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Natural Resource Stewardship and Science

Invasive Exotic Plant Monitoring at Dinosaur National Monument

Yampa River and the Echo Park and Mitten Park Extra Area, 2017 Field Season

Natural Resource Report NPS/NCPN/NRR—2018/1729



ON THE COVER

Musk thistle (*Carduus nutans*) along the Yampa River. NPS/Luke Gommermann

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Executive Summary

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 11 monitoring protocols to be implemented as part of its long-term monitoring program. During surveys conducted along 76 transects from June 29 to July 6, 2017, NCPN staff detected 11 priority IEP species and two non-priority species in a 92.1-hectare (228-acre) area along 76.0 kilometers of the Yampa River in Dinosaur National Monument. A total of 1,357 IEP patches were detected. Of those patches, 62.7% were smaller than 40 m^2 and 96.9% had a patch management index (PMI) of very low/low. Patch management index is a new tool that combines the size and density of an patch to assess its scale. Very low or low PMI indicates that chances for eradication of these patches is possible. Tamarisk (*Tamarix* sp.) and yellow sweetclover (*Melilotus officinalis*) were widespread. Musk thistle (*Carduus nutans*), Russian knapweed (*Centaurea repens*), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), and broadleaf pepperwort (*Lepidium latifolium*) were also common along the Yampa River. Whitetop (*Cardaria* sp.) and black henbane (*Hyocyamus niger*) were found in 2017 but not in the 2010 survey of the same area. From 2010 to 2017, there were general increases in yellow sweetclover, musk thistle, and Russian olive (*Elaeagnus angustifolia*), and a decrease in broadleaf pepperwort. The number of tamarisk and leafy spurge patches increased, but this was at least partially offset by a decrease in their size and PMI. Cheatgrass (*Bromus tectorum*) increased substantially in frequency and percent cover within transects along the Yampa River from 2010 to 2017. In the Echo Park and Mitten Park extra area along the Green River, nine IEP priority species were detected in a 31.1-hectare (77-acre) search. Tamarisk and broadleaf pepperwort were the most widespread IEPs in these areas. Musk thistle, Canada thistle, yellow sweetclover, bull thistle (*Cirsium vulgare*), and Russian knapweed were also common. Comparisons to previous monitoring efforts on the Green River will be completed when the entire Green River section below the confluence has been surveyed.

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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. 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, to the extent possible, tracks changes in the abundance and distribution of priority IEPs in parks along key invasive pathways.

Invasive exotic plants can spread into national parks via a number of different pathway types. 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."

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 may miss exotic plants dispersed to the interior areas of large parks by wind and/or animals.

This report summarizes data collected along the Yampa River and at Echo and Mitten parks along the Green River in Dinosaur National Monument during the summer of 2017.

Specific objectives of NCPN invasive exotic plant monitoring are:

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

2 Methods

Field work followed the invasive exotic plant monitoring protocol developed by Perkins and others (2016). 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).

We established a series of monitoring routes and transects for the Yampa River and conducted extra-area searches in Echo and Mitten parks. The transects, which are sampled in a quantitative manner, are used to make inference to the percent cover of IEPs located along the park's invasive pathways (i.e., the monitoring routes) and allow us to estimate trends in IEP percent cover over time. The monitoring routes, which are not quantitatively sampled, are used to increase the spatial coverage of mapping performed, with the goal of maximizing our opportunities for detecting IEPs in the park. Extra areas are used to cover areas of management concern that may be susceptible to invasive species invasions.

2.1 Developing a park priority IEP plant list

In 2010, NCPN and monument staff developed a list of priority IEPs for the park. The list was reviewed and updated for the 2011, 2014, and 2017 field seasons. The original list was developed by reviewing past park literature and state and county weed lists, and consulting with park staff and county weed managers. The priority IEP list (Table 2-1) includes 25 existing IEPs and potential IEPs of high management concern.

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

2.2 Monitoring routes and extra-area surveys

2.2.1 Minimum detection target size

The minimum detection target size (MDTS) represented the patch size that was 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 that 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 m^2 (0.01 acres, or approximately 20 × 20 ft) for all IEPs. Use of the MDTS was necessary because field technicians were not expected to find every single plant of every priority weed species during route surveys. Searching for single mature plants of some species, such as Russian olive (*Elaeagnus angustifolia*) and tamarisk (*Tamarix* sp.), is possible due to their large size, single plants of other species, such as puncture vine (*Tribulus terrestris*), are nearly impossible to detect in most field conditions.

2.2.2 Effective detection distance

The effective detection distance (EDD) was the maximum distance from which an observer could consistently detect (i.e., see and recognize) the MDTS of the least-visible priority species with at least 90% detection efficiency. Using fake plants of a targeted size, crew members were trained by walking away and determining the maximum distance from which they could consistently see and recognize the patch with complete confidence. The size of the EDD was then estimated in the field by crew members. The distance was measured either by pacing or using a laser rangefinder. The EDD in Dinosaur NM for 2017 was 2.5–10 meters, depending on vegetation density, topography, and mode of transport.

2.2.3 Effective detection swath width

Effective detection swath width (EDSW) was the maximum width of a linear search swath

Table 2-1. Priority IEP list for Dinosaur National Monument, 2017.

Scientific name (Utah)	Scientific name (Colorado)	Common name
Aegilops cylindrica[1]	*Cylindropyrum cylindricum*[1]	jointed goatgrass
Arctium minus	*Arctium minus*	burdock
Bromus tectorum[2]	*Anisantha tectorum*[2]	cheatgrass (transect only)
Cardaria sp.[3]	*Cardaria* sp.[3]	whitetop
Carduus nutans	*Carduus nutans*	musk thistle
Centaurea diffusa	*Acosta diffusa*	diffuse knapweed
Centaurea maculosa	*Acosta maculosa*	spotted knapweed
Centaurea repens	*Acroptilon repens*	Russian knapweed
Centaurea solstitialis[1]	*Leucantha solstitialis*[1]	yellow star-thistle
Cirsium arvense	*Breea arvensis*	Canada thistle
Cirsium vulgare	*Cirsium vulgare*	bull thistle
Cynoglossum officinale	*Cynoglossum officinale*	common houndstongue
Dipsacus sylvestris[1]	*Dipsacus fullonum*[1]	teasel
Elaeagnus angustifolia	*Elaeagnus angustifolia*	Russian olive
Euphorbia esula	*Tithymalus esula*	leafy spurge
Hyoscyamus niger	*Hyoscyamus niger*	black henbane
Lepidium latifolium	*Cardaria latifolia*	broadleaf pepperwort
Linaria dalmatica	*Linaria genistifolia* ssp. *dalmatica*	Dalmatian toadflax
Linaria vulgaris[1]	*Linaria vulgaris*[1]	butter-and-eggs
Lythrum salicaria	*Lythrum salicaria*	purple loosestrife
Melilotus officinalis	*Melilotus officinale*	yellow sweetclover
Onopordum acanthium	*Onopordum acanthium*	Scotch thistle
Taeniatherum caput-medusae	*Taeniatherum caput-medusae*	Medusahead
Tamarix sp.[4]	*Tamarix* sp.[4]	tamarisk
Tribulus terrestris	*Tribulus terrestris*	puncture vine

[1]Added in 2010–2011. All other IEPs have been on the priority list since 2003–2004.

[2]Transects only.

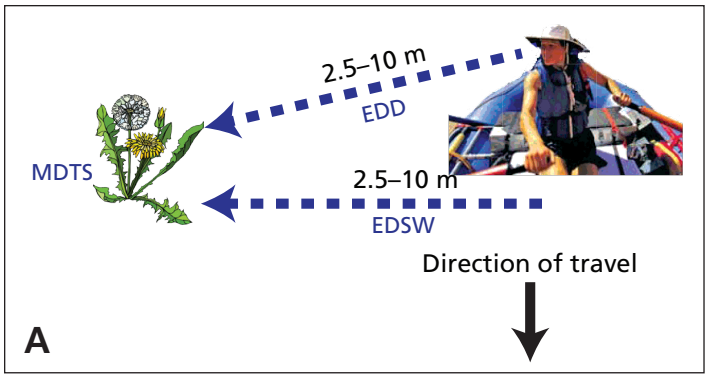
[3]Listed as *C. draba* in 2003–2004 and *C. chalepensis, C. draba,* and *C. pubescens* in 2010–2011.

[4]Listed as *T. ramosissima* in 2003–2004 and *T. chinensis* in 2010–2011.

(band transect) in which an observer was confident of visually detecting 90% of all priority species of the MDTS. For the monitoring routes along the Yampa River, the EDSW was equal to the EDD because the surveyor was on or near the river's edge and only looking to the right or left, but not both (Figure 2-1a). For the extra-area surveys and river sandbars, the EDSW was equal to two times the EDD because the surveyor was able to effectively detect weeds for one EDD on either side of his/her search route. In these locations, the EDSW for Dinosaur NM in 2017 was 5–20 meters (Figure 2-1b).

2.2.4 Patch separation resolution

We defined patch separation resolution (PSR) as the minimum distance between plants that must be considered members of separate patches. Individuals or clusters of a priority species separated by the PSR distance or more were recorded as separate patches. We considered plants separated by less than the PSR to be a single patch. The PSR was set at 50 meters, based on the assumption that most plants or groups of plants separated by less than 50 meters are typically considered to be one patch during planning and implementation of weed-control operations. If a patch was continuous for more than 50 meters, cover estimates were made every 50 meters to aid in developing an effective management strategy for the entire patch.



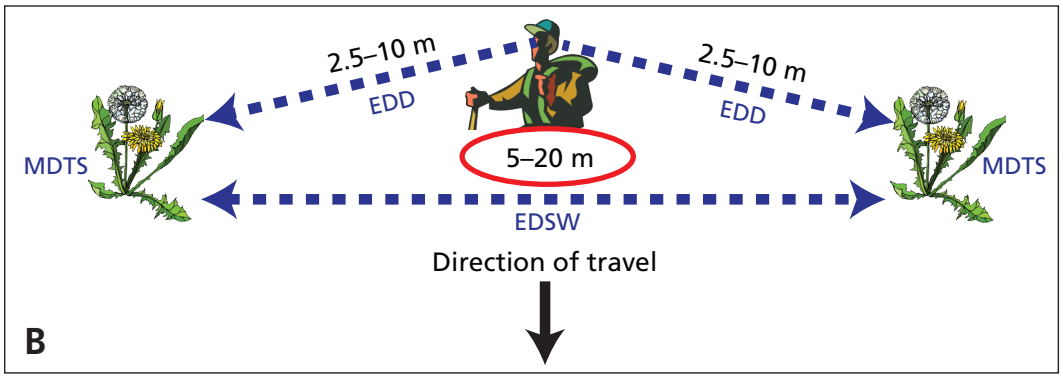


Figure 2-1. The maximum effective detection distance (EDD) at Dinosaur National Monument was 2.5–10 meters. For routes along the banks of the Yampa River (A), the effective detection swath width (EDSW) equaled the EDD. For all other routes, the EDSW was 5–20 meters (B).

2.2.5 Between-feature position

Between-feature positions (BFPs) allow electronic tracking of a user's route. A GPS unit was set to automatically generate these positions at a distance equal to the EDSW. Each time a surveyor traveled the equivalent of one EDSW, the GPS unit created a point.

2.2.6 Data collection methods

2.2.6.1 Echo Park and Mitten Park extra area

In the Echo Park and Mitten Park extra area, surveyors walked back and forth across the areas to monitor swaths that were analyzed similarly to—but separately from—monitoring routes. The BFP feature was used to determine where the last swath was. Distance between swaths approximately equaled the EDSW in order to effectively search the entire area. When an IEP was found, the surveyor stood in the center of the patch to enter the necessary data. As the extra area was traversed, locations of all priority species were documented using global positioning system (GPS) units with at least five-meter accuracy.

Only priority species were consistently recorded during monitoring routes. Survey crew members were permitted to record additional species if they were noteworthy. Because the purpose of the monitoring is to detect invasive plants rather than to control them, plants were generally not pulled unless they comprised an isolated population. When a priority IEP was discovered, we recorded the following information: (1) the monitoring route, (2) patch size class (see below), (3) whether the plant was pulled, (4) location, and (5) percent cover (see below). If several species were present with similar distributions at a single point, then we recorded a point for each individual species and assigned it its own sequential identification number. Invasions more than 50 meters (55 yards) apart were considered separate invasions and recorded with separate points.

Patch size class was estimated as follows:

1. 1–few (used for isolated single plants or very small patches (≤2 × 2 m)
2. few plants–40 m² (48 yd²)
3. 40–400 m² (48–478 yd²)
4. 400–1,000 m² (0.1–0.25 acre)
5. 1,000–2,000 m² (0.25–0.5 acre).

We recorded percent cover 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. Percent 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 (i.e., seedling, sapling, mature tree, old growth), evidence of prior treatment, and evidence of disturbances (e.g., recent fire, flood, small mammal disturbance).

During data analysis, we developed a patch management index (PMI) to quantify both the extent and the density of a patch into a single value that helps identify the scale of the problem. Park managers will be able to use this tool to help prioritize IEP treatment. PMI was determined using the following formula:

Patch size class (1–5) ×
Patch percent cover (1–5) =
Patch management index (1–25)

We then grouped the PMI into five classes:

1. Very low (1–5)
2. Low (6–10)
3. Moderate (11–-15)
4. High (16–20)
5. Very high (21–25)

Patches identified as very low or low PMI will generally be easier to control or remove than patches with a high or very high PMI. In many cases, directing resources toward controlling patches with very low or low PMI can be a highly effective management strategy; the goal of early detection is to allow managers to eliminate patches before they can grow into bigger problems. Other times, a species with many inventoried patches that are mostly very low or low in PMI may or may not be easier to treat (and possibly eradicate) than a different species that has few inventoried patches that are high or very high in PMI. Therefore, park managers should consider PMI within the context of information on species and patch numbers (see Chapter 4).

2.2.6.2 Yampa River monitoring routes

Methods used on the monitoring route were the same as for the extra area, except instead of covering an entire area, surveyors walked or searched from a raft, following linear routes on each side of the Yampa River. While traveling along the route, surveyors searched for IEPs by visually scanning the land within the width of the EDSW.

