



Exotic Plant Management and Revegetation of Disturbed Sites in Denali National Park and Preserve

Summary Report for 2017

Natural Resource Report NPS/DENA/NRR—2018/1627



**ON THIS PAGE**

Youth Conservation Corps volunteer aggressively controls invasive *Taraxacum officinale* near Primrose rest stop.
Photograph by Benjamin Virnston

ON THE COVER

Wendy Mahovlic and Student Conservation Association crew take a break from controlling invasive plants along the park road to soak up the natural beauty of Denali National Park and Preserve.
Photograph by Benjamin Virnston

Exotic Plant Management and Revegetation of Disturbed Sites in Denali National Park and Preserve

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Abstract

The 2017 DENA EPMT crew, consisting of NPS Revegetation Specialist Mahovlic and SCA Intern Virnston, was responsible for surveying and controlling invasive plant species within the boundaries of Denali National Park and Preserve and in surrounding areas that might serve as entry points for invasive species into the park. Manual and chemical control strategies were used to accomplish this in the 2017 field season, with the majority of control efforts being manual. In total, 742.2 field hours (NPS Staff and volunteer) were invested to remove 1302.5 pounds of invasive plants. Significant time and effort were invested in revegetation, an important strategy for preventing invasive plant infestation and stabilizing ecosystems after invasive plant removal. A total of 25,774 pounds of native seeds were collected for use in future revegetation projects. Five major de-vegetation projects and two major revegetation projects were completed in the 2017 field season, as well as two major volunteer events. Efforts to control exotic and invasive plants and ameliorate the damage they have caused within and around DENA in the 2017 field season were successful; however, the work is ongoing, and the constant vigilance of future DENA EPMTs is necessary to ensure the wilderness of Denali remains intact for the enjoyment of future generations.

Acknowledgments

The Denali National Park and Preserve Exotic Plant Management Team would like to thank the following individuals and organizations, in no particular order, for their contributions to our invasive plant control and revegetation efforts this season: Christopher Overbaugh, Joel Cusick, and Peter Frank for their invaluable orientation training at the beginning of the 2017 field season and their ongoing willingness to lend their expertise, technical and otherwise; Justin Fulkerson and Matthew Carlson for their extensive botany knowledge, assistance with plant identification, and work on AKEPIC; Kathleen Kelly for her volunteer coordination work, without which our Dandelion Demolition and Need for Seed events would not have been possible; the two Student Conservation Association Alaska Corps crews for their three weeks of hard work; the Youth Conservation Corps crew for volunteering a day with us; the five volunteers who made Need for Seed West productive and great fun, Colleen Marinucci, Joan Galt, Paul Joslin, Rachael Hogan, and Ellen Hathaway; and all other volunteers who gave their most valuable resource, time, to help with the daunting task of controlling invasive plants within this expansive and magnificent park.

List of Terms and Acronyms

AKNHP Alaska's Natural Heritage Program

AKEPIC Alaska Exotic Plants Information Clearinghouse

DEC Denali Education Center

DENA Denali National Park and Preserve

DVC Denali Visitor Center

EDRR Early Detection Rapid Response

EPMT Exotic Plant Management Team

GIS Geographic Information System

GPS Global Positioning System

MSLC Murie Science and Learning Center

NPS National Park Service

SCA Student Conservation Association

YCC Youth Conservation Corps

Introduction

Denali National Park and Preserve encloses approximately six-million acres of largely intact wilderness in the interior of Alaska. The park is located within the northern boreal forest biome, with habitats ranging from interior boreal lowlands to the unvegetated high alpine mountains of the Alaskan Range, culminating in the highest peak in North America, the eponymous Denali (Figure 1).

