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Natural Resource Stewardship and Science

Invasive Exotic Plant Monitoring at Dinosaur National Monument

Results of the 2019 Field Season on the Green River, and the Third Completed Monitoring Rotation

Natural Resource Report NPS/NCPN/NRR—2021/2332



ON THE COVER

Tamarisk along the Green River near Whirlpool Canyon. NPS/Amy Washuta.

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Natural Resource Report NPS/NCPN/NRR—2021/2332

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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. We also calculated a patch management index (PMI) to quantify the extent and density of invasive patches into a single value that helps identify the scale of the problem. Park managers can use this tool to help prioritize IEP treatment. At Dinosaur National Monument, the NCPN monitors IEPs in the Green and Yampa river corridors. This report summarizes data from monitoring on the Green River in 2019, and monitoring on the Yampa River in 2017, to represent the completion of the third monitoring rotation of the entire river corridor (2002–2005, 2010–2011, 2017–2019). During surveys conducted from June 26 to July 2, 2019, NCPN staff detected 12 priority IEP species and two non-priority species in a 84.6-hectare (209-acre) area along 74.4 kilometers of the Green River above ("upper") and below ("lower") its confluence with the Yampa. A total of 2,535 IEP patches were detected. Of those patches, 24.2% and 15.6% were smaller than 40 m^2 on the upper and lower Green River reaches, respectively. The patch management index (PMI) was low or very low for 95.7% of patches on the upper Green River and 90.9% of patches on the lower Green River. Tamarisk (*Tamarix* sp.), broad-leaf pepperwort (*Lepidium latifolium*), and yellow sweetclover (*Melilotus officinalis*) were the most widespread species. For the first time, NCPN monitoring detected teasel (*Dipsacus sylvestris*) on the upper Green River. Yellow sweetclover has increased on all three river reaches during the survey years. Musk thistle (*Carduus nutans*) was found at considerably lower levels than yellow sweetclover but has also increased on all three river reaches. Leafy spurge is increasing on the lower Green River and Yampa River. Cheatgrass was not monitored in the first rotation, but increased substantially in cover and percent frequency on all three river sections from 2010–2011 to 2017–2019. This increase may be due to a lack of recent high-flow scouring events. The highly regulated upper Green River generally has the highest number of IEPs, while the lower Green River has a moderate amount of IEPs. The largely unregulated flows of the Yampa River continue to result in a lower number of patches per kilometer, lower percent cover, and lower percent frequency than the upper or lower Green River. Network staff will return to the monument in 2022 to begin the fourth monitoring rotation.

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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, the NCPN 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 focuses 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.

At Dinosaur National Monument (NM), the NCPN monitors IEPs in the Green and Yampa river corridors. This report summarizes data from monitoring on the Green River above ("upper") and below ("lower") its confluence with the Yampa in 2019. It also includes results from monitoring on the Yampa River in 2017, to represent the completion of the second full monitoring rotation of the entire river corridor by NCPN (2010–2011, 2017–2019), and the third when surveys by Utah State University (2002–2005), with slightly different methods, are included.

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).

To monitor IEPs, we establish a series of monitoring routes and transects. 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 Dinosaur NM staff developed a list of priority IEPs for the park by reviewing past park literature and state and county weed lists, and consulting with park staff and county weed managers. The list was reviewed and updated for the 2011, 2014, 2017, and 2019 field seasons. The current priority list (Table 2-1) includes 24 existing and potential IEPs of high management concern. One additional species, cheatgrass (*Bromus tectorum*), is only monitored in transects due to its widespread presence.

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.

Table 2-1. Priority invasive exotic plant list for Dinosaur National Monument, 2019.

Scientific name (Utah)	Scientific name (Colorado)	Common name
Aegilops cylindrica[1]	*Aegilops cylindrica*	jointed goatgrass
Arctium minus	*Arctium minus*	burdock
Bromus tectorum[2]	*Anisantha tectorum*	cheatgrass
Cardaria sp.[3]	*Cardaria* sp.	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*	yellow star-thistle
Cirsium arvense	*Breea arvensis*	Canada thistle
Cirsium vulgare	*Cirsium vulgare*	bull thistle
Cynoglossum officinale	*Cynoglossum officinale*	common hound's tongue
Dipsacus sylvestris[1]	*Dipsacus fullonum*	teasel
Elaeagnus angustifolia	*Elaeagnus angustifolia*	Russian-olive
Euphorbia esula	*Tithymalus esula*	leafy spurge
Hyoscyamus niger	*Hyoscyamus niger*	black henbane
Lepidium latifolium	*Cardaria latifolia*	broad-leaf pepperwort
Linaria dalmatica	*Linaria genistifolia* ssp. *dalmatica*	Dalmatian toadflax
Linaria vulgaris[1]	*Linaria vulgaris*	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.	tamarisk
Tribulus terrestris	*Tribulus terrestris*	puncture vine

[1]Added in 2010–2011. All other IEPs have been on the priority list since 2002–2005. [2]Transects only. [3]Listed as *C. draba* in 2002–2005 and *C. chalepensis, C. draba*, and *C. pubescens* in 2010–2011. [4]Listed as *T. ramosissima* in 2002–2005 and *T. chinensis* in 2010–2011.

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 2019 was 1–10 meters, depending on vegetation density, topography, and mode of transport (Figure 2-1).

2.3 Effective detection swath width

Effective detection swath width (EDSW) was the maximum width of a linear search swath (band transect) in which an observer was confident of visually detecting 90% of all priority species of the MDTS. For monitoring routes along the Green 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 (see Figure 2-1).

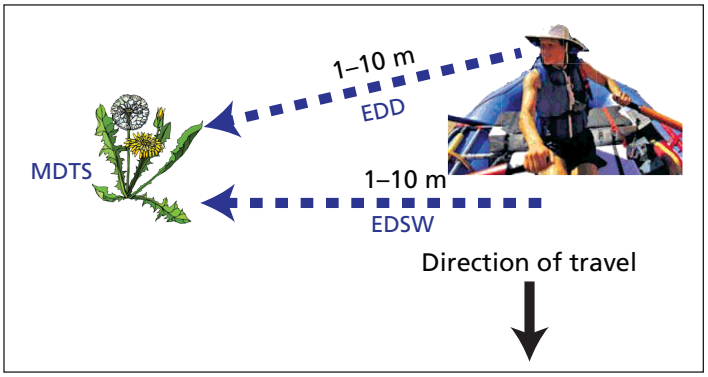


Figure 2-1. The maximum effective detection distance (EDD) at Dinosaur National Monument was 1–10 meters in 2019. The EDD equaled the effective detection swath width (EDSW).

2.3.1 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, then cover estimates were made every 50 meters to aid in developing an effective management strategy for the entire patch.

2.3.2 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.

2.3.3 Data collection methods

Only priority species were consistently recorded during monitoring routes. Survey crew members were permitted to record additional species if they were noteworthy. Surveyors walked or searched from a raft, following linear routes on each side of the Green River. While traveling along the route, surveyors searched for IEPs by visually scanning the land within the width of the EDSW. 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. 1–3 plants (used for isolated single plants or very small patches (≤2 × 2 m)
2. 4 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).

We recorded percent cover by estimating the amount, or "percentage," of ground covered by the vertical projection of plant matter as visually estimated from a bird's-eye view of the vegetation (Elzinga et al. 1998). This estimate included both the living and dead standing material 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 the extent and 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 with low or very low PMI scores will generally be easier to control or remove than patches with high or very high scores. In many cases, directing resources toward controlling patches with low or very 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 patches with mostly low or very low scores may or may not be easier to treat (and possibly eradicate) than a dif-

ferent species with a few patches that have high or very high scores. Therefore, park managers should consider PMI within the context of information on species and patch numbers (see Chapter 4).

2.4 Monitoring transects

2.4.1 Quadrat establishment

We established one transect with three vegetation quadrats perpendicular to the river's edge 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 transect line as the technician walked the monitoring route. In some cases, we leveled the sampling frame by propping up quadrat corners.

2.4.2 Data collection methods

In the monitoring quadrats, observers recorded all priority IEP species observed, as well as cheatgrass. For each quadrat, we recorded visual estimates of 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).

2.5 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.

2.6 Comparisons to previous surveys

The Green River corridor in Dinosaur National Monument was surveyed by Utah State University (USU) in 2002–2005 (USU; Dewey and Anderson 2005), and by NCPN in 2010–2011 (Perkins 2012). Since 2002–2005, twenty priority IEP species have been consistently monitored along the Green River (see Table 2-1). An additional four IEP species have been consistently monitored along the Green and Yampa rivers since 2010–2011. Unless otherwise mentioned, comparisons are only made for priority species monitored consistently between 2002–2005 and 2019. Methods were largely similar across these years, but the USU observers used different patch-area categories, such as polygons and lines, and a PSR of 50 yards in 2002–2005). Transects were completed using the same methods in 2010–2011 and 2017–2019. Therefore, only broad comparisons should be made between the USU and NCPN surveys.

3 Results

3.1 Target invasive exotic plant list

From June 26 to July 2, 2019, field crews searched on monitoring routes for priority IEP species at Dinosaur NM (see Table 2-1). 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's nomenclature will be used for scientific names in this report.

3.2 Monitoring routes

3.2.1 Green River

We surveyed 84.6 hectares (209 acres) along 74.4 kilometers (46.2 miles) of the Green River, detecting 12 priority IEP species and two non-priority species (Table 3-1 and Figures 3-1 to 3-17). One additional priority species, black henbane (*Hyoscyamus niger*) was found on the Yampa River in 2017, but not along the Green River in 2019.

A total of 2,535 priority IEP patches were recorded along the Green River monitoring routes in 2019 (Table 3-2, Appendix A at https://irma.nps.gov/DataStore/Reference/Profile/2256018). Tamarisk (*Tamarix* sp.), broad-leaf pepperwort (*Lepidium latifolium*), and yellow sweetclover (*Melilotus officinalis*) were the most widespread species (Table 3-3). Russian knapweed (*Centaurea repens*), musk thistle (*Carduus nutans*), and Canada thistle (*Cirsium arvense*) were also common. On the upper Green River, 24.2% of patches were less than 40 m^2 in size, compared to 15.6% on the lower Green River. In contrast, 62.7% of patches were less than 40 m^2 in size on the Yampa River in 2017. Similarly, large (>400 m^2) patches represented a larger proportion on the upper (10.0%) and lower (24.7%) Green River in 2019 than on the Yampa (9.7%) in 2017 (Table 3-3).

The largely unregulated Yampa River continues to have the fewest IEP patches per kilometer, followed by the lower Green River and then the upper Green River, whose flow is the most regulated of the three reaches. The Yampa River has 57% fewer patches per kilometer than the upper Green River. PMI

Table 3-1. Invasive exotic plants detected at Dinosaur National Monument, June 26–July 2, 2019.

Scientific name	Common name	Method detected	Park priority?
Arctium minus	burdock	Routes	Yes
Bromus tectorum	cheatgrass	Transects	No[1]
Cardaria sp.	whitetop	Routes	Yes
Carduus nutans	musk thistle	Routes	Yes
Centaurea repens	Russian knapweed	Routes, Transects	Yes
Cirsium arvense	Canada thistle	Routes, Transects	Yes
Cirsium vulgare	bull thistle	Routes	Yes
Dipsacus sylvestris	teasel	Routes	Yes
Elaeangus angustifolia	Russian-olive	Routes	Yes
Euphorbia esula	leafy spurge	Routes	Yes
Lepidium latifolium	broad-leaf pepperwort	Routes, Transects	Yes
Melilotus officinalis	yellow sweetclover	Routes, Transects	Yes
Tamarix sp.	tamarisk	Routes, Transects	Yes
Verbascum thapsus	wooly mullein	Routes, Transects	No

[1]Cheatgrass was recorded consistently in transects but not along monitoring routes.
[2]Found only along Yampa River in 2017.

