Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #1
Field Work Preparation

Version 1.06
December 2017

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	12/2011	K. Lund	Updates to equipment list	Needed equipment	1.01
1.01	9/2013	D. Perkins	Comments from peer review	Clarity	1.02
1.02	6/2015	K. Lund	Updates to equipment list	New equipment added and better organization	1.03
1.03	4/2016	A.W. Biel	Minor editorial	Publication preparation	1.04
1.04	3/2017	L. Gommermann/D. Perkisn	Editorial	Clarity	1.05
1.05	12/2017	L. Gommermann	Updates to equipment list	Needed equipment	1.06

Procedures

1. Prior to the field season each year, all observers should review the entire protocol.

2. The project manager will provide an overview of the project scope and methods. Prior to sampling, the project manager will provide a map of the park and reference frame.

3. The project manager should work with the GIS specialist to prepare maps of monitoring routes, plots, and extra areas for the field crew.

4. Monitoring will be conducted during the period coinciding with the growing season across the Colorado Plateau, generally May through September. Sampling dates should be scheduled and logistics organized prior to the start of each field season. Logistics include scheduling park housing, where possible, and the acquisition of backcountry camping permits, where necessary. A preliminary schedule should be approved by the PI (project

manager). Upon approval, resource staff of park units being visited should be notified (via an email message) of the dates when the invasives field crew will be in their parks. Just prior to when the field crew enters a park unit, the resource staff of the park will be provided with the actual dates when field crew members will be working in the park, a list of their names, and approximate locations of monitoring activity. Crew leaders should review the NCPN Backcountry Safety Plan for procedures for filing an itinerary with GLCA dispatch.

5. Equipment should be checked before visiting the field to provide sufficient time for ordering and repairing equipment. The following equipment is needed:

- GPS units with data dictionaries and batteries (2 per person, includes spare)
- GPS charging cords
- Memory cards (to back-up GPS)
- Overview maps with monitoring routes, monitoring plots, and any extra-area searches
- Data sheets (including 25% on write-in-the-rain paper)
- Backpack
- Unknown plant specimen forms
- Park Priority Invasive Plant List
- Park plant list
- Previous NCPN Invasives report for park
- Previous trip reports for park
- Collect voucher species list (Helen has provided this in the past)
- Field guides needed to identify exotic plants, including photographs of plants and similar species
- Flora set, including A Utah Flora & Intermountain Flora (also Uinta Flora for DINO trips)
- Unknown-plant collection kits, including ziplocks, masking tape & Sharpies (one kit per person)
- Trowel (e.g. U-Dig It)
- Plant press
- Inverter
- Waterproof topo map(s)
- Permit
- SOPs
- Access docs
- Clipboard/binder
- Hand lens (one per person)
- Pencils, Sharpies
- Compass
- Transect tapes measured in 10 meters (make sure not only feet, one per person)

- 2-m folding engineer's ruler (2 per person)
- Digital camera, including back-up battery and charger
- Field notebook to record accessory field observations(one per person)
- Laser rangefinders
- Binoculars
- Calculators
- Clinometer
- Back country first aid kit (one per person, check its fully stocked before departing)
- Satellite phones and charger (one or more)
- DeLorme inReach explorer and charger (one or more)
- Backcountry Travel Plan (1 for each communication device, also upload to Drive, print 1 copy for file on Doug's desk, and email GLCA Dispatch before leaving
- NCPN Field Safety plan
- NCPN Accident Report Logs
- NCPN Medical Information Forms
- BLCA only - Wilderness Entry Forms (request from Dangoule)
- Sunscreen
- Radios (one per person + at least one spare, small ziplocs labeled "Good" and "Bad")
- Spare batteries for radios
- Orange safety vests (if monitoring next to roads)
- Survey Crew road signs (if monitoring on the road; 2)
- Road-sign stands (if monitoring on the road; 2)

- Kitchen Box
- Cooler
- Table & camp chairs
- Stove (w/ regulator), propane, and hose (verify stove is in working condition before departing)
- Water

- Discuss contingency plans for crew member not getting back to camp before departing

Add the following for monitoring BLCA East Portal

- duckie (inflatable kayak) with associated equipment (paddle, repair kit, air pump, pdf, dry bag, PDFs, throw bag(s))
- Tecnu (poison ivy treatment)

Add the following for monitoring DINO river trips:

- Tecnu (poison ivy treatment)
- Extra radios for boatmen

- Small pelican cases and small Ziploc bags (hold backup SD cards & GPS batteries)
- Helmets & PFDs (1/person plus one backup PFD/boat)
- GoalZero Generator (fully charged)
- Transducer measurement equipment (in place measurements/not removing transducers)
- Small cooler for first night food, Yeti 125 cooler on boat
- Safety Talk
- Bug spray & headnets (for mosquitoes)
- Shuttle agreement (make sure to gas up in Dinosaur, CO!)
- Binoculars
- 20 L dry bags (2) for monitoring gear for each boat
- 100 L dry bag (1) for plant press and generator
- Closed-toed shoes are a must!
- Small backpack for walking along shore

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #2
Training Observers

Version 1.02
March 22, 2016

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	9/2013	D. Perkins	Editorial changes from peer review.	Clarity	1.01
1.01	3/2016	A.W. Biel	Minor editorial	Publication preparation	1.02

Monitoring must be conducted in a reliable and repeatable manner. Therefore, every effort must be made to hire and retain well-qualified staff to conduct this work. Necessary skills to be acquired or honed before beginning each season's field data collection are reviewed below.

Training Observers in Navigation

A. Knowledge of the use of a GPS is essential. GPS is used to navigate to plots, and to record information on infestations. SOP #6 (Use of a GPS) should be thoroughly reviewed. Questions on the use of a GPS should be directed to the NCPN GIS expert. Training sessions described below will require field crew members to use a GPS.

B. Training should include: Updating transect starting points, recording weed infestation points, and opening files in the GPS to start a monitoring route. How to reconnect the GPS receiver if disconnected, changing the BFP, and logging an EDSW change during a route should be reviewed.

Training Observers in Plant Identification

Observers are expected to be familiar with plant taxonomy and terminology in order to become quickly familiar with invasive exotic plants (IEPs) encountered at network parks. Field botanists should:

A. Obtain Target Invasive Exotic Plant Lists for each park that include the species that observers are likely to encounter in the field.

B. Prior to the start of the field season, all field botanists should:

   1. Review photographs, taxonomic keys, herbarium sheets, and notes on field identification.

   2. Practice plant identification, making use of herbarium specimens where possible.

   3. Spend time in the field to become familiar with the IEPs on the watch lists.

   4. Focus training efforts on field identification rather than on formal taxonomy.

   5. Be trained in actual detection with known infestations or placement of replicas.

   6. Determine EDSW per observer in varying habitats (changing density of vegetation and terrain).

C. Obtain field guide-based lists that highlight key vegetative characteristics used in field identification. Names and descriptions of look-alike species should also be provided. Observers should be encouraged to improve on keys for future use.

D. Incorporate plant-identification quizzes into field work to improve plant identification skills.

Training Observers in Foliar Plant Estimates

Foliar cover estimates provide an estimate of IEP abundance. Consequently, consistent measurements are important for tracking changes in cover over time. However, obtaining consistent estimates among observers is notoriously difficult. This problem is exacerbated with IEP monitoring, which requires integrating abundance over extremely large areas.

Foliar cover measures a vertical projection of the leaf area. This can be viewed as the ground area that would be obscured from a downward projection of light above the plant.

Instruct observers to conceive of plant cover in the cover classes outlined in SOPs 3, 4, and 5. This will cover both cover in an infestation detected during a monitoring route and cover within the 1-m^2 monitoring quadrats.

A. Train observers on cover estimation in a group setting, allowing for discussion of each other's estimates. With practice and discussion, foliar cover estimates by observers should begin to converge.

B. Encourage observers to memorize the cover class scale.

C. Practice estimating cover for different plant-forms, such as forbs, grasses, and shrubs.

D. Throughout the sampling season, review foliar cover estimation. Early in the field season, observers should calibrate themselves daily. Weekly calibration is recommended thereafter.

E. Ensure good communication among the crew about observer patterns of cover estimation.

F. As vegetation dies back, use methods for estimating foliar cover of senescing vegetation assuming plant is fully leafed out. This is not preferable to monitoring when vegetation is leafed out, but is acknowledging that not all IEPs will leaf out at the same time.

Safety is a top priority for monitoring crews. Permanent crew leaders should have Wilderness First Responder or Wilderness Advanced First Aid certifications. Safety training for the crew should include reviewing the NCPN Backcountry Safety Plan and First Aid/CPR.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #3
Monitoring Route Methods

Version 1.15
November 2019

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.00	04/09	D. Perkins	Streamlined plot set up, removed macroplot – plots are now done on transects	Make protocol more efficient while still covering the same area	1.01
1.01	12/09	D. Perkins	Changed distance for transect locations, minor changes for clarity	Better detect roadside invasions	1.02
1.02	12/10	D. Perkins	Editorial	Clarity	1.03
1.03	12/11	K. Lund	Editorial	Clarity	1.04
1.04	06/13	K. Lund	Added Dead Root category to Microhabitats for the plots; changed BFP to 20m; minor edits	Began including dead roots last year; changed BFP from EDSW to 20m	1.05
1.05	9/13	D. Perkins	Comments from Bozek Review	Clarity	1.06
1.06	5/14	K. Lund	Clarified relationship between EDSW and MDTS; minor edits	Difficulty with data repeatability & clarity	1.07
1.07	4/15	K. Lund	Quadrats along transects should be kept at original spacing. Tamarisk beetle is recorded as a separate disturbance. Editorial.	Quadrats should be kept at original spacing since small microclimate differences can affect invasive species. Impacts of tamarisk beetle on target species. Clarity.	1.08
1.08	6/18/15	D. Perkins	Added methods for dealing with dead (>1 year) and recently dead (>1 yr) plants in transects	Changed to reflect what has been done	1.09
1.09	3/16	A.W. Biel	Minor editorial, minor	Clarity, consistency with other	1.10

			corrections/additions, formatting	SOPs, and publication preparation	
1.10	6/16	D. Perkins	Changes to clarity based on 2016 field crew training	Changes to definitions of rock, sediment, few plants, and disturbance	1.11
1.12	3/17	L. Gommerman/D. Perkins	Changes to clarity	Editorial	1.13
1.13	12/17	L. Gommermann	Clarifying monitoring, added Completing Monitoring Route section, added safety & SPE Risk Assessment Model	Clarity and enhance crew safety	1.14
1.14	11/19	D. Perkins/L. Gommerman	Clarified version history table	Bookkeeping, version 1.15 was used in 2018 and 2019	1.15

This SOP gives step-by-step methods for the collection of field data for invasive exotic plants monitoring routes. Methods for extra area surveys and monitoring "lite" are found in SOPs 4 and 5, respectively. The methods outlined in this SOP closely follow the methods outlined by Utah State University (Anderson and Dewey 2007). In several cases, large portions of the text have been lifted directly from their handbook. We are grateful for their efforts on the Colorado Plateau and their expertise in this area.

1 Monitoring Routes

Monitoring routes will follow the roads, trails, and riparian areas in a park. As monitoring routes are traversed, locations of all priority species are documented using mapping-grade global positioning system (GPS) units with better than 5-meter accuracy.

Field locations of invasive exotic plants (IEPs) are recorded by GPS as UTM coordinates, and are later differentially corrected in the production of final digital products. The crews record invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception is not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps are then to be later converted to digital format.

2 Determine Settings

2.1 Determine the Park Priority Invasive Exotic Plant List

NCPN will work with park staff and other local cooperators to develop a priority invasive exotic plant species list of 20–30 invasive plant species that the NCPN crews will be responsible for detecting while surveying the monitoring routes in each park. This targeted list will allow for

better-targeted training prior to park visits. Because these surveys are designed to be rapid, they will be much more effective if crews can have a focused search image, rather than searching for every possible invasive plant species. The list will be updated annually to ensure that any species new to the area are added (SOP #9).

2.2 Determine the Minimum Detection Target Size

Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species, such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*), might be possible due to their large size, single plants of other species, such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*), might prove impossible under certain field conditions.

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 percent 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. NCPN monitoring will have a minimum detection target size of 0.01 acres (approximately 40 m^2 or 20 x 20 ft) for all invasive species, unless otherwise noted.

2.3 Determine Effective Detection Distance

The Effective Detection Distance (EDD) is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTS of the least-visible targeted species with at least 90% detection efficiency (Figure 3-1). If the MDTS is visualized as a square, then the EDD is the distance from the searcher to the center of the square (Figure 3-1).

Crew members calibrate themselves by walking away from a targeted patch size of the least-visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and priority species. Heavy cover and/or difficult-to-see species may require detection swath widths as narrow as 2 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater.

2.4 Determine Effective Detection Swath Width

Effective Detection Swath Width (EDSW) is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90%

of all priority species of the minimum specified infestation size (Figure 3-1). NCPN sets the maximum width of search-pattern swaths based on the goal of detecting at least 90% of all priority weed patches 0.01 acres or larger in size. The effective detection swath width (EDSW) is equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD from either side of his/her search route.

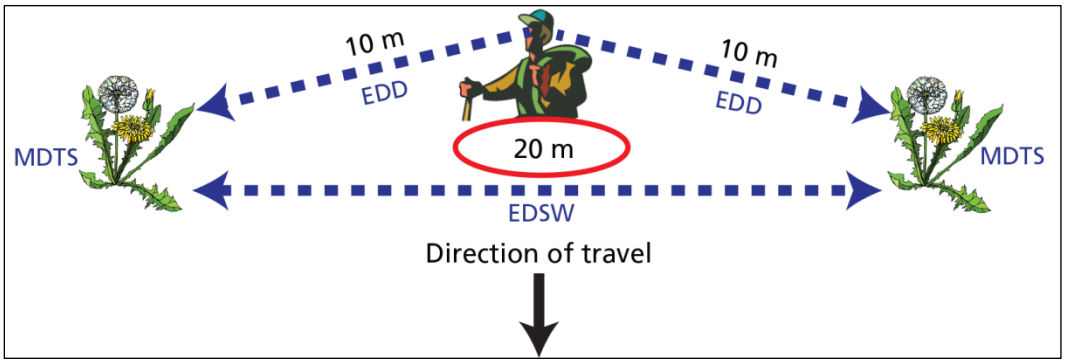


Figure 3-1. If the maximum Effective Detection Distance (EDD) for this MDTS is 10 meters, then the actual Effective Detection Swath Width would be 20 meters (from Anderson and Dewey 2007).

2.5 Patch Separation Resolution

Patch Separation Resolution (PSR) is defined as the minimum distance between plants that must be considered members of separate patches or infestations. Individuals or clusters of a priority species separated by the PSR distance or more must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR is set at 50 meters unless otherwise noted. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

2.6 Between Feature Position

Between Feature Positions (BFPs) allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models), this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. The default setting is 20 m. This needs to be set in the GPS under Settings every time a new route is started.

3 Conducting a Monitoring Route

3.1 Initiate Monitoring Route

A monitoring route is one continuous road, stream, or trail; for example, the park entrance road. In some cases where the road/stream/trail is extremely long, it may be broken up into smaller routes; for example, the north park entrance road and south park entrance road. If the GPS road, trail, or wash deviates from the actual road, trail, or wash, then the crew member should follow the actual road, trail, or wash.

Surveying will take place in different locations, depending on the type of route.

- For single-track trails, seldom-used roads, streams less than 1 m across (wetted width), and washes and drainages, the surveyor should walk directly down the middle of the feature and monitoring will only be done in one direction.

- For major roads (paved and well-maintained gravel) and streams larger than 1 m across (wetted width), the surveyor should walk 5 m away from the edge of the road or stream. Both sides of the road or stream should be walked.

While walking, the surveyor searches for species on the Priority Invasive Exotic Plant List by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for priority species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percentage of the time spent walking through a search area must be devoted to looking down at one's feet, then there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations, it is recommended that, at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

While surveying, crew safety is the highest priority. Crew members will often be working independently in the backcountry during monitoring and they are expected to make sound decisions that will maintain their personal safety at all times. If a crew member is conducting a monitoring route that they think is too dangerous to continue, they are strongly encouraged to stop monitoring this route.

3.2 Set the EDSW

Determine the EDSW (see Section 2.4) and enter it as a point feature into the GPS per monitoring route. This may take some walking around to familiarize yourself with the terrain

and visualizing the MDTS. It is not necessary to adjust the setting for small or temporary changes (going through a small patch of dense shrubs) in the EDSW along a route, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route). Depending on the terrain, it is common to use the same EDSW for a full monitoring route. In situations of major roads and streams larger than 1 m across, the EDSW will equal the EDD plus the distance away from the edge of the road/stream.

3.3 Set the BFP

Set the BFP (see Section 2.6) to 20 m.

3.4 Recording Invasive Plants

Once a weed patch/infestation has been discovered, the crew member records the data as a point feature into the GPS data dictionary (see SOP #6)[1]. Point features reflect a distinct location described as a single position coordinate (Figure 3-2).

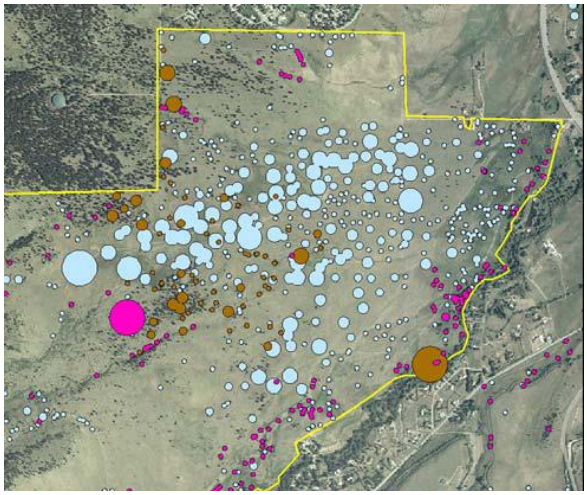


Figure 3-2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors (from Anderson and Dewey 2007).

[1] Occasionally, satellite coverage will not be available when an infestation is encountered. In these cases, use a permanent marker to plot the point on a hard copy map of the route. Label this point with the letter of your GPS unit followed by a number (e.g., K01). Proceed to enter infestation attributes (species name, size, cover, etc.) into the GPS as one would if satellite coverage were available. Under "Notes", be sure to type the point label that was used to label the infestation point on the hard copy map (e.g., K01). All infestation attribute data will be saved in the GPS. During data processing, the GIS Technician will use the hard copy map to locate this infestation electronically.

1. Record the following information for each infestation as a point feature in the GPS unit. (Table 3-1). If the GPS is set to automatically fill in the fields, double-check that all information is correct for each point feature.

Table 3-1. Attributes in the GPS data dictionary.

Attribute	Attribute explanation
SpeciesName	6-letter code for Latin name of the targeted invasive species. This list will be updated for each park visited, based on input from park staff. "Other" will always be a choice.
Size (visually estimated; see Section 3.5 for Estimating Size of Infestation)	Infestation size • 1–3 (patches 2×2 meters or less) • 4 plants–40 m^2 (48 $yards^2$ or 0.01 acres) • 40–400 m^2 (48–478 $yards^2$ or 0.01–0.10 acres) • 400–1,000 m^2 (0.1–0.25 acre) • 1,000–2,000 m^2 (0.25–0.5 acre)
CanopyCover (visually estimated; see Section 3.6 for Estimating Percent Cover)	Percent Canopy Cover: • Trace (<1%) • Low (1–5%) • Moderate (6–25%) • High (26–50%) • Majority (51–100%)
Pulled	Note if plant(s) pulled by observer: • Yes (pulled) • No (not pulled) –Default
GrowthStage	Growth stage of trees: • Seedling(s) • Sapling(s) • Mature Tree(s) • Old Growth
PriorTreatment	Note if area looks like it was previously treated for species being recorded, by any means (tree stumps, piles of weeds, spraying obvious, etc.): • Yes, area treated • No treatment –Default

Attribute	Attribute explanation
Disturbance	• This is disturbances other than would be normally observed along the road, trail, or riparian area that the route is following. So the disturbances listed below are in addition to and are noticed at the site: • Flooding • Grazing Impact • Hiking trails • Human occupation • Prehistoric occupation • Insect disturbance • Livestock • Recreation use • Roads/OHV Trails • Spring Source • Windthrow • Tamarisk beetle • Other
Surveyor	Name of person surveying the monitoring route
EDSW	Effective Detection Swath Width in meters (see Section 2.4)
PSR	Patch Separation Resolution–minimum distance between patches that constitutes separation of infestations (see Section 2.5)
Notes	Any comments regarding the site (can contain species name if "other")

- If several species are present with similar distributions, then a point must be recorded for each individual species. Stagger the points of different species so they are not mapped on top of each other.

- Tree species of different growth stages within a distance of 50 m are mapped as separate infestations. For classifying tree growth stage, use the following guidance. (However, it is not expected of crew members to directly measure individual trees; rather, visual estimates are sufficient for the purpose of this monitoring.)

  Seedlings = < 2.5 cm DBH (Diameter at Breast Height)

  Saplings = 2.5-15.0 cm DBH

  Mature Trees = >15.0 cm DBH

  Old Growth = notably large and/or established individuals over 15 cm DBH

- Invasions more than 50 m (55 yards) apart are considered separate invasions and must be marked as separate points.

- In the case of the same large infestation, the observer should continue recording a point every 50 m.
- If there is no satellite coverage, mark the point on the topo map using a letter or number system. Record the other relevant information (e.g., size, cover) in the GPS unit, noting the corresponding letter or number in the Notes section (see SOP 6).
- Generally, only the invasive species on the Priority Invasive Exotic Plant List should be recorded. Observers can also use their own judgment to record additional invasive species (i.e., a highly invasive plant that is not on the list and was not thought to be present) that they think would be useful to park management.
- Qualified surveyors may remove small, isolated populations of invasive plants. If they are at the head of a canyon far from a road and they are in a weed-free area, then a single specimen or a group of a small invasion should be removed. However, surveyors will need to use judgment on when to pull plants and exercise their knowledge of the plant's properties (e.g., poisonous, skin reactions, etc.). Surveyors should avoid pulling plants unless they have been trained in how to properly do so. In the vast majority of cases, invasions will require response commitments from parks and exotic plant management teams (EPMT).

3.5 Estimating Size of Infestation

The surveyor should envision the patch as a circle, oval, square, or rectangle—whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, the surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 3-3). In most cases, observers should learn to quickly place infestations into one of the associated size classes rather than pacing or using the rangefinder. The radius should be an average of 2 readings: the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters; see Table 3-2).

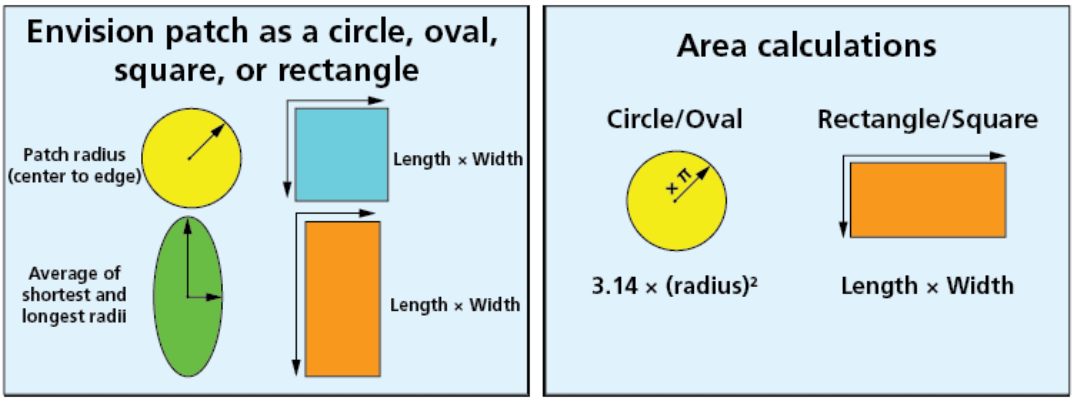


Figure 3-3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right) (from Anderson and Dewey 2007).

