



Invasive Exotic Plant Monitoring in Capitol Reef National Park

2011 Field Season

Natural Resource Technical Report NPS/NCPN/NRTR—2012/555



ON THE COVER

Oak Creek, Capitol Reef National Park. NPS photo.

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Abstract

Invasive exotic plant (IEP) species are a significant threat to natural ecosystem integrity and biodiversity, and controlling them is a high priority for the National Park Service. The Northern Colorado Plateau Network (NCPN) selected the early detection of IEPs as one of 10 monitoring protocols to be implemented as part of its long-term monitoring program. During surveys conducted on September 27–29, 2011, Capitol Reef National Park staff detected four IEP species on monitoring routes and transects along 7.3 kilometers of Oak Creek. Of the invasive species considered priority species for the park, only tamarisk (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*) were detected. Tamarisk was by far the most common (68 of 69 infestations) IEP detected along monitoring routes. While infestations were widespread, actual IEP percent cover was low in Oak Creek. Both tamarisk and Russian olive were present in numbers similar to those recorded during surveys in 2003.

Acronyms

BFP	Between Feature Position
CARE	Capitol Reef National Park
EDD	effective detection distance
EDSW	effective detection swath width
IEP	invasive exotic plant
MDTS	minimum detection target size
NCPN	Northern Colorado Plateau Network
NP	national park
NPS	National Park Service
PSR	patch separation resolution

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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 target 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 it may miss exotic plants dispersed to the interior areas of large parks by wind and/or animals. This report summarizes the 2011 field season at Capitol Reef National Park (CARE).

Specific objectives of NCPN invasive exotic plant monitoring are:

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

2 Methods

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

2.1 Developing a park target invasive exotic plant list

Prior to beginning monitoring in 2011, NCPN and Capitol Reef NP staff reviewed the park's list of high-priority target IEPs (see Appendix A), initially created in 2009. 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. Our high-priority target IEP list includes existing IEPs and potential IEPs of high management concern. Because these methods are designed to be rapid, field crews are trained to develop a focused search image on the target plants, instead of looking for every possible invasive plant species. The likelihood of eradicating these target species, or containing them within a park, is generally high. The list of priority species is reviewed before each field season. Although there were no changes to the list between the 2009 and 2010 field seasons, alfalfa (*Medicago sativa*) was dropped for the 2011 field season.

2.2 Monitoring routes

2.2.1 Minimum detection target size

The minimum detection target size (MDTS) represents the patch size that is large enough to be detected with a high level of confidence (typically at least 90% of the total number of patches of that size and larger in the monitoring area) under actual field conditions, but small enough so 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 m² (0.01 acres or approximately 20 × 20 ft) for all IEPs. Use of the MDTS was necessary because field technicians are not expected to find every single plant of every targeted weed species during route surveys. Searching for single mature plants of some species, such as Russian olive (*Elaeagnus angustifolia*) and tamarisk (*Tamarix ramosissima*), is possible due to their large size. Single plants of other species, such as field bindweed (*Convolvulus arvensis*), are nearly impossible to detect in most field conditions.

2.2.2 Effective detection distance

The effective detection distance (EDD) is the maximum distance from which a searcher could consistently detect (i.e., see and recognize) the MDTS of the least-visible targeted species with at least 90% detection efficiency. Using fake plants of a targeted size, crew members are trained by walking away and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The size of the EDD is then estimated in the field by crew members. The distance is measured either by pacing or using a laser range-finder. The EDD for CARE in 2011 was 10 m.

2.2.3 Effective detection swath width

Effective detection swath width (EDSW) is defined as the maximum width of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the MDTS (Figure 2-1). The effective detection swath width (EDSW) is equal to two times the EDD, because the surveyor is able to effectively detect weeds for one EDD on either side of his/her search route. The EDSW was 20 m at CARE in 2011.

2.2.4 Patch separation resolution

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

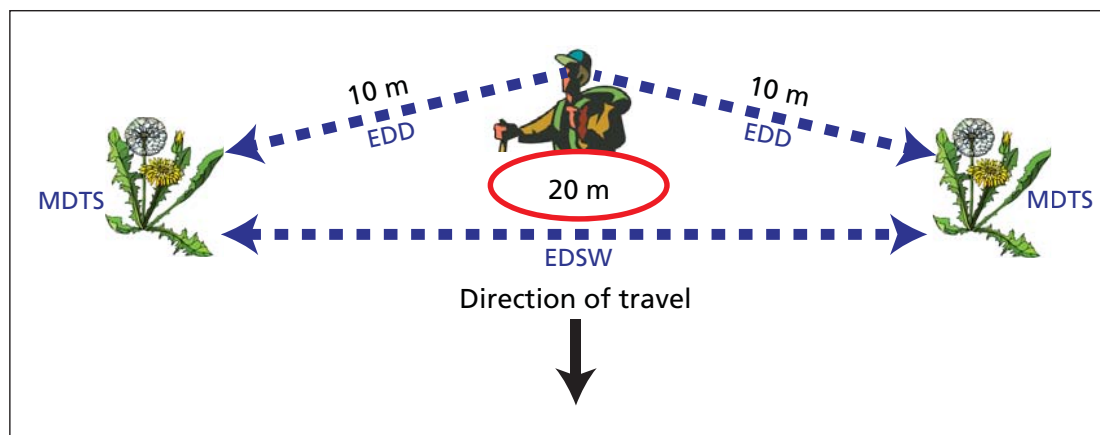


Figure 2-1. The maximum effective detection distance (EDD) at Capitol Reef NP was 10 meters, making the effective detection swath width (EDSW) 20 meters.