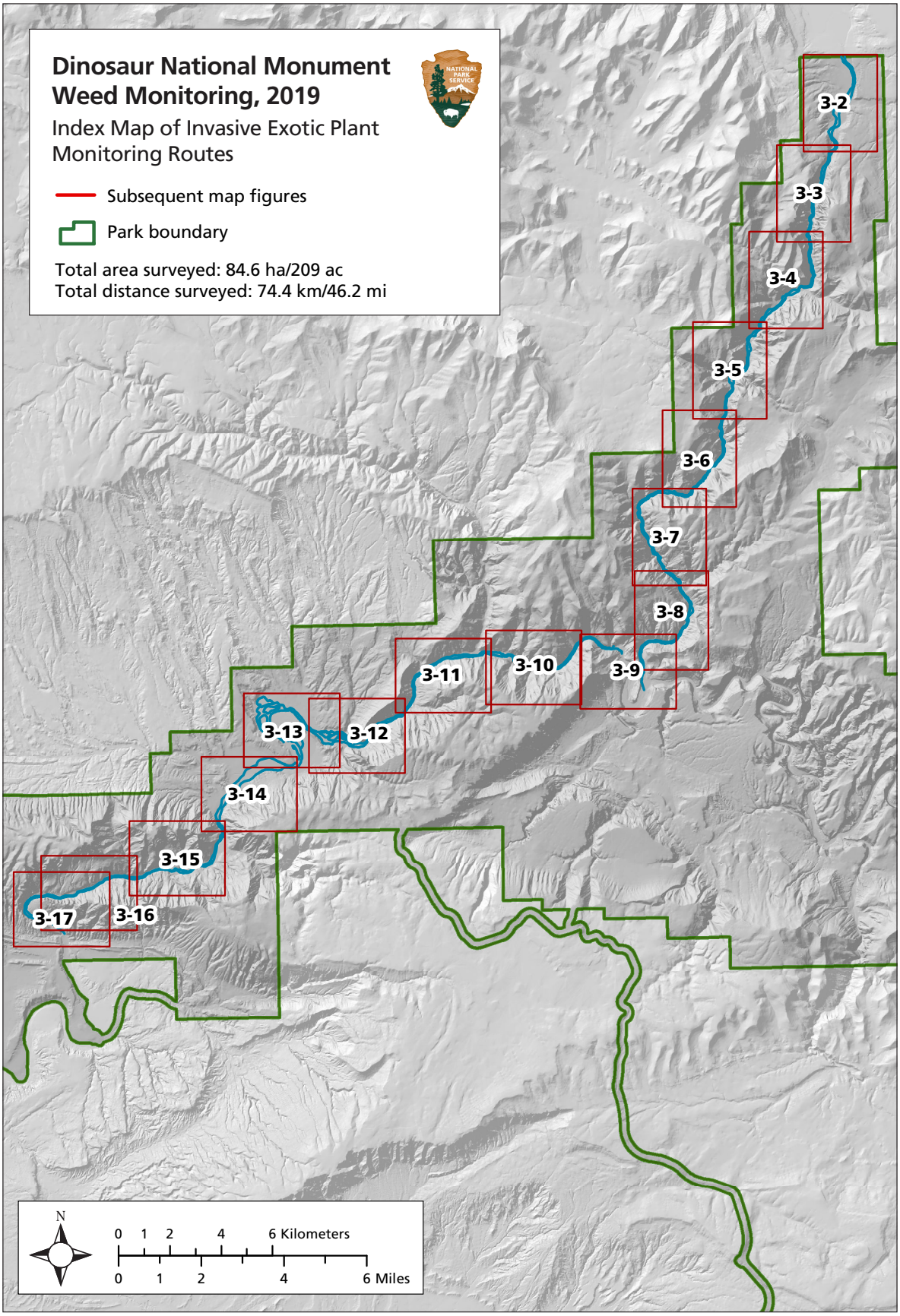


Figure 3-1. Index map for subsequent figures of routes monitored at Dinosaur National Monument, June 26 to July 2, 2019.

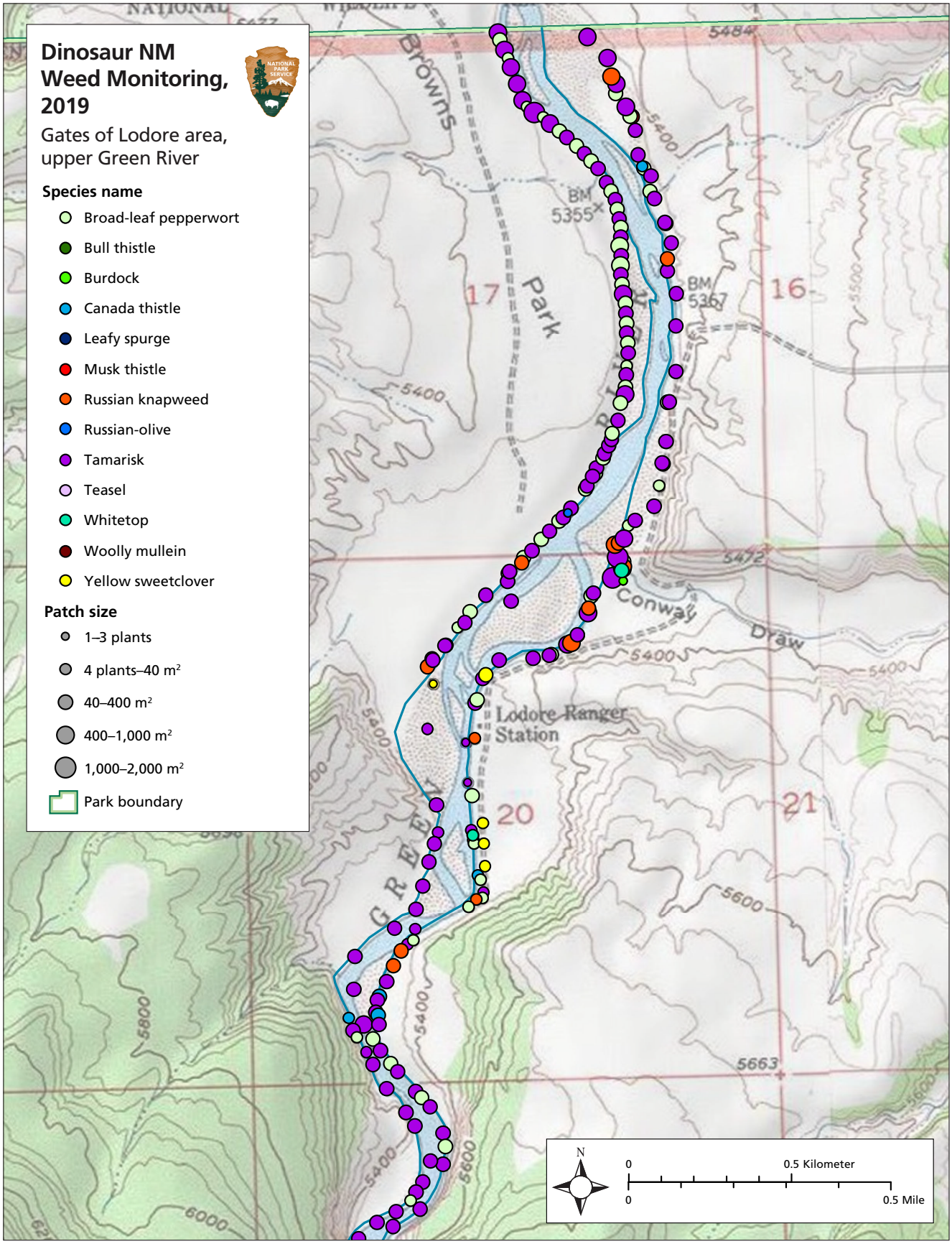


Figure 3-2. Invasive plants detected on monitoring routes around Gates of Lodore of the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

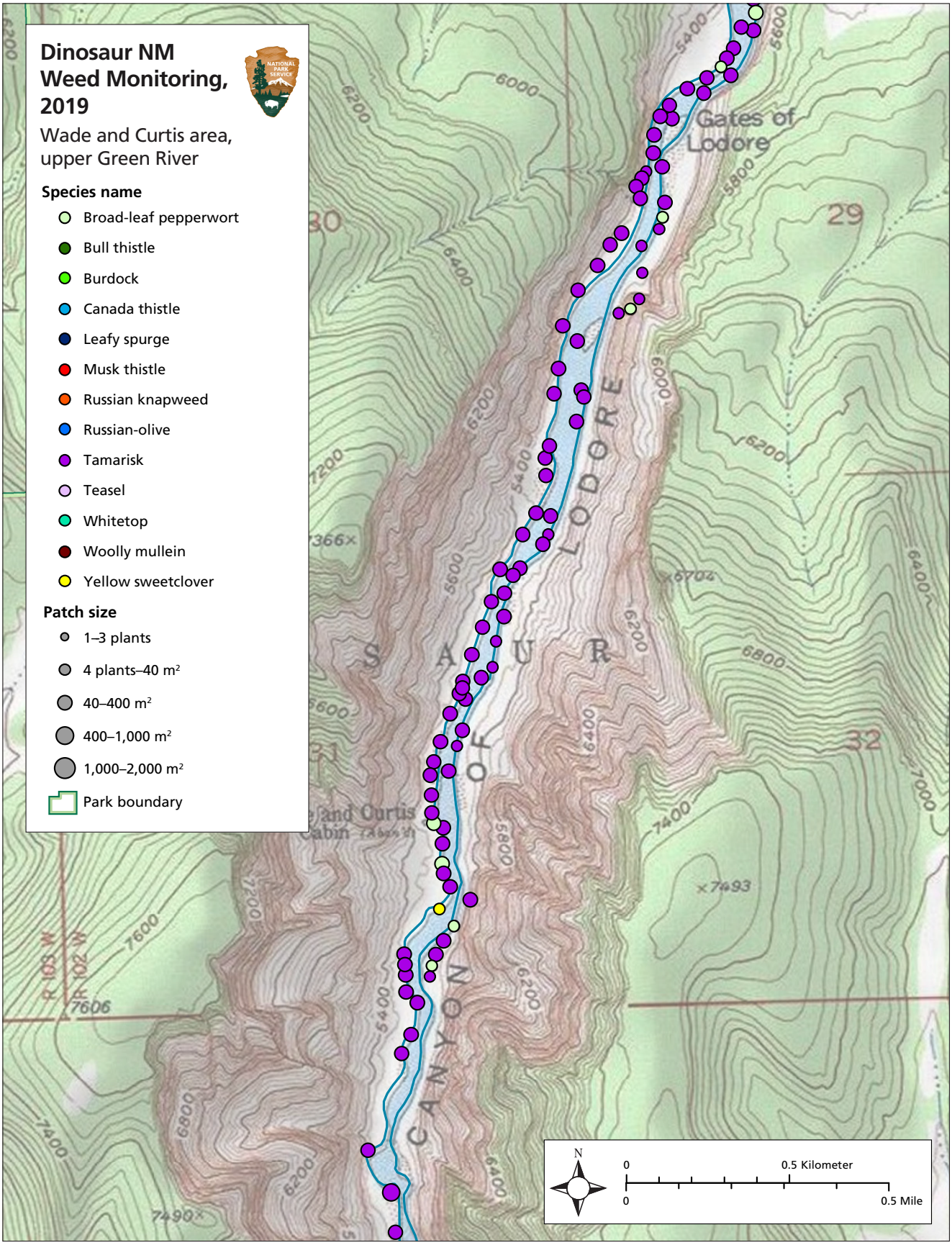


Figure 3-3. Invasive plants detected on monitoring routes around Wade and Curtis on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

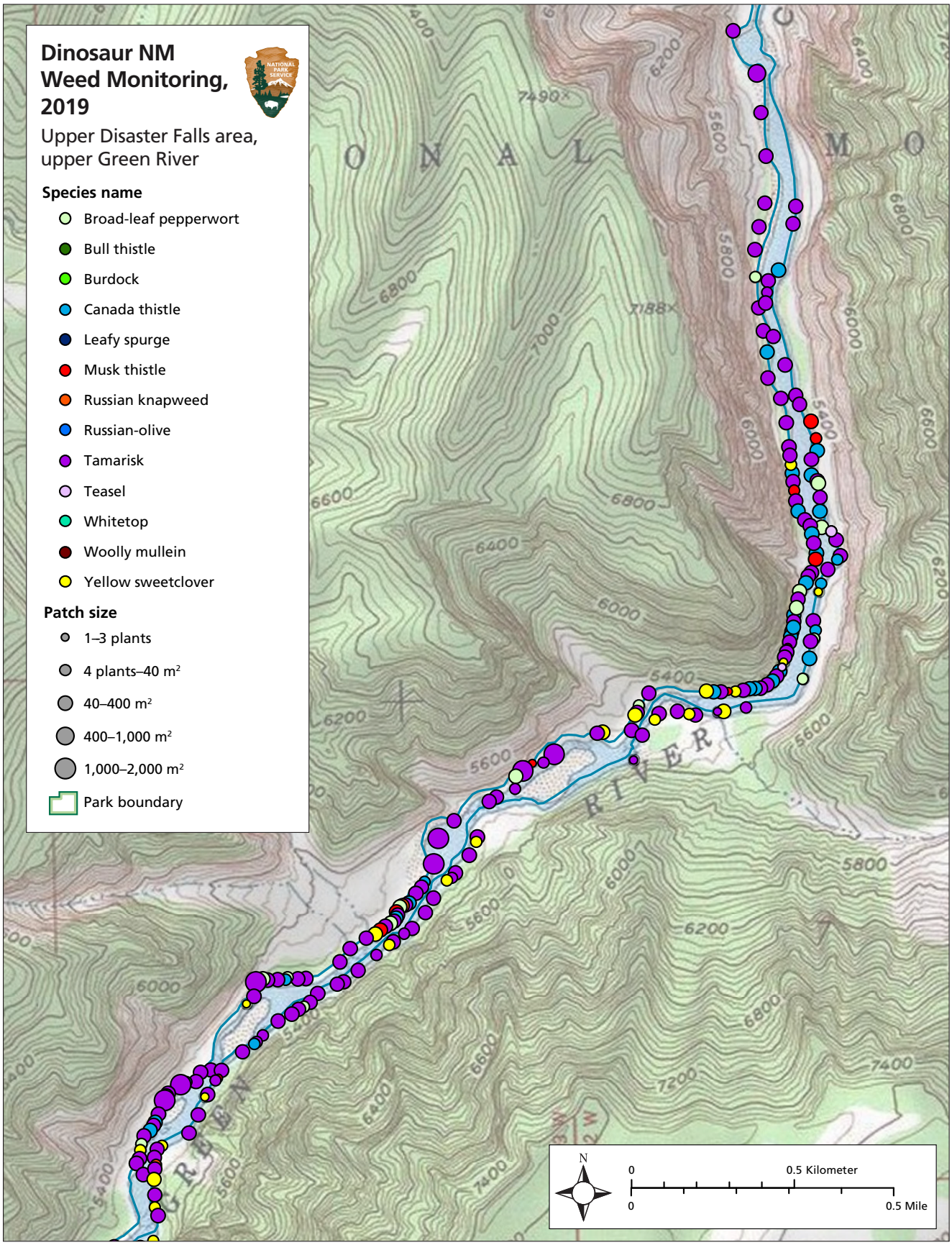


Figure 3-4. Invasive plants detected on monitoring routes above Upper Disaster Falls on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

