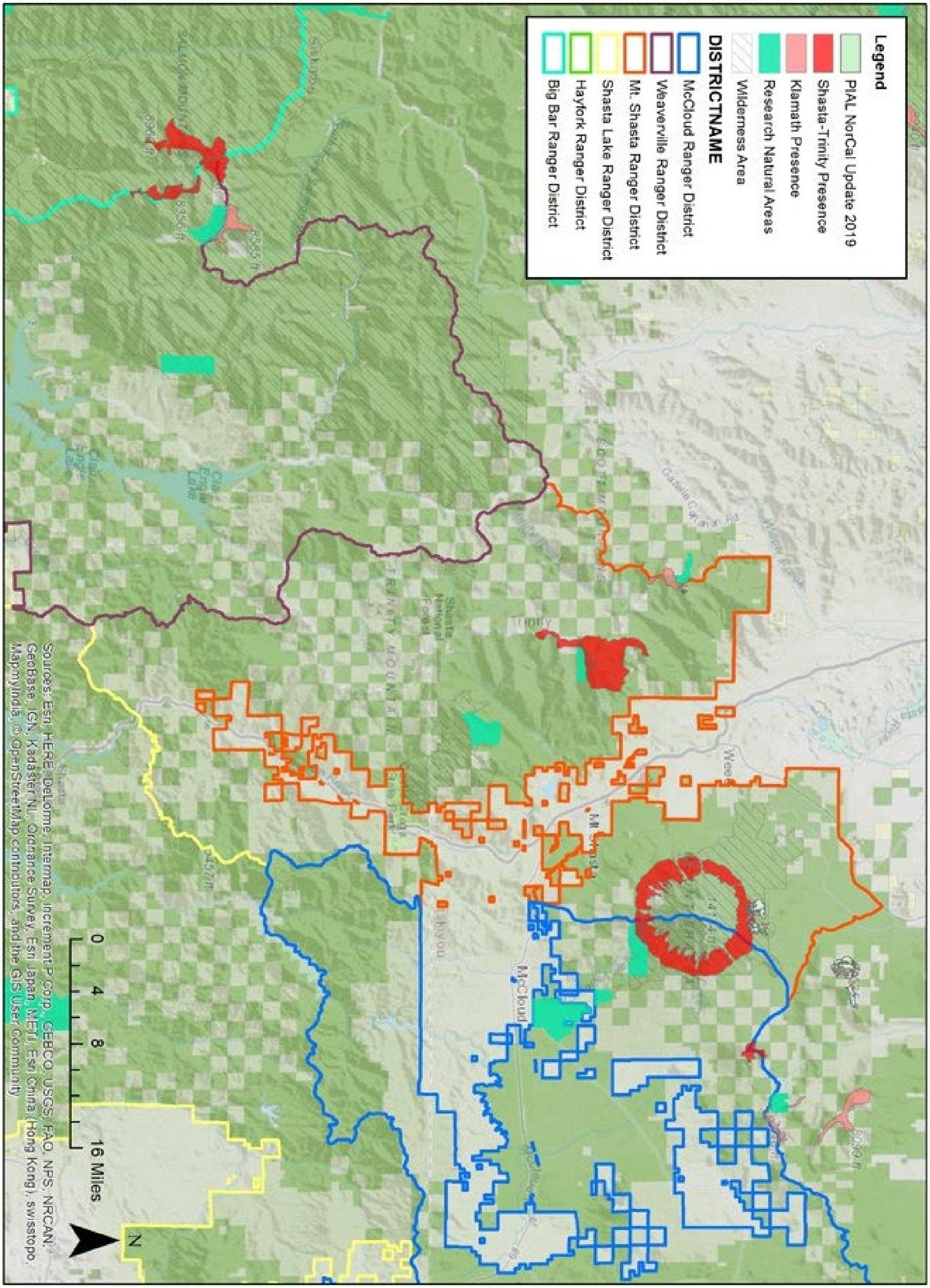
Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)



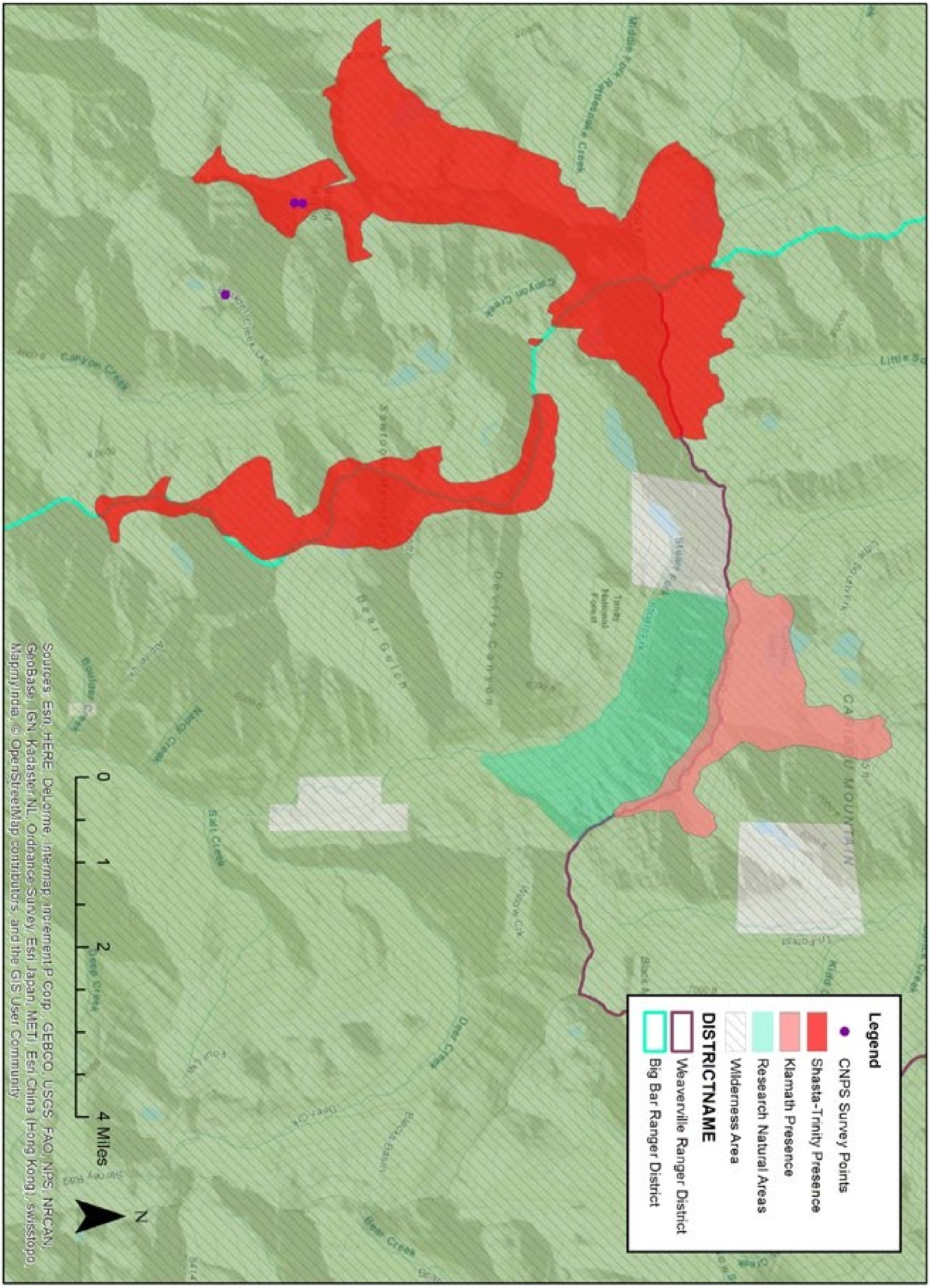
Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)



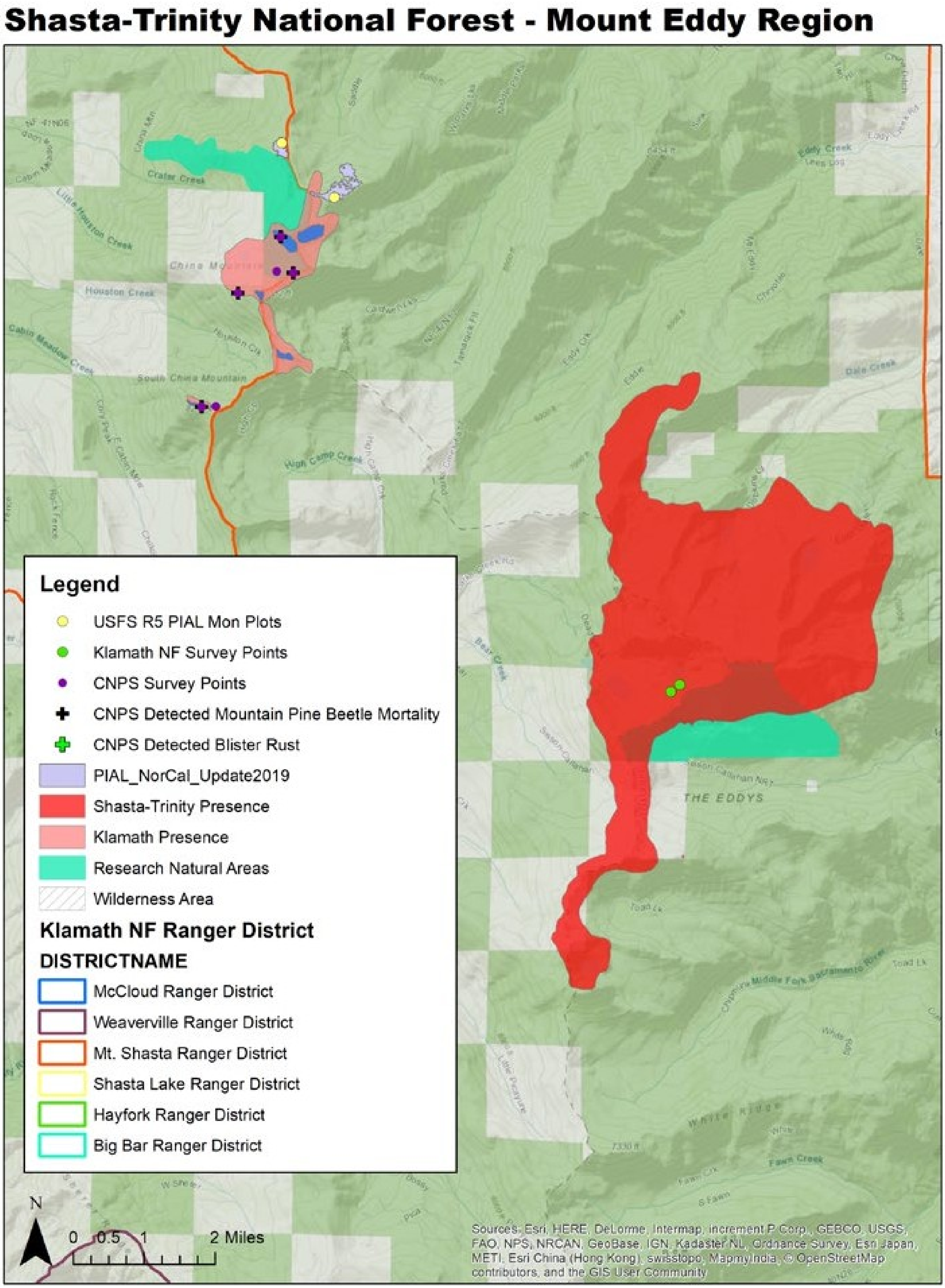
Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)



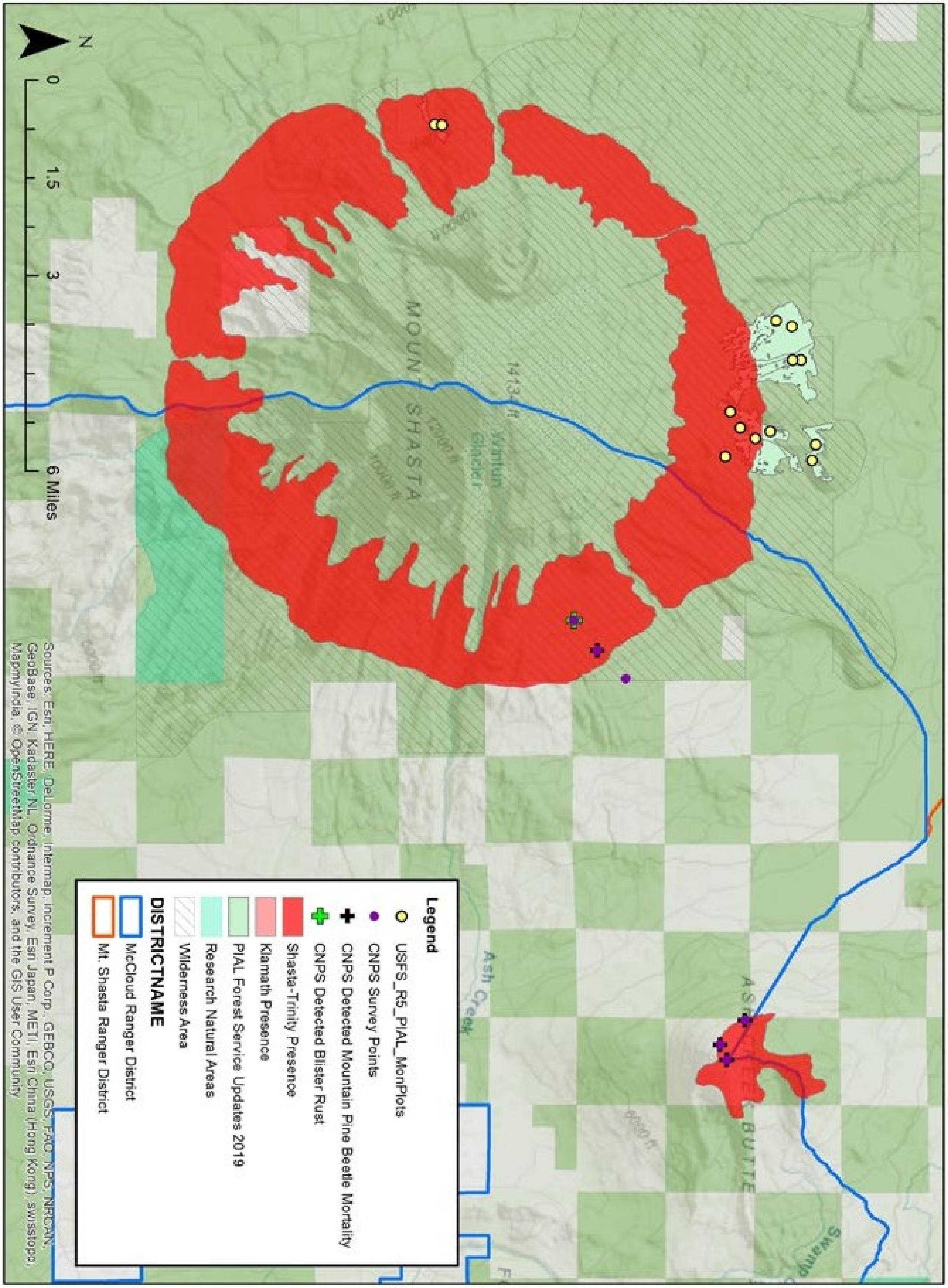
Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)



Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)

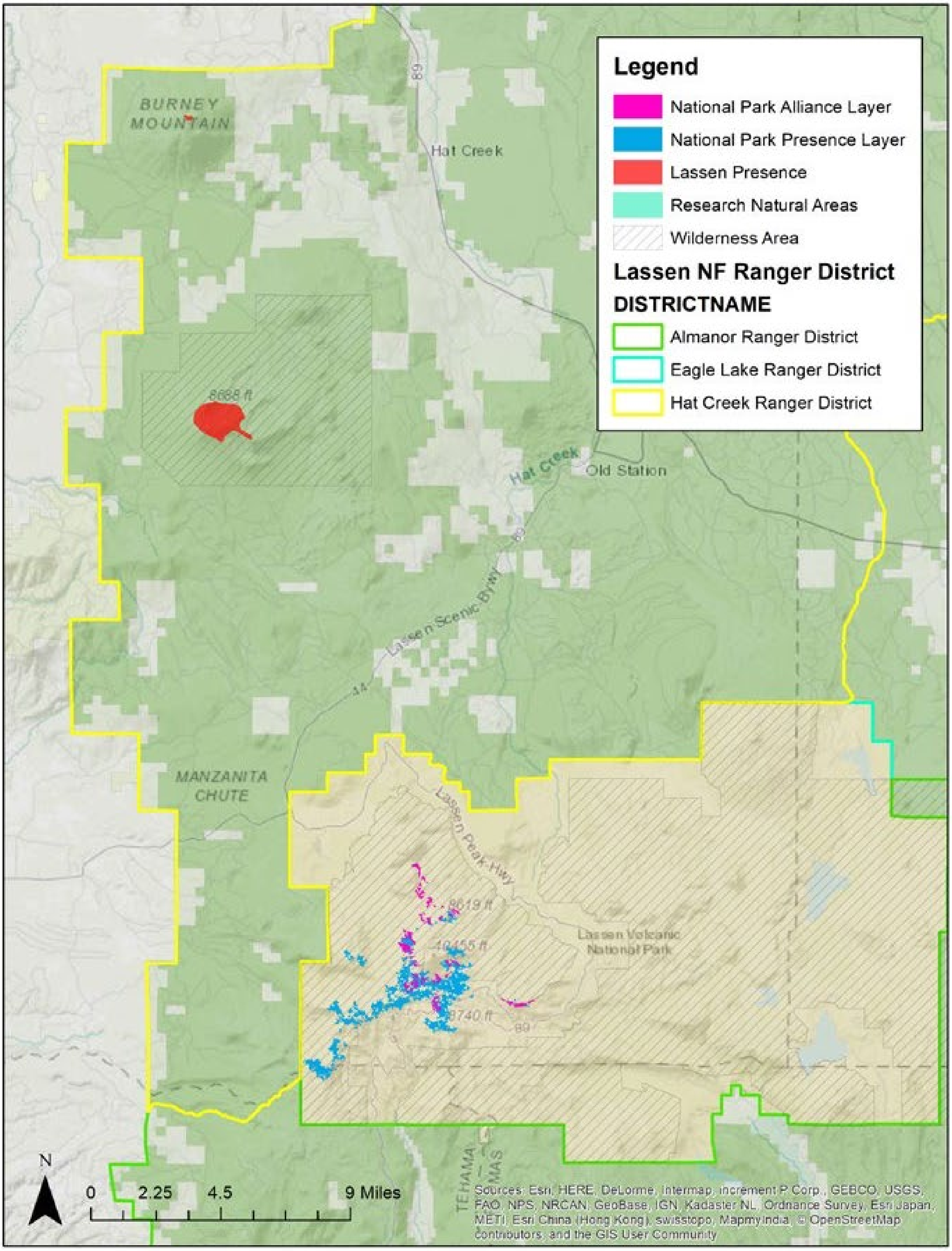


Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)

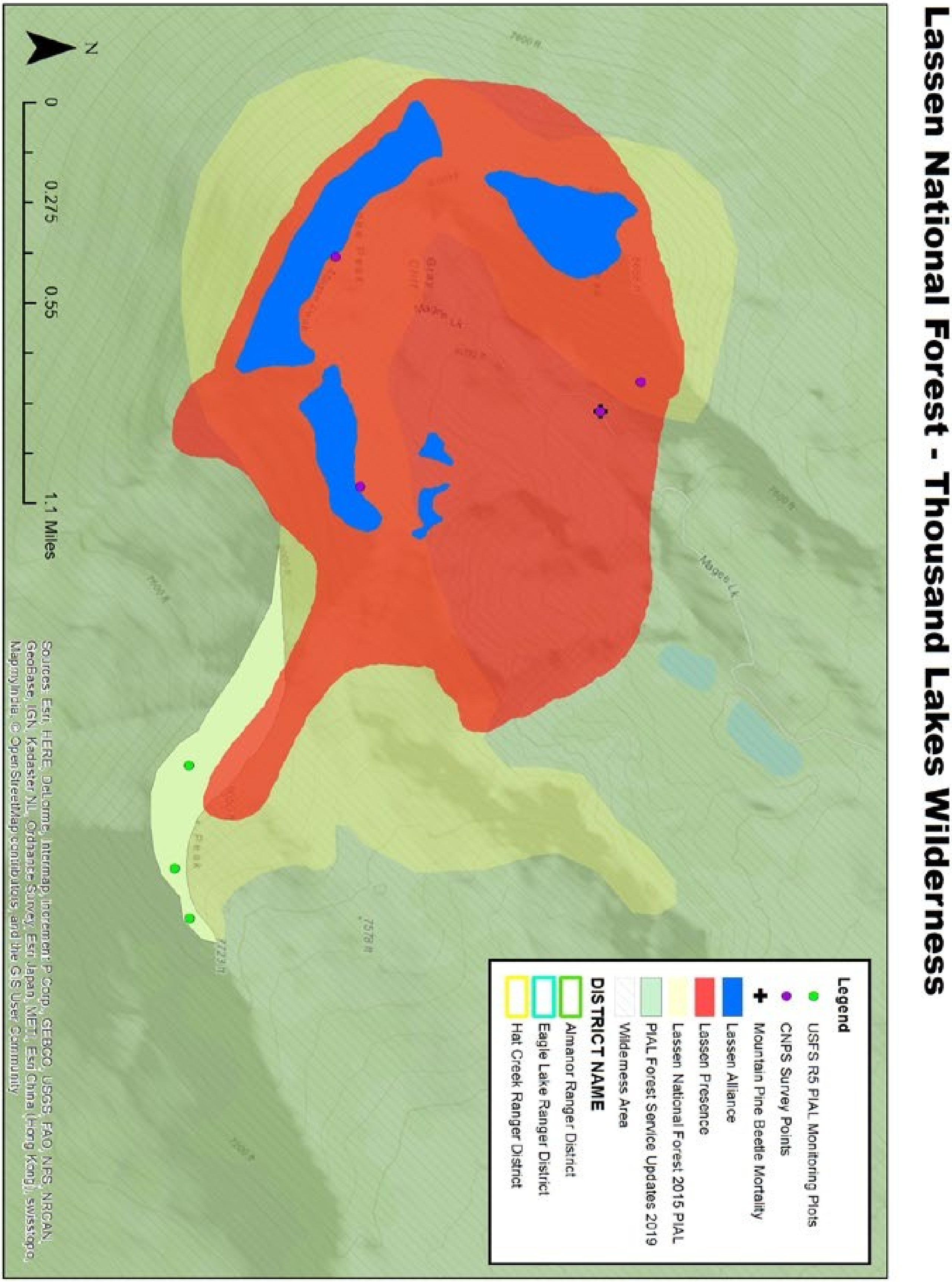


Appendix 1 - Figure 1. Klamath Cascades Region --- Range and Extent (Continued)

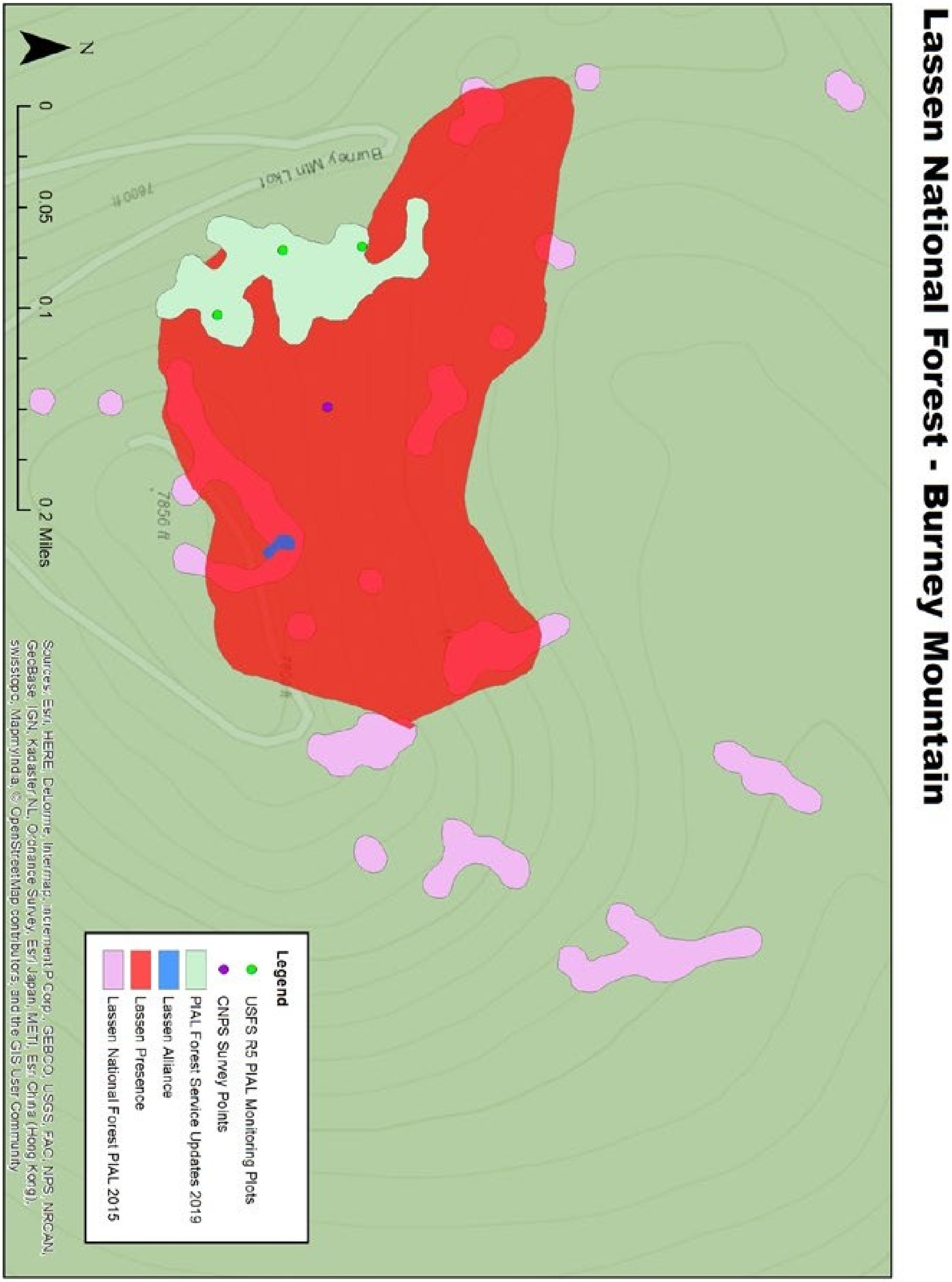
Lassen National Forest



Appendix 1 - Figure 2. Sierra Cascades Region --- Range and Extent

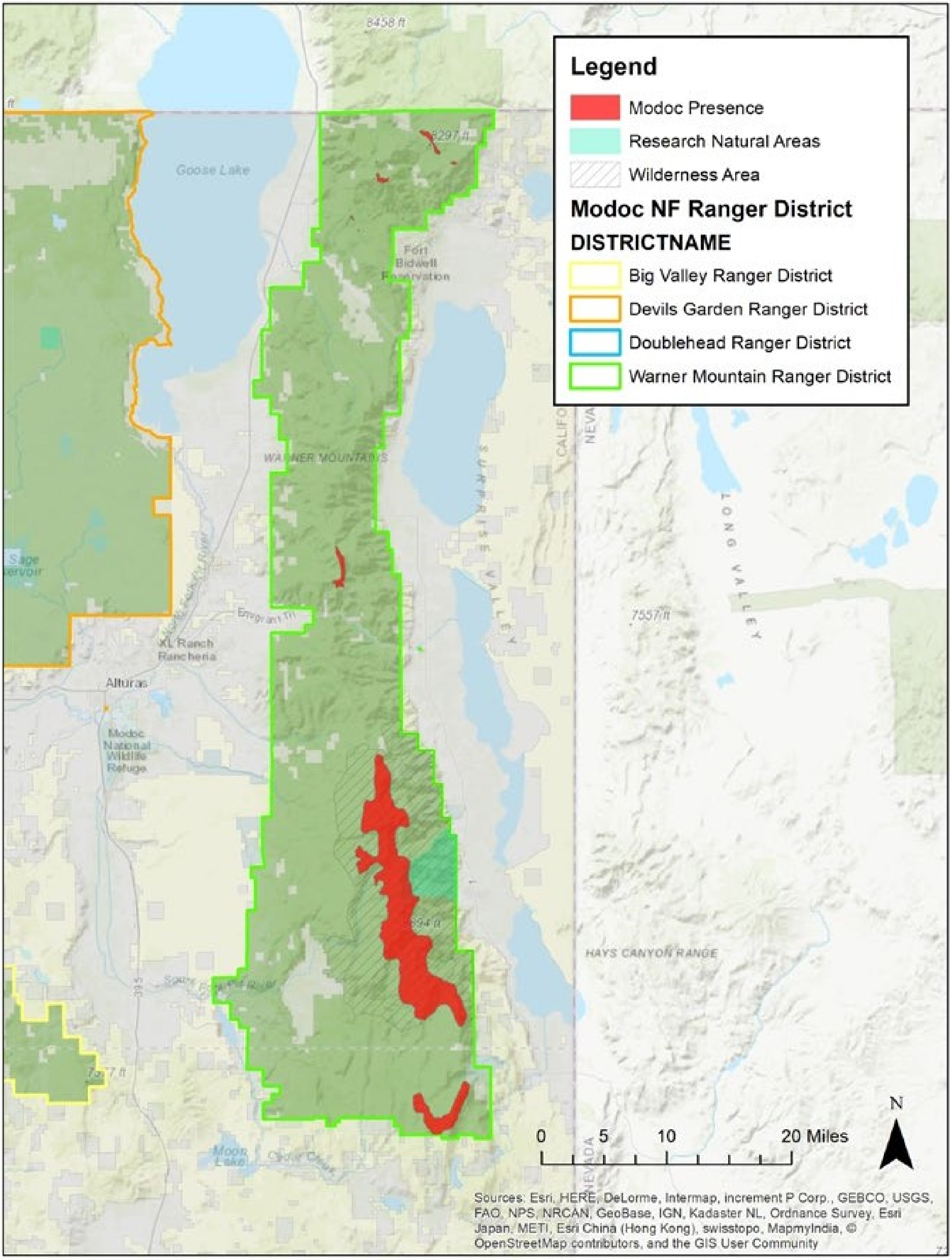


Appendix 1 - Figure 2. Sierra Cascades Region --- Range and Extent (Continued)