2.3 Monitoring transects

2.3.1 Quadrat establishment

We established one transect with three vegetation quadrats every kilometer along the monitoring route. We centered vegetation quadrats at 0.5, 5, and 10 meters away from the edge of the river on the side being monitored. A 1-m^2 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. Transects were done only on the Yampa River; not in the extra area.

2.3.2 Data collection methods

In the monitoring quadrats, observers recorded all priority IEP species observed, as well as cheatgrass (*Bromus tectorum*). 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, to the nearest 10%, of dominant soil 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 Analysis

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.

2.5 Comparisons to previous surveys

The Yampa River corridor in Dinosaur National Monument was surveyed by Utah State University in 2003–2004 (USU; Dewey and Anderson 2005), and by Dinosaur NM staff and others in 2010–2011 (Perkins 2012). Since 2003–2004, twenty priority (aka target) IEP species have been consistently monitored along the Yampa River (see Table 2-1). An additional four IEP species have been consistently monitored along the Yampa River since 2010–2011. Unless otherwise mentioned, comparisons are only made for priority species monitored consistently between the time periods of 2003–2004 to 2017. Nearly identical methods were used to record priority IEP patches along routes between 2003 and 2004, 2010 and 2011, and 2017 (with the exception of USU utilizing different patch area categories and a PSR of 50 yards in 2003–2004). Transects were completed using the same methods in 2010–2011 and 2017.

Comparisons to previous monitoring efforts on the Green River will be completed when the entire Green River section below the confluence is completed.

3 Results

3.1 Target invasive exotic plant list

From June 29 to July 6, 2017, field crews searched on monitoring routes for 24 IEP species identified as high priority at Dinosaur NM (see Table 2-1). Cheatgrass (*Bromus tectorum*) was only recorded in transects. Observers were trained to recognize priority species and given the freedom to map non-priority species. Therefore, presence and absence data for priority IEP species are reliable for the areas searched, but absence data for non-priority species are uncertain. Utah nomenclature will be used for scientific names in this report.

3.2 Monitoring routes

3.2.1 Yampa River

We surveyed a 92.1-hectare (228 acre) area along 76.0 kilometers of the Yampa River, detecting 11 priority IEP species and two non-priority species (Table 3-1 and Figures 3-1 to 3-4; figures begin on page 16).

A total of 1,357 patches were recorded (Table 3-2, Appendix A at https://irma.nps.gov/DataStore/Reference/Profile/2256018). Tamarisk (*Tamarix* sp.) and yellow sweetclover (*Melilotus officinalis*) were widespread. Broadleaf pepperwort (*Lepidium latifolium*), Russian knapweed (*Centaurea repens*), leafy spurge (*Euphorbia esula*), musk thistle (*Carduus nutans*), and Canada thistle (*Cirsium arvense*) were also common. The majority of patches (62.7%) were less than 40 m² in size, 27.6% were between 40–400 m², and 9.7% were over 400 m² (Table 3-2). Of the 711 tamarisk patches recorded, 59.5% were less than 40 m², 29.4% were between 40–400 m², and 11.1% were over 400 m².

PMI for most patches (96.9%) was very low or low (Table 3-2). Four whitetop (*Cardaria* sp.) patches (very low/low) and one black henbane (*Hyocyamus niger*) patch (very low) were found in 2017. These species were not detected in 2010–2011, though they were on the IEP priority search list. A total of 10 Russian olive (*Elaeagnus angustifolia*) patches with very low/low PMI were recorded. The majority (63.9%) of tamarisk patches had very low PMI. The rest were rated low (33.5%), medium (2.5%), and high (0.1%) (Table 3-3). Growth stage was recorded for 698 of 711 tamarisk patches: 21.2% were classified as seedlings, 64.1% as saplings, and 12.8% as mature trees (Table 3-3).

Table 3-1. Invasive exotic plants detected along routes and transects, Dinosaur National Monument, June 29–July 6, 2017.

Scientific name	Common name	Routes	Transects	Priority?	
				Yes	No
Bromus tectorum	cheatgrass	NA	X	X*	–
Cardaria sp.	whitetop	X	–	X	–
Carduus nutans	musk thistle	X	–	X	–
Centaurea repens	Russian knapweed	X	X	X	–
Cirsium arvense	Canada thistle	X	X	X	–
Cirsium vulgare	bull thistle	X	–	X	–
Elaeagnus angustifolia	Russian olive	X	–	X	–
Euphorbia esula	leafy spurge	X	–	X	–
Hyoscyamus niger	black henbane	X	–	X	–
Lepidium latifolium	broadleaf pepperwort	X	–	X	–
Melilotus officinalis	yellow sweetclover	X	X	X	–
Tamarix sp.	tamarisk	X	X	X	–
**Ulmus pumila*	*Siberian elm	X	–	–	X
**Verbascum thapsus*	*woolly mullein	X	–	–	X

*Transects only

Table 3-2. Number of patches by species, patch size class, and patch management index detected along Yampa River monitoring routes, Dinosaur National Monument, June 29–July 6, 2017.

Scientific name	Common name	Total patches	Patch size class[1]					Patch management index[2]				
			1	2	3	4	5	Very low	Low	Medium	High	Very high
Cardaria sp.	whitetop	4	1	3	0	0	0	3	1	0	0	0
Carduus nutans	musk thistle	27	4	15	6	1	1	18	9	0	0	0
Centaurea repens	Russian knapweed	81	10	39	19	8	5	29	40	9	3	0
Cirsium arvense	Canada thistle	24	3	7	7	5	2	9	11	4	0	0
Cirsium vulgare	bull thistle	2	1	1	0	0	0	2	0	0	0	0
Elaeagnus angustifolia	Russian olive	10	8	2	0	0	0	9	1	0	0	0
Euphorbia esula	leafy spurge	56	25	31	0	0	0	50	6	0	0	0
Hyoscyamus niger	black henbane	1	1	0	0	0	0	1	0	0	0	0
Lepidium latifolium	broadleaf pepperwort	90	16	48	16	7	3	75	15	0	0	0
Melilotus officinalis	yellow sweetclover	348	15	195	118	12	8	242	99	5	2	0
Tamarix sp.	tamarisk	711	121	302	209	51	28	454	238	18	1	0
**Ulmus pumila*	*Siberian elm	2	2	0	0	0	0	2	0	0	0	0
**Verbascum thapsus*	*woolly mullein	1	0	1	0	0	0	1	0	0	0	0
Total		**1,357**	**207**	**644**	**375**	**84**	**47**	**895**	**420**	**36**	**6**	**0**

*Not a priority species

[1]Patch size classes: 1 = 1–a few plants (≤2 × 2 m), 2 = few plants–40 m^2 (48 yd^2), 3 = 40–400 m^2 (48–478 yd^2), 4 = 400–1,000 m^2 (0.1–0.25 acre), 5 = 1,000–2,000 m^2 (0.25–0.5 acre).

[2]PMI classes: Very low (1–5), Low (6–10), Medium (11–15), High (16–20), Very high (21–25). PMI = Patch size class (1–5) × Patch percent cover (1–5).

Table 3-3. Growth stage for woody IEP species patches recorded on Yampa River monitoring routes, Dinosaur National Monument, June 29–July 6, 2017.

Scientific name	Common name	Total patches	Growth stage		
			Seedling	Sapling	Mature
Tamarix sp.	tamarisk	698	151	456	91
Elaeagnus angustifolia	Russian olive	10	3	7	0
**Ulmus pumila*	*Siberian elm	2	1	1	0

*Not a priority species.

3.2.2 Echo Park and Mitten Park extra area

We recorded 232 patches of 9 priority IEP species over a search area of 27.7 hectares (68.6 acres) in the Echo Park and Mitten Park extra area (Table 3-4, Figure 3-5). Tamarisk and broadleaf pepperwort were widespread. Musk thistle, Canada thistle, yellow sweetclover, bull thistle (*Cirsium vulgare*), and Russian knapweed were common. Patch size classes were somewhat evenly distributed, with 36.6% of patches less than 40 m², 33.2% between 40 and 400 m², and 30.2% over 400 m² (Table 3-4). PMI was very low or low for 83.2% of patches, and medium or high for the remaining 16.8% (Table 3-4). Of the 87 tamarisk patches recorded, three were in the seedling stage, 38 were in the sapling stage, and 46 were in the mature tree stage. Growth stage was not recorded for two patches (Table 3-5).

3.3 Monitoring transects

In 2017, a total of 76 transects were completed along the Yampa River (38 on river left and 38 on river right) (Appendix B at https://irma.nps.gov/DataStore/Reference/Profile/2256018). Five IEP priority species were recorded in transects (Table 3-6). Cheatgrass was the most widespread IEP priority species, found in 53.9% of transects. Tamarisk was found in 6.6% of transects, and yellow sweetclover in 5.3% in 2017. The average percent cover across all transects was less than 1% for all IEP species. Cheatgrass had the highest average percent cover, at 0.35%.

3.4 Results comparisons

Note: Comparisons to previous monitoring efforts on the Green River will be completed when the entire Green River section below the confluence is completed.

3.4.1 Monitoring routes: Number of patches

A total of 151.9 kilometers of the Yampa River through Dinosaur National Monument has been consistently monitored across three survey periods (2003–2004, 2010–2011, and 2017) (Figure 3-6). From the IEP priority lists, 13 species were found during one or more surveys (Table 3-7). The most common species (with at least 60 patches observed during each survey) included Russian knapweed, broadleaf pepperwort, yellow sweetclover, and tamarisk.

The number of tamarisk patches has increased over the three surveys. Leafy spurge and Russian olive have increased in number of patches each survey year. Musk thistle increased in 2017 relative to past surveys. Broadleaf pepperwort patches have decreased in each survey. Burdock (*Arctium minus*) and Dalmatian toadflax (*Linaria dalmatica*) were only found infrequently during the 2003–2004 surveys, and not in 2010–2011 or 2017. Whitetop was found infrequently in 2003–2004 and 2017. Black henbane was only documented in 2017.

3.4.2 Monitoring routes: Patch size and patch management index

Comparison of patch size and PMI are not comparable between 2003–2004 and later surveys due to differing patch size classes.

Eleven IEP species common to the 2010–2011 and 2017 priority list were detected during at least one survey (Table 3-8). Across all species, the number of patches increased from 1,109 in 2010–2011 to 1,354 in 2017. In particular, the number and proportion of patches in size classes 2 and 5 (see Section 2.2.6.1) increased from 2010–2011 to 2017. Over the same period, the number and proportion of very low PMI patches increased, while all other categories decreased.

The distribution of patch sizes and patch management indices of the four most commonly observed species are shown in figures 3-7 and 3-8 and summarized in Table 3-8 and below.

- From 2010–2011 to 2017, the number of broadleaf pepperwort patches decreased across all but the smallest patch size. Patches decreased in each PMI class.
- For Russian knapweed, the number of smaller-sized patches of very low or medium PMI increased from 2010–2011 to 2017. The number of larger-sized patches of high and very high decreased

in that time.

- Yellow sweetclover increased across most size and PMI classes.
- Tamarisk patches over 400 m^2 decreased from 113 to 79, while the number of patches between 4 and 40 m^2 increased from 91 in 2010–2011 to 302 in 2017. The number of tamarisk patches with medium–very high PMI decreased from 67 in 2010–2011 to 19 in 2017.

Patterns were also evident in less-frequently observed species:

- Though the total number of leafy spurge patches increased, the percentage of leafy spurge patches in the smallest size class increased from 25.7% to 44.6%.
- Over the same time period, the percent of musk thistle patches in the smallest class size decreased from 60% to 14.8%, while the three largest size classes (40–400 m^2, 400–1,000 m^2, and 1,000–2,000 m^2) increased from 0% to 22%, 3.7%, and 3.7%, respectively. PMI for musk thistle remained low/very low across all patches.
- There was an increase in small, isolated patches (mostly 1– few plants) of Russian olive.

3.4.3 Monitoring transects

In both 2010 and 2017, cheatgrass, yellow sweetclover, and tamarisk were detected (see Table 3-6). Cheatgrass was substantially more frequent in 2017 (53.9% of transects) than in 2010 (1.3% of transects). The average percent cover of cheatgrass also increased. Tamarisk presence in transects was similar between 2010 (7.5% of transects) and 2017 (6.6% of transects). The average percent cover of tamarisk decreased from 0.57% in 2010 to 0.08% in 2017. Russian knapweed and Canada thistle were each found in one transect in 2017 but were not found in transects in 2010.

Table 3-4. Number of patches by species, patch size class, and patch management index detected in Echo Park and Mitten Park extra area, Dinosaur National Monument, June 29–July 6, 2017.

Scientific name	Common name	Total patches	Patch size class[1]					Patch management index[2]				
			1	2	3	4	5	Very low	Low	Medium	High	Very high
Cardaria sp.	whitetop	1	0	0	0	0	1	1	0	0	0	0
Carduus nutans	musk thistle	37	5	9	3	5	15	27	6	4	0	0
Centaurea repens	Russian knapweed	5	0	3	1	0	1	2	3	0	0	0
Cirsium arvense	Canada thistle	16	0	10	5	1	0	8	6	2	0	0
Cirsium vulgare	bull thistle	9	4	3	2	0	0	6	3	0	0	0
Euphorbia esula	leafy spurge	1	1	0	0	0	0	1	0	0	0	0
Lepidium latifolium	broadleaf pepperwort	64	4	16	17	8	19	30	27	7	0	0
Melilotus officinalis	yellow sweetclover	10	3	5	2	0	0	10	0	0	0	0
Tamarix sp.	tamarisk	89	7	15	47	16	4	19	44	18	8	0
Total		**232**	**24**	**61**	**77**	**30**	**40**	**104**	**89**	**31**	**8**	**0**

[1]Patch size classes: 1 = 1–a few plants (≤2 × 2 m), 2 = few plants–40 m^2 (48 yd^2), 3 = 40–400 m^2 (48–478 yd^2), 4 = 400–1,000 m^2 (0.1–0.25 acre), 5 = 1,000–2,000 m^2 (0.25–0.5 acre).