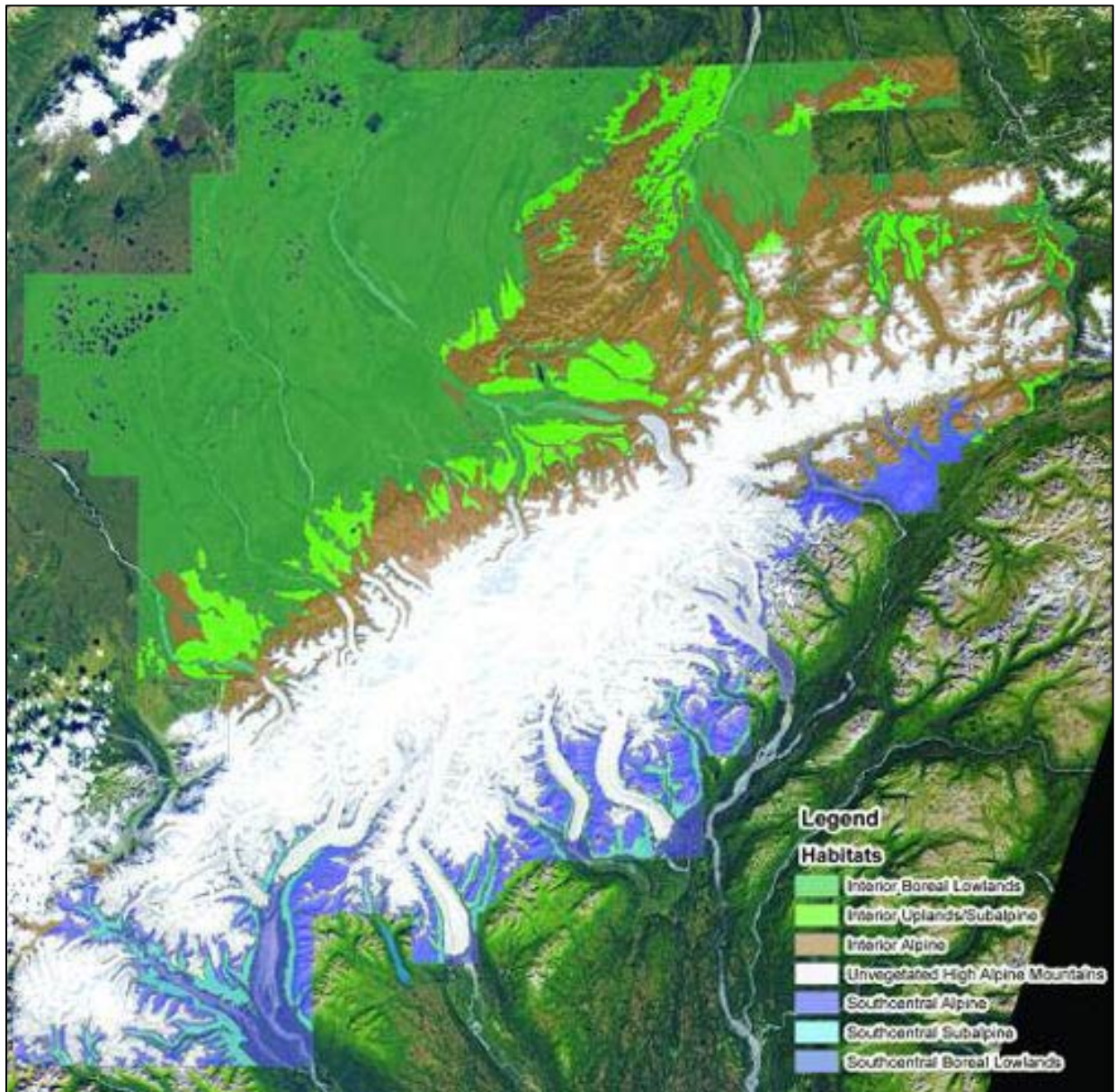


Figure 1. Satellite image of Denali National Park and Preserve with major habitats overlaid in color (NPS).

The Alaska Range creates a natural barrier between areas to its north and south, resulting in vastly different climates, habitats, and vegetation. The work of the DENA EPMT in the 2017 season

focused primarily on the park areas north of the range, where an arctic high pressure zone and the rain shadow effect increase seasonal temperature variability and limit precipitation. The terrain can be roughly divided by elevation into three habitat zones, with forests predominating below 2500 feet, spruce forests and scrub vegetation in the subalpine zone, and low tundra above 3500 feet. Above these habitable zones lies the mostly un-vegetated high alpine of glaciated or bare rock, comprising about a third of the park's land area. (Hooge et al. 2006)

While there has been a human presence in Denali for at least 11,000 years, with seasonal hunter-gatherers occupying the surrounding areas from the end of the last ice age until just before the park's creation in the early 20th century, a variety of factors have kept human influence to a minimum, ensuring that the Denali ecosystem has not been significantly altered by human activity. The area surrounding the Alaska Range was one of the last parts of Alaska to be explored by non-natives, owing to the lack of river access. A steady stream of explorers, prospectors, and trappers began entering the area by the close of the 19th century and a gold rush opened the next century with a heavier, albeit short-lived flow, especially to the areas surrounding Kantishna. Fear of overhunting led to the creation of Mount McKinley National Park in 1917, which halted further development and limited human impact on the park area. Completion of the Alaska Railroad, the Park Road, and the George Parks Highway in the subsequent decades permitted extensive tourist visitation of the park, with about half a million visiting the iconic park annually in recent years (Hooge et al. 2006). The majority of visitors confine themselves to the well-travelled entrance area and park road so despite heavy tourist traffic, the backcountry and wilderness areas remain largely free from human impact.

One form of human impact is the introduction of non-native plant species, which are plants brought to a new geographical area by humans. If such plants have characteristics that allow them to become established and rapidly spread in the new area, they may become invasive species. After a disturbance, invasive species can outcompete native plant species, decreasing plant diversity, depriving wildlife of their preferred food sources, and changing the structure of soils and waterways. Because Denali has been subjected to minimal development and human disturbance, relatively few invasive species have become established within the park's boundaries. Only 28 species of invasive plant have been discovered in Denali, compared to at least 760 native plant species. These numbers stand in stark contrast to similarly iconic parks in the contiguous US, such as Yellowstone's 200 invasive plant species (NPS 2017). Those that have become established are almost exclusively confined to the heavily trafficked areas of the park: the entrance area and along the park road. Accordingly, the DENA EPMT is in a unique position to not only limit the spread of particularly noxious invasive plant species, but to work toward eradicating these and lower priority non-native species entirely, an unimaginable goal in the lower 48.

There have been efforts to combat invasive plant species in Denali since at least the 1990s, but the DENA EPMT was not established, as part of the Alaska Region EPMT, until 2004. Since then, the team, consisting of the NPS Revegetation Technician, Wendy Mahovlic, and a Student Conservation Association intern (or two), has worked in concert with similar EPMT park crews across the Alaska Region to monitor and control the spread of invasive plant species in the state's vast park lands. Each field season, SCA interns are selected to join the team for pre-season orientation and training at the

regional office in Anchorage. This training covers the latest EPMT field and office protocols (Overbaugh and Frank 2017a and 2017b); basic botany and plant identification (native and non-native); use of handheld Trimble GPS units and mapping best practices; basic GIS theory and practice; use of the GPS Pathfinder Office and TerraSync software applications; and methods of control. Upon completion of this first week of training, each intern returns to their park unit for further training relevant to the specific conditions of their park. Once training is complete, exotic plant management work begins in earnest. Our primary responsibilities are controlling infestations with manual and chemical means; inventorying new and tracking existing infestations via GPS and photography; educating park visitors and community members to reduce inadvertent invasive species introductions and instill a sense of the importance of the work we do; monitoring construction projects and other disturbances for potential invasive species vectors; revegetating disturbed areas to prevent establishment of invasive species; and collecting native seeds for future revegetation projects.

Methods

The DENA EPMT conducted field work during the 2017 season according to the Alaska Exotic Plant Management Team: 2017 Field Protocol (Overbaugh and Frank 2017a). This field season, lasting from June 1st to August 25th, can be roughly divided into an initial de-vegetation phase, consisting of surveying and controlling invasive plant species, and a later revegetation phase, consisting of native seed collection and revegetation of disturbed areas.

De-vegetation

Once an area has become infested with invasive plants, the first phase in managing the infestation is de-vegetation, or removal of the invasive plant species through manual or chemical means.

Work Prioritization

Our strategy for the de-vegetation phase was informed by Alaska Region EPMT priorities. The Alaska EPMT prioritizes field work based on infestation size and site, target species, and timing variables (Overbaugh and Frank 2017c).

Size

Size considerations include whether the infestation is a small satellite of a larger motherlode infestation, the density of the infestation, and the characteristics of the infestation's leading edge. Small satellite infestations, being smaller in size and somewhat isolated from reintroduction, are prioritized because they tend to pose a greater threat to wilderness and backcountry areas owing to their separation from larger infestations in more heavily trafficked areas; additionally, effective control requires less time and effort rather than mere containment. Infestations of greater area and density take more resources to control and progress may be slow or halting, especially with a two-member park EPMT. Accordingly, a selective containment strategy may be necessary for large, densely populated infestations: wherein the leading edge—the edge of the infestation expanding into new areas—or potential vectors within the infested area (e.g., roads, trailheads, and vehicle storage areas) are prioritized for control efforts.