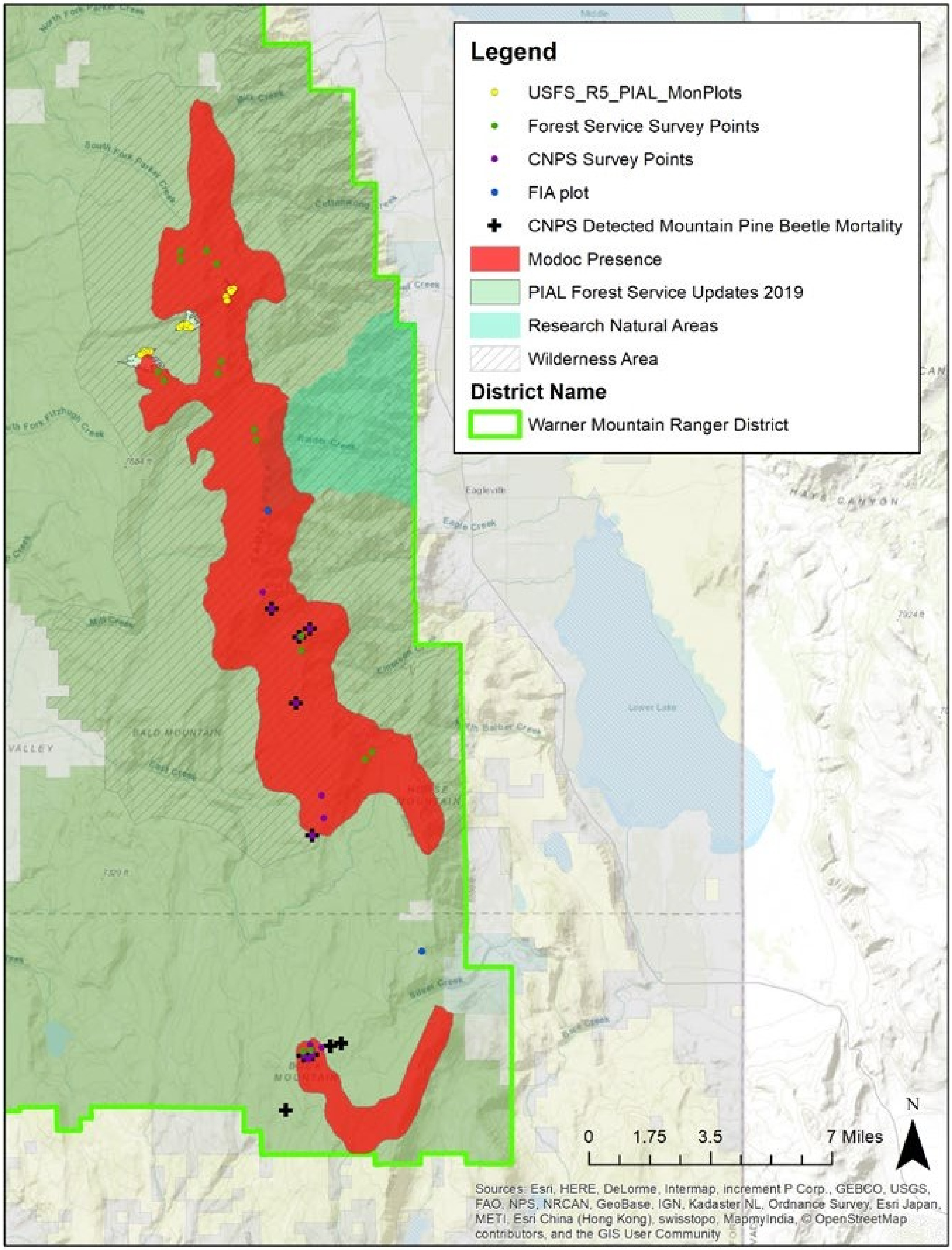
Appendix 1 - Figure 2. Sierra Cascades Region --- Range and Extent (Continued)

Modoc National Forest

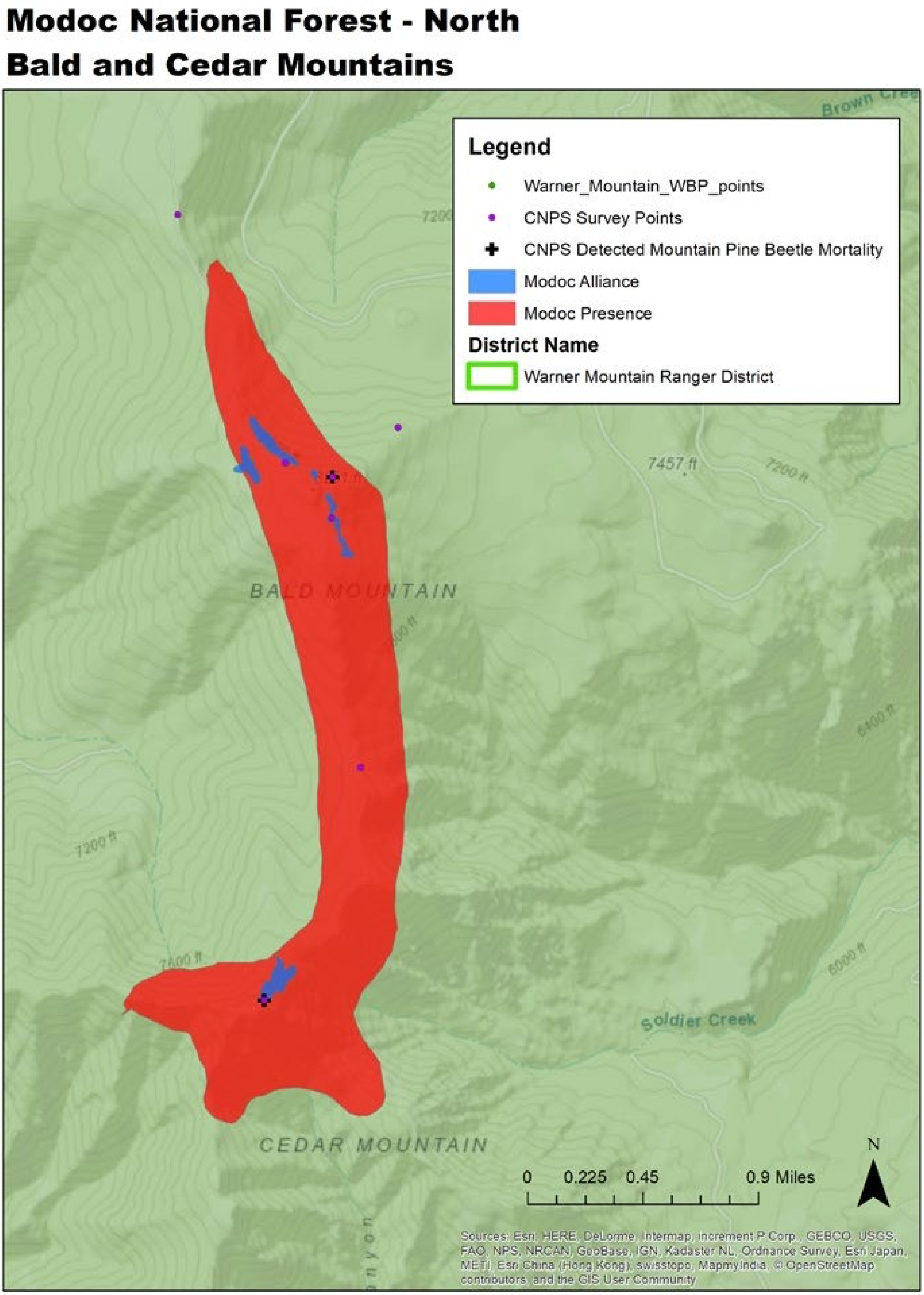


Appendix 1 - Figure 3. Modoc Region --- Range and Extent

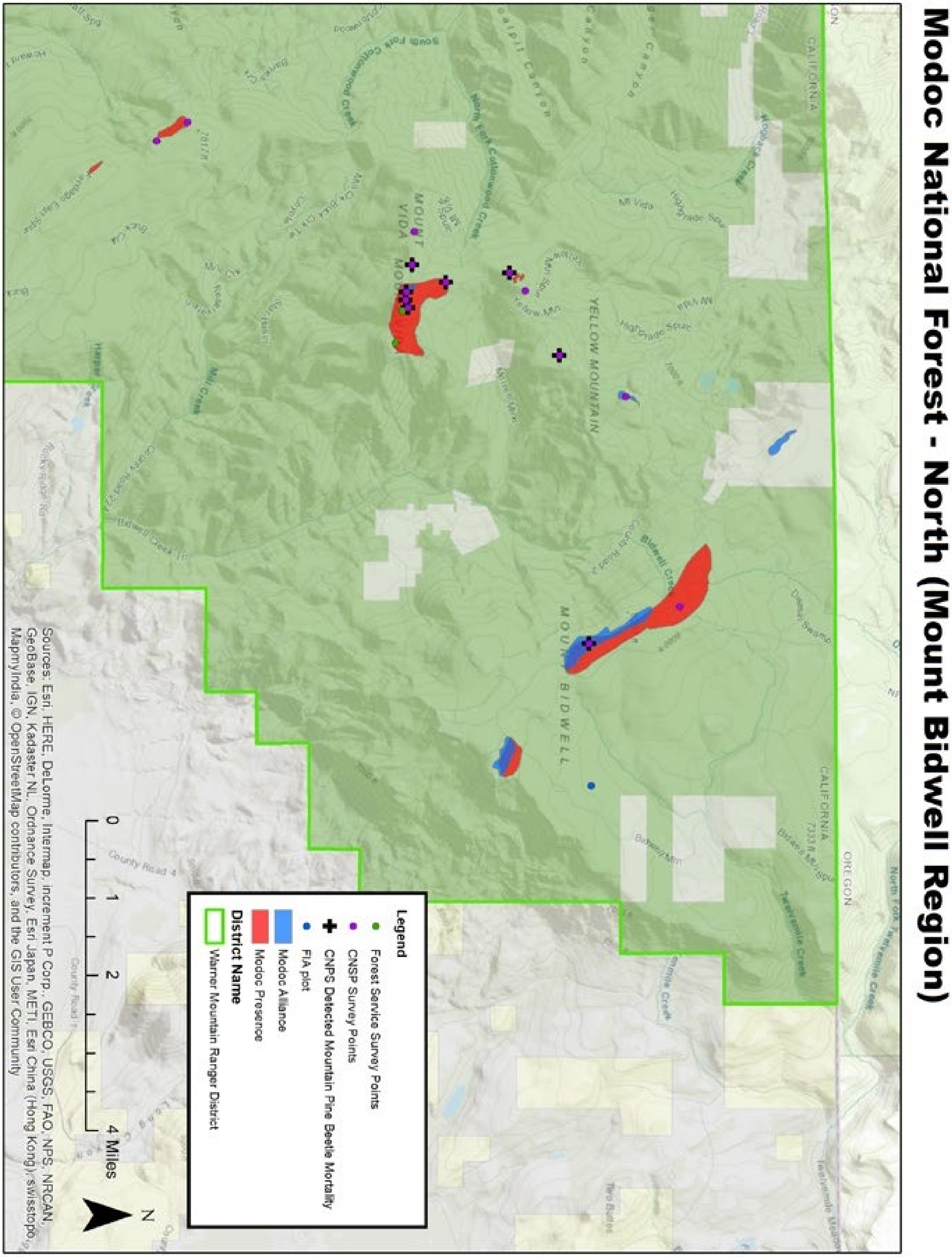
Modoc National Forest - Southern Warner Mountains



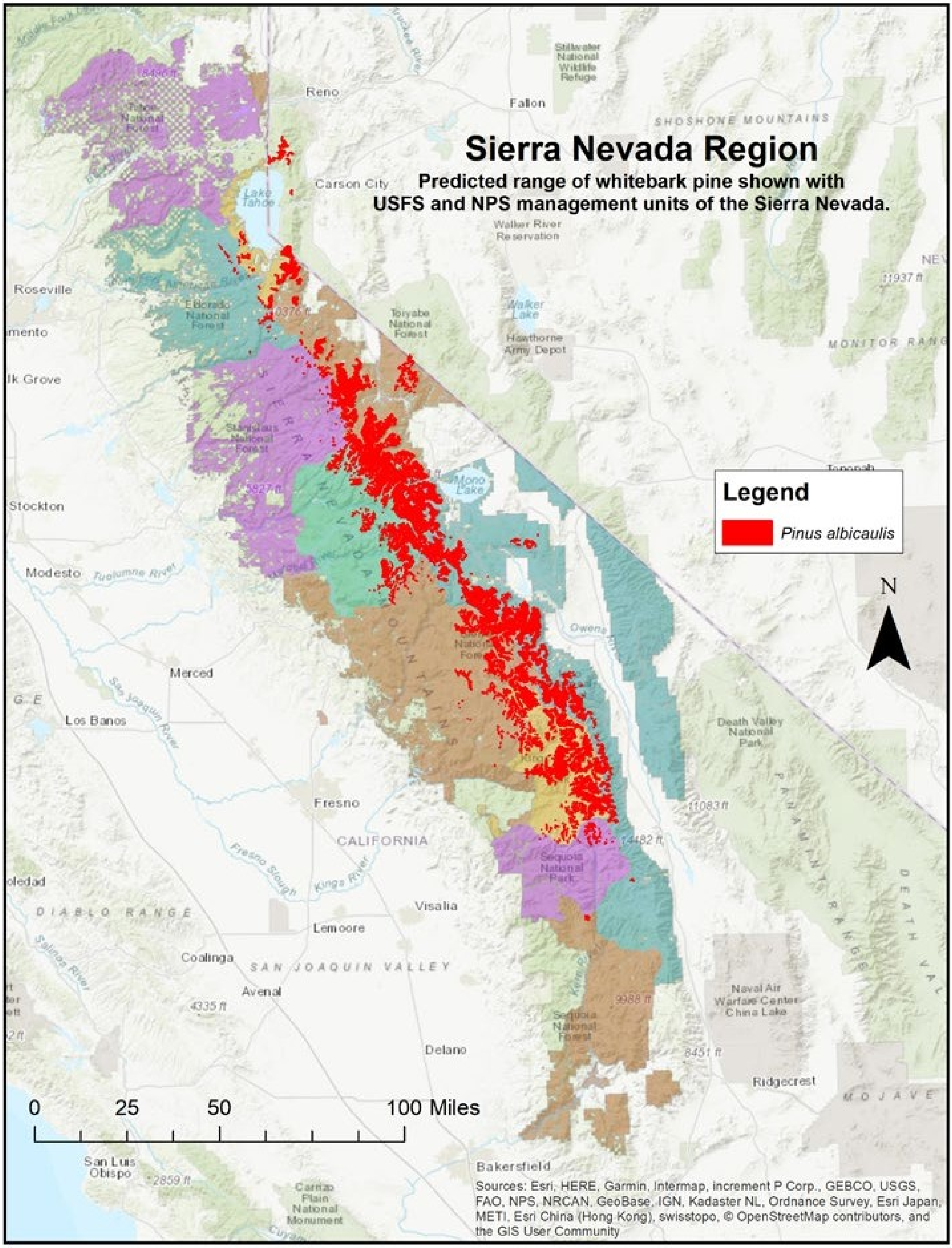
Appendix 1 - Figure 3. Modoc Region --- Range and Extent (Continued)



Appendix 1 - Figure 3. Modoc Region --- Range and Extent (Continued)

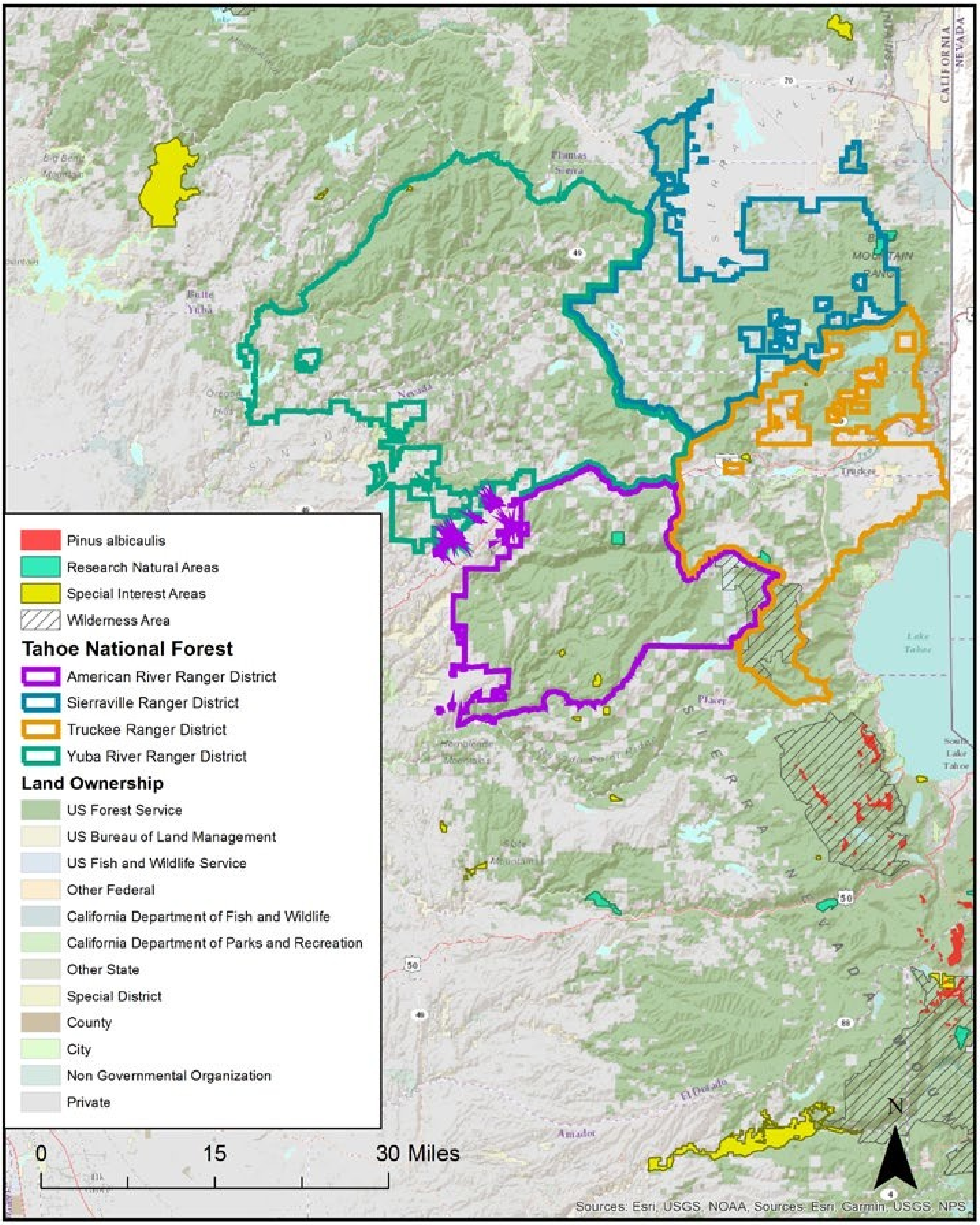


Appendix 1 - Figure 3. Modoc Region --- Range and Extent (Continued)



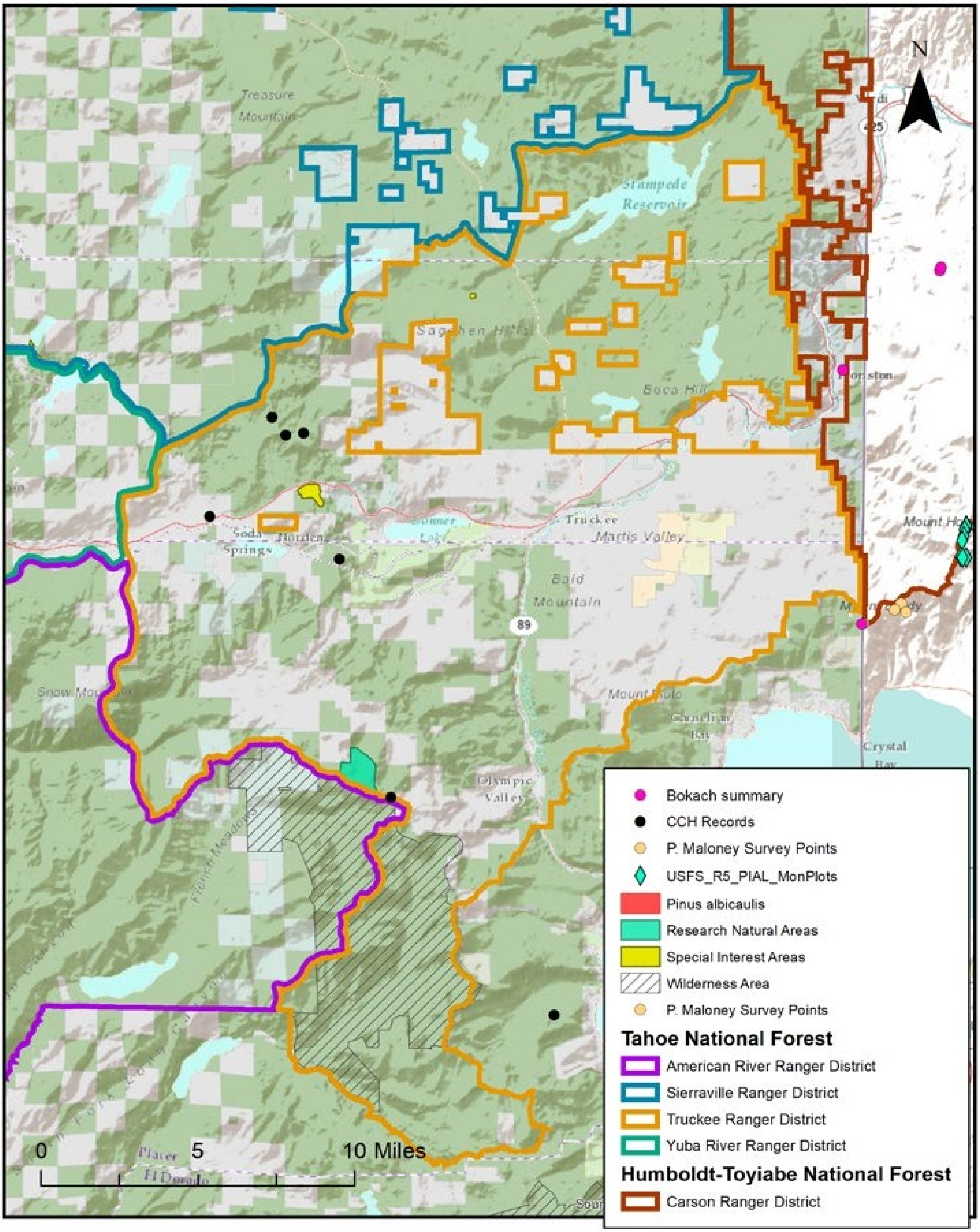
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent

Tahoe National Forest



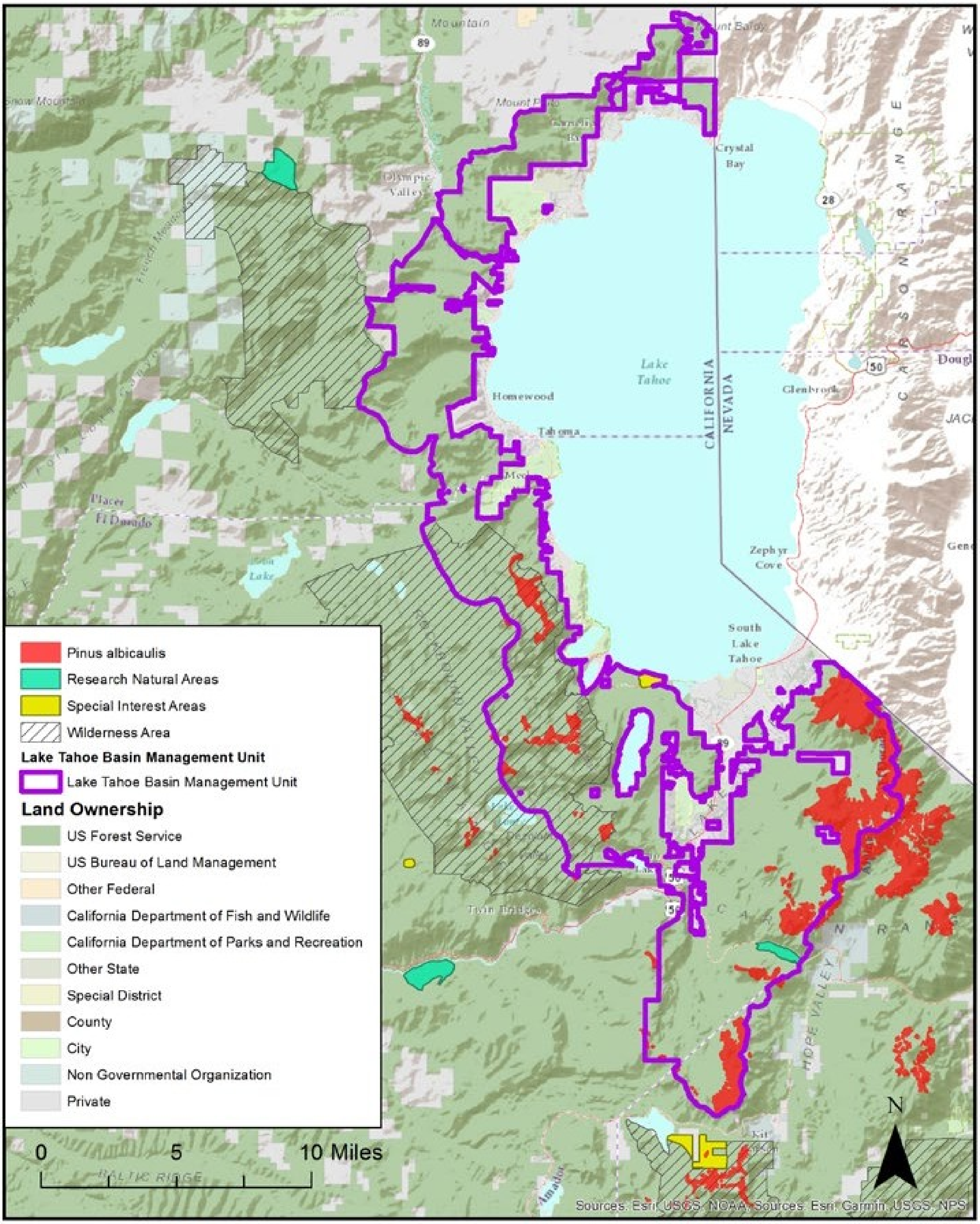
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Tahoe National Forest