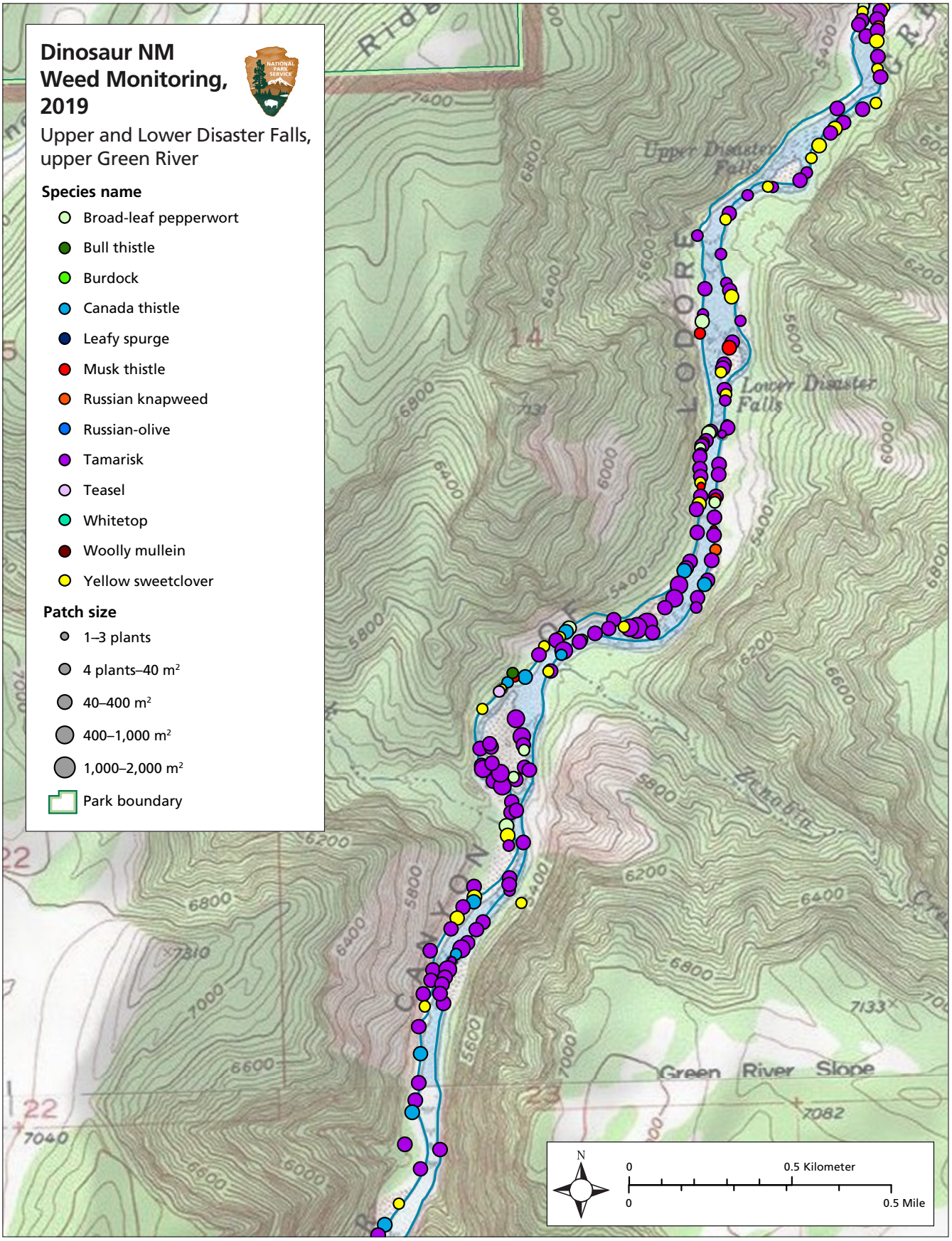


Figure 3-5. Invasive plants detected on monitoring routes around Upper and Lower Disaster Falls on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

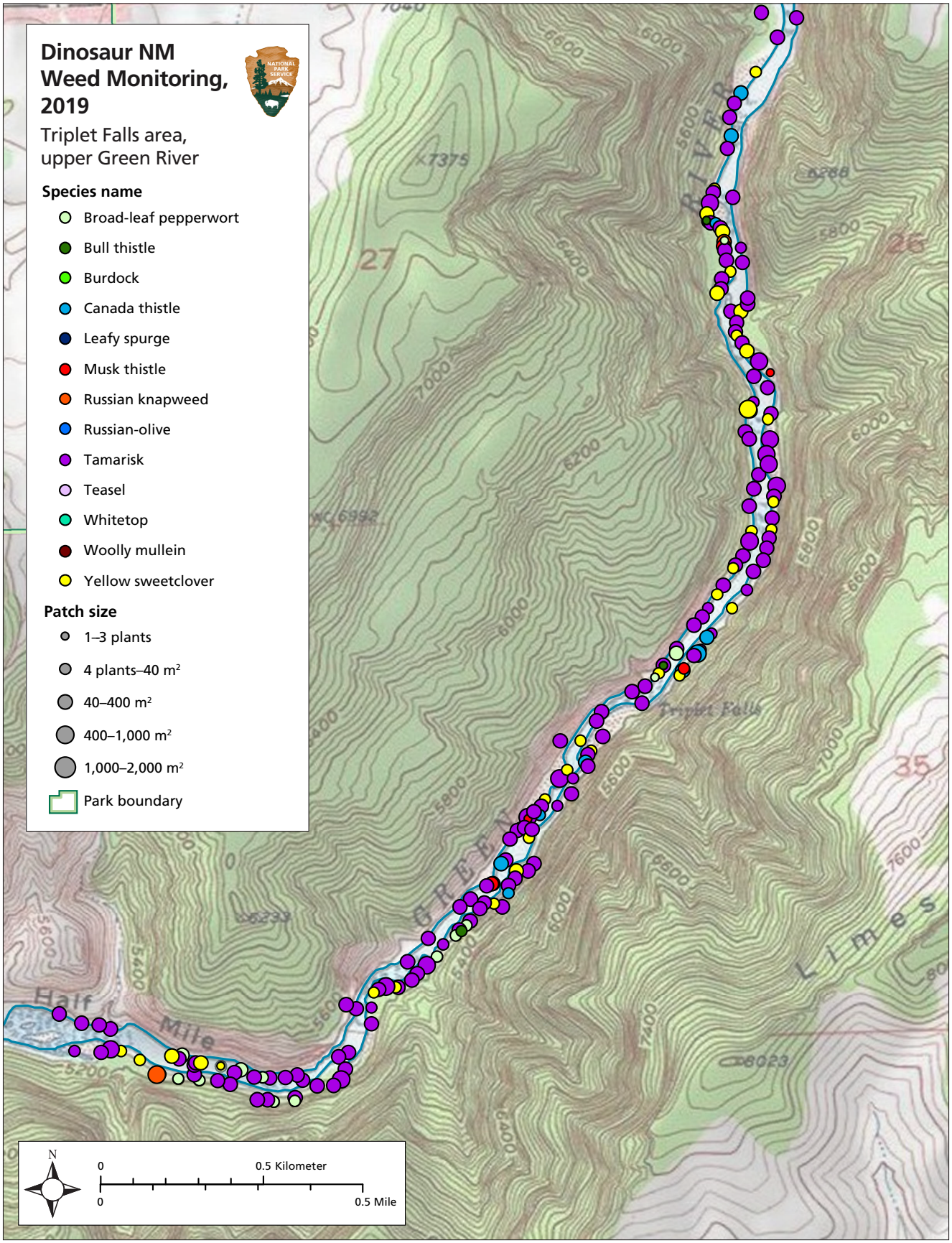


Figure 3-6. Invasive plants detected on monitoring routes around Triplet Falls on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

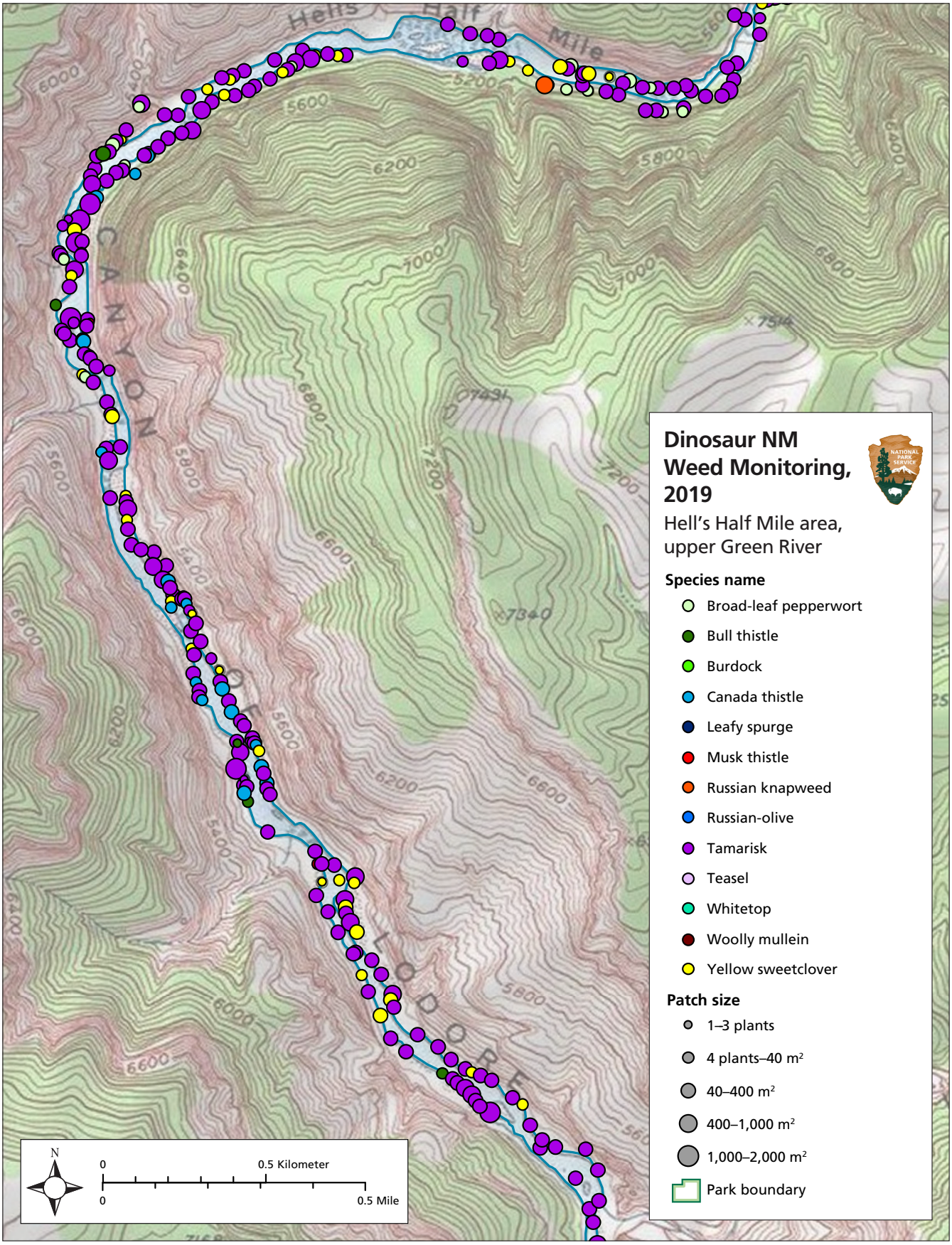


Figure 3-7. Invasive plants detected on monitoring routes around Hell's Half Mile on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

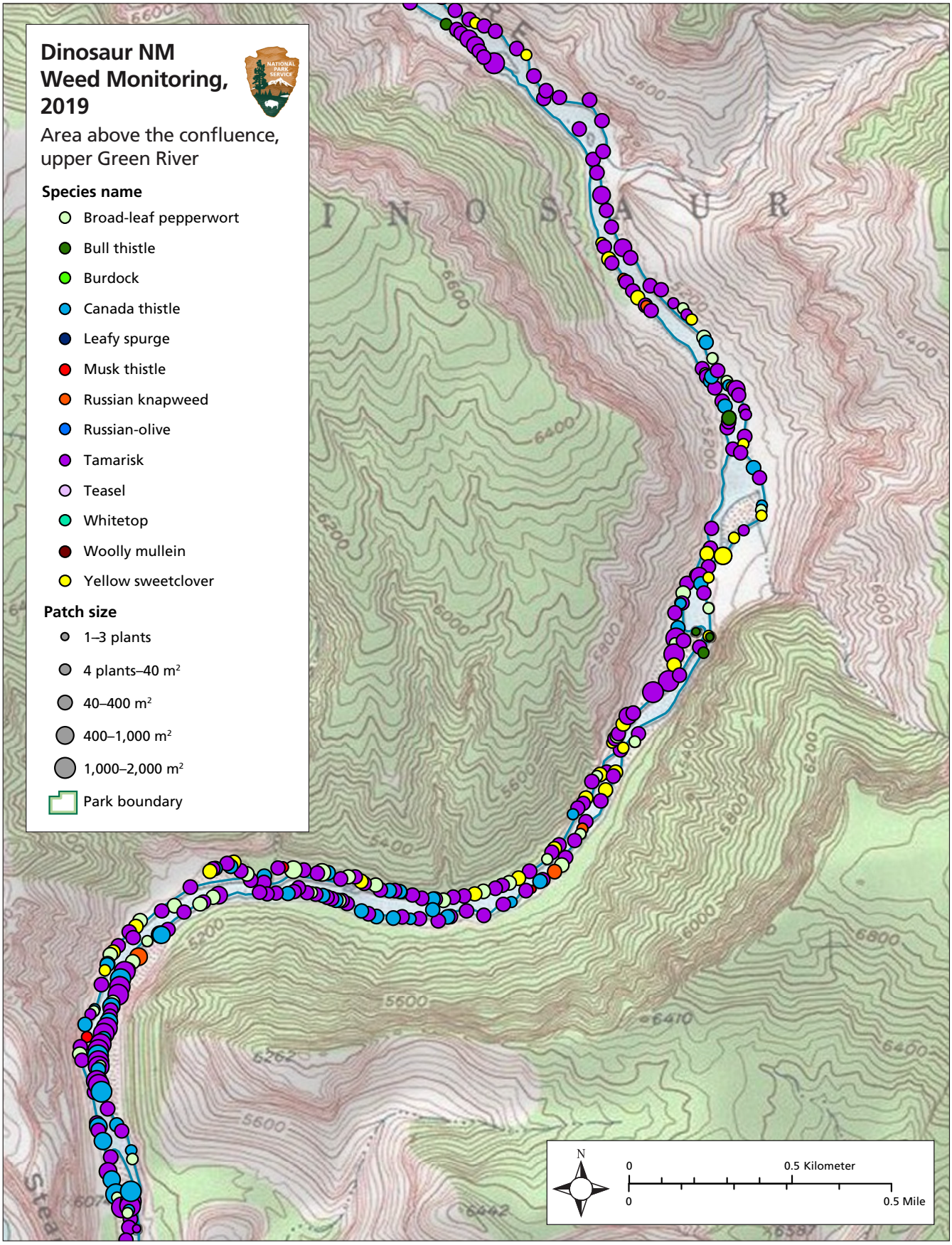


Figure 3-8. Invasive plants detected on monitoring routes above the confluence of the Green and Yampa Rivers at Dinosaur National Monument, June 26 to July 2, 2019.