Site

Site considerations include frequency and degree of human presence, the proximity of potential vectors, and habitat sensitivity. Backcountry and wilderness infestations are given top priority because these areas are the most important to keep pristine and unaltered for the enjoyment of current and future visitors. However, these sites are often remote and difficult to reach so one might only have once chance in a season to effect control. As previously stated, infestations adjacent to potential vectors—such as campgrounds, trailheads, roads, maintenance yards, vehicle and equipment staging areas, and gravel pits—are prioritized for their potential to transport invasive plant seeds beyond the initial infestation area. Infestations encroaching on sensitive habitats, including restoration sites or those with rare, endangered, or endemic species, are prioritized to protect the delicate balance of these sites.

Target Species

Target species are determined and prioritized according to an invasiveness ranking—0 (non-invasive) to 100 (highly invasive)—assigned based on the potential ecological impact, biological characteristics, dispersal ability, feasibility of control, and distribution of each non-native species within the three ecogeographic regions of Alaska (Carlson et al. 2008).

Timing

Timing is the final major consideration for the prioritization of Alaska EPMT field work and includes seasonality and phenology. Invasive species that germinate early in the field season (e.g., *Taraxacum officinale*, the common dandelion) must be prioritized to ensure effective control before these plants go to seed. It is vastly preferable to control an infestation before its constituent plants go to seed to avoid the further spread of the infestation. When controlling invasive plants that have already gone to seed, it is important to take precautions to ensure that control efforts do not further spread the seeds. Some invasive plant species may germinate multiple times within a field season necessitating repeat visits to certain sites.

Work Areas

While much of the DENA EPMT work in the 2017 field season was concentrated around the heavily trafficked entrance area and park road roadsides, surveys and control efforts were conducted at additional work areas outside of these heavily disturbed sites (Table 1).

Table 1. Major work areas and the invasive species surveyed and/or controlled therein during the 2017 field season.

Areas	Work Sites (ca. Mile)	Species of Concern
Entrance Area	Park Entrance and George Parks Highway Junction (0)	<i>Crepis tectorum</i> , <i>Melilotus albus</i> , <i>Taraxacum officinale</i>
	Park Road Roadside (0-3)	<i>Crepis tectorum</i> , <i>Taraxacum officinale</i>
	Wastewater Treatment Plant (0.3)	<i>Crepis tectorum</i>
	Denali Visitor Center (2)	<i>Hieracium umbellatum</i> , <i>Taraxacum officinale</i>
	Murie Science and Learning Center (2)	<i>Taraxacum officinale</i>
	Bus Depot (2)	<i>Crepis tectorum</i>
	C-Camp (3)	<i>Crepis tectorum</i> , <i>Hordeum jubatum</i> , <i>Taraxacum officinale</i>
	Maintenance Facilities (3)	<i>Crepis tectorum</i> , <i>Hordeum jubatum</i> , <i>Taraxacum officinale</i>
	Park Headquarters (3.4)	<i>Hordeum jubatum</i> , <i>Taraxacum officinale</i>
East End	Park Road Roadside (4-43)	<i>Taraxacum officinale</i>
	Primrose Rest Stop (17.5)	<i>Taraxacum officinale</i>
	Teklanika Rest Stop and Campground (30)	<i>Taraxacum officinale</i>
	Igloo Ranger Station (34)	<i>Taraxacum officinale</i>
	East Fork Cabin (43)	<i>Taraxacum officinale</i>

Table 1 (continued). Major work areas and the invasive species surveyed and/or controlled therein during the 2017 field season.

Areas	Work Sites (ca. Mile)	Species of Concern
West End	Park Road Roadside (70-92)	<i>Taraxacum officinale</i>
	Thorofare Gravel Pit (70)	<i>Taraxacum officinale</i>
	Wonder Lake Campground (84.4)	<i>Taraxacum officinale</i>
	Dalle-Molleville (84.6)	<i>Taraxacum officinale</i>
	Wonder Lake Ranger Station (86.5)	<i>Taraxacum officinale</i>
	Denali Backcountry Lodge Driveway (91)	<i>Taraxacum officinale</i>
	Friday Creek (92)	<i>Taraxacum officinale</i>
	Quigley Cabin (92.1)	<i>Taraxacum officinale</i> , <i>Vicia cracca</i>
	Kantishna Airstrip (92.2)	<i>Taraxacum officinale</i>
Backcountry	Lower Toklat Cabin (53)	<i>Hordeum jubatum</i>
George Parks Highway	Glitter Gulch (237-239)	<i>Crepis tectorum</i> , <i>Melilotus albus</i> , <i>Taraxacum officinale</i>
	Roadside (231-236)	<i>Crepis tectorum</i> , <i>Hieracium umbellatum</i> , <i>Melilotus albus</i> , <i>Taraxacum officinale</i> , <i>Vicia cracca</i>

Major Projects

Dandelion De-vegetation

As previously stated, *Taraxacum officinale* germinates and proceeds through its life cycle earlier in the field season than many other invasive plant species; thus, surveying and controlling the invasive dandelion comprised a majority of the DENA EPMT's field work in June. Our dandelion de-vegetation efforts occurred in three phases.

An SCA Corps crew assisted us for Dandelion De-vegetation East June 5-7 (figure 2). We began by manually controlling invasive dandelions around the park headquarters area and historic district. We then drove to the East Fork Cabin and manually controlled dandelions along the park road proceeding east to the Teklanika Rest Stop. Next, we controlled dandelions at the Teklanika Campground and continued working our way east to the Primrose Rest Stop. On June 27, a YCC crew helped us finish Dandelion De-vegetation East beginning at Primrose Rest Stop and proceeding to mile 4 of the park road.

Virnston coordinated a volunteer "Dandelion Demolition" event to manually control *Taraxacum officinale* in the entrance area on June 10. More information on this phase can be found in the Education and Outreach section below.

The last phase was Dandelion Devegetation West. Once again, we were assisted by the SCA Corps crew who drove with us to Friday Creek Camp on June 12. The next day, we began at mile 70 of the park road and worked our way west until reaching the end of the park road on June 15, controlling dandelions at Wonder Lake Campground, Dalle-Molleville, Wonder Lake Ranger Station, Denali Backcountry Lodge driveway, Friday Creek, Quigley Cabin, and Kantishna Airstrip along the way.

Mahovlic chemically controlled *Taraxacum officinale* in the vicinity of Friday Creek Camp, but all other control efforts were manual.



Figure 2. First SCA Alaska Corp crew weigh dandelions removed in Dandelion Devegetation West. Photograph by Benjamin Virnston.

