



Invasive Exotic Plant Monitoring at Zion National Park

2023 Field Season



View from the West Rim Trail in Zion National Park.
NPS / AMY WASHUTA

Invasive Exotic Plant Monitoring at Zion National Park: 2023 Field Season

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Abstract

Invasive exotic plant (IEP) species are a significant threat to natural ecosystem integrity and biodiversity and controlling them is a high priority for the National Park Service. The Northern Colorado Plateau Network (NCPN) selected the early detection of IEPs as one of ten monitoring protocols to be implemented as part of its long-term monitoring program. NCPN staff conducted surveys at Zion National Park (NP) from May 24 to May 31, 2023, representing the second component of the third monitoring rotation. Of 55 total IEP patches recorded, 22 patches of four priority IEP species were detected along 83.1 km (51.6 miles). The majority of patches (81.8%) were 40 m² or smaller, with cover low enough to make management feasible. The most prevalent IEP priority species was Scotch thistle (*Onopordum acanthium*), with whitetop (*Cardaria* sp.) also common. These two species represented 81.8% of all patches recorded in 2023. On average, trails had more IEP priority patches per kilometer than roads. The trail with the highest density of patches was Sawmill Spring Trail (1.87 patches/km). There were ten trails that had no priority species detected. The road with the highest density of patches was Smith Mesa (0.64 patches/km). Priority species were not found on two roads. IEPs were found on 131 of 260 transects monitored. Almost all of these detections were cheatgrass (*Bromus tectorum*). Cheatgrass was present in 50.4% of transects, with an estimated cover of 0.50% across all transects sampled. Cheatgrass has decreased in frequency and in percent cover since 2015–2016. Scotch thistle and Siberian elm (*Ulmus pulima*) have decreased since 2012–2013 and 2015–2016.

Acknowledgments

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1 Introduction

Invasive exotic species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1998) and represent one of the most serious threats to natural ecosystem integrity (NRC 2002). Biological invasions are occurring at accelerated rates in nearly every major ecosystem (Mooney and Hobbs 2000). Exotic plants negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant communities and animal habitat, and increasing trail maintenance needs (Loope 1992). Recognizing these challenges, Northern Colorado Plateau Network (NCPN) parks identified invasive exotic plants (IEPs) as a high-priority vital sign for long-term monitoring (O'Dell et al. 2005).

IEPs are a subset of exotic plants “whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112). With the aim of facilitating strategic control approaches, this monitoring program detects early invasions, identifies existing invasions, and tracks, to the extent possible, changes in the abundance and distribution of priority IEPs in parks along key invasive pathways.

Invasive exotic plants can spread into national parks via multiple types of pathways. Predictable IEP pathways include roads, trails, and riparian corridors. Long-distance dispersal through cargo containers and air freight are examples of sudden pathways. Anthropogenic pathways include horticultural escapes and seeds transported on shoes and in restoration seed mixes. For the National Park Service (NPS), the consequences of these plant invasions present a significant challenge to the agency’s ability to maintain natural resources “unimpaired for the enjoyment of future generations” (NPS 1916).

Because regular, comprehensive monitoring of the distribution and abundance of all exotic plant species within NCPN units is beyond the fiscal capabilities of the network and parks, the NCPN is focusing on the most likely areas where a broad range of invasive exotic plants may occur: riparian corridors, roads, trails, areas of high visitor impact (e.g., campgrounds), and park boundaries. This approach is cost-effective for finding many new invasions in areas where they are most likely to occur, but it may miss exotic plants dispersed to the interior areas of large parks by wind and/or animals.

Specific objectives of NCPN invasive exotic plant monitoring are:

1. To detect incipient populations and new introductions of invasive plant species before they become established in areas of management significance and invasion pathways; and
2. To determine status and trends of selected invasive plant populations of management significance.

This report summarizes IEP monitoring results from the 2023 field season that is a portion of the third rotation of monitoring routes at Zion National Park (NP).

2 Methods

We followed the invasive exotic plant monitoring protocol developed by the NCPN (Perkins et al. 2016), adapted from Andersen and Dewey (2007). The protocol emphasizes the quick collection of IEP location and abundance data in order to maximize the amount of area searched, thus increasing our chances of finding a higher percentage of both new invasions and established IEPs. By focusing on roads, trails, and waterways, which are major vectors for invasive plants, we will capture the greatest amount of information (i.e., benefit) with the least amount of time and effort (i.e., cost).

2.1 Developing a Park Target Invasive Exotic Plant List

Prior to the start of monitoring, NCPN and Zion NP staff reviewed the park's list of priority IEPs (Table 1). The list was developed by reviewing past park literature, state and county weed lists, and consulting with park staff and county weed managers. The high-priority target IEP list includes existing IEPs and potential IEPs of high management concern. This list is reviewed before each field season. In 2015, little bur-clover (*Medicago minima*) was added to the list. The list did not change from 2015–2018. In 2023, spring whitlow-grass (*Draba verna*), Mediterranean grass (*Schismus* sp.), and puncture vine (*Tribulus terrestris*) were added to the list.

Table 1. Priority invasive plant list, Zion National Park, 2023.

Scientific Name	Common Name
<i>Alhagi maurorum</i>	camelthorn
<i>Bassia scoparia</i> ^A	summer cypress
<i>Brassica tournefortii</i>	Asian mustard
<i>Cardaria</i> spp.	whitetop
<i>Carduus nutans</i>	musk thistle
<i>Centaurea diffusa</i>	diffuse knapweed
<i>Centaurea melitensis</i>	Maltese starthistle
<i>Centaurea repens</i>	Russian knapweed
<i>Centaurea solstitialis</i>	yellow starthistle
<i>Centaurea virgata</i> ^B	squarrose knapweed
<i>Chrysanthemum leucanthemum</i> ^C	ox-eye daisy
<i>Cirsium arvense</i>	Canada thistle
<i>Conium maculatum</i>	poison-hemlock

^A Listed as *Kochia scoparia* (kochia) in the 2012 report.

^B Listed as *Centaurea squarrosa* in the 2012 and 2013 reports.

^C Listed as *Leucanthemum vulgare* in the 2012 and 2013 reports.

^D Added to priority list in 2023.

^E Added to priority list in 2015.

^F Taken off priority list in 2023 but still monitored in transects.

Table 1 (continued). Priority invasive plant list, Zion National Park, 2023.

Scientific Name	Common Name
<i>Cynodon dactylon</i>	Bermudagrass
<i>Draba verna</i> ^D	spring whitlow-grass
<i>Eragrostis cilianensis</i>	stinkgrass
<i>Euphorbia esula</i>	leafy spurge
<i>Hyoscyamus niger</i>	black henbane
<i>Hypericum perforatum</i>	St. Johnswort
<i>Isatis tinctoria</i>	Dyer's woad
<i>Lepidium latifolium</i>	broad-leaf pepperwort
<i>Linaria dalmatica</i>	dalmatian toadflax
<i>Linaria vulgaris</i>	butter-and-eggs
<i>Lythrum salicaria</i>	purple loosestrife
<i>Medicago minima</i> ^E	little bur-clover
<i>Onopordum acanthium</i>	Scotch thistle
<i>Poa bulbosa</i> ^F	bulbous bluegrass
<i>Potentilla recta</i>	sulfur cinquefoil
<i>Schismus</i> sp. ^D	Mediterranean grass
<i>Sorghum halepense</i>	Johnson-grass
<i>Taeniatherum caput-medusae</i>	medusahead
<i>Tribulus terrestris</i> ^D	puncture vine
<i>Ulmus pumila</i>	Siberian elm

^A Listed as *Kochia scoparia* (kochia) in the 2012 report.

^B Listed as *Centaurea squarrosa* in the 2012 and 2013 reports.

^C Listed as *Leucanthemum vulgare* in the 2012 and 2013 reports.

^D Added to priority list in 2023.

^E Added to priority list in 2015.

^F Taken off priority list in 2023 but still monitored in transects.

Because these methods are designed to be rapid, field crews are trained to develop a focused search image for the target plants, instead of looking for every possible invasive plant species. The likelihood of eradicating these target species, or containing them within a park, is generally high.

2.2 Monitoring Routes

2.2.1 Minimum Detection Target Size

The minimum detection target size (MDTS) represents the patch size that is large enough to be detected with a high level of confidence—typically at least 90% of the total number of patches of that size and larger in the monitoring area—under actual field conditions, but small enough so any missed patches smaller than the MDTS could still feasibly be eradicated if not found until the next scheduled

monitoring visit. We established an MDTs of 40 m² (0.01 acres or approximately 20 × 20 ft) for all IEPs. Use of the MDTs was necessary because field technicians are not expected to find every single plant of every targeted IEP species during route surveys. Searching for single mature plants of some species, such as Siberian elm (*Ulmus pumila*), is possible due to their large size. Single plants of other species, such as little bur-clover (*Medicago minima*), are very difficult to detect in most field conditions unless the observer is very close to the patch.

2.2.2 Effective Detection Distance

The effective detection distance (EDD) is the maximum distance from which a searcher could consistently detect—that is, see and recognize—the MDTs of the least-visible targeted species with at least 90% detection efficiency (Figure 1). Using fake plants of a targeted size, crew members are trained by walking away and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The size of the EDD is then estimated in the field by crew members. The distance is measured either by pacing or by using a laser rangefinder. The EDD for Zion NP in 2023 was 2–5 meters.

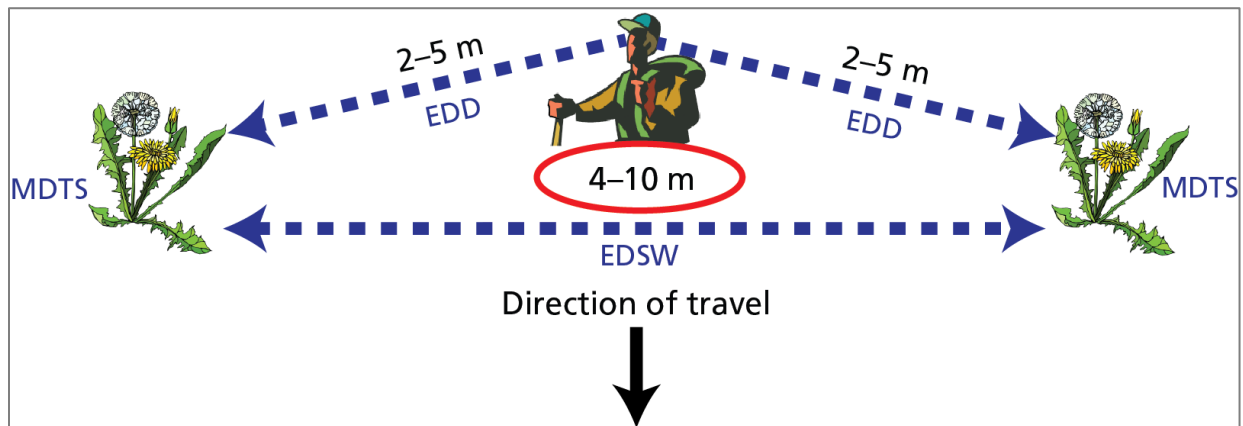


Figure 1. The maximum Effective Detection Distance (EDD) at Zion National Park ranged from 2–5 m in 2023, making the Effective Detection Swath Width (EDSW) 4–10 m.

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2.2.3 Effective Detection Swath Width

Effective detection swath width (EDSW) is defined as the maximum width of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the MDTs (Figure 1). The effective detection swath width (EDSW) is equal to twice the EDD, because the surveyor is able to effectively detect IEPs up to one EDD on either side of the search route. The EDSW was 4–10 meters at Zion NP in 2023.

2.2.4 Patch Separation Resolution

We define patch separation resolution (PSR) as the minimum distance between plants that must be considered members of separate patches. Individuals or clusters of a target species separated by the PSR distance or more are recorded as separate patches. We consider plants separated by less than the PSR to be a single patch. The PSR is set at 50 m, based on the assumption that most plants or groups

of plants separated by less than 50 m are typically considered to be one patch during planning and implementation of IEP-control operations. If a patch is continuous for more than 50 m, then cover estimates are made every 50 m to aid in developing an effective management strategy for the entire patch.

2.2.5 Between Feature Position

“Between-feature positions” allow electronic tracking of a user’s route. A GPS (global positioning system) unit is set to automatically generate these positions at a distance equal to the EDSW. Each time a surveyor walks the equivalent of one EDSW, the GPS unit creates a point.

2.2.6 Data Collection Methods

We established monitoring routes with advice from Zion NP staff (see Figure 2). While walking, we searched for IEPs by visually scanning—side to side—all of the land within the borders of the swath. However, if the terrain was uneven or steep and the observer had to glance frequently at the ground to ensure safe foot placement, searchers stopped approximately every 4–10 m (the length of one EDSW) and visually scanned the area in all directions. As monitoring routes were traversed, locations of all target species were documented using GPS units with at least 5 m accuracy. Only priority species were consistently recorded during monitoring routes. Survey crew members were permitted to record additional species if they were noteworthy.