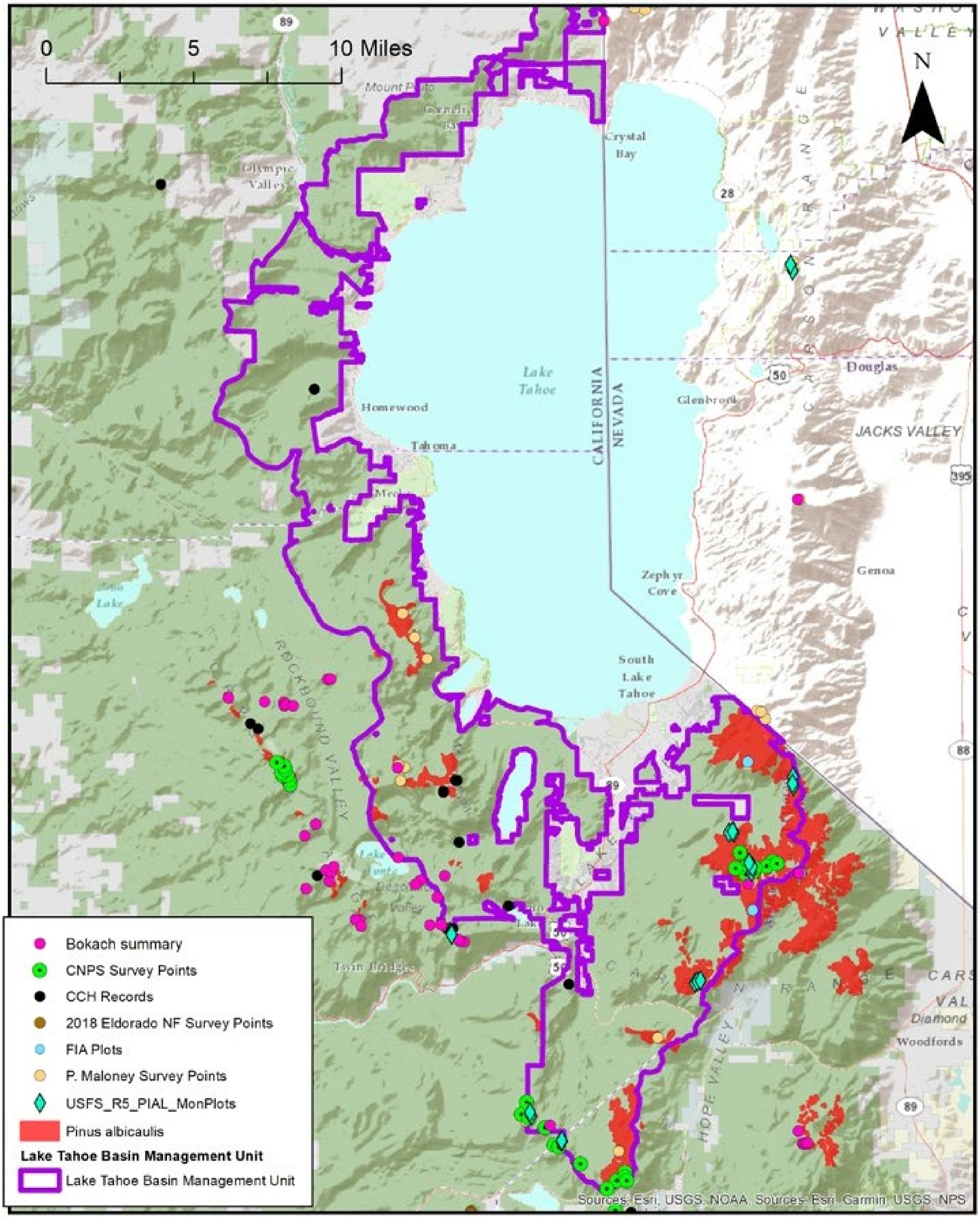
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Lake Tahoe Basin Management Unit



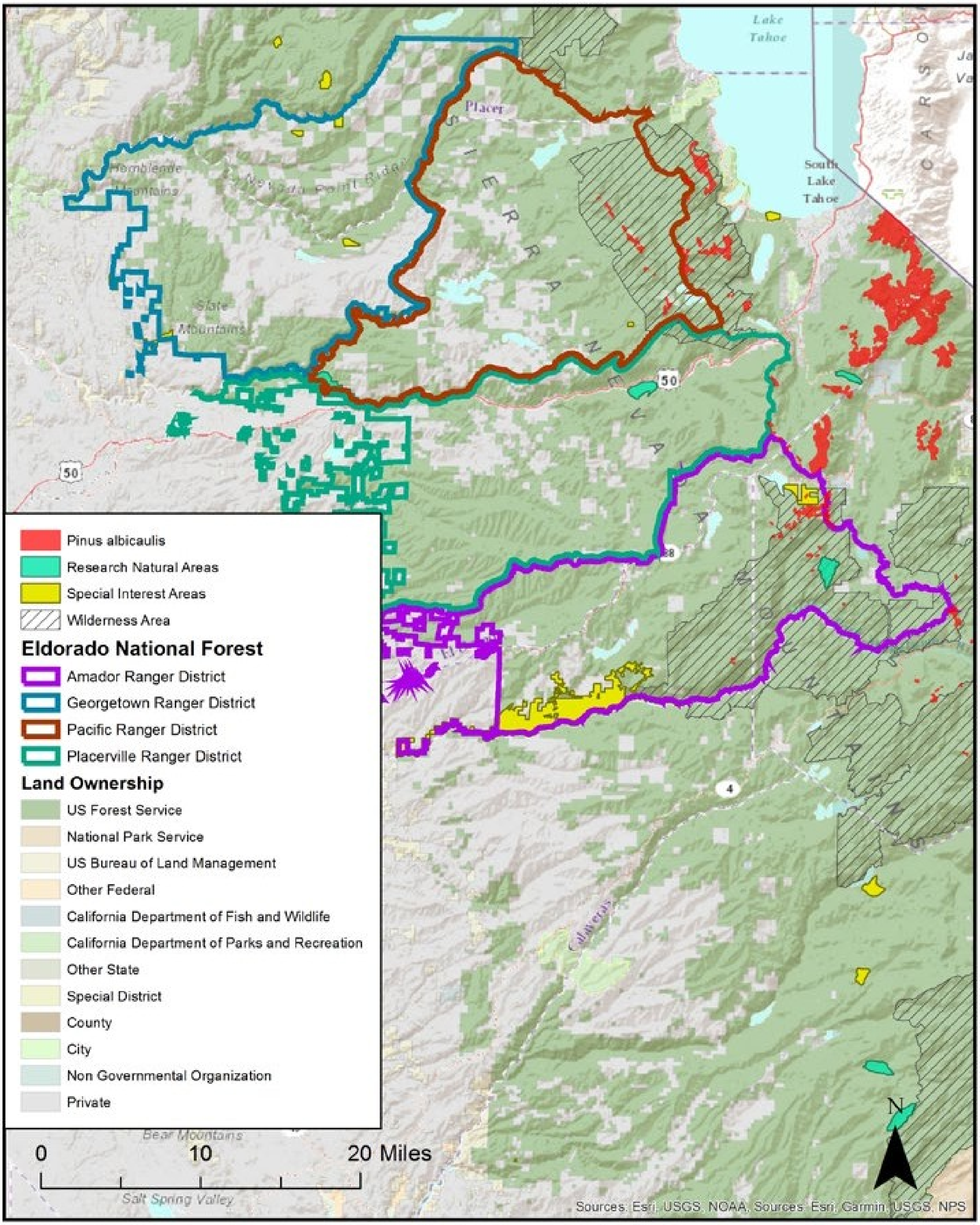
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Lake Tahoe Basin Management Unit



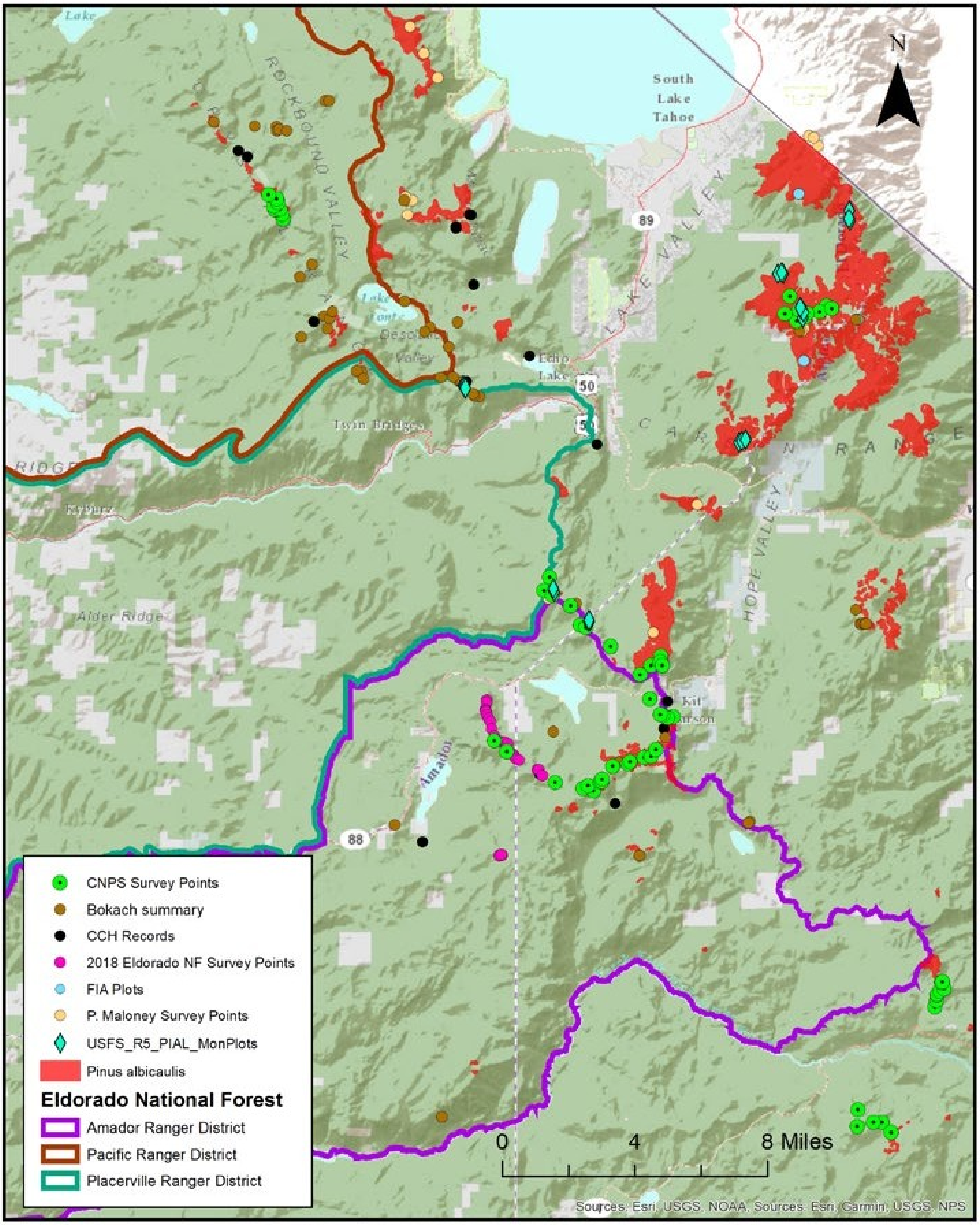
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Eldorado National Forest



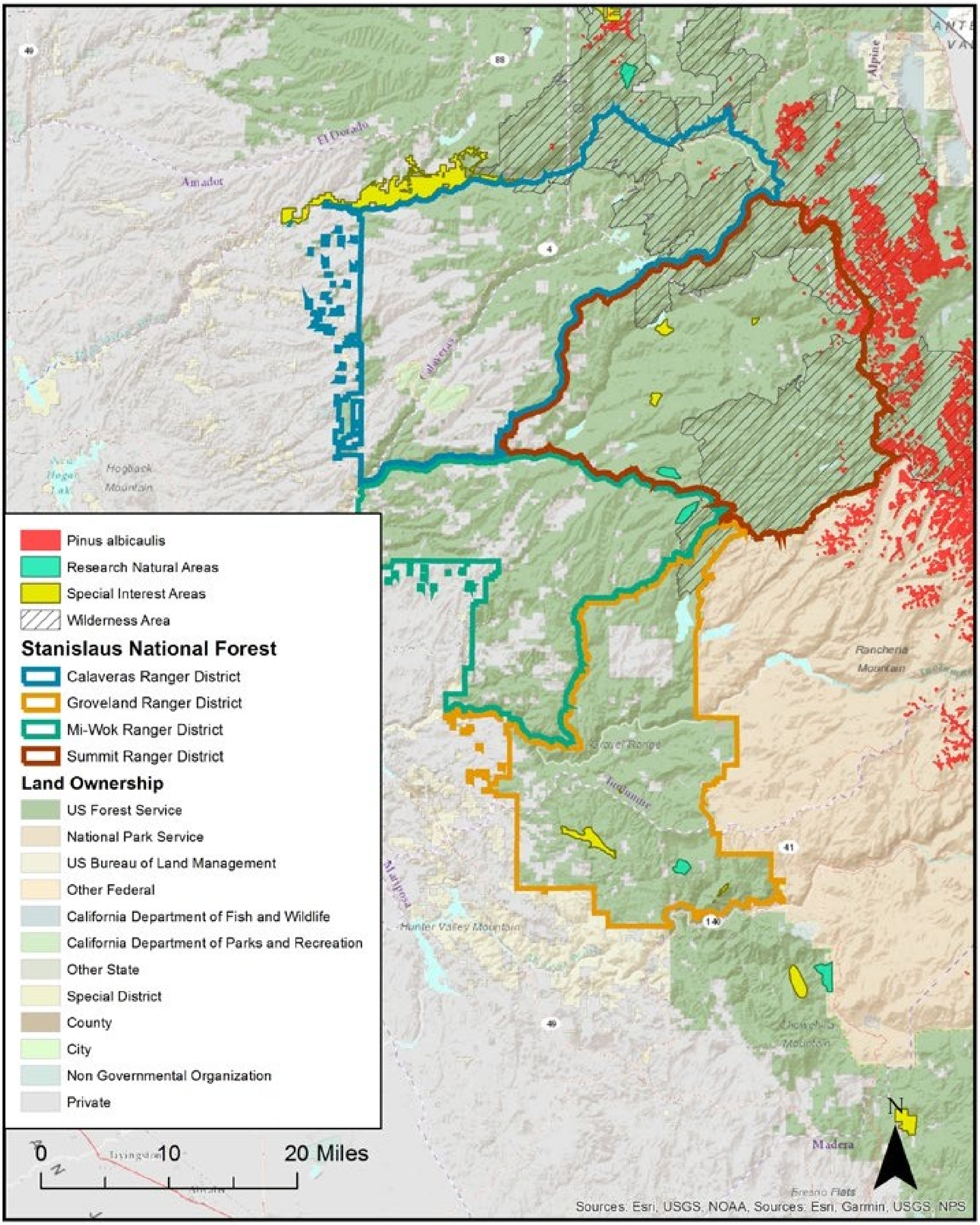
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Eldorado National Forest



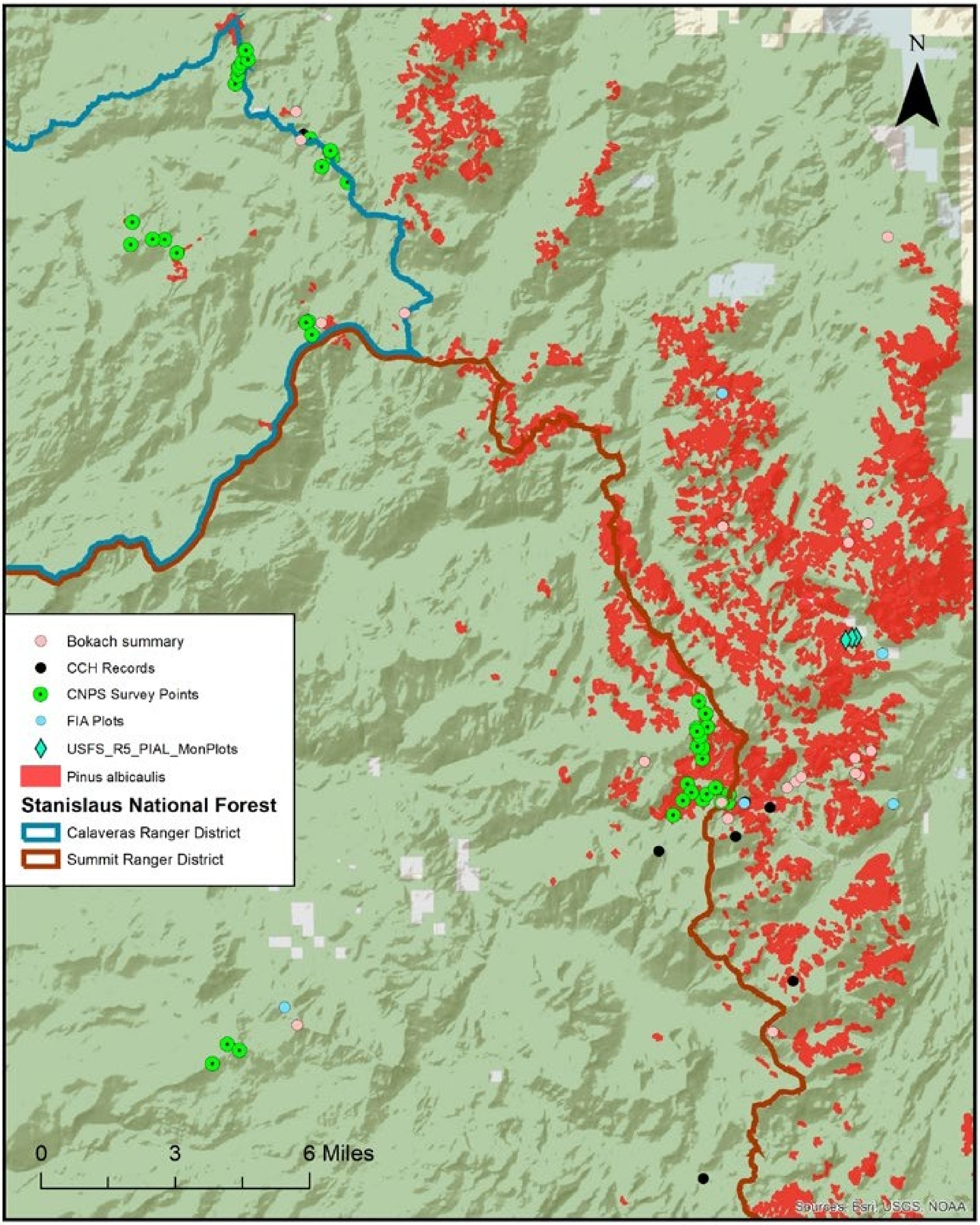
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Stanislaus National Forest



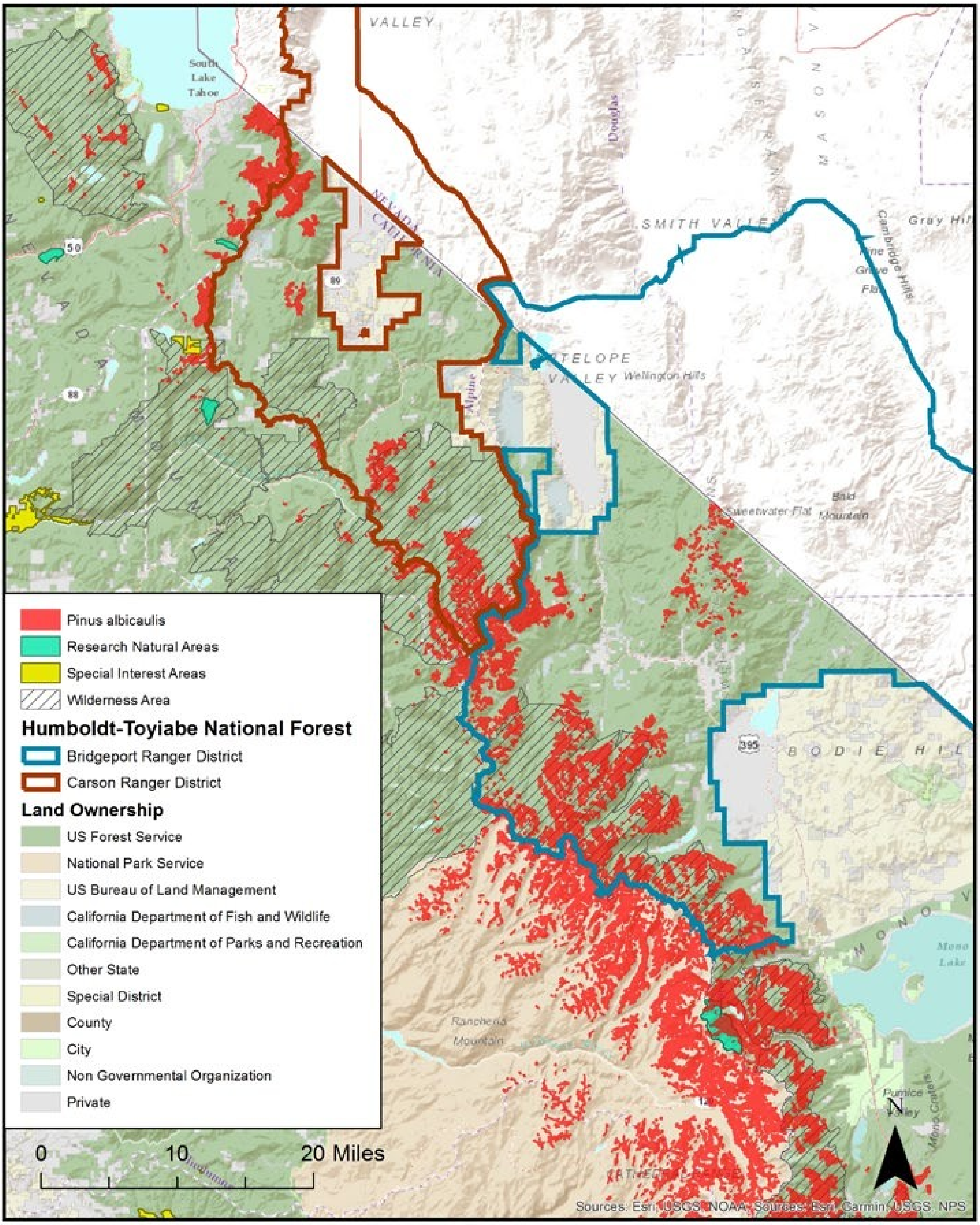
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Stanislaus National Forest



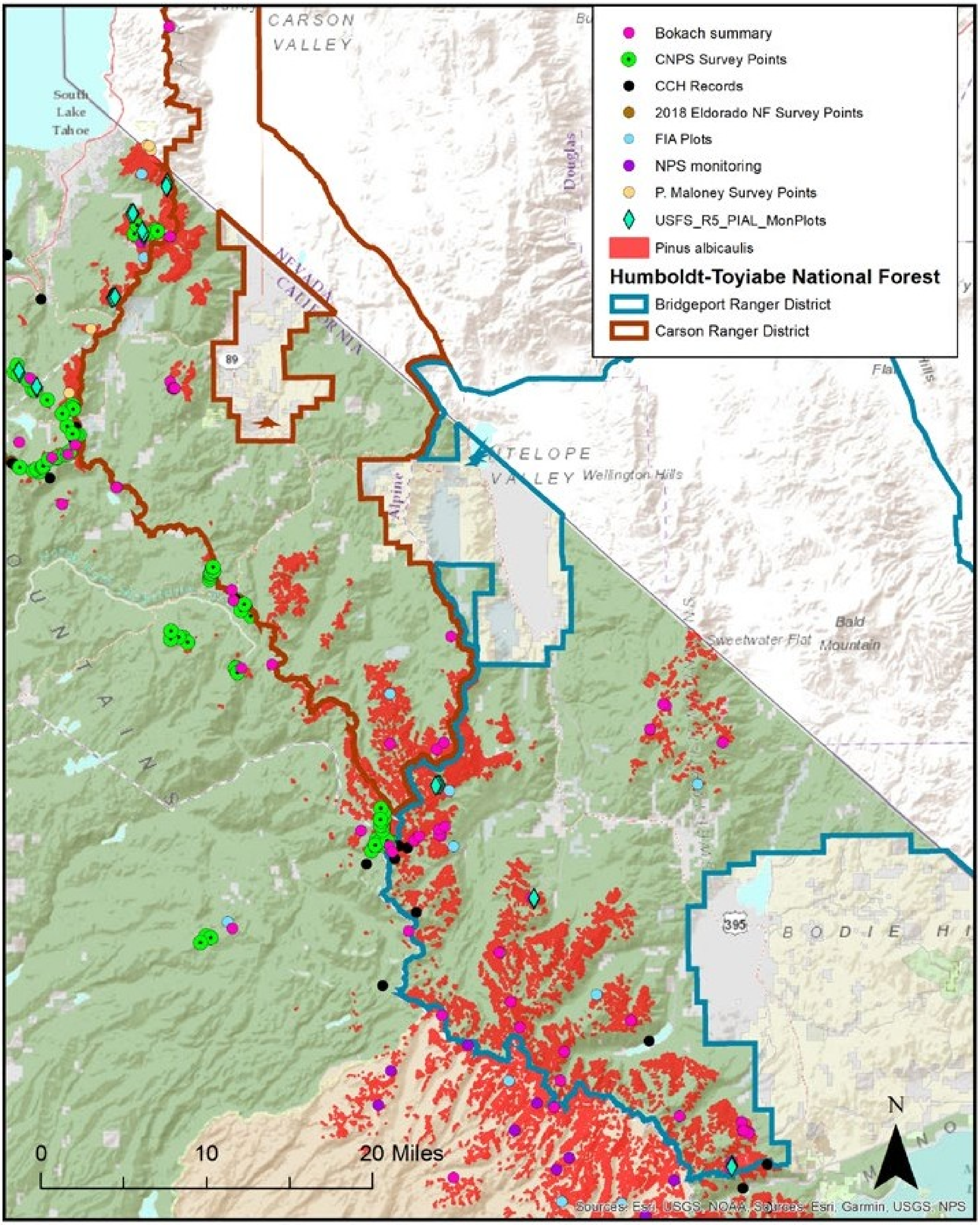
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Humboldt-Toiyabe National Forest



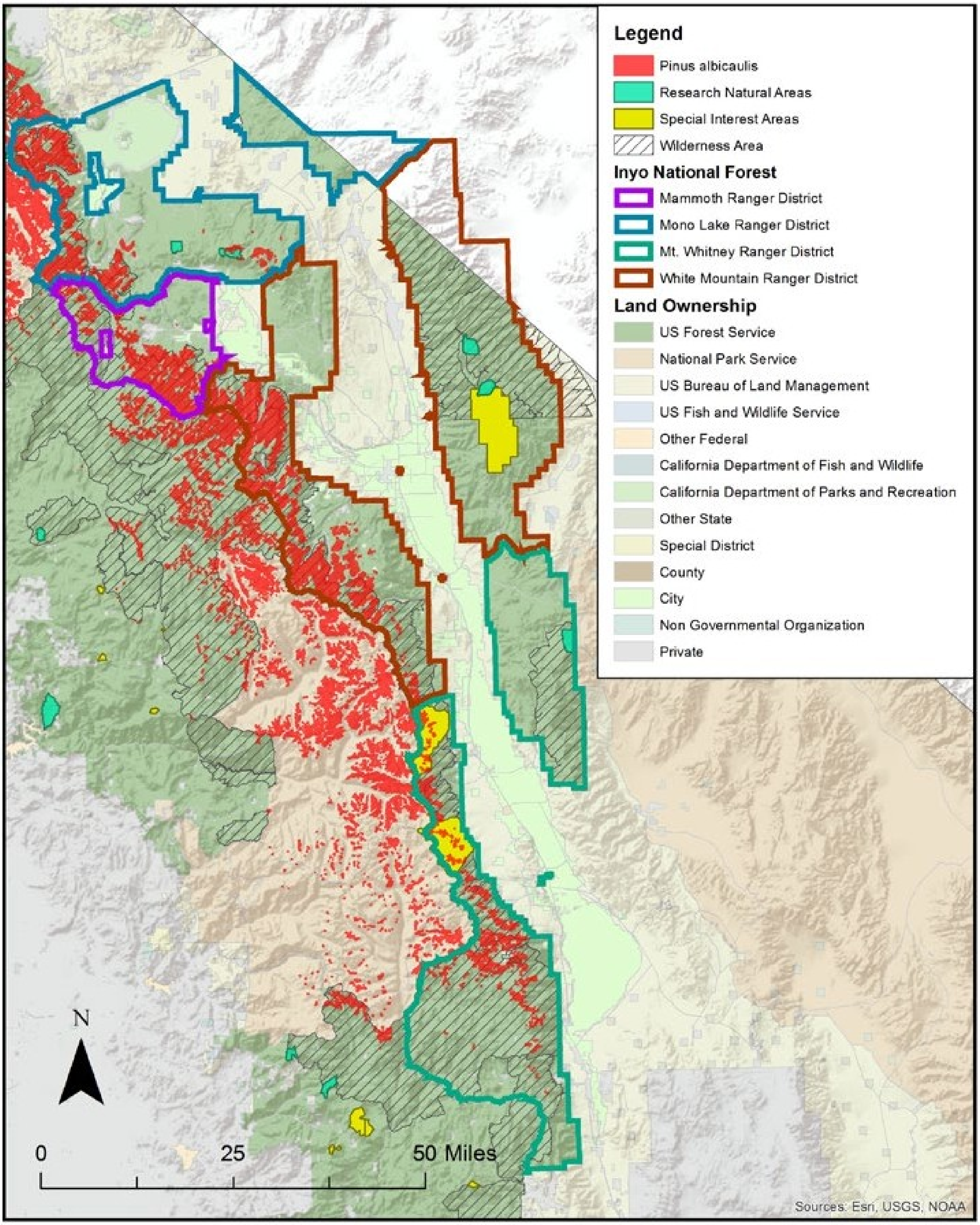
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Humboldt-Toiyabe National Forest