Crepis Sweeps

As our dandelion de-vegetation efforts wrapped up, our focus transitioned to the next invasive species to begin flowering: *Crepis tectorum*, or narrowleaf hawksbeard. Virnston conducted sweeps, surveying for and manually controlling *Crepis*, along the park road in the entrance area between the Wastewater Treatment Plant entrance and the Wilderness Access Center on June 23 and in the Bus Depot on June 24. Then, on June 27, the YCC crew assisted us in *Crepis* de-vegetation of the Wastewater Treatment Plant.

George Parks Highway and Glitter Gulch Sweeps

Crepis tectorum remained a priority as the DENA EPMT began sweeping the George Parks Highway from Glitter Gulch south to Denali Village. These sweeps also targeted *Melilotus albus*, or tall white sweet clover. The first sweep was carried out on June 28. A second sweep for late-germinating *Crepis* and *Melilotus* was conducted on August 1 and 2.

Mahovlic and Overbaugh Chemical Control

While Virnston was on leave, Chris Overbaugh assisted Mahovlic in chemically controlling *Vicia cracca* (bird vetch), *Descurainia sophia* (flixweed), and *Melilotus albus* (tall white sweet clover) in various heavily infested sites, including Tek Pit, Wastewater Treatment Plant, and along the George Parks Highway.

Lower Toklat Cabin Helicopter Trip

The DENA EPMT received reports of a *Hordeum jubatum*, or foxtail barley, infestation at the Lower Toklat Cabin, which is approximately 30 miles north of the park road mile 53 (figure 3). This infestation had penetrated far into the backcountry, away from high-traffic areas where invasive plants are more common, so removal became an immediate priority. This site is remote and inaccessible by normal means employed by the DENA EMPT during the field season, so it took some time to plan and carry out this project. We were eventually able to gain approval for a helicopter trip to the location. We found one large patch of *Hordeum* in the vicinity of where sled dogs are bedded during the winter, indicating the seeds were transported there either on the dogs or in their feed. We surveyed and manually controlled this small infestation with a two-person team in approximately three hours; no other infestations were found nearby. To maximize the efficiency of our helicopter usage, we were also asked to perform other tasks in the area, including sweeping the nearby Toklat River for a large discarded tire that had been reported, taking photographs of the cabin's exterior for Joel Cusick of the GIS team at the NPS Alaska Regional Office, taking photographs of the cabin's interior for the Cultural Resources team, and restocking the cabin with food and other supplies in preparation for its use as a ranger cabin in the winter.



Figure 3. Left. Lower Toklat Cabin with foxtail barley infestation in foreground. Photograph by Benjamin Virnston. **Right.** Virnston, wearing a bug shirt, holds a manually controlled foxtail barley plant near Lower Toklat Cabin. Photograph by Wendy Mahovlic.

Control Methods

Manual Control

Most of the DENA EPMT's de-vegetation field work in the 2017 season consisted of manual control of invasive species. While the morphology and growth habit of each species necessitates a slightly different means of manual control, there are some universally applicable methods.

The tool of choice for manual control is a dandelion digger, a hand tool consisting of a handle, a short metal shaft, and a sharpened v-shaped tip. This tool is preferred for most invasive species because it allows removal of most or all of the plant's root system, which is vital for effective control. Many species of invasive plant produce long taproots that penetrate deep into the soil. If one merely pulls on the above-ground vegetative portion of the plant, the roots typically break away and remain in the soil, allowing the plant to regenerate later in the season or in the next growing season. Only complete removal of the root system ensures effective control.

For invasive plants already in seed, especially those that utilize wind dispersal, extra care must be taken to prevent seed dispersal during manual control efforts. Typically, this means cutting off the seed head and disposing of it properly before proceeding to removal of the vegetative portion. Even if control occurs in the flowering stage, some invasive species, especially those in the family Asteraceae (e.g., *Taraxacum officinale*), are capable of producing viable seeds from flowers that are removed before maturation. Accordingly, it is important to properly dispose of flowers from members of this family.

Once an infestation has been manually controlled, plant materials are placed in sealed plastic garbage bags and stored securely until winter, at which point they are disposed of in a controlled burn by the DENA Fire Team.

Chemical Control

Although chemical control methods were used minimally by the DENA EPMT in the 2017 field season, they are still a necessary and important control strategy for certain species and infestation types. *Vicia cracca* is nearly impossible to control manually because of its ability to regenerate from even small fragments of root left behind in the soil. Because the DENA EPMT consists of only two individuals responsible for a 6-million acre park and preserve, particularly dense or expansive infestations must be controlled chemically, a more efficient and less labor-intensive means of effecting control.

We were trained in the safe and effective use of two chemical herbicides in our first week of training in Anchorage: Milestone and AquaMaster. These herbicides are procured as concentrates and must be diluted properly and sometimes mixed with dyes and surfactants to indicate the presence of herbicide or enhance its efficacy, respectively. The constituents are mixed in the tank of a backpack sprayer according to ratios that depend on one's individual calibration rate, desired application rate, and size of infestation. Other factors to consider when chemically controlling invasive species are weather conditions, sensitivity of surrounding ecosystems, personal protective equipment (PPE), and risk-reward calculations relative to manual control. Great care must be taken when utilizing chemical control methods.

Revegetation

The second phase of invasive plant management is revegetation, or the reintroduction of native plant species to disturbed areas. Revegetation restores the delicate ecological balance that is upset by disturbance, increasing the area's resilience against future infestations. Assuming there is an intact native seed bank or nearby native plants, revegetation occurs naturally given sufficient time; however, many invasive species are adapted to germinate and proceed through their life cycle rapidly after a disturbance, allowing them to colonize and consolidate the disturbed area before native species are able to revegetate naturally. Thus, it is usually advisable to revegetate the disturbed area artificially to speed up the process and minimize the risk of (re)infestation. Most of the disturbances necessitating revegetation for the 2017 DENA EPMT field season were either construction projects or heavily infested areas that had been de-vegetated.

Revegetation Projects

DENA NPS Headquarters and Historic District

Most of the Headquarters area and Historic District had been paved and used as a parking lot decades ago. In an effort to restore the area to its historic appearance and create a more naturalistic setting around the park's headquarters, much of this parking area was removed and revegetated. Most of this work was completed before the 2017 field season, there were still some areas of bare soil. This was rectified by the DENA EPMT with the assistance of two SCA Corps crews throughout the season (figure 4).

The first phase of this revegetation project occurred on June 5: our first SCA Corps crew sowed annual rye seeds in front of the resources building and sowed a native seed mix around the B-22 building.

Phase two was carried out in July with the help of the DENA Trail Crew, who took tundra mats extracted from a new trail project and installed them in front of the Resources building where the annual rye had been sown previously. The DENA EPMT was then responsible for fertilizing and watering the new mats until they were established.