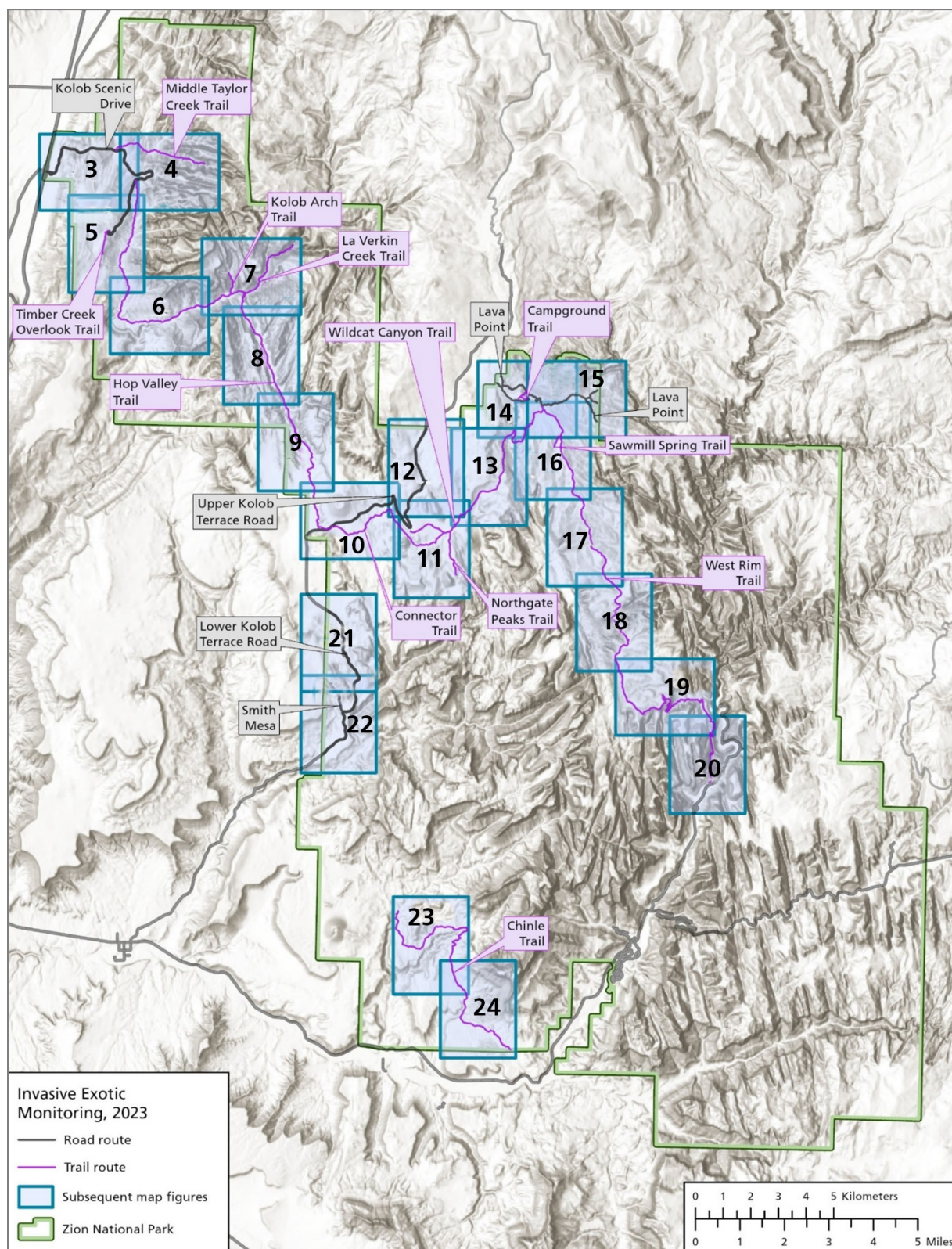


Figure 2. Index map of invasive plant monitoring routes by figure number, Zion National Park, May 24–31, 2023.

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When a priority IEP was discovered, we recorded the following information: (1) the monitoring route, (2) the sequential number of the invasion per monitoring route, (3) patch size class (see below), (4) whether the plant was pulled, and (5) canopy cover class (see below). If several species were present with similar distributions at a single point, we recorded a point for each individual species and assigned it its own sequential identification number. Invasions more than 50 m (55 yards) apart were considered separate invasions and recorded with separate points.

Patch size class was estimated as follows:

1. 1–3 plants (used for isolated single plants or very small patches $\leq 2 \times 2$ m),
2. 4 plants–40 m² (48 yd²),
3. 40–400 m² (48–478 yd²),
4. 400–1,000 m² (0.1–0.25 acre), and
5. 1,000–2,000 m² (0.25–0.5 acre).

We recorded canopy cover class by estimating the amount, or percentage, of ground covered by the vertical projection of plant matter as visualized from a bird's-eye view of the vegetation (Elzinga et al. 1998). This estimate included both the living and dead standing material of the vegetation of a single plant species. Canopy cover of a patch was recorded using the following classes:

1. Trace (<1%)
2. Low (1–5%)
3. Moderate (6–25%)
4. High (26–50%)
5. Majority (51–100%).

We recorded the following ancillary information with every patch: descriptive notes (e.g., hillside, distance to road, wetland, stream); the growth stage of exotic trees (e.g., sapling, pole, mature); evidence of prior treatment; and evidence of disturbances (e.g., recent fire, flood, small mammal disturbance).

2.3 Monitoring Transects

We established transects with three vegetation quadrats every 500 m along monitoring routes.

2.3.1 Quadrat Establishment

We centered vegetation quadrats at 0.5, 5, and 10 m away from the edge of a road on the same side as the route being walked and on alternating sides for riparian areas, small roads, or trails. A 1 m² sampling frame, used to sample vegetation cover and soil surface features, was placed on the right side of the transect line as the technician walked the monitoring route. In some cases, we leveled the sampling frame by propping up quadrat corners.

2.3.2 Data Collection Methods

In the monitoring quadrats, all priority IEP species observed were recorded, as well as cheatgrass (*Bromus tectorum*), bulbous bluegrass (*Poa bulbosa*), and Russian thistle (*Salsola* sp.). For each quadrat, we recorded percent cover of each IEP using the following classes: < 1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100%. We also recorded percent cover of surface features (i.e., dead wood, dung, fungus, lichen, litter/duff, live root/bole, mineral soil/sediment, moss, biological soil crust, road, rock, standing water/flooded, stream, or trash/junk).

2.4 Analyses

We calculated the mean number of patches per kilometer for monitoring routes. Percent cover estimates were generated from the monitoring-quadrat data. We calculated the mean and standard error of percent cover by species for monitoring quadrats. Due to differences in observers' knowledge, only priority species should be used when comparing results from year to year.

3 Results

3.1 Target Invasive Exotic Plant List

There were 32 IEP species on the Zion NP priority list for 2023 (see Table 1). Observers are trained to recognize priority species but are given the freedom to map additional species. Therefore, presence and absence data for priority species are reliable for the areas searched, but absence data for non-priority species are suspect. In addition, cheatgrass, bulbous bluegrass, and Russian thistle were recorded consistently in transects.

We recorded a total of four priority IEP species in 288 total patches on monitoring routes and no priority IEP species in transects in 2023 (Tables 2 and 3). An additional five non-priority species were recorded on routes and three on transects. We covered 83.1 km (51.6 miles) of monitoring routes in 2023 and mapped 55 patches (Figures 3–24).

Table 2. Invasive exotic plants detected at Zion National Park, May 24–31, 2023.

Scientific Name	Common Name	Method Detected	Park Priority
<i>Aegilops cylindrica</i>	jointed goatgrass	Routes	No
<i>Avena</i> sp.	oat	Routes	No
<i>Bassia scoparia</i>	summer-cypress	Routes	Yes
<i>Bromus rubens</i>	red brome	Transects	No
<i>Bromus tectorum</i>	cheatgrass	Transects	No
<i>Cardaria</i> spp.	whitetop	Routes	Yes
<i>Elaeagnus angustifolia</i>	Russian-olive	Routes	No
<i>Marrubium vulgare</i>	common horehound	Routes	No
<i>Moluccella laevis</i>	shellflower	Routes	No
<i>Onopordum acanthium</i>	Scotch thistle	Routes	Yes
<i>Salsola</i> sp.	Russian thistle	Transects	No
<i>Ulmus pumila</i>	Siberian elm	Routes	Yes

Table 3. Monitoring routes surveyed, route type, length, number of IEP infestations, and number of infestations/km, Zion NP, May 24–31, 2023.

Route	Type of Route	Length (km)	Area (ha)	# of Infestations	Infestations/km
Kolob Scenic Drive	Road	17.41	8.53	14	0.80
Lava Point	Road	7.89	6.31	0	0.00
Lower Kolob Terrace Road	Road	13.09	5.62	0	0.00
Smith Mesa	Road	3.11	2.47	2	0.64
Upper Kolob Terrace Road	Road	18.85	9.43	3	0.16
<i>Road Total</i>	–	60.35	32.36	19	0.31

Table 3 (continued). Monitoring routes surveyed, route type, length, number of IEP infestations, and number of infestations/km, Zion NP, May 24–31, 2023.

Route	Type of Route	Length (km)	Area (ha)	# of Infestations	Infestations/km
Barneys Trail	Trail	0.42	0.25	0	0.00
Campground Trail	Trail	0.36	0.29	0	0.00
Chinle Trail	Trail	11.20	6.72	0	0.00
Connector Trail	Trail	6.37	2.55	0	0.00
Hop Valley Trail	Trail	10.43	6.25	1	0.10
Kolob Arch Trail	Trail	0.91	0.55	0	0.00
La Verkin Creek Trail	Trail	13.76	9.36	0	0.00
Middle Taylor Creek Trail	Trail	3.84	2.30	1	0.26
Northgate Peaks Trail	Trail	1.75	0.70	0	0.00
Sawmill Spring Trail	Trail	0.53	0.43	1	1.87
Timber Creek Overlook Trail	Trail	0.99	0.60	0	0.00
West Rim Trail	Trail	23.29	15.93	0	0.00
Wildcat Canyon Trail	Trail	9.26	9.26	0	0.00
<i>Trail Total</i>	–	83.12	55.19	3	0.04

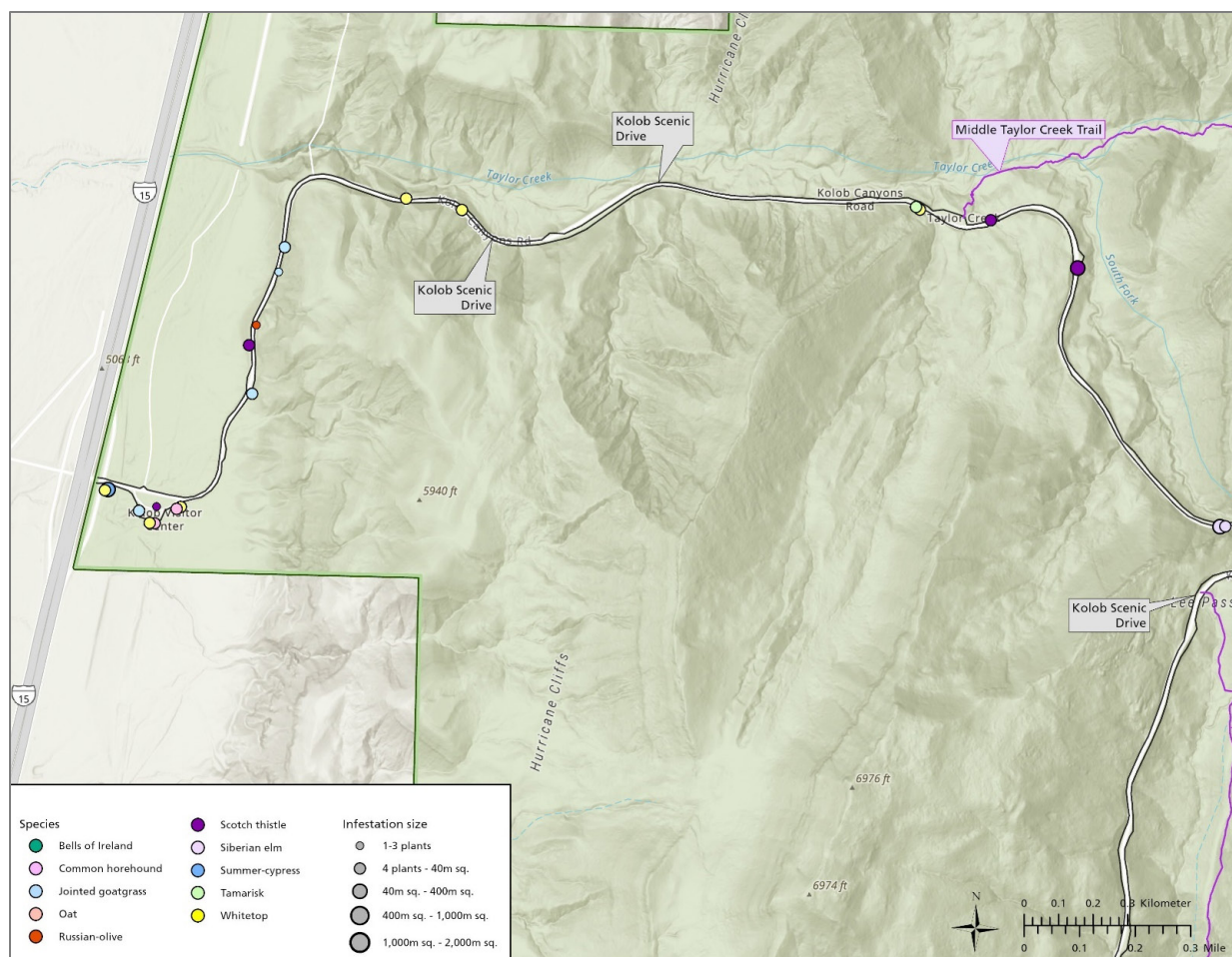


Figure 3. Monitoring routes and transects in the western Kolob Scenic Drive area, Zion National Park, May 24–31, 2023.

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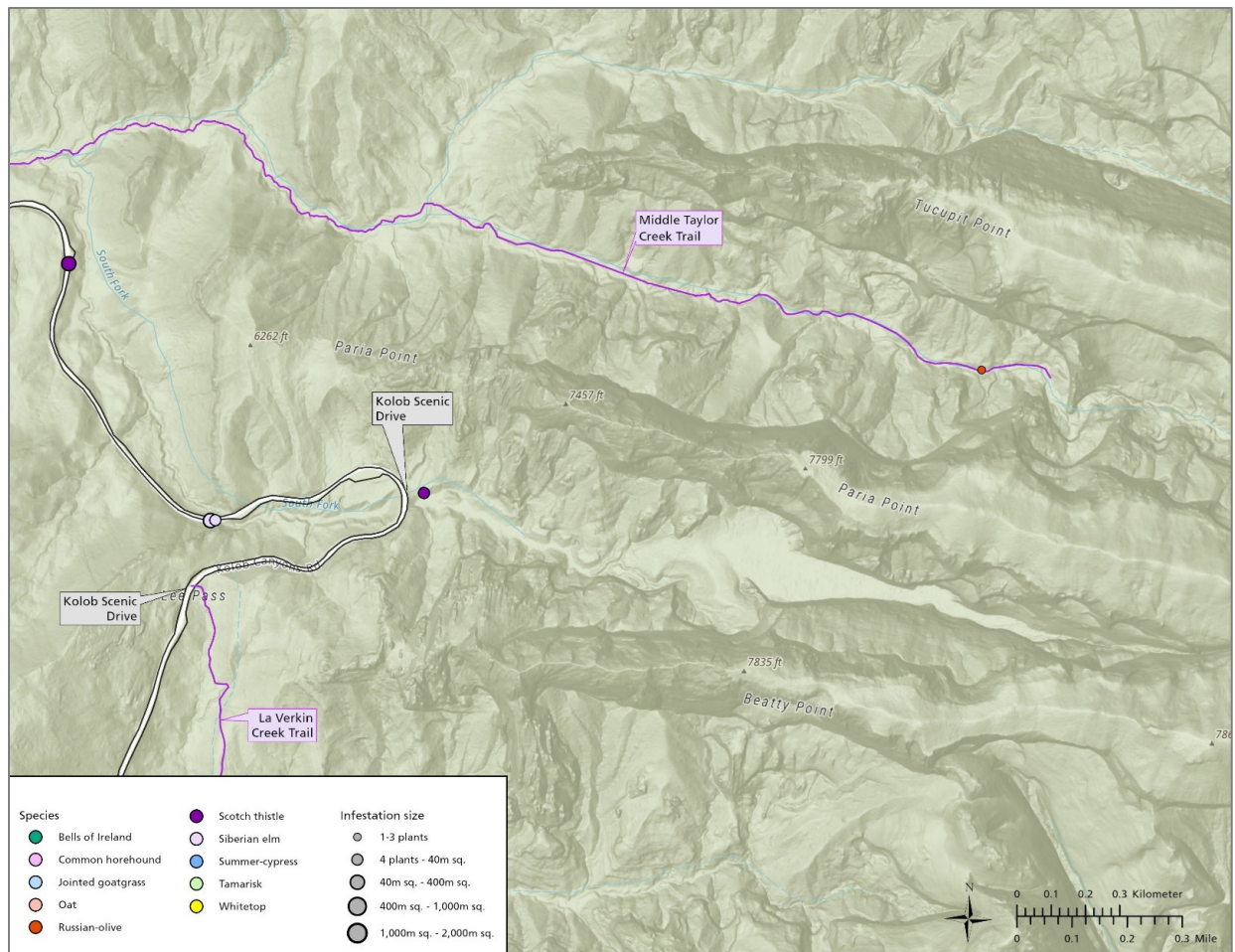


Figure 4. Monitoring routes and transects in the central Kolob Scenic Drive area, Zion National Park, May 24–31, 2023.