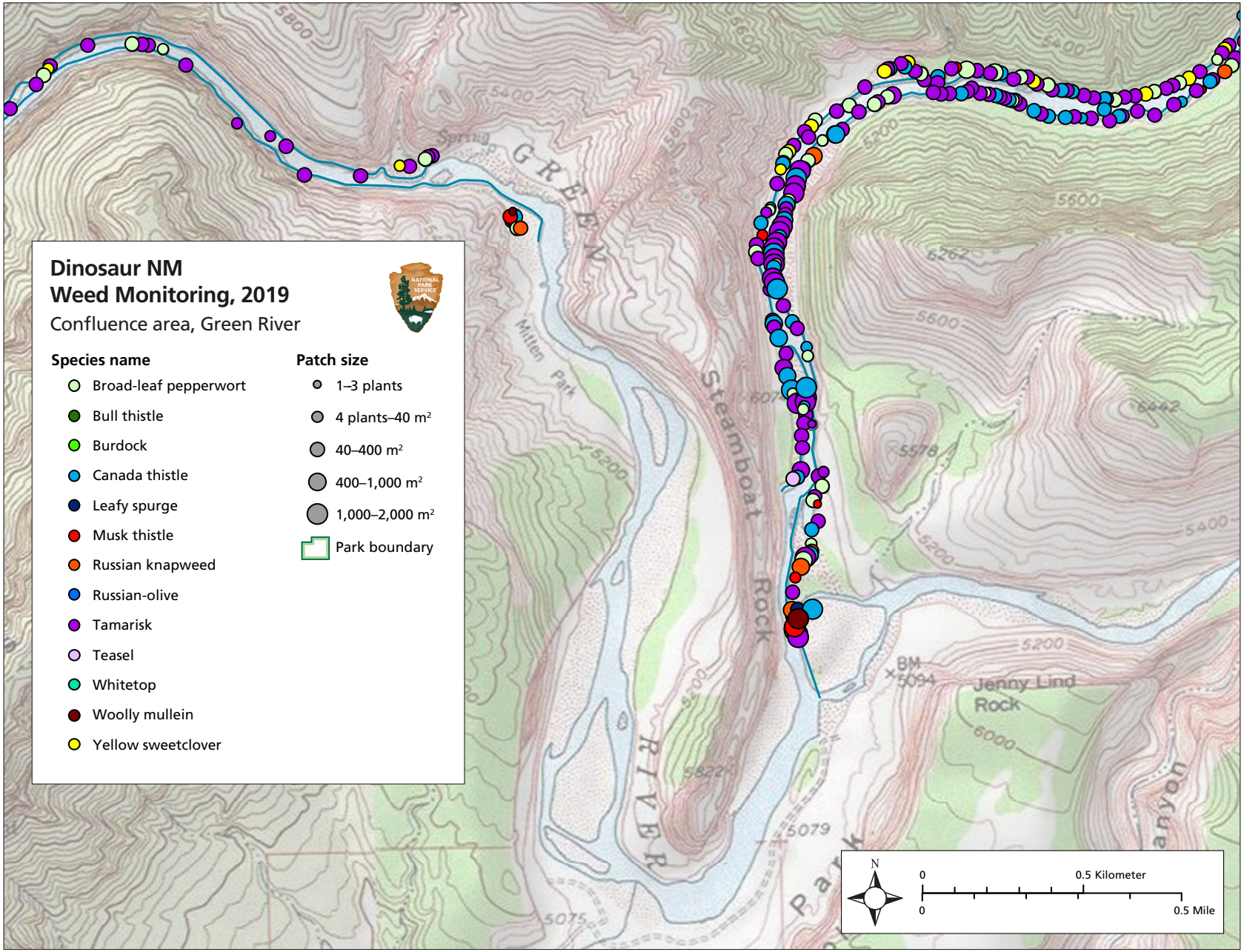


Figure 3-9. Invasive plants detected on monitoring routes around the confluence of the Green and Yampa Rivers at Dinosaur National Monument, June 26 to July 2, 2019. Note that the section with no species mapped was surveyed in 2017 (see Washuta et al. 2018), so was not mapped for this report.

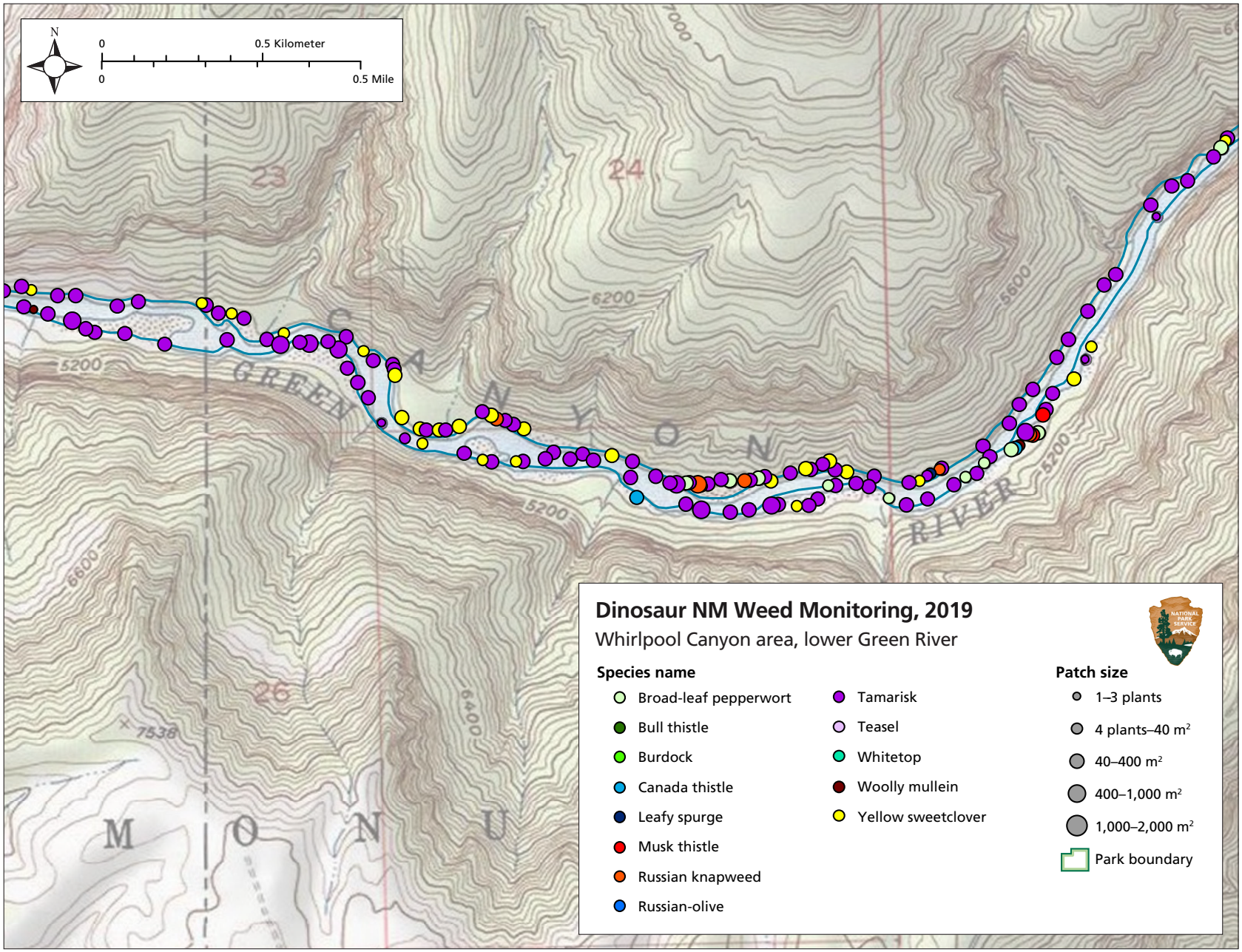


Figure 3-10. Invasive plants detected on monitoring routes around Whirlpool Canyon on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

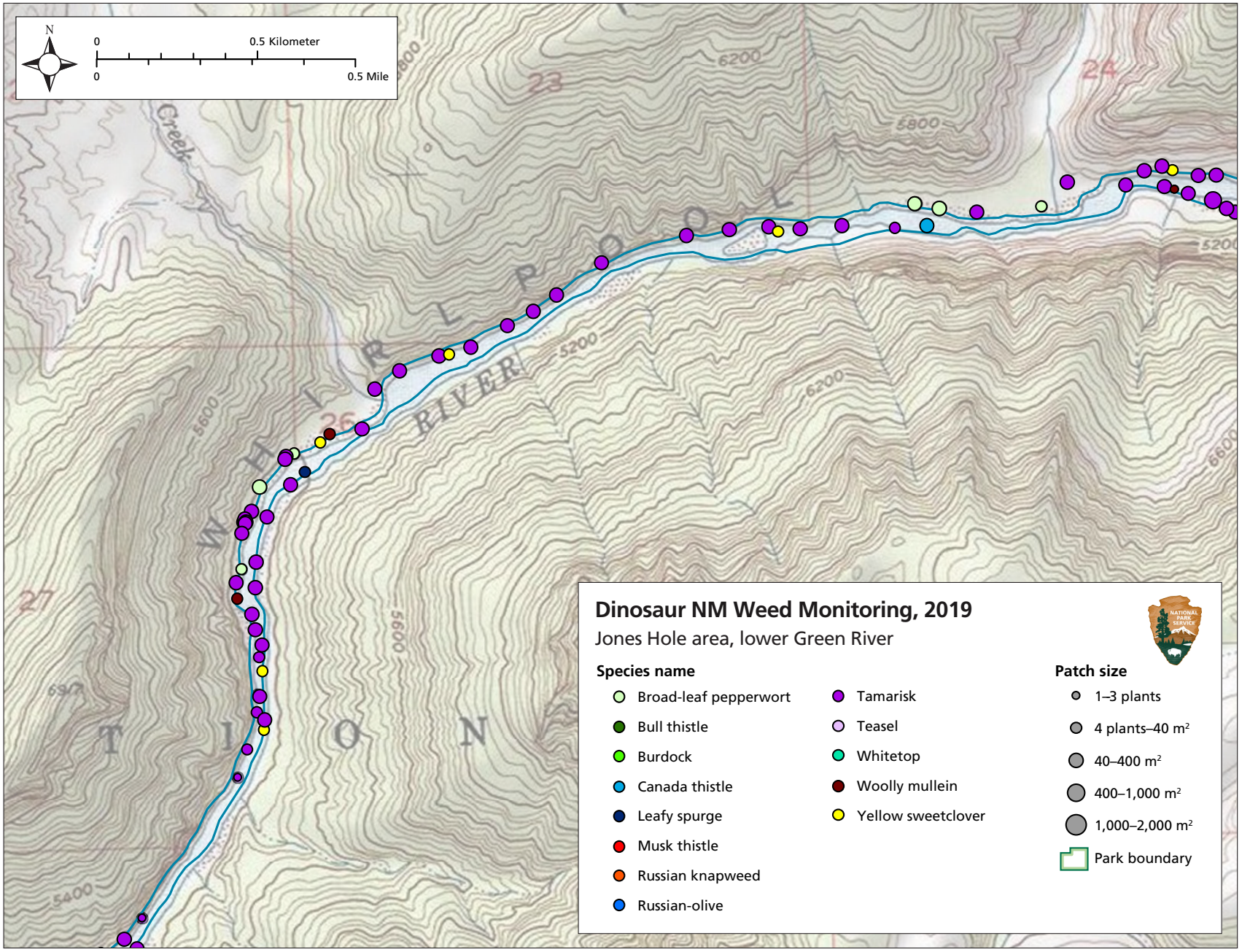


Figure 3-11. Invasive plants detected on monitoring routes around Jones Hole on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