Table 3-2. Reference table for metric and English measurements.

Meters²	Acres	Square yards	Radius (m)	Radius (yards)	Diameter (m)	Diameter (yards)
40	0.01	48	3.6	3.9	7.2	7.8
400	0.1	478	11.3	12.3	22.6	24.6
1,000	0.25	1,120	17.9	18.9	35.7	37.8
2,000	0.5	2,420	25.3	27.8	50.1	55.5

3.6 Estimating Percent Cover

Percent cover must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 3-4). The infestation's density, or canopy cover designation, would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 10 m away from its nearest neighbor, then all of the plants would still be considered part of the same infestation. The total area infested would be 0.12 hectares, with a very low density, or canopy cover designation (Figure 3-4).

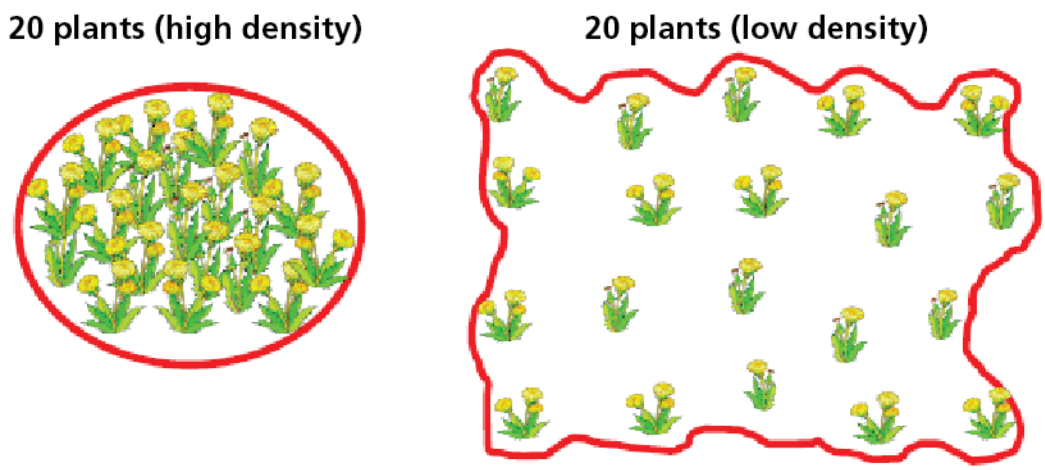


Figure 3-4. On the left, 20 plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single, high-density infestation of 0.001 hectare in size. On the right, 20 plants are separated by 10 meters from one area over another area. Collectively, the extent of the plants is slightly less than the PSR (~40 m), and are therefore still considered a single infestation. However, this patch is very low in density and is 1.92 hectares in size (from Anderson and Dewey 2007).

The term "canopy cover" refers to a visual estimate of 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). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes:

1) trace = less than 1%
2) low = 1–5%
3) moderate = 6–25%
4) high = 26–50%
5) majority = 51–100%.

A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 3-5). To estimate canopy cover, the surveyor considers the midpoint value between 0 and 100 percent, and asks, "Is the percent cover greater or less than 50 percent?" If the answer is "less," then the surveyor selects the midpoint value between 0 and 50, and asks, "Is the percent cover

greater or less than 25 percent?" If the answer is "less," then the next question becomes, "Is the percent cover between 25 and 12.5 percent, or between 12.5 and 0 percent?"

This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy cover class is then chosen and selected from the GPS menu. The same process applies whether estimating the canopy cover of a 0.5-acre infestation or a small infestation. However, single-plant infestations would always be in the majority (>51%) cover class.

3.6.1

Figure 3-5. The percent canopy cover is estimated from within the perimeter of the actual infested area (from Anderson and Dewey 2007).

4 Invasion on Inaccessible Land

4.1 Offsetting or Projecting

If mapping in terrain where reaching a visible weed infestation is difficult or impossible, it is still possible to accurately record that location as a point feature using an "offset" command in Trimble GPS models, the "projecting" option in certain Garmin GPS units, or similar functions in other brands and models of GPS units. Offsetting or projecting allows the surveyor to safely map those identifiable infestations found on steep terrain, across canyons, and across rivers without actually having to stand on that site (Figure 3-6). It allows the observer to maintain better accuracy than might be achieved by drawing the infestation by hand on a paper map or a touch-screen GPS unit. If no GPS signal is available, then the location may be noted on a paper map.

Figure 3-6. Offsetting to a weed patch on a steep hillside across an impassable river (from Anderson and Dewey 2007).

Offsetting or projecting requires a determination of the compass bearing and the horizontal distance between the observer and the target. If an accurate elevation value is required, then the vertical distance between the observer and the patch also is needed. Equipment needed for offsetting/projecting distant weed infestations includes a basic field compass, a laser rangefinder, a simple clinometer, and a calculator capable of computing basic trigonometry equations.

4.1.1 Bearing

A compass is used to determine the bearing to the center of the targeted weed infestation. It is easiest if the GPS is configured to magnetic north rather than true north. Otherwise, you will have to adjust the compass reading to compensate for declination. It is also important to hold the compass as far away as possible from your body, metal, electronic equipment (such as the GPS unit), or other objects that could influence the compass needle.

4.1.2 Horizontal distance

The horizontal distance is easiest to determine if the targeted infestation is at the same elevation as the observer. In this situation, simply use the laser rangefinder to determine the exact distance from your location to the center of the targeted weed patch. However, if the infestation is significantly above or below your present location, the distance determined by the rangefinder will be greater than the true horizontal distance. This distance determined by the laser rangefinder is referred to as the as the visual distance or slope distance (hypotenuse of a right triangle, Figure 3-7). If the visual distance, rather than the true distance, is used in the offsetting function, then the weed point's placement on a map will be incorrect (placed further away from the observer than was actually the case).

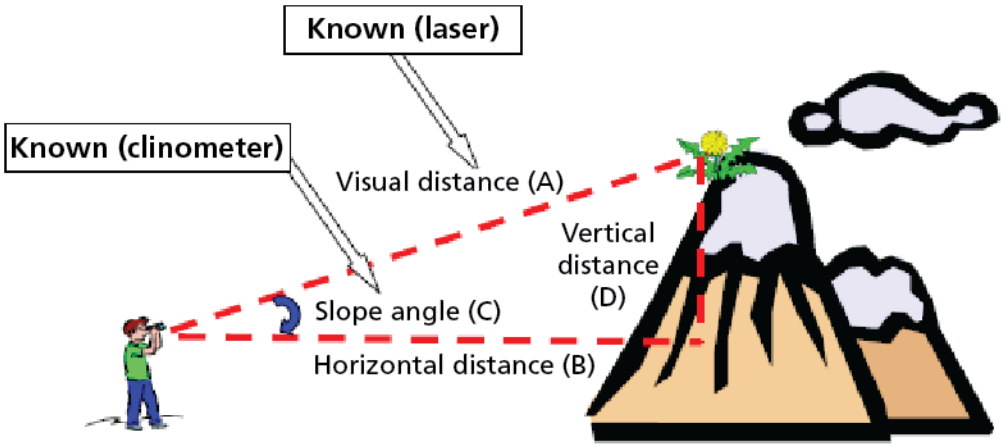


Figure 3.7. The visual distance between the observer and the weed (A) as measured by a laser rangefinder is greater than the true horizontal distance (B). Simple trigonometry can be used to calculate the horizontal distance and the vertical distance (D) (from Anderson and Dewey 2007).

To determine the true horizontal distance requires use of some basic trigonometry, as per the following equation (based on the letters indicated in Figure 3.7):

(Cosine of C) × A = B. In other words, the cosine of the slope angle (C), multiplied by the visual distance (A), equals the horizontal distance (B).

The vertical angle can be determined by one of several methods. A clinometer is the most accurate tool, and some models can be relatively inexpensive. The field compasses can come equipped with a built-in clinometer.

4.1.3 Vertical distance

The vertical distance is the difference in elevation between the observer and the targeted infestation (Figure 3.7). Vertical distance is calculated using the following equation (see Figure 3.7):

(Sine of C) × A = D In other words, the sine of the slope angle (C), multiplied by the visual distance (A) equals the vertical distance (D).

4.2 Estimating Infestation Size from a Distance

One of the challenges associated with offsetting is visually estimating the size of a distant weed infestation. The size of a remote weed patch can be estimated with surprising accuracy by using essentially the same measurements and calculations described above for offsetting. Two compass bearings are used to estimate the width of the patch (in degrees), and the degrees are

converted to a distance using a slight variation of the trigonometric equation described earlier for vertical distance.

4.2.1 Circular patches

To approximate the size of a distant weed infestation that is roughly round or square, you will need to determine distance between the surveyor and the center of the patch, as well as the radius or width of the patch.

a) The first step is to determine the distance to the approximate center of the patch (B) by using a laser rangefinder (Figure 3-8). The width of the patch is measured by determining the compass bearings of the right and left edges. The difference in degrees between the two edges is considered the width angle (Figure 3-9).

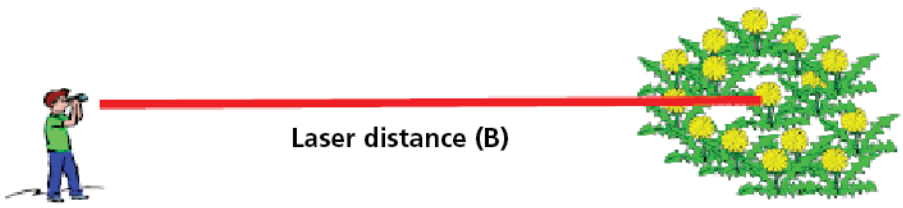


Figure 3-8. Side view of the surveyor determining the laser distance (B) to the center of a remote weed patch (from Anderson and Dewey 2007).

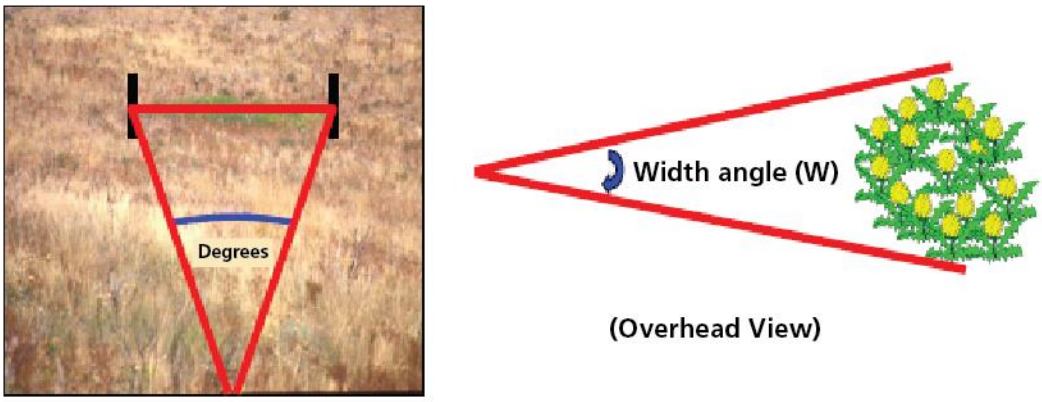


Figure 3-9. To determine the width angle, the surveyor must find the compass bearings of the left and right edges of the patch. The difference between the two bearings is the width angle (W). For example, if the left edge bearing is 88 degrees and the right edge bearing is 100 degrees, then the width angle (W) is 12 degrees (from Anderson and Dewey 2007).

b) The next step is to determine the patch radius. To do this requires the radius angle (C), which is simply one half of the width angle described above. In Figure 3.10, the radius angle is identified by the letter "C" and the patch radius is designated as "D".

c) Patch radius is calculated using the following equation (see Figure 3.10): (Tangent of C) × B = D

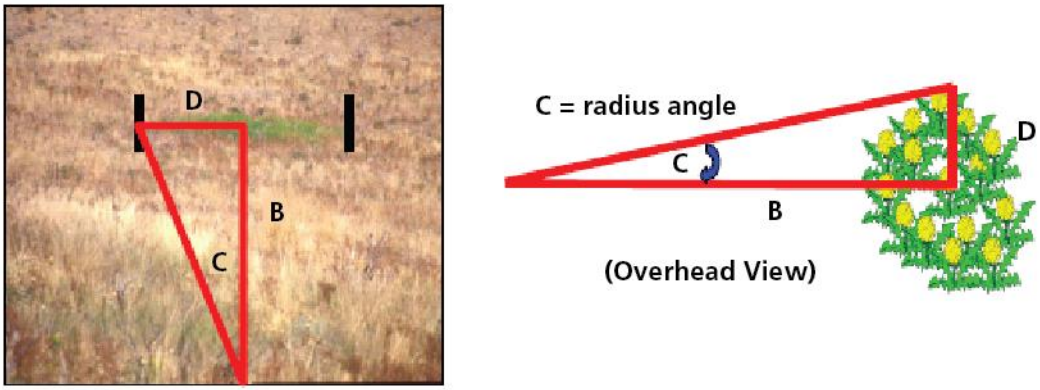


Figure 3-10. The radius angle (C) is equal to one half of the width angle (W in Figure 3-9). If the width angle of this leafy spurge patch was determined to be 12 degrees, then the radius angle would be 6 degrees (from Anderson and Dewey 2007).

The area of a circular patch is calculated by using the following equation: Area = 3.14 × (radius^2).

4.2.2 Square patches

The same procedure could be followed, up to the point of having determined the value corresponding to "D" (patch radius). But instead of using that value in the formula for determining the area of a circle, the calculated radius value would be considered half of the width of the square patch.

4.2.3 Other-shaped patches

In situations where the shape of a remote patch is not circular or square, the observer is encouraged to envision it as a rectangle. The objective then becomes to estimate its length and width, then multiply the two together to determine the total area. The simplest approach is to first determine its width or length using the tangent equation described above. If a length is determined, then the width value is estimated visually based on the ratio (percentage) of the width's dimension to the "measured" length value. The length of the patch is calculated using the same trigonometric equation described for determining the radius of a circular patch. However, the value resulting from this calculation (158 meters) is equal to only half of the total patch length, and so must be multiplied by 2 (Figure 3.11). (Tangent of 37 degrees) × 210 meters = 158 meters.

The width of the patch is estimated using the calculated length value as a standard of measure. In other words, the surveyor estimates the ratio between the length and width distances, and then multiplies the length by the corresponding percentage to determine the width. The surveyor estimates that the width of the saltcedar patch is approximately 20 percent of its

length. By multiplication, the width is calculated to be an average of 63 meters (316 × 0.20) (Figure 3-11).

Figure 3-11. On the left, the length of the patch is equal to twice the value determined for "D" (see Figure 3-10). If "D" is 158 meters, then the total patch length would be 316 meters. On the right, the width of the patch is estimated to average approximately 20% of the patch length. Thus, 20% of 316 meters is 63 meters (from Anderson and Dewey 2007).

5 Conducting Monitoring Transects and Quadrats

In order to collect data to make trend estimates over time, more quantitative methods than the monitoring routes are needed. Transects with 3 monitoring quadrats are established along monitoring routes. Quadrats are more statistically sound and increase the power of the data collected by allowing for greater inference across unsampled areas. This method makes the samples comparable to other monitoring standards (e.g., Forest Health Monitoring, Forest Inventory and Analysis, USGS Modified- Whittaker technique, and others).

These quadrats provide an estimate of actual cover, a method to calibrate ocular and other cover estimates, and a method for understanding which habitats and sites are being invaded. They also model the patches of missed and less-sampled non-native species. Transects with 3 vegetation quadrats are established every 500 m along monitoring routes.

5.1 Establishing the Transect

Transect locations are pre-set in the GPS and will be shown along the routes in the GPS and on the maps. When a location is reached, the transect is established by updating the point (double-clicking on the icon and updating the file by logging 10 points; see SOP 6) in the GPS and extending measuring tape perpendicular from the monitoring route (see Figure 3.8).

In the event that a road, trail, or wash is different in the GPS than in actuality, the observer should walk along the actual trail and establish the transect in the location along the trail that is closest to the GPS transect location.

- For single-track trails, seldom-used roads, streams less than 1 m across (wetted width), and washes and drainages, establish transects on alternating sides relative to the middle of the feature. If one side cannot be sampled, then establish the transect on the same side as the previous transect. Continue alternating sides from there.

- For major roads (paved and well-maintained gravel) and streams larger than 1 m across (wetted width): the two sides of the road or river should be treated as separate routes. Therefore, transects will always start at the edge of the feature (major road/large stream) and proceed away from the feature.

- If the transect location cannot be reached (e.g., cliff wall), then establish the transect in the closest location possible. Efforts should be taken to not skip transects.

5.2 Establishing the Quadrats

Establish 3 vegetation quadrats (1×1 m) along the transect at 0, 4.5, and 9.5 m (centered at 0.5, 5, and 10 m; Q1, Q2, Q3, respectively) from the monitoring route. The quadrat is placed on the right side of the transect line as the technician walks from the monitoring route.

- If there is not 10 m between the monitoring route and a constrained area (e.g., cliff face, NPS boundary, etc.), sample only the quadrats available, even if it is only 1–2 quadrats. Keep original spacing of the quadrats along the transect and do not move quadrats to new locations along transect.

- If there is not 1 m between the monitoring route and a constrained area (e.g., cliff face, NPS boundary, etc.) where a quadrat can safely be placed down, continue walking along the route until a location is reached where at least one quadrat can safely be placed down.

- For transects along single track trails, seldom used roads, and streams and washes with water less than 1 m across, place the 0 quadrat along edge of the trail, road, or stream with water present.

- For transects along dry washes and ephemeral streams, place the 0 quadrat in the center of the drainage

- For transects along roads, place the 0 quadrat at the edge of the asphalt.

- For transects along big rivers, place the 0 quadrat at the water’s edge.

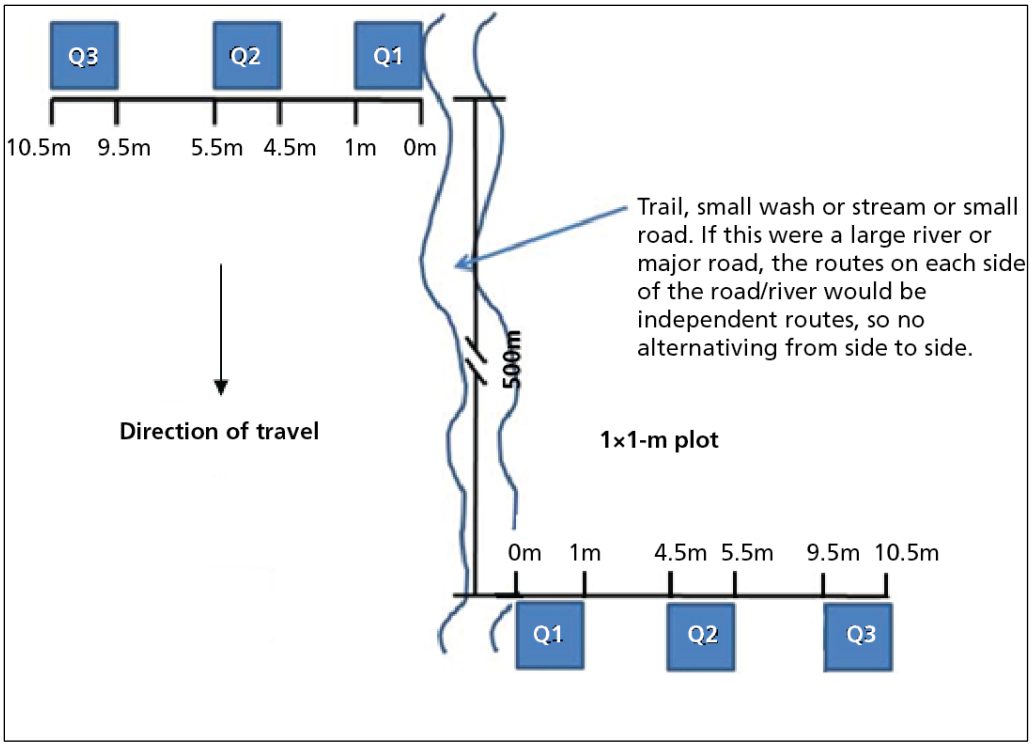


Figure 3-12. Location of 1×1-m plots along a monitoring route.

5.3 Measuring the Vegetation Quadrats

1. Invasive plant diversity and cover and microhabitat cover measurements are taken for each quadrat. Identify any plant species from the Priority Invasive Exotic Plant List as well as park-requested widespread invasives (e.g., cheatgrass) as determined by park staff. Other invasive species do not need to be recorded in the quadrats. Record 6-letter species code and estimate each species' respective percent cover of plants that are alive or were alive in that year to the following classes: 0, <1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40 . . . 100%. Only estimate cover on plants or portion of plant that fall(s) inside the quadrat (ones that hang over but are rooted outside are counted). If there are plants that are dead and appear to have died more than a year ago, record them as above noting a "D" for dead next to the percent cover. Calibration for particular species (e.g. *Salsola, Bromus*) may be necessary before conducting independent field observations.

2. Identify dominant microhabitats (Table 3-3) and estimate percent cover using the above classes within the 1-m^2 quadrat. The total percent cover for the microhabitats should be equal or greater than 100%. With the invasive cover, there will often be overlap of plant species and microhabitats. Therefore, total cover for a quadrat may exceed 100%.

Table 3-3. Microhabitat variables.

Microhabitat	Description
Dead wood	Log and slash (>10 cm diameter), stump, branches and limbs
Dung	
Fungus	On ground, not rocks
Lichen	On ground, not rocks
Litter/Duff	Accumulation of dead, detached organic matter over mineral soil (<10 cm diameter)
Live root/Bole	Living stems and roots at the base of plants or trees exposed at ground surface and cross-sectioned area of tree boles at the ground surface. Dead annual growth from the current growing season is Live root/Bole.
Dead root/Bole	Dead stems and roots at the base of plants or trees exposed at ground surface and cross-sectioned area of tree boles at the ground surface. Dead annual growth from previous growing seasons are Dead root/Bole.
Mineral soil/Sediment	Physically weathered geologic material that may or may not also be chemically and biologically altered. This is less than 2 mm in size.
Moss	
Biological soil crust	Darkened cyanobacterial soil crust, typically black in color
Road/Fill	Including transported rock material and road fill
Rock	A large rock or boulder or accumulations of pebbles or cobbles, originating from location geology. In order to be classified as rock the rock/cobble/pebble must be larger than 2 mm.
Standing water/Flooded	Ponding or flowing water that is not contained within banks.
Stream	Body of flowing water contained within banks
Trash/Junk	

Familiarize yourself with what certain cover estimates (e.g., 10%, 50%, 80%) look like and use them as reference sizes. For example, if you know that 1% cover is about the same size as your fist, use your fist as a reference (Appendix A). Use the enclosed 1% square to become familiar with estimating percentages. Calibrate ocular estimates amongst the crew on a regular basis to ensure consistency with the data.