[2]PMI classes: Very low (1–5), Low (6–10), Medium (11–15), High (16–20), Very high (21–25). PMI = Patch size class (1–5) × Patch percent cover (1–5).

Table 3-5. Growth stage for woody IEP species patches recorded for Echo Park and Mitten Park extra area, Dinosaur National Monument, June 29–July 6, 2017.

Scientific name	Common name	Total patches	Growth stage		
			Seedling	Sapling	Mature
Tamarix sp.	tamarisk	87	3	38	46

Table 3-6. Priority IEP species observed in transects on the Yampa River and average percent cover across all transects, Dinosaur National Monument, 2010 and 2017.

Scientific name (Common name)	Year (# of transects)	% transects present	Avg. % cover (SE)
Bromus tectorum (cheatgrass)	2010 (80)	1.3%	0.04% (0.04)
	2017 (76)	53.9%	0.35% (0.10)
Centaurea repens (Russian knapweed)	2010 (80)	0.0%	0%
	2017 (76)	1.3%	0.02% (0.02)
Cirsium arvense (Canada thistle)	2010 (80)	0.0%	0%
	2017 (76)	1.3%	0.01% (0.01)
Melilotus officinalis (yellow sweetclover)	2010 (80)	2.5%	0.02% (0.02)
	2017 (76)	5.3%	0.16% (0.10)
Tamarix sp. (tamarisk)	2010 (80)	7.5%	0.57% (0.31)
	2017 (76)	6.6%	0.08% (0.05)

Survey dates: July 5–24, 2010; June 29–July 6, 2017.

Table 3-7. Number of patches of IEP priority species patches detected along the Yampa River, Dinosaur National Monument, 2003–2004, 2010–2011, and 2017.

Scientific name	Common name	2003–2004	2010–2011	2017
Arctium minus	burdock	4	0	0
**Cardaria* sp.	whitetop	7	0	4
Carduus nutans	musk thistle	6	5	27
Centaurea repens	Russian knapweed	68	62	81
Cirsium arvense	Canada thistle	25	44	24
Cirsium vulgare	bull thistle	2	5	2
Elaeagnus angustifolia	Russian olive	4	6	10
Euphorbia esula	leafy spurge	12	35	56
Hyocyamus niger	black henbane	0	0	1
Lepidium latifolium	broadleaf pepperwort	216	183	90
Linaria dalmatica	Dalmatian toadflax	1	0	0
Melilotus officinalis	yellow sweetclover	83	261	348
Tamarix sp.	tamarisk	407	508	711

*Recorded as *C. draba* prior to 2010.

Survey dates: August 13, 18, 19, 2003 and June 3–9, 2004; July 18–25, 2010 and July 25, 2011; June 29–July 6, 2017.

Table 3-8. Total number and percentage of IEP patches by species, patch size class, and patch management index along Yampa River monitoring routes, Dinosaur National Monument, 2010–2011 and 2017.

Scientific name (Common name)	Year	Total patches	Patch size class (%)					Patch management index (%)				
			1	2	3	4	5	Very low	Low	Medium	High	Very high
Cardaria sp. (whitetop)	2010	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2017	4	1 (25.0)	3 (75.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (75.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)
Carduus nutans (musk thistle)	2010	5	3 (60.0)	2 (40.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (60.0)	2 (40.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2017	27	4 (14.8)	15 (55.5)	6 (22.2)	1 (3.7)	1 (3.7)	18 (66.7)	9 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)
Centaurea repens (Russian knapweed)	2010	62	2 (3.2)	19 (30.6)	18 (29.0)	21 (33.9)	2 (3.2)	7 (11.3)	24 (38.7)	18 (29.0)	12 (19.4)	1 (1.6)
	2017	81	10 (12.3)	39 (48.1)	19 (23.4)	8 (9.9)	5 (6.1)	29 (35.8)	40 (49.4)	9 (11.1)	3 (3.7)	0 (0.0)
Cirsium arvense (Canada thistle)	2010	44	5 (11.3)	15 (34.1)	21 (47.7)	3 (6.8)	0 (0.0)	11 (25.0)	24 (54.5)	8 (18.2)	1 (2.3)	0 (0.0)
	2017	24	3 (12.5)	7 (29.2)	7 (29.2)	5 (20.8)	2 (8.3)	9 (37.5)	11 (45.8)	4 (16.7)	0 (0.0)	0 (0.0)
Cirsium vulgare (bull thistle)	2010	5	1 (20.0)	4 (80.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (40.0)	3 (60.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2017	2	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Elaeagnus angustifolia (Russian olive)	2010	6	5 (83.3)	0 (0.0)	1 (16.7)	0 (0.0)	0 (0.0)	5 (83.3)	0 (0.0)	1 (16.7)	0 (0.0)	0 (0.0)
	2017	10	8 (80.0)	2 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	9 (90.0)	1 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)
Euphorbia esula (leafy spurge)	2010	35	9 (25.7)	22 (62.9)	4 (11.4)	0 (0.0)	0 (0.0)	25 (71.4)	10 (28.6)	0 (0.0)	0 (0.0)	0 (0.0)
	2017	56	25 (44.6)	31 (55.4)	0 (0.0)	0 (0.0)	0 (0.0)	50 (89.3)	6 (10.7)	0 (0.0)	0 (0.0)	0 (0.0)
Hyoscyamus niger (black henbane)	2010	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2017	1	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Lepidium latifolium (broadleaf pepperwort)	2010	183	13 (7.1)	66 (36.1)	69 (37.7)	35 (19.1)	0 (0.0)	121 (66.1)	58 (31.7)	4 (2.2)	0 (0.0)	0 (0.0)
	2017	90	16 (17.8)	48 (53.3)	16 (17.8)	7 (7.8)	3 (3.3)	75 (83.3)	15 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)
Melilotus officinalis (yellow sweetclover)	2010	261	29 (11.1)	100 (38.3)	106 (40.6)	24 (9.2)	2 (0.8)	163 (62.5)	90 (34.5)	7 (2.7)	1 (0.4)	0 (0.0)
	2017	348	15 (4.3)	195 (56.0)	118 (33.9)	12 (3.4)	8 (2.2)	242 (69.5)	99 (28.4)	5 (1.4)	2 (0.6)	0 (0.0)
Tamarix sp. (tamarisk)	2010	508	133 (26.2)	91 (17.9)	171 (33.7)	105 (20.7)	8 (1.6)	218 (42.9)	223 (43.9)	51 (10.0)	15 (3.0)	1 (2.0)
	2017	711	121 (17.0)	302 (42.5)	209 (29.4)	51 (7.2)	28 (3.9)	454 (63.9)	238 (33.5)	18 (2.5)	1 (0.1)	0 (0.0)
2010 totals		**1,109**	**200 (18.0)**	**319 (28.8)**	**390 (35.2)**	**188 (17.0)**	**12 (1.1)**	**555 (50.0)**	**434 (39.1)**	**89 (8.0)**	**29 (2.6)**	**2 (0.2)**
2017 totals		**1,354**	**205 (15.1)**	**643 (47.5)**	**375 (27.7)**	**84 (6.2)**	**47 (3.5)**	**892 (65.9)**	**420 (31.0)**	**36 (2.7)**	**6 (0.4)**	**0 (0.0)**

[1]Patch size classes: 1 = 1–a few plants (≤2 × 2 m), 2 = few plants–40 m^2 (48 yd^2), 3 = 40–400 m^2 (48–478 yd^2), 4 = 400–1,000 m^2 (0.1–0.25 acre), 5 = 1,000–2,000 m^2 (0.25–0.5 acre).

[2]PMI classes: Very low (1–5), Low (6–10), Medium (11–15), High (16–20), Very high (21–25). PMI = Patch size class (1–5) × Patch percent cover (1–5).

Survey dates: July 18–25, 2010 and July 25, 2011; June 29–July 6, 2017.

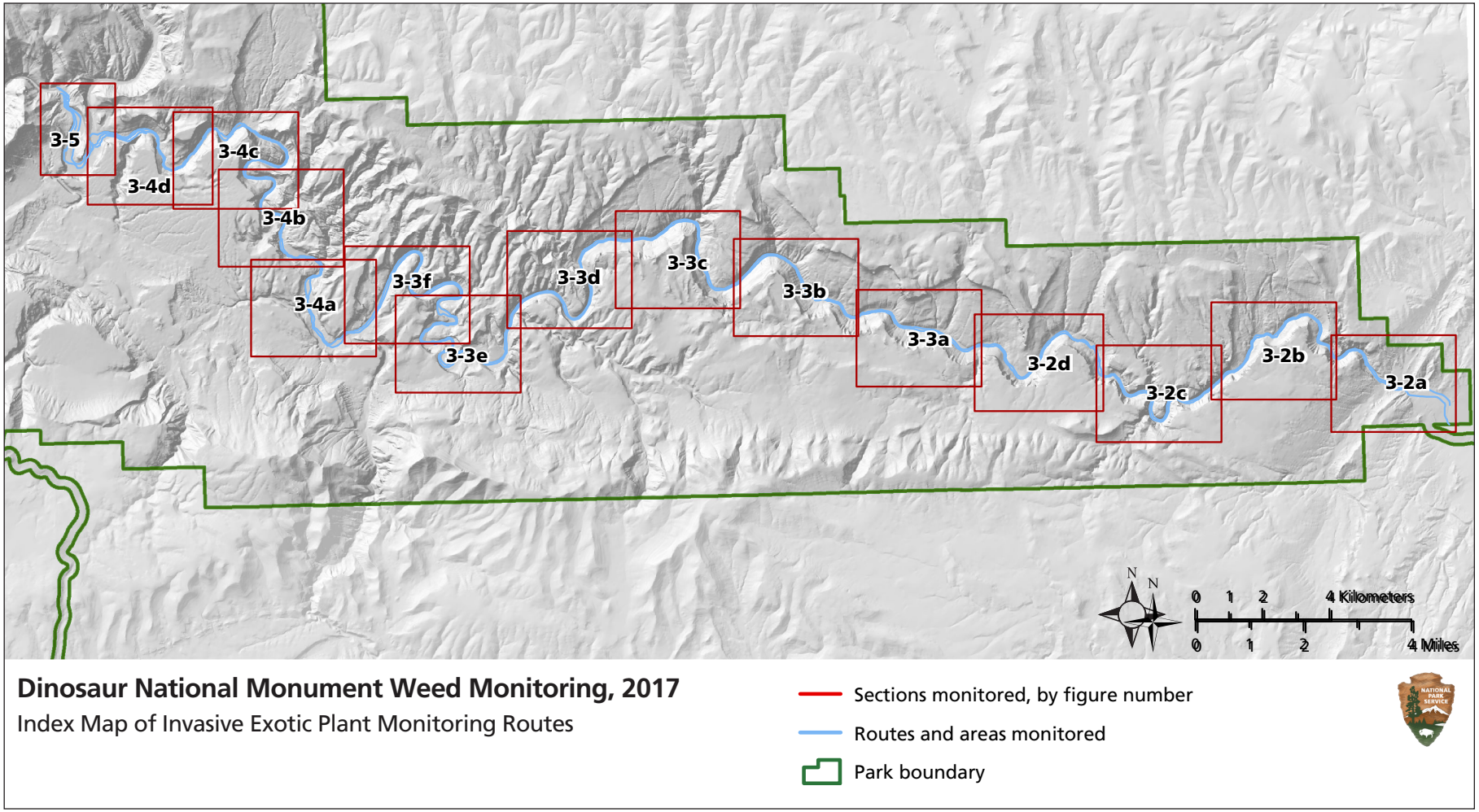


Figure 3-1. Index map for invasive plant monitoring, Dinosaur National Monument, June 29–July 6, 2017.

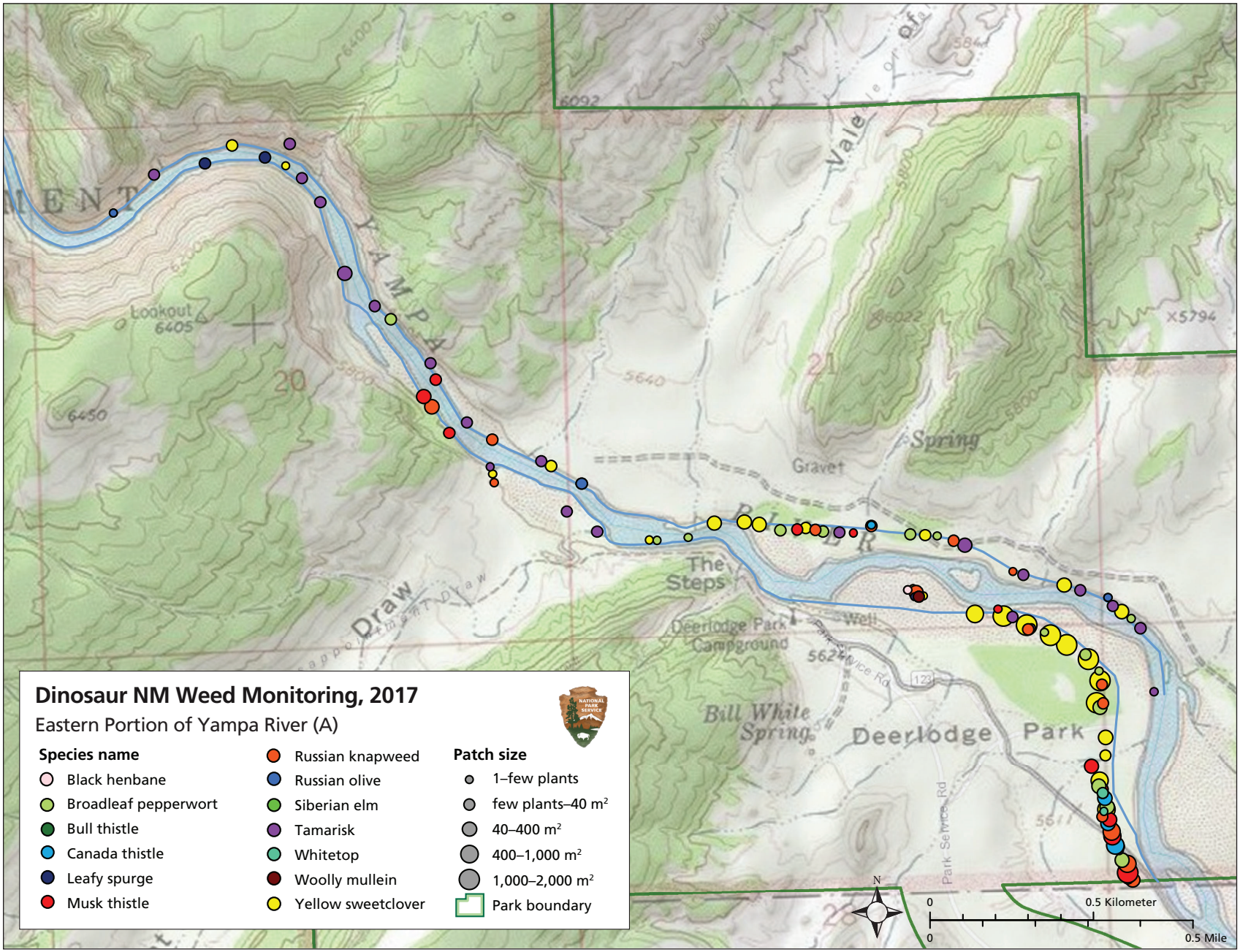


Figure 3-2a. Invasive plant patches detected along the eastern portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