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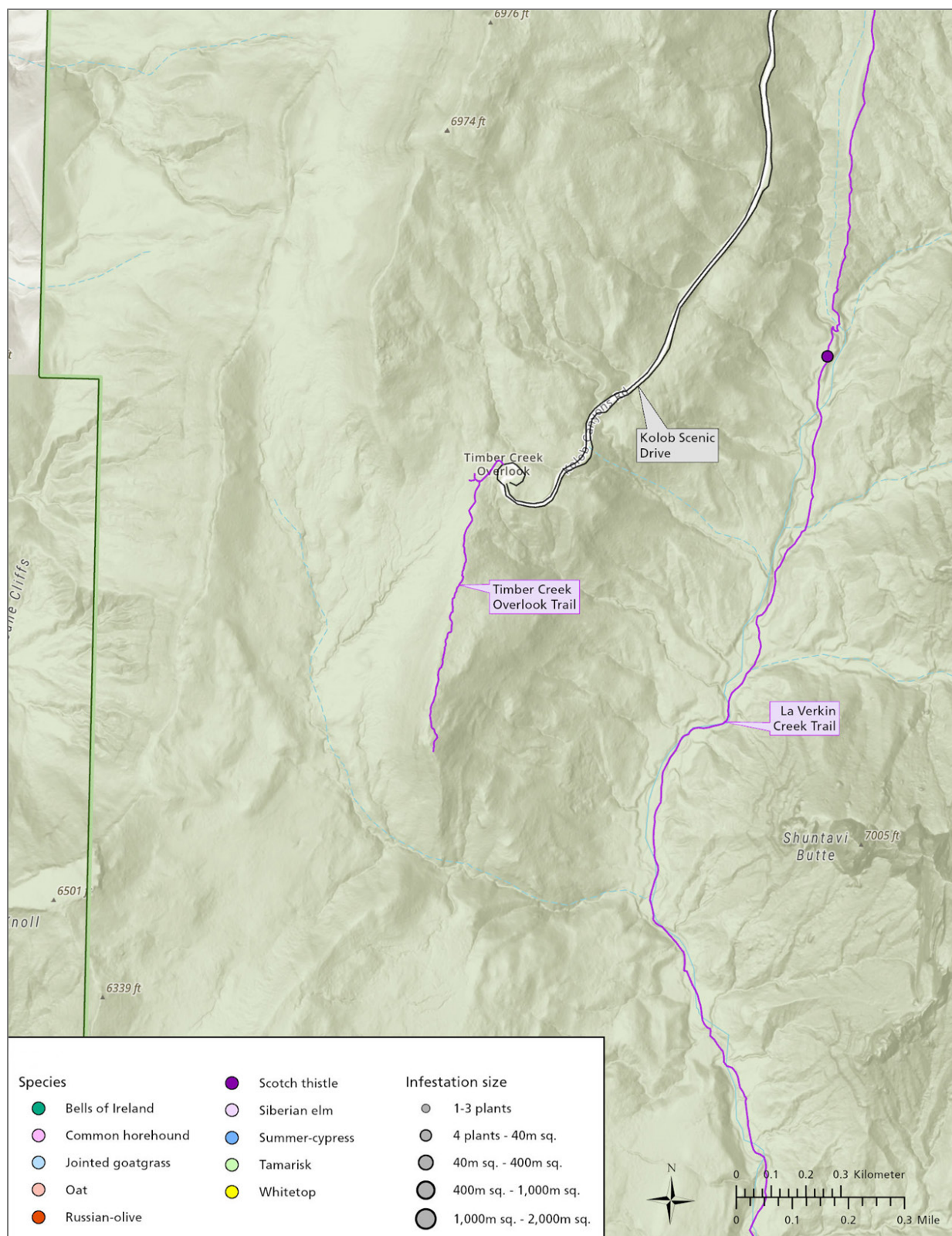


Figure 5. Monitoring routes and transects in the southern Kolob Scenic Drive area, Zion National Park, May 24–31, 2023.

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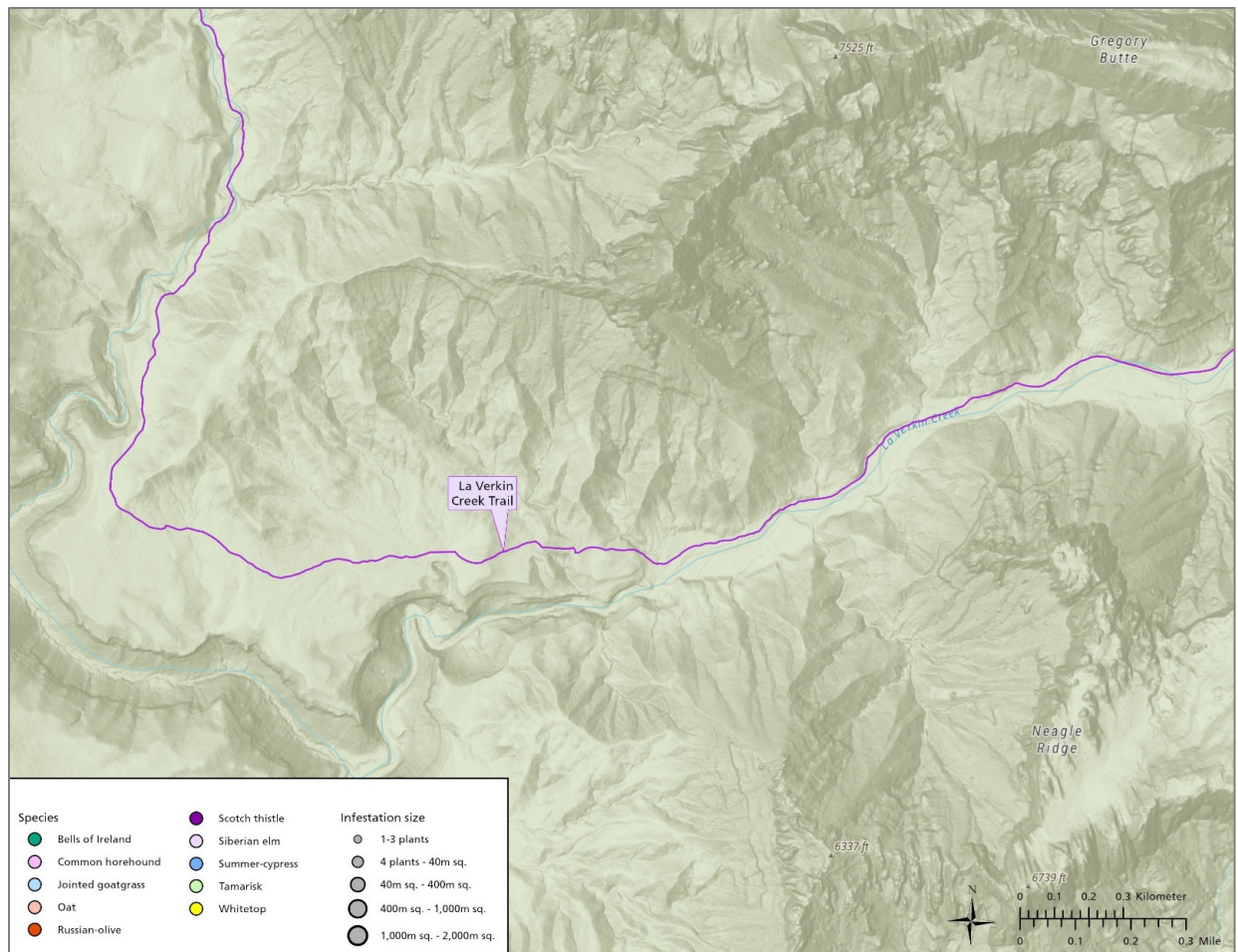


Figure 6. Monitoring routes and transects in the central La Verkin Creek Trail area, Zion National Park, May 24–31, 2023.

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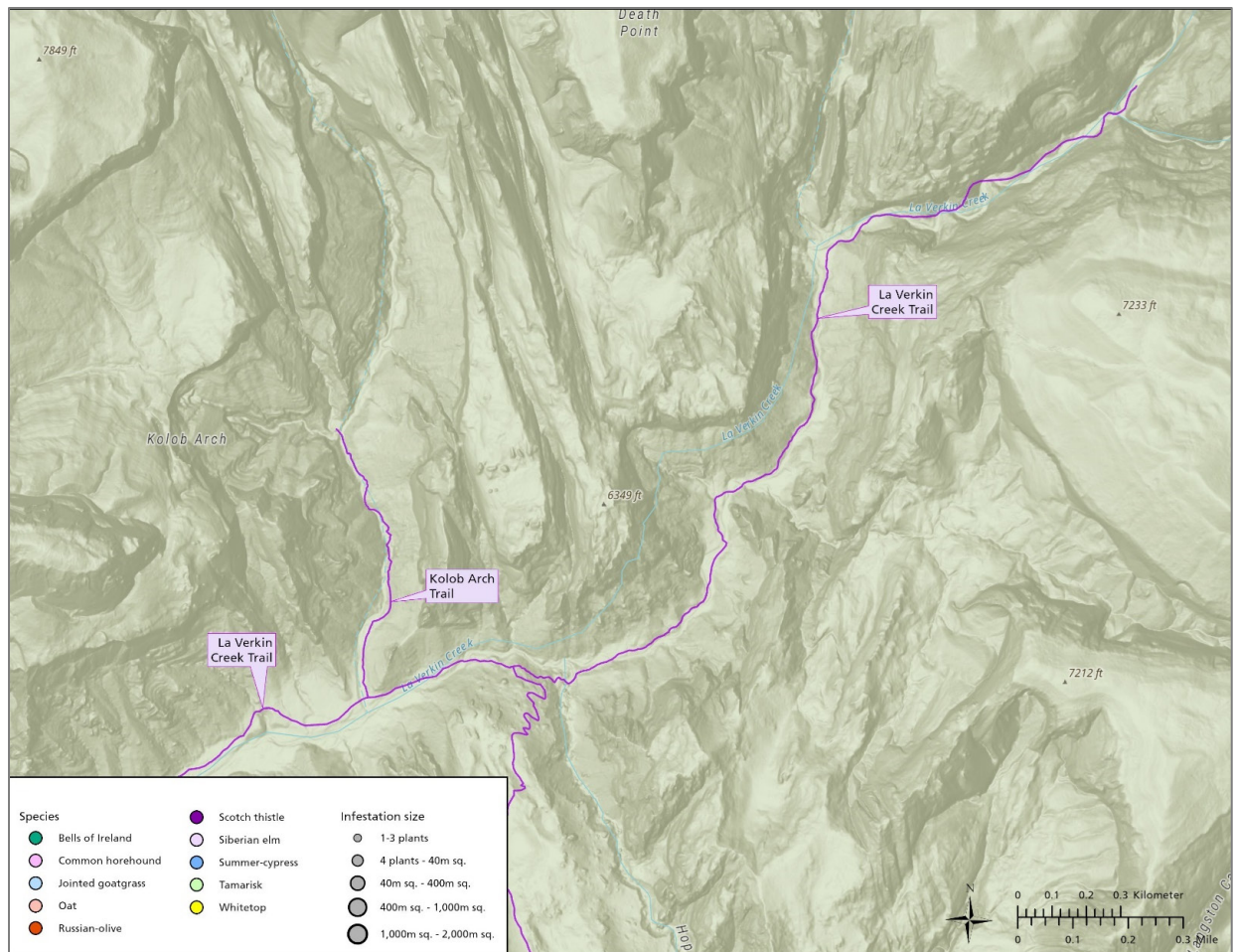


Figure 7. Monitoring routes and transects in the eastern La Verkin Creek Trail area, Zion National Park, May 24–31, 2023.