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

2.2.5 Between feature position

Between Feature Positions (BFPs) allow electronic tracking of a user's route. A GPS unit is set to automatically generate these positions at a distance equal to the EDSW. Each time a surveyor walks the equivalent of one EDSW, the GPS unit creates a point.

2.2.6 Data collection methods

We have established a four-year rotation of monitoring routes at CARE that covers Highway 24, Pleasant Creek cattle trails, Oak Creek cattle trails, and the Cathedral monitoring route (to be established in 2012) (Table 2-1, Figure 2-2). In 2013, the first round of the monitoring panel will be completed and re-visits will begin. Along Highway 24, the observer walks out on one side of the road and walks back on the other. For all other routes, the observer walks down the center of the trail/route. The Oak Creek cattle trail was monitored in 2011.

While walking, we searched for IEPs by visually scanning (side-to-side) all of the land within the borders of the swath. However, if the terrain was uneven or steep, and the observer had to glance frequently at the ground

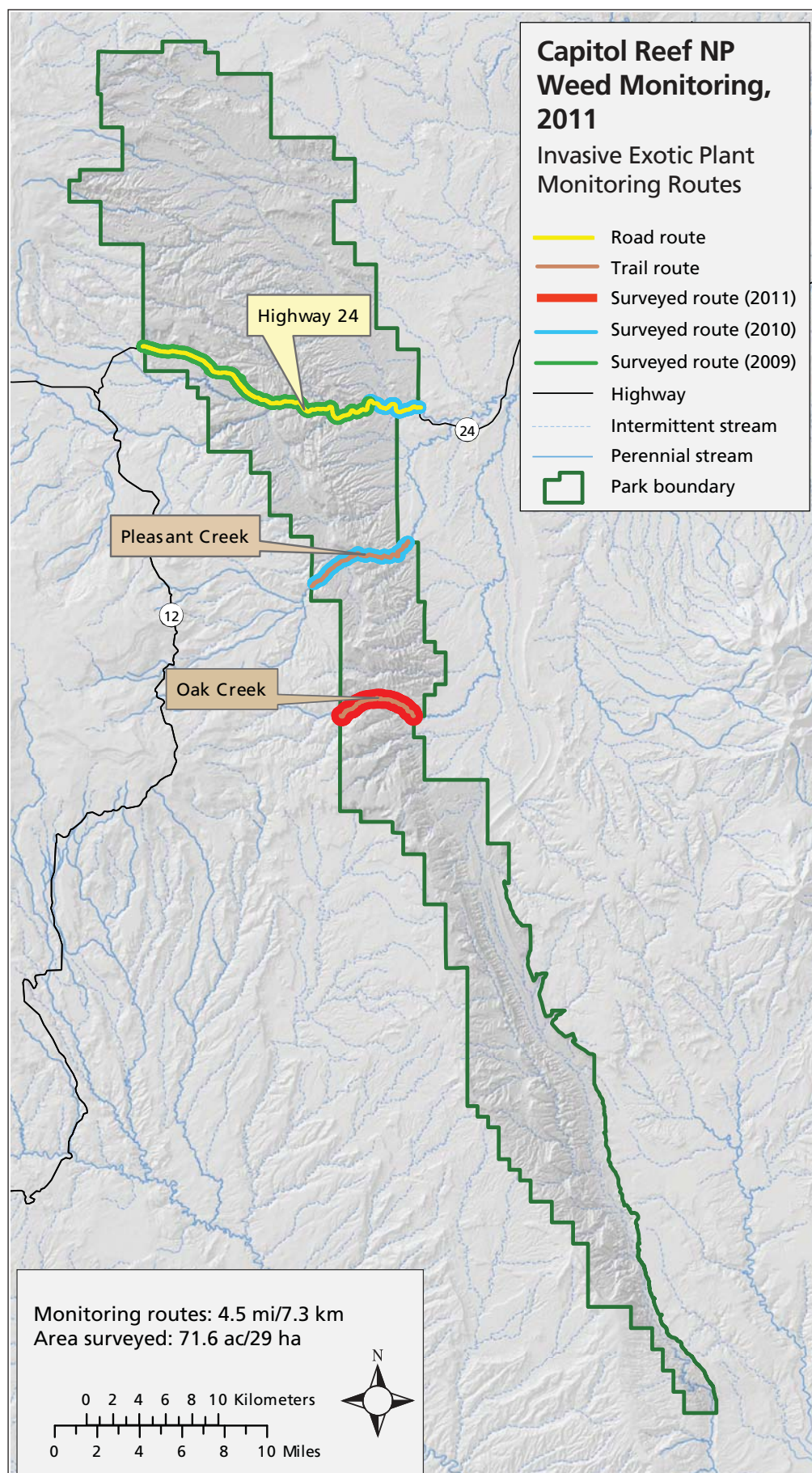
to ensure safe foot placement, then searchers stopped approximately every 20 m (the length of one EDSW) and visually scanned the area in all directions. As monitoring routes were traversed, locations of all target species were documented using global positioning system (GPS) units with at least five-meter accuracy. Only priority species were consistently recorded during monitoring routes. Survey crew members were permitted to record additional species if they were noteworthy.