On August 24, our second SCA Corps crew helped us complete phase three of this revegetation project. First, annual rye was removed from areas we had sown earlier in the season and a native seed mix was sown in its place. Next, an infestation of invasive species resulting from construction near one of the permanent housing units was controlled and native seeds were sown in the disturbed area. Then, native seeds were sown in an area disturbed by the pouring of a new concrete walkway in front of the Superintendent's Building. Finally, a section of the Rock Creek Bridge culvert that had been washed out was reinforced with additional fill and sown with native seeds. 0.11 acres of native seeds were planted in the areas revegetated in 2017.



Figure 4. Left. SCA Alaska Corps crew sow native seed mix near Resources Building in park headquarters. Photograph by Benjamin Virnston. **Right.** Virnston sows native seed mix around new walkway to Superintendent's building in park headquarters. Photograph by Wendy Mahovlic.

Need for Seed

Preferred revegetation methods involve sewing native plants and seed collection efforts must be ongoing to ensure a steady supply of native seed mixtures. The DENA EPMT carried out three native seed collection efforts in the 2017 field season, dubbed “Need for Seed” events. As with our dandelion de-vegetation efforts, Need for Seed was subdivided into the west and east ends of the park, with a third volunteer event open to the public that focused on the entrance area and headquarters (figure 5). Virnston coordinated the latter and more details can be found in the Education and Outreach section below.

Need for Seed West occurred between August 14 and 18. The DENA EPMT was joined by a team of five volunteers to collect native seeds on the west end of the park. We set up camp at Wonder Lake Campground and struck out from there to our collection sites each day. We collected *Elymus* sp. (wheatgrass), *Hedysarum alpinum* (eskimo potato), *Oxytropis campestris* (Northern oxytrope), *Delphinium glaucum*, *Leymus innovatus* (fat cat), *Arnica lessingii*, and several other native plant species between Toklat and Kantishna.



Figure 5. Virnston and Need for Seed West volunteers collect various native seeds along the park road. Photograph by Benjamin Virnston.

Need for Seed East occurred between August 21 and 24. We were aided by our second SCA Corps crew in native seed collection efforts near the Nenana River and along the park road near the Sanctuary River (figure 6). We collected similar species to Need for Seed West.



Figure 6. Mahovlic helps second SCA Alaska Corps crew identify native plant species for Need for Seed East along the Nenana River. Photograph by Benjamin Virnston.

Revegetation Methods

Native Seed Collection, Storage, and Sowing

The park's regulations stipulate that native seeds must be collected within 20 miles of where they are used for revegetation. Thus, it is important to keep a large and diverse stock of native seeds from each major area of the park where some disturbance is expected (i.e., construction, infestation, etc.). Once an area has been selected for native seed collection, there are two additional factors to consider: native species present and plant phenology at the time of intended collection.

Not all native plant species present in an area of seed collection are suitable for use in revegetation projects. First succession, or pioneer, species are ideal for revegetation work because they germinate and proceed through their life cycle rapidly and do not rely on other species being present to thrive. For this reason, most native plant species used by the DENA EPMT for revegetation projects are

small, herbaceous perennials. Many of these are from the family Fabaceae, or the legumes, owing to their ability to form mutualisms with nitrogen-fixing bacteria. These nitrogen-fixing bacteria convert inaccessible atmospheric nitrogen into an available form in the soil, regenerating soil health after a disturbance and allowing other plant species to colonize the area. However, even otherwise perfectly suitable plant species are not always used for revegetation. Many members of the family Asteraceae (the daisy family) have wind-dispersed seeds with the widely recognizable puffball seed heads. These seeds are extremely time-consuming and difficult to properly clean for long-term storage, making many species of this family less than ideal for revegetation work.

A plant species desirable for revegetation projects being present does not guarantee one will be able to collect and use it. Each plant species germinates and proceeds through its life cycle at different rates. Accordingly, the DENA EPMT had to research each intended collection site to see what was there, and more importantly, what was ready to harvest. We had to learn the morphology of mature, viable seeds for each species to ensure we were collecting at the right time. We then had to train each of our volunteers to recognize mature seeds.

Once an area has been selected containing mature seeds from desirable plant species, collection may begin. Collection technique depends on the plant species as the morphology of seed-bearing structures varies widely. For some species, e.g., *Hedysarum alpinum* and *Hedysarum boreale ssp. mackenziei*, the seeds hang in-line along an inflorescence, allowing one to “zip” the majority of the seeds off with one motion. For some Asteraceae species, e.g., *Aster sibericus*, the seed head can be easily plucked off when it is mature. Many of the rest require one to use scissors to snip the seed head away from the vegetative portion of the plant.

Once removed from the plant, the seeds are collected, segregated by species, in paper bags labelled with species, collection date, and location. At the end of each collection effort, the seeds from the same species, date, and location are consolidated onto separate drying racks, consisting of a wood-framed mesh screen overlaid with muslin cloth. These racks are then arranged on shelves in a warm, dry area and left to dry for a number of days dependent on their moisture content at the time of collection. The dried seeds are then cleaned to separate the seeds from the chaff, sealed in labelled freezer bags, and stored in a freezer until needed for revegetation work. The seeds of some plant species, e.g., *Oxytropis campestris*, must be scarified before they’re sown. Scarification mimics the natural process of weathering that the seeds of some plant species must undergo before germination. These species tend to have thick, durable seed coats to survive long periods of dormancy in the soil before germination; the seeds will not germinate unless this seed coat has been worn down.

When the time comes to use native seeds for revegetation work, they must first be combined into a native seed mix (figure 7). First, native plant species are selected based on the needs of the site to be revegetated. Next, seeds that require scarification undergo this process. Then, a layer of sand is added to the seed mixture container. After that, the various seeds are added to the sand. Next, extended-release fertilizer is added to the mixture. Finally, the first layer is mixed and this process is repeated until a sufficient quantity of native seed mix has been created.



Figure 7. Virnston and Mahovlic add various seeds to native seed mix. Photograph by Benjamin Virnston.

After the native seed mix has been made, sowing may begin. Typically, areas with compacted bare soil or recently removed invasive species infestations must first be tilled. This is usually accomplished with a Pulaski, a hafted tool with an adze and an axe head (figure 8). Once the soil has been aerated, the native seed mix is broadcast over the area and raked to a depth of about 1/8 in.



Figure 8. SCA Alaska Corps crewmember uses Pulaski to till area in preparation for sowing native seeds.