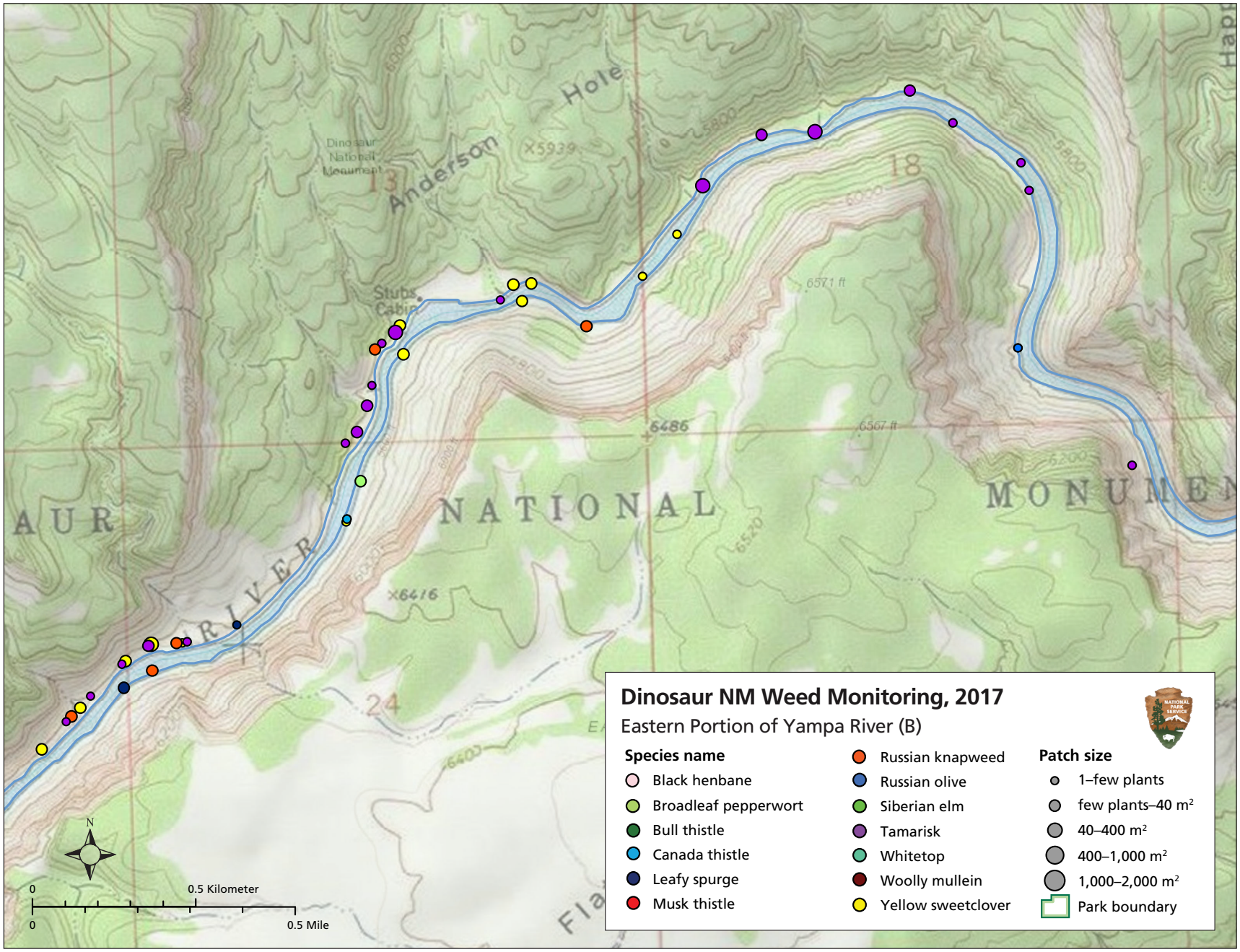


Figure 3-2b. Invasive plant patches detected along the eastern portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

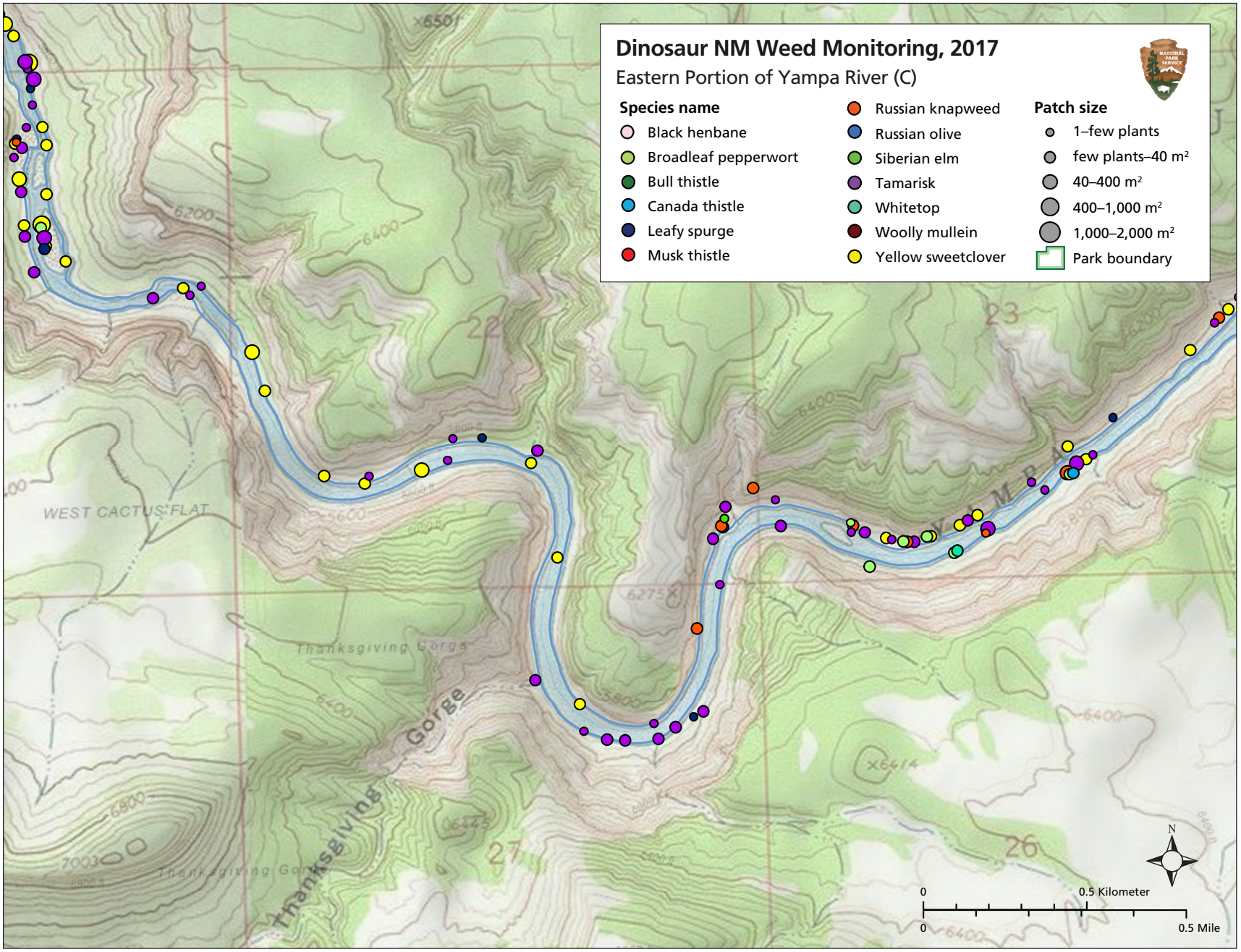


Figure 3-2c. Invasive plant patches detected along the eastern portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

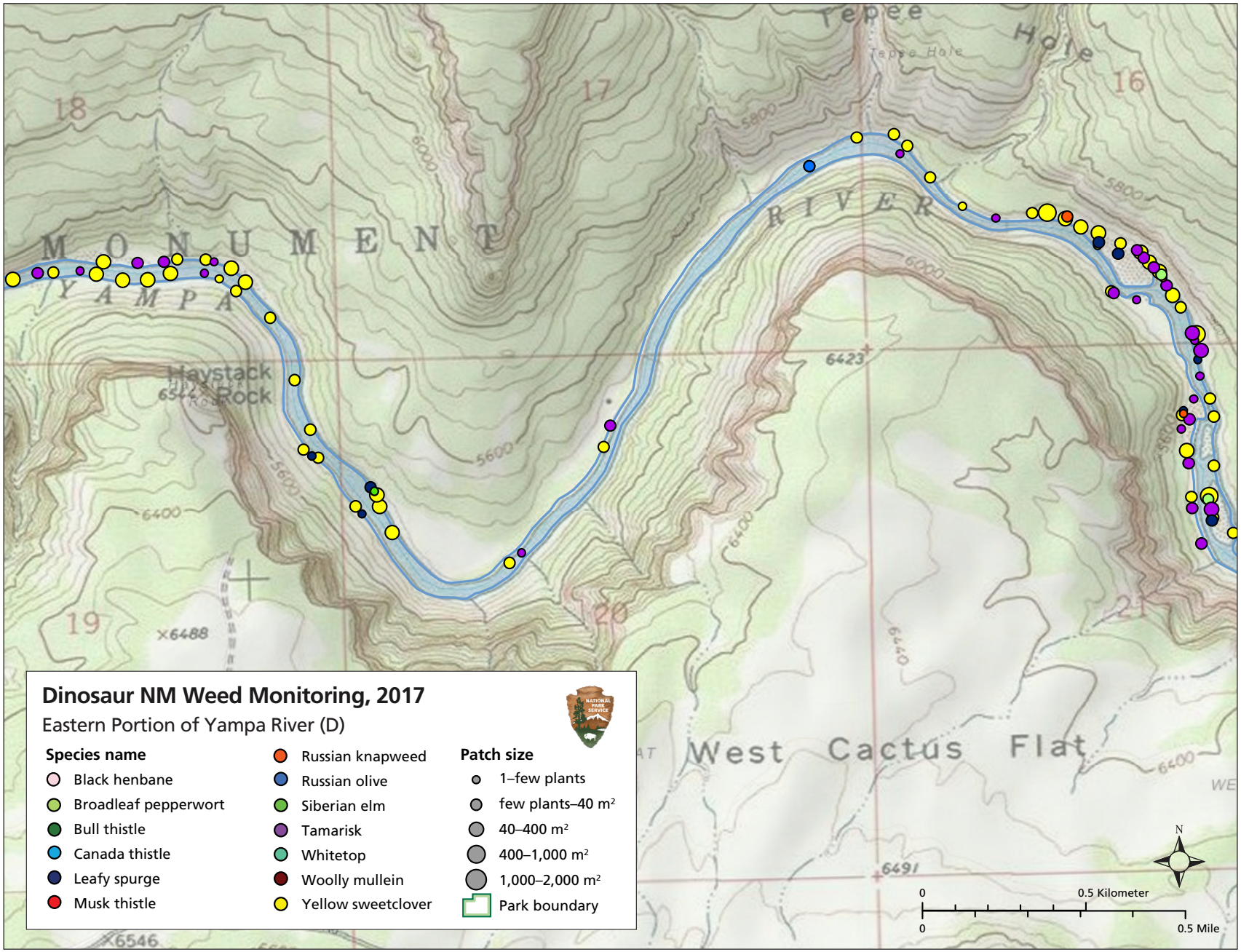


Figure 3-2d. Invasive plant patches detected along the eastern portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