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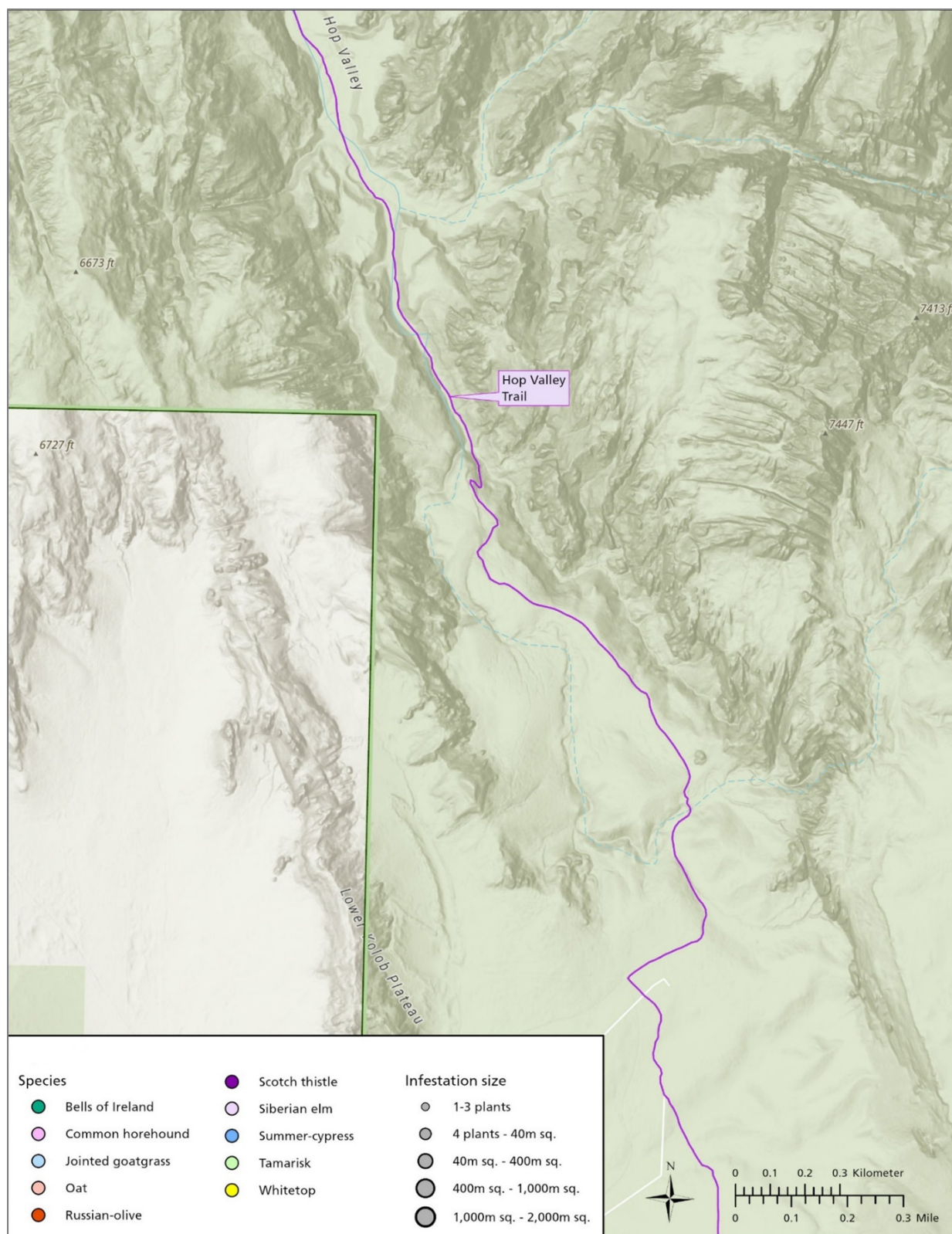


Figure 9. Monitoring routes and transects in the central Hop Valley Trail area, Zion National Park, May 24–31, 2023.

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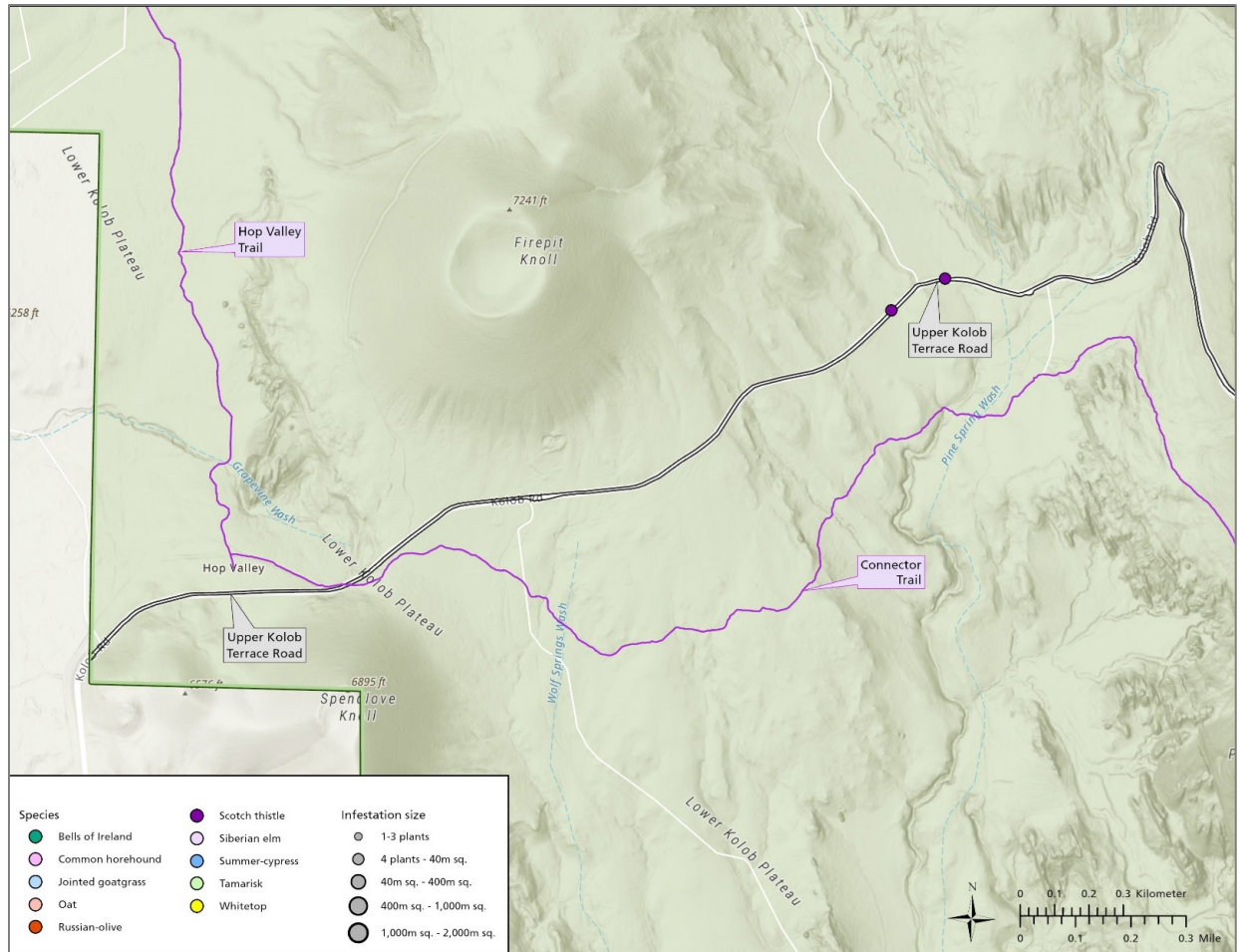


Figure 10. Monitoring routes and transects in the western Upper Kolob Terrace Road area, Zion National Park, May 24–31, 2023.

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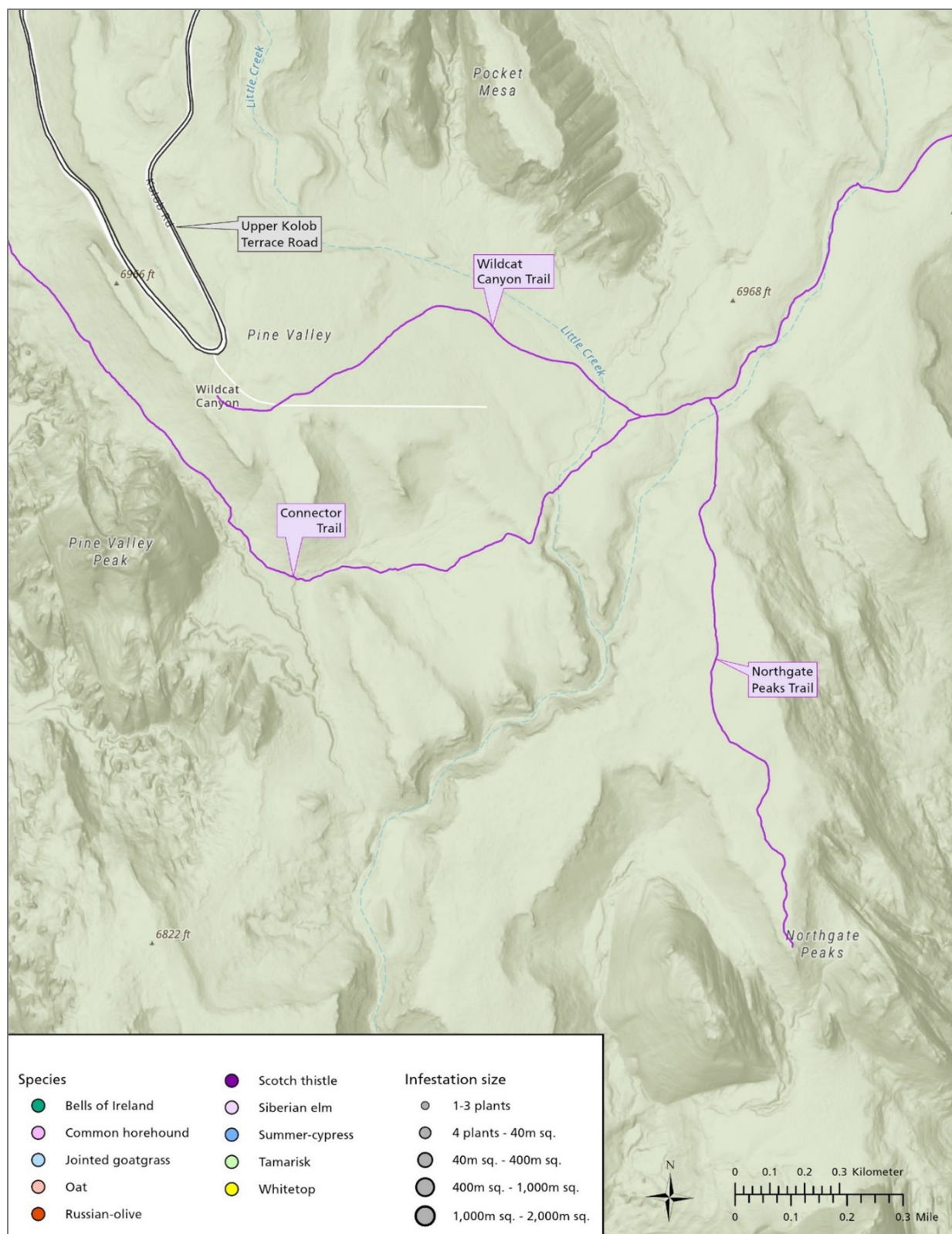


Figure 11. Monitoring routes and transects in the Connector Trail and Wildcat Canyon Trail areas, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

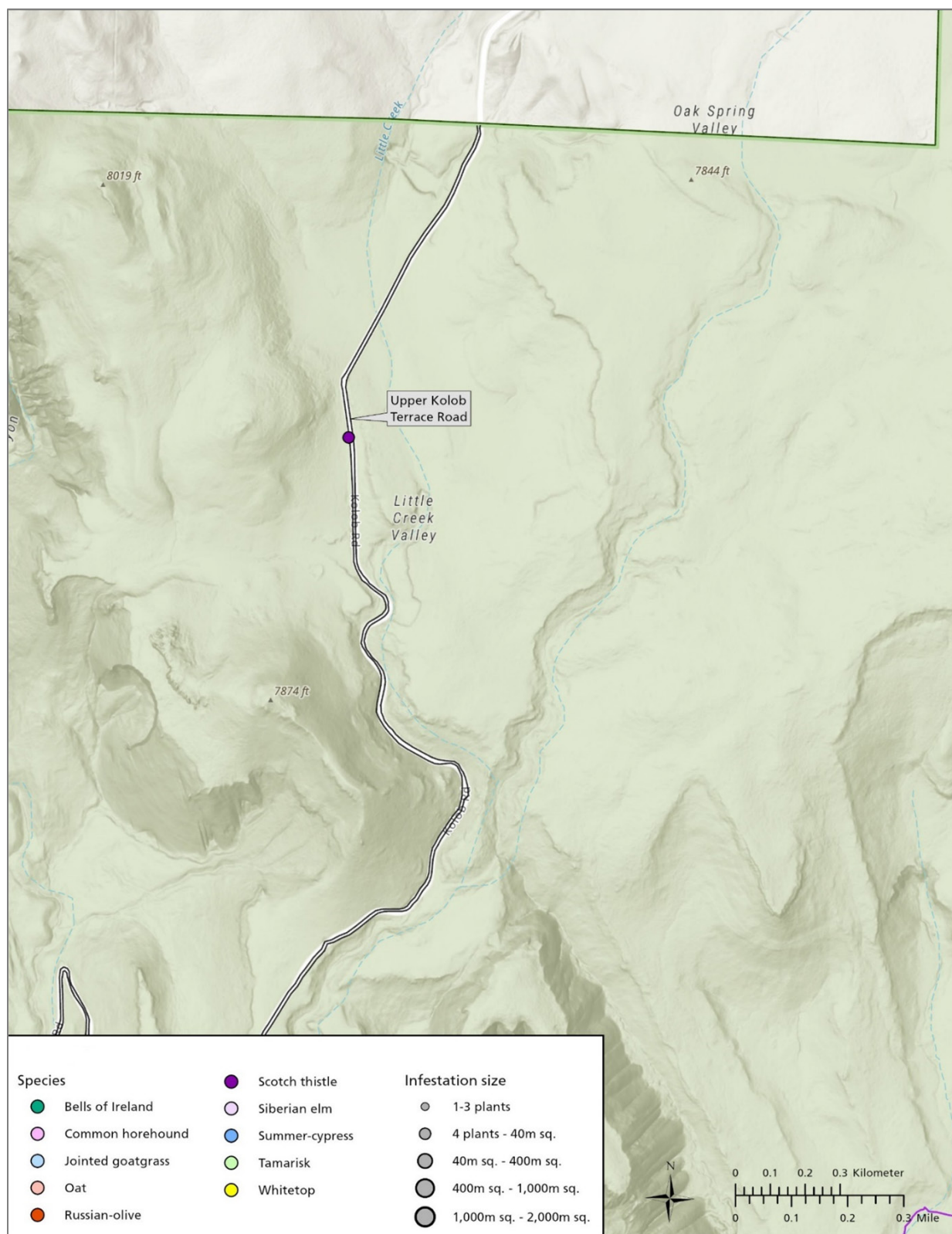


Figure 12. Monitoring routes and transects in the eastern Upper Kolob Terrace Road area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