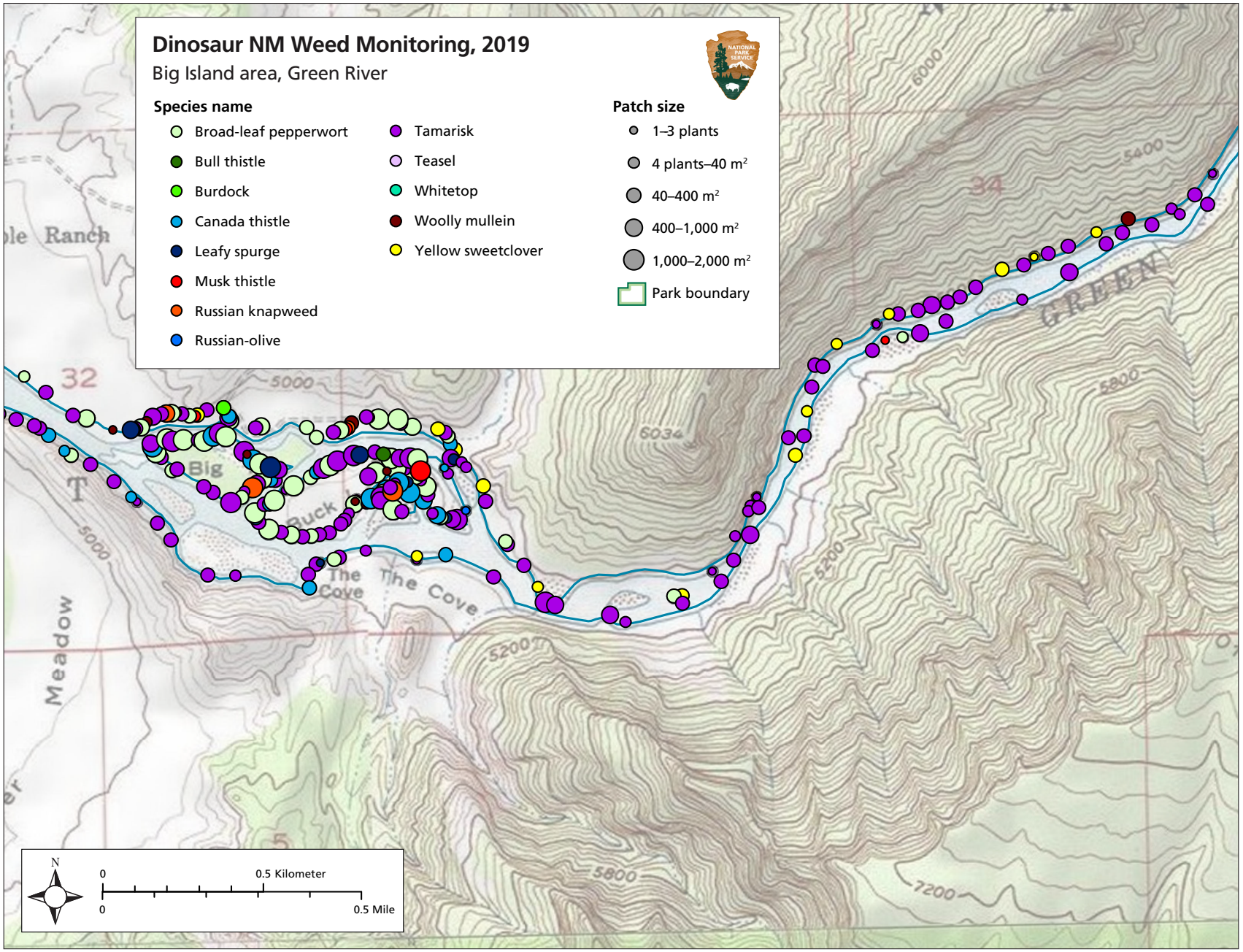


Figure 3-12. Invasive plants detected on monitoring routes around Big Island on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

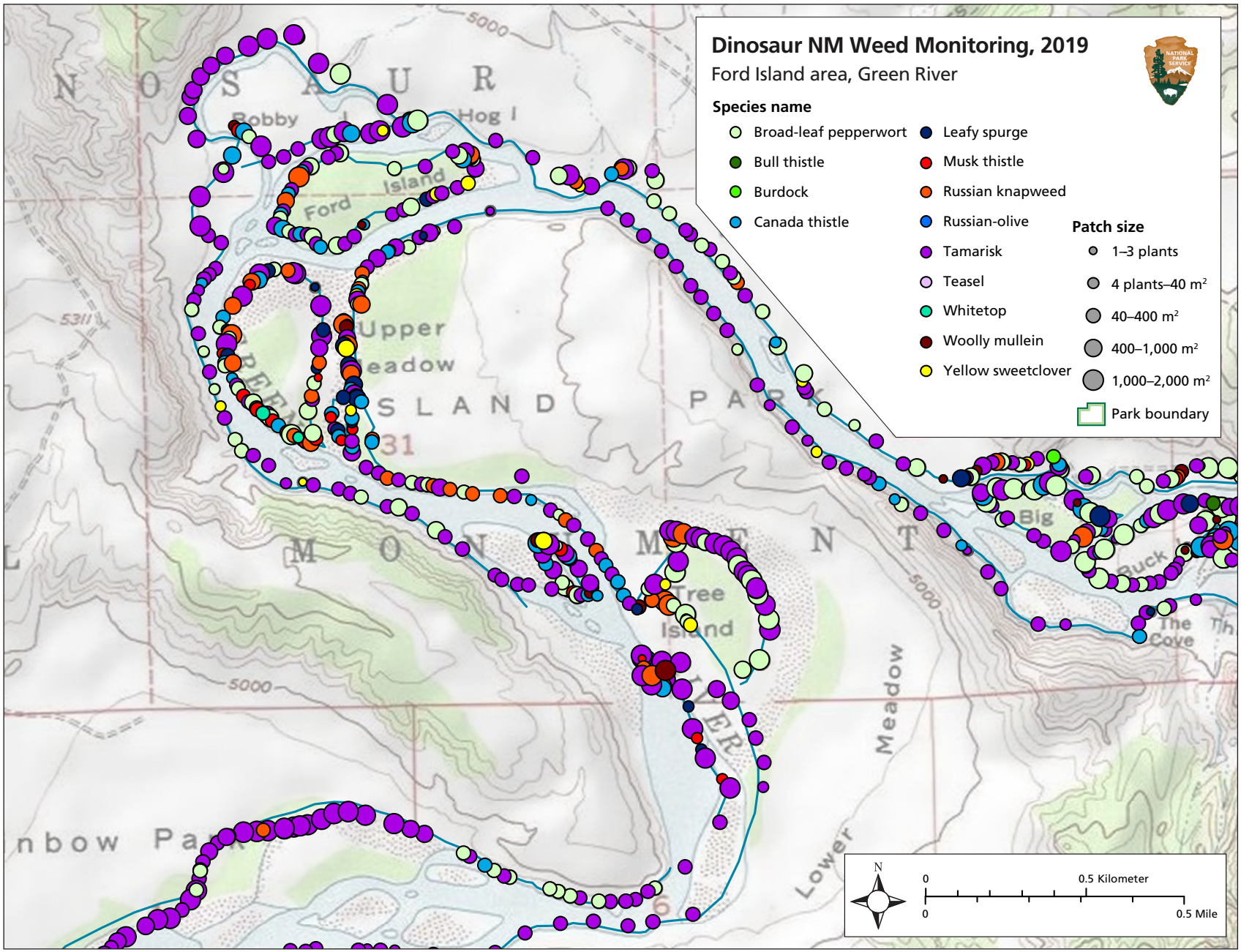


Figure 3-13. Invasive plants detected on monitoring routes around Ford Island on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

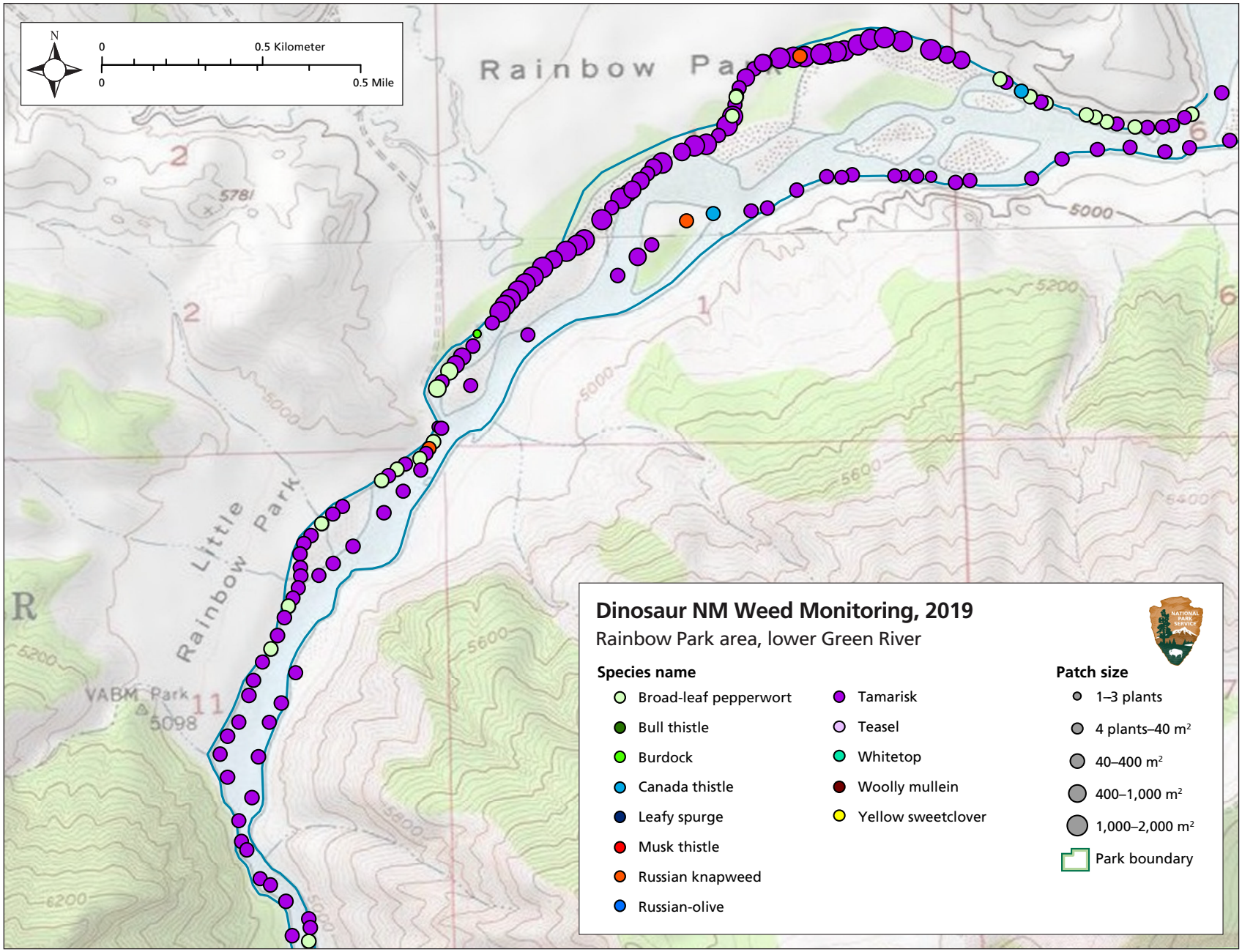


Figure 3-14. Invasive plants detected on monitoring routes around Rainbow Park on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

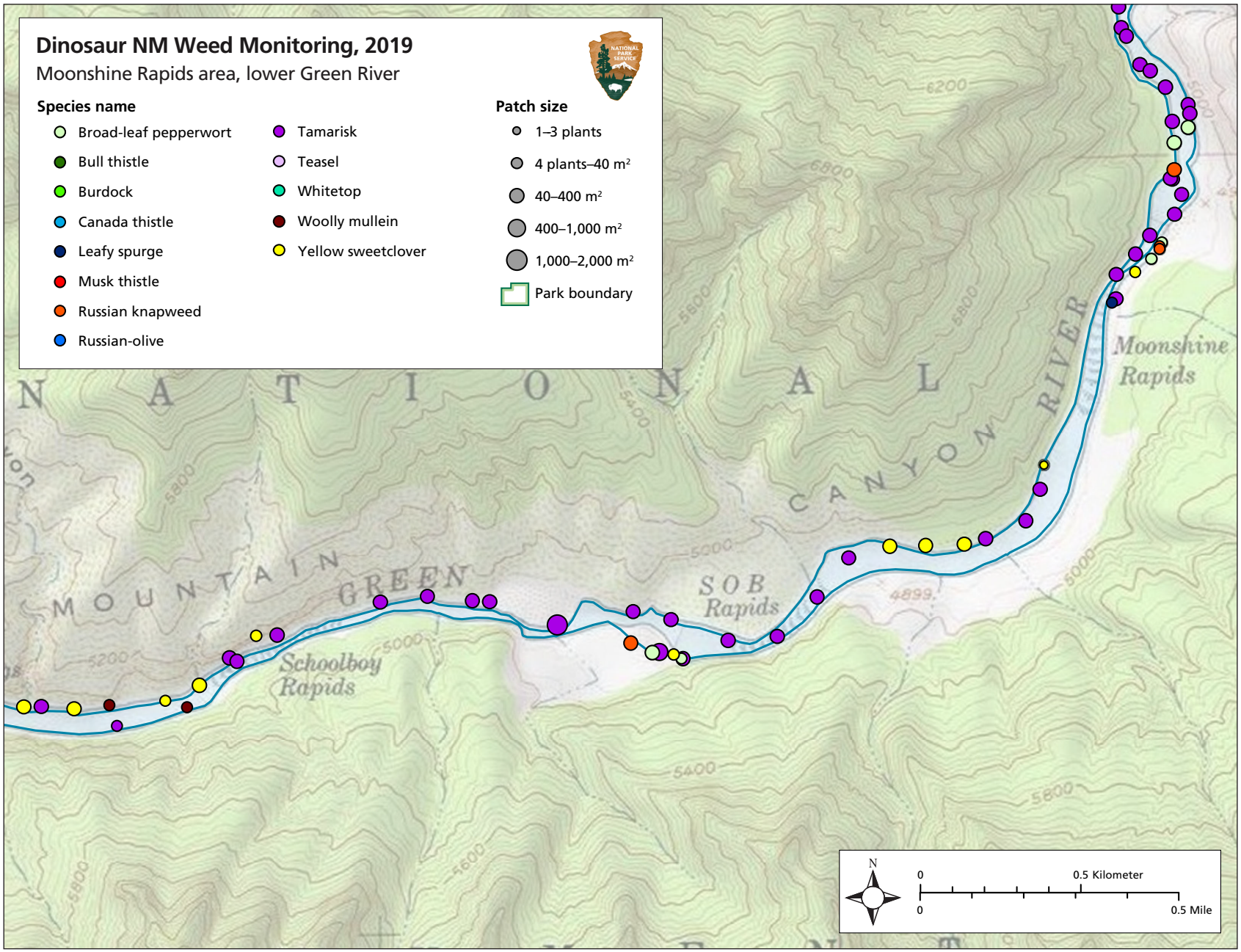


Figure 3-15. Invasive plants detected on monitoring routes around Moonshine Rapids on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