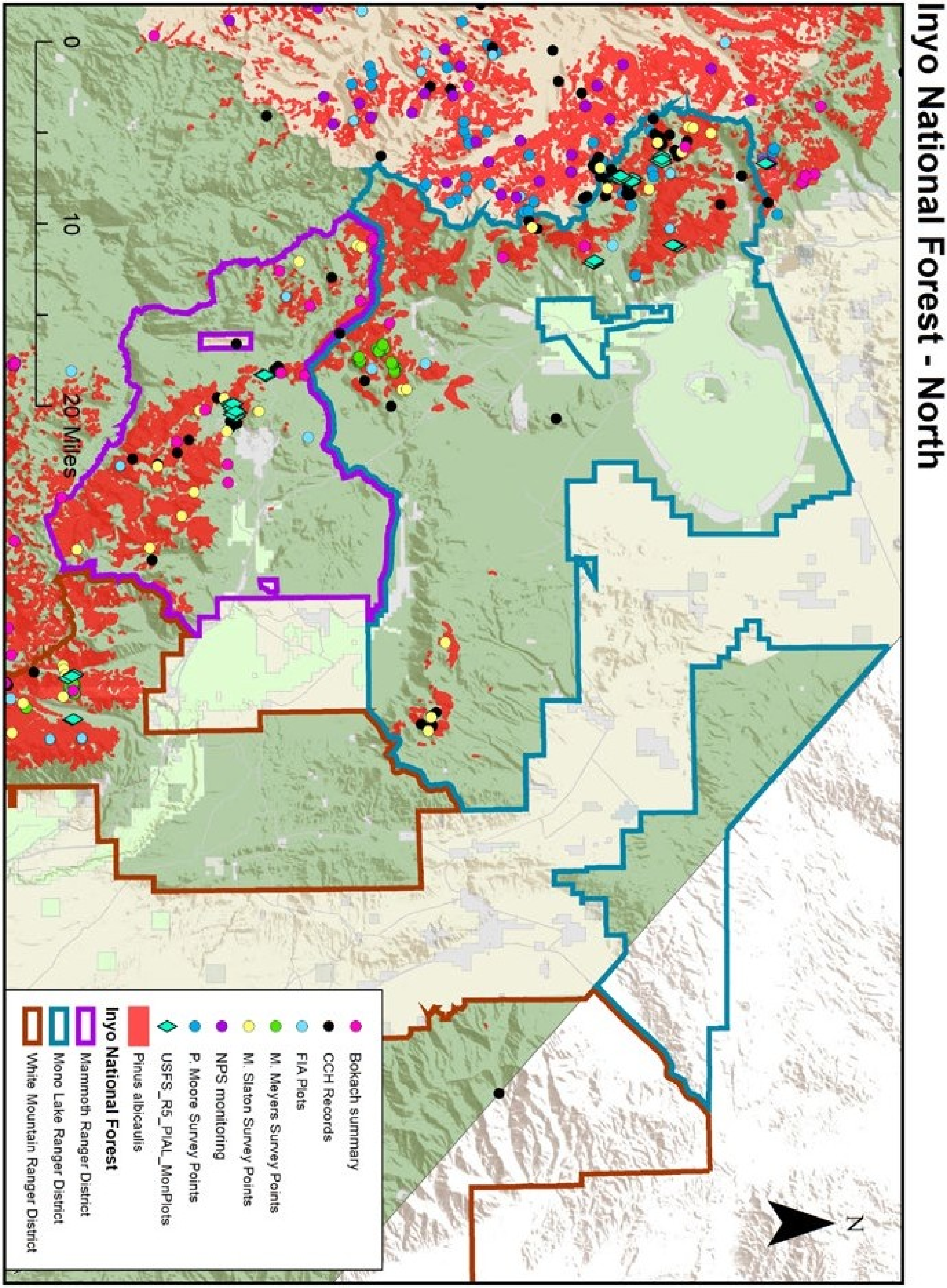


Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

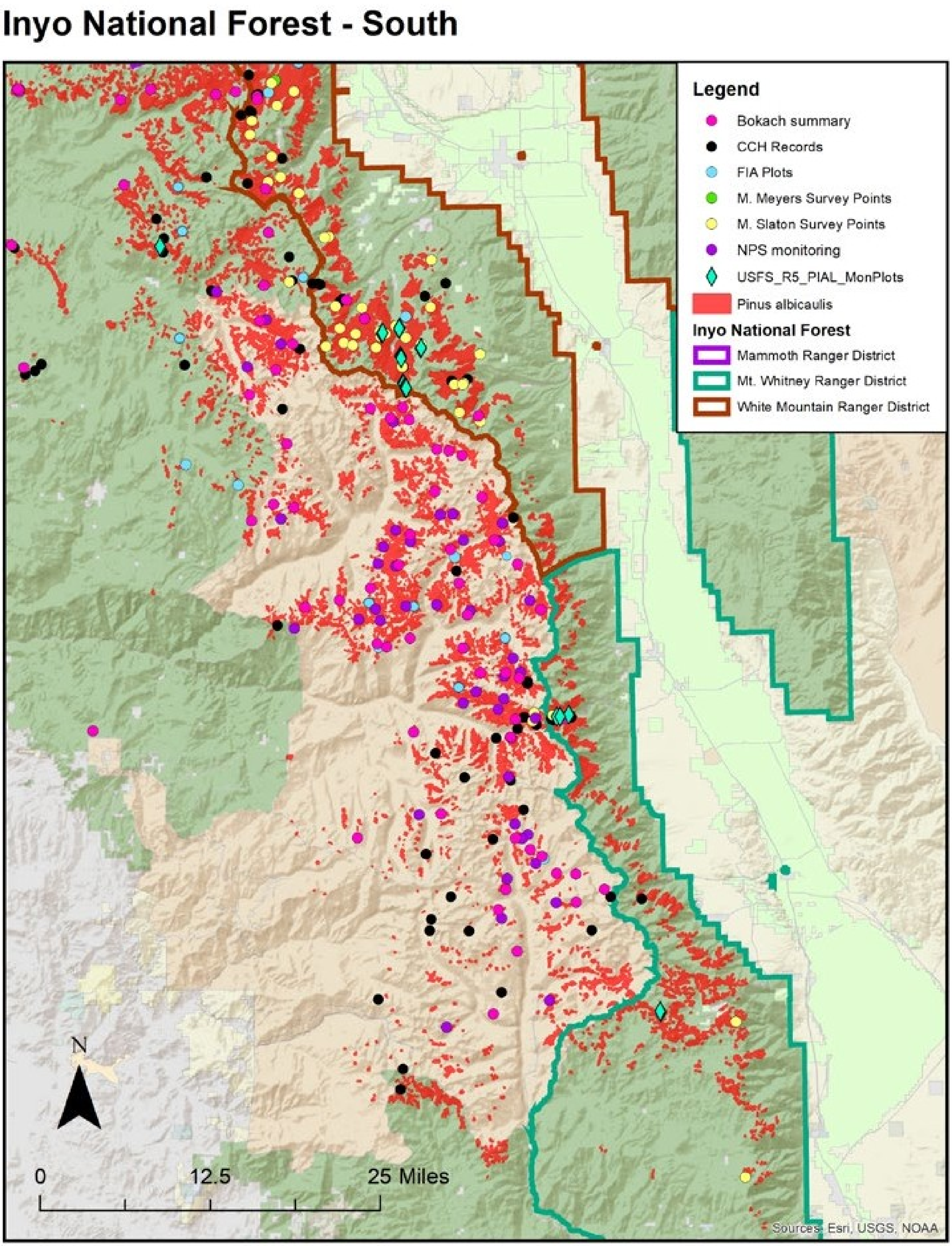
Inyo National Forest



Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

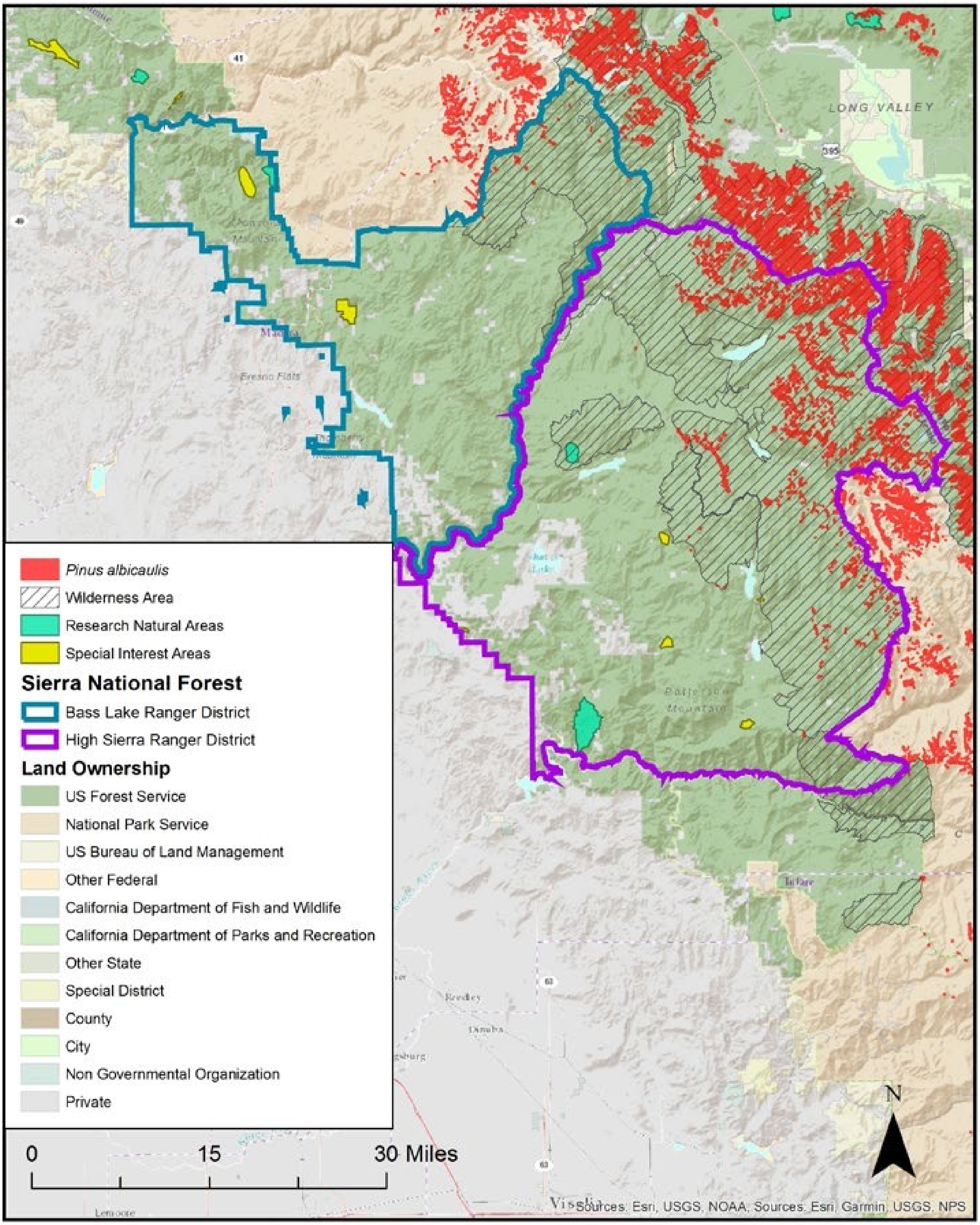


Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)



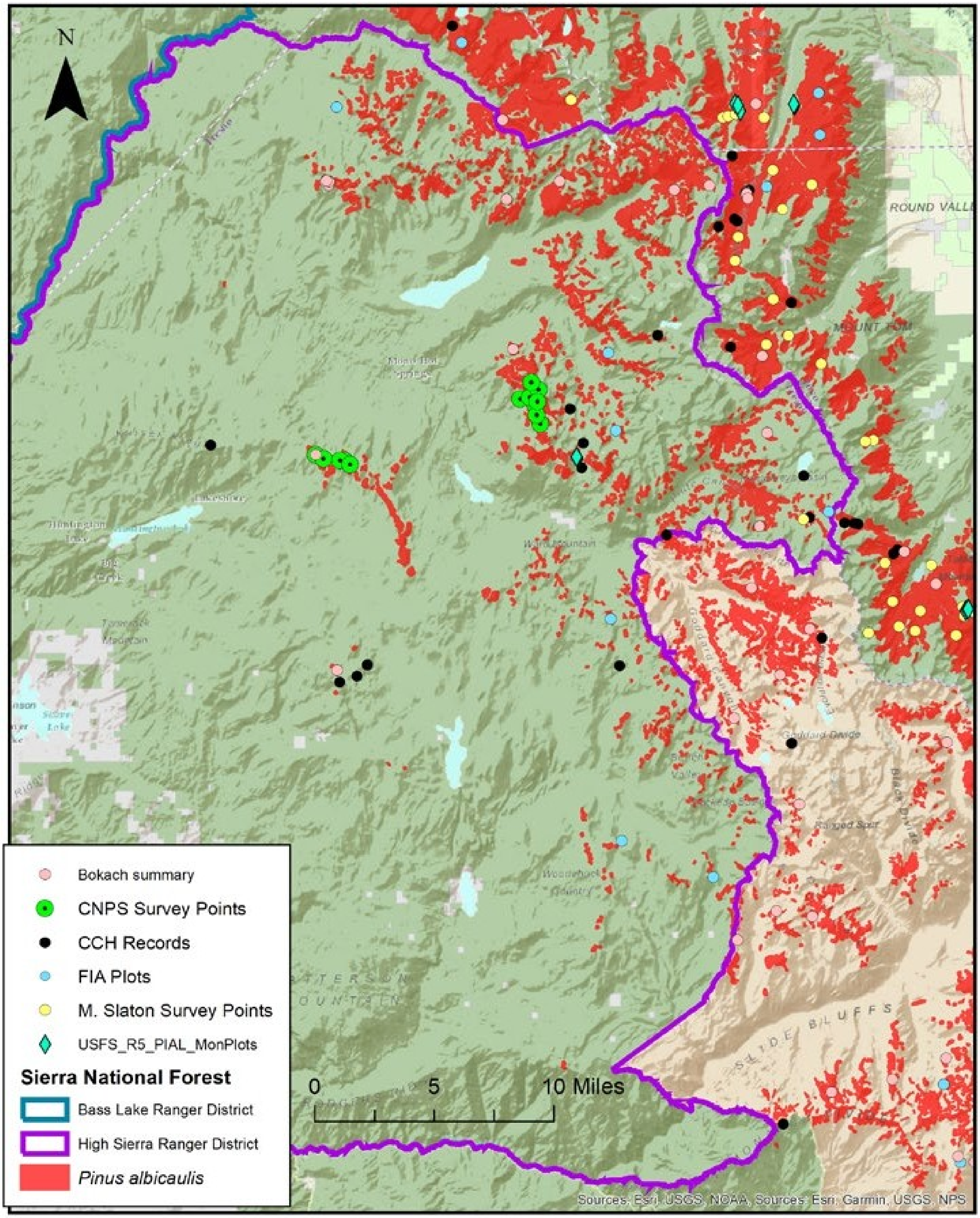
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Sierra National Forest



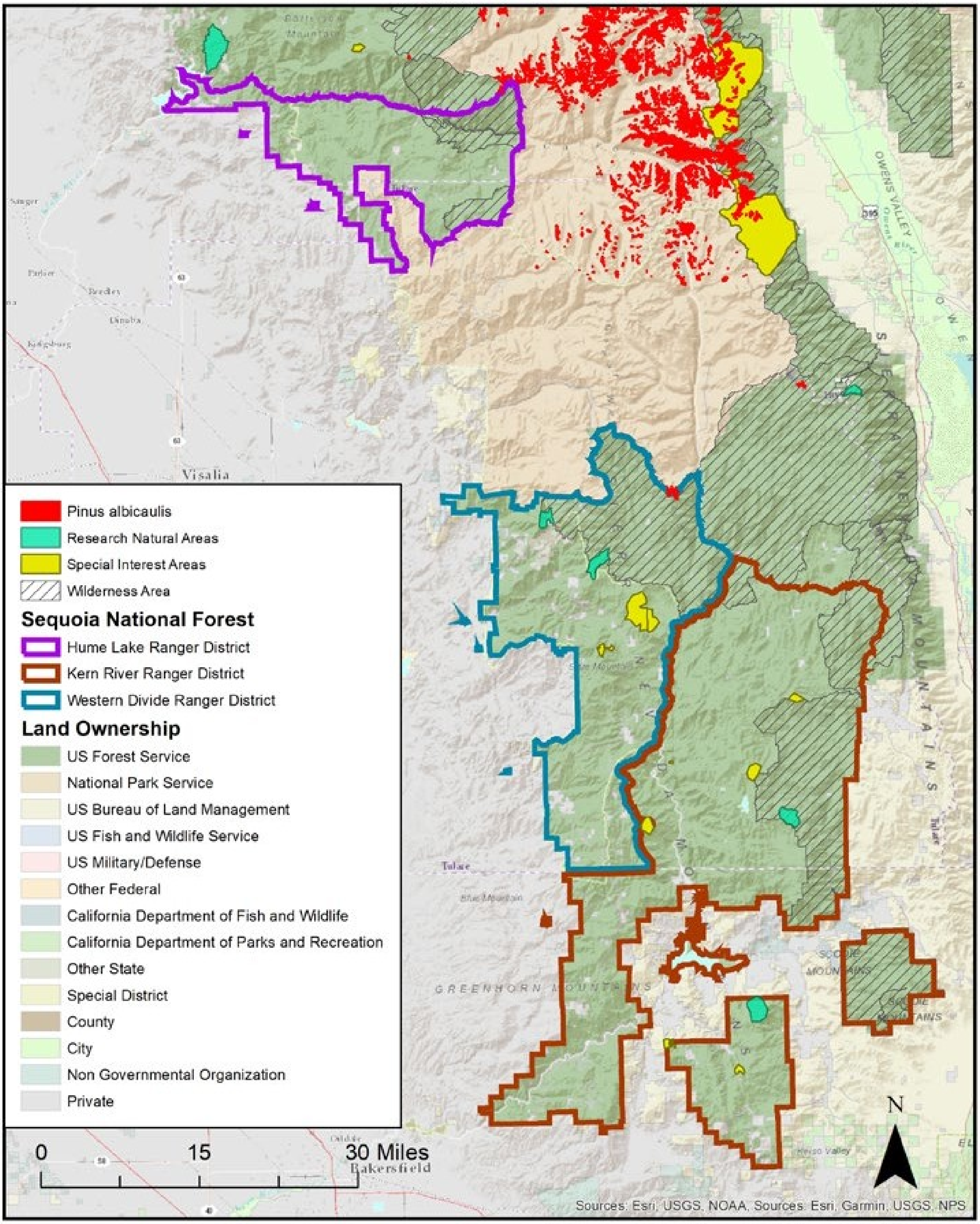
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Sierra National Forest



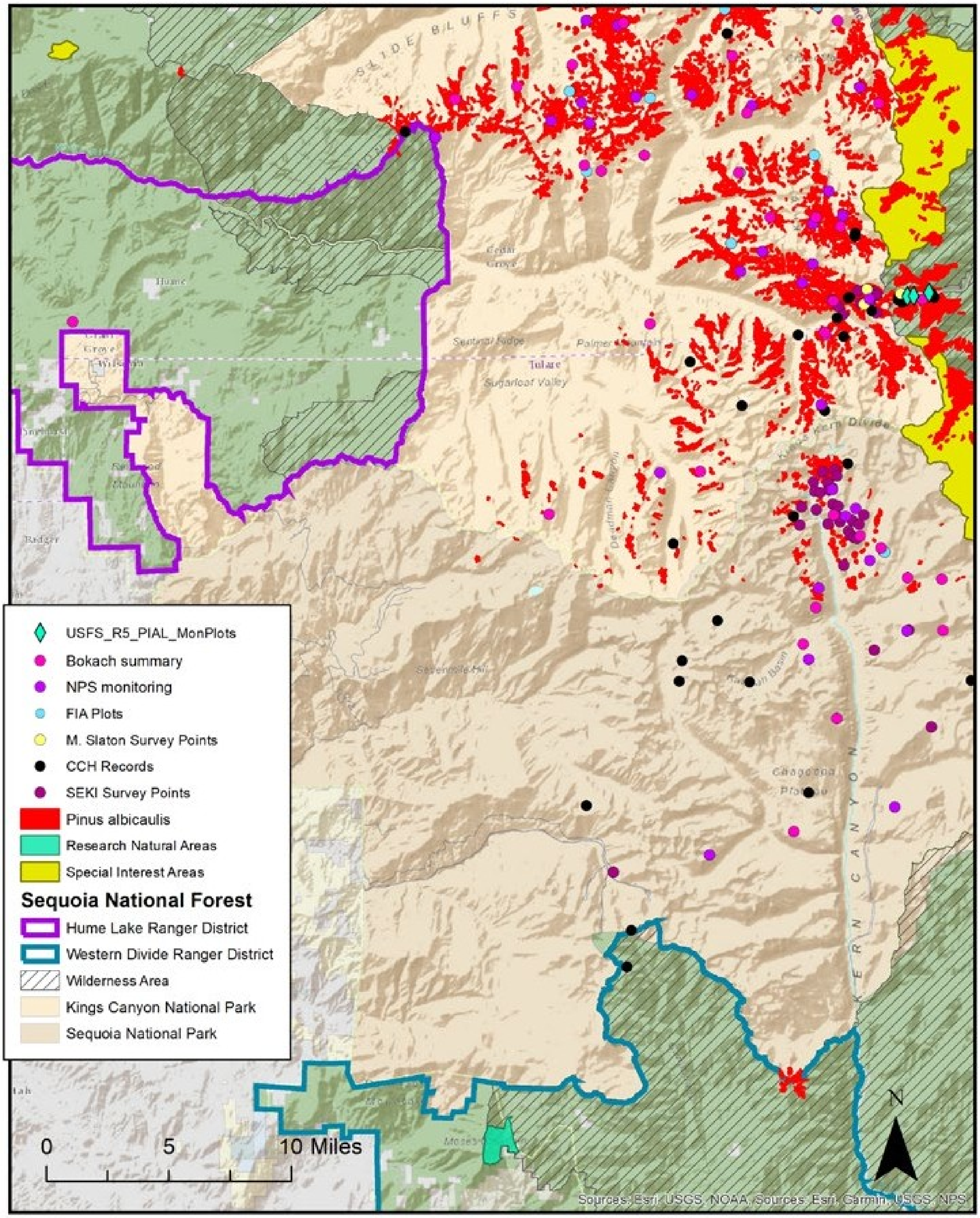
Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Sequoia National Forest



Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Sequoia National Forest



Appendix 1 - Figure 4. Sierra Nevada Region --- Range and Extent (Continued)

Appendix 2: National Forest Surveys - Insects and Disease

Introduction

The presence and severity of white pine blister rust (WPBR) and mountain pine beetle (MPB) represented by our maps reflects observations and monitoring efforts undertaken by numerous agencies and individuals, including those with the US Forest Service, US Geological Survey, National Park Service, UC Davis, Humboldt State University, CNPS, Western Ecological Research Center, CDFW, Tahoe Environmental Research Center, LTBMU (Lake Tahoe Basin Management Unit).

Oftentimes the goals of these monitoring efforts differed depending on the necessity for knowledge in that region (baseline assessment, management, etc.) and the immediacy of the threat of WPBR and/or MPB. Therefore, the interpretation of the data represented, in any given map, should acknowledge the goals of the monitoring effort, plot selection, and on-the-ground monitoring protocols (Table 2-2).

Point observations represent whitebark pine with the presence or absence of WPBR or MPB. Where possible, we represented the proportion of living individuals with and without WPBR or MPB, as well as mortality.

We have grouped forests and management areas into one of four regions: the Klamath, southern Cascades, Warners (Modoc), and Sierra. Results from monitoring efforts presented here, began as early as 1997 (Nate Stephenson), but for the most part occurred after 2010.

Data collection efforts were conducted using a variety of protocols with similar, but not always comparable methods. Across the state, and for each of the regions described below, we include a synopsis of the protocols used for data collection and data presentation.

We sought feedback from regional experts using survey questionnaires distributed electronically. Responses to the questionnaire is summarized in Table 2-3.

Materials and Methods

Statewide

While our maps present observations at the National Forest level, many of the datasets used to produce these points recorded data across the state of California. For these datasets we summarize their data collection protocol and our mapping protocol here:

California Native Plant Society (CNPS)

In collaboration with the USFS, CNPS initiated field surveys in 2013 and 2018 to assess the extent and status of whitebark pine in areas lacking ground surveys in California. Five national forests in the Sierra Nevada (Eldorado, Sequoia, Sierra, Stanislaus, and Lake Tahoe Basin Management Unit), and four national forests in the Cascade, Warner, and Klamath mountains (Klamath, Lassen, Modoc, and Shasta-Trinity), were selected for field surveys.

In addition to verifying the distribution and status of whitebark pine, data collection included conducting a modified rapid assessment and reconnaissance survey on whitebark pine and related stands (Buck-Diaz et al. 2018, Kauffman et al. 2014, Taylor et al. 2014). The modifications were additional attributes to capture health and demography data specific to whitebark pine.

Point locations, as well as status and health of whitebark pine, are presented in our maps and Table 1 summarizes the number of rapid assessments and reconnaissance efforts per forest or management area.

Table 2-1. Number of Rapid Assessment and Reconnaissance sampling units per National Forest or management area recorded by CNPS Monitoring efforts from years 2013 to 2016.

National Forest	Rapid Assessment (RA)	Reconnaissance (Recons)
Eldorado NF	20	18
Humboldt-Toiyabe NF	0	3
Klamath NF	37	0
Lassen NF	5	0
LTBMU	11	9
Modoc NF	34	0
Shasta-Trinity NF	9	0
Sierra NF	13	3
Stanislaus NF	23	21

Monitoring on the Margins Data

Data collected on all five-needle pines, including species, year, and the presence/absence of WPBR and/or MPB throughout California and western North America. "Presence" could constitute a single infected stem or it could mean nearly 100% mortality due to WPBR or MPB (M. Bokach 2013).

This data for whitebark pine is represented as point locations.

National Parks Inventory and Monitoring Program (I&M)

National Parks Service monitoring protocols were developed to address threats to all five-needle pine species, as well as set a baseline criteria for assessing how pests and pathogens (as well as other threats) would impact whitebark pine population viability long-term. Monitoring plots are 50m x 50m and inventoried all species susceptible to WBPR (five-needle pine) and MPB (all *Pinus* ssp.) were assessed for signs and symptoms of pests and pathogens (Jules et al. 2017, McKinney et al. 2012, Stucki et al. 2012).

Point locations, as well as status and health of whitebark pine, are presented in our maps.

Forest Inventory Analysis (FIA)

Forest Inventory Analysis reports on numerous metrics regarding status, presence, and land use recording data on forest area and location; species size, health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership. Plots are usually resampled every 10 years. The standard plot design consists of four 24-foot fixed-radius subplots for trees greater than 5 inches d.b.h, and and four 6.8-foot fixed-radius microplots for seedlings and trees >1 and <5 inches d.b.h. (Burrill et al. 2018).

For mapping purposes, we extracted location data by state and selected for plots labeled with a PIAL forest type in any year (n=54) as well as any plots that listed PIAL in the tree table in any year (n=34) (123 surveys were selected, many plots were surveyed twice and had PIAL listed both times, such that there were 86 plots selected in this manner. Only 52 of them were included in the selection by forest type, thus an additional 34 plots were selected with whitebark presence).

Note that coordinates for these locations may be fuzzed up to a mile from their precise location. In addition, some locations are actually swapped with other plots with similar characteristics in the same county (Burrill et al. 2018).

USFS Long-term Monitoring & Trend Analysis dataset (Meyer et al. 2019)

Data collected as a part of a California-wide monitoring survey where plot locations were selected using stratified sampling of PIAL.

This data is represented as point locations in our maps.

White pine blister rust in the high-elevation forests of California (P. Maloney, 2011)

Data collected as a part of a California-wide survey in 2004-2006 to evaluate the incidence and distribution of white pine blister rust in high-elevation white pine forests. Presence of both MPB and WPBR are displayed for 49 plots in whitebark pine forests.

Consortium of California Herbaria

Herbaria records, both historic and current, of all WBP in California with location data available. Represented in our maps as point locations. This data does not include information regarding pests or disease occurrence.

Klamath - Cascades Region

The Klamath Region is comprised of parts of the Klamath and Shasta-Trinity national forests. Statewide monitoring efforts are also reflected in the maps regarding this region, including those conducted by CNPS, the USFS Long-term Monitoring and Trend Analysis, FIA, and Margins.

Data Collection and Mapping

In addition to point locations and status data provided by statewide monitoring efforts (see Statewide subsection), the other dataset used to create maps for this region includes monitoring by Cynthia Snyder in 2010, which is represented by point locations with data regarding MPB and WPBR presence (C. Snyder 2019).