6 Completing the Monitoring Route

Crew members will continue monitoring a route and conducting transects until they either complete all transects and reach the end of the route (line feature on GPS) or come to a hazard

that the crew member deems too great to continue safely past. While we are never free of risk during our operations, crew members are expected to assess hazards as they are encountered in the field, and due to the isolated nature of this work, should prioritize maintaining personal safety over productivity during monitoring. For example, crew members should never "drop their pack" to enable them to proceed along a route that would otherwise be too difficult to continue along if their backpack remained on, even if only for a short distance, as their backcountry first aid kit and emergency communication device will be left behind.

If a crew member cannot, using their best judgement, decide whether to proceed along a monitoring route due to the presence of a hazard, they are encouraged to consult the SPE (Severity x Probability x Exposure) Risk Assessment Model (Appendix 2). In such a case, it is recommended that crew members discontinue a monitoring route if the SPE value is greater than 39.

7 References

Andersen, K. A., and S. A. Dewey. 2007. USU Wildland weed mapping methods training supplement. Master's thesis. Utah State University, Logan, Utah. 107 pp. plus appendix.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. USDI-BLM Technical Ref. 1730-1. Bureau of Land Management, Denver, Colorado. 477 pp.

Appendix 1. Data Sheet and Examples of Percent Cover

(see next 2 pages)

NCPN Invasive Plant Monitoring				SOP #3, v1.11, June 2016		Entered by:	Proofed by:		
Park:	Route:			Transect:		Date:	Obs:		
	% cover						% cover		
Microhabitat	Q1@0m	Q2@4.5m	Q3@9.5m	Cover classes		Species from Priority Invasive Exotic Plant List	Q1@0m	Q2@4.5m	Q3@9.5m
Dead wood (>10 cm diameter)				0	10				
Dung				<1	20				
Fungus				1	30				
Lichen				2	40				
Litter/Duff				3	50				
Live root/Bole				4	60				
Dead root/Bole				5	70				
Mineral soil/Sediment				6	80				
Moss				7	90				
Biological Soil Crust				8	100				
Road				9					
Rock									
Standing water/flooded									
Stream									
Trash/junk									

NCPN Invasive Plant Monitoring				SOP #3, v1.11, June 2016		Entered by:	Proofed by:		
Park:	Route:			Transect:		Date:	Obs:		
	% cover						% cover		
Microhabitat	Q1@0m	Q2@4.5m	Q3@9.5m	Cover classes		Species from Priority Invasive Exotic Plant List	Q1@0m	Q2@4.5m	Q3@9.5m
Dead wood (>10 cm diameter)				0	10				
Dung				<1	20				
Fungus				1	30				
Lichen				2	40				
Litter/Duff				3	50				
Live root/Bole				4	60				
Dead root/Bole				5	70				
Mineral soil/Sediment				6	80				
Moss				7	90				
Biological Soil Crust				8	100				
Road				9					
Rock									
Standing water/flooded									
Stream									
Trash/junk									

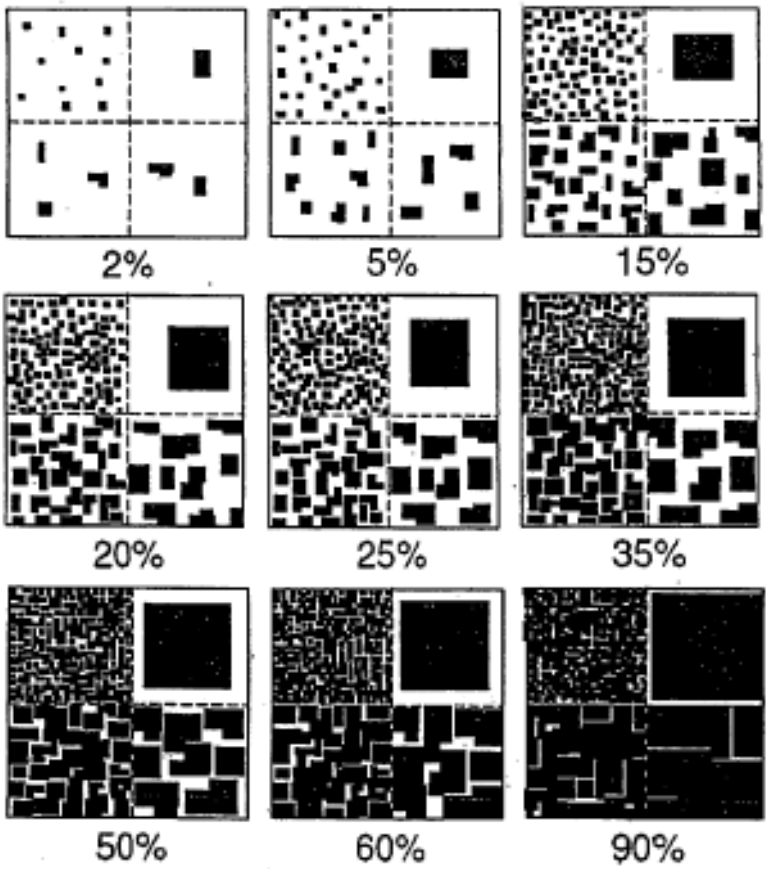
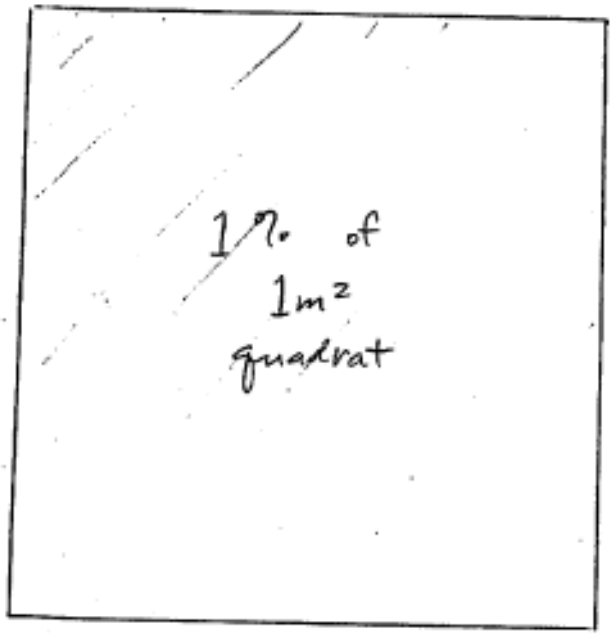


Figure 5. Guide for estimating percent of area covered (from Schoeneberger et al. 2002).



Appendix 2. SPE Risk Assessment Model

SEVERITY x PROBABILITY x EXPOSURE (SPE)		
SEVERITY	**PROBABILITY**	**EXPOSURE**
1. None or slight	1. Impossible or remote in any conditions	1. None or below average
2. Minimal	2. Unlikely under normal conditions	2. Average
3. Significant	3. About 50 / 50	3. Above average
4. Major	4. Greater than 50%	4. Great
5. Catastrophic	5. Very likely to happen	
VALUES	**RISK LEVEL**	**ACTION**
80-100	Very High	Discontinue, Stop
60-79	High	Immediate Correction
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed
1-19	Slight	Possibly Acceptable

SPE Risk Assessment Steps

1. Clearly identify and define the specific hazard and state the outcome you are concerned with.

2. Consider Severity, Probability, and Exposure and assign a number

   Severity describes the potential loss or consequences of an accident. For example, if what you said could happen in step 1 actually happens, what is the most likely outcome? In terms of personal injury, the options are:

   1 Little consequence
   2 Basic first aid, no loss of work time
   3 Medical treatment from a doctor, lost work time
   4 Long-term hospitalization and permanent disability
   5 Death

   Probability describes the likelihood that a given exposure to the hazard, the projected consequence will occur. For example, if you did encountered the hazard 100 times, how many times would the projected consequence occur?

   1 Rare
   2 Unlikely
   3 Possible
   4 Likely
   5 Frequent

Exposure describes the amount of time you are exposed to the hazard, the proportion of people present at risk, the amount of equipment involved, and/or the number of times a task is done. **Hint**: If there is only one person exposed to the hazard and they must proceed, the exposure is 4.

1 Below Average
2 Average
3 Above Average
4 Great

3. Compute the total risk for the task using the formula: **Risk = Severity x Probability x Exposure**.

4. Determine whether the overall level of risk is acceptable using the following table:

Values	Risk Level	Action
80-100	Very High	Discontinue, Stop
60-79	High	Immediate Correction Required
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed/Proceed with Caution
1-19	Slight	Possibly Acceptable/Proceed

5. Manage, control, or eliminate the risk.

   Severity: Personal protective equipment, first aid, pre-accident plans, etc.

   Probability: Training, awareness, attitude change, briefings, etc.

   Exposure: Reducing the number of people involved, the number of events, cycles, evolutions, amount of time exposed to the hazard, etc.

6. Monitor the situation and evaluate the risk control measures selected. Re-evaluate the risk if necessary.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #4
Extra-Area Search Methods

Version 1.04
February 2018

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	12/2010	D. Perkins	Editorial	Clarity	1.01
1.01	3/2016	A.W. Biel	Editorial and formatting	Publication preparation	1.02
1.02	3/2017	L. Gommerman/D. Perkins	Editorial	Clarity	1.03
1.03	2/2018	L. Gommermann	Editorial	Statement added to 2.7 clarifying routes within extra-areas should be monitored separately	1.04

This SOP gives step-by-step methods for the collection of field data for invasive plants extra-area searches. Each year, up to 25% of NCPN survey effort within a park can be directed toward extra areas. Extra areas are places where park personnel determine that an invasive plant survey is of utmost importance. Examples could be places with a new burn, a change in land management within a park or adjacent to a park, or an anecdotal report of a threatening new invasive plant. In some years, there may not be any extra areas conducted; in others, multiple surveys may be needed. The methods outlined in this SOP essentially follow the methods outlined by Utah State University (Anderson and Dewey 2007). In several cases, large portions of the text have been lifted directly from their handbook. We are grateful for their efforts on the Colorado Plateau and their expertise in this area.

1. Search Types

1.1 Transect Searches

Transects are an effective way to ensure that an area is covered thoroughly. Transects are the preferred method in large areas of relatively featureless flat terrain. However, this method is generally impractical in steep terrain or along winding river corridors or canyon bottoms.

A transect pattern consists of searching along straight parallel lines, usually by following a UTM northing/easting (preferred) or a compass bearing. The surveyor walks to a starting position on the edge of the intended search area corresponding to a convenient UTM value (perhaps ending in one, two, or three zeros). Using a compass, the surveyor takes a declination-corrected bearing from that point and aims for a landmark on the distant horizon in the direction of desired travel (grid-north, grid-south, grid-east, or grid-west). It is important to remember that UTM northings and eastings are based on grid north, rather than true north or magnetic north. When using UTM northings or eastings as search transects, mapping crews should generally keep the GPS's north reference set to "magnetic." This helps reduce confusion if wanting to use the GPS bearing reference for navigation (and have it be the same as the compass bearing). Note from the appropriate topographic map the correct declination for the area being surveyed.

While glancing occasionally at the horizon landmark and UTM location displayed on the GPS screen to stay on course, the surveyor walks along, searching on either side of the transect center. When a weed patch is found, the surveyor leaves the transect, stands in the center of the patch, enters the necessary data, and then uses the GPS to return to the same place on the transect. A quick check of the horizon (or compass) indicates the desired direction of travel.

1.2 Contouring (Topographic) Searches

This is the method preferred for hilly country. Searchers using a contouring search pattern walk as perpendicular as possible to the direction of the slope, essentially paralleling the elevation lines of a topographic map. Having completed a full "pass" across a slope, the surveyor then moves up or down slope one effective detection swath width (see Section 2.4, below) and repeats the process in the opposite direction. This creates a series of parallel contiguous search swaths that allows surveyors to sample all micro-habitats associated with the terrain—ridges, draws, and side slopes—over the full range of aspects, elevations, and plant communities. Equally important, it minimizes the physical exertion required to search hilly terrain.

The main challenge of the contour method is staying relatively level. A clinometer can help to alleviate some of this frustration. In open, hilly terrain, a surveyor uses the clinometer to identify a landmark a few hundred meters ahead at the same elevation. The surveyor walks toward that landmark without climbing or going downhill any more than necessary. The

surveyor re-checks the landmark from time to time with the clinometer to be sure s/he is staying at the desired elevation. In timbered, hilly terrain, if visibility is limited so that the use of distant visual landmarks is not feasible, use the elevation reading of the GPS unit to stay at approximately the same level.

2. Determine Settings

2.1 Determine the Park Priority Invasive Exotic Plant List

At each park, NCPN staff will work with park staff and other local cooperators to develop a priority invasive exotic plant species list of 20–30 invasive plant species that the NCPN crews will be responsible for detecting while surveying the monitoring routes. This targeted list will allow for better-targeted training prior to park visits. Because these surveys are designed to be rapid, they will be much more effective if crews can have a focused search image, rather than searching for every possible invasive plant species. The list will be updated annually to ensure that any species new to the area are added (SOP #9).

2.2 Determine the Minimum Detection Target Size

Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species, such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*), might be possible due to their large size, single plants of other species, such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*), might prove impossible under certain field conditions.

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 percent of the total number of patches of that size and larger in the inventory 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. NCPN surveys will have a minimum detection target size of 0.01 acres (approximately 40 m^2 or 20 × 20 ft) for all invasive species, unless otherwise noted.

2.3 Determine Effective Detection Distance

The Effective Detection Distance (EDD) is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTS of the least-visible targeted species with at least 90 percent detection efficiency (Figure 4-1). Crew members calibrate themselves by walking away from a targeted patch size of the least-visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of

an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and priority species.

2.4 Determine Effective Detection Swath Width

Effective Detection Swath Width (EDSW) is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all priority species of the minimum specified infestation size (Figure 4-1). NCPN sets the maximum width of search-pattern swaths based on the goal of detecting at least 90% of all priority weed patches 0.01 acres or larger in size. The effective detection swath width (EDSW) is equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD on either side of his/her search route. Determine the EDSW and enter into the GPS. It is not necessary to adjust the setting for small or temporary changes in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route).

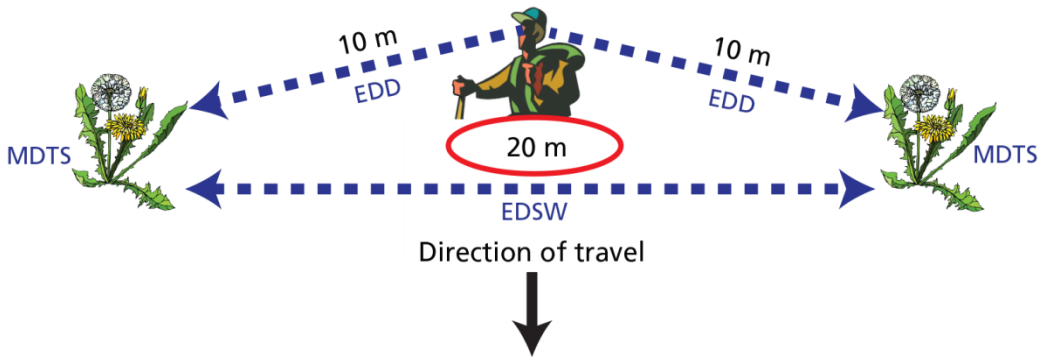


Figure 4-1. If the maximum Effective Detection Distance (EDD) for this MDTS is 10 meters, then the Effective Detection Swath Width is 20 meters (from Anderson and Dewey 2007).

2.5 Determine the Patch Separation Resolution

Patch Separation Resolution (PSR) is defined as the minimum distance between plants that must be considered members of separate patches or infestations. Individuals or clusters of a priority species separated by the PSR distance or more must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR is set at 50 meters, unless otherwise noted. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

2.6 Set the Between Feature Position

Between feature positions (BFP) allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models), this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. The default setting is 20 m. This needs to be set in the GPS under Settings every time a new route is started.

2.7 Initiate Survey Route

While walking, the surveyor searches for priority weeds by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for priority species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percentage of the time spent walking through a search area must be devoted to looking down at one's feet, then there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations, it is recommended that at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

If an invasives route (see SOP #3 and 5) falls within an extra-area search, the route should be monitored in addition to the extra-area search (i.e., the route should be monitored as though it were any other route).

2.8 Determine the Spacing of Survey Routes

In most cases, the areas will be surveyed comprehensively, and transects will be placed one EDSW apart, so that the entire extra area is covered. In some cases, however, park staff may only want a quick look to determine if additional surveys should be completed. In this situation, the spacing of transects would be determined in cooperation with the pertinent park staff.

2.9 Recording Invasive Plants

Once a weed patch/infestation from the Target Invasive Exotic Plant List has been discovered, a mapping crew must record (1) the survey unit, (2) the number of the invasion per survey unit, (3) the dimension of a point, and (4) an estimate of canopy cover. It is important to note that not all non-native species found will be mapped as points. For example, cheatgrass that is dominant across a park or a portion of the park might not be individually mapped. These large infestations can be marked as gross areas (see below).

A. Verify that the pre-recorded information on the GPS pertaining to the extra area is correct. This information is normally generated automatically by the GPS.
B. Record the location of the infestation as a point feature. NCPN crews will map all invasive plant infestations as points. In the case of large infestations, the observer can record multiple points 50 m apart. If several species are present with similar distributions, a point must be recorded for each individual species, each with its own sequential identification number that is automatically generated. Invasions more than 50 m (55 yards) apart are considered separate invasions and must be marked as separate points.

1. Point features reflect a distinct location described as a single position coordinate (Figure 4-2). Included with each point feature should be a buffer to estimate the infestation size. The size of each infestation is recorded as a point feature that is estimated visually and placed in the size category that most closely matches its actual area:

1) 1–3 plants (isolated single plants or very small patches, 2 × 2 meters or less),

2) 4 plants–40 m^2 (48 $yards^2$ or 0.01 acres),

3) 40–400 m^2 (48–478 $yards^2$ or 0.01–0.10 acres),

4) 400–1,000 m^2 (0.1–0.25 acre), or

5) 1,000–2000 m^2 (0.25–0.5 acre) (see Table 4.1).

2.10 Estimating Size of Infestation

The surveyor should envision the patch as a circle, oval, square, or rectangle—whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, the surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 4-3). In most cases, observers should learn to quickly place infestations into one of the associated size classes, rather than pacing or using the rangefinder. The radius should be an average of 2 readings: the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters).

Table 4-1. Reference table for metric and English measurements.

Meters^2	Acres	Square Yards	Radius	Radius	Diameter (m)	Diameter

			(m)	(Yards)		(Yards)
40	0.01	48	3.6	3.9	7.2	7.8
400	0.1	478	11.3	12.3	22.6	24.6
1,000	0.25	1,120	17.9	18.9	35.7	37.8
2,000	0.5	2,420	25.3	27.8	50.1	55.5

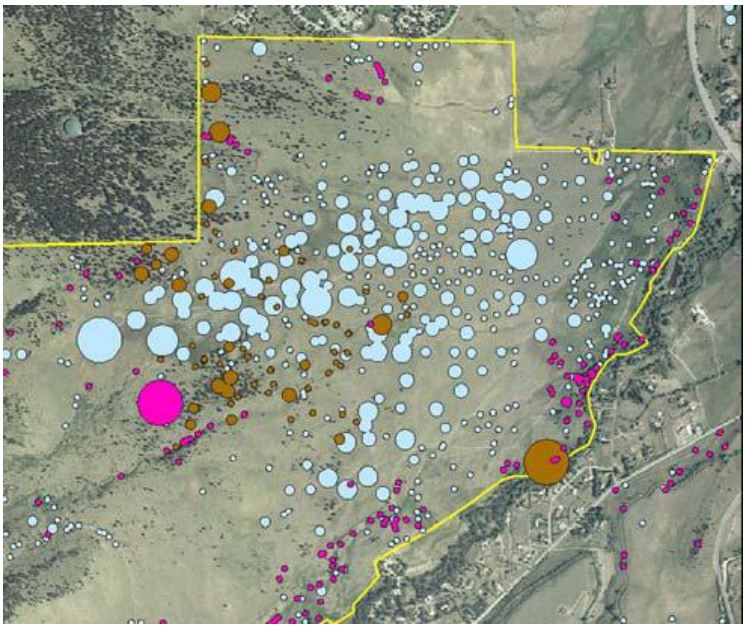


Figure 4-2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors (from Anderson and Dewey 2007).

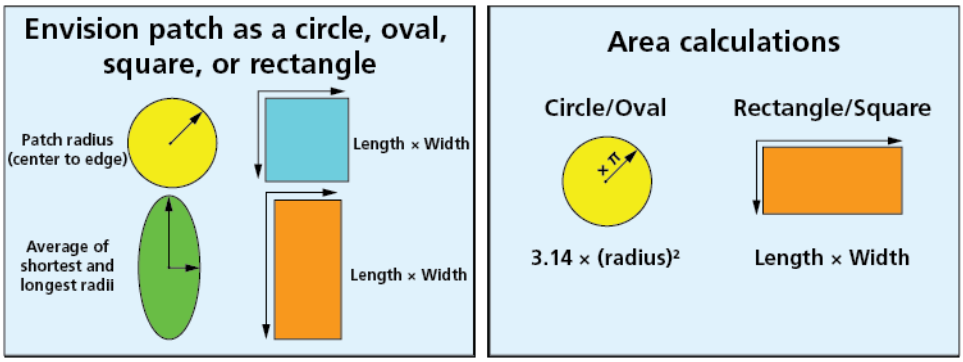


Figure 4-3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right) (from Anderson and Dewey 2007).

2.11 Estimating Percent Cover

These measurements must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 4-4). The infestation's density, or canopy cover designation, would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 10 m away from its nearest neighbor, all of the plants would still be considered part of the same infestation. The total area infested would be 0.12 hectares, with a very low density, or canopy cover designation (Figure 4-4).

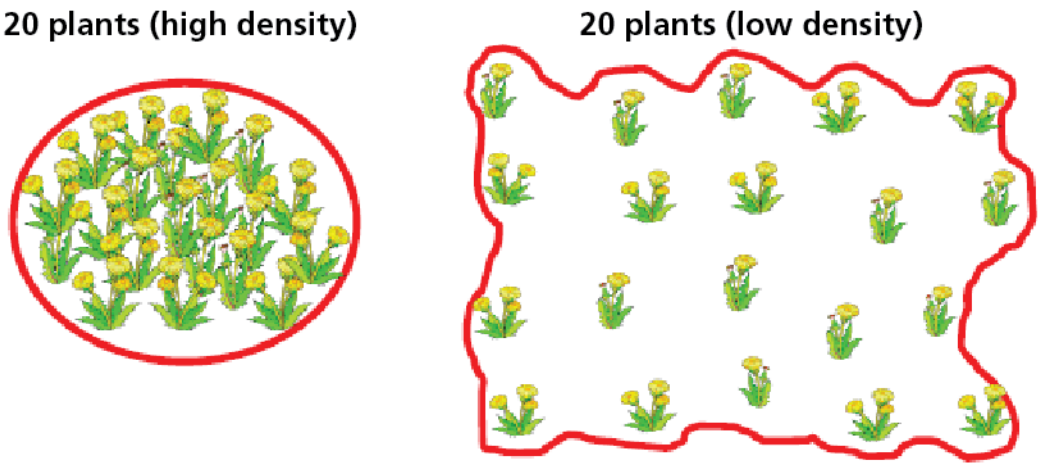


Figure 4-4. On the left, 20 plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single, high-density infestation of 0.001 hectare in size. On the right, 20 plants are separated by 10 meters from one area over another area. Collectively, the extent of the plants is slightly less than the PSR (~40 m), and are therefore still considered a single infestation. However, this patch is very low in density and is 1.92 hectares in size (from Anderson and Dewey 2007).