When a priority IEP was discovered, we recorded the following information: (1) the monitoring route, (2) the sequential number of the invasion per monitoring route, (3) infestation size class (see below), (4) whether the plant was pulled, and (5) canopy cover

Table 2-1. Planned monitoring revisit design for invasive plant monitoring at Capitol Reef National Park.

Year	Monitoring routes
2009	Highway 24/Fremont Corridor
2010	Pleasant Creek
2011	Oak Creek
2012	Cathedral
2013	Highway 24/Fremont Corridor
2014	Pleasant Creek
2015	Oak Creek
2016	Cathedral
2017	Highway 24/Fremont Corridor
2018	Pleasant Creek
2019	Oak Creek
2020	Cathedral

Figure 2-2. Overview of invasive plant monitoring routes surveyed at Capitol Reef NP, September 27–29, 2011 (Oak Creek), July 12–September 24, 2010 (Pleasant Creek and the eastern portion of Highway 24), and July 28–October 8, 2009 (western portion of Highway 24).



class (see below). If several species were present with similar distributions at a single point, we recorded a point for each individual species and assigned it its own sequential identification number. Invasions more than 50 m (55 yards) apart were considered separate invasions and recorded with separate points.

Infestation size class was estimated as follows:

1. 1–a few plants (used for isolated single plants or very small patches ($\leq 2 \times 2$ 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), and
5. 1,000–2,000 m² (0.25–0.5 acre).

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

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

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

2.3 Monitoring transects

We established transects with three vegetation quadrats every 500 m along monitoring routes (see Figure 2-3). Our methods for sampling the monitoring quadrats were based on Stohlgren and others (2005). If no

invasives were detected for four consecutive transects (12 quadrats), then transects were established every 1,000 m. If invasive plants were found in categories greater than 1 for canopy cover class or infestation size class, then we reverted back to establishing transects every 500 m.

2.3.1 Quadrat establishment

We centered vegetation quadrats at 0.5, 5, and 10 m away from the edge of a road on the same side as the route being walked and on alternating sides for riparian areas, small roads, or trails. A 1-m² sampling frame, used to sample vegetation cover and soil surface features, was placed on the right side of the transect line as the technician walked the monitoring route. In some cases, we leveled the sampling frame by propping up quadrat corners. In 2009, quadrats were placed at 1, 6, and 11 m away from the monitoring route.

2.3.2 Data collection methods

In the monitoring quadrats, all priority IEP species observed were recorded, as well as cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola tragus*). 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 Analyses

We calculated the mean number of infestations per 100 m 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.