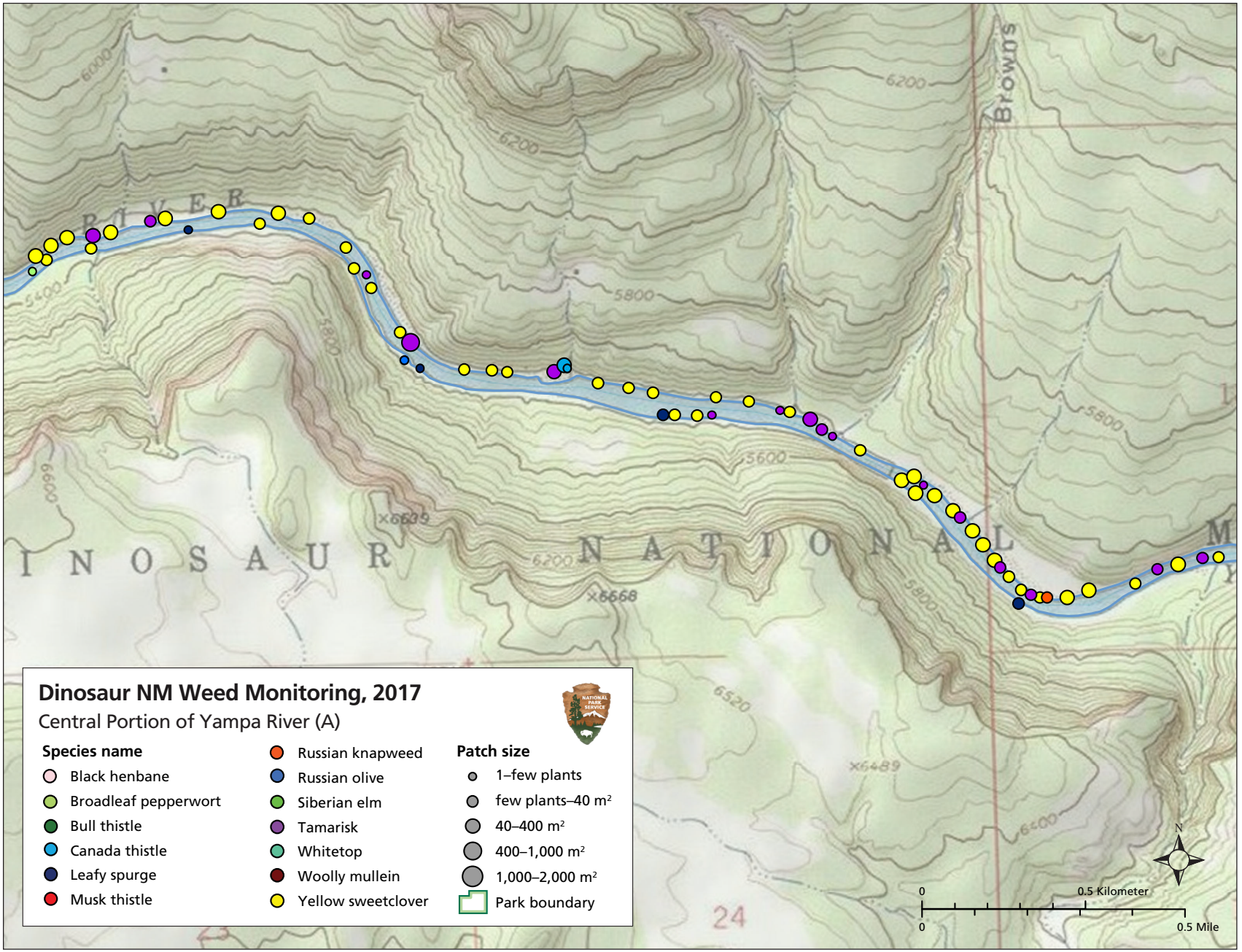


Figure 3-3a. Invasive plant patches detected along the eastern portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

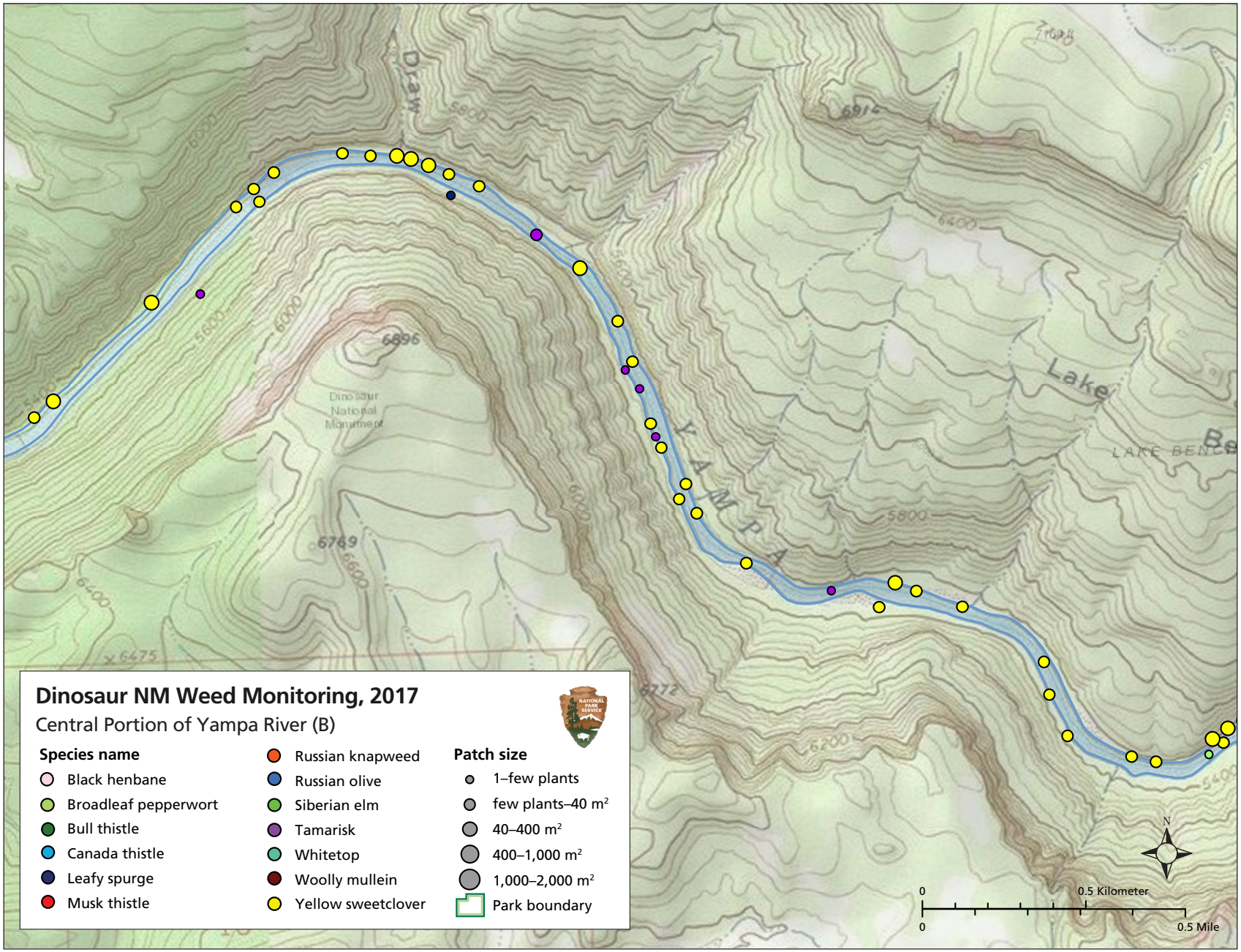


Figure 3-3b. Invasive plant patches detected along the central portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

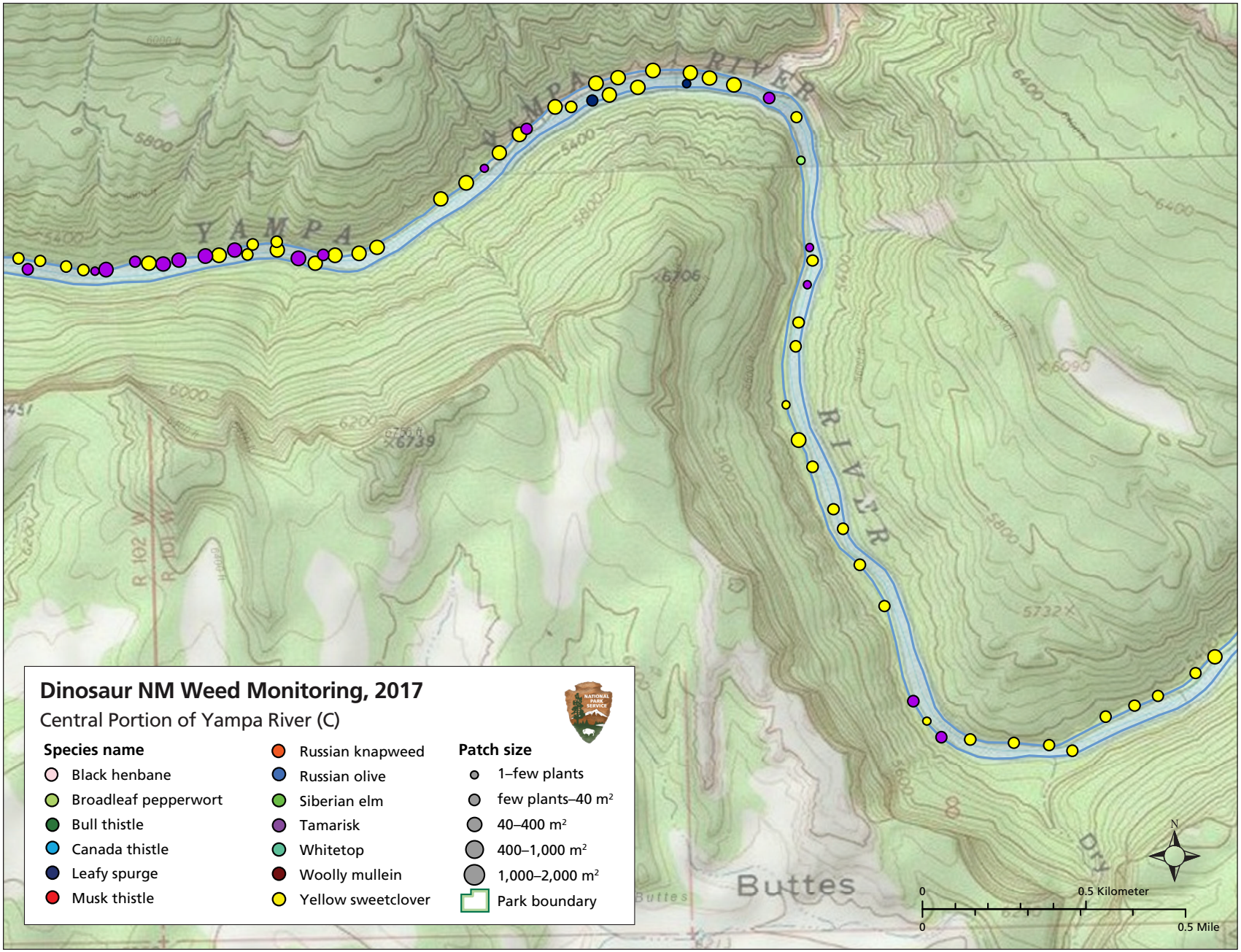


Figure 3-3c. Invasive plant patches detected along the central portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

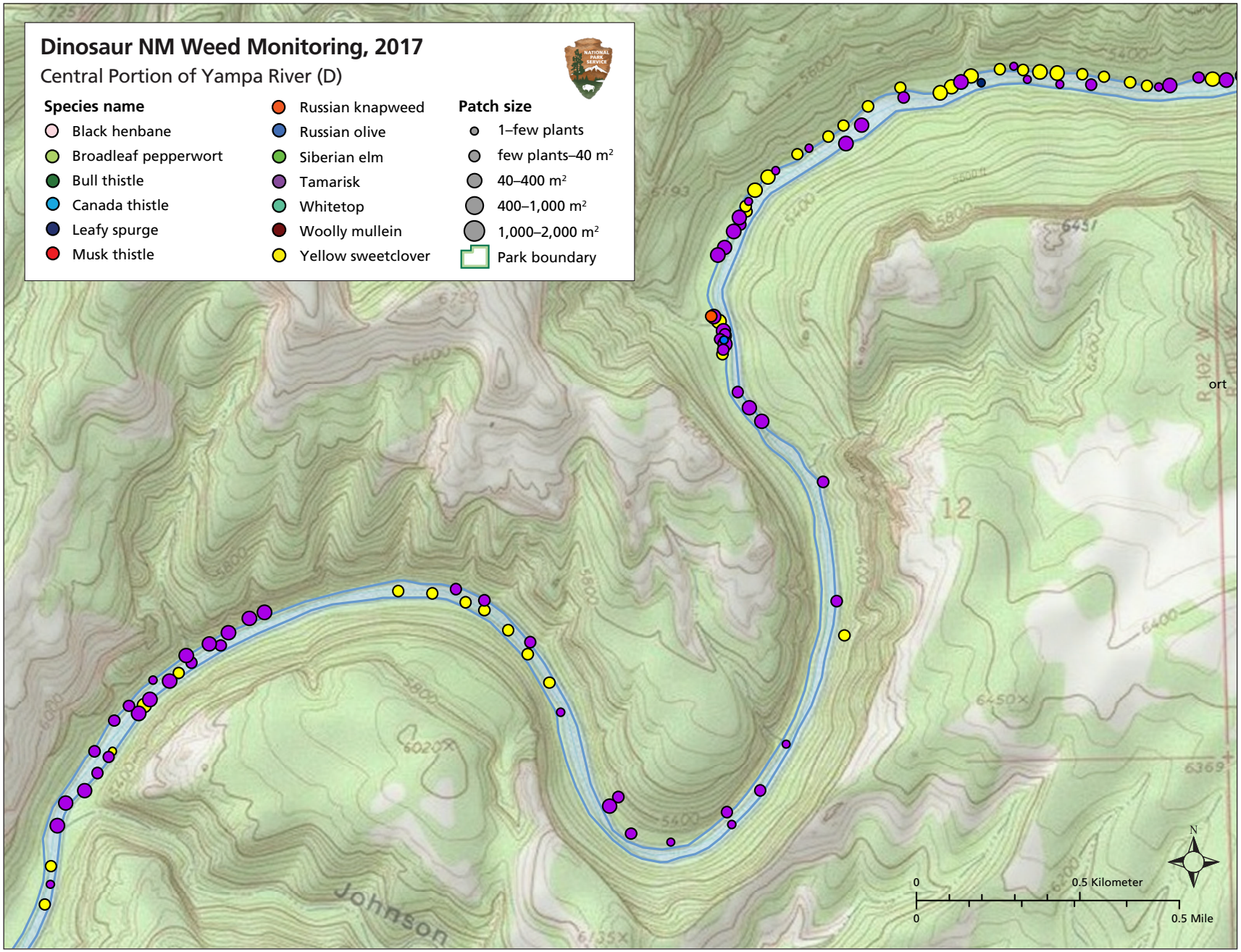


Figure 3-3d. Invasive plant patches detected along the central portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