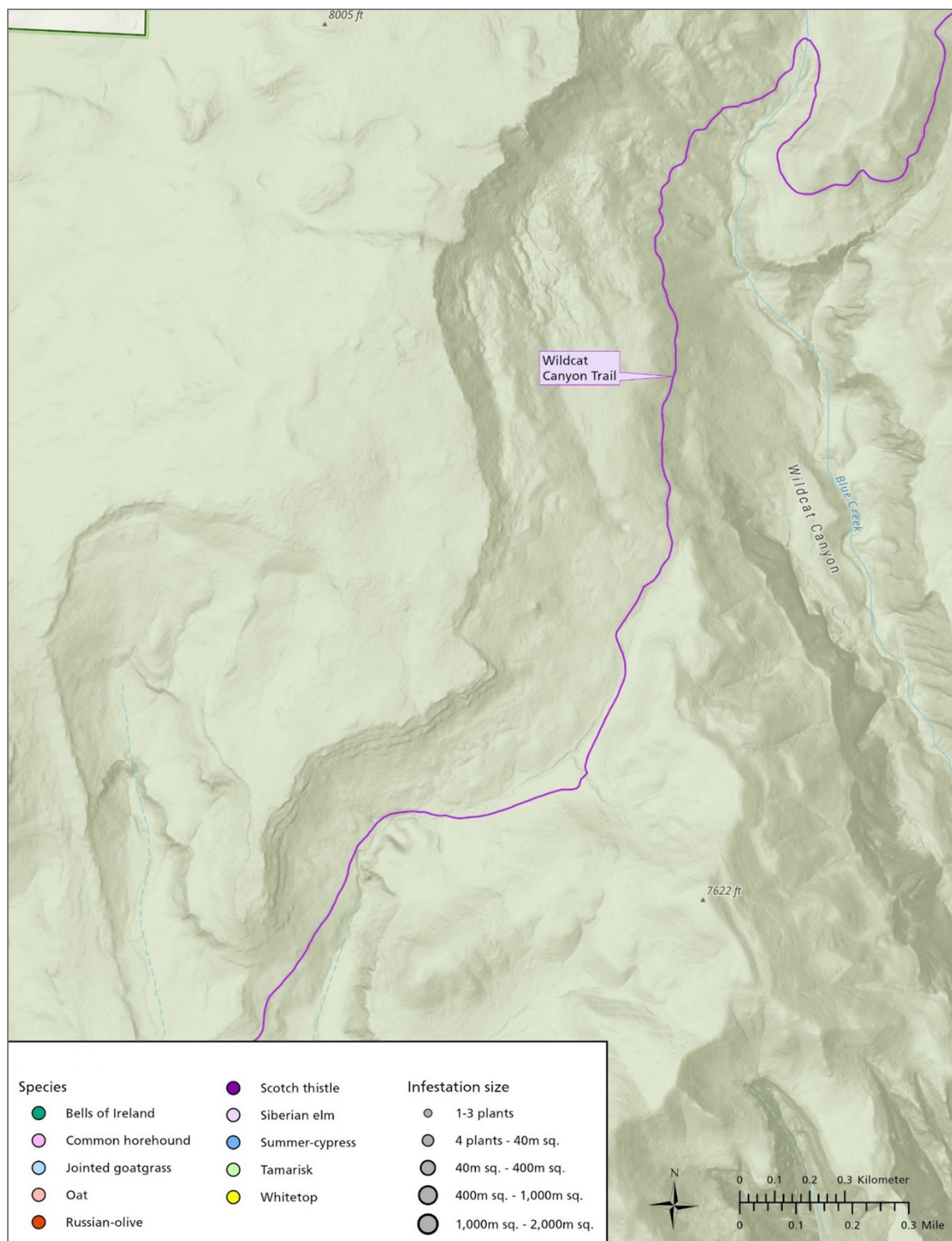


Figure 13. Monitoring routes and transects in the eastern Wildcat Canyon Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

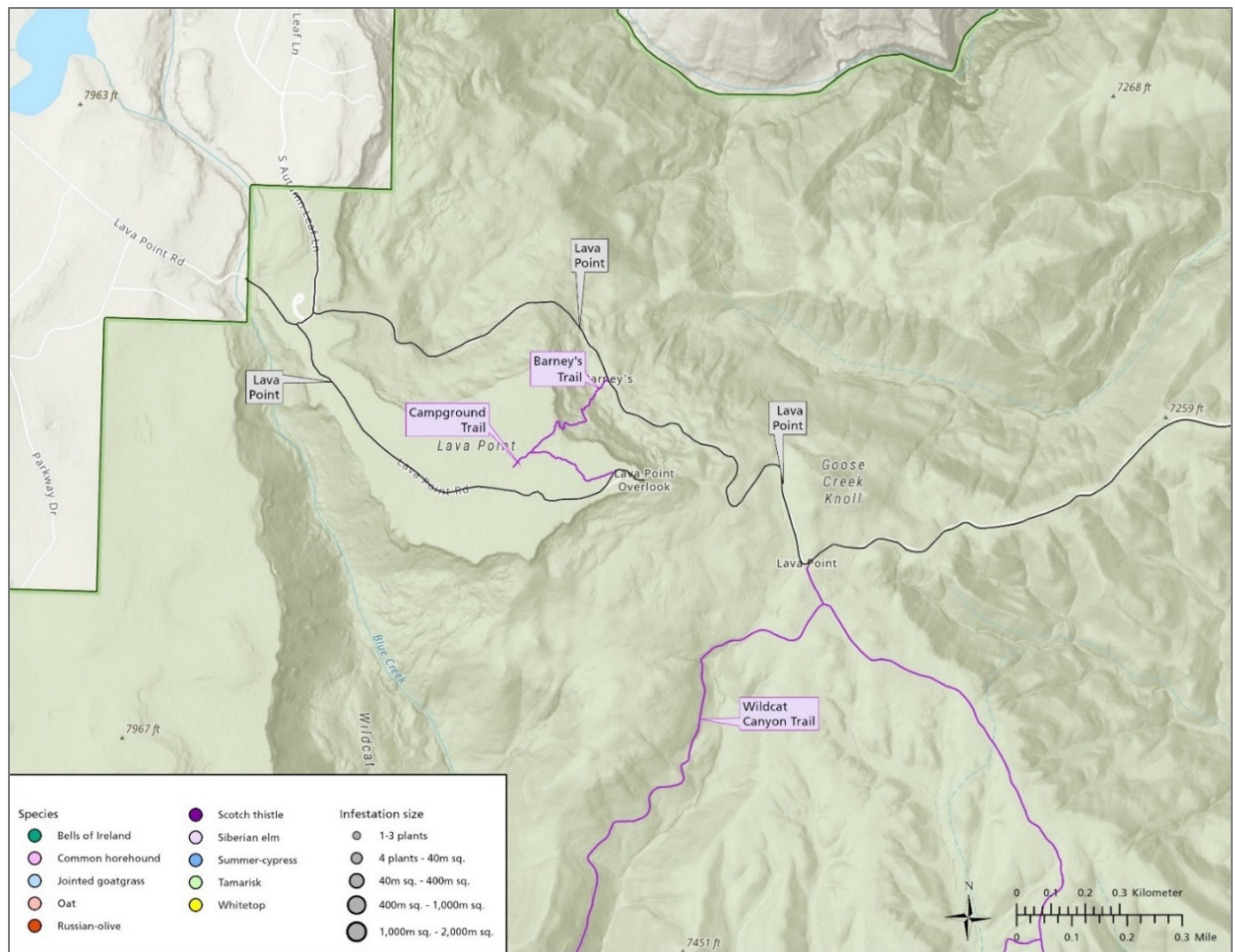


Figure 14. Monitoring routes and transects in the western Lava Point Road area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

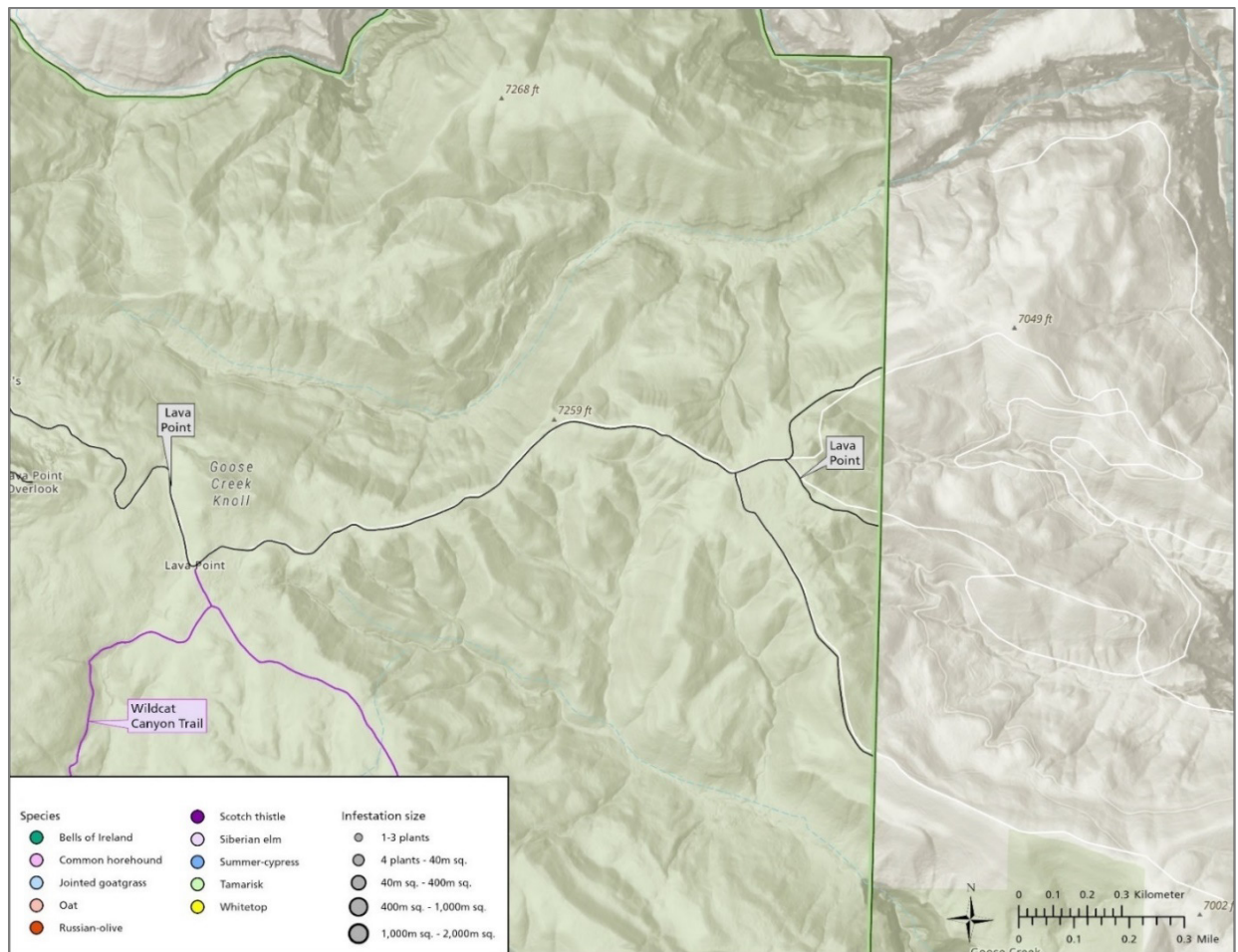


Figure 15. Monitoring routes and transects in the eastern Lava Point Road area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

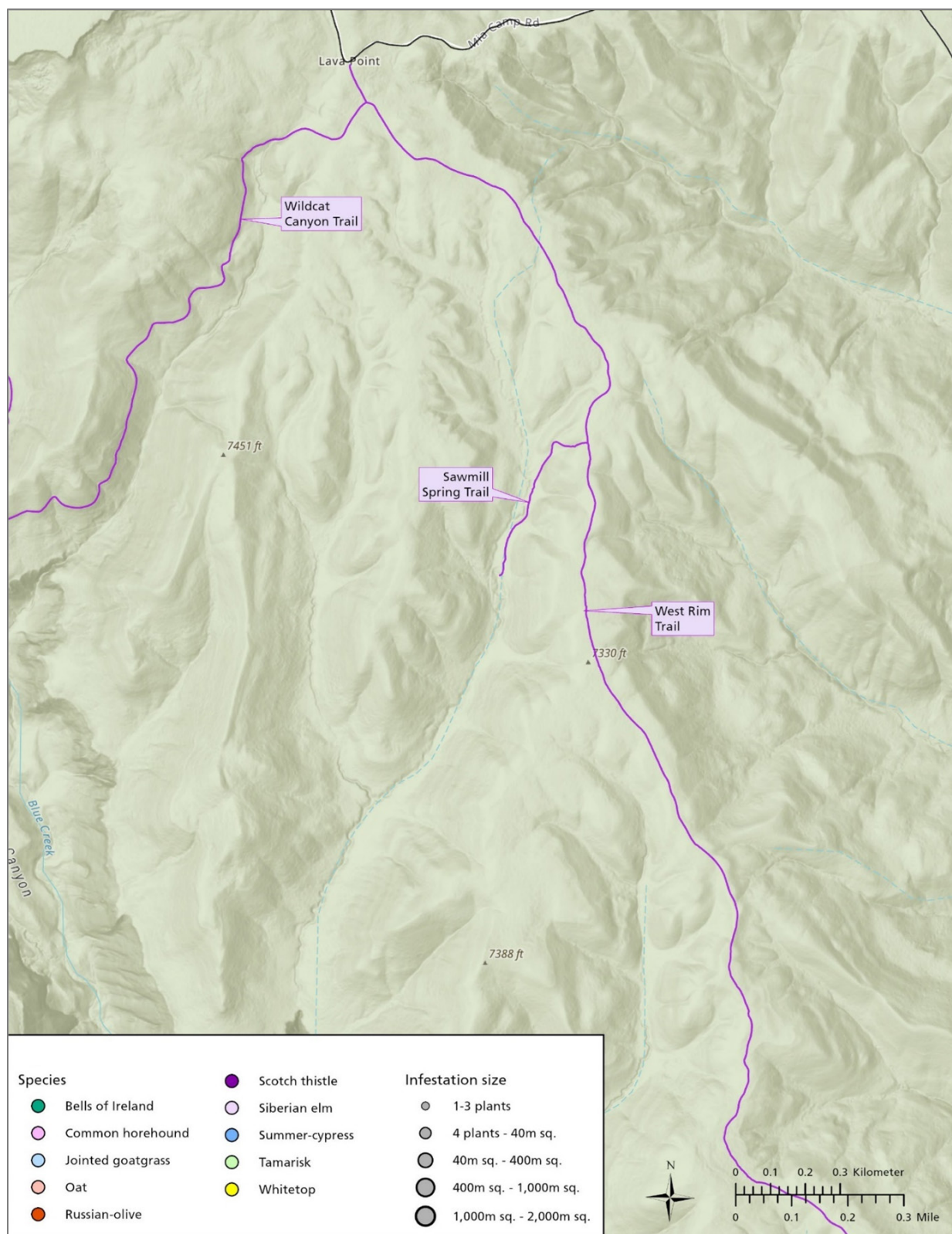


Figure 16. Monitoring routes and transects in the West Rim Trail and Wildcat Canyon Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