The term “canopy cover” refers to a visual estimate of 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). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes:

1) trace = less than 1%,

2) low = 1–5%,

3) moderate = 6–25%,

4) high = 26–50%, or

5) majority = 51–100%.

A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 4-5). To estimate canopy cover, the surveyor first considers the midpoint value between 0 and 100 percent, and asks, “Is the percent cover greater or less than 50 percent?” If the answer is “less,” then the surveyor selects the midpoint value between 0 and 50, and asks, “Is the percent cover greater or less than 25 percent?” If the answer is “less,” then the next question becomes, “Is the percent cover between 25 and 12.5 percent, or between 12.5 and 0 percent?”

This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy cover class is then chosen and selected from the GPS menu. The same process applies whether estimating the canopy cover of a 0.5-acre infestation or a single plant. However, single-plant infestations would always be in the majority (>51%) cover class.

Figure 4-5. The percent canopy cover is estimated from within the perimeter of the actual infested area (from Anderson and Dewey 2007).

2.12 Ancillary Information

2.12.1 Note Whether the Species was Pulled

Qualified surveyors may remove small populations. Surveyors will need to use judgment on when to pull plants. If they are at the head of a canyon far from a road and in a weed free area, then a single specimen or a group of a small invasion should be removed. If there are several small invasions, then they should be left for park personnel to control. In the vast majority of cases, invasions will require response commitments from parks and EPMTs. Note whether the species was pulled.

2.12.2 Other Information

Record the following ancillary information with every infestation: the growth stage of trees, evidence of prior treatment, and any disturbance features (e.g., recent fire, flood, small mammal disturbance).

3. Invasion on Inaccessible Land

3.1 Offsetting or projecting

If mapping in terrain where reaching a visible weed infestation is difficult or impossible, it is still possible to accurately record that location as a point feature using an “offset” command in Trimble GPS models, the “projecting” option in certain Garmin GPS units, or similar functions in other brands and models of GPS units. Offsetting or projecting allows the surveyor to safely map those identifiable infestations found on steep terrain, across canyons, and across rivers without actually having to stand on that site (Figure 4-6). It allows the observer to maintain better accuracy than might be achieved by drawing the infestation by hand on a paper map or a touch-screen GPS unit. If no GPS signal is available, then the location may be noted on a paper map.

Figure 4-6. Offsetting to a weed patch on a steep hillside across an impassable river (from Anderson and Dewey 2007).

Offsetting or projecting requires a determination of the compass bearing and the horizontal distance between the observer and the target. If an accurate elevation value is required, then the vertical distance between the observer and the patch also is needed. Equipment needed for offsetting/projecting distant weed infestations includes a basic field compass, a laser rangefinder, a simple clinometer, and a calculator capable of computing basic trigonometry equations.

3.1.1 Bearing

A compass is used to determine the bearing to the center of the targeted weed infestation. It is easiest if the GPS is configured to magnetic north rather than true north. Otherwise, you will have to adjust the compass reading to compensate for declination. It is also important to hold the compass as far away as possible from your body, metal, electronic equipment (such as the GPS unit), or other objects that could influence the compass needle.

3.1.2 Horizontal Distance

The horizontal distance is easiest to determine if the targeted infestation is at the same elevation as the observer. In this situation, simply use the laser rangefinder to determine the exact distance from your location to the center of the targeted weed patch. However, if the infestation is significantly above or below your present location, the distance determined by the rangefinder will be greater than the true horizontal distance. This distance determined by the laser rangefinder is referred to as the as the visual distance, or slope distance (hypotenuse of a right triangle, Figure 4-7). If the visual distance, rather than the true distance, is used in the offsetting function, then the weed point's placement on a map will be incorrect (placed further away from the observer than was actually the case).

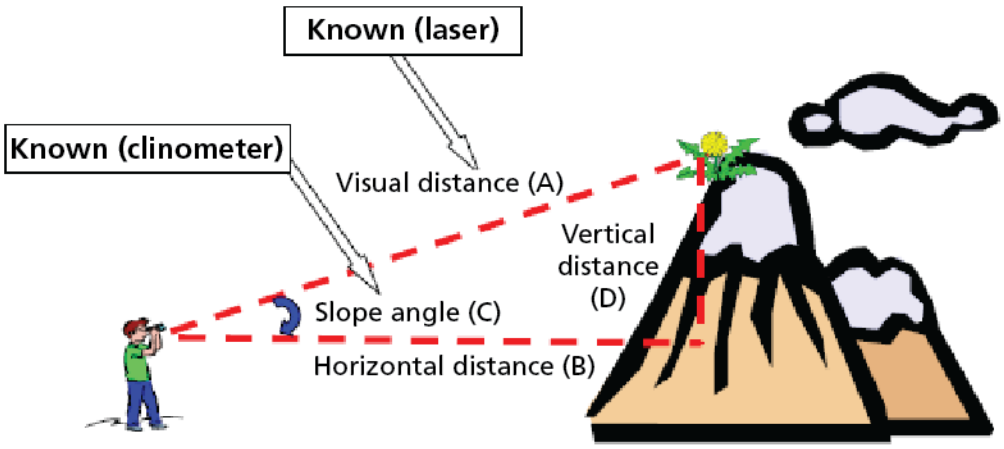


Figure 4-7. The visual distance between the observer and the weed (A) as measured by a laser rangefinder is greater than the true horizontal distance (B). Simple trigonometry can be used to calculate the horizontal distance and the vertical distance (D) (from Anderson and Dewey 2007).

To determine the true horizontal distance requires use of a little basic trigonometry as per the following equation (based on the letters indicated in Figure 4-7):

> (Cosine of C) × A = B. In other words, the cosine of the slope angle (C), multiplied by the visual distance (A), equals the horizontal distance (B).

The vertical angle can be determined by one of several methods. A clinometer is the most accurate tool, and some models can be relatively inexpensive. The field compasses can come equipped with a built-in clinometer.

3.1.3 Vertical Distance

The vertical distance is the difference in elevation between the observer and the targeted infestation (Figure 4-7). Vertical distance is calculated using the following equationFigure 4-:

> (Sine of C) × A = D In other words, the sine of the slope angle (C), multiplied by the visual distance (A) equals the vertical distance (D).

3.2 Estimating Infestation Size from a Distance

One of the challenges associated with offsetting is visually estimating the size of a distant weed infestation. The size of a remote weed patch can be estimated with surprising accuracy by using essentially the same measurements and calculations described above for offsetting. Two compass bearings are used to estimate the width of the patch (in degrees), and the degrees are converted to a distance using a slight variation of the trigonometric equation described earlier for vertical distance.

3.2.1 Circular Patches

To approximate the size of a distant weed infestation that is roughly round or square, you will need to determine distance between the surveyor and the center of the patch, as well as the radius or width of the patch.

> a) The first step is to determine the distance to the approximate center of the patch (B) by using a laser rangefinder (Figure 4-8). The width of the patch is measured by determining the compass bearings of the right and left edges. The difference in degrees between the two edges is considered the width angle (Figure 4-9).

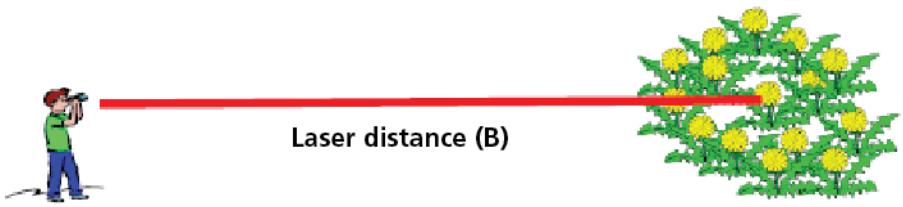


Figure 4-8. Side view of the surveyor determining the laser distance (B) to the center of a remote weed patch (from Anderson and Dewey 2007).

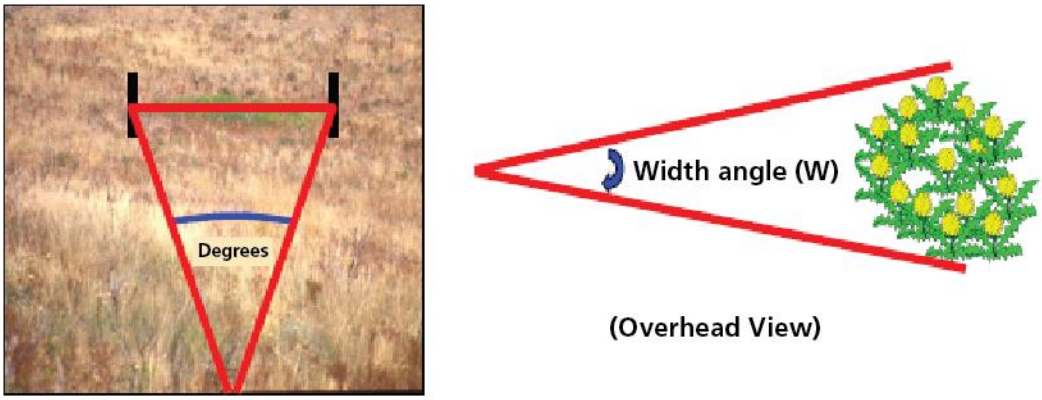


Figure 4-9. To determine the width angle, the surveyor must find the compass bearings of the left and right edges of the patch. The difference between the two bearings is the width angle (W). For example, if the left edge bearing is 88 degrees and the right edge bearing is 100 degrees, then the width angle (W) is 12 degrees (from Anderson and Dewey 2007).

b) The next step is to determine the patch radius. To do this requires the radius angle (C), which is simply one half of the width angle described above. In Figure 4-10, the radius angle is identified by the letter "C" and the patch radius is designated as "D".

c) Patch radius is calculated using the following equation (see Figure 4-10): (Tangent of C) × B = D

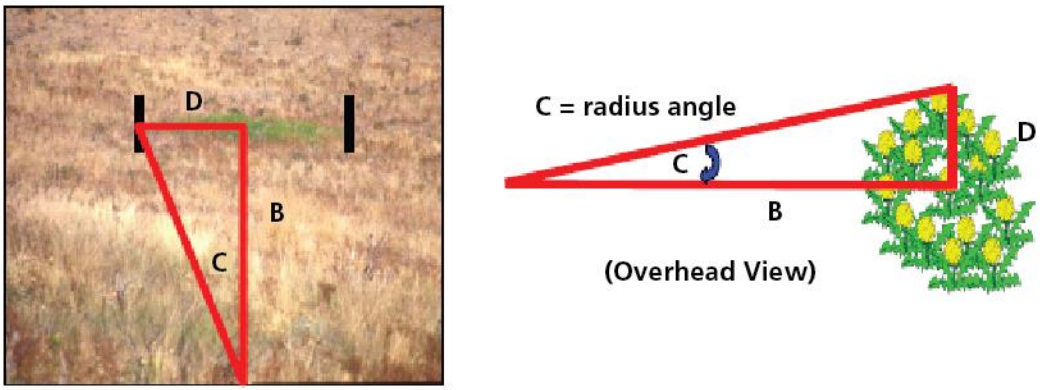


Figure 4-10. The radius angle (C) is equal to one half of the width angle (W in Figure 4-9). If the width angle of this leafy spurge patch was determined to be 12 degrees, then the radius angle would be 6 degrees (from Anderson and Dewey 2007).

The area of a circular patch is calculated by using the following equation: Area = 3.14 × (radius^2)

3.2.2 Square Patches

The same procedure could be followed, up to the point of having determined the value corresponding to "D" (patch radius). But instead of using that value in the formula for determining the area of a circle, the calculated radius value would be considered half of the width of the square patch.

3.2.3 Other-Shaped Patches

In situations where the shape of a remote patch is not circular or square, the observer is encouraged to envision it as a rectangle. The objective then becomes to estimate its length and width, then multiply the two together to determine the total area. The simplest approach is to first determine its width or length using the tangent equation described above. If a length is determined, then the width value is estimated visually based on the ratio (percentage) of the width's dimension to the "measured" length value. The length of the patch is calculated using the same trigonometric equation described for determining the radius of a circular patch. However, the value resulting from this calculation (158 meters) is equal to only half of the total patch length, and so must be multiplied by 2 (Figure 4-11). (Tangent of 37 degrees) × 210 meters = 158 meters.

The width of the patch is estimated using the calculated length value as a standard of measure. In other words, the surveyor estimates the ratio between the length and width distances, and then multiplies the length by the corresponding percentage to determine the width. The surveyor estimates that the width of the saltcedar patch is approximately 20 percent of its

length. By multiplication, the width is calculated to be an average of 63 meters (316 × 0.20) (Figure 4-11).

Figure 4-11. On the left, the length of the patch is equal to twice the value determined for "D" (see Figure 4-10). If "D" is 158 meters, then the total patch length would be 316 meters. On the right, the width of the patch is estimated to average approximately 20 percent of the patch length. Thus, 20 percent of 316 meters is 63 meters (from Anderson and Dewey 2007).

4. 3 References

Andersen, K. A., and S. A. Dewey. 2007. USU Wildland weed mapping methods training supplement. Master's thesis. Utah State University, Logan, Utah. 107 pp. plus appendix.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. USDI-BLM Technical Ref. 1730-1. Bureau of Land Management, Denver, Colorado. 477 pp.

Stohlgren, T. J., D. T. Barnett, and S. E. Simonson. 2005. Beyond North American Weed Management Association standards. http://www.nawma.org/documents/Mapping%20 Standards/BEYOND%20NAWMA%20STANDARDS.pdf.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #5
Monitoring Lite

Version 1.02
March 28, 2017

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	3/2016	A.W. Biel	Minor editorial and formatting	Publication preparation	1.01
1.01	3/2017	L. Gommermann/ D. Perkins	Editorial	Clarity	1.02

This SOP gives step-by-step methods for the collection of field data for invasive plants along roads, trails, and other areas where park personnel might visit. This is a modification of SOP #3, Monitoring Route Methods, to allow park staff, volunteers, or students who may not have extensive botanical information to still collect exotic plant information. Unlike SOP# 3, routes are conducted opportunistically as staff or volunteers conduct other park tasks. The methods outlined in this SOP essentially follow the methods outlined by Utah State University (Anderson and Dewey 2007). In several cases, large portions of the text have been lifted directly from their handbook. We are grateful for their efforts on the Colorado Plateau and their expertise in this area.

Monitoring Routes

Monitoring routes will follow the roads, trails, and riparian areas in a park. As monitoring routes are traversed, locations of all target species are documented using mapping-grade global positioning system (GPS) units with better than 5-meter accuracy.

Field locations are recorded by GPS as UTM coordinates, and are later differentially corrected in the production of final digital products. The crews record invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception is not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps are converted to digital format.

Determine Settings

1.1 Determine the Minimum Detection Target Size

Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species, such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*), might be possible due to their large size, single plants of other species, such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*), might prove impossible under certain field conditions.

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 percent 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. NCPN monitoring will have a minimum detection target size of 0.01 acres (approximately 40 m^2 or 20 × 20 ft) for all invasive species, unless otherwise noted.

1.2 Determine Effective Detection Distance

The Effective Detection Distance (EDD) is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTS of the least-visible targeted species with at least 90 percent detection efficiency (Figure 5-1). Crew members calibrate themselves by walking away from a targeted patch size of the least-visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and target species. Heavy cover and/or difficult-to-see species may require slowly walking detection swath widths as narrow as 5–7 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater for an EDD of 1 $meter^2$.

1.3 Determine Effective Detection Swath Width

Effective Detection Swath Width (EDSW) is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the minimum specified infestation size (Figure 5-1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90% of all target weed patches 0.01 acres or larger in size. The effective detection swath width (EDSW) is

equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD on either side of his/her search route.

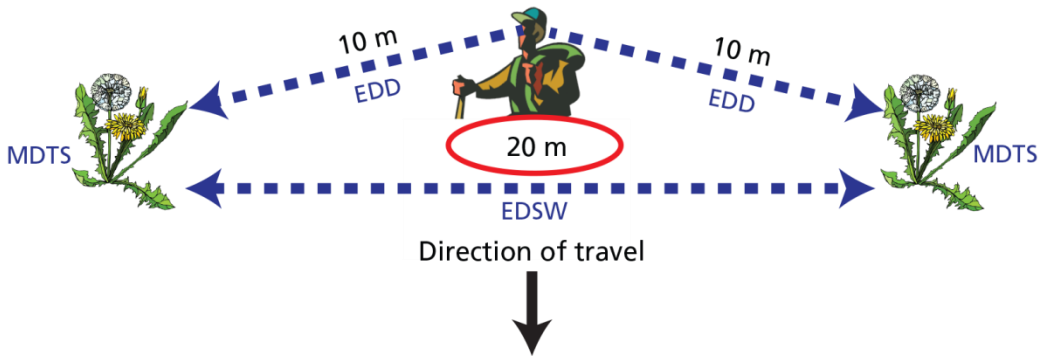


Figure 5-1. If the maximum Effective Detection Distance (EDD) for this MDTS is 10 meters, the Effective Detection Swath Width would be 20 meters (from Anderson and Dewey 2007).

1.4 Determine Patch Separation Resolution

Patch Separation Resolution (PSR) is defined 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 must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR is set at 50 meters unless otherwise noted. This is the same whether an infestation is mapped as a point or polygon. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

1.5 Between Feature Position

Between feature positions (BFP) allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models), this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. The default setting is 20 m. This needs to be set in the GPS under Settings every time a new route is started.

Conducting a Monitoring Route

1.6 Set the EDSW

Determine the EDSW (see Section 2.3) and enter into the GPS. It is not necessary to adjust the setting for small or temporary changes in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route.)

1.7 Set the BFP

Set the BFP (see Section 2.5) to 20 m.

1.8 List the Target Invasive Species that Can be Detected by the Observer

The observer enters in the species that they are targeting and can reliably detect and identify.

1.9 Initiate Monitoring Route

Monitoring will take place directly along the road, trail, riparian corridor, or other area that is being traversed. While walking, the surveyor searches for target weeds by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for target species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percentage of the time spent walking through a search area must be devoted to looking down at one's feet, then there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations, it is recommended that at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

1.10 Recording Invasive Plants

Once a weed patch/infestation has been discovered, a mapping crew must record: (1) the monitoring route, (2) buffered point, and (3) an estimate of canopy cover. It is important to note that not all non-native species that are found will be mapped.

1. Record the monitoring route.

2. All invasions will be recorded as buffered points. If several species are present with similar distributions, then a point must be recorded for each individual species. Invasions more than 50 m apart are considered separate invasions and must be marked separately. Point features reflect a distinct location described as a single position coordinate. Included with each point feature should be an estimate of infestation size and density. Point features should be buffered to reflect the recorded patch size. Buffered points can be displayed to scale as circular polygons representing the area of individual patches (Figure 5-2). In other words, an infestation deemed to be 0.5 hectares in size will appear on the map as a dot that is 0.5 hectares in size.

    a. Size of point. To estimate the size of a point infestation, the surveyor should envision the patch as a circle, oval, square, or rectangle—whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, then the surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 5-3). The radius should be an average of 2 readings: the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters).

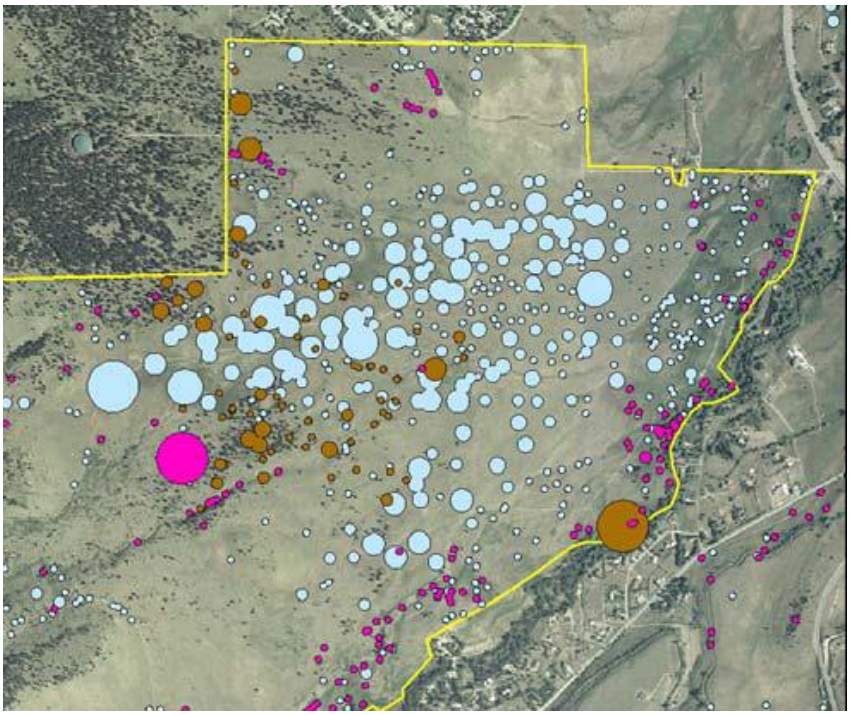


Figure 5-2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors (from Anderson and Dewey 2007).

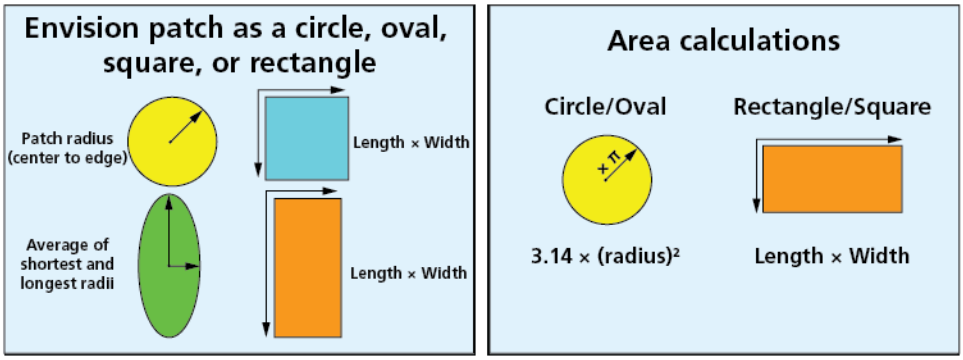


Figure 5-3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right) (from Anderson and Dewey 2007).

b. Point dimensions. Using the size recordings above, enter the infestation as a point feature in the size category most closely matched to its actual area:

1) 1–3 plants (isolated single plants or very small patches, 2 × 2 meters or less),

2) 4 plants–40 m^2 (48 $yards^2$ or 0.01 acres),

3) 40–400 m^2 (48–478 $yards^2$ or 0.01–0.10 acres),

4) 4) 400–1,000 m^2 (0.1–0.25 acre), or

5) 1,000–2000 m^2 (0.25–0.5 acre) (see Table 5-1).

Table 5-1. Reference table for metric and English measurements.

Meters^2	Acres	Square Yards	Radius (m)	Radius (Yards)	Diameter (m)	Diameter (Yards)
40	0.01	48	3.6	3.9	7.2	7.8
400	0.1	478	11.3	12.3	22.6	24.6
1,000	0.25	1,120	17.9	18.9	35.7	37.8
2,000	0.5	2,420	25.3	27.8	50.1	55.5

c. Linear infestations as points. When an infestation follows a linear pattern, such as along a road or waterway (Figure 5-4), it can be mapped as a point or series of points using the following procedure:

- Envision the infestation as a much-elongated rectangle.
- Estimate the average width and approximate length of the infestation.
- Determine area by multiplying length by width.
- Stand in the middle of the infestation to record the GPS location.