Annual Rye Sowing

The process for sowing annual rye seed is similar to that of the native seed mix, described above: disturb the soil, broadcast the seed, and rake it into a shallow depth. Since this species of rye is annual it will not continue to grow after the first season. Therefore, annual rye is used to temporarily revegetate a vulnerable area if permanent revegetation is not yet desired.

Tundra Mats

Tundra mats are a way to skip the early stages of succession, thereby introducing a stable, established community of plants to an area in need of revegetation. They are similar to sod in that squares of plant material are extracted from the ground with a layer of topsoil intact. Once extracted, the mats can be stored on pallets until ready to use if watered regularly. When they are needed for revegetation, they are simply arranged to cover the disturbed area and watered regularly until fully established. If the revegetation site varies significantly from where they were extracted, succession may still occur: some plants die off but they are replaced by native plants whose seeds were likewise transported in the intact soil layer.

Surveying and Geospatial Data

In addition to controlling invasive plant species, the DENA EPMT surveyed the location, size, and attributes of invasive species infestations. This was accomplished using a handheld Trimble GeoExplorer 2008 Series GeoXT GPS unit. The data dictionary provided by the AK EPMT at the beginning of the field season provided a framework for collecting useful GIS data about infestations.

Once a rover file is created on the unit, there are eight options for adding data, but the DENA EPMT only used three of these options extensively. The point to buffer option allows one to map an infestation concentrated in a roughly circular pattern. The distance from the center of the circle to the farthest plants (the radius) is the buffer distance. Buffer distances for point features should never be larger than three meters. Line to buffer maps an infestation along a line with a chosen buffer distance (1/2 of the total width of the line). Buffer distances for line features should never be larger than five meters. Polygon is used to map infestations of irregular shape or a size greater than the maximum buffer distance for the other two options. Once the infestation has been enclosed within one of the shape options, we fill in attribute data on the GPS unit to provide a more complete picture of each infestation. Attribute data includes site description, disturbance type, taxon (which invasive plant species was found), action taken (inventory or various means of control), the latest phenology of plants within the infestation, the percent cover of invasive plants within the mapped area, and the level of effort needed to control the infestation. If one selects a control method for the action taken attribute, additional attributes populate the list depending on the control method selected.

After GPS data is collected in the field, it requires post-correction and editing before being submitted to the EPMT data manager. Both processes are carried out in the software application GPS Pathfinder Office. The data is transferred from the handheld unit to a computer with Pathfinder, which provides tools for post-correction and editing. Post-correction compares rover file data collected in the field to standardized data collected by nearby GPS stations and corrects for various sources of error, resulting in more accurate data. Editing consists of correcting any mistakes in the attribute data filled out in the field, adding additional attribute data if necessary, and correcting user errors and GPS artifacts. One such GPS artifact usually caused by user error is a “rat’s nest,” a convoluted, overlapping portion of the GPS data geometry easily fixed in GPS Pathfinder Office (figure 9).

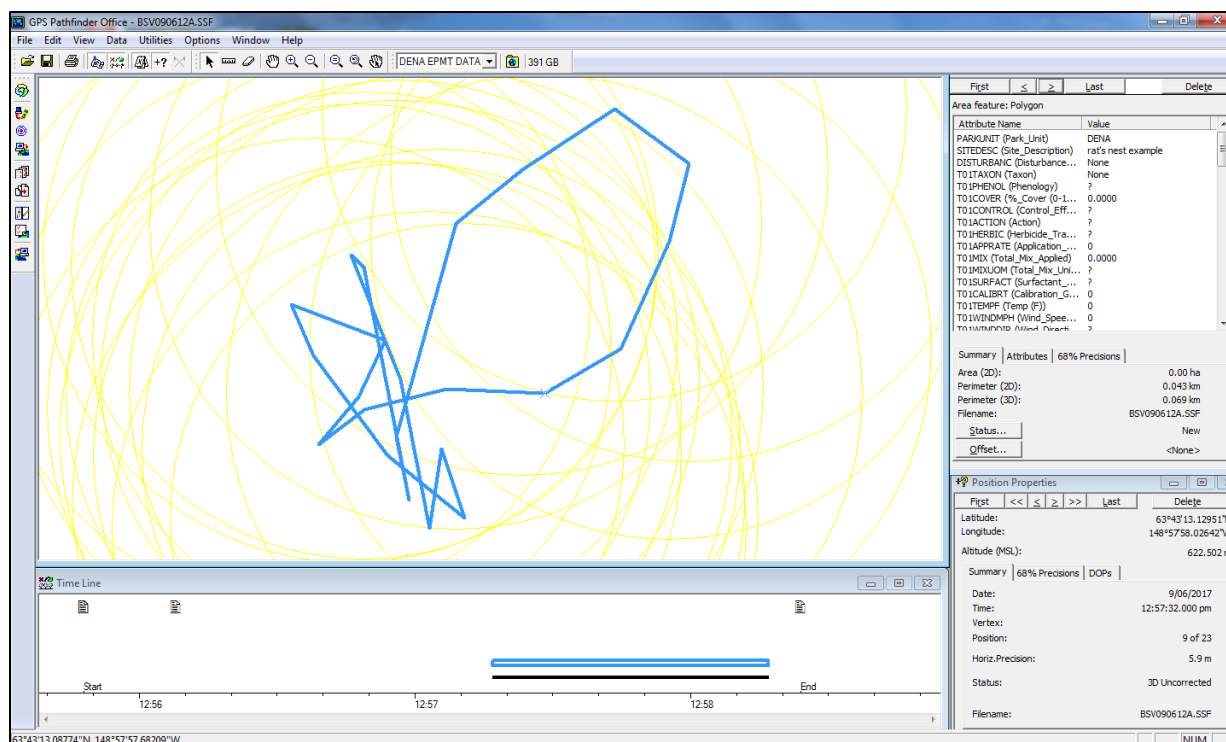


Figure 9. GPS Pathfinder Office workspace with example of “rat’s nest” artifact.

Education and Outreach

The primary duty of the DENA EPMT is surveying and controlling invasive plant species, but as a two-person team in a six-million acre park, there is more work needed than we could hope to accomplish in a four-month field season. Accordingly, it is important that we concentrate some of our time and effort on recruiting others to the cause of eliminating the spread of invasive plant species. There are a variety of ways this can be accomplished, including educating the public on best practices for outdoor activities to limit the introduction and spread of invasive species and coordinating volunteer events to enlist and engage members of the public.