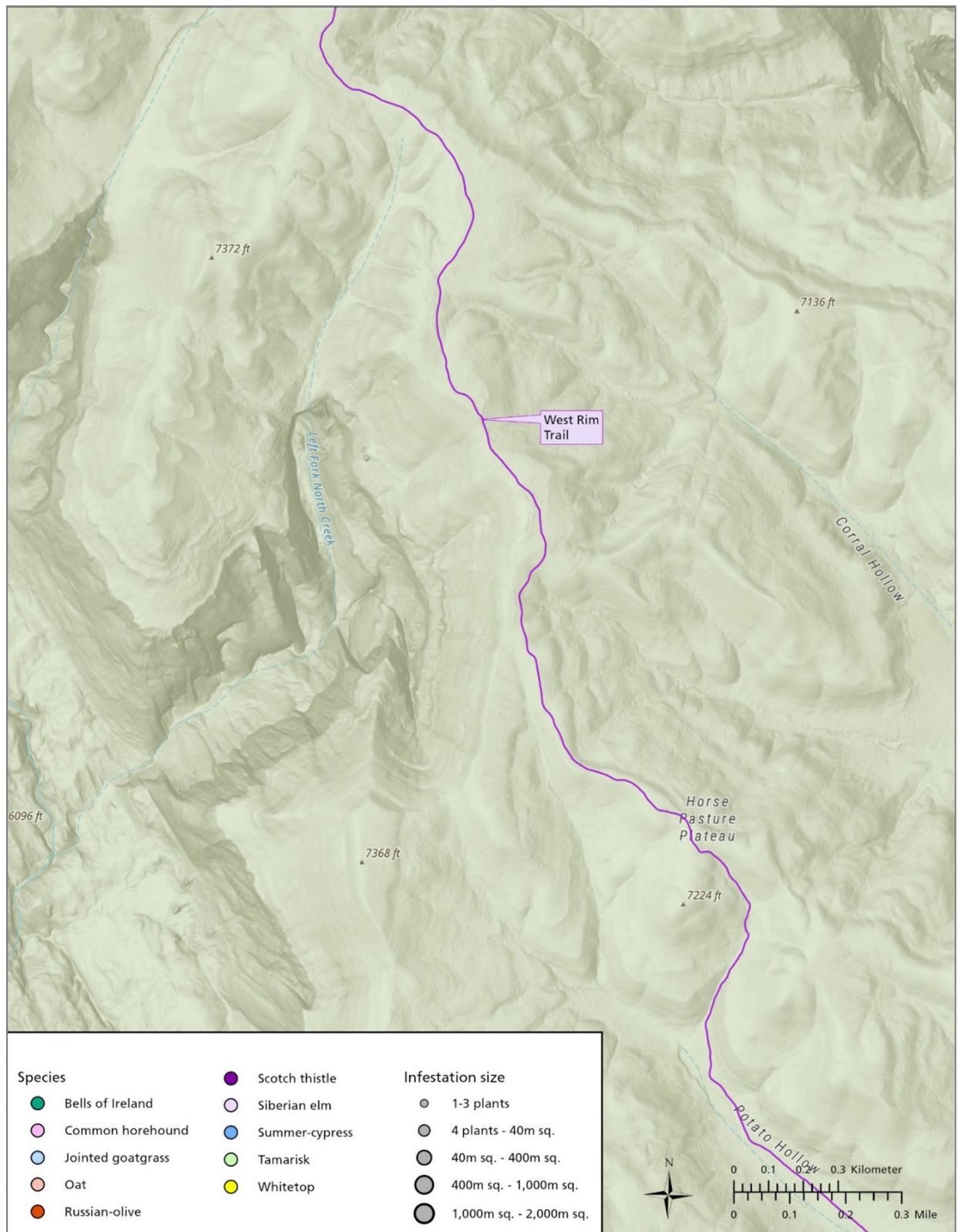


Figure 17. Monitoring routes and transects in the northern West Rim Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

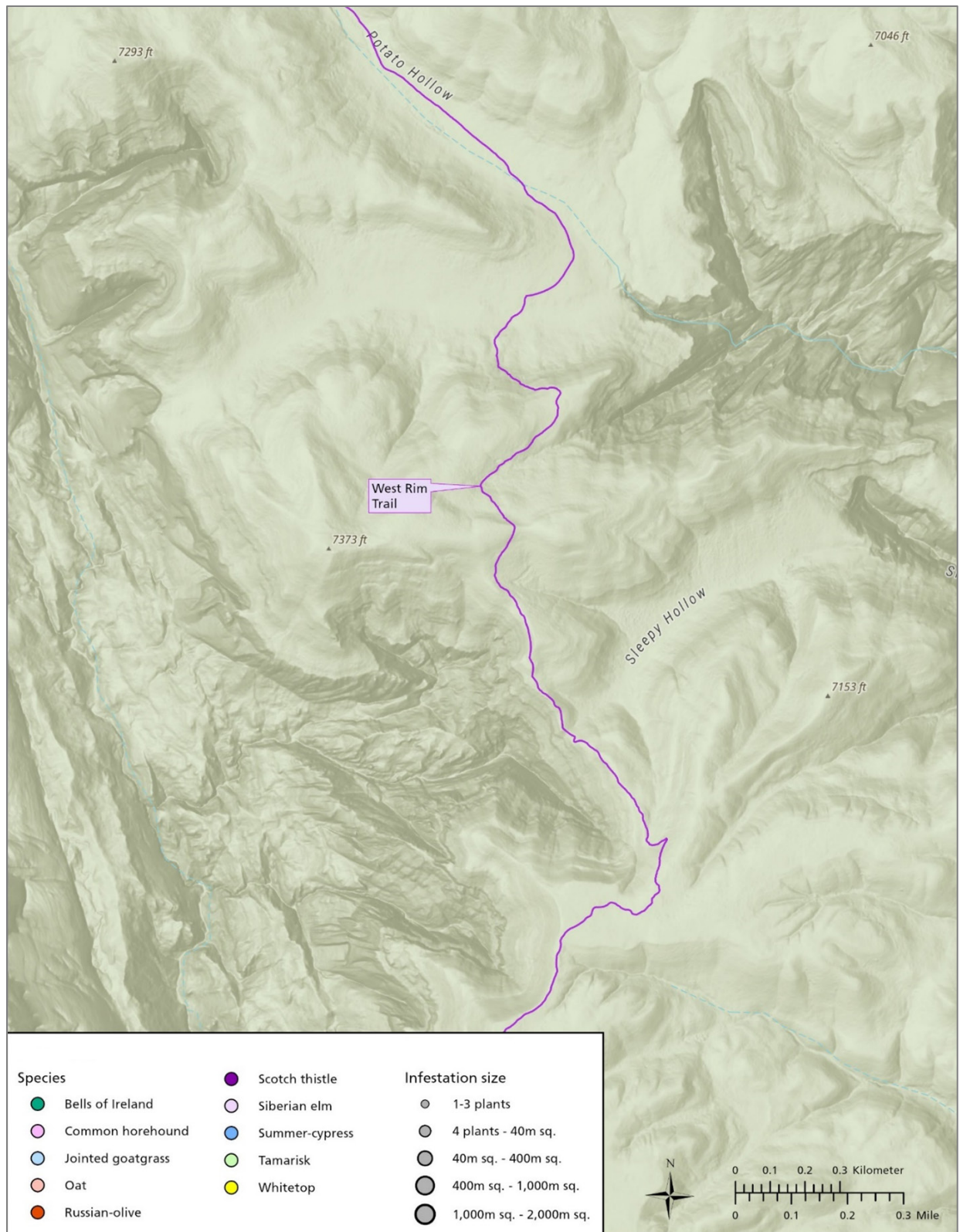


Figure 18. Monitoring routes and transects in the central West Rim Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

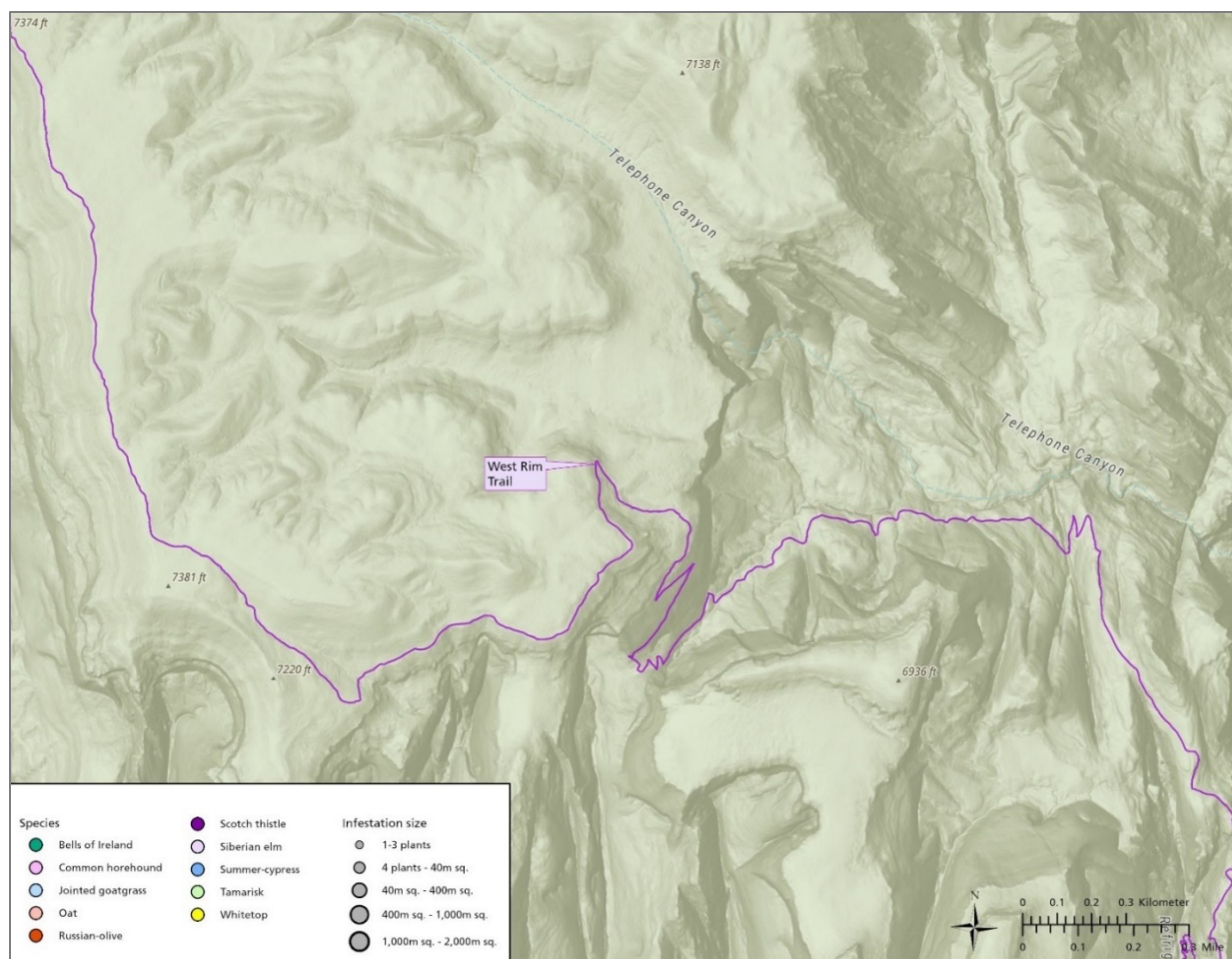


Figure 19. Monitoring routes and transects in the central West Rim Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

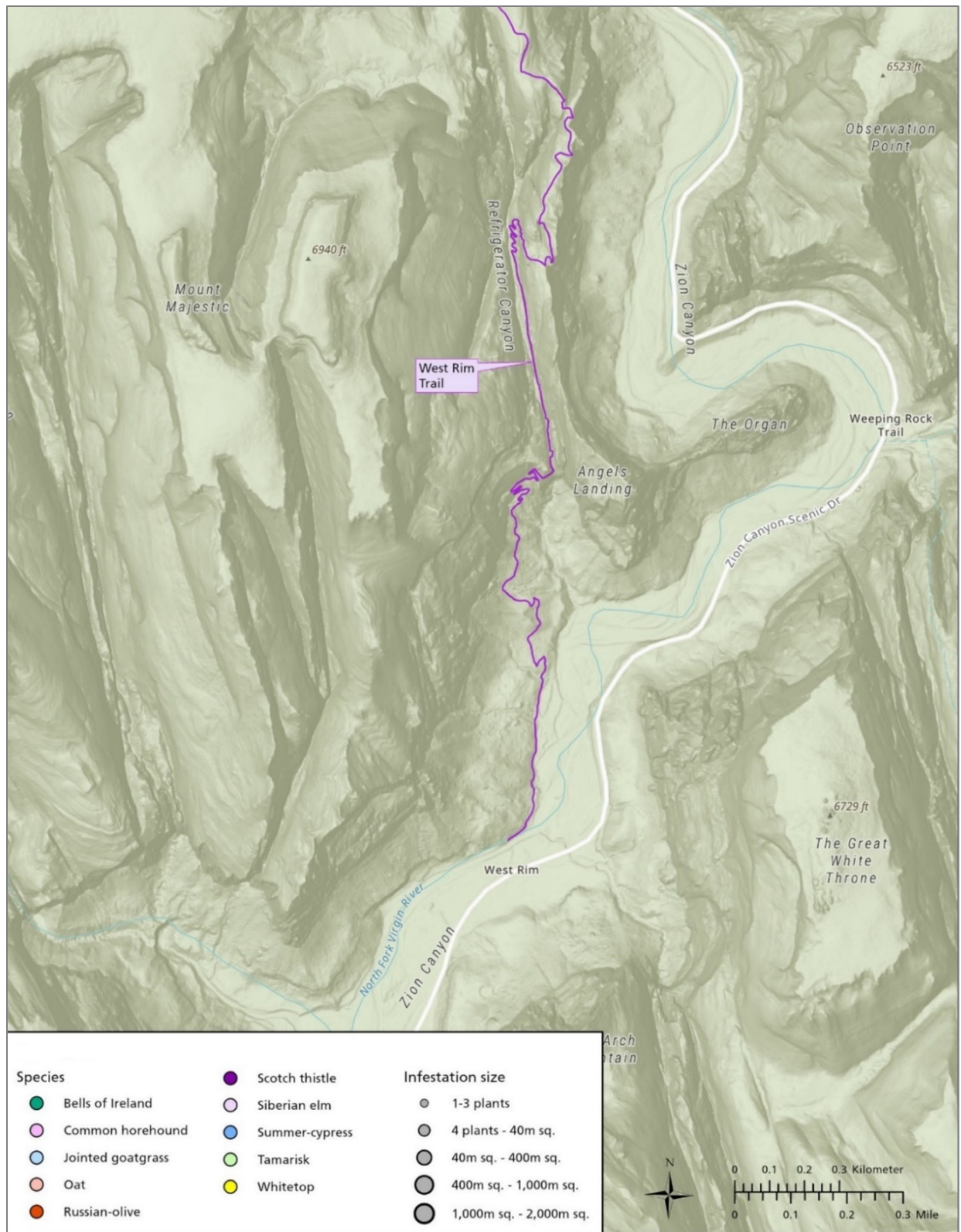


Figure 20. Monitoring routes and transects in the southern West Rim Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