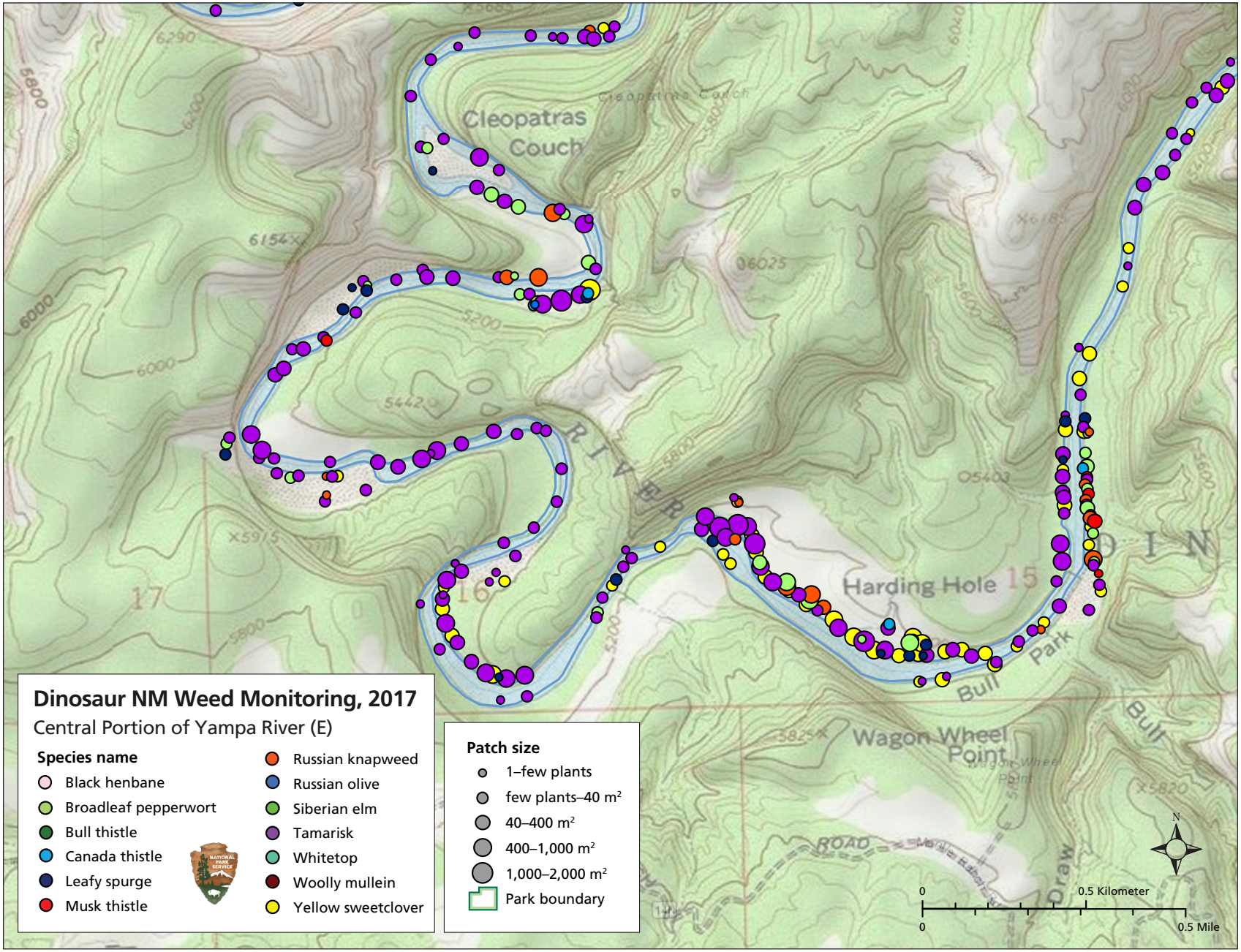


Figure 3-3e. Invasive plant patches detected along the central portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

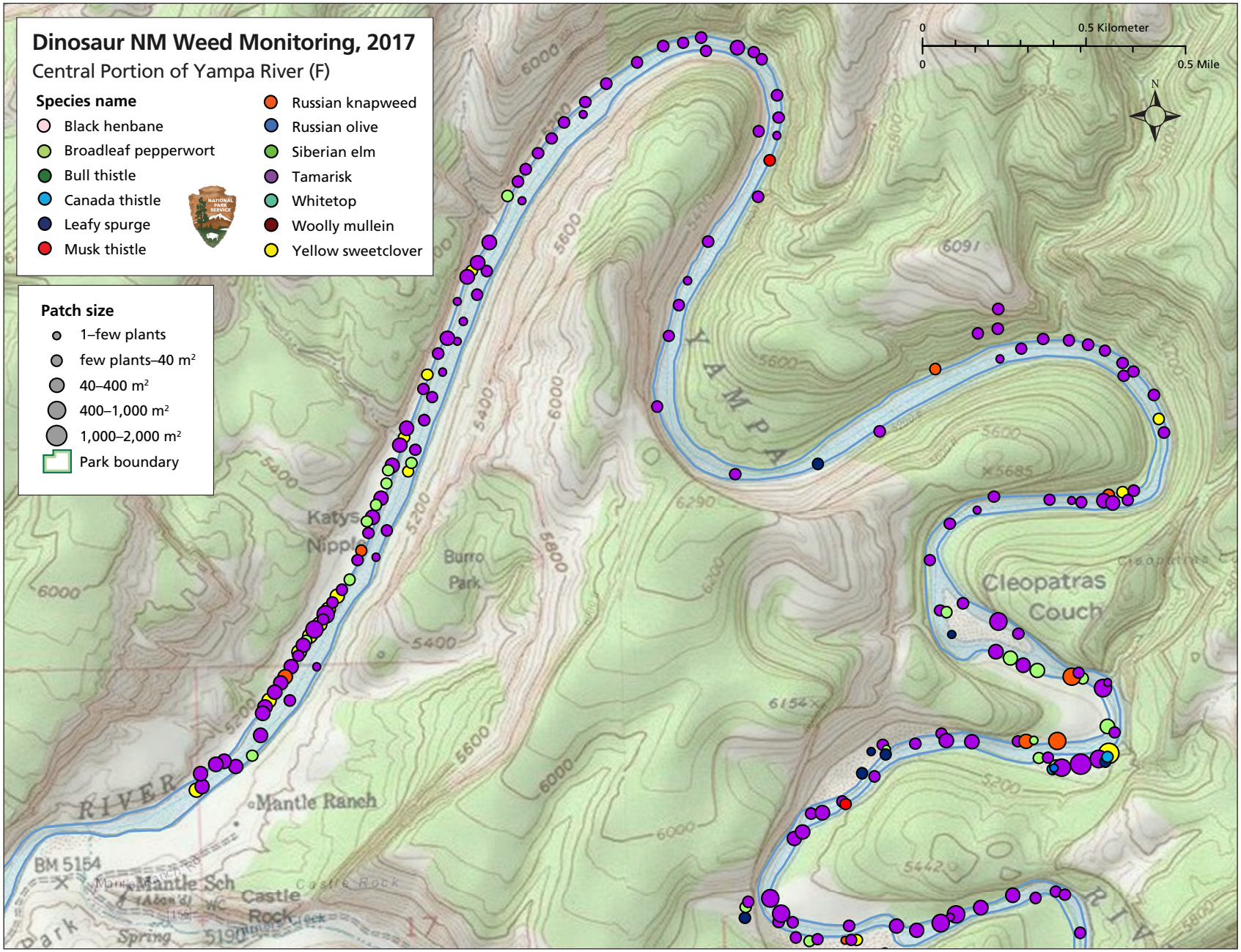


Figure 3-3f. Invasive plant patches detected along the central portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

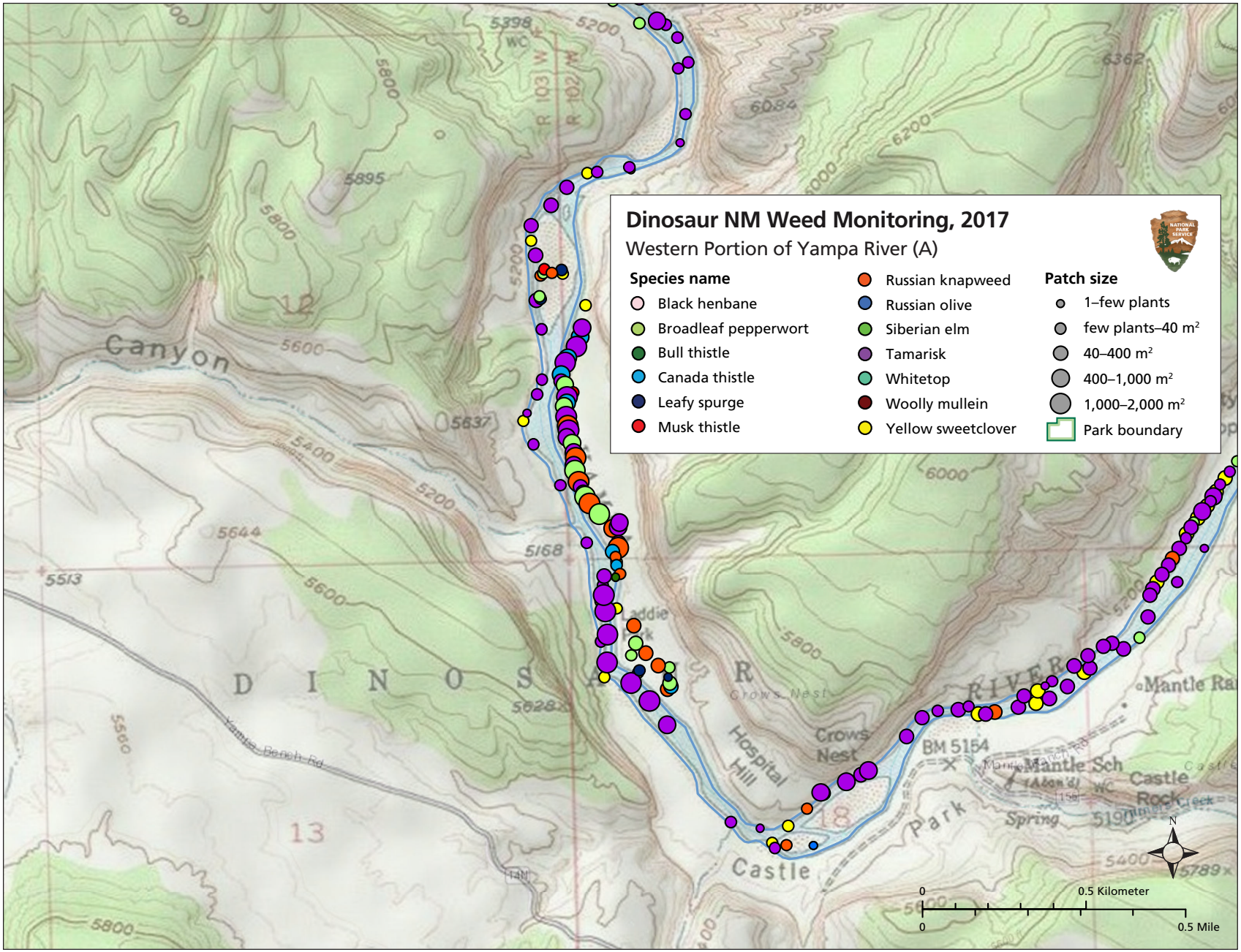


Figure 3-4a. Invasive plant patches detected along the western portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

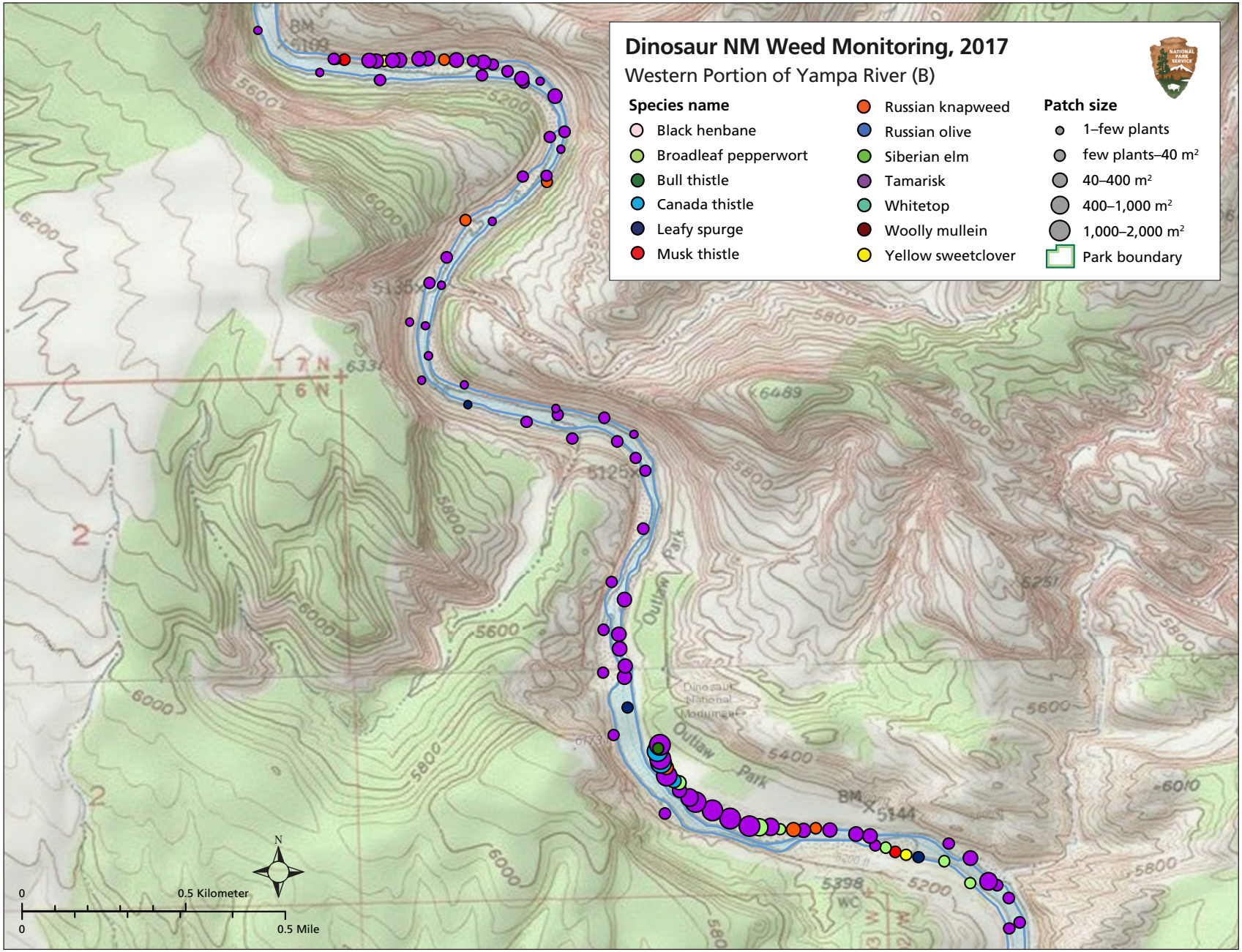


Figure 3-4b. Invasive plant patches detected along the western portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