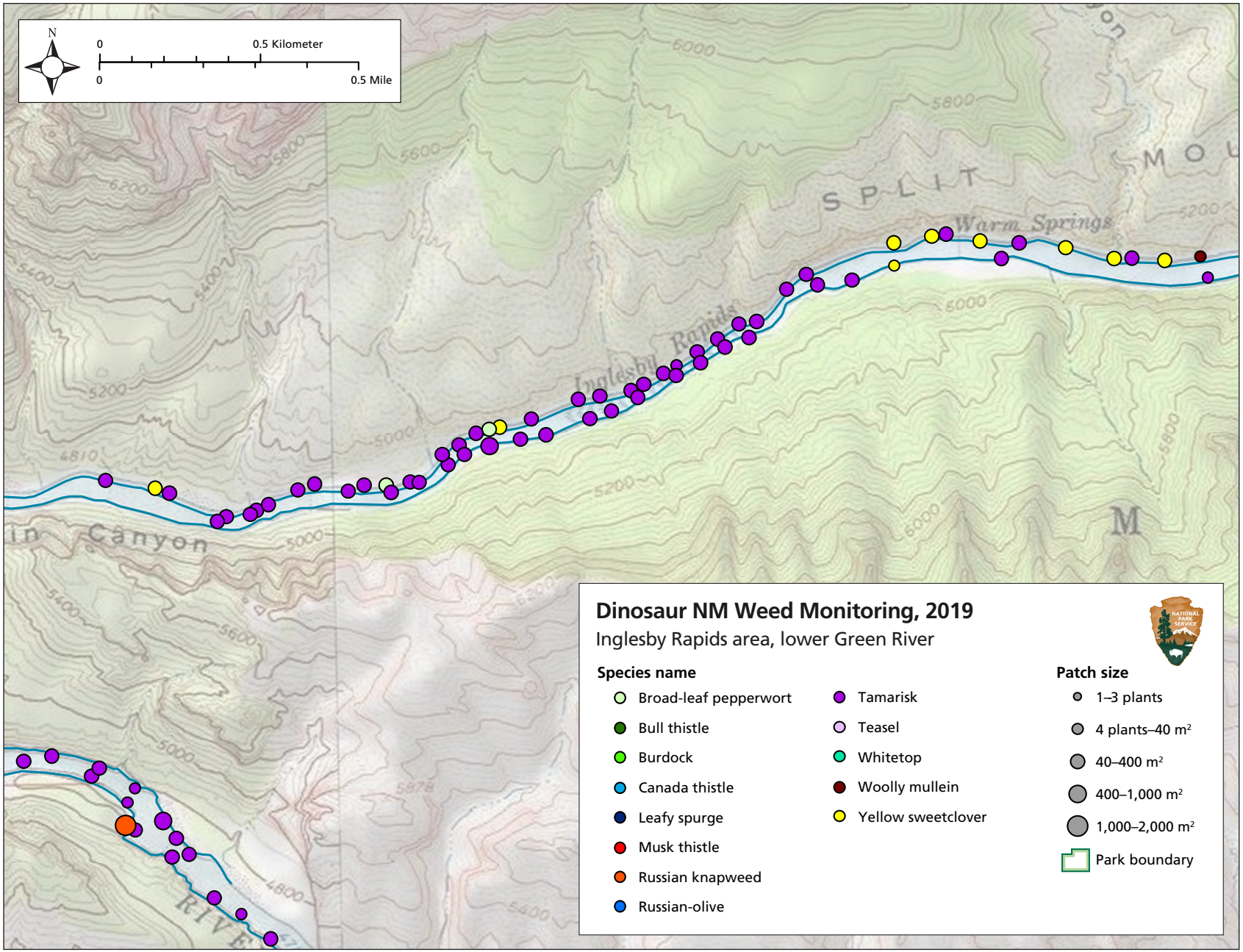


Figure 3-16. Invasive plants detected on monitoring routes around Inglesby Rapids on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

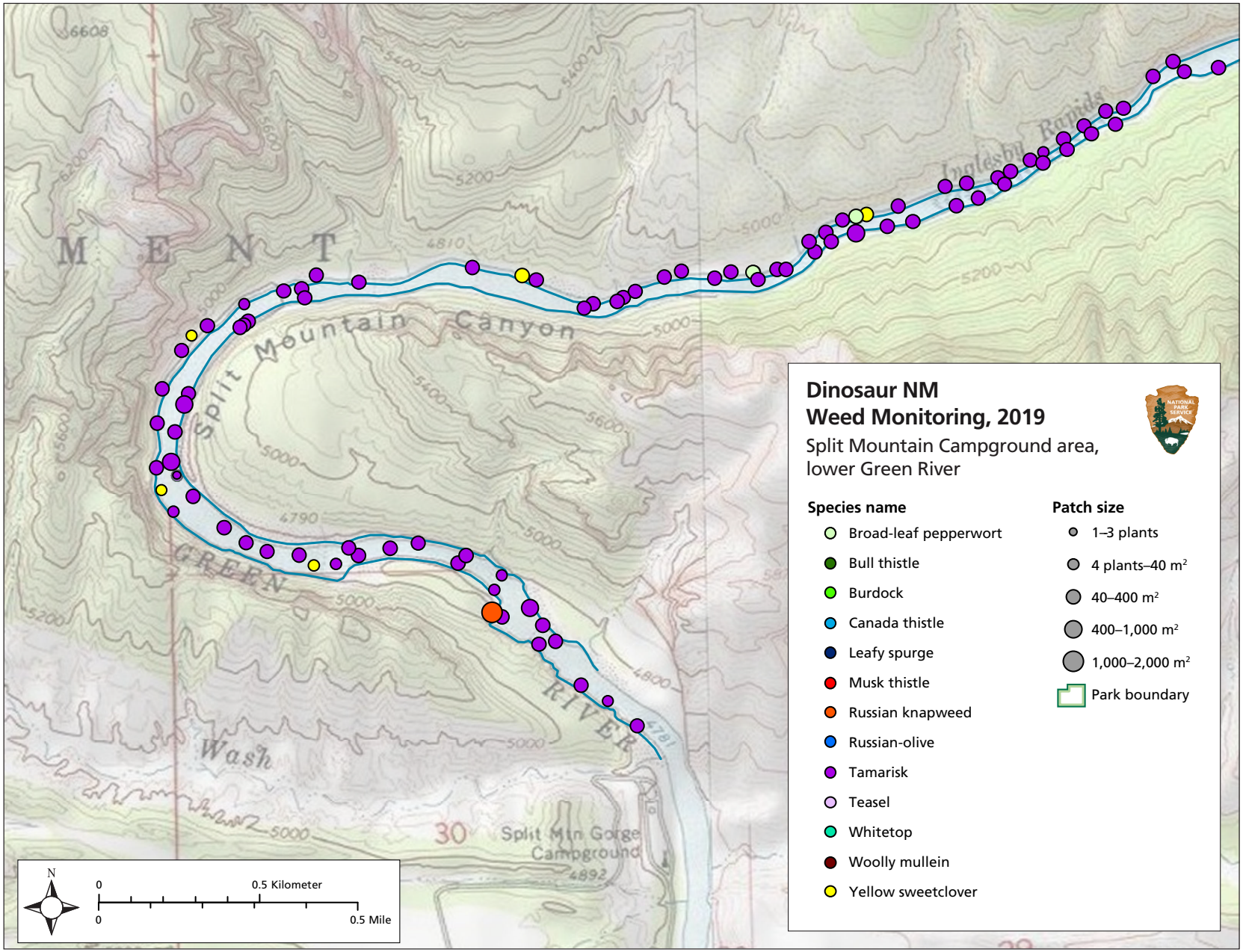


Figure 3-17. Invasive plants detected on monitoring routes around the Split Mountain Campground on the Green River at Dinosaur National Monument, June 26 to July 2, 2019.

Table 3-2. Number of priority IEP patches per route surveyed at Dinosaur National Monument, June 29–July 6, 2017 and June 26–July 2, 2019.

Route	Year	Length (km)	Patches	Patches/km
Upper Green River	2019	65.861	1,378	20.92
Lower Green River	2019	82.889	1,157	13.96
Yampa River	2017	151.910	1,354	8.91

Table 3-3. Species observed, patch size, and patch management index along the upper Green River (UG), lower Green River (LG), and Yampa (YA) River monitoring routes, Dinosaur National Monument, June 29–July 6, 2017 (Yampa River) and June 26–July 2, 2019 (Green River).

Scientific name	Common name	River	Total patches (#/km)	Patch size class[1]					Patch management index[2]				
				1	2	3	4	5	1	2	3	4	5
Arctium minus	burdock	UG	1 (0.02)	1	0	0	0	0	1	0	0	0	0
Arctium minus	burdock	LG	2 (0.02)	1	0	1	0	0	1	1	0	0	0
Arctium minus	burdock	YA	0 (0.00)	0	0	0	0	0	0	0	0	0	0
Cardaria sp.	whitetop	UG	2 (0.02)	0	1	1	0	0	1	1	0	0	0
Cardaria sp.	whitetop	LG	2 (0.02)	0	1	1	0	0	0	2	0	0	0
Cardaria sp.	whitetop	YA	4 (0.03)	1	3	0	0	0	3	1	0	0	0
Carduus nutans	musk thistle	UG	38 (0.58)	16	12	9	0	1	26	12	0	0	0
Carduus nutans	musk thistle	LG	32 (0.39)	6	12	13	0	1	14	17	1	0	0
Carduus nutans	musk thistle	YA	27 (0.18)	4	15	6	1	1	18	9	0	0	0
Centaurea repens	Russian knapweed	UG	30 (0.46)	0	8	13	8	1	5	16	8	1	0
Centaurea repens	Russian knapweed	LG	59 (0.71)	0	6	31	10	12	5	25	26	3	0
Centaurea repens	Russian knapweed	YA	81 (0.53)	10	39	19	8	5	29	40	9	3	0
Cirsium arvense	Canada thistle	UG	127 (1.93)	0	34	77	9	7	33	80	11	3	0
Cirsium arvense	Canada thistle	LG	74 (0.89)	1	11	39	13	10	6	48	18	2	0
Cirsium arvense	Canada thistle	YA	24 (0.16)	3	7	7	5	2	9	11	4	0	0
Cirsium vulgare	bull thistle	UG	13 (0.20)	5	6	2	0	0	9	4	0	0	0
Cirsium vulgare	bull thistle	LG	1 (0.01)	0	0	1	0	0	0	0	1	0	0
Cirsium vulgare	bull thistle	YA	2 (0.01)	1	1	0	0	0	2	0	0	0	0

[1]Patch size classes: 1 = 1–3 plants (≤2 × 2 m), 2 = 4 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]Patch size class × Patch density. 1–5 = very low, 6–10 = low, 11–15 = moderate, 16–20 = high, 21–25 = very high.

Table 3-3 (cont.). Species observed, patch size, and patch management index along the upper Green River (UG), lower Green River (LG), and Yampa (YA) River monitoring routes, Dinosaur National Monument, June 29–July 6, 2017 (Yampa River) and June 26–July 2, 2019 (Green River).