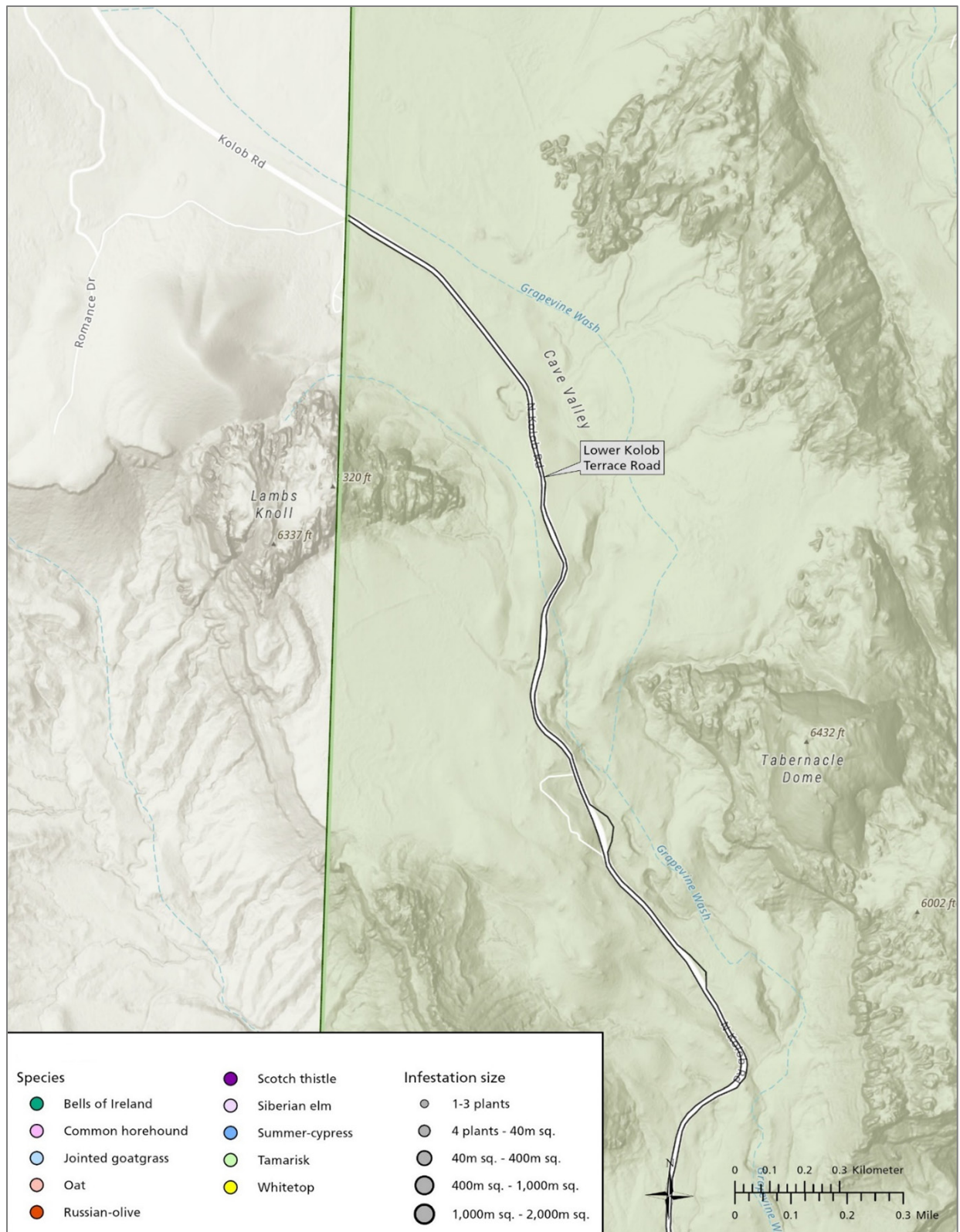


Figure 21. Monitoring routes and transects in the northern Lower Kolob Terrace Road area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

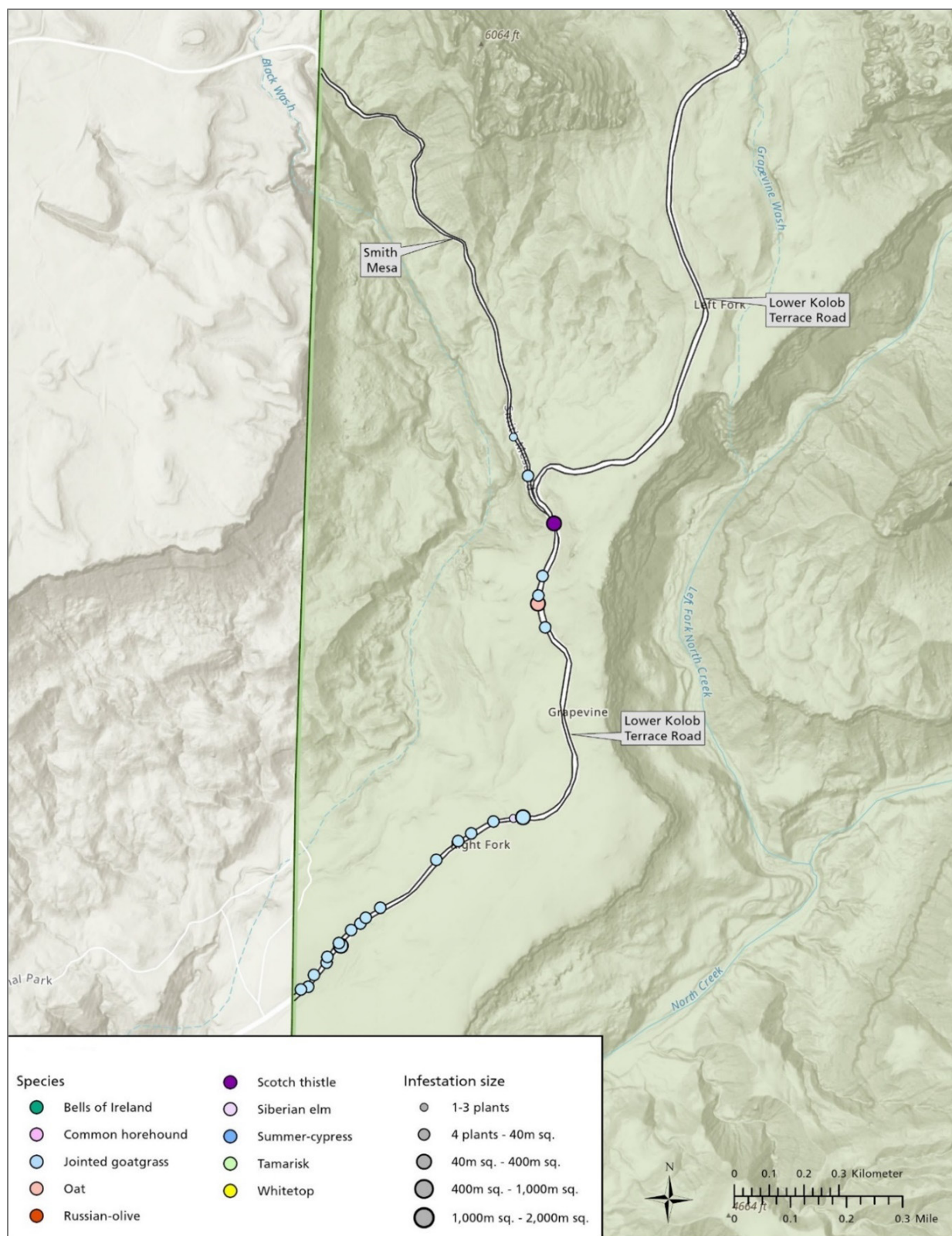


Figure 22. Monitoring routes and transects in the southern Lower Kolob Terrace Road and Smith Mesa area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

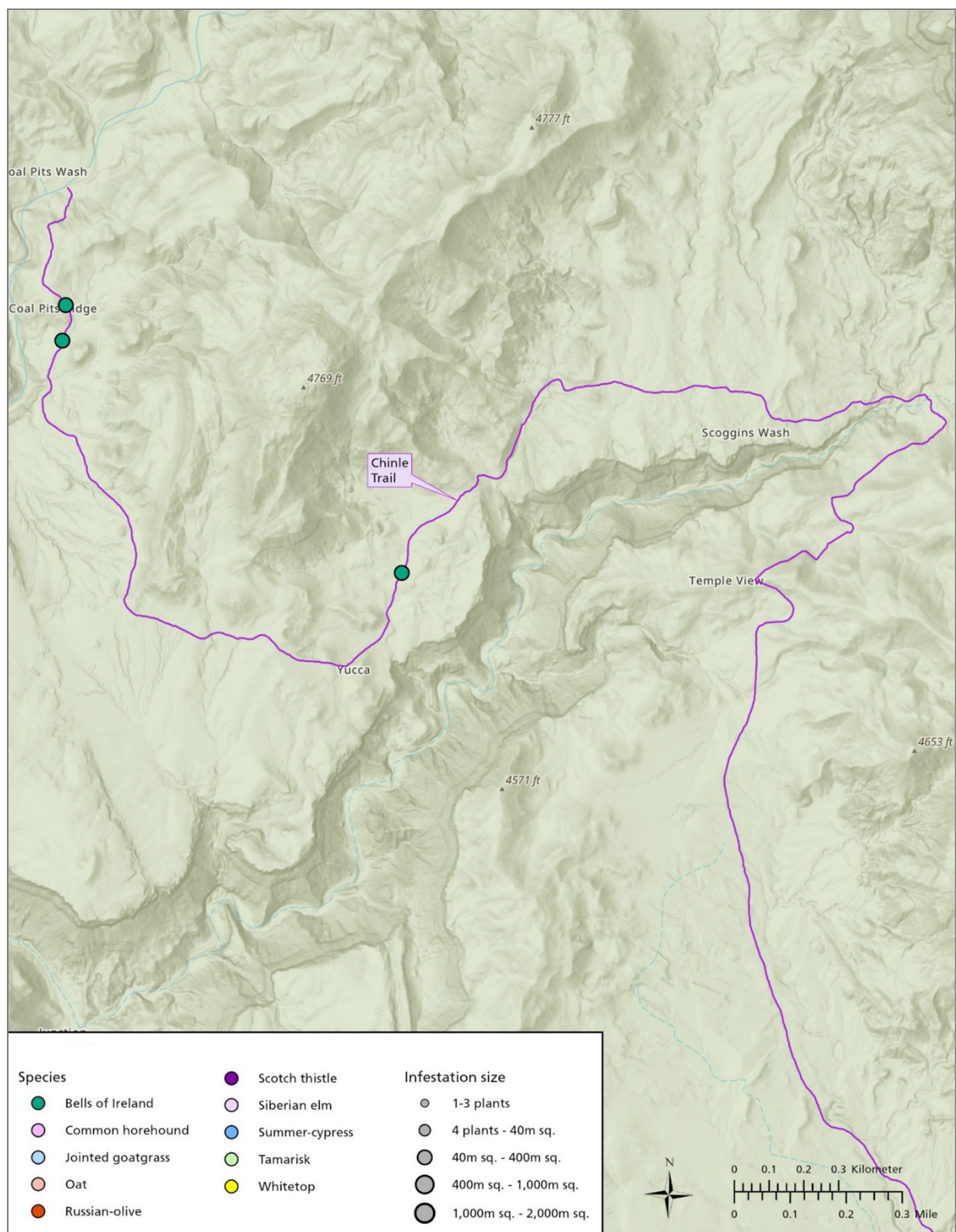


Figure 23. Monitoring routes and transects in the northern Chinle Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

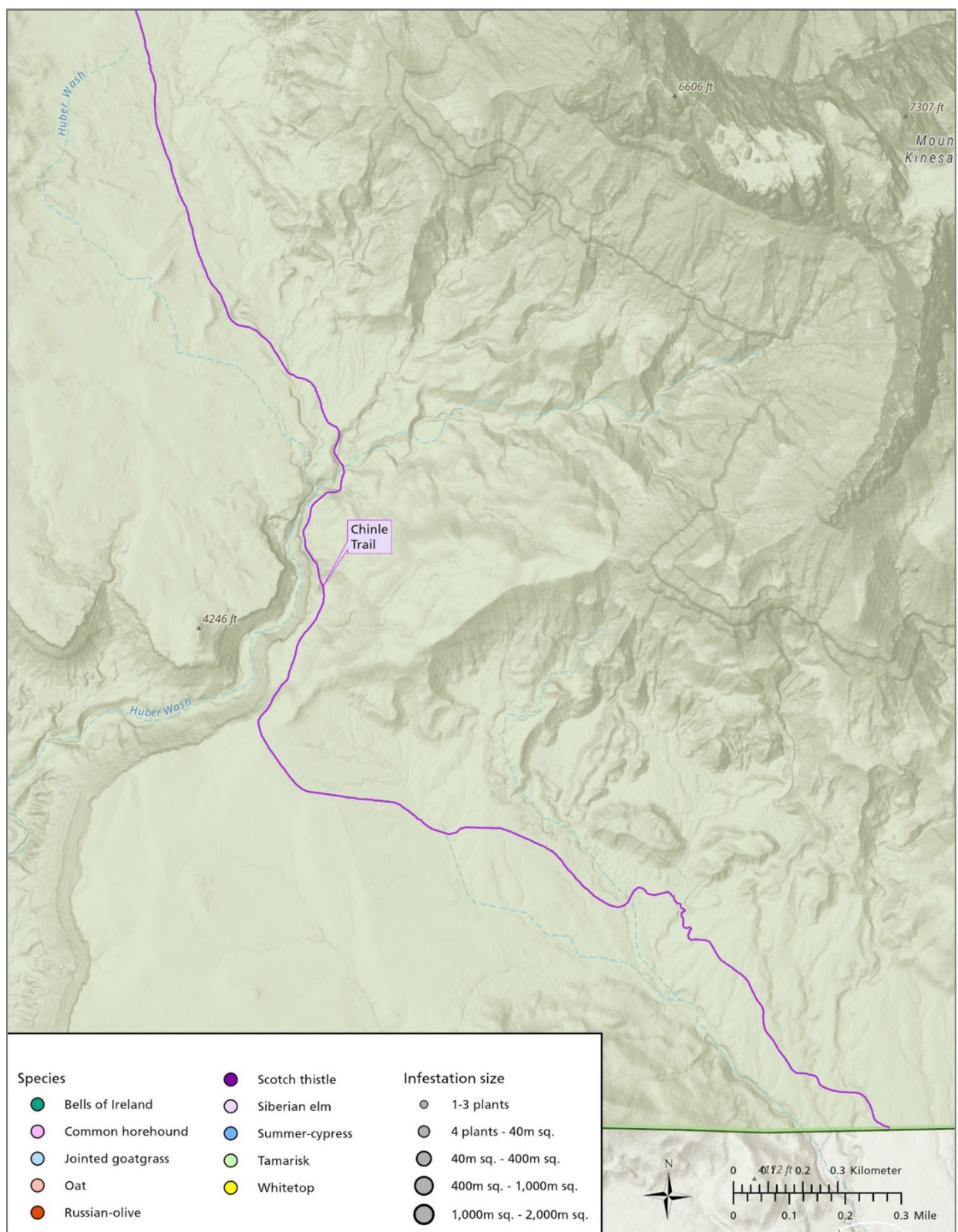


Figure 24. Monitoring routes and transects in the southern Chinle Trail area, Zion National Park, May 24–31, 2023.