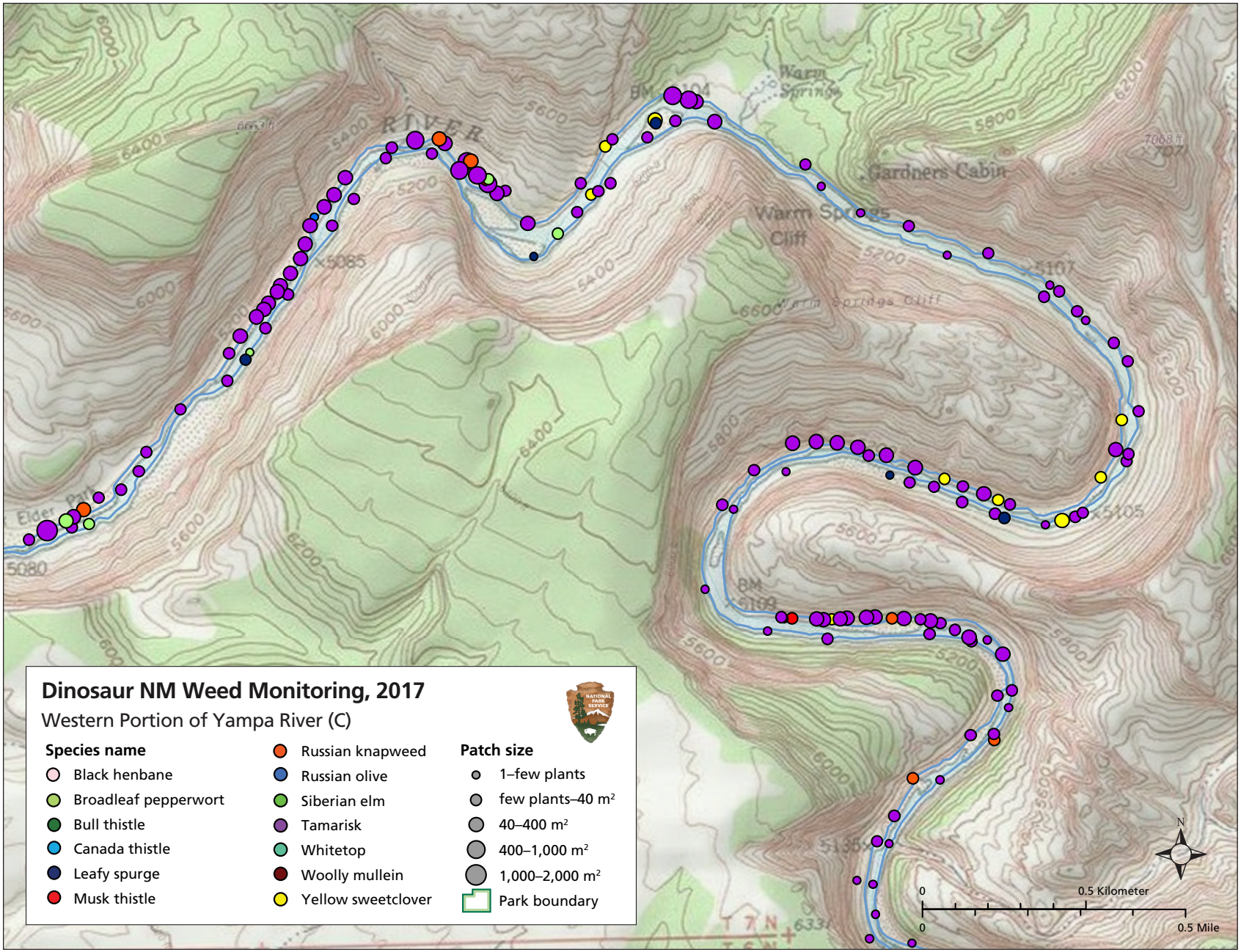


Figure 3-4c. Invasive plant patches detected along the western portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

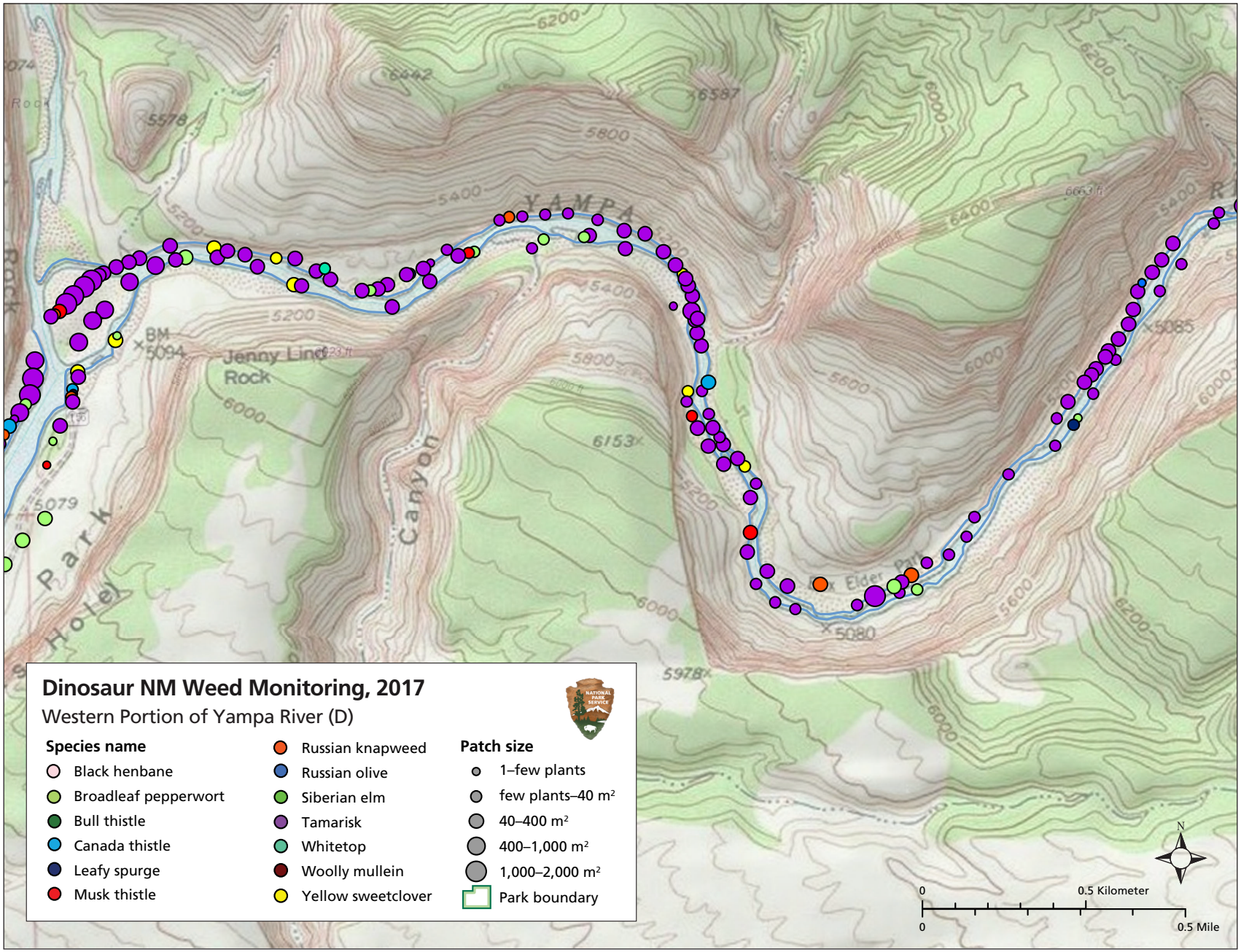


Figure 3-4d. Invasive plant patches detected along the western portion of the Yampa River, Dinosaur National Monument, June 29–July 6, 2017.

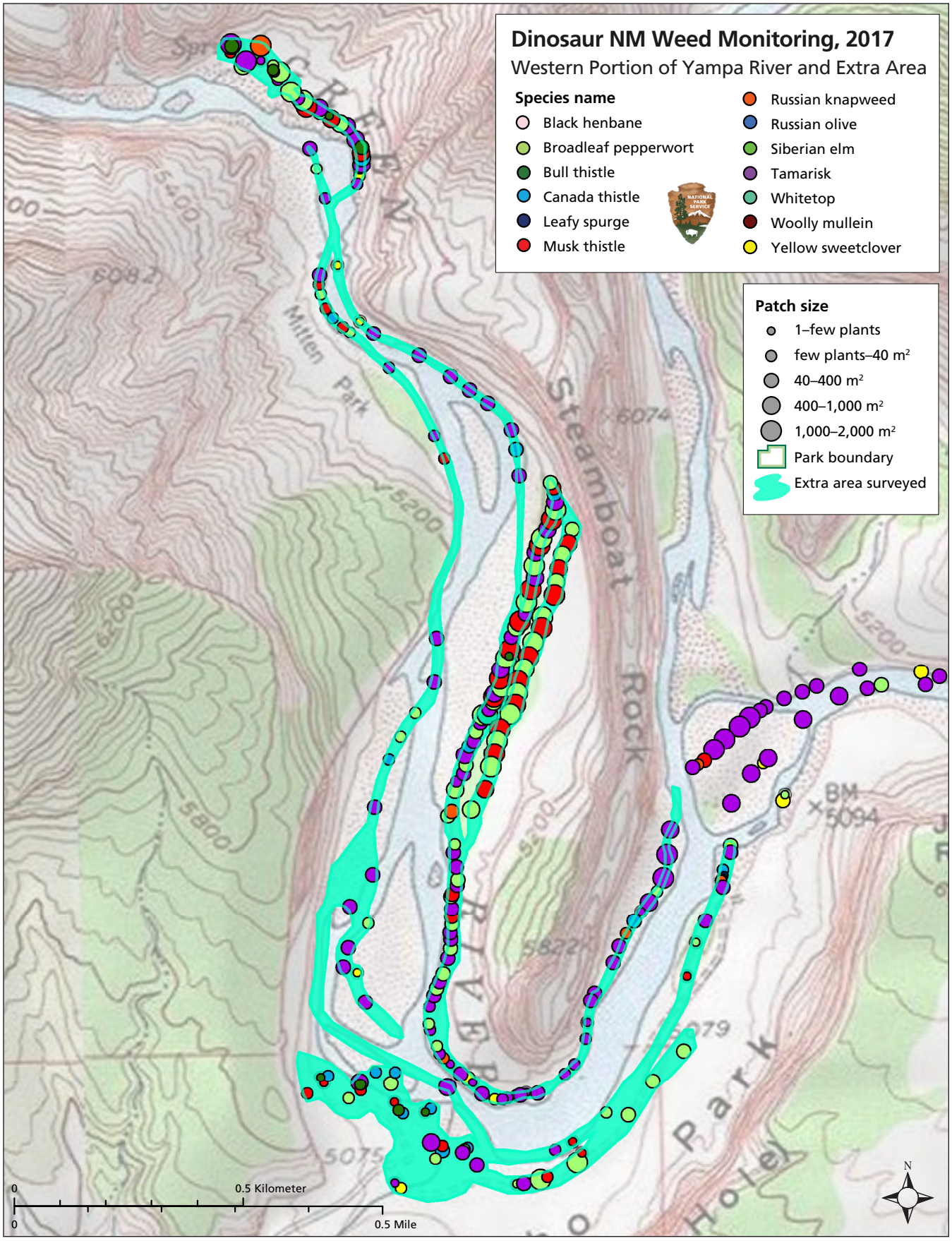


Figure 3-5. Invasive plant patches detected along the western portion of the Yampa River, including extra area, Dinosaur National Monument, June 29–July 6, 2017.