Scientific name	Common name	River	Total patches (#/km)	Patch size class[1]					Patch management index[2]				
				1	2	3	4	5	1	2	3	4	5
Dipsacus sylvestris	teasel	UG	4 (0.06)	1	2	1	0	0	3	1	0	0	0
Dipsacus sylvestris	teasel	LG	0 (0.00)	0	0	0	0	0	0	0	0	0	0
Dipsacus sylvestris	teasel	YA	0 (0.00)	0	0	0	0	0	0	0	0	0	0
Elaeagnus angustifolia	Russian-olive	UG	1 (0.02)	1	0	0	0	0	1	0	0	0	0
Elaeagnus angustifolia	Russian-olive	LG	1 (0.01)	1	0	0	0	0	1	0	0	0	0
Elaeagnus angustifolia	Russian-olive	YA	10 (0.07)	8	2	0	0	0	9	1	0	0	0
Euphorbia esula	leafy spurge	UG	2 (0.02)	0	0	2	0	0	0	2	0	0	0
Euphorbia esula	leafy spurge	LG	33 (0.40)	3	13	10	6	1	7	21	5	0	0
Euphorbia esula	leafy spurge	YA	56 (0.37)	25	31	0	0	0	50	6	0	0	0
Hyoscyamus niger	black henbane	UG	0 (0.00)	0	0	0	0	0	0	0	0	0	0
Hyoscyamus niger	black henbane	LG	0 (0.00)	0	0	0	0	0	0	0	0	0	0
Hyoscyamus niger	black henbane	YA	1 (0.01)	1	0	0	0	0	1	0	0	0	0
Lepidium latifolium	broad-leaf pepperwort	UG	161 (2.44)	2	70	84	5	0	96	65	0	0	0
Lepidium latifolium	broad-leaf pepperwort	LG	170 (2.05)	0	20	84	34	32	34	121	14	1	0
Lepidium latifolium	broad-leaf pepperwort	YA	90 (0.59)	16	48	16	7	3	75	15	0	0	0
Melilotus officinalis	yellow sweetclover	UG	149 (2.26)	13	87	47	2	0	123	24	2	0	0
Melilotus officinalis	yellow sweetclover	LG	86 (1.04)	3	44	37	2	0	65	20	1	0	0
Melilotus officinalis	yellow sweetclover	YA	348 (2.29)	15	195	118	12	8	242	99	5	0	0
Tamarix sp.	tamarisk	UG	850 (12.91)	10	64	670	67	39	256	560	33	1	0
Tamarix sp.	tamarisk	LG	697 (8.41)	16	43	473	71	94	168	496	32	1	0
Tamarix sp.	tamarisk	YA	711 (4.68)	121	302	209	51	28	454	238	18	1	0
Verbascum thapsus[3]	woolly mullein	UG	1 (0.02)	0	0	0	0	1	0	1	0	0	0
Verbascum thapsus[3]	woolly mullein	LG	29 (0.35)	7	13	8	0	1	21	8	0	0	0
Verbascum thapsus[3]	woolly mullein	YA	1 (0.01)	0	1	0	0	0	1	0	0	0	0
Total priority species		UG	1,378 (20.92)	49	284	906	91	48	554	765	54	5	0
Total priority species		LG	1,157 (13.96)	31	150	690	136	150	301	751	98	7	0
Total priority species		YA	1,354 (8.91)	205	643	375	84	47	892	420	36	6	0

[1]Patch size classes: 1 = 1–3 plants (≤2 × 2 m), 2 = 4 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]Patch size class × Patch density. 1–5 = very low, 6–10 = low, 11–15 = moderate, 16–20 = high, 21–25 = very high.
[3]Not a priority species

for most patches was low or very low on all three reaches (Yampa, 96.9%; upper Green, 95.7%; lower Green, 90.9%). (Table 3-3). The majority (63.9%) of tamarisk patches on the Yampa had very low PMI, but that percentage dropped to 30.1% on the upper Green and 24.1% on the lower Green. The percentage of tamarisk patches recorded as mature trees was lower on the Yampa River (12.8%) than on the upper (51.4%) or lower (57.5%) Green River (Table 3-4).

3.3 Monitoring transects

In 2019, a total of 75 transects were completed along the upper (33) and lower (42) Green River (Appendix B at https://irma.nps.gov/DataStore/Reference/Profile/2256018). Five priority IEP species were recorded in transects (Tables 3-5, 3-6). Cheatgrass was the most widespread priority species, found in 48.4% (upper) and 64.3% (lower) of Green River transects. Tamarisk was found in 30.3% (upper) and 40.5% (lower) of transects, and yellow sweetclover in 15.2% (upper) and 16.7% (lower). Percent cover was similar among species and total percent cover between the upper and lower Green River. However, the Yampa River had lower percent covers than either stretch of the Green River (Table 3-7).

3.4 Results comparisons

The upper and lower Green River and Yampa River through Dinosaur National Monument have now been monitored three times (Dewey and Anderson 2005; Perkins 2012; Washuta et al. 2018). Fifteen species from the IEP priority lists were found during one or more surveys (Table 3-8). The most common species included broad-leaf pepperwort, yellow sweetclover, and tamarisk.*

Due to differences in methodology, only broad comparisons can be made between the surveys conducted by USU in 2002–2005 and the two more recent sampling periods completed by NCPN staff (Figures 3-18 to 3-20). When there are similar patterns between the monitoring routes and the monitoring transects, there is more confidence that these results are biologically meaningful.

The total number of IEP patches has generally increased on the Yampa River, while being more stable on the upper and lower Green River (see Table 3-8). While not mapped on the monitoring routes, percent cover and percent frequency of cheatgrass increased on all three river sections between 2010–2011 and 2017–2019. The number of

*Because some areas were not surveyed in all three time periods, numbers in tables 3-8, 3-9, 3-10 only reflect areas commonly surveyed over all three time periods. For this reason, they do not match numbers from the same areas listed in this report and previous reports.

Table 3-4. Growth stage for woody invasive exotic plant species patches recorded for Yampa River monitoring routes (2017) and Green River (2019), Dinosaur National Monument.

Scientific name	Common name	River	Total patches	Growth stage			Not designated
				Seedling	Sapling	Mature	
Elaeagnus angustifolia	Russian-olive	UG	1	0	0	1	0
Elaeagnus angustifolia	Russian-olive	LG	1	0	1	0	0
Elaeagnus angustifolia	Russian-olive	YA	10	3	7	0	0
Tamarix sp.	tamarisk	UG	850	4	405	437	4
Tamarix sp.	tamarisk	LG	697	1	289	401	6
Tamarix sp.	tamarisk	YA	711	151	456	91	13
Ulmus pumila[1]	Siberian elm	YA	2	1	1	0	0

[1]Not a priority species

Table 3-5. Priority IEP species observed in transects on the upper Green River and average percent cover across all transects in Dinosaur National Monument, 2010–2011 and 2019.

Scientific name	Common name	Year (transects)	% transects present	Average percent cover (SE)
Bromus tectorum	cheatgrass	2010–2011 (n=72)	8.3%	0.11% (0.05)
Bromus tectorum	cheatgrass	2019 (n=33)	48.4%	2.77% (0.97)
Centaurea repens	Russian knapweed	2010–2011 (n=72)	2.8%	0.12% (0.10)
Centaurea repens	Russian knapweed	2019 (n=33)	3.0%	0.01% (0.01)
Cirsium arvense	Canada thistle	2010–2011 (n=72)	18.1%	0.31% (0.15)
Cirsium arvense	Canada thistle	2019 (n=33)	9.1%	0.32% (0.31)
Lepidium latifolium	broad-leaf pepperwort	2010–2011 (n=72)	20.8%	0.40% (0.28)
Lepidium latifolium	broad-leaf pepperwort	2019 (n=33)	0.0%	0%
Melilotus officinalis	yellow sweetclover	2010–2011 (n=72)	1.3%	<0.01% (<0.01)
Melilotus officinalis	yellow sweetclover	2019 (n=33)	15.2%	0.18% (0.08)
Tamarix sp.	tamarisk	2010–2011 (n=72)	52.7%	3.59% (1.04)
Tamarix sp.	tamarisk	2019 (n=33)	30.3%	1.48% (0.72)
All priority species		2010–2011 (n=72)	70.8%	4.54% (1.06)
All priority species		2019 (n=33)	69.7%	4.59% (1.34)

Table 3-6. Priority IEP species observed in transects on the lower Green River and average percent cover across all transects in Dinosaur National Monument, 2010–2011 and 2019.

Scientific name	Common name	Year (transects)	% transects present	Average percent cover (SE)
Bromus tectorum	cheatgrass	2010–2011 (n=97)	47.4%	0.21% (0.09)
Bromus tectorum	cheatgrass	2019 (n=42)	64.3%	3.30% (1.05)
Cirsium arvense	Canada thistle	2010–2011 (n=72)	3.1%	<0.01% (<0.01)
Cirsium arvense	Canada thistle	2019 (n=42)	9.5%	0.42% (0.25)
Lepidium latifolium	broad-leaf pepperwort	2010–2011 (n=72)	2.1%	0.01% (0.01)
Lepidium latifolium	broad-leaf pepperwort	2019 (n=42)	9.5%	0.14% (0.11)
Melilotus officinalis	yellow sweetclover	2010–2011 (n=72)	4.1%	0.01% (0.01)
Melilotus officinalis	yellow sweetclover	2019 (n=42)	16.7%	0.18% (0.09)
Tamarix sp.	tamarisk	2010–2011 (n=72)	27.8%	1.45% (0.53)
Tamarix sp.	tamarisk	2019 (n=42)	40.5%	1.87% (0.65)
All priority species		2010–2011 (n=72)	63.9%	2.26% (0.59)
All priority species		2019 (n=42)	83.3%	5.74% (1.42)

Table 3-7. Priority IEP species observed in transects on the Yampa River and average percent cover across all transects in Dinosaur National Monument, 2010–2011 and 2017.

Scientific name	Common name	Year (transects)	% transects present	Average percent cover (SE)
Bromus tectorum	cheatgrass	2010 (n=80)	1.3%	0.04% (0.04)
Bromus tectorum	cheatgrass	2017 (n=76)	53.9%	0.35% (0.10)
Centaurea repens	Russian knapweed	2010 (n=80)	0.0%	0.00%
Centaurea repens	Russian knapweed	2017 (n=76)	1.3%	0.02% (0.02)
Cirsium arvense	Canada thistle	2010 (n=80)	0.0%	0.00%
Cirsium arvense	Canada thistle	2017 (n=76)	1.3%	0.01% (0.01)
Melilotus officinalis	yellow sweetclover	2010 (n=80)	2.5%	0.02% (0.02)
Melilotus officinalis	yellow sweetclover	2017 (n=76)	5.3%	0.16% (0.10)
Tamarix sp.	tamarisk	2010 (n=80)	7.5%	0.57% (0.31)
Tamarix sp.	tamarisk	2017 (n=76)	6.6%	0.08% (0.05)
All priority species		2010 (n=80)	15.3%	0.68% (0.30)
All priority species		2017 (n=76)	60.5%	0.61% (0.14)

Table 3-8. Number of IEP priority species along the upper Green River (UG), lower Green River (LG), and Yampa River (YA) monitoring routes in Dinosaur National Monument during three sample periods (2002–2005, 2010–2011, and 2017–2019).[1]

Scientific name	Common name	Reach	2002–2005	2010–2011	2017–2019
Arctium minus	burdock	UG	2	0	1
Arctium minus	burdock	LG	13	3	2
Arctium minus	burdock	YA	4	0	0
Cardaria sp.[2]	whitetop	UG	3	0	2
Cardaria sp.[2]	whitetop	LG	0	0	3
Cardaria sp.[2]	whitetop	YA	7	0	4
Carduus nutans	musk thistle	UG	22	14	38
Carduus nutans	musk thistle	LG	2	34	69
Carduus nutans	musk thistle	YA	6	5	27
Centaurea maculosa	spotted knapweed	UG	0	1	0
Centaurea maculosa	spotted knapweed	LG	0	0	0
Centaurea maculosa	spotted knapweed	YA	0	0	0
Centaurea repens	Russian knapweed	UG	31	45	30
Centaurea repens	Russian knapweed	LG	63	39	64
Centaurea repens	Russian knapweed	YA	68	62	81
Cirsium arvense	Canada thistle	UG	178	178	127
Cirsium arvense	Canada thistle	LG	219	120	90
Cirsium arvense	Canada thistle	YA	25	44	24
Cirsium vulgare	bull thistle	UG	30	21	13
Cirsium vulgare	bull thistle	LG	10	4	10
Cirsium vulgare	bull thistle	YA	2	5	2
Dipsacus sylvestris	teasel	UG	0	0	4
Dipsacus sylvestris	teasel	LG	0	0	0
Dipsacus sylvestris	teasel	YA	0	0	0
Elaeagnus angustifolia	Russian-olive	UG	0	0	1
Elaeagnus angustifolia	Russian-olive	LG	0	5	1
Elaeagnus angustifolia	Russian-olive	YA	4	6	10
Euphorbia esula	leafy spurge	UG	0	1	2
Euphorbia esula	leafy spurge	LG	12	6	34
Euphorbia esula	leafy spurge	YA	12	35	56
Hyocyamus niger	black henbane	UG	0	0	0
Hyocyamus niger	black henbane	LG	0	0	0
Hyocyamus niger	black henbane	YA	0	0	1
Lepidium latifolium	broad-leaf pepperwort	UG	307	223	161
Lepidium latifolium	broad-leaf pepperwort	LG	352	377	23
Lepidium latifolium	broad-leaf pepperwort	YA	216	183	90

[1]Note that these are different totals than elsewhere in the report due to matching the same areas monitored over all three sampling periods.

[2]Recorded as *Cardaria draba* in 2002–2005.

Table 3-8 (cont.). Number of IEP priority species along the upper Green River (UG), lower Green River (LG), and Yampa River (YA) monitoring routes in Dinosaur National Monument during three sample periods (2002–2005, 2010–2011, and 2017–2019).

Scientific name	Common name	Reach	2002–2005	2010–2011	2017–2019
Linaria dalmatica	Dalmatian toadflax	UG	0	0	0
Linaria dalmatica	Dalmatian toadflax	LG	0	0	0
Linaria dalmatica	Dalmatian toadflax	YA	1	0	0
Melilotus officinalis	yellow sweetclover	UG	24	98	149
Melilotus officinalis	yellow sweetclover	LG	261	220	96
Melilotus officinalis	yellow sweetclover	YA	83	261	348
Tamarix sp.	tamarisk	UG	569	266	850
Tamarix sp.	tamarisk	LG	1,831	904	786
Tamarix sp.	tamarisk	YA	407	508	711
All species 2010–2019		UG	1,166	849	1,378
All species 2010–2019		LG	NA	1,712	1,389
All species 2010–2019		YA	835	1109	1,354

[1]Note that these are different totals than elsewhere in the report due to matching the same areas monitored over all three sampling periods.

[2]Recorded as *Cardaria draba* in 2002–2005.