Southern Cascades Region

The southern Cascades region includes Lassen Volcanic National Park (LAVO) and Lassen National Forest. Statewide monitoring efforts are also reflected in the map regarding this region, including those conducted by CNPS, the USFS Long-term Monitoring and Trend Analysis, FIA, and Margins.

Data Collection and Mapping

Lassen Volcanic National Park

The status and health of whitebark pine across 30 plots were recorded as a part of the National Park Service Inventory and Monitoring Program from 2012-2014 (Jules et al. 2017). Also represented, is point data from an NPS mapping effort which noted the presence or absence of WBP (NPS 2012).

High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Mostly in the Sierran Forests, but 6 observations of WBP recorded here, one with MPB and WPBR presence.

Lassen National Forest

Only includes data from statewide projects listed under Southern Cascades heading.

Warner Mountains

The Warner Mountains represent the most easterly extent of whitebark pine in California and are found on the Modoc National Forest. Statewide monitoring efforts are also reflected in the map regarding this region, including those conducted by CNPS, the USFS Long-term Monitoring and Trend Analysis, FIA, and Margins.

Data Collection and Mapping

Monitoring efforts in the Warner Mountains presented in our maps include:

- Point locations from 2012 revisits to long-term monitoring plots in the south Warners from a Master's thesis (P. Figura et al. 2012), noting MPB mortality.
- Monitoring by Danny Cluck in 2010, which is represented by point locations with data regarding MPB and WPBR presence (Simons and Cluck 2010). Plots were originally established in 2006.
- CNPS mapping and inventorying in 2013 and 2018.

Sierra Region

The Sierra Region is comprised of eight national forests (Eldorado, Humboldt-Toiyabe, Inyo, Sequoia, Sierra, Stanislaus, Tahoe, and Lake Tahoe Basin Management Unit) and two National Parks (Yosemite and Sequoia-Kings Canyon). Statewide monitoring efforts are also reflected in the map regarding this region, including those conducted by CNPS, the USFS Long-term Monitoring and Trend Analysis, FIA, and Margins.

Data Collection and Mapping

Inyo National Forest

Marc Meyer 2012 is a subset of the USFS Ecology plots which uses an earlier, somewhat different protocol from other monitoring performed by this group (Meyer et al. 2019). Using a 100m grid sampling protocol, based on sampling protocols for the Greater Yellowstone (GYWPMG 2016), WBP dominant stands with recent MPB mortality were selected for comparisons against control stands with no recent MPB mortality. Ocular estimates of the vegetation cover, by strata (herbaceous and shrub), were also recorded. The goals of this monitoring effort included establishing eight future treatment areas. We display point data and MPB presence.

USFS Eastern CA Ecology dataset where tree, shrub, and herb vegetation strata were recorded in successive subplots (Slaton 2018). Point locations of WBP are presented.

High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Some points are only observations of WBP, while others assessed MPB and WPBR presence.

Eldorado National Forest

Monitoring efforts presented in our map include:

- Point locations of whitebark pine and WPBR by rangers (included in Margins data, Bokach 2013)
- Point locations of observations of whitebark pine by the 2018 Ecology Monitoring Crew (USFS 2018).
- Point locations of plots associated with a study regarding the Ecology of WBP in relation to WPBR (Maloney et al. 2012).
- High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Some points are only observations of WBP, while one is assessed MPB and WPBR presence.

Yosemite and Sequoia & Kings Canyon National Parks

Monitoring efforts presented in our map include:

- Point locations of 79 plots set up for monitoring of five-needle pines, including whitebark pine, conducted by the NPS I&M Program, and first established in 2011. The majority are dominated by WBP, while 12 are *Pinus balfouriana* plots where WBP was present.
- Point locations of vegetation surveys associated with the mapping effort for Sequoia & Kings Canyon National Park between 2000 and 2003. Only the presence of WBP is noted here (NPS 2014).
- Location of a long-term monitoring effort regarding a population comprised of whitebark pine tree and krummholz leaders which was first monitored in 1997 (N. Stephenson, 2019). This monitoring effort aims to record annual rates of mortality, recruitment, leaders release rates, and changes in krummholz mat heights and areas.
- Point locations of 22 permanent plots including whitebark pine that were established as a part of the YOSE Vegetation Inventory and Type Mapping Project conducted by the National Park Service and various partners in 1998 and 1999 (NPS 2003).
- Point locations of 33 permanent plots including whitebark pine that were surveyed between 1991 and 1993 by NPS field crews as part of a Natural Resources Inventory (NPS 1993).
- High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Some points are only observations of WBP, while others assessed MPB and WPBR presence.

Lake Tahoe Basin Management Unit (LTBMU)

Monitoring efforts presented in our map include:

Point locations of plots associated with a study regarding the Ecology of WBP in relation to WPBR (P. Maloney 2011). Presence of WPBR is displayed.

Humboldt-Toiyabe National Forest

High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Some points are only observations of WBP, while others assessed MPB and WPBR presence.

Sierra Monitoring Project/Ecoregional Biodiversity Monitoring project (D. Wright et al. 2016).

Sequoia National Forest

No additional sources included.

Sierra National Forest

High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. One point only an observation of WBP.

USFS Eastern CA Ecology dataset where tree, shrub, and herb vegetation strata were recorded in successive subplots (Slaton 2018). Point locations of WBP are presented.

Stanislaus National Forest

High Elevation Species and Natural Communities in the Northern Sierra (Stewart et al. 2017) for CDFW. Points were assessed for MPB and WPBR presence.

Tahoe National Forest

No additional sources included.

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Table 2-2. Protocol details for datasets.

Dataset	Curators and Affiliation	Location (s)	Years	Number of plots or transects	Plot Selection	Measuring unit (plots, individuals, stands, transects)	MPB	WPBR	Protocol Modified from…
CNPS Rapid Assessment Reconnaissance Data	Kauffman, M. et al., CNPS	See Table 2-1	2013 to 2018	200	Homogeneous vegetation (similar structural and compositional integrity)	Relevè-plot based, all species recorded. Plot size determined by community type. Rapid Assessment-Stand based, 12 to 20 of the dominant species and cover values	Categorical scale from 0-3, with "0" representing no signs of attack and "3" representing attack of >50% of the bole	Estimated percent of population impacted, as well as percent mortality attributed to WPBR	Combination of CNPS Rapid Assessment and Relevè Protocols
USFS Long-term Monitoring and Trend Analysis	Mark Meyer, Michèle Slaton, Shana Gross, USFS	Sierra Nevada, southern Cascades, and other Region 5 populations. A minimum of 5 to 10 plots/stands were monitored in each sampling unit.	2012-2019	163	Stratified Random sampling in various ranges within USFS Region 5. Focused on areas with recent mortality related to MPB and WPBR.	Individuals in stands dominated or co-dominated by whitebark pine. Two plot sizes: (1) 0.08 ha plots or (2) 100-m sampling grid laid over small, isolated stands or isolated areas of interest.	Categorical scale from 0-3, with "0" representing no signs of attack and "3" representing attack of >50% of the bole. Populations monitored after mid-July to beginning of August	Symptoms (cankers, branch flagging, branch swelling, bark discoloration, rodent chewing, aecia) and location (main stem, branches, or basal sprouts) noted	GYWPMWG Monitoring Protocol
Margins	Matt Bokach: formerly USFS	Statewide	1954-2011	334	Stratified Random sampling in various ranges within USFS Region 5. Focused on areas with recent mortality related to MPB and WPBR.	Individuals in stands dominated or co-dominated by whitebark pine. Two plot sizes: (1) 0.08 ha plots or (2) 100-m sampling grid laid over small, isolated stands or isolated areas of interest	Presence/absence	Presence/absence	GYWPMWG Monitoring Protocol

Dataset	Curators and Affiliation	Location (s)	Years	Number of plots or transects	Plot Selection	Measuring unit (plots, individuals, stands, transects)	MPB	WPBR	Protocol Modified from…
Inyo National Forest	Marc Meyer, Shana Gross, and Michèle Slaton, USFS	Inyo NF	2012	64	Stratified Random sampling in various ranges within USFS Region 5. Focused on areas with recent mortality related to MPB and WPBR.	Individuals in stands dominated or co-dominated by whitebark pine. Two plot sizes: (1) 0.08 ha plots or (2) 100-m sampling grid laid over small, isolated stands or isolated areas of interest	Categorical scale from 0-3, with "0" representing no signs of attack and "3" representing attack of >50% of the bole. Populations monitored after mid-July to beginning of August	Symptoms (cankers, branch flagging, branch swelling, bark discoloration, rodent chewing, aecia) and location (main stem, branches, or basal sprouts) noted	GYWPMWG Monitoring Protocol; *subset of USFS Long term Monitoring and Trend Analysis monitoring effort
El Dorado National Forest	USFS Rangers, USFS	Eldorado NF	2004	34	Casual observations of WBP and infected WBP	Individual trees	Not noted	Presence/absence	*included in Bokach datasets
Sierra Network-NPS Inventory and Monitoring	Jonathan Nesmith et al.	Sequoia & Kings Canyon National Parks	2011 - ongoing	79	Stratified random sampling	All species in 50m x 50m square plots	Presence/Absence (as determined by presence of J-galleries, pitch tubes, or frass)	Infection denoted as active (presence of active canker) or inactive (presence of 3 or more symptoms; ie. Flagging, swelling, rodent chewing, roughened bark, and oozing sap) or old aecia. Bole and branch divided into thirds and assessed individually.	McKinney et al. 2012
Klamath Network-NPS Inventory and Monitoring	Sean Smith[1], Erik S. Jules[2] [1]National Parks Service, [2]Humboldt State University	Lassen Volcanic and Crater Lake National Parks	2012 - ongoing	30 (each park)	Stratified random sampling	All species in 50m x 50m square plots	Presence/Absence (as determined by presence of J-galleries, pitch tubes, or frass)	Infection denoted as active (presence of active canker) or inactive (presence of 3 or more symptoms; ie. Flagging, swelling, rodent chewing, roughened bark, and oozing sap) or old aecia. Bole and branch divided into thirds and assessed individually.	McKinney et al. 2012

Dataset	Curators and Affiliation	Location (s)	Years	Number of plots or transects	Plot Selection	Measuring unit (plots, individuals, stands, transects)	MPB	WPBR	Protocol Modified from…
WBP Long-term Monitoring	Cynthia Snyder, USFS	Klamath and Shasta-Trinity NF	2010	6	Plots strategically placed in a north to south orientation across stands where WBP is the dominant tree.	All pines in 50m X 10m transects with a minimum number of 25 WBP available for sampling	Type of attack (whole tree, top kill, strip attack, and <5 hit) and location of attack	"Presence" as defined by the presence of orange active aecia, or "suspected" defined as the presence of 3 of 5 symptoms (i.e. rodent chewing, sapping, swelling, flagged branches, and roughened bark); noted presence of herbaceous vectors of WPBR	GYWPMWG Monitoring Protocol
WBP Long-term Monitoring	Danny Cluck, USFS	Modoc	2010	18	Plots strategically placed in a north to south orientation across stands where WBP is the dominant tree.	All pines in 50m X 10m transects with a minimum number of 25 WBP available for sampling	Type of attack (whole tree, top kill, strip attack, and <5 hit) and location of attack	"Presence" as defined by the presence of orange active aecia, or "suspected" defined as the presence of 3 of 5 symptoms (i.e. rodent chewing, sapping, swelling, flagged branches, and roughened bark); noted presence of herbaceous vectors of WPBR	GYWPMWG Monitoring Protocol
High Elevation Species and Natural Communities of the Northern Sierra	Joseph Stewart, D.H. Wright, Stacy Anderson, Canh Nguyen CDFW	Sierra Nevada & southern Cascades	2017	110 plots (43 assessed for MPB and WPBR)	Randomly located plots >3000m elevation, one per FIA hexagon, stratified across 6 elevation zones	0.2-acre plots	Presence/absence	Presence/absence	
Structure and Dynamics of WBP forests in the Warner Mountains	Pete Figura, CDFW	South Warners, Modoc NF	1994, 2006, & 2012		Plots strategically placed in a north to south orientation across stands where WBP is the dominant tree.	Transect surveys and relevè plots	Unclear- probably same as Cluck 2010	Unclear- probably same as Cluck 2010	

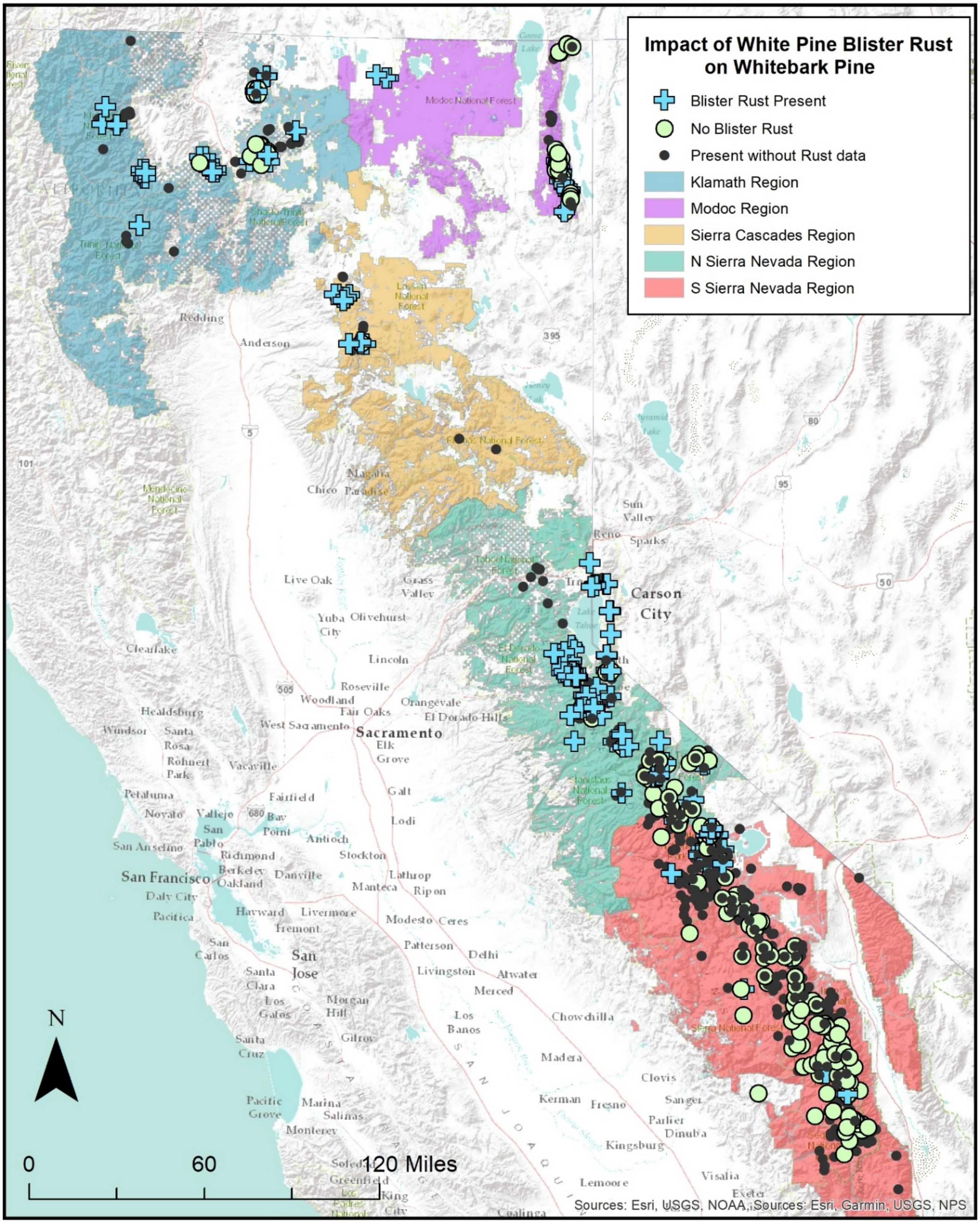
Dataset	Curators and Affiliation	Location (s)	Years	Number of plots or transects	Plot Selection	Measuring unit (plots, individuals, stands, transects)	MPB	WPBR	Protocol Modified from…
Ecology of WBP in relation to WPBR	Patricia Maloney et al.	Statewide	2012	49	Eight study populations placed in landscapes ranging in size from 200 to 600 ha	Three 40m x 100m replicate plots within each population	Presence/Absence (as determined by presence of J-galleries, pitch tubes, or frass)	"Presence" as defined by the presence of orange active aecia, or "suspected" defined as the presence of 3 of 5 symptoms (i.e. rodent chewing, sapping, swelling, flagged branches, and roughened bark)	
Yosemite National Park, Long term monitoring	Nathan Stephenson	Yosemite	1997-ongoing	1	Sampling grid overlaid isolated WBP population	Isolated WBP stand	Presence/absence	Presence/absence	

Table 2-3. Responses to Health Questionnaire.

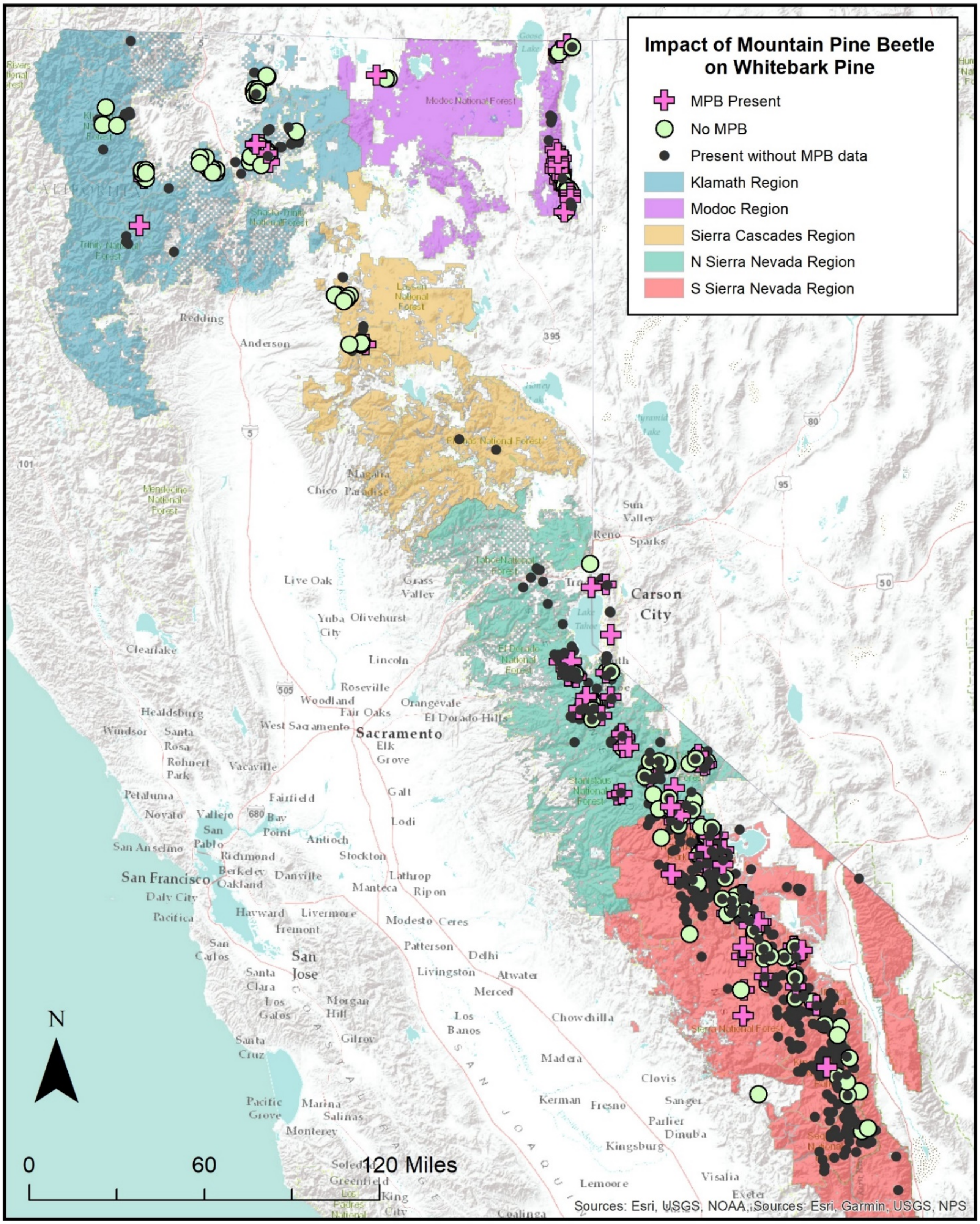
Management unit	Respond-ents	Initial Time of Infection	Seed Collections	Monitor understory species?	MPB and BR interaction	Protocol active vs. inactive	Criteria for calling a tree infected?	Modoc MPB map	Modoc Rust Map	Lassen MPB Map	Lassen Rust Map
Modoc/ Lassen	Danny Cluck, Pete Figura, Todd Keeler-Wolf	Blister rust has been observed in the Warners as much as 20 years ago but it is likely it arrived earlier than that.	No respondents have collected or screen wbp seed; however, Region 6 and/or P. Maloney have collected seed.	D. Cluck- no, but note presence of vector species. Otherwise, no.	No	GYE or searching for cankers, aecial blisters on cankers, and other signs of fruiting structures	-	MPB extent matches what he has seen on the ground. Central Warners have less MPB mortality. - D. Cluck. Todd-Keeler Wolf confirms low mortality in Central Warners, presumably because of low tree densities. Near Eagle Peak, MPB was unimportant from 1994-2006, but the primary source of PIAL mortality from 2006-2012 (based on permanent monitoring plots). - P. Figura	Maps accurately reflect what has been seen on the ground. Rust found on <1% of wbp stems and no rust was observed on regeneration and no infections were associated with mortality. USFS Forest Health team observed blister rust 20 years ago in the Emerson Lakes area. Rust locations near Tule Lake seem inaccurate.- D. Cluck In 2006, rust found on <1% of stems near Eagle Peak.- P. Figura	Mapping in Lassen NF looks accurate. Questions about mapping symbology and two observations on the northern extent of Lassen NF. -D. Cluck Die off of wbp leaders on Lassen Peak, between 9200 and 9700ft, observable through Google Earth. -Todd Keeler-Wolf	Observed top-killed trees from hwy in Lassen National Park. -D. Cluck

Management unit	Respond-ents	Initial Time of Infection	Seed Collections	Monitor understory species?	MPB and BR interaction	Protocol active vs. inactive	Criteria for calling a tree infected?	Modoc MPB map	Modoc Rust Map	Lassen MPB Map	Lassen Rust Map
Southern Sierra	Bob Westfall	2007	no	yes	no	presence of aecia	presence of aecia				
Klamath-Shasta Trinity	None										
Northern Sierra	Danny Cluck, Teri Banka, Joan Dudney, Joseph Sherlock	No. Check with genetics group in Placerville, CA	Talk to P. Maloney for Tahoe Area. Yes. Collections of seed from wbp and sugar pine that appear asymptomatic. Needle sample testing, pending. -T. Banka	Informal observations of Ribes sp. - T.Banka	No. Trees that have died from onset MPB were probably left suseptible by prolonged drought and not wpbr. T. Banka Yes. Trees have both.	Look for evidence of partial resistance (SRR). For example, bark reactions on saplings, healed over cankers at the base of trees. - T. Banka Active infections have recently dried pitch on infections of recently dead or live branches/ boles, inactive cankers	Presence of red, dying branches, and confirmed by cankers, pitch streaming, aecia. -T. Banka Crews scanned each tree from all sides searching for signs of blister rust, using binoculars on tall trees, and counted branch and bole cankers. Branch cankers were included only if all of the following symptoms were present: pitching, swelling or sunken bark, and discoloration	Northern Sierra	Danny Cluck, Teri Banka, Joan Dudney, Joseph Sherlock	No. Check with genetics group in Placerville, CA	Talk to P. Maloney for Tahoe Area. Yes. Collections of seed from wbp and sugar pine that appear asymptomatic. Needle sample testing, pending. -T. Banka

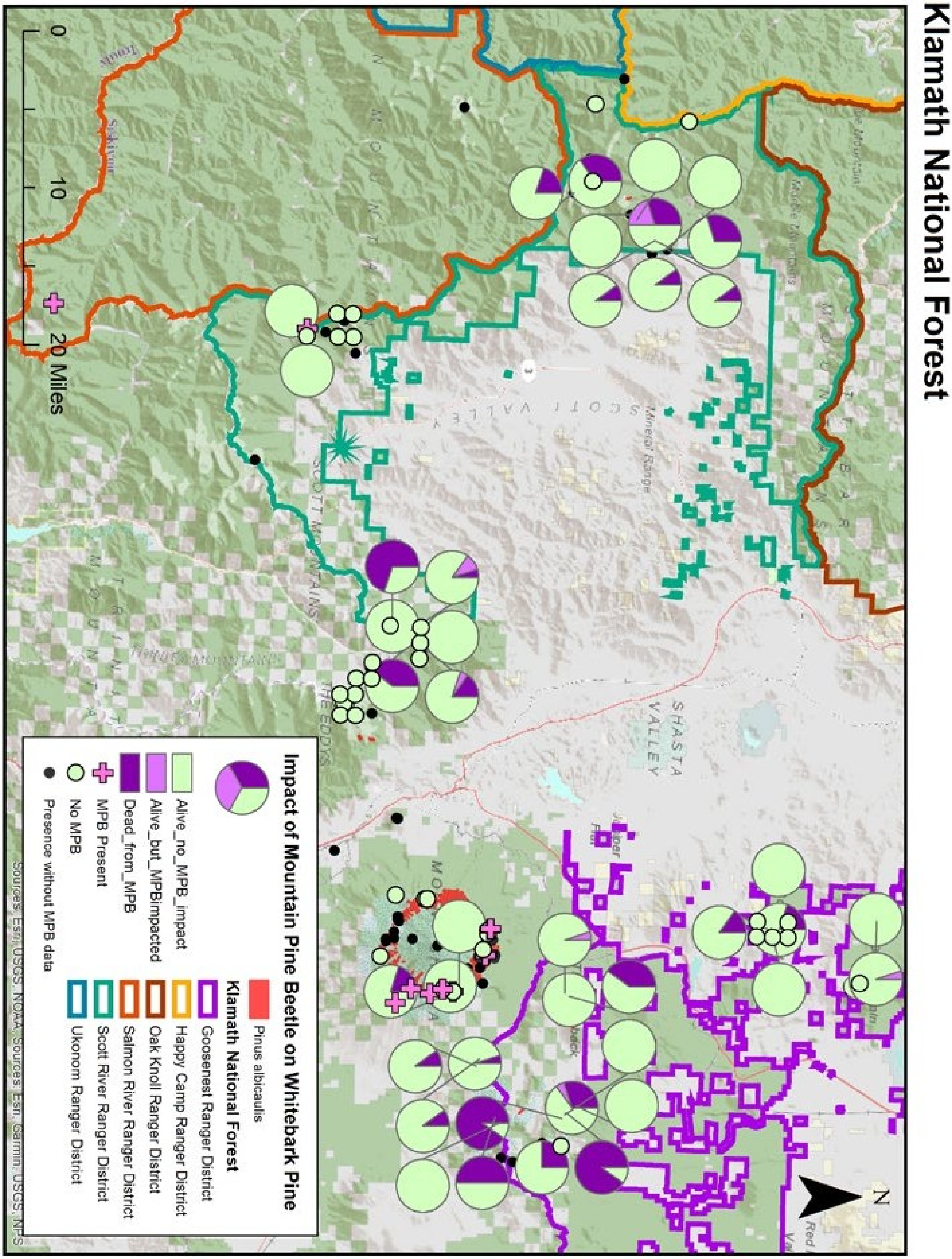
Managem ent unit	Respond-ents	Initial Time of Infection	Seed Collections	Monitor understory species?	MPB and BR interaction	Protocol active vs. inactive	Criteria for calling a tree infected?	Modoc MPB map	Modoc Rust Map	Lassen MPB Map	Lassen Rust Map
						typically show signs of very old, dried pitch and the infected area has been dead for a while (>3 years). -J. Dudney	of the bark on a specific section of the branch. Rodent chewing and aeciospores were included in the diagnosis when present. Bole cankers were verified by the following symptoms: heavy pitching from a specific area, swelling or sunken bark and an "entry point" (i.e., a branch canker that clearly led to bole canker). Rodent chewing and aeciospores were also included when present. - J. Dudney				