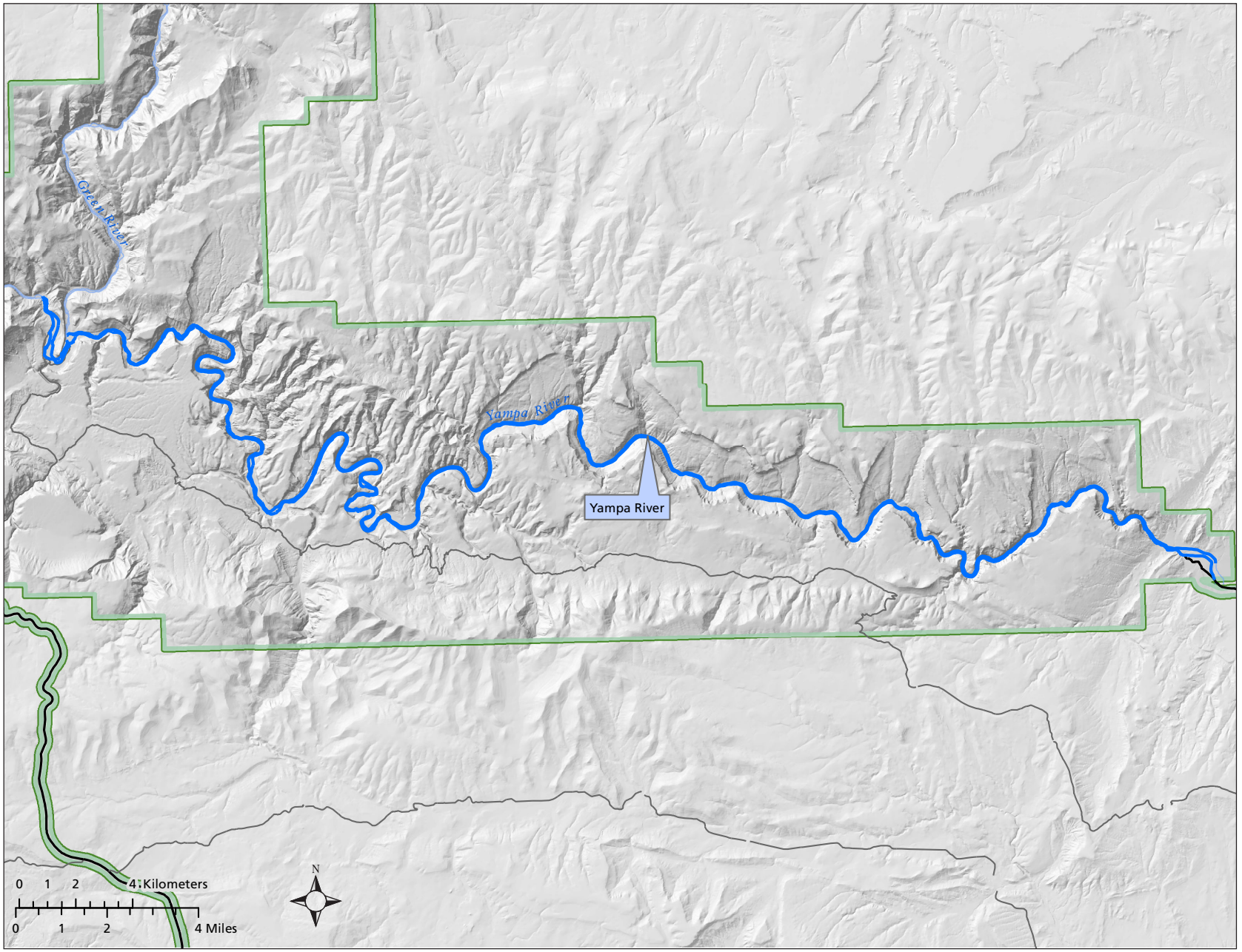


Figure 3-6. Common section of the Yampa River in Dinosaur National Monument mapped during 2003–2004, 2010–2011, and 2017. Note that ~1.5 river miles past the confluence of the Yampa and Green rivers were not analyzed in this report.

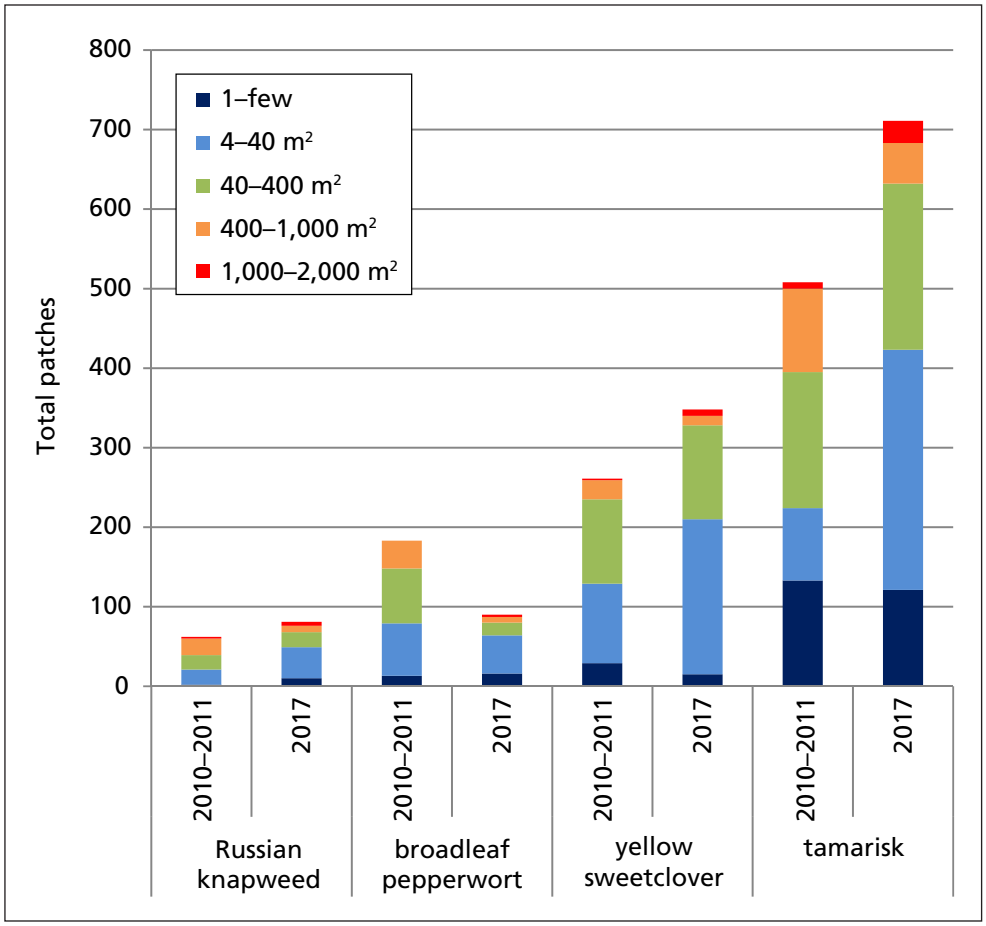


Figure 3-7. Size classes of priority IEP species most frequently observed during 2010–2011 and 2017 surveys.

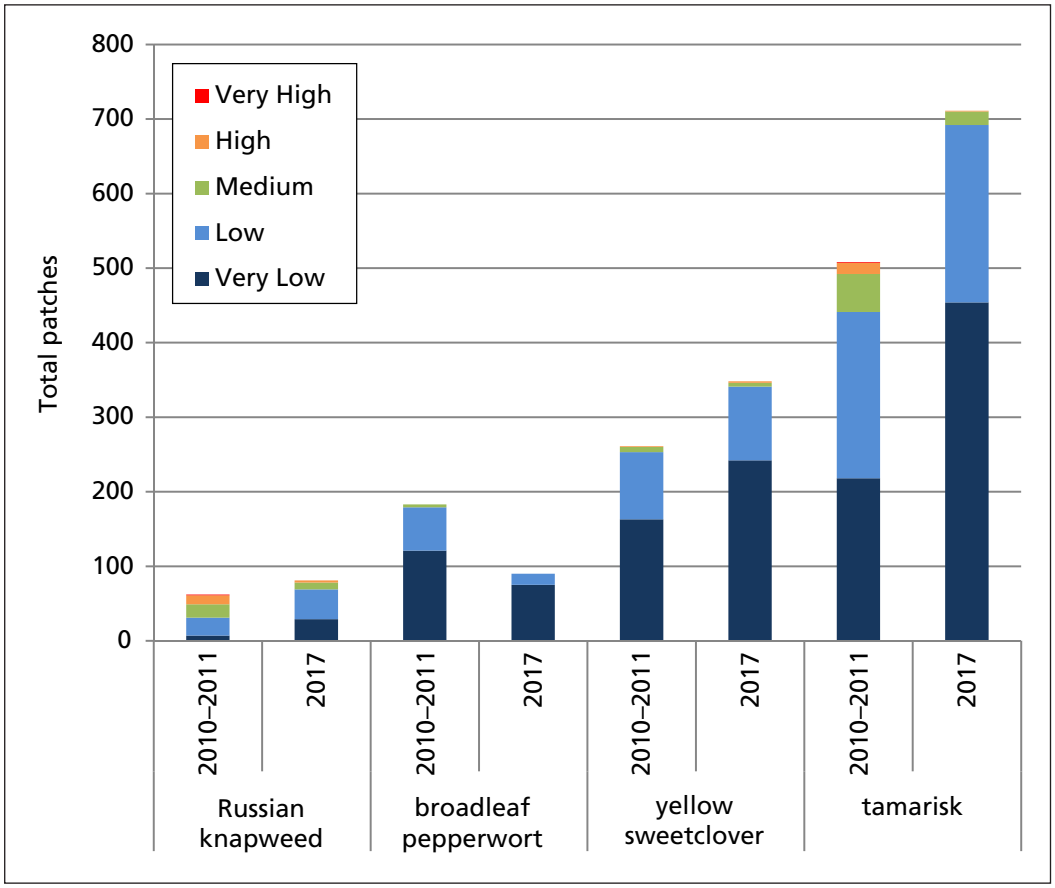


Figure 3-8. PMI classes of priority IEP species most frequently observed during 2010–2011 and 2017 surveys.

4 Discussion

4.1 Priority invasive exotic plant 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, and presence data for other species, should be reliable for the area surveyed. However, absence data for non-priority species are suspect, because not all observers recorded all of these species in all years.

4.2 Possibilities for management control

In 2006, Dinosaur NM completed an invasive plant management plan and environmental assessment that established procedures and outlined areas for priority management (NPS 2005). That plan identified "threats to native plant communities and the wildlife that depend on them; threats to natural river processes and aquatic resources; and concerns from downriver agricultural producers regarding the increased invasion of perennial pepperweed and Russian knapweed into irrigated pastures" as primary management concerns. It further identified the Yampa and Green river corridors as the highest priority area for "future management prescription development."

The most prevalent IEP species along the Yampa River and at Echo and Mitten parks was tamarisk. From 2003 to 2017, there was an increase in the number of recorded tamarisk patches, mostly of small patch size. However, between 2010 and 2017, a decline in larger-sized patches and patches of medium, high, and very high PMI was also observed. These changes could be due to alteration in the distribution of tamarisk along the river corridor toward increasingly sporadic patches. It should be noted that the biocontrol, tamarisk beetle (*Diorhabda elongata*), was released in the monument in 2006 and 2007. It is also likely that removal efforts by monument staff and volunteers between 2010 and 2017 have affected tamarisk populations.

The increase in small patches could be due, at least in part, to new recruitment of tamarisk. Alternatively, these changes could result from a shift in observers and/or the way patches are recorded across years. It is a formidable task to map a widely distributed species while moving through a river corridor. Tamarisk, woolly mullein, musk thistle, and bull thistle were manually controlled (by shovel) at Mitten Park from 2016 to 2018.

Yellow sweetclover is widespread across monitoring areas and has been increasing over the survey years. It appears to be ubiquitous and is encountered frequently, but tends to have low percent cover. Cheatgrass became substantially more widespread from 2010 to 2017, though it is generally sparse in cover. The steep rise in the number of transects containing cheatgrass from 2010 to 2017 could be due to the expansion of this species in the river corridor—but could also be due, at least in part, to observer biases. It was also conjectured that the increase could be related to differing flow levels during sampling, but the discharge of the Yampa River turned out to be very similar during the two trips (1,350–2,310 cubic feet per second (cfs) during the 2010 trip and 1,180–2,400 cfs during the 2017 trip).

This change could be related to a relative lack of sufficient flood-stage events prior to the 2017 trip that would otherwise have scoured grasses from the banks. In the six years prior to 2010, there was one peak above 20,000 cfs and four peaks above 15,000 cfs. In the six years prior to 2017, there were no floods above 20,000 cfs and two above 15,000 cfs. Changes in precipitation could also have influenced the presence of cheatgrass, an annual plant.

While PMI was originally intended to elucidate trends in IEP populations over time, it can also be used to inform treatment decisions. A very low or low classification indicates a patch that is either small in area, sparse in cover, or both small in area and sparse in cover. *However, patches with very low or low PMI should not be interpreted as insignificant.* On the contrary, these patches may be some of the most important areas to treat, especially for isolated and/or uncommon species. Prioritizing treatment of small-scale patches can effectively prevent future spread and possible eradication.

For more widespread species, such as yellow sweetclover, the large number of patches with very low and low PMI indicates that this species is sparsely scattered across a broad landscape. Therefore, while controlling an individual patch might require minimal effort, controlling the population will require traversing large areas. Similarly, while patches with higher PMI will be more difficult to manage and treat due to their larger size and denser cover, they also represent opportunities for possible eradication if patch numbers for a given species are low. Ultimately, managers should consider species traits (e.g., how likely and quickly plants may spread) and environmental conditions (precipitation and temperature), and combine this information with patch number and PMI values when determining treatment priorities.

Several species with rising or steady populations are potential candidates for control or are already being treated. Russian knapweed and Canada thistle have not changed dramatically over the survey years and are encountered regularly along the rivers. Broadleaf pepperwort has declined, but is still encountered regularly. Musk thistle and leafy spurge are relatively infrequent, but their patch numbers are increasing on the Yampa River. Leafy spurge has been increasing despite control efforts by monument staff. Invasive plant management (pulling and bagging) and mapping have occurred for leafy spurge on the Yampa River twice a season for over 10 years. These efforts, started as searching and pulling in a couple of drainages (Anderson Hole and Tepee Draw), have turned into multi-day efforts to find and manually control exponentially increasing populations. Manual control of leafy spurge will continue in 2018. However, a new strategy needs to be developed, likely to include the use of herbicide, to keep up with the increasing effort needed to manage this species in the river corridor.

The least-common species we encountered from the IEP priority list were found very infrequently and have the best chance for eradication. Only 10 patches of Russian olive were recorded on the Yampa River. All but one were in the smallest size class and composed of either seedlings or saplings. Between 2010 and 2017, Russian olive was actively removed along some sections of the river by monument staff and volunteers. Whitetop was recorded as four patches with very low or low PMI, and bull thistle as two patches with very low PMI, representing relatively low-effort eradication opportunities. Black henbane was also documented as one small patch of very low PMI at Deerlodge, at the upstream end of the Yampa River in the monument. This lone patch was pulled during monitoring and removed as a potential seed source for downstream spread. This serves as an example of how combining species information, patch number, and PMI can be used to inform management action.

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