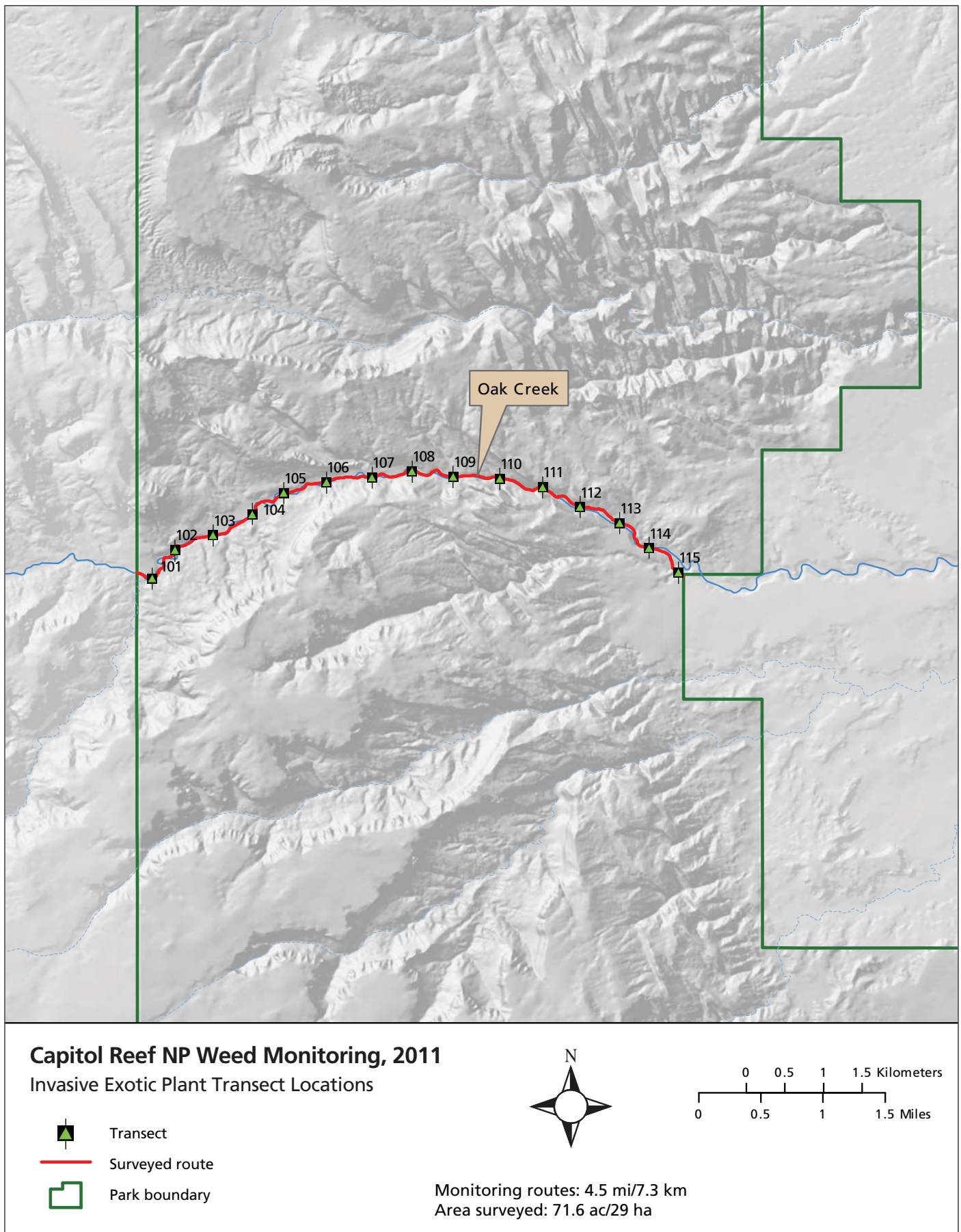


Figure 2-3. Monitoring routes and transects along the cattle trail at Oak Creek, Capitol Reef NP, September 27–29, 2011.

3 Results

3.1 Target invasive exotic plant list

There are 22 IEP species identified as priority species on the Capitol Reef NP target IEP list (Appendix A). Observers also record cheat-grass in monitoring quadrats if present, but none was found in quadrats in 2011. Observers are trained to recognize priority species, but given the freedom to map additional species; therefore, presence and absence data for priority species are reliable for the areas searched, but absence data for other species are suspect.

We recorded a total of four IEP species on monitoring routes and transects in 2011. Two IEP species were recorded on monitoring routes and three on monitoring transects. Of the eight IEP species detected, two were priority species (Table 3-1). We covered 29.0 hectares (71.6 acres) along 7.3 km (4.52 miles) of monitoring routes in 2011. A total of 160.0 hectares (419.9 acres) has been monitored over the past three years. Results from 2009 and 2010 are displayed in the table for

reference but not discussed in this report, as they have been addressed in previous years (Perkins 2010; Perkins and Lenhart 2011).

3.2 Monitoring routes

The survey crew covered the entire Oak Creek corridor in 2011, Pleasant Creek in 2010, and the entire Highway 24 corridor over 2009 (Perkins 2010) and 2010 (Perkins and Lenhart 2011). The results from previous years are shown in tables as reference but not discussed further. A total of 69 infestations of two different species (both priority species) were detected along the monitoring routes (Table 3-2; Figures 3-1, 3-2; Appendix B) in 2011. Sixty-eight of these infestations were tamarisk, while the other one was a Russian olive. This resulted in 0.95 priority infestations per 100 m along Oak Creek. Of the 68 tamarisk infestations, 41% were larger than 40 m² (Table 3-3). Both invasive species detected were trees. Of the 69 tree infestations, 20 were in the sapling stage and 49 were mature trees (see Appendix B). Oak Creek had more infestations in the western portion than the eastern portion (see Figures 3-1 and 3-2).

Table 3-1. Invasive exotic plants detected at Capitol Reef National Park, September 27–29, 2011.

Scientific name	Common name	Method detected		Park priority?
		Route	Transect	
<i>Elaeagnus angustifolia</i>	Russian olive	X		Yes
<i>Tamarix chinensis</i>	five-stamen tamarisk	X	X	Yes
<i>Melilotus officinalis</i>	yellow sweetclover		X	No
<i>Salsola</i> spp.	Russian thistle		X	No

Only priority species were mapped and recorded. Species not on the target list were opportunistic observations.

Table 3-2. Number of IEP infestations per route surveyed, Capitol Reef National Park, 2009–2011.

Route	Type of route	Length (m)	ha	Priority infestations	
				Total	Per 100 m
Oak Creek (2011)	Riparian/Trail	7,267	28.98	69	0.95
Highway 24 (2009/2010)	Riparian/Road	50,055	101.36	385	0.77
Pleasant Creek (2010)	Trail	9,888	39.60	94	0.95

Monitoring was conducted on September 27–29, 2011, July 12–September 24, 2010, and July 28–October 8, 2009.