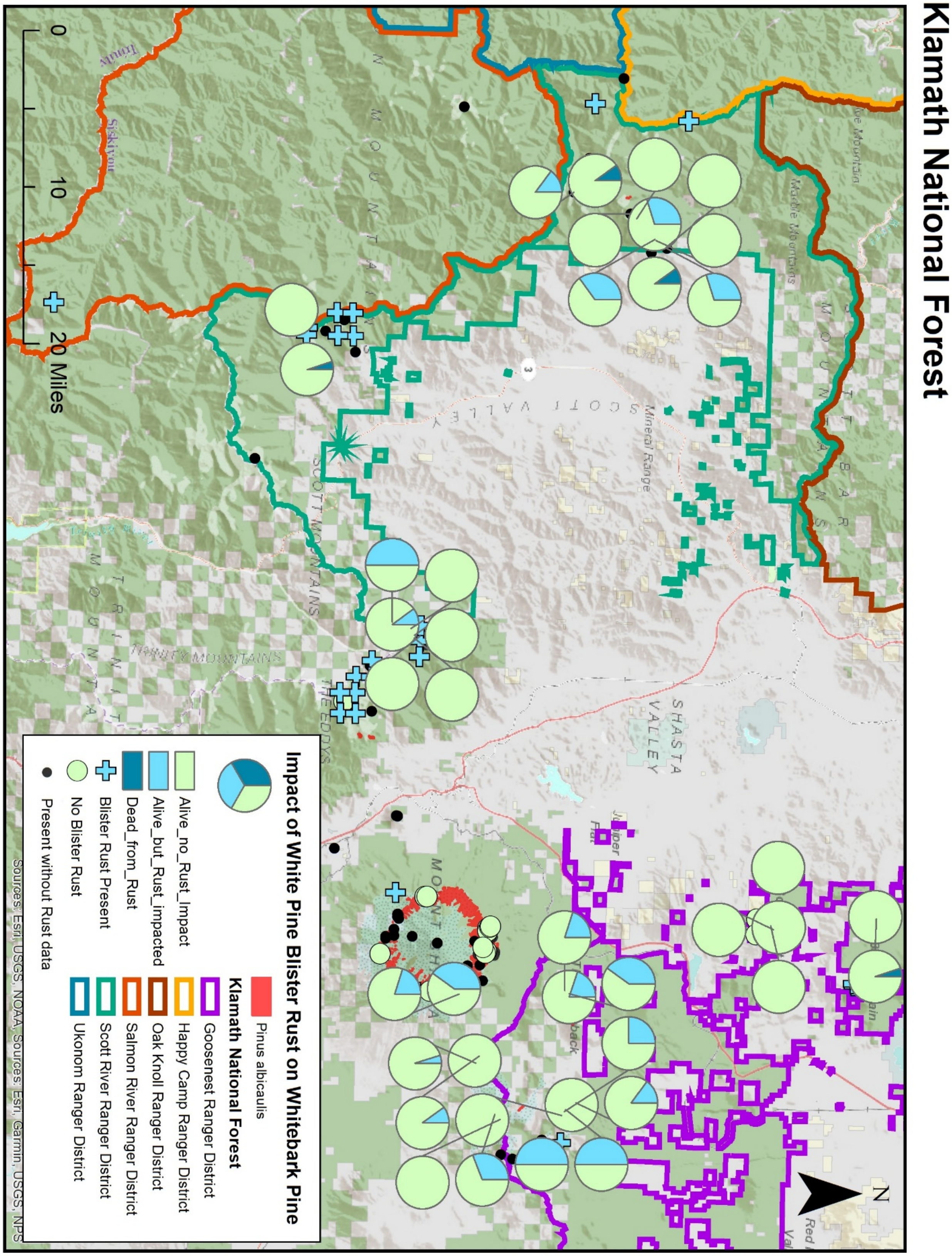
Appendix 2 - Figure 1. Statewide --- Insect and Disease



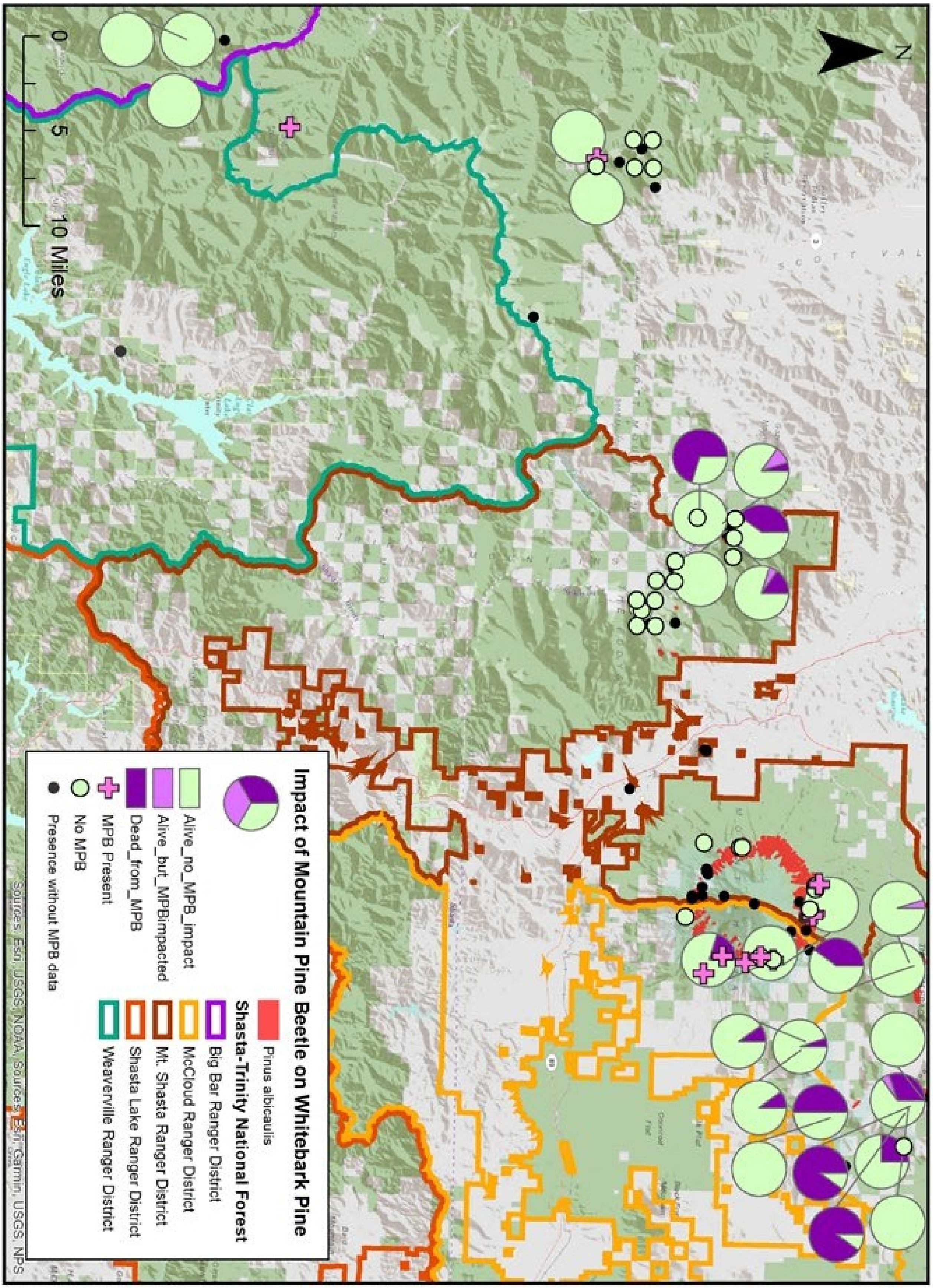
Appendix 2 - Figure 1. Statewide --- Insect and Disease (Continued)



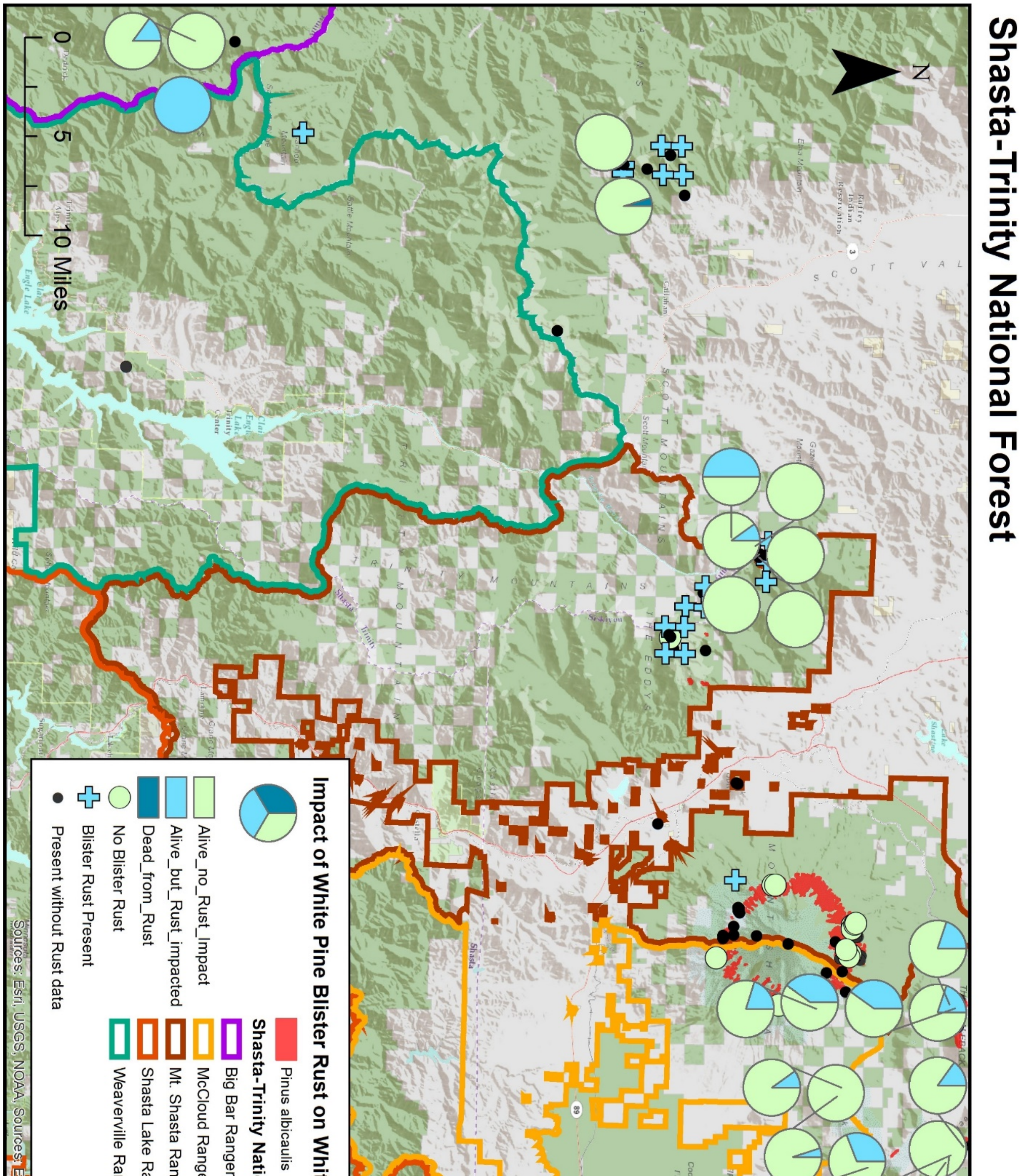
Appendix 2 - Figure 2. Klamath Cascades Region --- Insect and Disease



Appendix 2 - Figure 2. Klamath Cascades Region --- Insect and Disease (Continued)

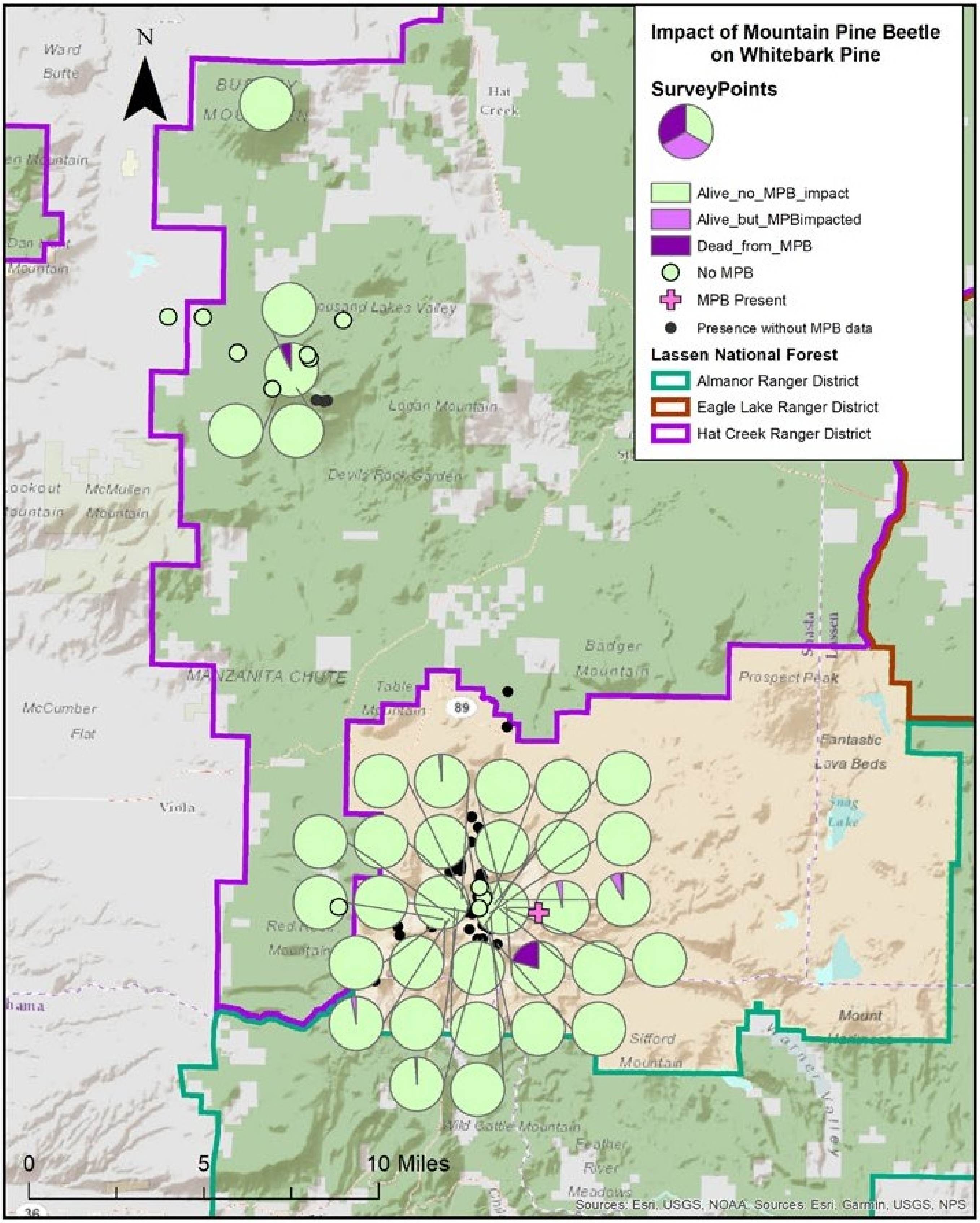


Appendix 2 - Figure 2. Klamath Cascades Region --- Insect and Disease (Continued)



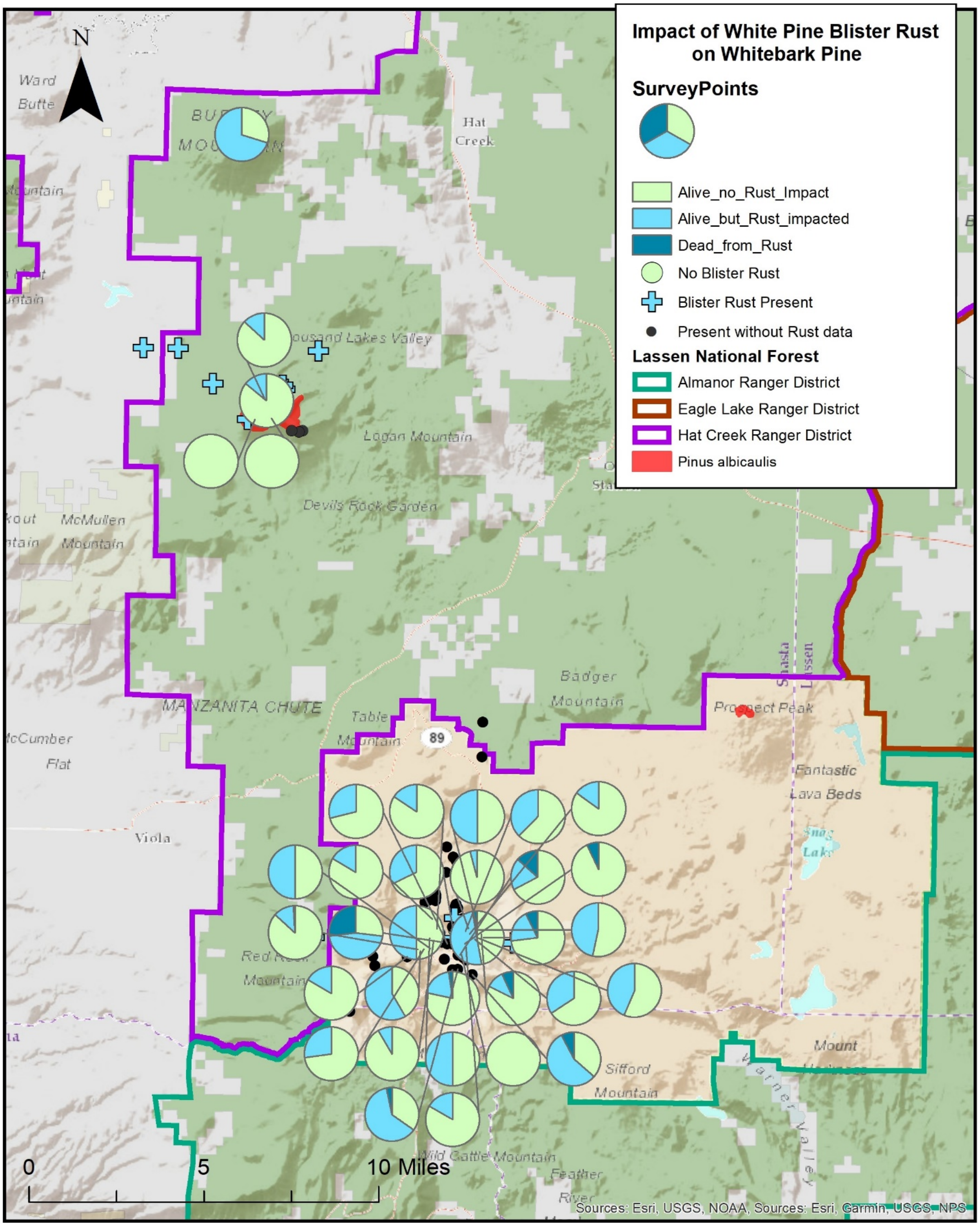
Appendix 2 - Figure 2. Klamath Cascades Region --- Insect and Disease (Continued)

Lassen National Forest

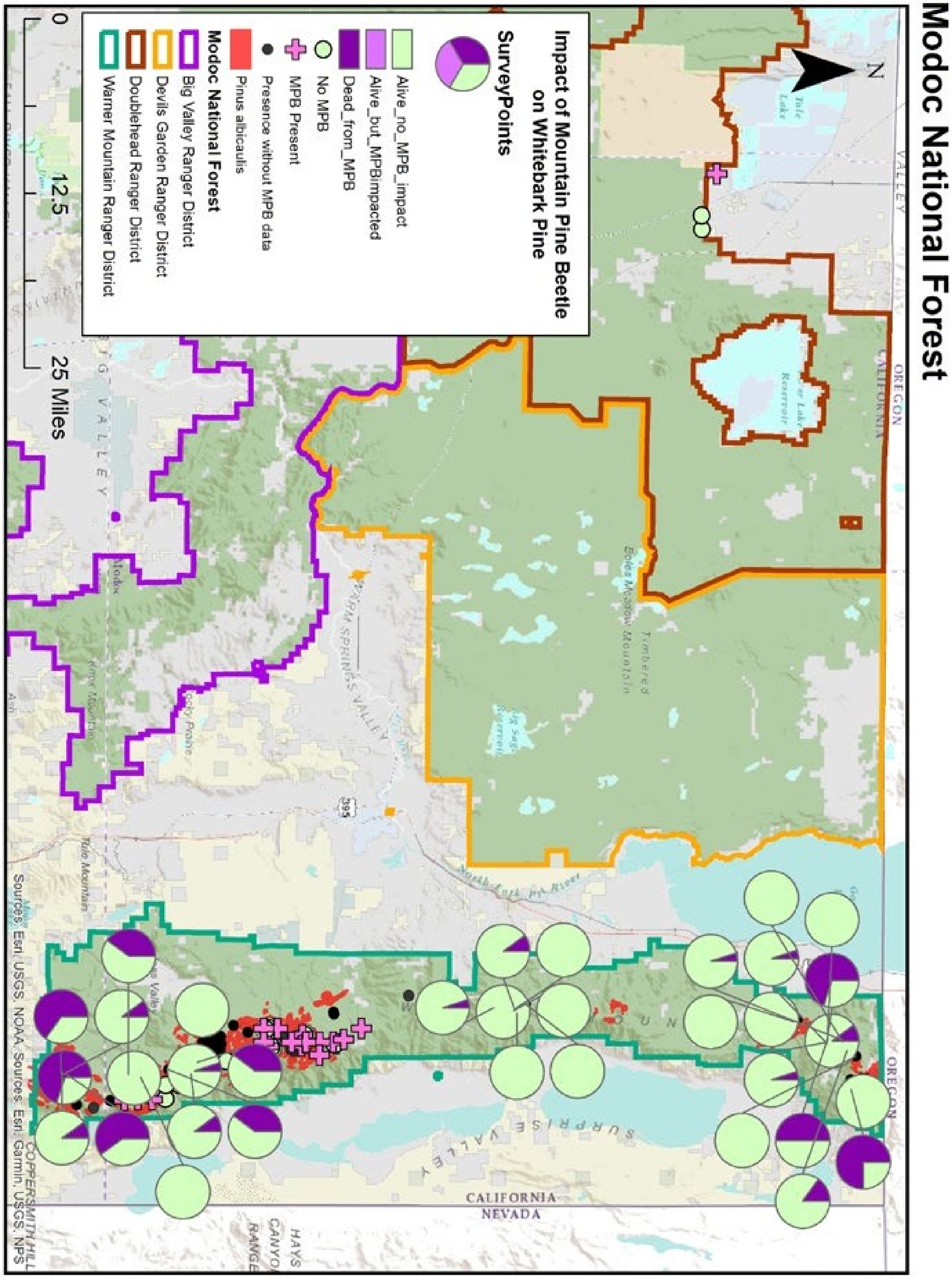


Appendix 2 - Figure 3. Sierra Cascades Region --- Insect and Disease

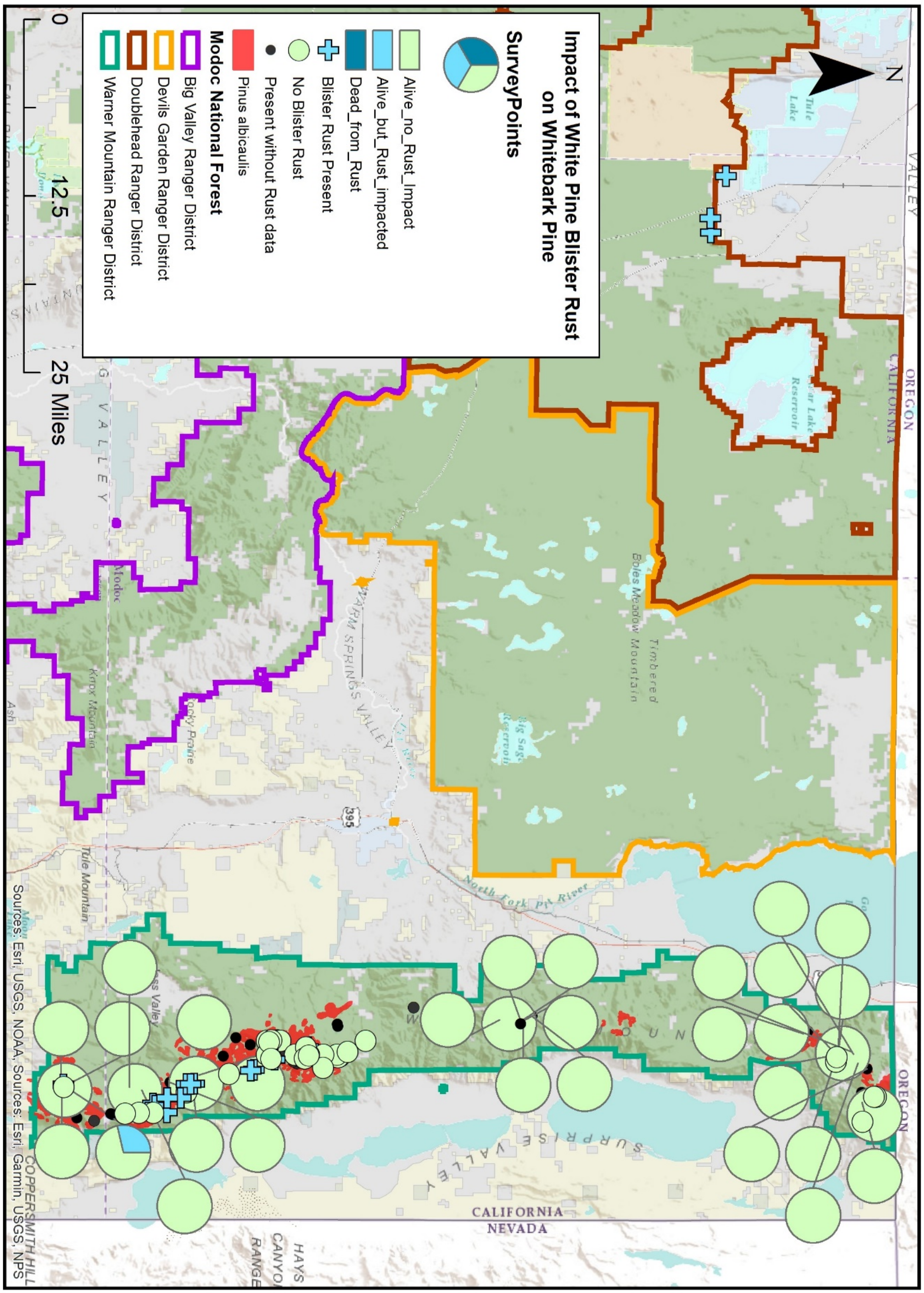
Lassen National Forest



Appendix 2 - Figure 3. Sierra Cascades Region --- Insect and Disease (Continued)