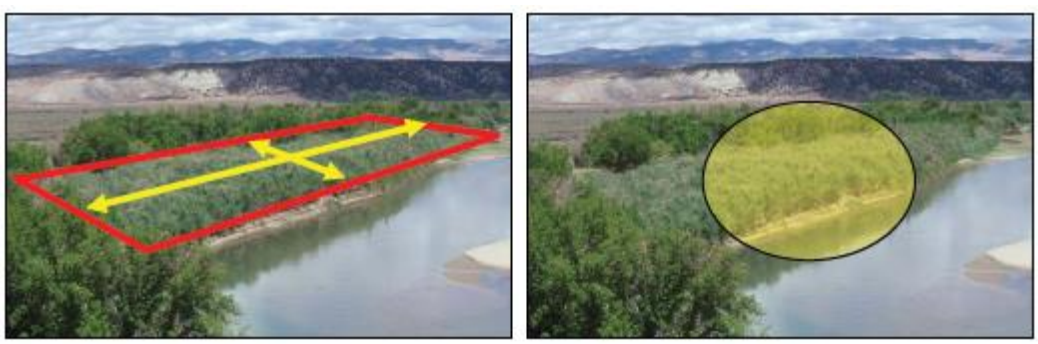


Figure 5-4. The infestation is envisioned as a long rectangle for which length and average width can be determined. The area of the rectangle is then represented as a single buffered point centered in the patch (from Anderson and Dewey 2007).

If the length or overall size of a linear infestation is considered too great to represent as a single point, then it can be visually divided into 2 or more contiguous segments, with a

separate point feature recorded for each segment (Figure 5-5). If the surveyor wishes to record a linear infestation as a series of points rather than a single point, then use the following procedure:

- Determine the average width of the first infestation segment.
- Choose an appropriate point size category.
- Calculate the corresponding length required to equal that size.
- Walk half the calculated distance (so as to be in the center of the first segment).
- Record the location as a point feature.
- Walk the full calculated distance (to be in the center of the second segment).
- Record the second location.
- Repeat as long as the infestation continues, adjusting point size if patch segment width changes.

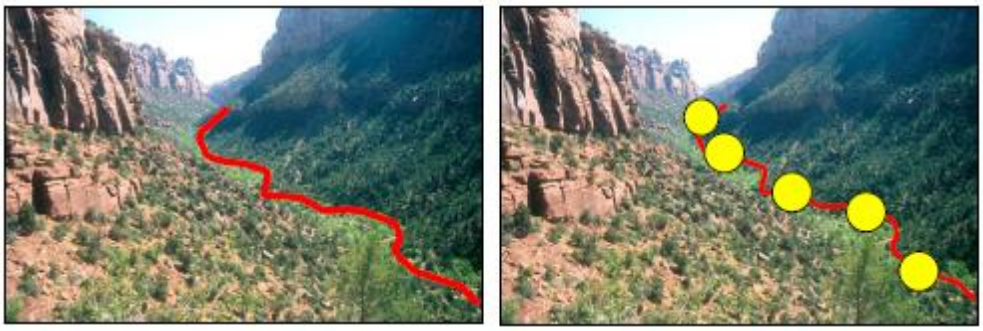


Figure 5-5. To map a linear infestation as a series of points, the surveyor begins by estimating the average width of the infestation, deciding upon the appropriate point size category, calculating the necessary patch segment length based upon that size category, and then placing a new point each time an infested area of that distance is walked (from Anderson and Dewey 2007).

If several species are present with similar distributions, then the same procedure is followed for each individual species. The surveyor calculates the estimated width of each species, determines the appropriate size category, and then calculates the necessary segment length for each species (Figure 5-6). Each time the surveyor walks a determined patch segment length, points are recorded for each species present. This allows the surveyor to map multiple linear species without having to duplicate search efforts.

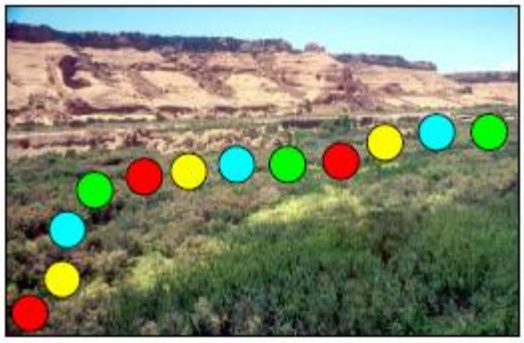


Figure 5-6. Continuous linear infestations of four intermixed weed species mapped as staggered point features. Each point of the same color represents a 0.1-hectare segment of a continuous line of that species (from Anderson and Dewey 2007).

3. Weed density or canopy cover must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all

growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 5-7). The infestation's density, or canopy cover designation, would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 10 m away from its nearest neighbor, all of the plants would still be considered part of the same infestation. The total area infested would be 0.12 hectares, with a very low density, or canopy cover designation (Figure 5-7).

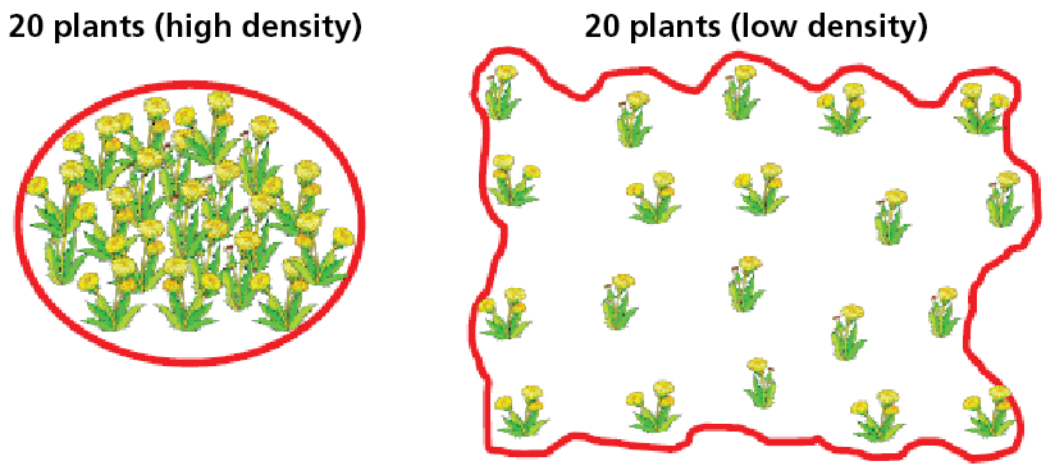


Figure 5-7. On the left, 20 plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single, high-density infestation of 0.001 hectare in size. On the right, 20 plants are separated by 10 meters from one area over another area. Collectively, the extent of the plants is slightly less than the PSR (~40 m), and are therefore still considered a single infestation. However, this patch is very low in density and is 1.92 hectares in size (from Anderson and Dewey 2007).

The term "canopy cover" refers to a visual estimate of 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). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes:

1) trace = less than 1%,
2) low = 1–5%,

3) moderate = 6–25%,
4) high = 26–50%, or
5) majority = 51–100%.

A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 5-8). To estimate canopy cover, the surveyor first considers the midpoint value between 0 and 100 percent, and asks, “Is the percent cover greater or less than 50 percent?” If the answer is “less,” then the surveyor selects the midpoint value between 0 and 50, and asks, “Is the percent cover greater or less than 25 percent?” If the answer is “less,” then the next question becomes, “Is the percent cover between 25 and 12.5 percent or between 12.5 and 0 percent?” This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy cover class is then chosen and selected from the GPS menu. The same process applies whether estimating the canopy cover of a 0.5-hectare infestation or a single plant. However, single-plant infestations would always be in the majority (>51%) cover class.

Figure 5-8. The percent canopy cover is estimated from within the perimeter of the actual infested area (from Anderson and Dewey 2007).

4. Qualified surveyors may remove small populations if under a threshold size (i.e., if it would take less time to remove the plants than it would to hike back out to remove them later), but larger populations require rapid response commitments from parks. Note whether the species was pulled.

5. (Optional) Record the following ancillary information with every infestation: slope and aspect, topography (hillside, distance to road, wetland, or stream, etc.), and any disturbance features (e.g., recent fire, flood, small mammal disturbance)

References

Andersen, K. A., and S. A. Dewey. 2007. USU Wildland weed mapping methods training supplement. Master's thesis. Utah State University, Logan, Utah. 107 pp. plus appendix.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. USDI-BLM Technical Ref. 1730-1. Bureau of Land Management, Denver, Colorado. 477 pp.

Appendix A: Monitoring Lite GPS Instructions

Point_Weed and Area_Weed Features

These point and area features are used to map invasive exotic plant infestations while traveling along a monitoring route.

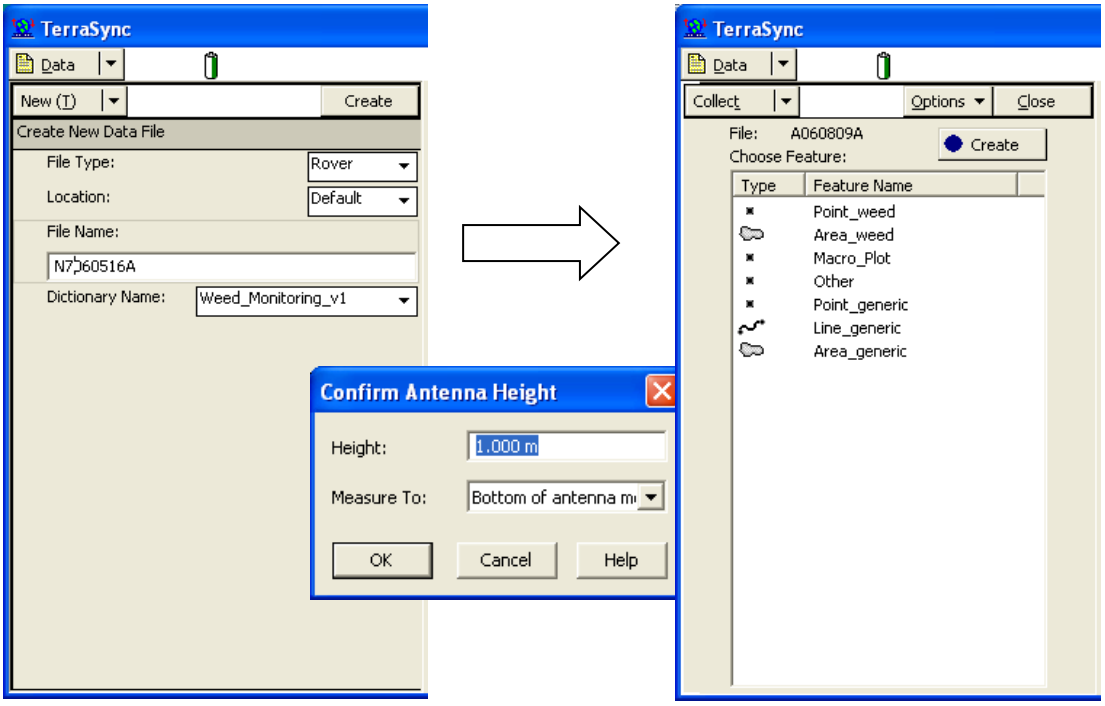
When multiple species are noted within one area (within the PSR, see SOP#5, section 2D) and you are mapping these locations as point features, collect the data for species #1, then walk a step or two, and collect the data for species #2 and continue until one point per species is collected. If mapping an infestation of multiple species as a polygon, attribute the polygon with the primary species, and note the remaining species in your field notebook along with the InfestationID of the polygon.

Point_Weed or Area_Weed	Attribute Explanation	Entry	Type
InfestationID	Unique ID. One unique letter per field crew member, numbers automatically generated by GPS unit	Entry **required** in the field	Text
SpeciesName	Common name of invasive plant. This list will be updated for each park visited, based on input from park staff. "Other" will always be a choice.	Entry **required** in the field	Menu
Size	Infestation size • 1 to few plants • few plants – 40m sq. • 40 – 400m sq. • 400 – 1000m sq. • 1000 -2000m sq.	Entry **required** in the field	Menu
CanopyCover	Percent Canopy Cover: • Trace (<1%) • Low (1 – 5%) • Moderate (6 – 25%) • High (26 – 50%) • Majority (51 – 100%)	Entry **required** in the field	Menu
Pulled	Note if plant(s) pulled by observer: • Yes (pulled) • No (not pulled) -Default	Entry permitted in the field	Menu
GrowthStage	Growth stage of trees: • Seedling(s) • Sapling(s) • Mature Tree(s) • Old Growth	Entry permitted in the field	Menu
Disturbance	Disturbances noticed at the site: • Flooding • Grazing Impact • Hiking trails • Human occupation • Prehistoric occupati(on) • Insect disturbance • Livestock • Recreation use • Roads/OHV Trails • Spring Source • Windthrow • Other	Entry permitted in the field	Menu
Surveyor	Name of person surveying the monitoring route	Entry permitted in the field	Menu

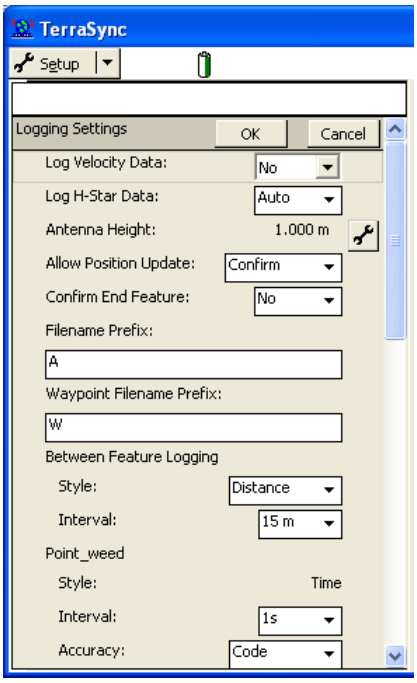
EDSW	Effective Detection Swath Width in meters (see SOP #5 section 2,C for further explanation)	Entry **required** in the field	Numeric
PSR	Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#5, sec 2,D)	Entry permitted in the field	Numeric
Notes	Any comments regarding the site (can contain species name if "other")	Entry permitted in the field	Text – Optional

Beginning Invasive Exotic Plant GPSing

Open TerraSync. From the opening satellite **Status** screen, choose **Data** from the dropdown menu. Choose New(T) (it should be the default). Leave File Type, Location and File Name alone, but be sure that *Weed_Monitoring_v2_DINO* is chosen for the Dictionary Name. Tap Create. The Antenna Height window will pop open, tap OK. You should then see the **Data** screen with the features in the data dictionary displayed.

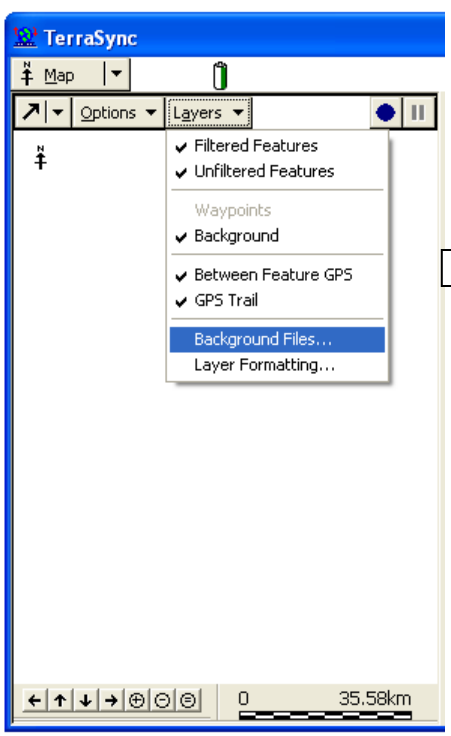


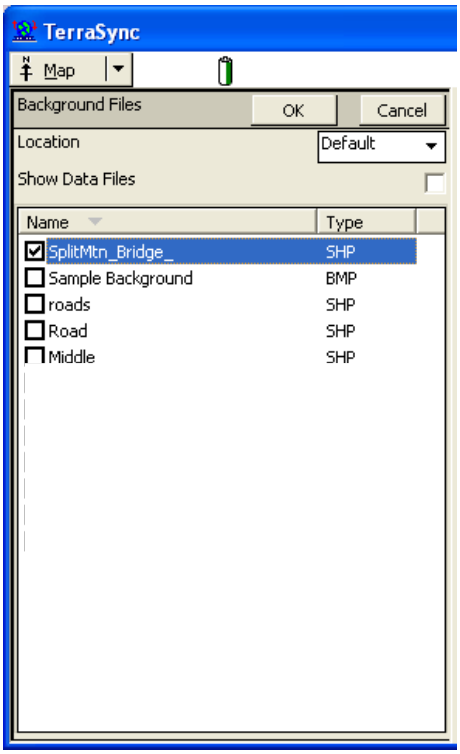
Once a file has been created, you'll need to determine what the EDSW (Effective Detection Swath Width) and then set the Between Feature Logging to that distance. To set the Between Feature Logging, tap the down arrow next to **Data**, and select **Setup**.

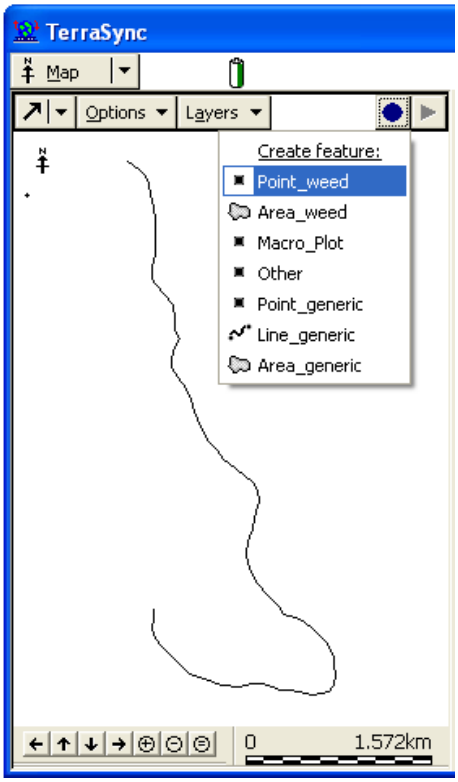


On the **Setup** menu, choose Logging Settings. On the logging settings screen, scroll down until you see Between Feature Logging. For Style, choose Distance and for Interval, type in your EDSW. Tap OK. This sets the Between Feature distance for the file, so you won't have to change it again, unless you feel that the EDSW changes for the monitoring route you are walking.

The monitoring routes are available to display on the **Map** Screen as a background file if you choose to use them. To add a background layer, choose **Map** from the dropdown menu on the upper left corner. Then tap the Layers button in the middle of the screen, and choose Background Files. The four monitoring routes are listed, choose the one you'll be following and tap OK.

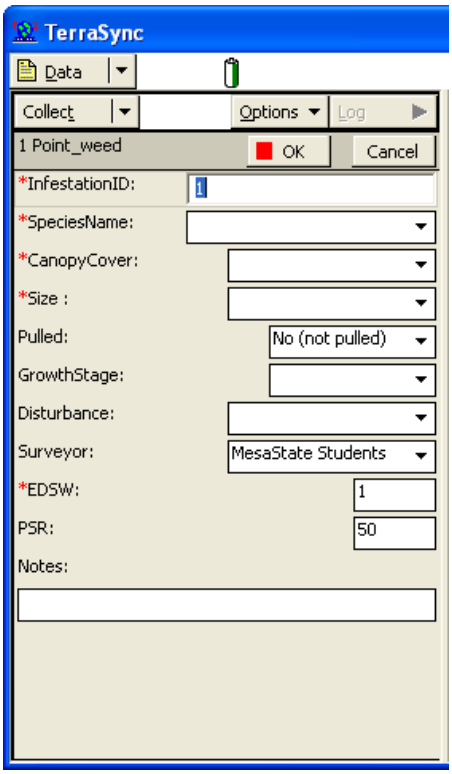






As you begin walking the route, and you come across a species of weed which you need to log, tap the blue dot and your data dictionary will appear. The majority of the time, you'll be using the Point_Weed feature.

Once you have reached the middle of a weedy infestation, select the Point_Weed feature and the data dictionary items for that feature will be displayed.



Record the data for the weedy patch.

Multiple Species:
If there are more than one weed species, fill in the information for species #1, then take two steps, and log the information for species #2.

Required Fields:
The items in the Data Dictionary with a red asterisk (*) are items that must be recorded, or Terra Sync will not let you close the feature.

Log / Pause:
In the upper right corner, there's a button that says Log. If you tap that button, it will temporarily pause the logging (the button is a toggle between Log and

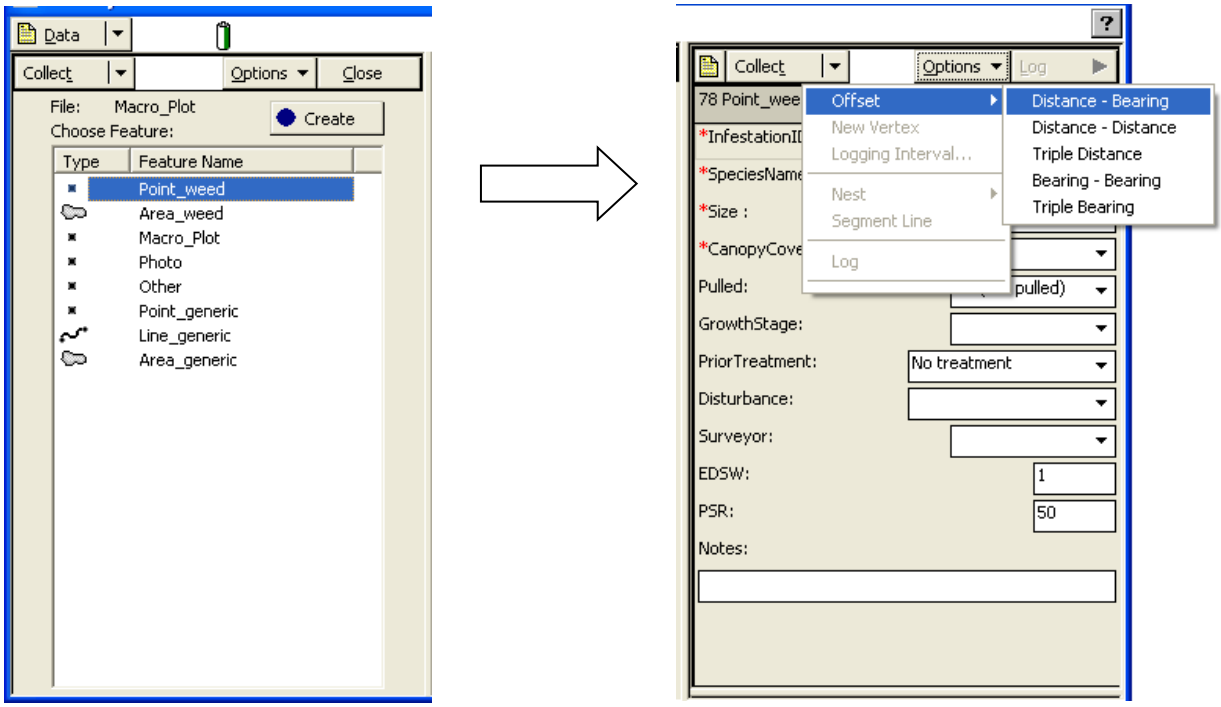
Pause). As you log the feature (GPS) and record data, there will be a little satellite icon on the top of the screen that will record the number of "hits" from the satellite. This number should be at least 10-20 hits. Each time the GPS receives a hit, the GPS unit will beep (if the sound is turned on).