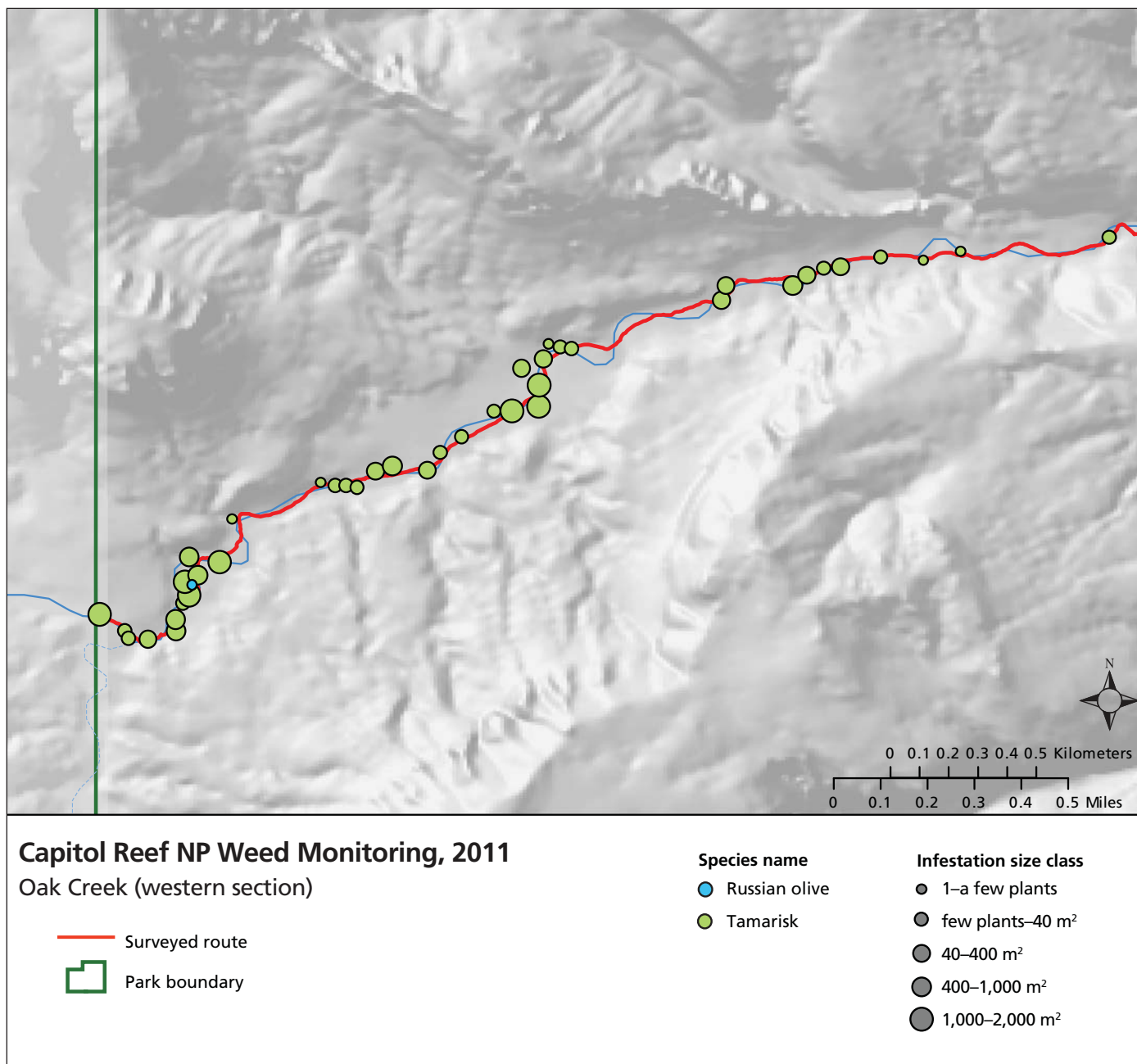


Figure 3-1. Invasive plants detected on monitoring routes on cattle trail along the western section of Oak Creek, Capitol Reef National Park, September 27–29, 2011.