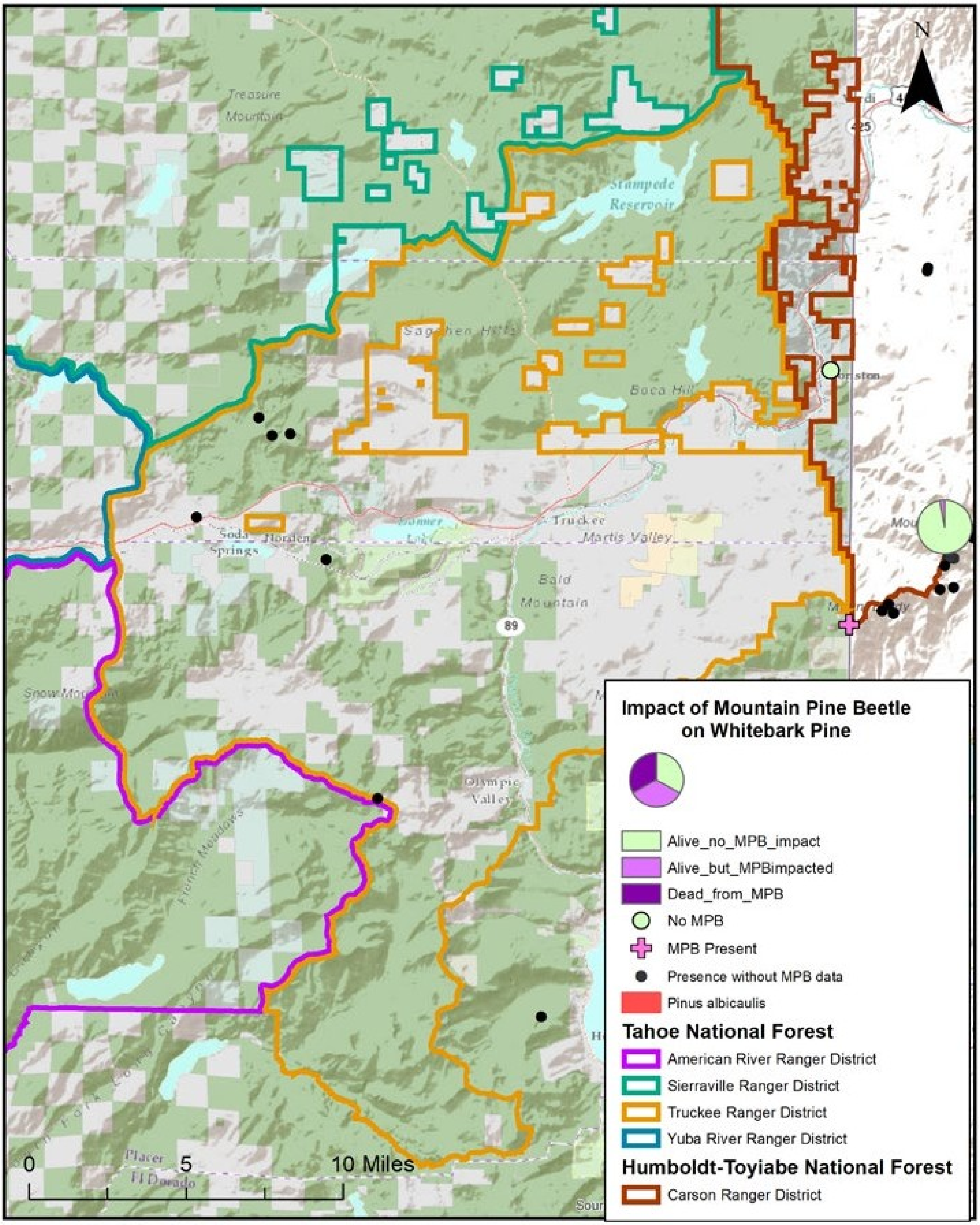


Appendix 2 - Figure 4. Modoc Region --- Insect and Disease



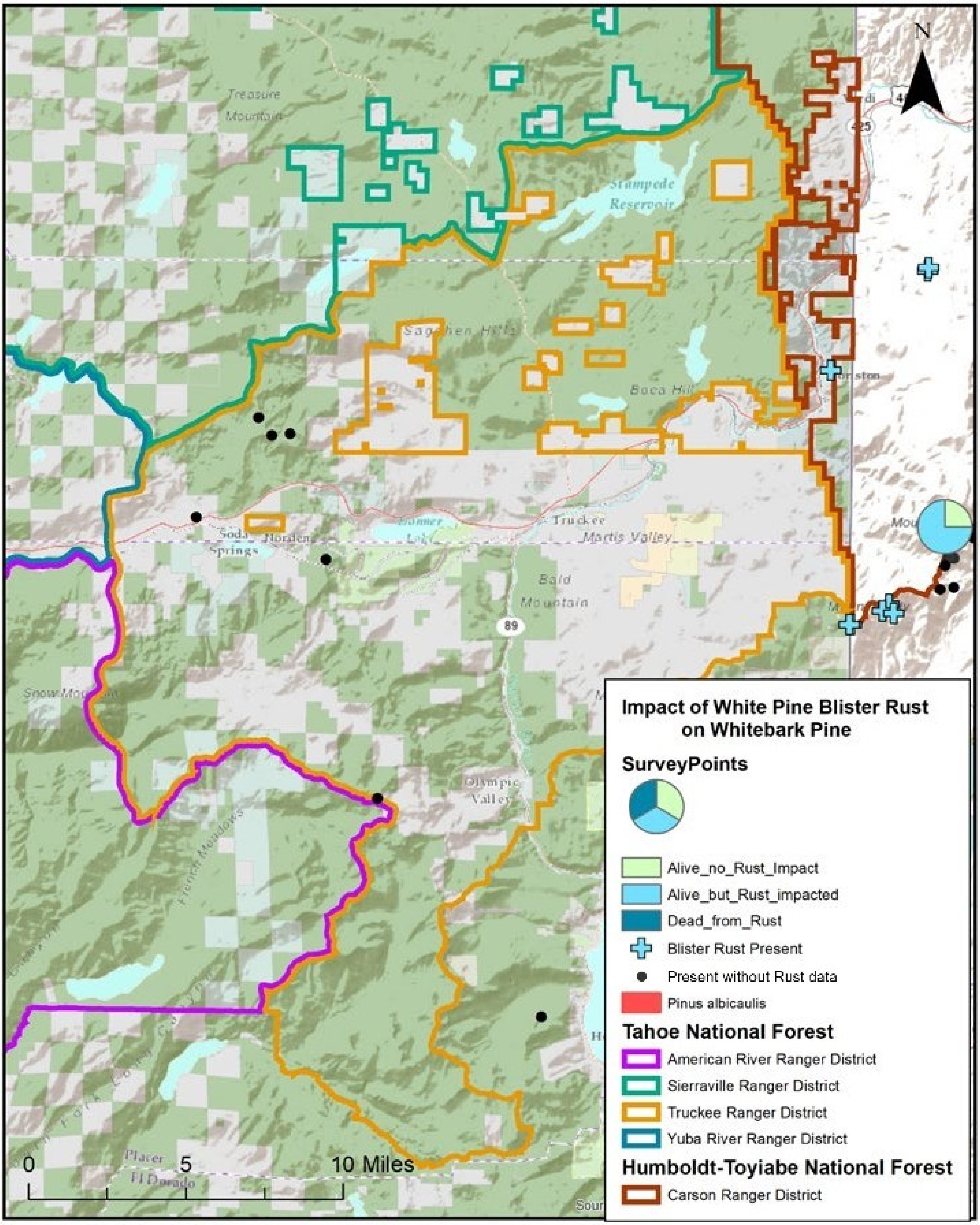
Appendix 2 - Figure 4. Modoc Region --- Insect and Disease (Continued)

Tahoe National Forest



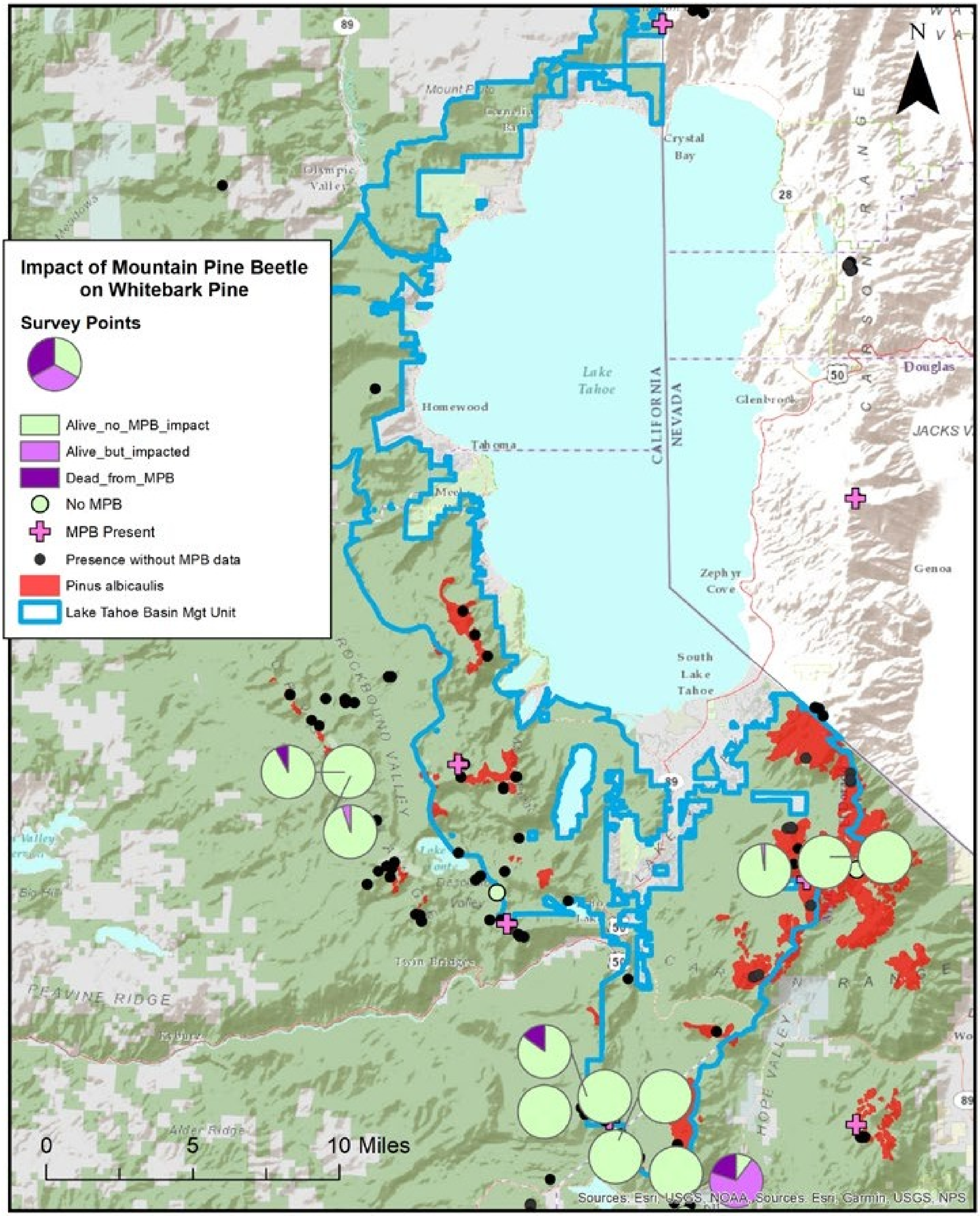
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease

Tahoe National Forest



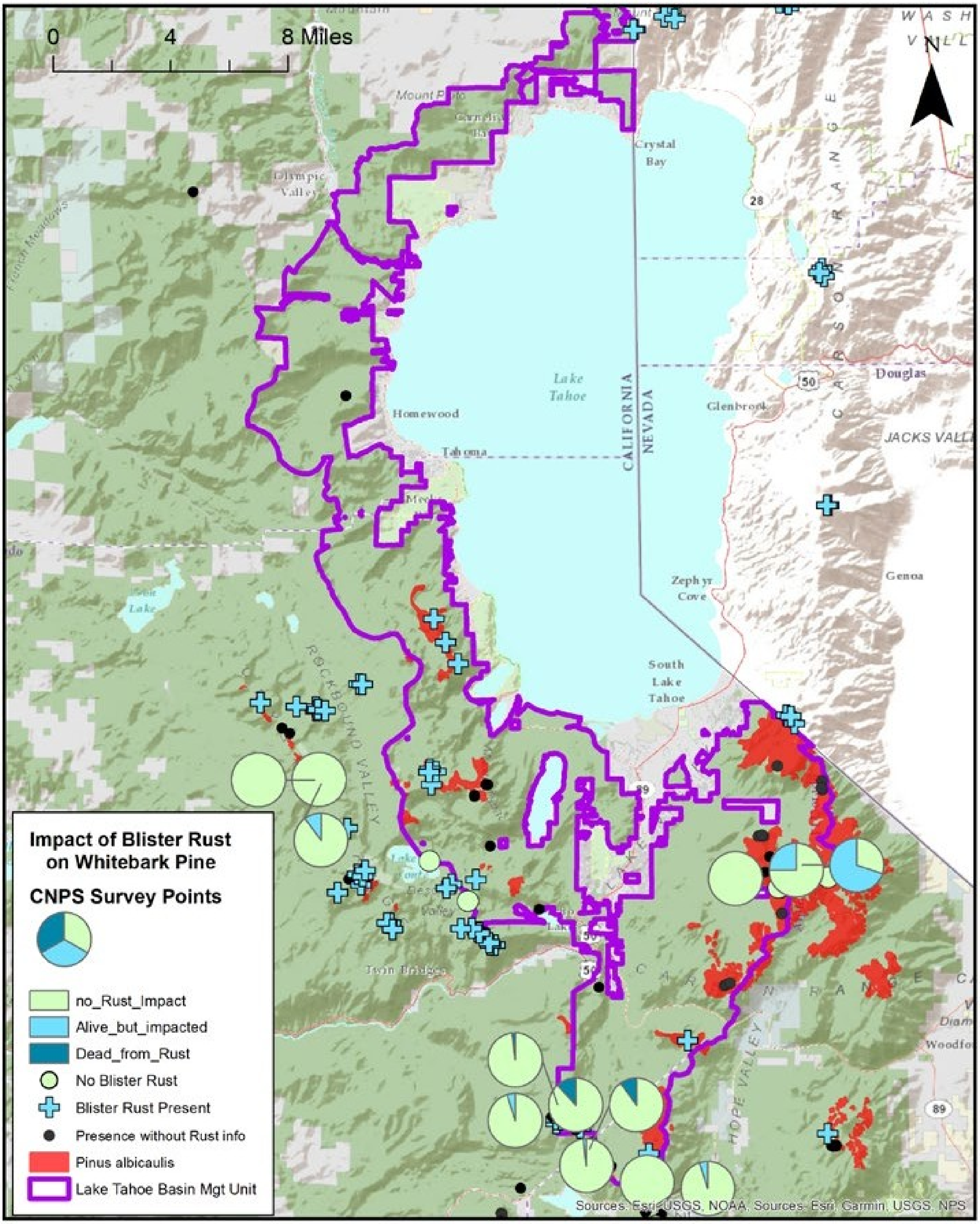
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Lake Tahoe Basin Management Unit



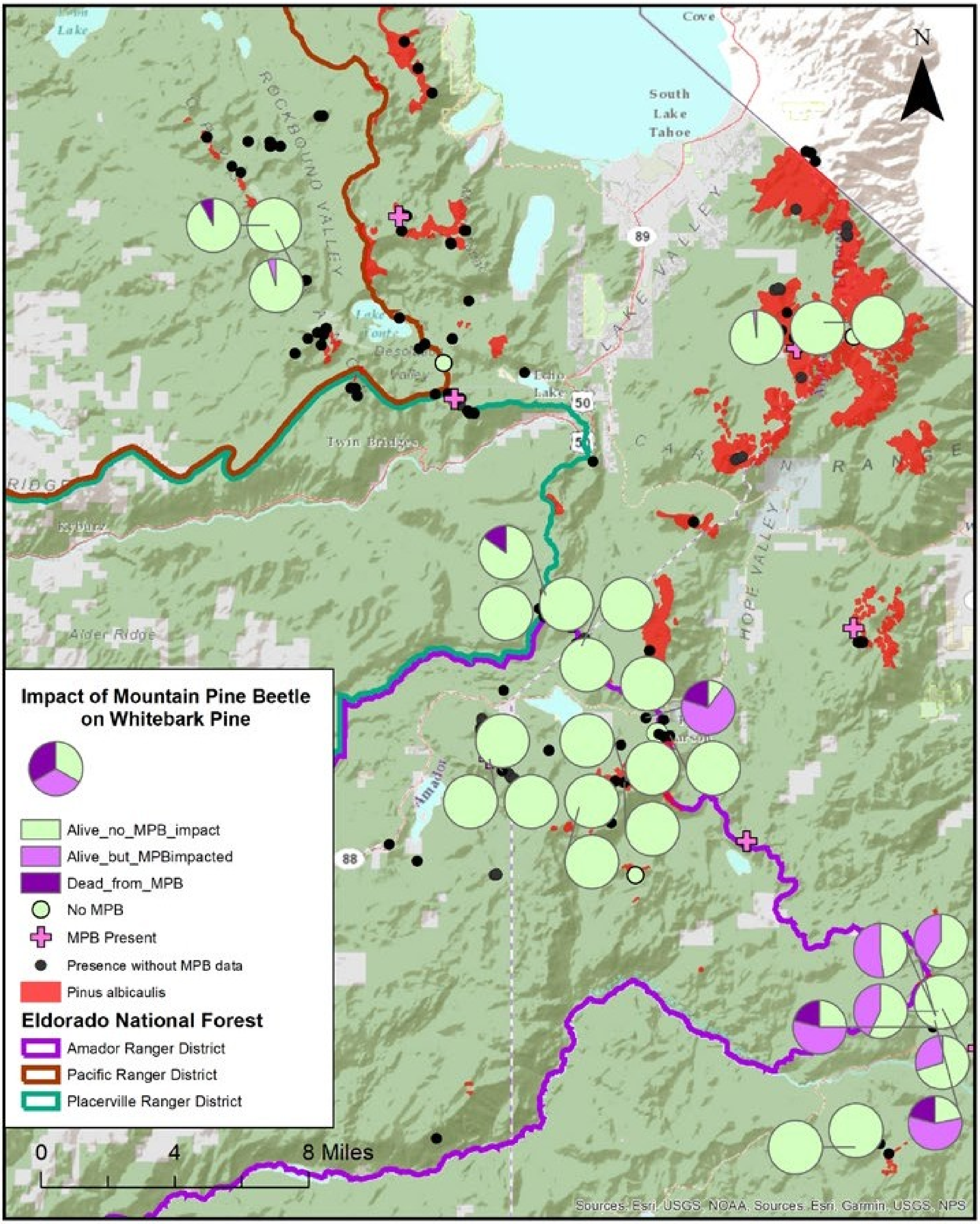
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Lake Tahoe Basin Management Unit



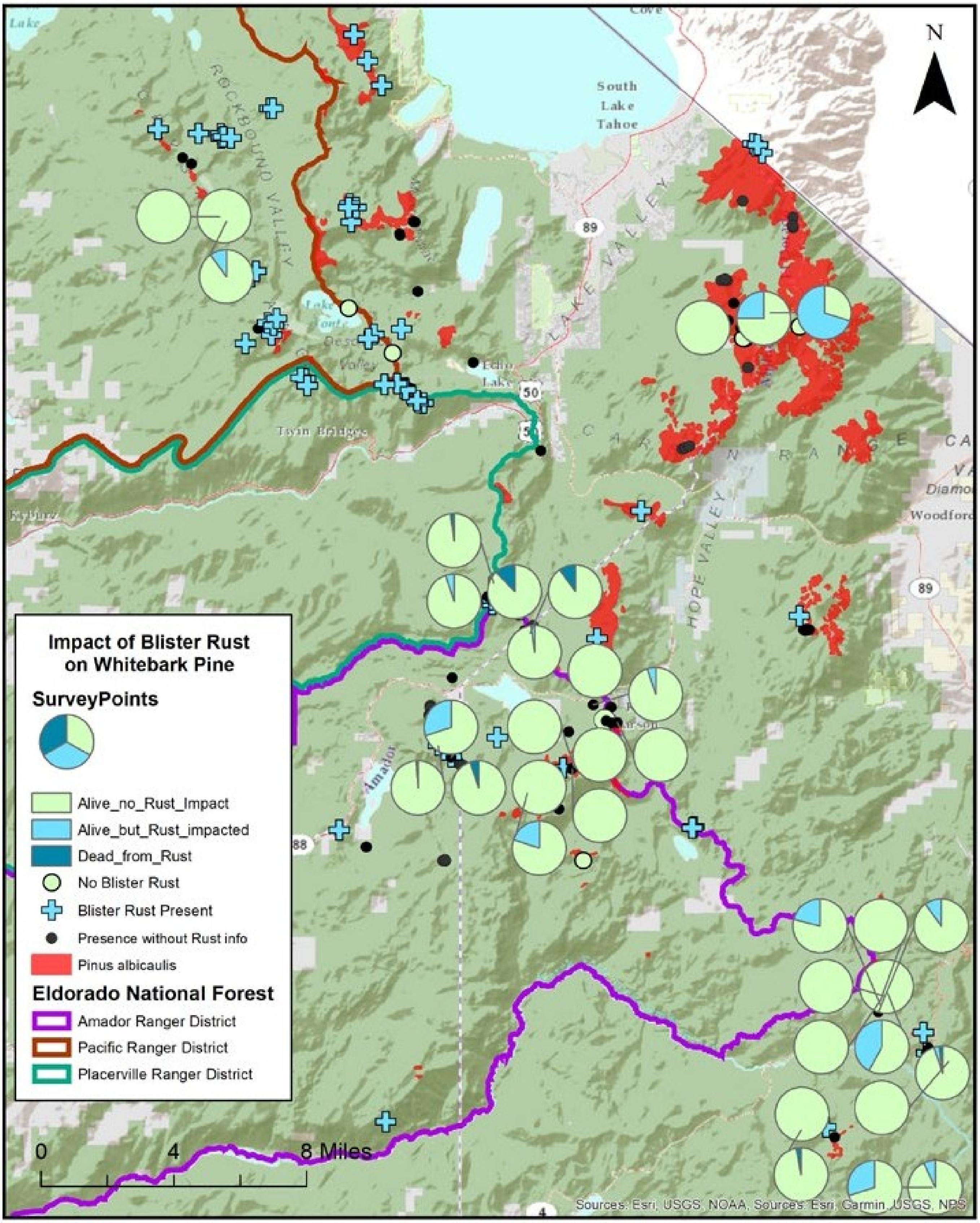
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Eldorado National Forest



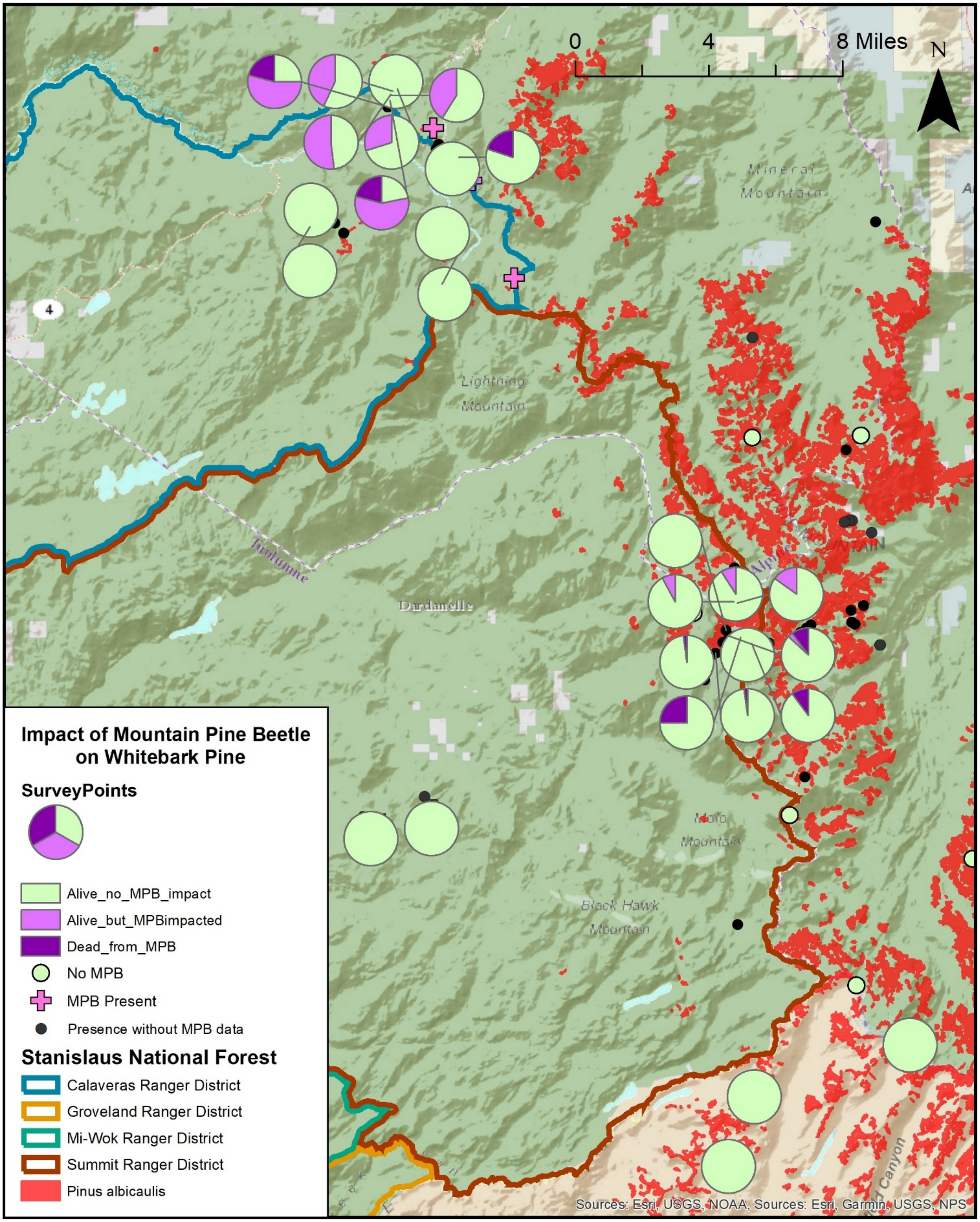
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Eldorado National Forest



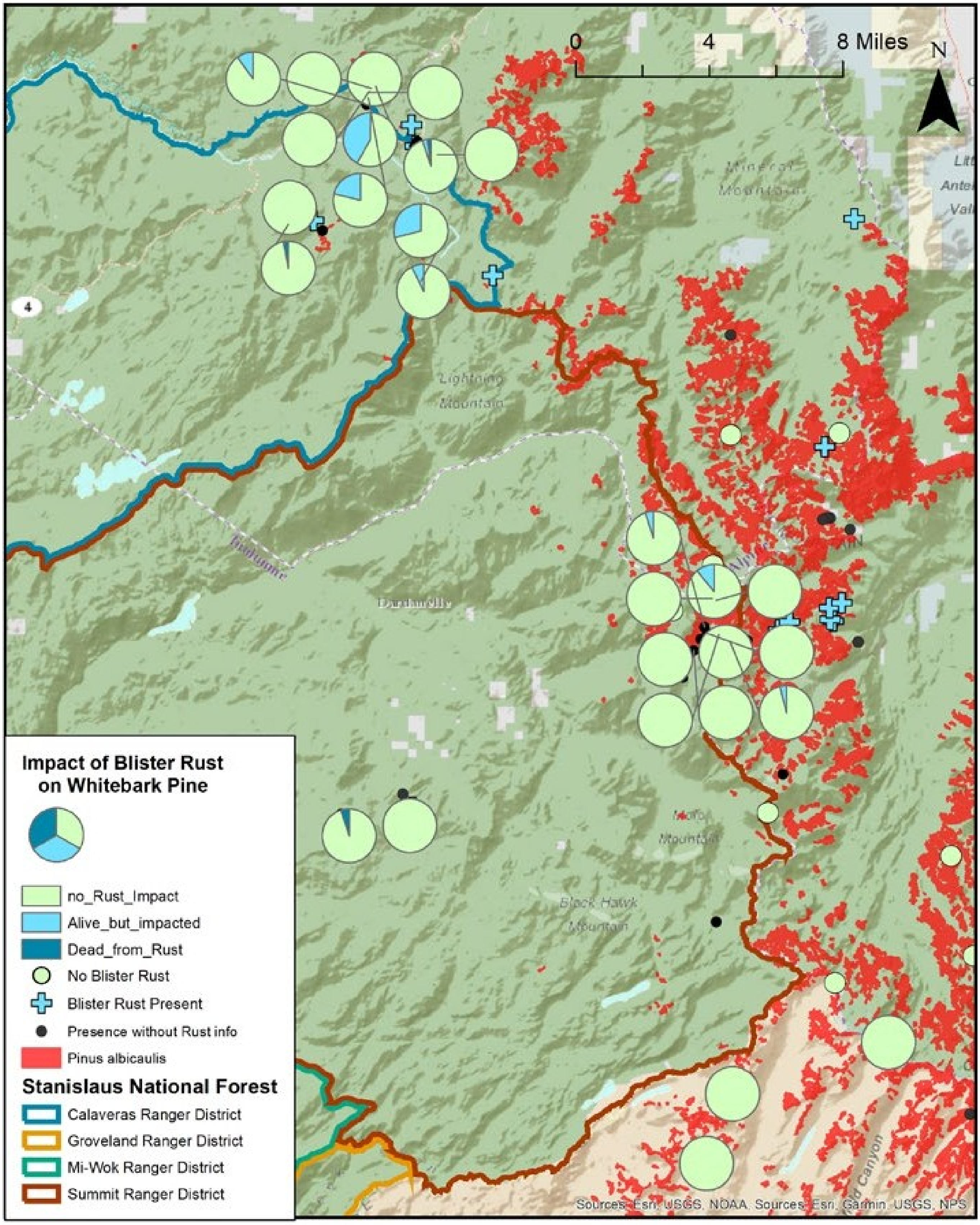
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Stanislaus National Forest