Cancel:
If you began to collect (log) a point and have decided not to, tap the Cancel button while in the data dictionary, and tap Yes to Abandon feature.

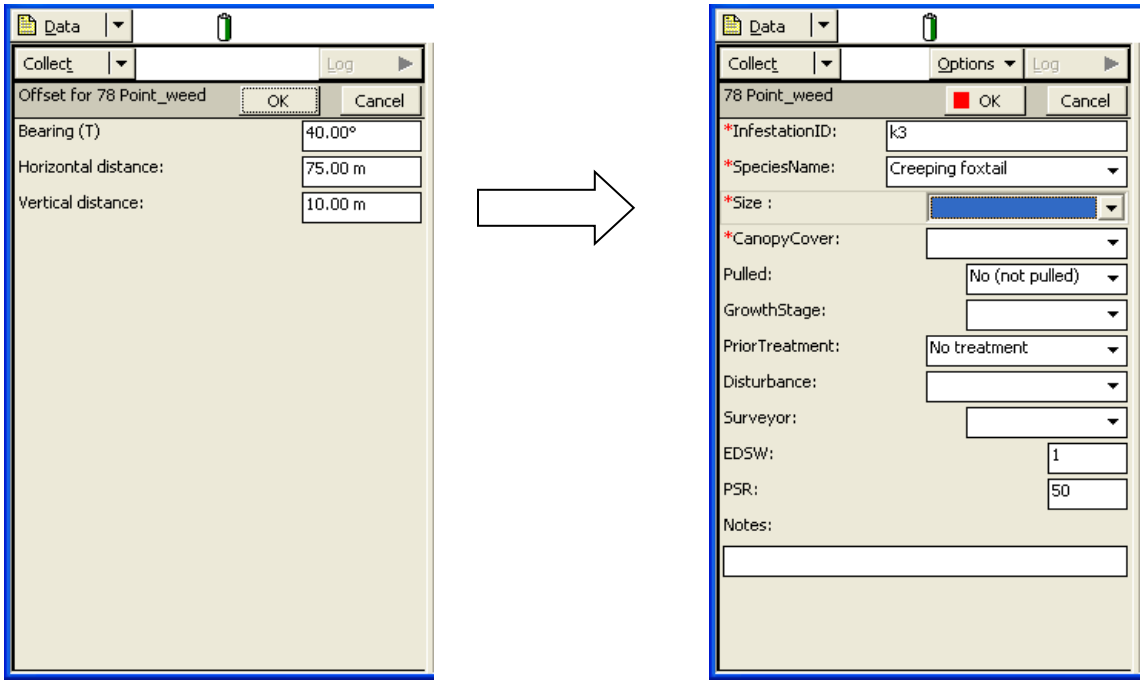
When you've finished recording the data, tap the OK button.

Once you've completed your monitoring route, close the file. Tap the menu choices in the upper left corner, choose Data. On the right side of the screen, tap Close. TerraSync will ask you if you are sure, tap Yes if you are sure. You can then create a new file or shut TerraSync down by tapping the X in the upper right corner.

Point Offset
If a weed population is noted in a difficult location (such as across a drainage/river), but you'd like to log the species you see there, you can do that with the Offset feature. Create the Point_Weed feature and tap the Options dropdown menu. Select Offset/Distance – Bearing.



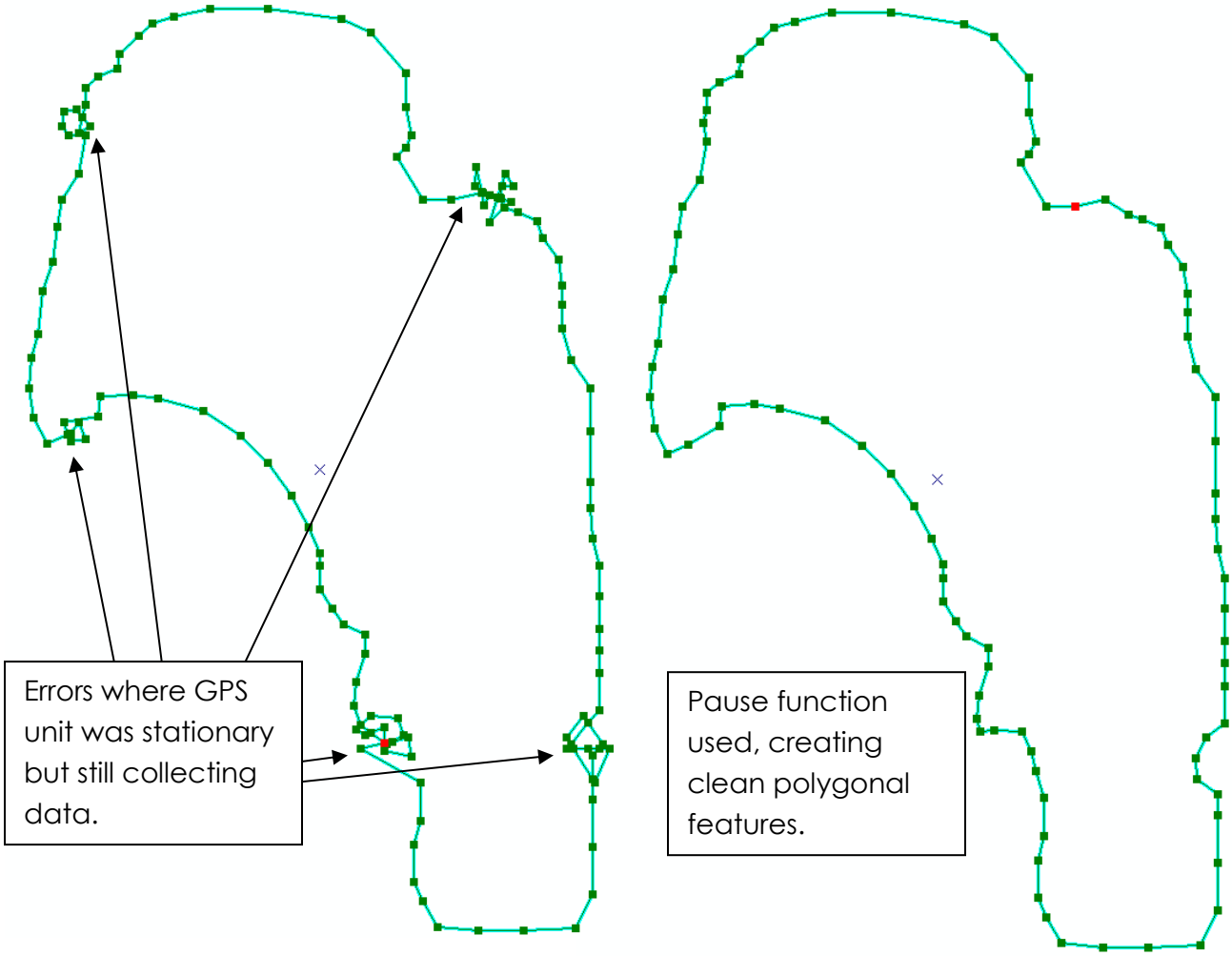
The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location.



There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (the location of your vehicle, an archaeology site, etc.), use the Other feature point, and type in a comment regrading that location.

GPSing Areas

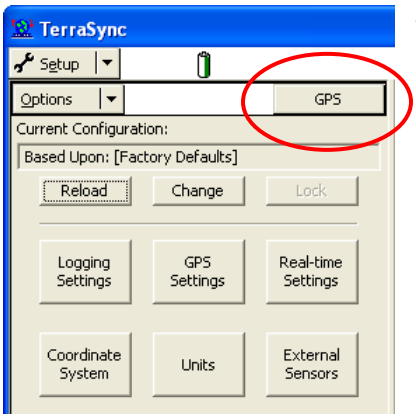
If you choose to map an invasive exotic plant infestation as a polygon feature (Area_Weed), the data dictionary items are the same as they are for Point_Weed. When collecting an Area_Weed feature, you will need to walk the perimeter of the infestation in its entirety while the GPS is mapping your progress. As you walk, it is important that you do not stop moving while the GPS is collecting locational data, or the polygon will have errors. If you need to navigate over difficult terrain or someone stops you to ask questions, etc., pause the logging of the polygon until you are ready to resume.



Tips:

- Log a point feature for a minimum of 10 "hits" (10 seconds).
- Holding the power button down for 30 seconds will soft re-boot the XM GPS. Holding the power button down for 60 seconds will hard re-boot the XM GPS. Neither of these re-boots will loose any data, but you should recheck the coordinate system.
- To re-boot the Junos, there is a little hole on the top left side (next to the expansion card). Push that with the tip of the stylus to re-boot the Juno.
- There is a sliding button near the power button, if it is slid down, this will "lock" the Juno off so it won't turn on while bouncing around in a backpack or something while getting to the beginning of the monitoring route. Using this to turn the unit off (and on) seems to help conserve battery life (and seems to behave if TerraSync is left open).
- The NCPN has a copy of the TerraSync Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.
- Label the back (or case) of your GPS unit with your name on a piece of masking tape so you'll be able to use the same unit throughout a field stint.

- If the GPS gets disconnected, go to the Setup screen and tap the GPS button on the upper right side.



- Report any idiosyncrasies with the Trimble GPSes to the NCPN data management staff.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #6 Using Global Positioning System (GPS) Units

Version 1.06

March 28, 2017

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.00	7/8/2009	A. Wight	Macroplot to transect	Methodology changed	1.01
1.01	6/29/2010	A. Wight	Added EDSW feature, deleted Area_weed feature, other minor edits	Need for tracking EDSW	1.02
1.02	6/4/2012	A. Wight	Updated App A, and added SD card data backup instructions	Software changes	1.03
1.03	6/6/2013	A. Wight	Added instructions for data collection when satellites not available	Catching infestation data in data dictionary when GPS can't see satellites	1.04
1.04	3/22/2016	A.W. Biel	Editorial and formatting	Preparation for publication	1.05
1.05	3/28/2017	L. Gommermann/ D. Perkins	Editorial	Clarity	1.06

This Standard Operating Procedure (SOP) explains the procedures and considerations that all observers should follow when navigating to and/or collecting invasive exotic plant geospatial data.

This SOP assumes that each observer is familiar with the operation and function of the GPS unit to be used for this project. This SOP is intended to complement, not replace, the operations manual accompanying the GPS unit. Each observer should be familiar with the use of their particular GPS unit before entering the field to collect data or navigating to monitoring routes.

1 GPS Requirements

The NCPN project lead, GIS tech, and park personnel will establish monitoring routes to locate and monitor invasive exotic species. The NCPN requires the use of a **mapping-grade** GPS unit

(requirements listed below) to record invasive exotic patch locations along the monitoring routes and transect locations.

1.1 Minimum GPS Receiver Requirements

- Capable of uploading (pre-determined) monitoring routes and transect points
- Capable of utilizing data dictionary utilities (NCPN Exotics Data Dictionary, see section 1.3)
- Capable of utilizing park-specific background GIS data layers (points, lines and polygons)
- Capable of navigation
- Capable of maintaining 4 or more satellites
- Capable of maintaining horizontal errors of less than 5 meters (PDOP or equivalent error reading of less than 6), or recording error readings
- Capable of taking “Between Feature” points (breadcrumbs)
- Capable of offsetting point features
- Capable of post-data collection correction (differential correction)
- Capable of storing date, time, elevation, and coordinates of features collected (in addition to data dictionary items)
- Capable of exporting features collected to a GIS data format

1.2 GPS Unit Setup

The NCPN currently uses the Trimble line of mapping-grade GPS units and TerraSync Professional software to capture the spatial data for Invasive Exotic Plant Monitoring. The requirements should be transferable to other mapping-grade GPS receivers (e.g., Leica).

Positional accuracy can be affected by several factors which mapping-grade GPS units can track and, to some extent, compensate for. Table 1 lists these functions, their definitions, and the standard settings.

The GPS should have the Between Feature Logging feature available and enabled for this protocol. This feature enables the GPS unit to automatically generate positions at a set distance or time interval, basically tracking the field crew’s progress along a route. For tracking purposes, use a setting of 20 meters between tracking points.

Table 1. Minimum GPS receiver settings standards.

Name	Definition	Standard
Almanac	GPS unit collects data containing estimated position of satellites, time corrections, and atmospheric delay parameters.	The unit will automatically collect the almanac. Acquire within 10 days prior to data collection or navigating, download to computer.
Altitude reference	Ellipsoid model	Height Above Ellipsoid (HAE)
Antenna heights	GPS unit height above the ground (average)	1.0–1.5 meters
Between Feature positions	Positions automatically logged by the GPS at either a time or distance interval defined by the user.	20 meters
Coordinate System	A reference system consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions.	Universal Transverse Mercator (UTM)
Datum	Geodetic model designed to fit a point on the earth's surface to the ellipsoid	NAD 1983 (Conus)
Elevation mask	The minimum angle at which a GPS receiver will track satellite vehicles	15 degrees
Logging intervals	Time interval between positions gathered	Point: 1 second Line and Polygon: 3–5 seconds
Minimum number of positions for a point feature	Number of positions received then averaged to create a point feature	10–20
Mode	2-Dimensional or 3-Dimensional	3-Dimensional (4 satellites)
PDOP Mask	Positional Dilution of Precision is a measurement of the geometry of the satellites.	6.0 or less
Satellite vehicles	Number of satellites, currently a constellation of 28 DOD satellites	4
SNR Mask	Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to background noise.	4.0
Unit of Measure	Units of measure	Meters
Zone	In UTM coordinate system, the globe is divided into 60 north-south zones.	Zone 12 North (N)* *Black Canyon & Curecanti are Zone 13 N

1.3 Data Dictionary

A data dictionary should be created to facilitate field data collection and ensure that necessary data items are (correctly) collected. The minimum elements necessary for the invasive data

dictionary features are shown below. All point features in the Invasive Data Dictionary should have the default feature settings of:

Feature	Setting
Logging Interval	Time = 1 second
Minimum Positions	3
Accuracy	Code
Label 1	PlotID (for transects)

Prior to data collection, a comprehensive list of invasive exotic species should be obtained from the park where invasive exotic monitoring will be occurring to update the data dictionary. Surveyor names may need to be updated as well.

The digital data dictionary file on the next page (.ddf) can be obtained by contacting the NCPN Data Management staff.

1.3.1 EDSW (Effective Detection Swath Width) Feature

This feature point is used to record the Effective Detection Swath Width (EDSW) in meters. A point should be taken at the beginning of the monitoring route, indicating the EDSW at that location. If/when that EDSW figure changes (when going into a narrow canyon, for example), another EDSW point should be recorded. Type in the EDSW, in meters, in the EDSW field and continue along the monitoring route.

EDSW	Attribute Explanation	Entry	Type
EDSW	Effective Detection Swath Width in meters (see SOP #3 section 2,D for further explanation)	Entry permitted in the field	Numeric

1.3.2 Point_Weed Feature

The following point and area features are used to map invasive exotic plant infestations while traveling along a monitoring route. When multiple species are noted within one area (within PSR, see SOP #3) and you are mapping these locations as point features, collect the data for species #1, then walk a step or two, and collect the data for species #2 and continue until one point per species is collected.

Point_weed	Attribute explanation	Entry	Type
SpeciesName	Common name of invasive plant. This list will be updated for each park visited, based on input from park staff. “Other” will always be a choice.	Entry **required** in the field	Menu

Point_weed	Attribute explanation	Entry	Type
Size	**Infestation size:** 1–3 4 plants–40 m^2 40–400 m^2 400–1,000 m^2 1,000–2,000 m^2	Entry **required** in the field	Menu
CanopyCover	**Percent canopy cover:** Trace (<1%) Low (1–5%) Moderate (6–25%) High (26–50%) Majority (51–100%)	Entry **required** in the field	Menu
Pulled	**Note if plant(s) pulled by observer:** Yes (pulled) No (not pulled) -Default	Entry permitted in the field	Menu
GrowthStage	**Growth stage of tree species:** Seedling(s) Sapling(s) Mature Tree(s) Old Growth	Entry permitted in the field	Menu
PriorTreatment	**Note if area looks like it was previously treated, by any means (tree stumps, piles of weeds, spraying obvious, etc.):** Yes, area treated No treatment -Default	Entry permitted in the field	Menu
Disturbance	**Disturbances noticed at the site:** • Flooding • Grazing Impact • Hiking trails • Human occupation • Prehistoric occupati(on) • Insect disturbance • Livestock • Recreation use • Roads/OHV Trails • Spring Source • Windthrow • Other	Entry permitted in the field	Menu
Surveyor	Name of person surveying the monitoring route	Entry permitted in the field	Menu
PSR	Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#3, sec 2,D)	Entry permitted in the field	Numeric

Point_weed	Attribute explanation	Entry	Type
Notes	Any comments regarding the site (can contain species name if "other"). Use for sequential IDs if no feature positions are able to be collected.	Entry permitted in the field	Text – Optional

1.3.3 Monitoring Transect Feature Point

This feature point is used to map the transect location. The locations will be uploaded to the GPS unit, spaced at 500-meter intervals (intervals may change yearly and by park), along the monitoring route. The field personnel will need to move perpendicular (and on alternating sides) away from the monitoring route and the points along that monitoring route (see SOP #3). When the transect location is established, the point on the GPS unit then needs to be updated (logged).

Transect_start	Attribute Explanation	Entry	Type
PlotID	Numeric code. PlotIDs will be generated in the office, no entry necessary in the field	Entry **not permitted** in the field	Text
Comments	Any comments regarding the site	Entry permitted in the field	Text – Optional

1.3.4 Other Point Feature - OPTIONAL

This point feature is used for incidental observations the monitoring crews may encounter. For example, if you found lithic scatter or spring/hanging garden or wanted to mark the location of your vehicle or a photo you've taken, you may want to mark the location with this point feature, briefly commenting why you marked the location.

Other Attributes	Attribute Explanation	Entry	Type
Comment	Incidental observation comment	Entry permitted in the field	Text – Optional
Comment2	Incidental observation comment	Entry permitted in the field	Text – Optional

1.4 Uploading Transect Monitoring Locations

Mapping-grade GPS units have the ability to upload data points to be used in concert with the data dictionary. Invasive exotic transects will be taken at a given interval along established monitoring routes. These points will be generated in the office, then imported with the Invasive Data Dictionary and uploaded to the GPS unit(s) by the NCPN GIS technician. Importing points (uploading) to the GPS unit eliminates the need to type in unique identifiers in the field and allows the user to navigate more easily to the approximate location of the transect start point. Points will appear directly on the monitoring routes; the field personnel will need to position themselves in the appropriate direction (see SOP #3). Multiple GPS import files will be created

and placed on the GPS unit. This serves two functions. Using more than one file per field hitch lessens the chance of data loss, and also eliminates Trimble's "time-out" feature from interrupting data collection throughout the field session.

Background data layers can be used to assist with navigation. One necessary layer is the monitoring routes (line) file. This can be combined with the park boundary to assist in navigation. Either shapefiles or TerraSync background files can be used.

Trimble GPS units are equipped with a sound function; each task you perform has a distinct sound. For this protocol, it's useful to have the sound turned on, as when you are approaching a Transect_start, the warning sound will beep, and for each Between Feature Point automatically logged, a small beep will sound, alerting you that the unit is functioning properly. The sound for each GPS unit can be turned on by tapping the sound icon on the top task bar.

1.5 Collecting Data

Once you've discovered an invasive patch, it's time to collect the necessary GPS locations (either points or a transect start point). Appendix A contains detailed instructions for use with the Invasive Data Dictionary and various files.

Within TerraSync, open the existing file of transect start points. This will also open the data dictionary "Weed_Monitoring_v#.ddf." Open the background file containing the monitoring routes to assist in navigation. Once the Transect points and Invasive Data Dictionary are open, choose the appropriate feature type and begin logging the point and data required. Each point collected should be allowed to receive 10–20 positions before ending data collection and moving onto collecting another feature along the monitoring route(s). Using the Navigation feature and/or watching your progress along the monitoring route on the Map screen will assist in knowing when you've arrived at a transect location. Pause the GPS reception and enter the necessary data dictionary fields.

There will be times when GPS satellite reception will be compromised because of the terrain you are monitoring (e.g., narrow canyons or a dense overstory). If you find that the GPS is unable to see satellites, and moving a small, reasonable distance from the infestation won't alleviate the situation, fill in the data dictionary and save the feature even though there is no locational data associated with the data in the data dictionary. In the Notes field, write an ID ("A" or "01" etc.) and then note that same ID on your invasive field maps as close to the location as you can.

Each crew member will keep a daily log of where they traversed which species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they feel may be of importance to the project. This data will be used during the quality control process.

At the end of each field day, each GPS unit used should be backed up using SD cards to prevent data loss. Simply copy and paste the TerraSync files from the TerraSync directory to the SD card, each day replacing the files on the SD card (see Appendix A, Section 2.8). The SD card(s) should be stored separately from the GPS unit(s).

1.6 Downloading

When data collection is finished, the GPS data needs to be downloaded. The NCPN GIS technician will download the data from the GPS unit(s) after each field excursion, and then differentially correct the data, using the appropriate (closest) base station. The corrected GPS files are then exported to a GIS data format. The attributes to capture while exporting the corrected GPS data into a GIS data format ("turn on" in Pathfinder Office) are shown below.

- PDOP
- Correction Status
- Receiver Type
- Date Recorded
- Time Recorded
- Update Status
- Data File Name
- Total Positions
- Filtered Positions
- Data Dictionary Name
- Height
- Vertical Precision
- Horizontal Precision
- Standard Deviation
- Position

Data should be exported using the same coordinate system used in the field (UTM, NAD83 Conus, Zone 12 or 13, meters).

Data are usually exported to a geospatial format; however, if data were collected without locational information, the data will also need to be exported as a dBase file.

The project lead and GIS technician will perform quality assurance/quality control measures on the downloaded and differentially corrected field data at the end of each field excursion to catch any data edits or additions necessary (as in areas drawn on field maps when satellite reception was not possible).

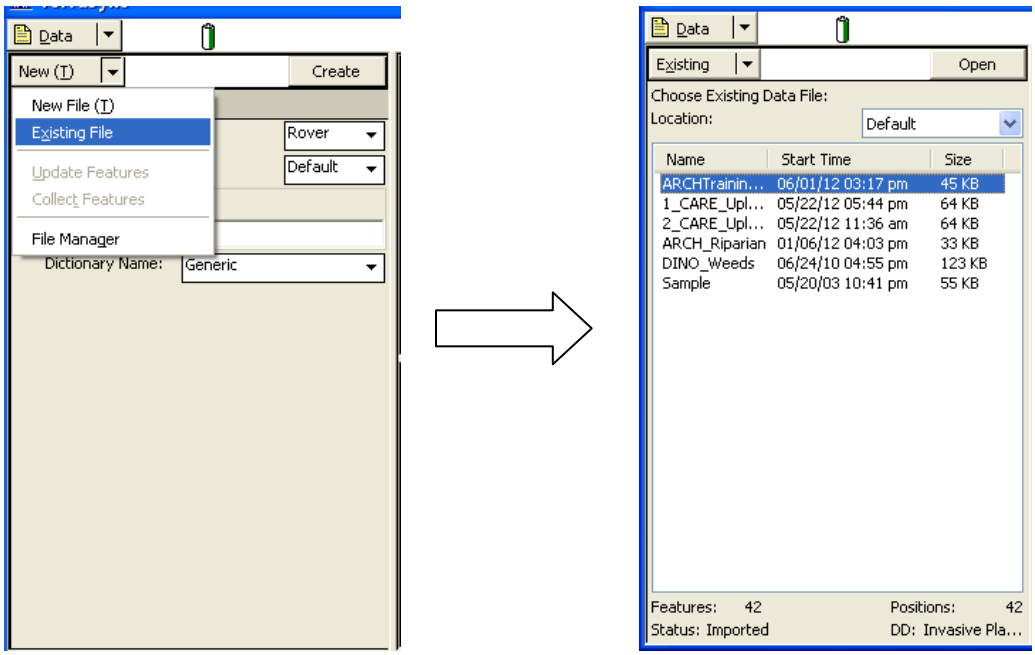
1.7 Uploading to the Working Invasive Database

Once the GPS field data are validated and verified (GPS points given a visual review, additions added, attributes checked and corrected if necessary) in ArcMap, the data are ready to be uploaded into the working Invasive Database. The GPS data are exported from ArcMap into an Excel spreadsheet for importing into the Invasive Database (see SOP #7).