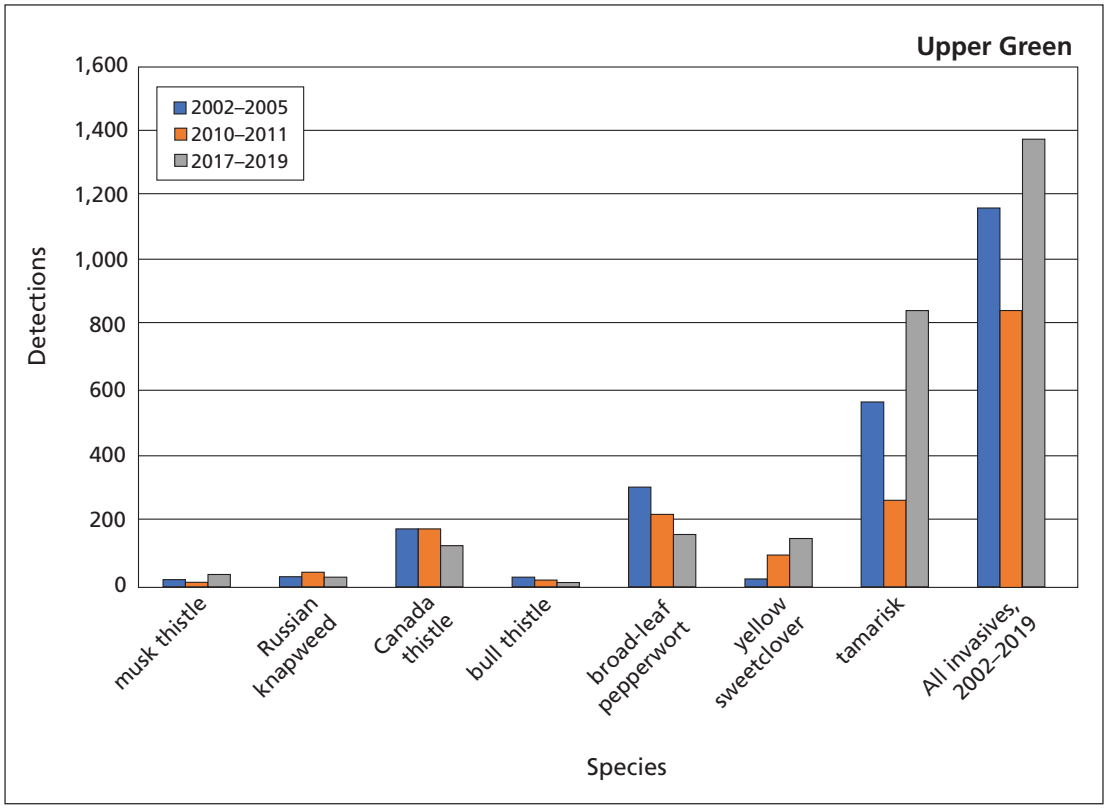


Figure 3-18. Invasive plants detected on three rotations of monitoring routes along the Green River above the confluence with the Yampa River from 2002 to 2019. Only species with more than 50 total detections are shown.

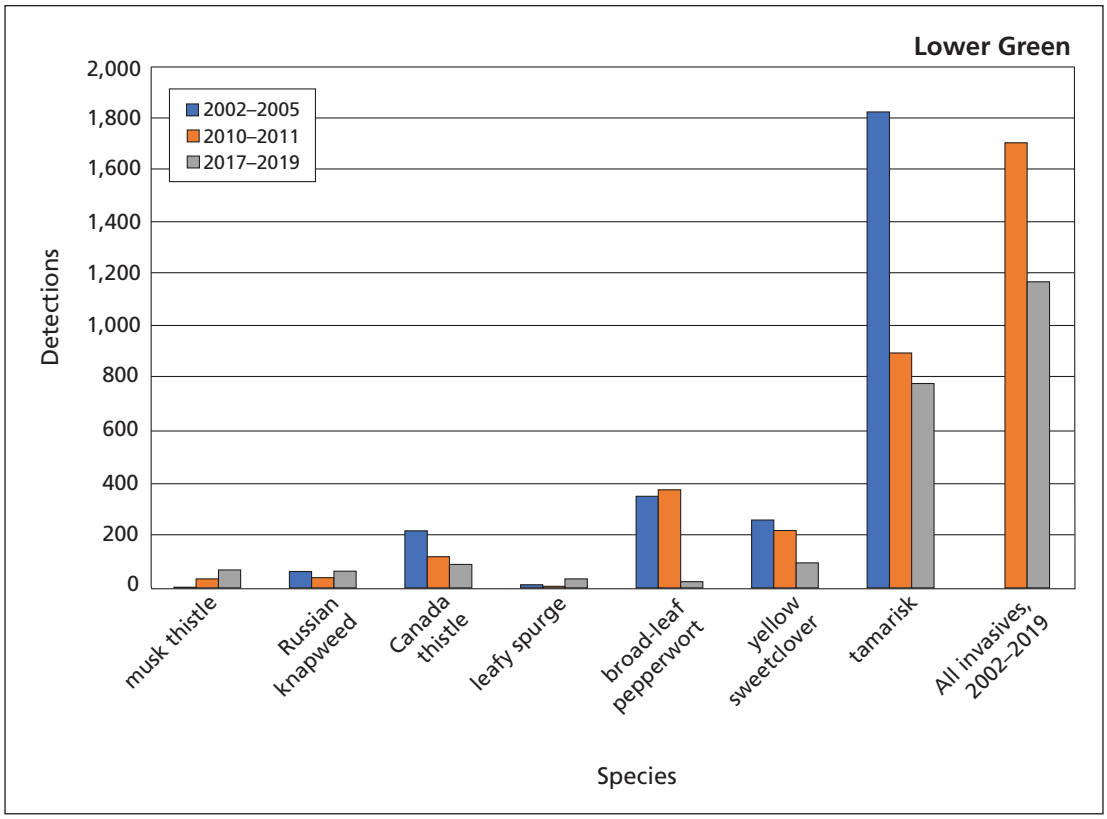


Figure 3-19. Invasive plants detected on three rotations of monitoring routes along the Green River below the confluence with the Yampa River from 2002 to 2019. Only species with more than 50 total detections are shown. Totals for all invasives are not comparable across all years due to differences in survey methodology.

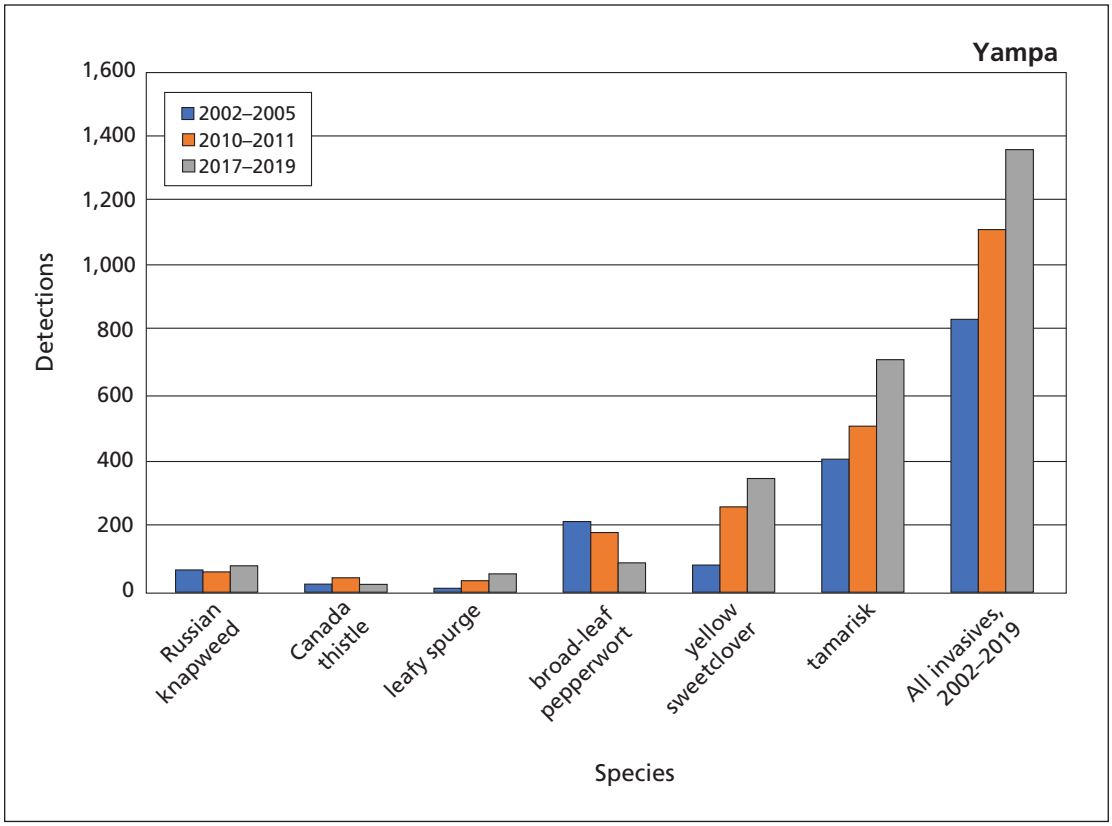


Figure 3-20. Invasive plants detected on three rotations of monitoring routes along the Green River above the confluence with the Yampa River from 2002 to 2019. Only species with more than 50 total detections are shown.

musk-thistle patches increased on all three river reaches over the three sample periods.

On the upper Green River, yellow sweetclover has increased in percent cover, percent frequency, and number of patches. Tamarisk has notably increased in patch numbers but not in percent cover or percent frequency since 2010–2011. Conversely, broad-leaf pepperwort patches have generally decreased in percent cover, percent frequency, and number of patches. In 2019, NCPN monitoring detected teasel for the first time, on the upper Green River.

On the lower Green River, yellow sweetclover and tamarisk have increased in percent frequency—but the number of sweetclover patches has decreased, while tamarisk largely stayed the same from 2010–2011 to 2017–2019. Leafy spurge patches have increased on the lower Green River and Yampa River over the three time periods. Yellow sweetclover and tamarisk patches have increased on the Yampa River.

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. Absence data for non-priority species are less reliable, 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 [broad-leaf pepperwort] 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 largely unregulated flows of the Yampa River continue to maintain a more native riparian vegetation community than that of the regulated Green River, as reported by Perkins and others (2015). The Yampa River continues to have lower numbers of IEP patches, lower percent cover, and lower percent frequency of IEPs. The lower Green River, which is partially restored (less regulated) below its confluence with the Yampa, has moderate numbers of IEPs, while the highly regulated upper Green River has the highest numbers of IEPs. The upper Green River has more than twice as many IEP patches per kilometer than the Yampa River. The Green River also has a higher percentage of large (>40 m^2) patches than the Yampa. The Yampa has lots of small (<40 m^2) tamarisk patches with the potential to be removed by the next round of scouring floods. The Green River also has more patches with higher PMI than the Yampa does, and a larger percentage of tamarisk patches classified as mature trees. Patches that are larger, higher in PMI, and more mature all represent older, more established patches.

Tamarisk has consistently been the most prevalent IEP species on all monitoring routes. From 2002 to 2017, tamarisk generally increased on the Yampa River, while remaining more stable on the upper and lower Green River—perhaps even decreasing on the lower Green River. The number of patches along the Yampa continues to be lower than on the Green River. The increases on the Yampa likely indicate there is still niche space available for invasives to colonize there, while on the upper Green River, most spaces are already occupied with invasives. It should be noted that the tamarisk beetle (*Diorhabda elongata*) was released as a biocontrol in the monument in 2006 and 2007. It is also likely that removal efforts by monument staff and volunteers between 2010 and 2019 have affected tamarisk populations, particularly in the more dense patches on the Green River. However, increases on the Yampa River should be continued to be monitored and controlled where possible.

The Colorado Department of Agriculture has coordinated with monument staff to release two insect species for biological control of Russian knapweed in Yampa Canyon: the gall midge (*Jaapiella ivannikovi*) and the gall wasp (*Aulacidea acroptilonica*). A release of 4,000 insects occurred at six sites on May 6–7, 2021. If the insects take to the sites, there will be additional releases in 2022 and 2023. We will attempt to follow any effects these insects have on knapweed in future reports.

Yellow sweetclover is widespread across monitoring areas and has increased on all three river reaches 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 and increased in cover

from 2010–2011 to 2017–2019. The steep rise in the number of transects containing cheatgrass from 2010–2011 to 2017–2019 could indicate an expansion of this species in the river corridor. When higher covers occur, this fire-prone species can alter the fire regime.

The increase in cheatgrass could be related to a comparative lack of flood-stage events sufficient to have scoured grasses from the banks prior to monitoring in 2017 and 2019. On the Yampa River, there was one peak above 20,000 cfs and four peaks above 15,000 cfs in the six years prior to 2010. But in the six years prior to 2017, there were no floods above 20,000 cfs and just two above 15,000 cfs. A large (27,400 cfs) flood in 2011 likely scoured away vegetation, but the next surveys did not take place until six years later, in 2017. Similarly, on the Green River, there were four peaks above 20,000 cfs in the six years prior to summer sampling in 2011, including the largest flood in the last 20 years (32,200 cfs, in 2011). But in the eight years prior to 2019, the gage at Jensen, Utah, recorded just three flows above 20,000 cfs. Changes in precipitation could also have influenced the amount of cheatgrass, an annual plant.

Several IEPs with rising or steady populations are potential candidates for control, or are already being treated.

- Musk thistle has increased on all three river reaches.
- Yellow sweetclover has increased on all three river reaches.
- Leafy spurge is increasing on the lower Green River and Yampa River.
- Teasel has always been a concern to park managers. It showed up for the first time in NCPN monitoring in 2019, with four patches on the upper Green River.

IEPs will generally be monitored at the same time of year. Consistency in timing of monitoring should ensure consistency in detection probabilities and cover estimates of most species. For many species, sampling any time from post-peak flow in late May through September is not expected to drastically alter the chances of detecting invasive species at a level larger than the minimum detection target size. Long-term trend reporting will focus on trends in species distributions, trends in percent cover of individual species, and changes in IEP percent cover of priority species by monitoring route. Extra-area surveys will also be considered for inventories at the park's request. NCPN will return to Dinosaur NM in 2022 to begin the fourth monitoring rotation.

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