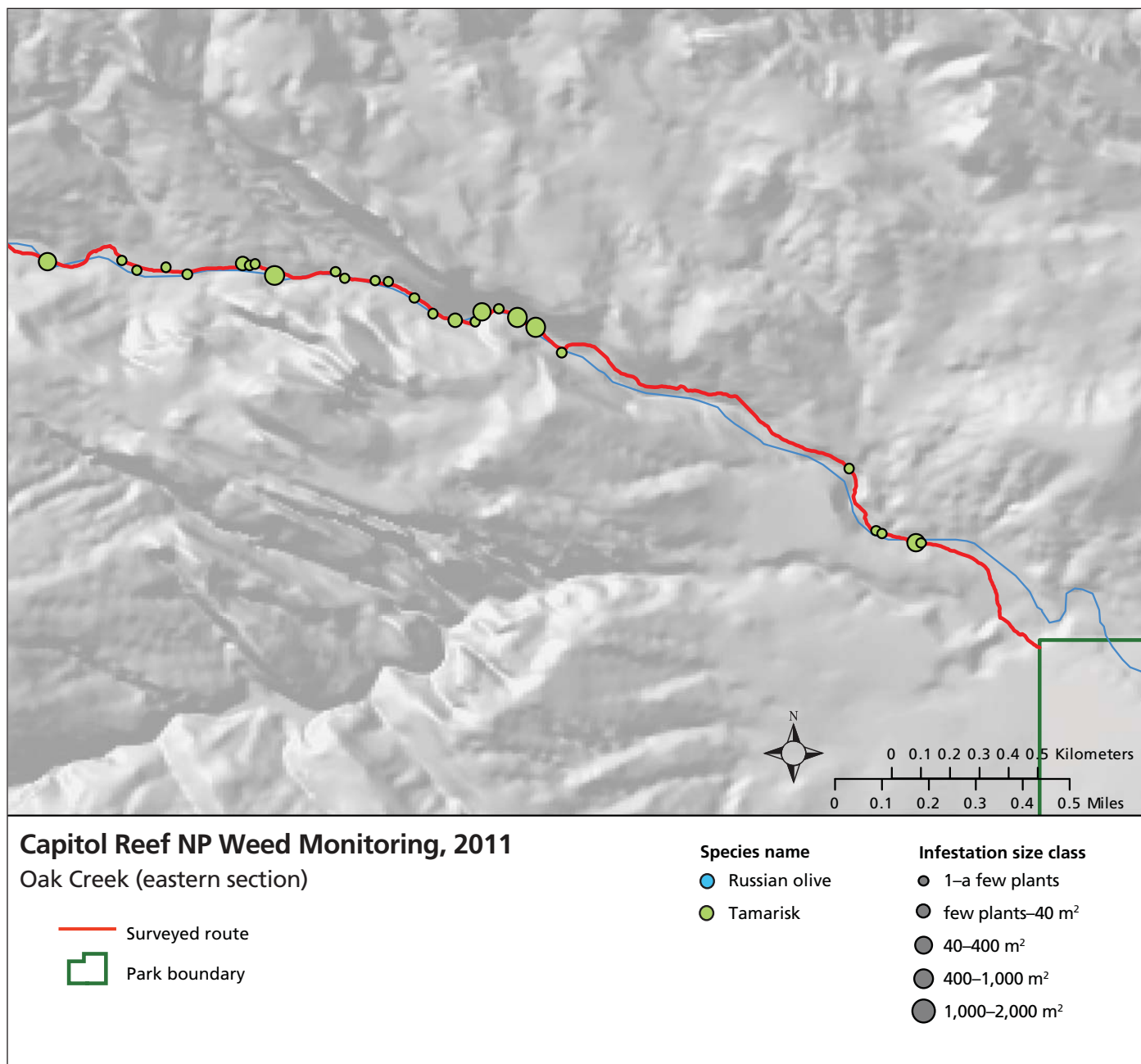


Figure 3-2. Invasive plants detected on monitoring routes on cattle trail along the eastern section of Oak Creek, Capitol Reef National Park, September 27–29, 2011.

Table 3-3. Species observed and size of infestation detected along monitoring routes at Capitol Reef National Park, 2009–2011.

Scientific name	Common name	Total infestations	Infestation size class*				
			1	2	3	4	5
Oak Creek (2011)							
<i>Elaeagnus angustifolia</i>	Russian olive	1	1	2	2	2	2
<i>Tamarix chinensis</i>	five-stamen tamarisk	68	24	16	12	9	7
Total		69	25	16	12	9	7
Highway 24 (2009/2010)							
<i>Ailanthus altissima</i>	tree of heaven	1	1	0	0	0	0
<i>Asparagus officinalis</i>	asparagus	1	1	0	0	0	0
<i>Elaeagnus angustifolia</i>	Russian olive	16	9	7	0	0	0
<i>Tamarix chinensis</i>	five-stamen tamarisk	203	29	49	124	1	0
Highway 24 Total		221	40	56	124	1	0
Pleasant Creek (2010)							
<i>Medicago sativa</i>	alfalfa	31	2	13	16	0	0
<i>Elaeagnus angustifolia</i>	Russian olive	3	2	1	0	0	0
<i>Tamarix chinensis</i>	five-stamen tamarisk	60	41	14	5	0	0
Pleasant Creek Total		94	45	28	21	0	0

Monitoring was conducted on September 27–29, 2011, July 12–September 24, 2010, and July 28–October 8, 2009.

*Infestation size classes: 1 = 1–a few plants (used for isolated single plants or very small patches ($\leq 2 \times 2$ 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).

3.3 Monitoring transects

A total of 15 transects were sampled in 2011 (Table 3-4; see Figure 2-3, Appendix C). Three IEP species were detected on transects. IEPs were only found on four transects (27% of transects), with an average of 0.33 IEP species detected per plot. Percent cover of these invasives in Oak Creek was less than 0.1% for all three species. Russian thistle was the most widespread species, present on 20% of the transects along Oak Creek. Tamarisk and yellow sweetclover were only present on one transect (7%) each.

3.4 Results comparison: 2011 and 2003

In 2003, Dewey and Anderson (2005) surveyed the same general sections of Oak Creek that the NCPN surveyed in 2011. The survey methods in 2011 were based on the methods

used by Dewey and Anderson (2005) and were similar for this particular route. However, the 2003 route covered more area, as Dewey and Anderson surveyed the entire drainage bottom and the 2011 surveys were limited to the EDSW along the cattle trail. Park staff decided to focus on the cattle trail for the 2011 surveys because cattle are possible vectors of terrestrial and riparian invasive species. Also, because the cattle trail travels both through the riparian corridor, immediately adjacent to the creek, and across nearby benches, which are upland in nature, it was deemed a good measurement of invasives in the drainage.

The two priority species detected in 2011 were also target species in 2003. There were slightly fewer detections of tamarisk and Russian olive along Oak Creek in 2011 (Table 3-5).

Table 3-4. Number of monitoring transects where exotic plant species were detected, mean percent cover, and standard error by sampling area, Capitol Reef National Park, 2009–2011.

Scientific name	Common name	2011 Oak Creek (15)		2009/2010 Highway 24 (50)*		2010 Pleasant Creek (20)	
		No. of transects	Percent cover (SE)	No. of transects	Percent cover (SE)	No. of transects	Percent cover (SE)
<i>Bromus tectorum</i>	cheatgrass	0	0.00 (0.00)	8	0.22 (0.14)	0	0.00 (0.00)
<i>Melilotus officinalis</i>	yellow sweetclover	1	0.67 (0.67)	5	0.73 (0.57)	6	0.55 (0.34)
<i>Salsola tragus</i>	Russian thistle	3	0.06 (0.03)	27	4.87 (1.43)	6	5.13 (3.00)
<i>Tamarix chinensis</i>	five-stamen tamarisk	1	0.02 (0.02)	3	2.64 (1.54)	1	0.67 (0.67)

Total number of transects per route are listed in parentheses in the header row.