Education

Invasive plant species are often spread by visitors to the park who do not realize they are a vector for seed dispersal. Seeds can become lodged in tire or boot tread or cling to clothes and camping gear allowing for easy transport from visitors’ home locations or other travel destinations into the park. Teaching visitors to use infestation prevention best practices while they enjoy the park can dramatically reduce the spread of invasive plants. Best practices include using boot scrapers, located around the entrance area, to clean hiking boots before proceeding onto trails or into the backcountry; cleaning hiking, camping, and other outdoor activity gear before and after using them in the park; and washing cars, especially tire tread, before driving into the park. These best practices should also be followed by park employees to reduce spread and provide a good example to members of the public.

Virnston manned an informational booth during the Denali Centennial Summerfest Event, where he distributed informational literature, gave away relevant swag, and answered questions. This provided members of the public the chance to learn about the work of the DENA EPMT and how it fits into the broader mission of Denali National Park and Preserve and the National Park Service.

Opportunities for education abound when conducting invasive species field work in the vicinity of heavily trafficked areas, especially the entrance area of the park. At various points in the season, members of the public approached the DENA EPMT, curious about the work being done. This allowed us to directly show them the work we were doing, its importance, and how they can help. Even in less-frequented areas of the park opportunities for education present themselves. One illustrative example of this occurred while Virnston led the second SCA Corps crew of the season in a native seed collection effort along the park road around mile 24: a tour bus stopped beside the worksite and the driver inquired what we were doing, allowing Virnston to enter the bus and give a quick talk and answer questions about native seed collection and invasive species control (figure 10).



Figure 10. YCC crew member passes on knowledge about invasive dandelions, learned from Virnston and Mahovlic, to park visitors curious about her work.

Additionally, the DENA EPMT incorporates education about invasive species prevention into their inspections of construction equipment and other interactions with construction contractors. Construction projects can be a vector for invasive plant species in the same way as visitors (that is, seeds on gear, tire treads, construction equipment, etc.) as well as via the importation of potentially contaminated fill material (e.g., gravel and soil) from outside the park.

Volunteer Events

Virnston coordinated two volunteer events in the 2017 field season as mentioned above. These provided the DENA EPMT another avenue for educating and engaging the public to enlist them in our important work.

Dandelion Demolition

With the assistance of Mahovlic, Lindsey Selene, and Kathleen Kelly, Virnston planned, prepared, and coordinated a volunteer dandelion de-vegetation effort in the entrance area of the park on June 10 (figure 11). Once the plan was set and all of the materials were gathered, Virnston met Selene and Kelly at the Murie Science and Learning Center (MSLC) to greet the volunteers and prepare them for the volunteer work. Kelly had them sign the required volunteer agreements and explained the benefits and responsibilities of volunteering for the park. Then, Selene and Virnston gave a wildlife safety talk to ensure the volunteers would know how to handle a wildlife encounter. Next, Virnston trained the volunteers on the identification and distinguishing features of the native and invasive dandelion species found in the park as well as the proper technique for manually controlling the invasive species. After that, the volunteers were set to work around the MSLC, Denali Visitor Center (DVC), and parking areas. Virnston alternated between the sites answering questions, dumping bags of dandelions, guiding volunteers to new work sites, and mapping control efforts on the GPS unit. When the work was finished, the dandelions were weighed and prizes were awarded to the best workers in a number of categories, including most collected, biggest taproot found, and best team effort.



Figure 11. **Left.** Volunteers gather to weight their demolished dandelions. **Right.** Volunteer examines vanquished dandelion foe before confining it to plastic captivity. Photographs by Benjamin Virnston.

Need for Seed

Again with the assistance of Kelly, Virnston planned, prepared, and coordinated a native seed collection event around the park headquarters area on August 5. Virnston met Kelly in the DVC parking lot to greet visitors and explain the work and safety concerns. Everyone then reconvened in the headquarters parking lot where Virnston trained volunteers on the identification and proper seed collection of native plant species, outfitted them with the necessary gear and safety equipment, and showed them the sites where collection would occur. After volunteers collected the seeds (figure 12), they were segregated based on species, dried, cleaned, and placed in storage in accordance with the methods described for the other Need for Seed events above.



Figure 12. Volunteers work in teams to collect native seeds (*Elymus* sp.) on the Rock Creek Bridge culvert. Photograph by Benjamin Virnston.

Results

In the course of the 2017 field season the DENA EPMT completed seven major projects: five de-vegetation and two revegetation. In addition, Virnston coordinated two major volunteer projects, one each of de-vegetation and revegetation. Total field hours (broken down into EPMT and volunteer hours), acres surveyed, acres infested, and acres treated, with a comparison to previous years, can be found in table 2.

Table 2. Annual overview of field work conducted by the DENA EPMT from 2004 to 2017.

Year	EPMT Personnel		Volunteer Crews		Total Person Field Hours	Invasive GPS Data NPS Lands(non-NPS lands)		
	# pers.	Field Hours	# pers.	Field hours		Species Acres Surveyed	Species Acres Infested ^A	Acres Treated ^B
2004	1	39	1	25	64	2.553 (6.557)	0.934 (6.557)	0.450 (0.035)
2005	1	224	8	544	768	16.713 (2.321)	12.877 (1.531)	3.261 (0.186)
2006	1	454	8	679	1,133	750.313 ^C (2.958)	16.866 (0.349)	10.211 (0.121)
2007	2	743	16	1,173	1,916	805.951 ^C (7.826)	11.329 (0.301)	8.368 (0.289)
2008	2	626	10	454	1,080	741.687 ^C (11.982)	12.750 (7.968)	11.051 (0.649)
2009	2	571	5	385	956	749.459 ^C (4.210)	20.437 (0.317)	11.370 (0.317)
2010	3	1,893	16	2,560	4,453	159.034 (35.245)	16.766 (2.616)	14.125 (2.586)
2011	3	764	3	143	907	290.592 (23.395)	29.348 (7.228)	10.290 (2.010)
2012	2	478	35	912	1390	61.872 (6.397)	19.108 (2.366)	10.519
2013	2	500	27	980	1480	118.85 (8.3)	5.783 (1.89)	4.56 (.461)
2014	2	443	14	337	780	80.33 (0.23)	6.24 (0.04)	0.84 (0.03)
2015	3	1040	14	1350	2390	73.55 (0.41)	5.66 (0.03)	4.71 (0.03)
2016	2	1288	159	2338	3626	3.28 (0.18)	0.80 (0.07)	0.80 (0.07)
2017	2	580	79	894	1474	13.16 (3.77)	0.95 (0.19)	0.89 (0.19)

^A Acres infested represent the area of a mapped infestation multiplied by the percent cover of invasive plants in that mapped area.

^B Acres treated represent the area of a mapped infestation multiplied by the percent cover of invasive plants in that mapped area and by the percent of the infestation treated.