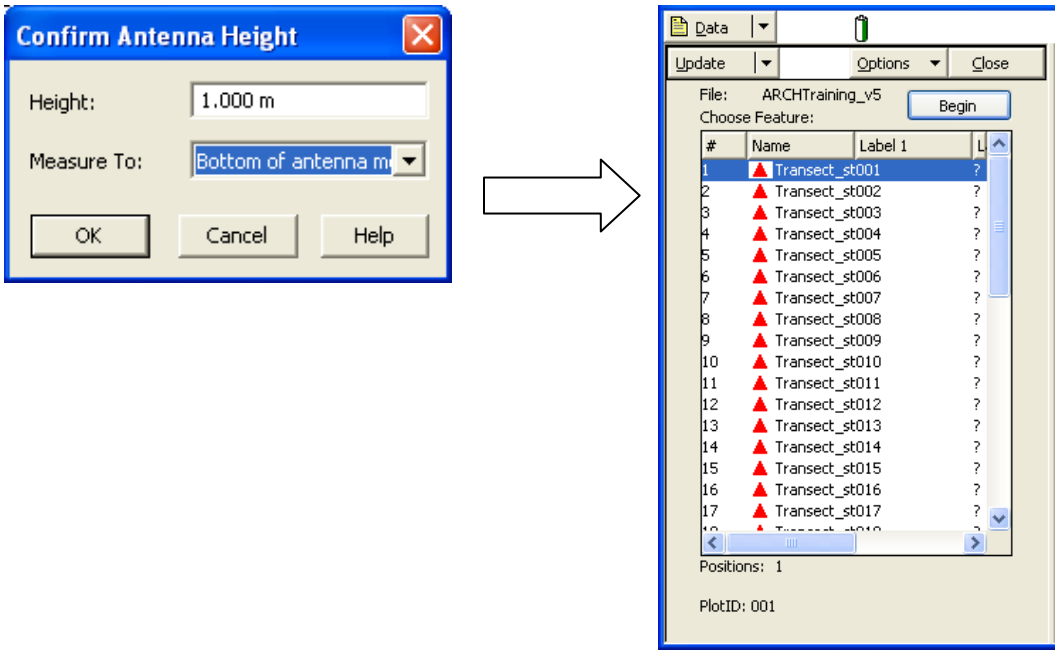
Appendix A. Instructions for GPS Use

A1. Beginning Invasive Exotic Plant GPSing

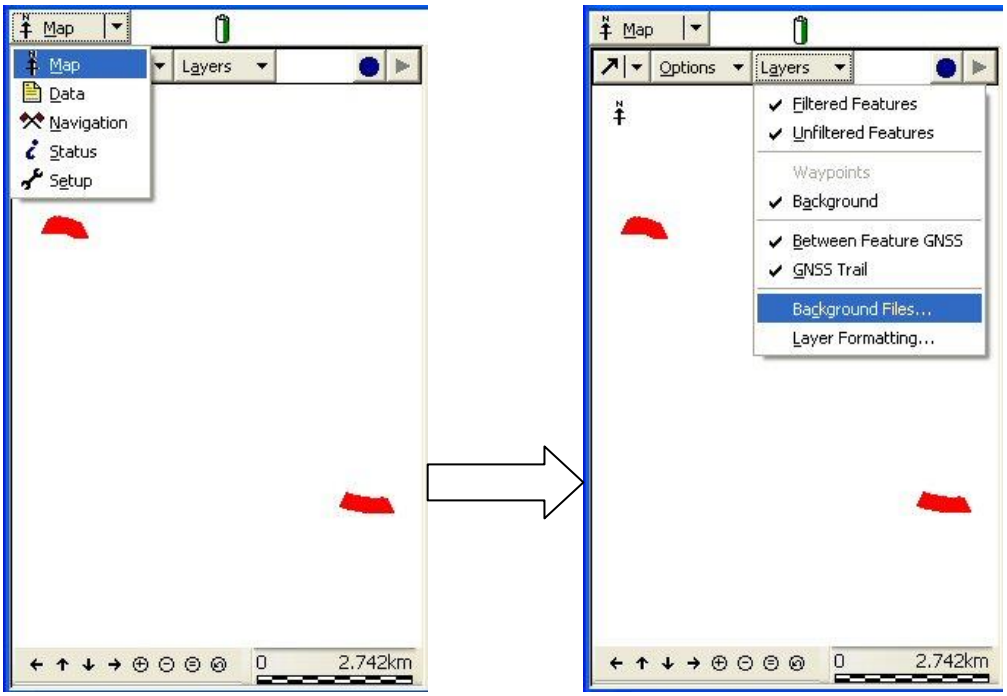
Open TerraSync. To open the transect start points, from the opening satellite status screen, choose Data/Existing File. Choose the file ("ARCHTraining", in this example) and tap the Open button.



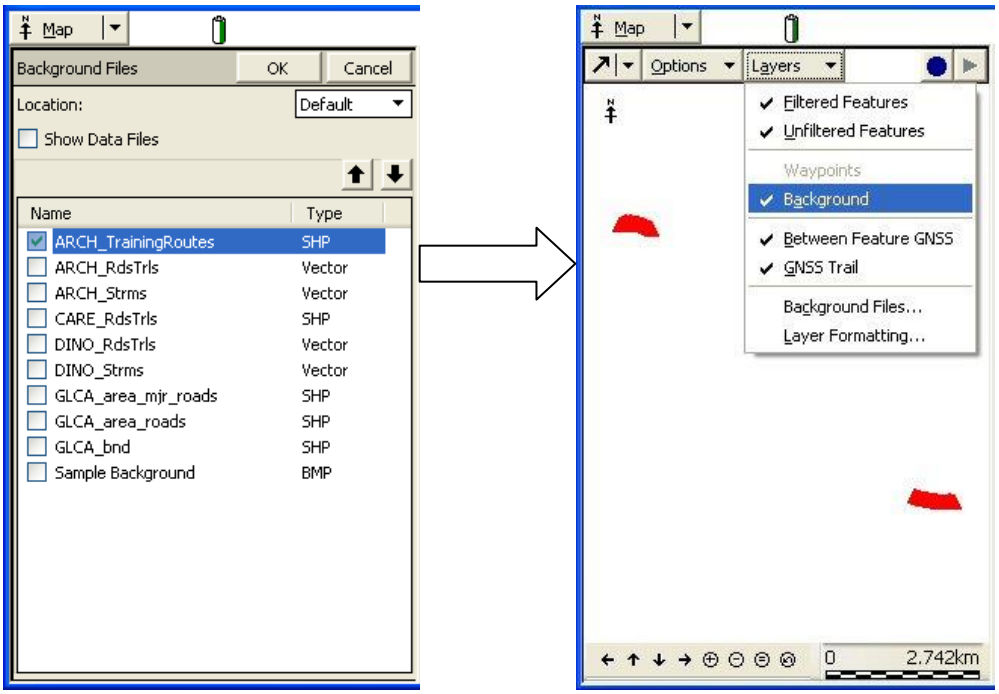
The Confirm Antenna Height window will appear. Enter 1.000 m for Height, and choose "Bottom of antenna mount" for the Measure To: portion. Once you've set this, most of the time you can merely OK this window. A list of all the predetermined locations of transects will then appear.



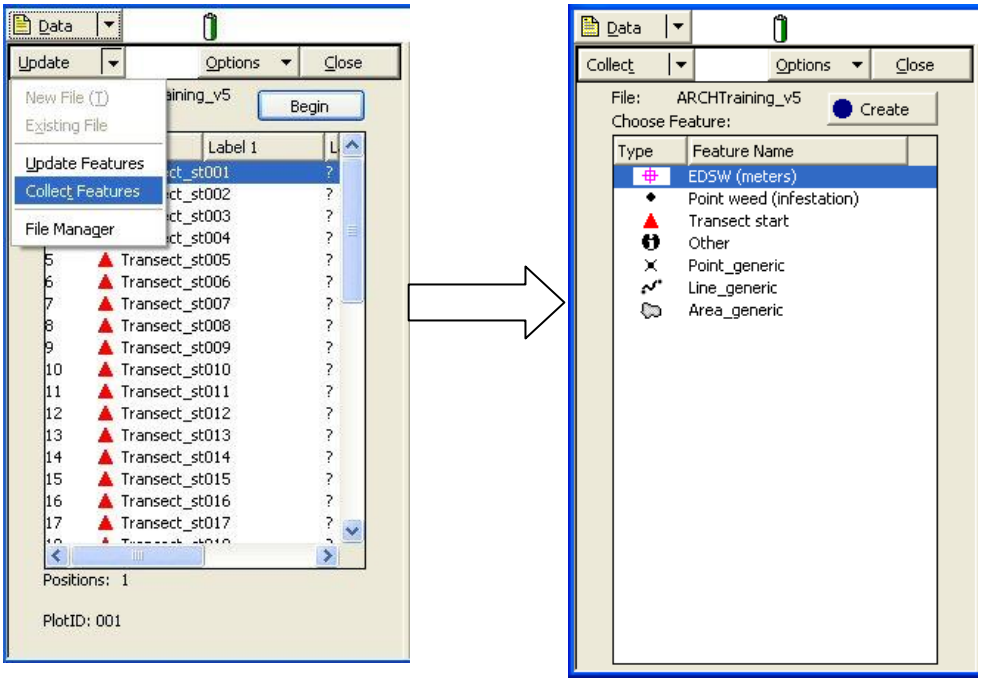
To set up the background layers to assist in navigation, choose Map from the upper left menu button. Then tap on the Layers menu button, and choose Background Files:



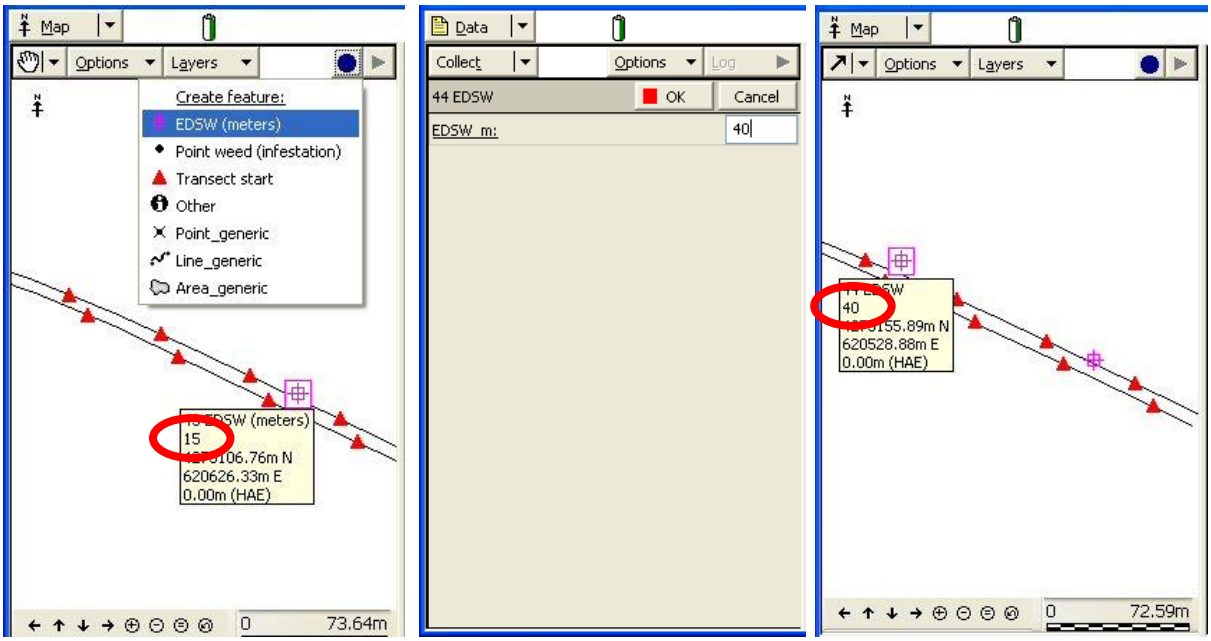
Check the box next to the layer file(s) you need displayed and click OK. Make sure, on the Layers menu, that Background is checked; if not, merely tap it to check it. Then your background layer(s) will appear on your map screen:



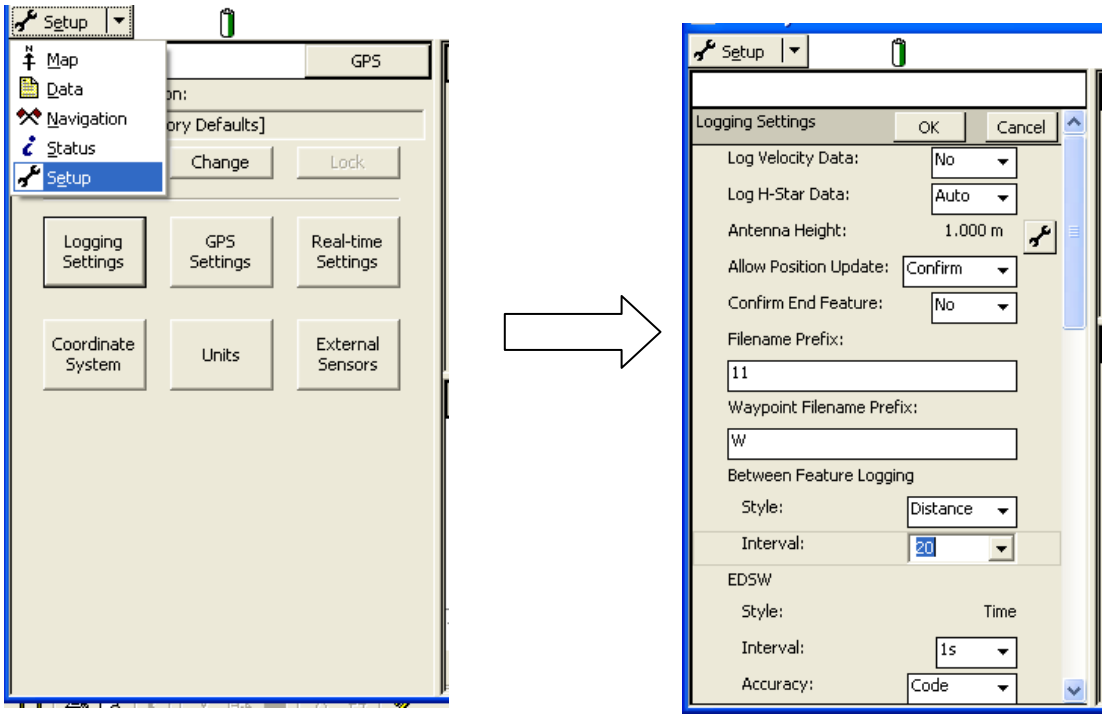
Tap the Data screen, and the list of transects appears. Change the function from Update to Collect features (the drop-down list under the top left button). This will change the screen to display the features in the Invasive Data Dictionary:



The first feature listed in the data dictionary is an EDSW feature point. When you begin your weed monitoring route, create and log a point. Within the data dictionary, type in the EDSW (in meters) for the route. As you traverse a given route, whenever the EDSW changes, log a quick EDSW point to indicate the change in the EDSW. Create *at least* ***one*** EDSW point per monitoring route.

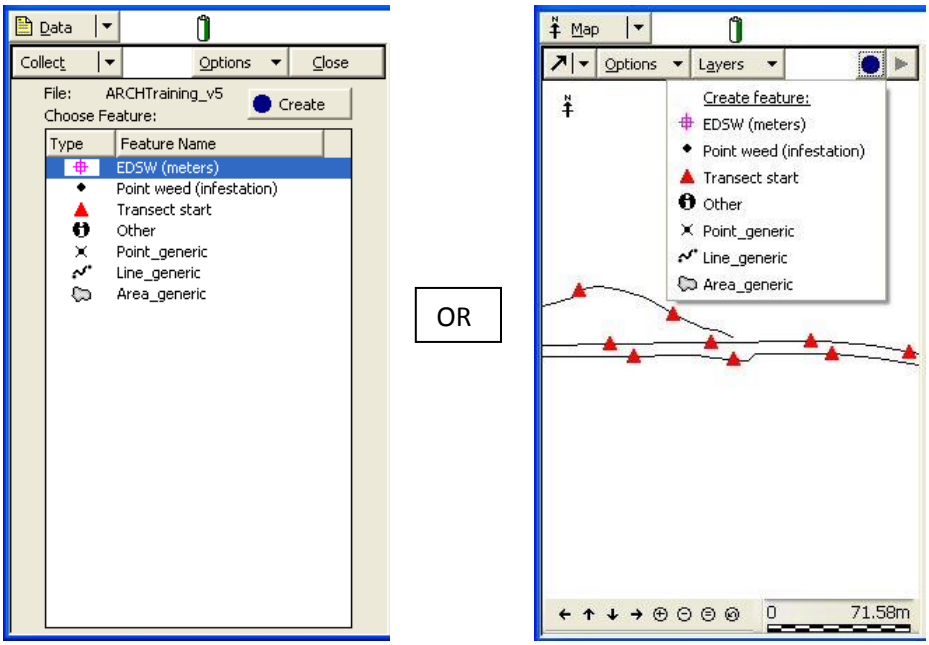


To track the routes you take and collect “negative” data, you’ll need to ensure that the Between Feature Logging feature is enabled and set to 20 meters. Tap the button menu on the upper left corner and choose Setup. On the Setup Menu, choose Logging Settings. On the Logging Settings screen, scroll down until you see Between Feature Logging. For Style, choose Distance and for Interval, type in 20 (meters). Tap OK. This sets the Between Feature distance for the file, so you won’t have to change it again.

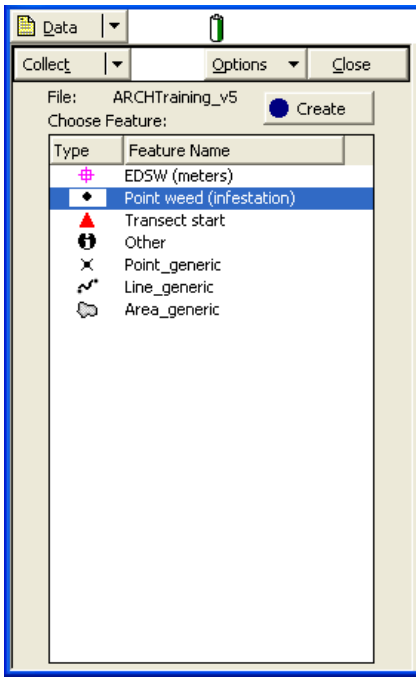


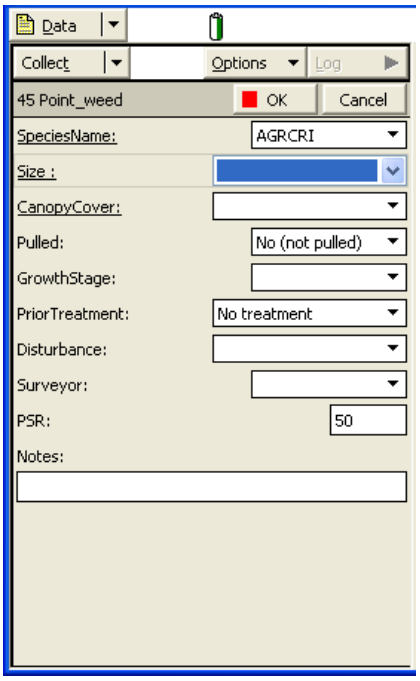
A2. Collecting Point Weed features

Now you’re ready to collect GPS data. A lot of the data you’ll be collecting will be Point_Weed data. There are two ways to reach the data dictionary. You can choose Collect Features from the Data screen, or use the blue dot/circle on the Map screen.

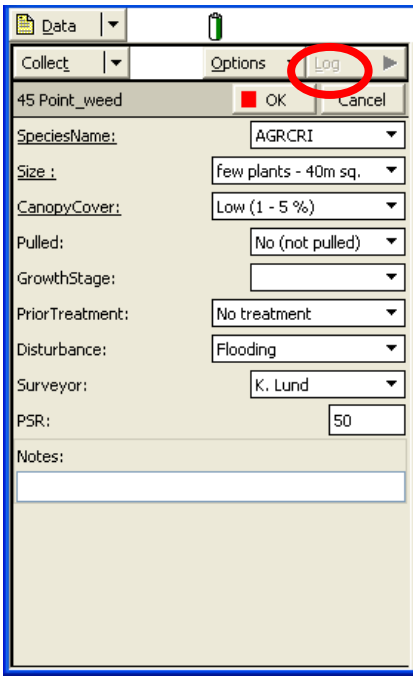


To create a Point_Weed, highlight it from the data dictionary and tap the Create button. This will open the data dictionary feature.





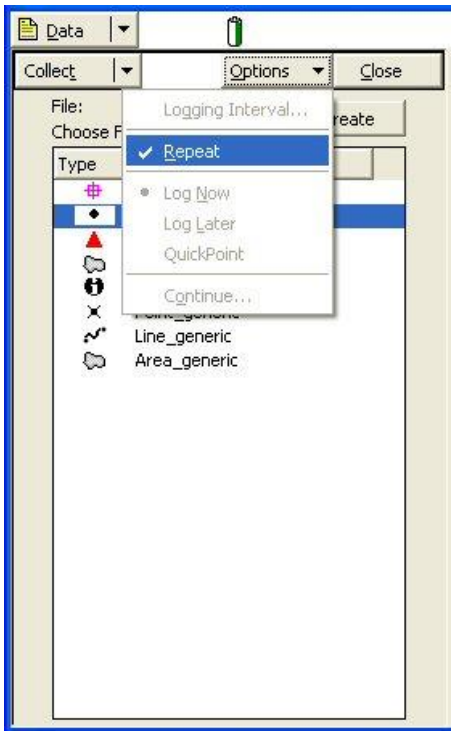
Please note that the items which are <u>required</u> are displayed as <u>underlined</u>; this means that you **must** fill in *at least* those items before TerraSync will allow you to close the feature and move on.

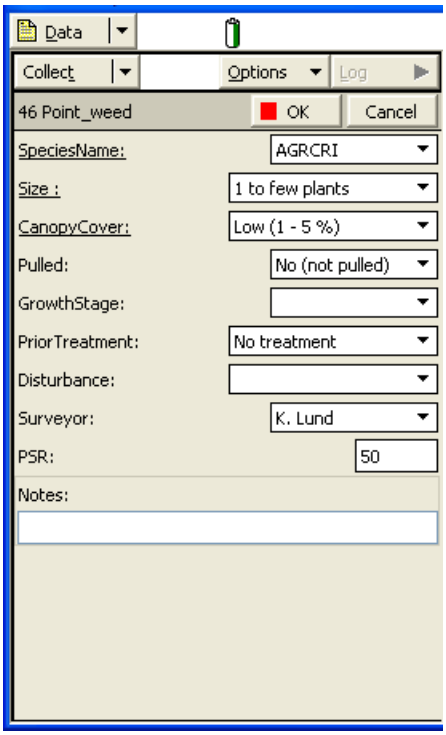


Fill in the necessary and appropriate fields. You may wish to use the Pause/Log button at the bottom of the screen while filling in the data. This pauses the GPS unit from continuing to receive satellite signals. A total of 10–20 “hits” is plenty to log the weed infestation. (The number of “hits” would appear where the red circle is.)