Monitoring was conducted on September 27–29, 2011, July 12–September 24, 2010, and July 28–October 8, 2009.

*The majority of Highway 24 was sampled in 2009.

Table 3-5. Priority species observed and size of infestations detected along Oak Creek, Capitol Reef National Park, September 27–29, 2011, compared to data collected along the same route in 2003–2005.

Scientific name	Common name	Number of infestations	
		2011	2003–2005
<i>Elaeagnus angustifolia</i>	Russian olive	1	3
<i>Tamarix chinensis</i>	five-stamen tamarisk	68	89
Total		69	91

4 Discussion

4.1 Priority IEP List

The NCPN will continue to work with park staff and area weed 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.

After review, it was determined that the following changes will be made to the priority species list for 2012:

1. Plumeless thistle (*Carduus acanthoides*) will be dropped, as it has not been found in Capitol Reef NP and is not reported from Utah.
2. Black henbane (*Hyoscyamus niger*), common houndstongue (*Cynoglossum officinale*), and African mustard (*Malcolmia africana*) will be added. The first two species are found along road corridors in Wayne County and could potentially be in the park. African mustard does occur at the park, and if it is found in new areas, it would be worth controlling.

4.2 Possibilities for management control

While relatively few IEP species were detected, a few were widespread—most notably tamarisk, which was well-established along Oak Creek. There were few changes in the number of tamarisk infestations since the 2003 surveys, which may indicate that tamarisk has filled most of the niches available to it along Oak Creek. Forty-one percent of tamarisk infestations recorded during the most recent surveys were larger than 40 m², and 71% of the infestations were mature trees, demonstrating tamarisk's widespread prevalence and the length of time the species has been present. Continued monitoring will show the effects of future control efforts and the effects of the tamarisk beetle (*Diorhabda elongata*) as a biological control agent. The tamarisk beetle's presence was confirmed for the first time along the Fremont River in 2010 (G. Lenhart, pers. comm.) and in areas close to Oak Creek, and it is expected that the beetle will reach Oak Creek in the near future. Major control efforts for tamarisk should

likely be postponed until the effects of the beetle can be determined.

The tamarisk infestations along Oak Creek tended to be smaller than those along Highway 24 (near the Fremont River) and more similar to infestations found in Pleasant Creek, indicating that control efforts may be more feasible along the creeks than along Highway 24. While all areas monitored at the park have relatively low percent cover of priority invasive species, Oak Creek had lower cover than either Pleasant Creek or Highway 24, as well as the least number of IEPs present, as found on monitoring routes. Infestations should be controlled before they become more widespread. The lower prevalence of invasives in the western sections could be due to the narrower confines as Oak Creek enters the Waterpocket Fold—composed of Navajo Sandstone—where more forceful flood currents may have decreased the ability of invasives to become well-established. In some places, the cattle trail is actually in Navajo Sandstone, so the available substrate is bedrock.

It should be noted that estimates of percent cover in this report (see Table 3-4) are limited to the routes surveyed; actual percent cover of IEPs across the entire park cannot be inferred with these methods. Because we have chosen to monitor along areas most likely to be invaded by a broad suite of IEPs, it is plausible that the percent cover for most IEP species is lower in the interior of the park than along the monitoring routes.

4.3 Future monitoring efforts

IEPs at Capitol Reef NP will generally be monitored at the same time each year. Consistency in timing of monitoring should ensure consistency in detection probabilities and cover estimates of most species. For many species, sampling at any time from 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. In 2012, the NCPN will expand monitoring efforts to the Cathedral monitoring route (exact route to be determined in 2012). In addition, park staff will add the Scenic Drive as a monitoring route; whether this route remains as a long-term route will depend on the data collected. We may also complete some extra-area surveys in locations yet to be determined. Because any previous detections could have been eradicated by park staff, the locations

of monitoring quadrats are re-generated each year. 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. The NCPN invasive plant monitoring protocol was submitted for peer review in December 2010.

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Appendices

Appendix A. Priority invasive exotic plant list, Capitol Reef National Park, 2011.

Scientific name (Utah)	Common name
<i>Ailanthus altissima</i>	tree-of-heaven
<i>Arctium minus</i>	burdock
<i>Asparagus officinalis</i>	asparagus
<i>Cardaria draba</i>	hoary cress
<i>Carduus acanthoides</i>	plumeless thistle
<i>Carduus nutans</i>	musk thistle
<i>Centaurea diffusa</i>	diffuse knapweed
<i>Centaurea maculosa</i>	spotted knapweed
<i>Centaurea repens</i>	Russian knapweed
<i>Cirsium arvense</i>	Canada thistle
<i>Cirsium vulgare</i>	bull thistle
<i>Convolvulus arvensis</i>	field bindweed
<i>Elaeagnus angustifolia</i>	Russian olive
<i>Elymus repens</i>	quackgrass
<i>Euphorbia esula</i>	leafy spurge
<i>Isatis tinctoria</i>	Dyer's woad
<i>Lythrum salicaria</i>	purple loosestrife
<i>Marrubium vulgare</i>	common horehound
<i>Onopordum acanthium</i>	Scotch thistle
<i>Tamarix</i> spp.	tamarisk
<i>Ulmus pumila</i>	Siberian elm
<i>Verbascum thapsus</i>	woolly mullein

Appendix B. Exotic plant invasions detected on monitoring routes, Oak Creek, Capitol Reef National Park, September 27–29, 2011.