^C This acreage includes the actual road surface of the Denali Park Road.

Taraxacum officinale, the common dandelion, comprised the bulk of our de-vegetation field work. We manually removed an estimated total of 608 pounds of this invasive species and invested 557 person hours. Because it is the most populous of the invasive species found in the park and has the greatest potential to spread outside of its current containment in the visitor-heavy portions of the park, its removal was our primary priority for the first month of the field season. A breakdown of the pounds removed and person hours invested for each invasive plant species can be found in table 3.

Table 3. Species breakdown of estimated DENA EPMT manual removal work in the 2017 field season.

Invasive Species	Pounds Removed	Person Hours
<i>Taraxacum officinale</i>	608	557
<i>Crepis tectorum</i>	62	100
<i>Melilotus albus</i>	73	17
<i>Hordeum jubatum</i>	543	64
<i>Hieracium umbellatum</i>	0.5	0.2
<i>Descurainia sophia</i>	16	4
Total	1302.5	742.2

Elymus sp., or wheatgrass, comprised a majority of our native seed collection efforts in the 2017 field season. Its easily harvested seeds and wide distribution within the park make it an ideal native plant species for seed collection and revegetation. Additionally, many of the seed collection sites used this season were former revegetation sites wherein this species was used extensively and our seed collection events coincided with the maturation of this species' seeds so it was not surprising to find an abundance of this species with seeds ready to harvest. A breakdown of pounds collected and cleaned for each species can be found in table 4.

Table 4. Species breakdown of estimated DENA EPMT seed collection work in the 2017 field season.

Native Species	Pounds Collected^A	Pounds Cleaned^B
<i>Elymus</i> sp.	14.5	2.5
<i>Leymus innovatus</i>	3.3	0.2
<i>Oxytropis campestris</i>	1.9	1.6
<i>Hedysarum alpinum</i>	4.2	0.4
<i>Delphinium glaucum</i>	0.8	0.4
<i>Hedysarum boreale</i> ssp. <i>mackenziei</i>	0.1	0.1
<i>Poa alpina</i>	0.4	0.5
<i>Lupinus arcticus</i>	0	0.1
<i>Castilleja</i> spp.	0	0.1
<i>Pedicularis labradorica</i>	0.1	0.1
<i>Saxifraga tricuspidata</i>	0.1	0
<i>Calamagrostis purpurescens</i>	0.1	0
<i>Aster sibericus</i>	0.03	0
<i>Polemonium acutiflorum</i>	0.02	0
<i>Aconitum delphinifolium</i>	0.004	0

^A Includes cleaned and uncleaned seeds.

^B Not all seeds collected this season were cleaned and some seeds cleaned this season were collected in previous seasons.

Table 4 (continued). Species breakdown of estimated DENA EPMT seed collection work in the 2017 field season.

Native Species	Pounds Collected ^A	Pounds Cleaned ^B
<i>Parnassia palustris</i>	0.02	0
<i>Arnica lessingii</i>	0.2	0
Total	25.774	6

^A Includes cleaned and uncleaned seeds.

^B Not all seeds collected this season were cleaned and some seeds cleaned this season were collected in previous seasons.

Vicia cracca (Bird Vetch): Five populations of bird vetch have been found growing in the DOT right-of-way between miles 231.75 to 240.5 of the Parks Highway. During 2016 and 2017, chemical control was carried out on all observed infestations. Two populations that were treated in 2016 were not observed during 2017, but will need continued monitoring in the future. Table 5 displays the percent cover for all infestations that were treated in 2016 and 2017. All new infestations that were observed in 2017 were chemically controlled.

Melilotus albus, or white sweet clover, was chemically controlled for the first time in DOT right-of-way areas on miles 235-236 of the Parks Highway. Follow-up control work will be necessary in future as the infestations were in areas without much native vegetation and because this plant puts out large amounts of seed.

Table 5. Percent cover of *Vicia cracca* on Parks Hwy.

Location	Date	Percent Cover
Mile 231.75	7/5/2016	100%
	7/6/2017	10.5%
Mile 238	7/5/2016	100%
	7/5/2017	20%
Mile 238.5	7/5/2016	100%
	–	Not Detected
Mile 238.8	7/5/2016	100%
	–	Not Detected
Mile 240.5	7/5/2016	100%
	7/5/2017	100%

Future Considerations

Despite great successes in de-vegetation, native seed collection, revegetation projects, GPS surveying, volunteer events, and outreach efforts in the DENA EPMT's 2017 field season, there is always room for improvement and many projects are ongoing, requiring the continued attention and efforts of the DENA EPMT in future field seasons.

Areas of Improvement

- 1) Owing to the coincidence of Virnston's and Mahovlic's leave, there were a number of weeks in July wherein less work was accomplished. Because July is an important month for controlling certain invasive plant species (i.e., *Crepis tectorum*), we likely missed an opportunity to reduce these infestations to a greater extent. The 2018 (and beyond) DENA EPMT should discuss planned leave at the beginning of the field season and how to minimize its impact on work priorities.
- 2) Our data collection and organization tended toward ex post facto scribbles on data sheets and scraps of paper. While our numbers for field hours, pounds of invasive plants removed, and pounds of native seeds collected and cleaned should be reasonably accurate estimates, better data recording practices would increase accuracy, ensure no data is lost, and reduce the time and effort required to compile the data at the end of the field season.
- 3) There is a backlog of uncleaned native seeds collected this season and in previous seasons. It might be wise for future DENA EPMTs to concentrate some of their Need for Seed personnel and volunteer hours on cleaning seeds once sufficient amounts of native seeds are collected.

Ongoing and Future Projects

- 1) The revegetation of the headquarters area and historic district will require ongoing attention to ensure full establishment and document progress.
- 2) The Rock Creek bridge culvert will likely have washouts during heavy rain events in the future and in that case will require further revegetation
- 3) Another trip to Lower Toklat Cabin should be planned for the 2018 field season to ensure complete eradication of *Hordeum jubatum*.
- 4) *Crepis* sweeps should continue (and perhaps be intensified) along the first three miles of the park road and in the bus depot as this invasive species appears to be expanding its range within the park.
- 5) Sweeps of the George Parks Highway and Glitter Gulch should continue (and perhaps be intensified or expanded) because of the aesthetic impact and potential for this highway to serve as a vector into and out of DENA.

- 6) A number of construction projects are planned to begin after the 2017 field season, including the C-Camp leech field, Toklat utilities, and Giglioni Bridge reconstruction projects. The impact of these projects should be considered and appropriate revegetation strategies employed upon their completion.

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