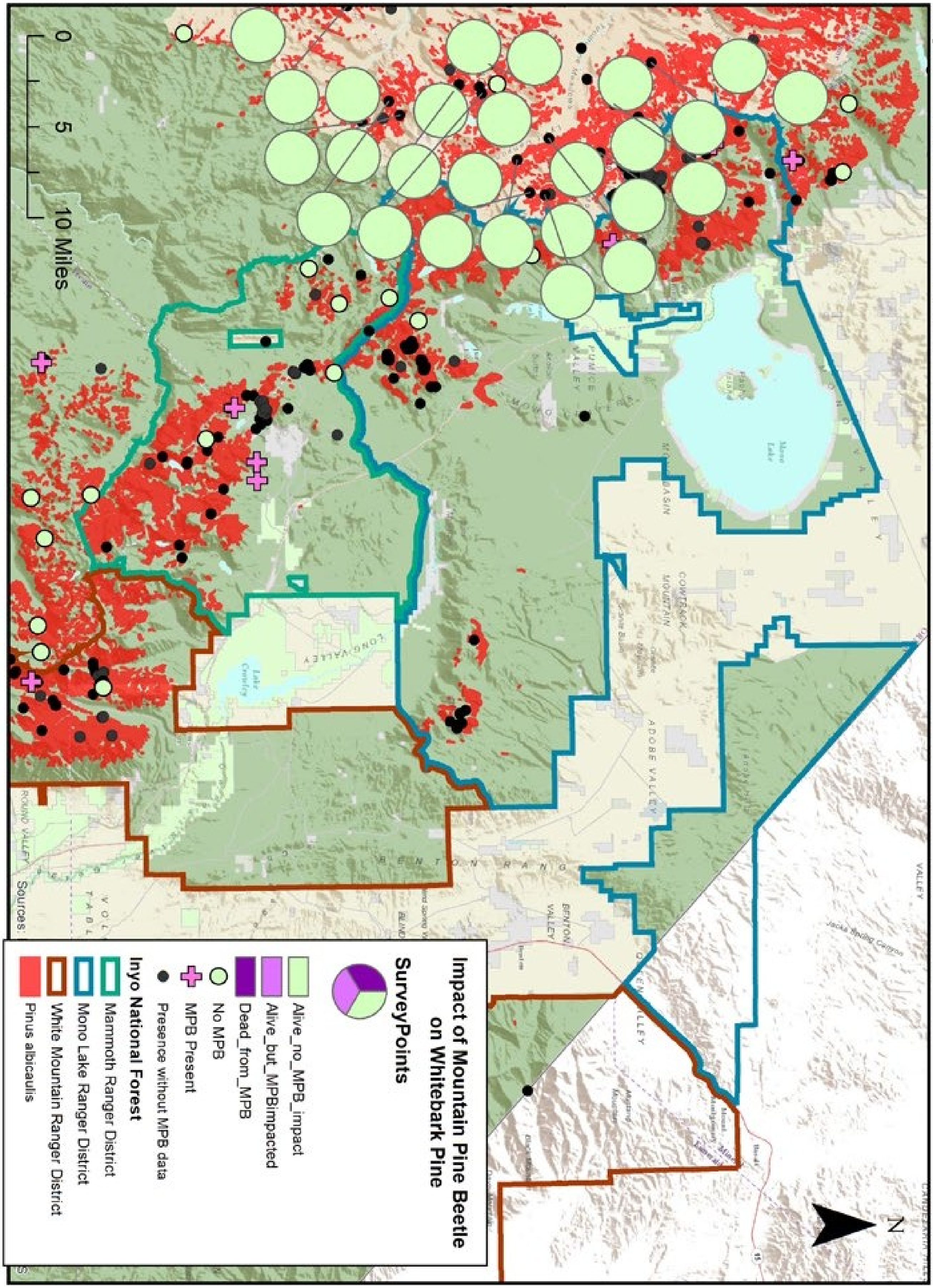


Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

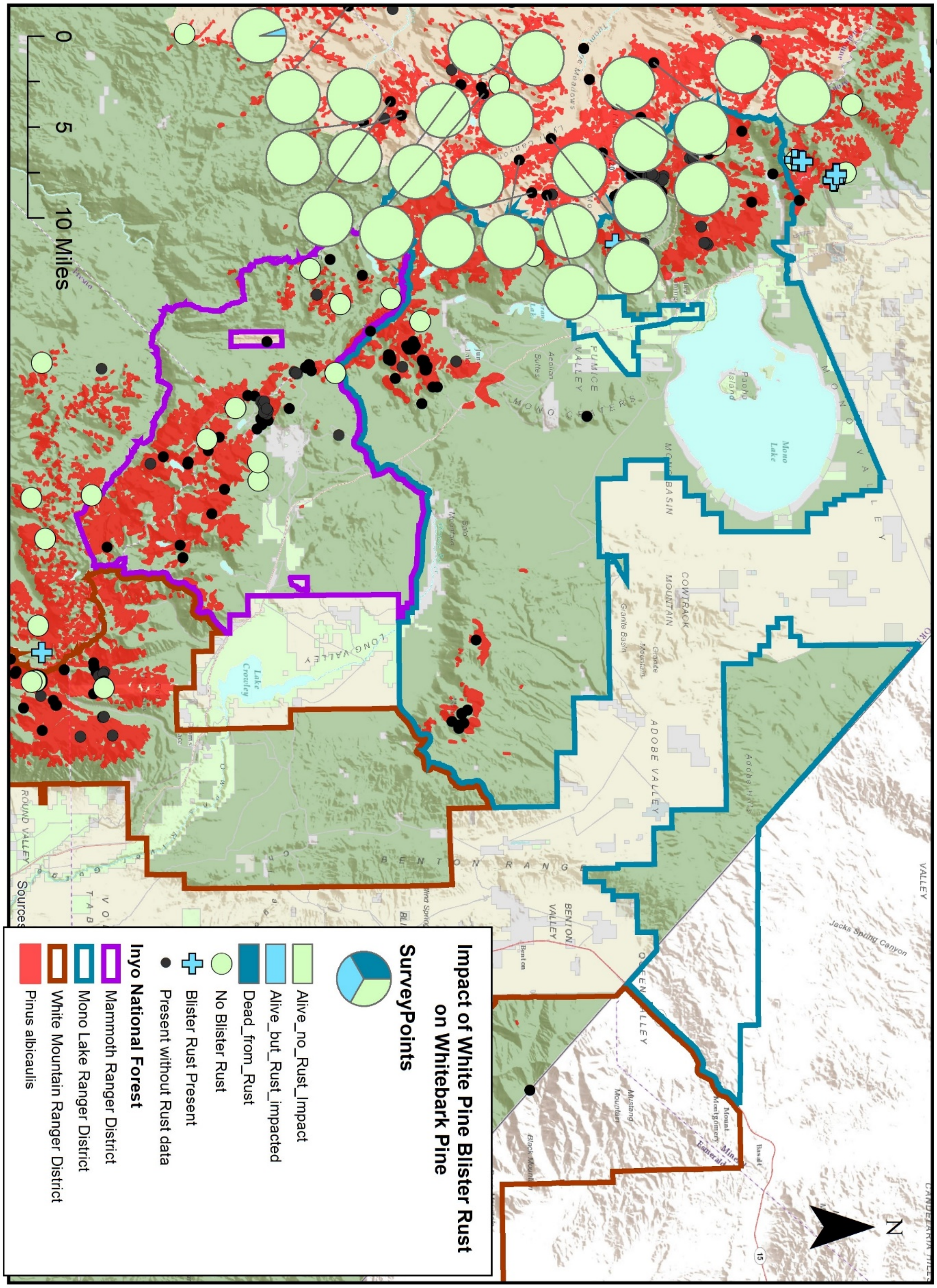
Stanislaus National Forest



Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

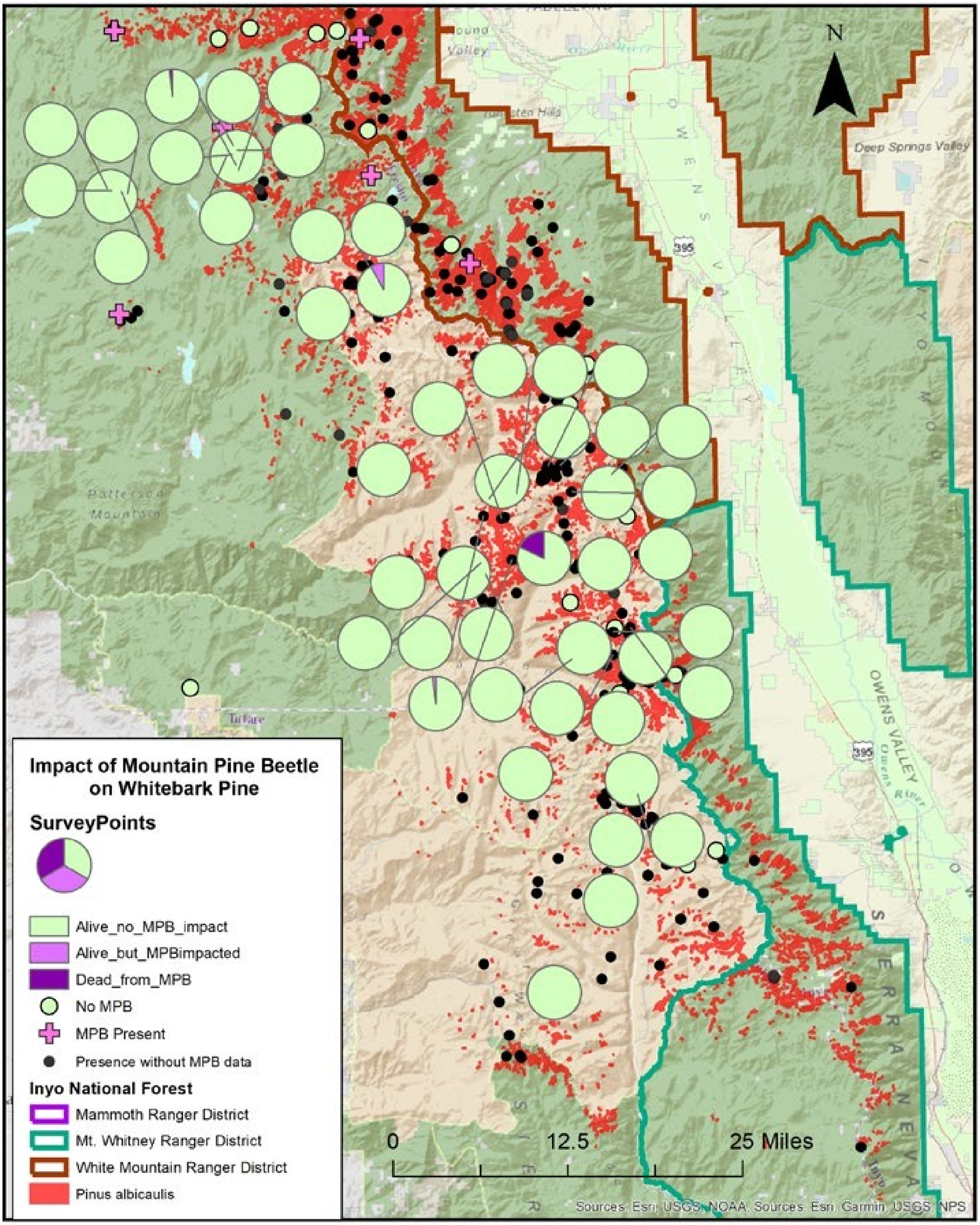


Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)



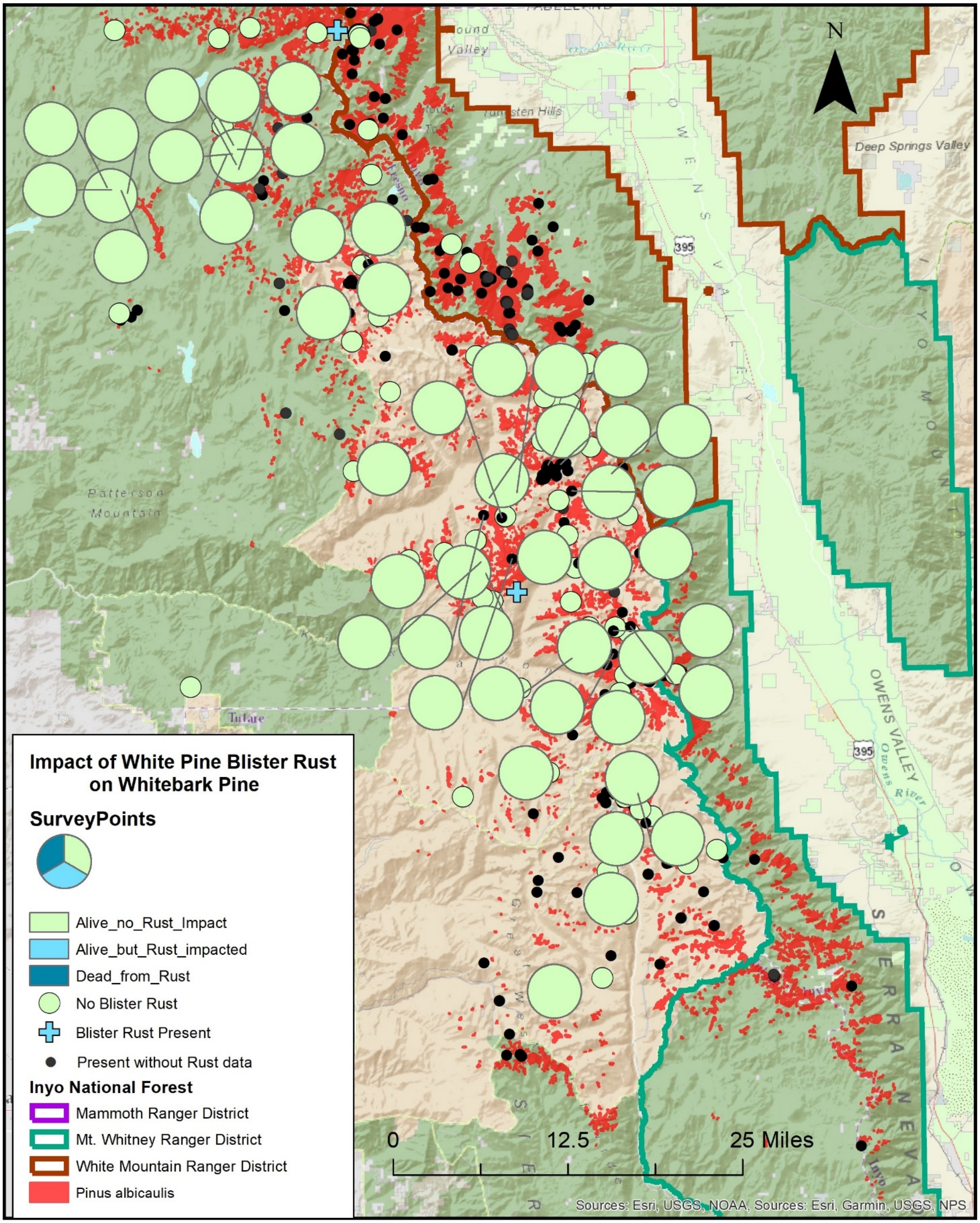
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Inyo National Forest - South



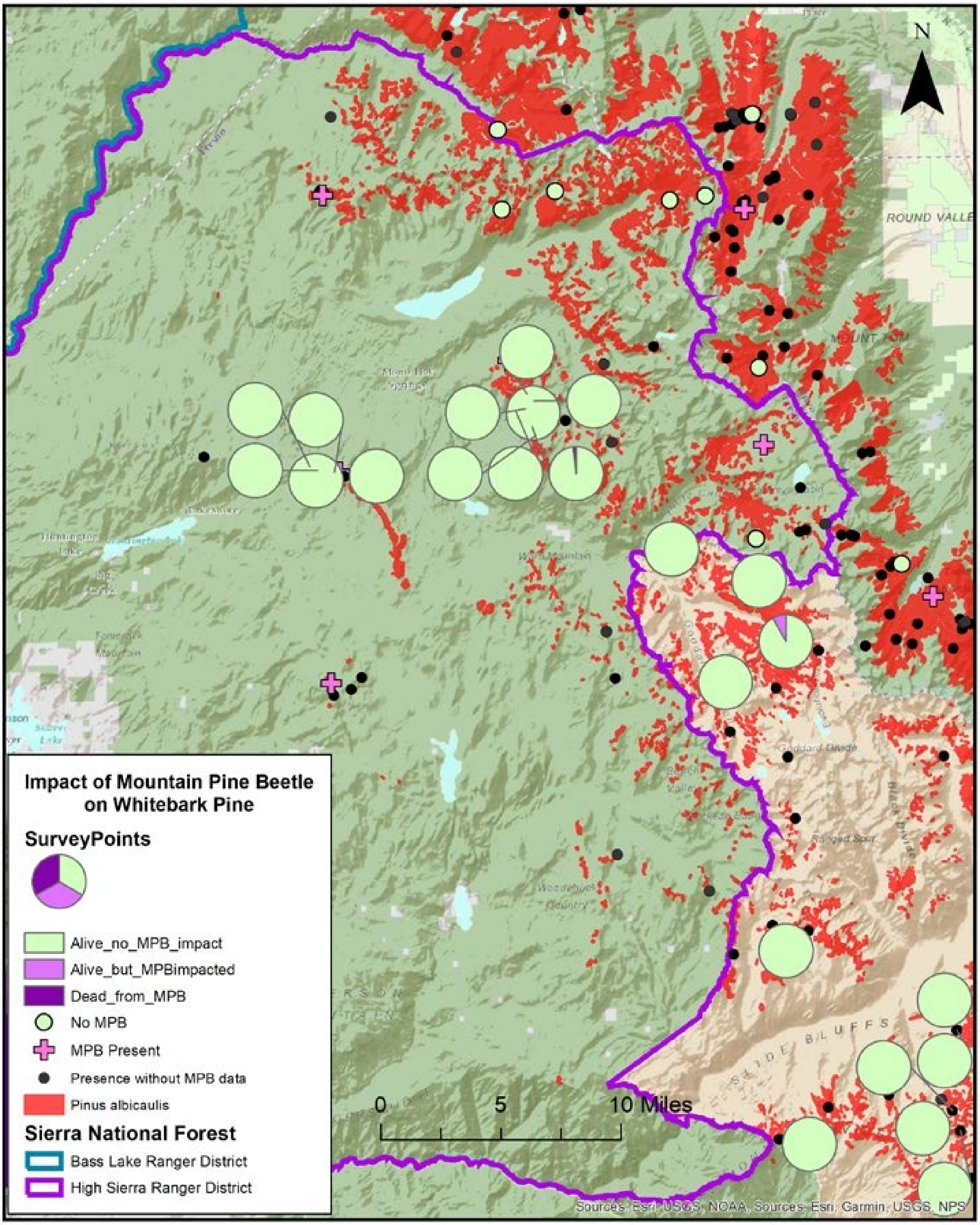
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Inyo National Forest - South



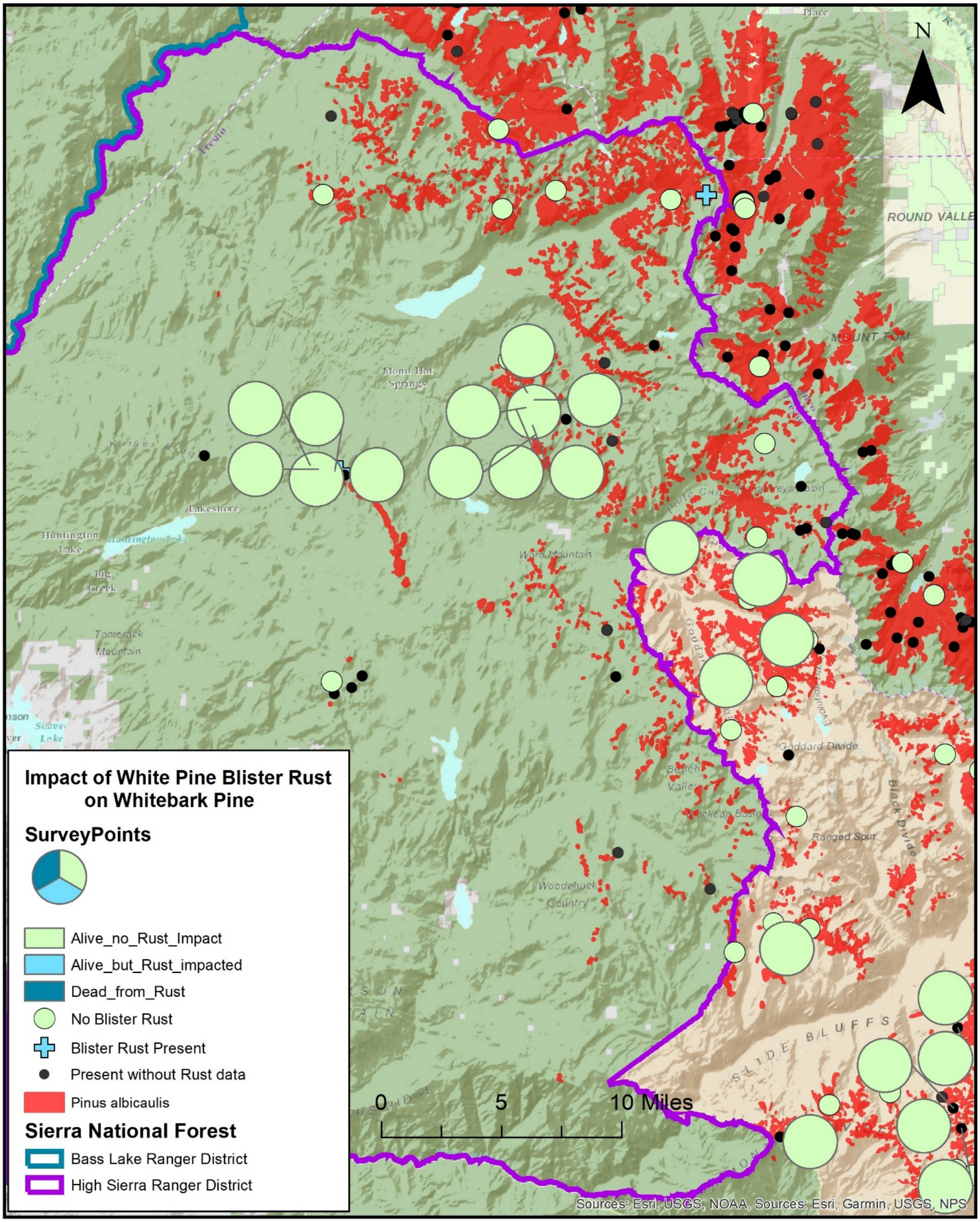
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Sierra National Forest



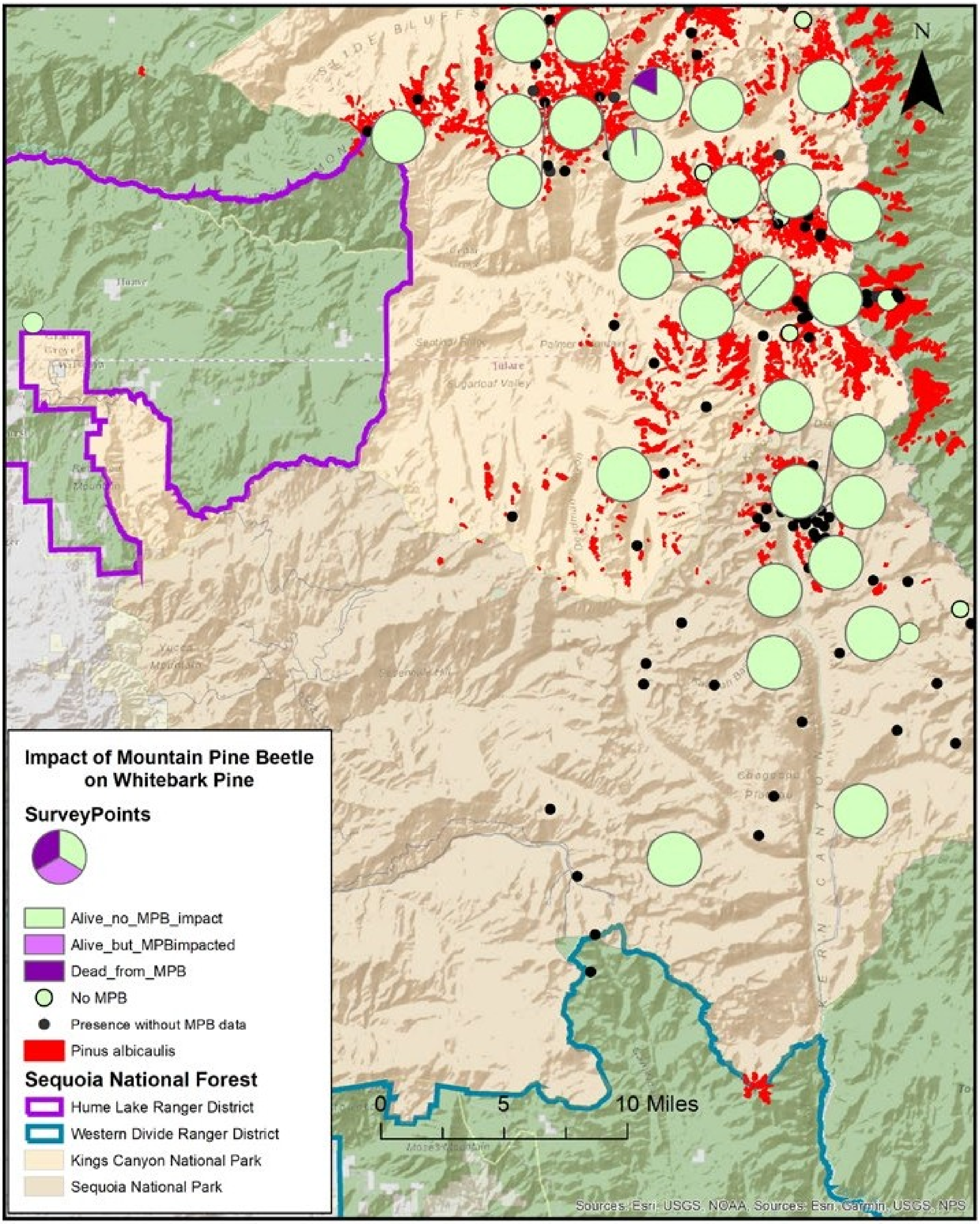
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Sierra National Forest



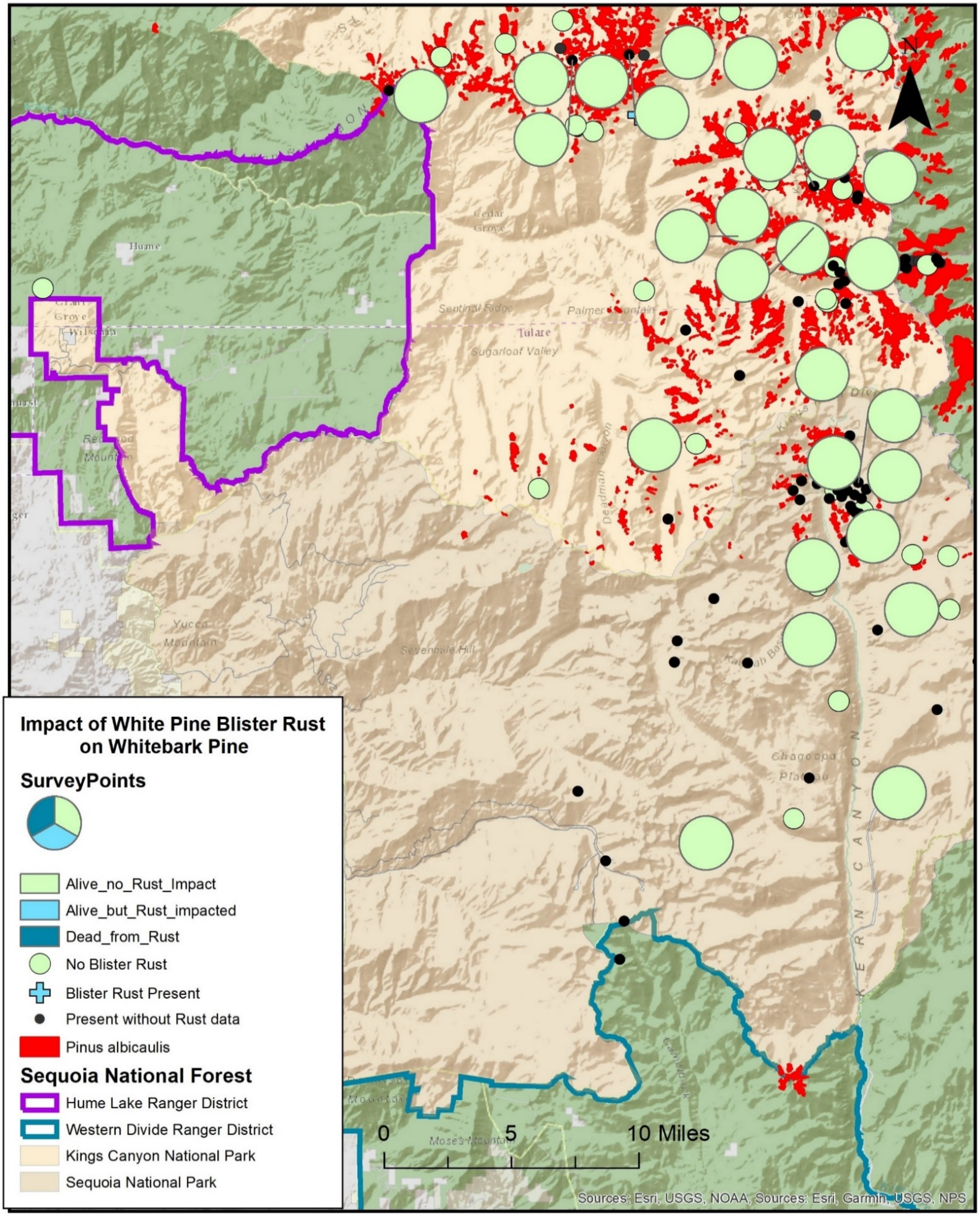
Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Sequoia National Forest



Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)

Sequoia National Forest



Appendix 2 - Figure 5. Sierra Nevada Region --- Insect and Disease (Continued)