Scientific name	Common name	Infestation size class	Canopy cover class	Growth stage	Pulled?	Northing	Easting
<i>Elaeagnus angustifolia</i>	Russian olive	1	4	Mature Tree(s)	No	4214200	483850.6
<i>Tamarix chinensis</i>	Five-stamen tamarisk	1	3	Mature Tree(s)	No	4215304	487294.8
			3	Mature Tree(s)	No	4215338	485932.6
			3	Mature Tree(s)	No	4215296	487377.1
			3	Mature Tree(s)	No	4214652	488657.4
			3	Mature Tree(s)	No	4215049	487880.9
			2	Sapling(s)	No	4215183	487532.5
			2	Mature Tree(s)	No	4215156	487647.3
			3	Sapling(s)	No	4215292	487412
			2	Sapling(s)	No	4215318	486868.2
			3	Mature Tree(s)	No	4214429	488746.6
			3	Mature Tree(s)	No	4215350	487036.9
			3	Mature Tree(s)	No	4215326	487268.9
			2	Sapling(s)	No	4215366	486691.7
			2	Sapling(s)	No	4215353	487052.2
			4	Mature Tree(s)	No	4215342	486811.1
			3	Sapling(s)	No	4215237	487482.7
			3	Mature Tree(s)	No	4214437	488730
			2	Mature Tree(s)	No	4214396	488851.3
			3	Mature Tree(s)	No	4215198	487710.9
			4	Mature Tree(s)	No	4215307	485831.8
			4	Mature Tree(s)	No	4215332	486732.8
			3	Sapling(s)	No	4214426	483958.3
			3	Mature Tree(s)	No	4215025	484816.9
			3	Mature Tree(s)	No	4214550	484199
		2	3	Sapling(s)	No	4215012	484848.6
			2	Sapling(s)	No	4214707	484581.2
			3	Mature Tree(s)	No	4215385	486334.4
			2	Mature Tree(s)	No	4215320	485716.3
			2	Sapling(s)	No	4214653	484522.8
			2	Mature Tree(s)	No	4215281	485561.1
			3	Mature Tree(s)	No	4215356	487017.9
			2	Mature Tree(s)	No	4214793	484668.5
			4	Mature Tree(s)	No	4215160	487592.2
			3	Sapling(s)	No	4215008	484878.7
			2	Sapling(s)	No	4214541	484238.8
			2	Sapling(s)	No	4214541	484267.7
			4	Mature Tree(s)	No	4214534	484297.5
			2	Sapling(s)	No	4214019	483678
			3	Sapling(s)	No	4214043	483667.4
			2	Sapling(s)	No	4214138	483825.3
		3	2	Mature Tree(s)	No	4215258	485515.4
			2	Mature Tree(s)	No	4214973	484802.8
			2	Sapling(s)	No	4214014	483731.2
			2	Sapling(s)	No	4215285	485607.6

Appendix B. Exotic plant invasions detected on monitoring routes, Oak Creek, Capitol Reef National Park, September 27–29, 2011, cont.

Scientific name	Common name	Infestation size class	Canopy cover class	Growth stage	Pulled?	Northing	Easting
<i>Tamarix chinensis</i>	Five-stamen tamarisk	3	3	Mature Tree(s)	No	4215222	485297.4
			2	Mature Tree(s)	No	4215363	486490.8
			4	Mature Tree(s)	No	4215189	487665.1
			4	Mature Tree(s)	No	4214588	484347.9
			2	Mature Tree(s)	No	4214398	488836.8
			2	Sapling(s)	No	4215173	485285
			2	Sapling(s)	No	4214591	484488.7
			3	Mature Tree(s)	No	4214940	484743.9
		4	3	Mature Tree(s)	No	4215314	487103.8
			2	Mature Tree(s)	No	4214083	483806.1
			3	Mature Tree(s)	No	4214233	483865.5
			2	Mature Tree(s)	No	4215222	485477.2
			4	Mature Tree(s)	No	4215136	487810.6
			2	Mature Tree(s)	No	4214041	483807.4
			3	Mature Tree(s)	No	4214606	484393.6
			3	Mature Tree(s)	No	4215170	487761.2
			4	Mature Tree(s)	No	4214295	483842.8
		5	3	Mature Tree(s)	No	4214100	483600.3
			3	Mature Tree(s)	No	4214210	483831.4
			3	Mature Tree(s)	No	4214165	483843
			2	Mature Tree(s)	No	4214883	484790.9
			3	Mature Tree(s)	No	4214278	483925.6
			3	Mature Tree(s)	No	4214795	484717.6
			3	Mature Tree(s)	No	4214809	484789.6

Appendix C. Invasive exotic plant percent cover detected by monitoring transects along Oak Creek, Capitol Reef NP, September 27–29, 2011.

Transect #	Scientific name	Common name	Mean cover	Northing	Easting
101	<i>Melilotus officinalis</i>	yellow sweetclover	1	4837478	4214020
101	<i>Tamarix chinensis</i>	five-stamen tamarisk	0.333333	4837478	4214020
102	<i>Salsola</i> sp.	Russian thistle	0.333333	4839798	4214385
105	<i>Salsola</i> sp.	Russian thistle	0.166667	4850928	4215119
106	<i>Salsola</i> sp.	Russian thistle	0.333333	4855276	4215256

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