NPS / ANETH WIGHT

3.2 Monitoring Routes

Of 55 total IEP patches recorded, 22 patches of four different priority species were detected along Zion NP monitoring routes in 2023 (see Table 2; Figures 3–24; NCPN 2025a). The majority of patches (81.8%) were 40 m² or smaller. The most common priority species (Table 4) was Scotch thistle (*Onopordum acanthium*). Scotch thistle represented 54.5% of the priority infestations found. The next-most common priority species was whitetop (*Cardaria* sp.). Together, these two species represented 81.8% of all patches recorded in 2023. Five non-priority IEPs were recorded in 33 patches on monitoring routes. Siberian elm (*Ulmus pumila*) and Russian olive (*Elaeagnus angustifolia*) were the only tree species detected. Of the 55 patches recorded, four patches contained trees. Two were seedlings (3.6%), one was a sapling (1.8%), one was a mature tree (1.8%) and one patch did not have growth stage recorded (see NCPN 2025a).

Table 4. Priority species observed and infestation size class detected along all monitoring routes, Zion NP, May 24–31, 2023.

Species	Total Infestations	Size of Infestation				
		1 to Few Plants	Few Plants–40 m ²	40–400 m ²	400–1000 m ²	>1000 m ²
<i>Ulmus pumila</i>	3	1	1	1	0	0
<i>Onopordum acanthium</i>	12	2	8	2	0	0
<i>Cardaria</i> sp.	6	0	6	0	0	0
<i>Bassia scoparia</i>	1	0	0	1	0	0
Priority Species	22	3	15	4	0	0

On average, trails had more priority IEP patches per kilometer than roads (see Table 3). Priority IEP patches were detected on Kolob Scenic Drive, Smith Mesa, and Upper Kolob Terrace Roads. No priority IEP species were detected on Lava Point and Lower Kolob Terrace Roads. All roads had relatively low patch density; however, the roads with the highest patch density were Kolob Scenic Drive (0.8 patches/km) and Smith Mesa (0.64 patches/km). The trail with the highest patch density was the Sawmill Spring Trail (1.87 patches/km). There were no priority IEP species detected along 10 of the trails monitored.

3.3 Monitoring Transects

A total of 260 transects were sampled in 2023 (Table 5; see Figures 3–24; NCPN 2025b). No IEPs were found on transects. Three non-priority species were detected on transects: cheatgrass, Russian thistle, and red brome (*Bromus rubens*, found on only one transect).

Cheatgrass was by far the most widespread species, present in 50.4% of transects sampled in 2023 (Table 5). Cheatgrass also had the highest percent cover of any detected species, averaging 0.50% across all transects in 2023. Russian thistle and red brome each had < 0.1% average percent cover. Russian thistle and red brome were present in 0.77% and 0.38% of transects, respectively.

Table 5. Number of monitoring transects where exotic plant species were detected/total number of transects monitored, mean percent cover, and standard error by area at Zion NP, May 24–31, 2023. Barneys Trail, Campground Trail, Kolob Arch Trail, Lava Point Road, and Sawmill Spring Trail did not detect IEPs in transects.

Route	<i>Bromus tectorum</i> ^A		<i>Salsola</i> sp. ^A		<i>Bromus rubens</i> ^A		All Invasive Species	
	Detected/ Total	Percent Cover (SE)	Detected/ Total	Percent Cover (SE)	Detected/ Total	Percent Cover (SE)	Detected/ Total	Percent Cover (SE)
Chinle Trail	9/16	0.38(0.17)	–	–	–	–	9/16	0.38(0.17)
West Rim Trail	5/47	0.04(0.02)	–	–	–	–	5/47	0.04(0.02)
Northern Routes ^B	56/73	0.58(0.10)	1/73	0.01(0.01)	1/73	0.002(0.002)	58/73	0.59(0.10)
Upper Border Routes ^C	31/92	0.23(0.05)	1/92	0.01(0.01)	–	–	32/92	0.23(0.05)
Western Routes ^D	30/32	1.81(0.47)	–	–	–	–	30/32	1.81(0.47)
All Routes	131/260	0.50(0.07)	2/260	0.004(0.003)	1/260	0.001(0.001)	134/260	0.52(0.07)

^A Not on priority list, but a species that is consistently looked for and recorded, if present, in all transects.

^B Kolob Scenic Drive Road, La Verkin Creek Trail, Middle Taylor Creek Trail, and Timber Creek Overlook Trail routes.

^C Connector Trail, Hop Valley Trail, Northgate Peaks Trail, Upper Kolob Terrace Road, and Wildcat Canyon Trail routes.

^D Lower Kolob Terrace Road and Smith Mesa Road routes.

3.4 Results Comparison: 2012–2013, 2015–2016, 2018, and 2023

Two rotations of monitoring routes were completed in 2012–2013 and 2015–2016 (Perkins 2013, 2014; Karinen and Perkins 2016). A third rotation began in 2018 (Washuta and Perkins 2019) and continued in 2023. Due to budget cuts and alterations from COVID-19, not all routes were able to be monitored every year. Therefore, this report compares results from routes monitored in 2023 to the same routes completed in 2012–2013 and 2015–2016. Comparisons only included IEP species common to all monitoring years. Little bur-clover, spring whitlow grass, Mediterranean grass, and puncture vine are excluded because they were added to the priority IEP list in 2015 and 2023.

Overall patches per kilometer across consistent routes was highest in 2015–2016 (0.98 patches/km) and lowest in 2023 (0.24 patches/km), with 2012–2013 (0.98 patches/km) falling in between (Table 6). Lava Point, Upper Kolob Terrace Road, Lower Kolob Terrace Road, Connector Trail, West Rim Trail, and Wildcat Canyon routes have decreased in IEP patches per kilometer from 2015–2016. Kolob Scenic Drive and Smith Mesa Road have increased in IEP patches per kilometer from 2015–2016. All other routes have remained stable in number of patches per kilometer. There were no IEP detections at Lava Point, Lower Kolob Terrace Road, Barneys Trail, Campground Trail, Chinle Trail, Connector Trail, Kolob Arch Trail, La Verkin Creek Trail, Northgate Peaks Trail, Timber Creek Overlook Trail, West Rim Trail, and Wildcat Canyon Trail.

Table 6. Patches per kilometer on routes surveyed for the same priority IEP species in Zion NP, 2012–2013, 2015–2016, 2018, and 2023.

Route	Route Type	Patches/km			
		2012–2013	2015–2016	2018	2023
Kolob Scenic Drive	Road	1.03	0.52	–	0.80
Lava Point	Road	0.00	0.52	–	0.00
Lower Kolob Terrace Road	Road	0.61	0.15	–	0.00
Smith Mesa	Road	0.00	0.32	–	0.64
Upper Kolob Terrace Road	Road	3.29	5.78	–	0.16
Barneys Trail	Trail	0.00	0.00	–	0.00
Campground Trail	Trail	–	0.00	–	0.00
Chinle Trail	Trail	0.00	0.00	0.00	0.00
Connector Trail	Trail	0.00	0.94	–	0.00
Hop Valley Trail	Trail	0.00	1.63	–	0.10
Kolob Arch Trail	Trail	–	–	–	0.00
La Verkin Creek Trail	Trail	0.00	0.07	–	0.00
Middle Taylor Creek Trail	Trail	0.00	0.00	–	0.26
Northgate Peaks Trail	Trail	0.57	2.86	–	0.00
Sawmill Spring Trail	Trail	0.00	0.00	–	1.87
Timber Creek Overlook Trail	Trail	0.00	0.00	–	0.00
West Rim Trail	Trail	0.00	0.04	–	0.00

Table 6 (continued). Patches per kilometer on routes surveyed for the same priority IEP species in Zion NP, 2012–2013, 2015–2016, 2018, and 2023.

Route	Route Type	Patches/km			
		2012–2013	2015–2016	2018	2023
Wildcat Canyon Trail	Trail	1.71	2.81	–	0.00
Averages	–	0.45	0.92	0.00	0.22

On the Chinle Trail, Russian thistle was not detected in 2015–2023, and cheatgrass occurrences have remained stable. Cheatgrass percent cover, however, has increased from 2015–2016 (0.15%) to 2023 (0.38%). On the Northern Trails, cheatgrass detections increased from 2015–2016 (20%) to 2023 (76.6%), and percent cover increased from 0.07% to 0.58%, respectively. Scotch thistle has decreased in number of patches from 2015–2016 to 2023, and no patches in 2023 were above 40 m². Overall, the number of patches of Siberian elm, Bermudagrass, little bur-clover, bulbous bluegrass, Johnsongrass, and Scotch thistle have decreased from 2015–2016 to 2023. We examined individual priority IEP species over time in the same routes.

4 Discussion

4.1 Priority IEP List

The NCPN will continue to work with park staff and area IEP experts to review and update the list of priority species each year. Presence and absence data for most priority species should be reliable for the area surveyed. However, data for non-priority species should not be assumed to be complete, as these species were not reliably mapped across observers, routes, or years.

4.2 Possibilities for Management Control

The most common priority IEP species was Scotch thistle, with a total of 12 patches recorded (see Table 4). Across the same routes, Scotch thistle patches decreased from 46 patches in 2015–2016 to 12 patches in 2023. The next most common priority species is whitetop, and it was found in 6 patches. The decline in Siberian elm from 2015–2016 to 2023 across the same routes might be explained by mechanical and chemical treatments. Hop Valley continues to be a park priority for treatments annually due to grazing on private inholdings within Hop Valley. The decline of Scotch thistle across the same routes is likely due, at least in part, to control efforts. Consistent disturbances have allowed Scotch thistle and bull thistle (*Cirsium vulgare*) infestations to persist in other areas of the park.

In transects, cheatgrass was the most widespread invasive plant species, representing 50% of all invasive plant patches detected over the course of this third rotation. All cheatgrass patches were relatively low and had an average percent cover of 0.50%. Cheatgrass on the Western Routes had the highest percent cover (1.81%). After 2018 monitoring, staff at Zion NP began a pre-emergent treatment series using the herbicide Esplanade. Treatments began in late summer and early fall and continued throughout the winter. Nearly every fall and spring, on a rotational basis, staff apply the pre-emergent herbicide Rejuvra to exhaust annual *Bromus* sp. seed banks. Treatments occur every 2–3 years as needed. Areas treated with Rejuvra have seen an increase in Russian thistle patches. This may be due to ongoing disturbance from visitor use. Areas with less disturbance have shown less of an infestation with Russian thistle.

On average, trails had more priority IEP patches per kilometer than roads. Control efforts should continue in high-use, main-canyon areas that tend to have the most invasive plants. It should also be noted that overall IEP percent cover was very low, and many monitoring routes had either few or no priority invasive plants. Efforts should be made to keep these areas IEP-free. In 2015, the Kolob Terrace Road Rehabilitation Project occurred. This project included road widening, shoulder work, and repaving. This level of disturbance provides an opportunity for invasive species to invade and may contribute to the increase in infestations on the Upper Kolob Terrace Road. Saltlover (*Halogeton glomeratus*) has invaded the area post-disturbance and, although it has been treated multiple times, persists. There was a low number of priority invasive species found, and we recommend continued observation and efforts to eradicate IEPs from this area.

Estimates of percent cover in this report (see Table 5) are limited to the routes surveyed; actual percent cover of IEPs across the entire park cannot be inferred with these methods. Because we have

chosen to monitor along areas most likely to be invaded by a broad suite of IEPs, it is plausible that the percent cover for some IEP species is lower in the interior of the park than along the monitoring routes. However, it is also possible that some remote disturbed areas (e.g., burned areas) may have significant infestations of common weeds, such as cheatgrass.

During 2023 field monitoring, numerous non-priority exotic species were observed (Table 2). Some of these were occasionally recorded in the GPS unit (see Figures 3–24). Saltlover, Russian olive (*Elaeagnus angustifolia*), salt cedar (*Tamarisk* sp.), jointed goatgrass (*Aegilops cylindrica*), bells of Ireland (*Moluccella laevis*), and horehound (*Marrubium vulgare*) could be considered for addition to the priority IEP list for the next monitoring rotation. It will be important to consider the overall length of the priority IEP list, as well as the potential for control when adding species. We could also consider adding some species to transect monitoring only.

4.3 Future Monitoring Efforts

IEPs at Zion NP will generally be monitored at the same time each year. Consistency in the timing of monitoring should ensure consistent detection probabilities and cover estimates of most species. For many species, sampling at any time from May through September is not expected to significantly alter the chances of detecting invasive species at a level larger than the minimum detection target size.

In 2025, NCPN will return to Zion NP to finish the third rotation and start the fourth rotation of invasive plant monitoring. New monitoring transect locations are regenerated each year to maintain an unbiased sampling frame, due to park exotic control efforts. Long-term trend reporting will focus on trends in species distributions, percent cover of individual species, and changes in IEP percent cover of priority species by monitoring route.

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