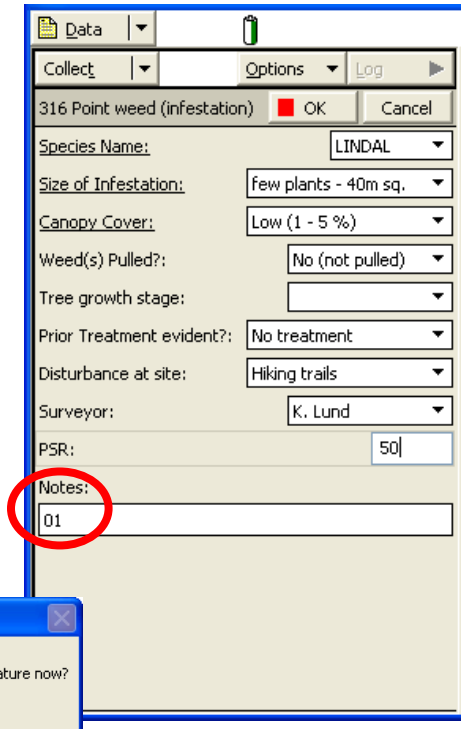
If TerraSync gives you the message “Unable to append to a file over one week old,” close the file and open the next numerical file contained on the GPS (something like 2DINO_weeds).

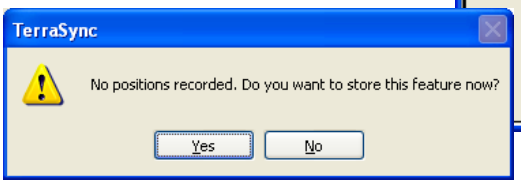
You'll notice, as you go through the items, that there are a fair number of fields that will be the same throughout the monitoring route and/or park (PSR, Surveyor, Pulled, perhaps even SpeciesName). Once you've closed an open feature, tap the Options button. Choose Repeat. This will repeat the data taken for the next series of points, leaving ALL data fields filled. Be sure to change any fields that do need changing if you choose to use this feature. The Repeat function can be toggled on and off, using the Options/Repeat menu.



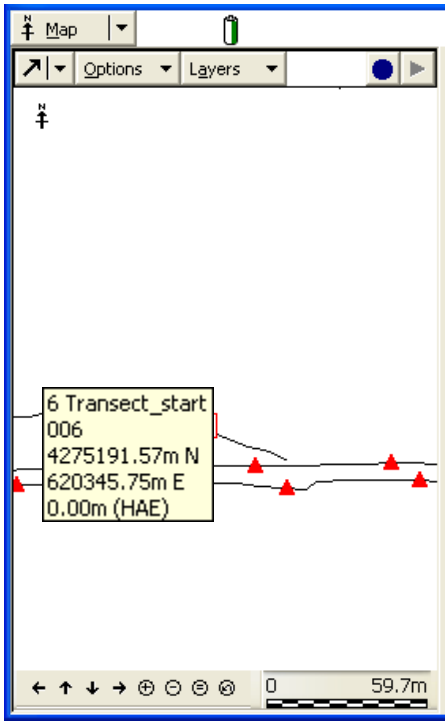


At times, you will not be able to collect a GPS point because the terrain you are monitoring (e.g., tight canyons or thick canopy cover) is blocking the communication of the GPS unit with the satellites. First, try moving a reasonable, small distance away from the infestation to log the location. If that does not work, go ahead and fill out the data dictionary normally and, in the Notes section, add a (sequential) ID. When TerraSync questions saving the feature without positions, tap Yes. On your invasive field map, record the same ID at the point where you think you're located. When you are done with the park, pass your field maps to the GIS tech.



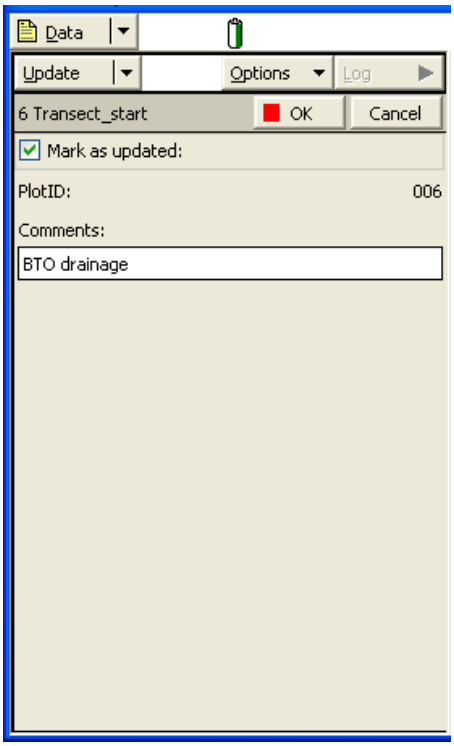


A3. Logging Transect Starts



Transect start points are created in the office and uploaded to the GPS unit. These points are placed on the monitoring route and will not be in the exact location where the transect needs to be placed (see SOP #3). These points are placed the correct distance apart, but you will need to move to the appropriate side and distance away from the monitoring route. Notice that the second line of identifying text is the unique transect ID. Once you update the transect feature location, the UTMs will change, and the last line of text will be populated (Height Above Ellipsoid, aka Elevation).

For each transect, you need to log a GPS location. When you arrive at a transect point, update (collect satellite data) for that transect start point. To do this, double-tap on the point to enter the data dictionary and allow a new and accurate position to be recorded.



Notice that the PlotID is already filled in. Once you log the point, the “Mark as updated:” box will be checked. Unless you wish to type in some comments about the site, that is all you need do on the GPS unit for transects.

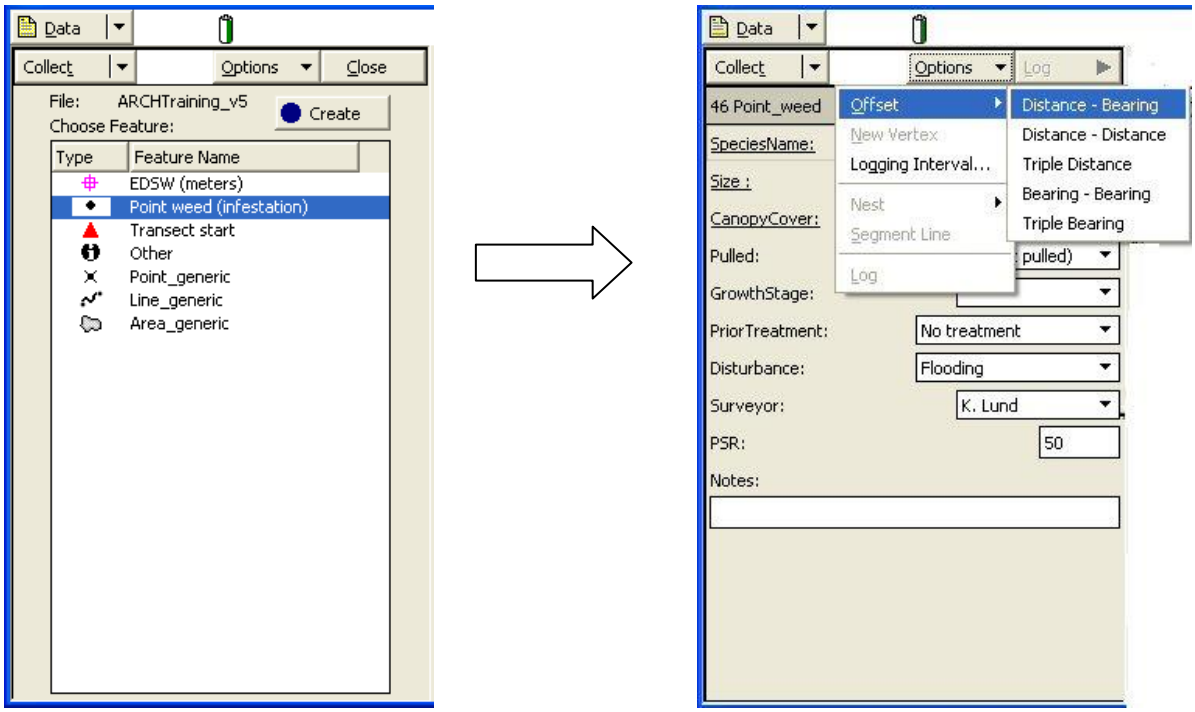
Note: The Comments field may be filled in with the monitoring route name. These data are here for your benefit, but if you feel you need to write in a comment, please do so. Maintaining the route names is not necessary.

A4. Other Data Dictionary Features

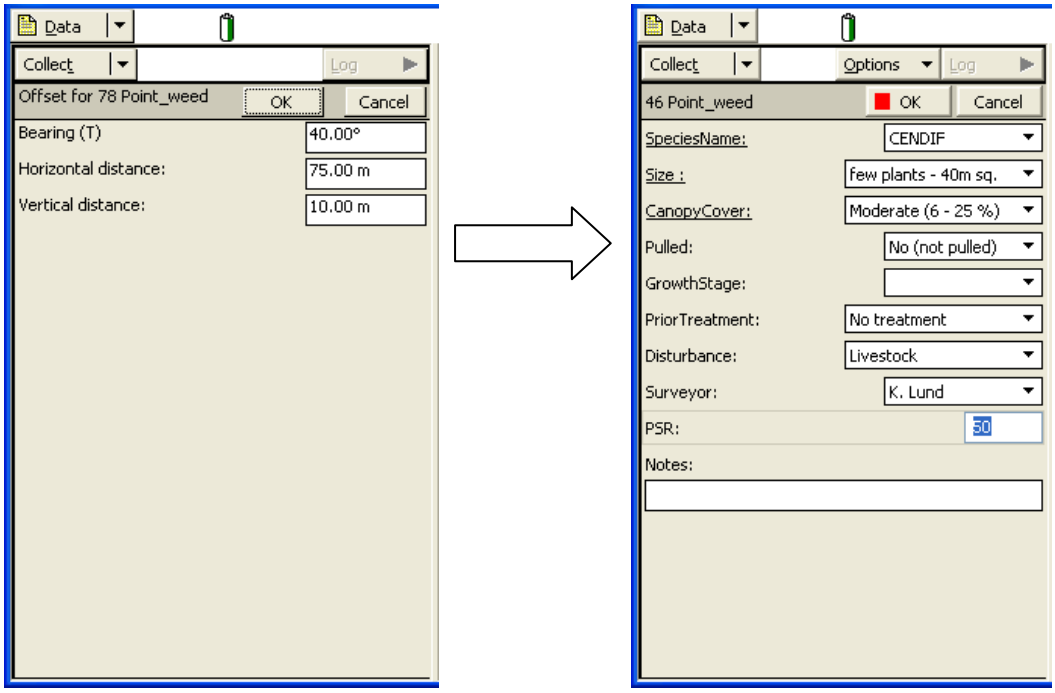
There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (e.g., the location of your vehicle, an archaeology site), use the Other feature point.

A5. Offsetting a Point Feature

If a weed population is noted in a difficult location (such as across a drainage/river), but you'd like to log the species you see there, you can do that with the Offset feature. Create the Point_Weed feature and tap the Options dropdown menu. Select Offset/Distance - Bearing.



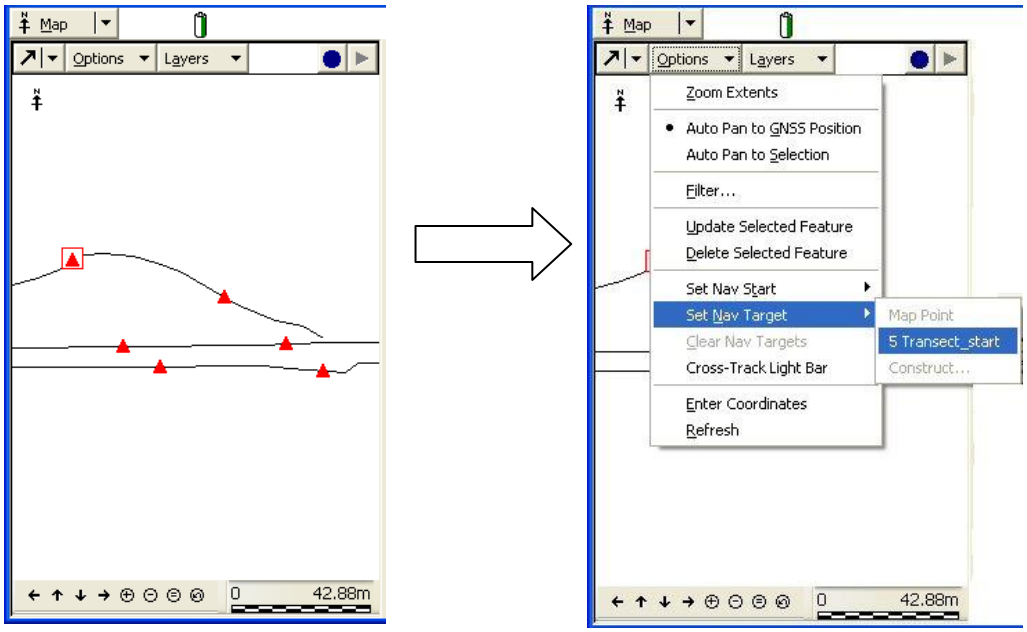
The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location.



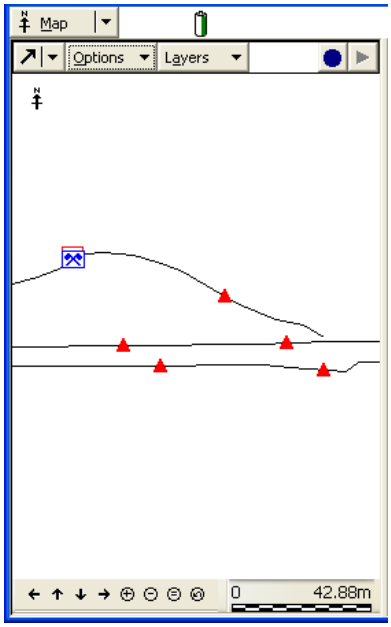
A6. Navigation

As you traverse a monitoring route, knowing where to stop to collect the transect and quadrat data is important. Locations 500 meters apart have been generated in the office to help you know where to collect the transect data.

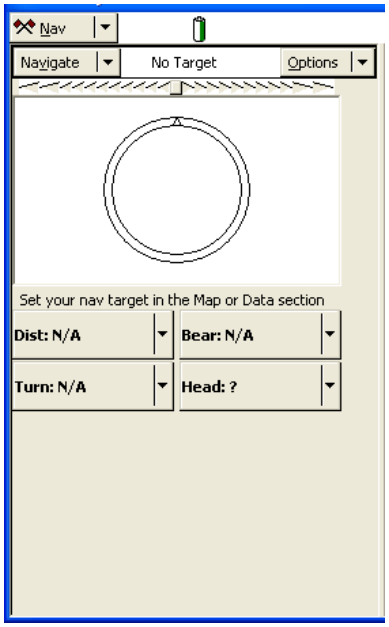
From the map screen, select (note square box around point) the point feature to which you wish to navigate. Choose the Options button and choose Set Nav Target. From that menu, select the one point listed (it will be named).



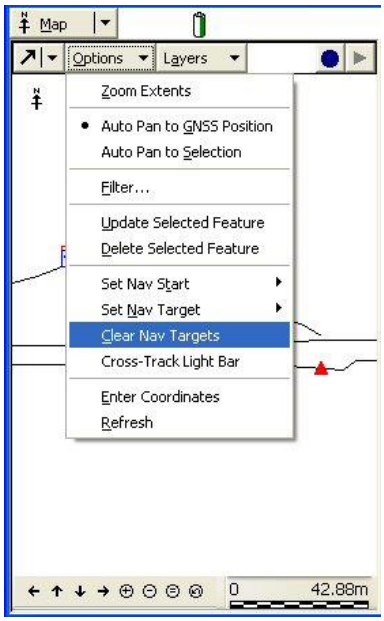
On the map screen, you'll notice that a blue, crossed-flags icon covers the point. You can track your progress from this screen (Map screen) or you can tap on the Map button and select Navigation. The Navigation screen will then tell you (once you are moving) the distance and bearing to your target point. When you get close to the point (within 5-ish meters), an alarm will sound (if you have the sound turned on) and the screen will change from a compass to a bullseye map.



OR



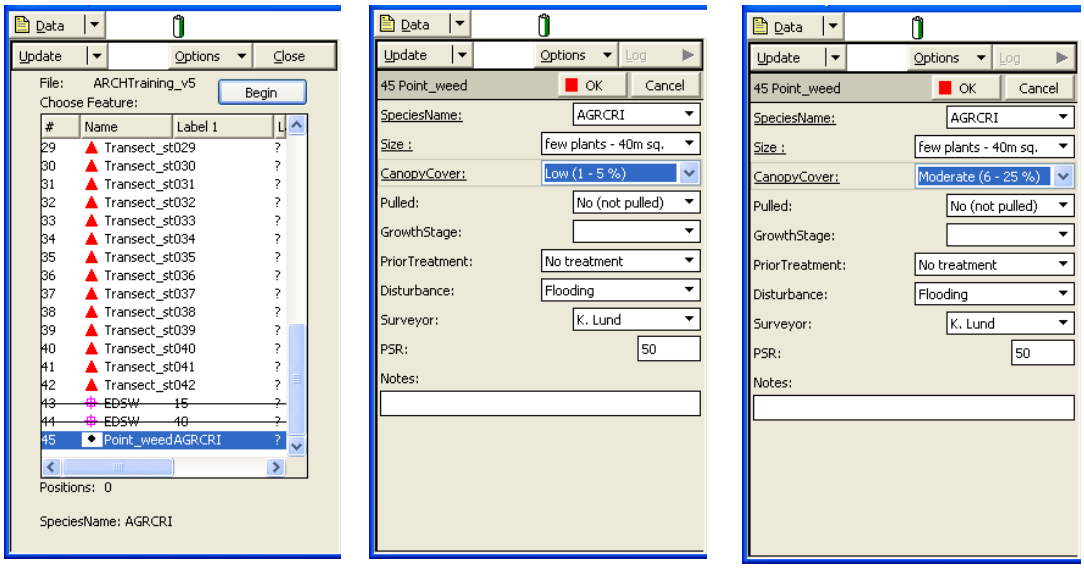
To clear the navigation target, tap the Options button, then tap Clear Nav Target. Now you are ready to set a new navigation target.



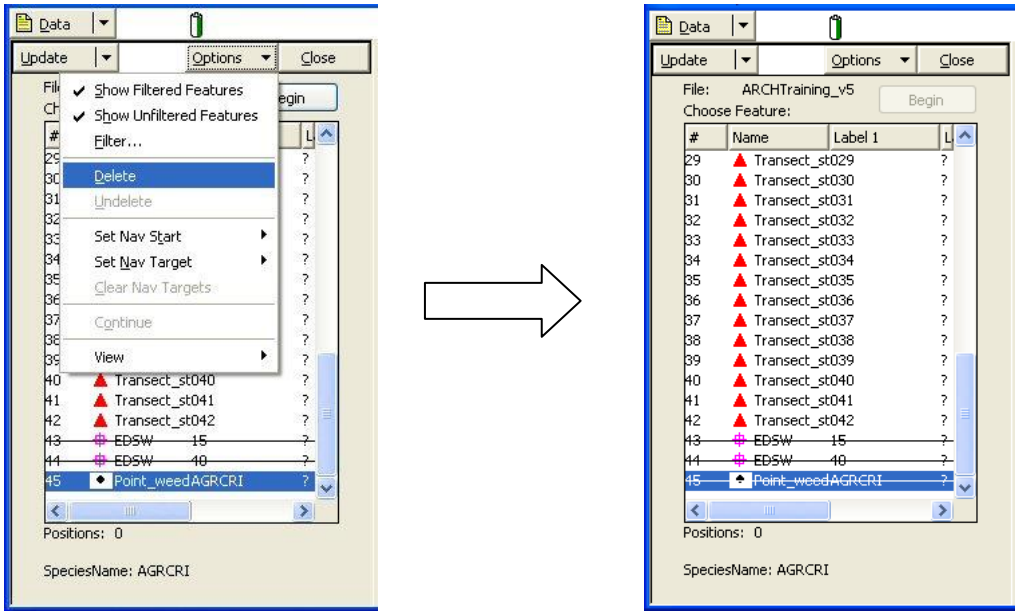
TIP: When viewing the map screen, if you tap and hold on a point, a menu will appear, allowing you to Update, Delete or Set Target. If used to Set Target, you will still need to clear the target under the Options menu.

A7. Editing a Feature

If you need to edit a point that you've already GPSed and closed, you may do so by "Updating" the feature. On the dropdown menu in the upper left, choose Data. In the menu at right below, choose Update. A list of the features logged will show up. Double tapping a feature will open the data dictionary, allowing you to change any information, and/or log more GPS "hits" (doing so will average what's already been collected with the previous locations). Generally, updating the data within the data dictionary is all that you need to do. Click the OK button when you've edited the data.



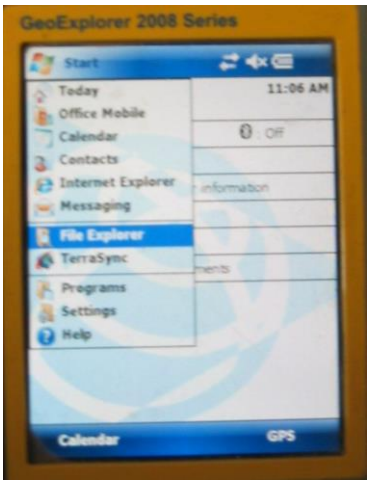
You may also want to delete a point, which is also possible from the Update menu. Tap Options Menu and choose Delete. The feature will have a line through it and the deleted feature will not appear on the Map screen. You may also Undelete a feature.

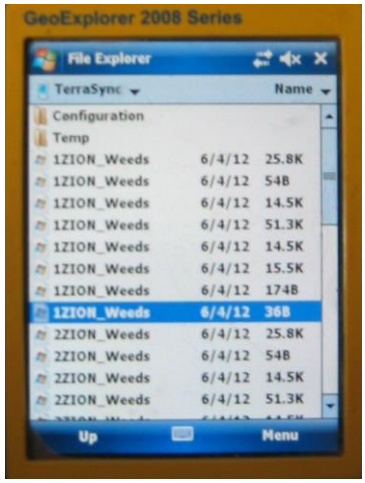


A8. Backing up GPS Data

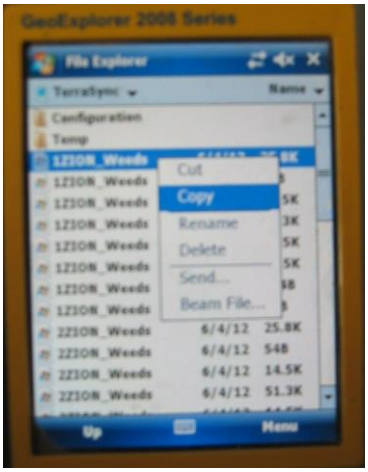
At the end of the day, create a copy of your GPS data on the SD card(s). BE SURE you have CLOSED the file in TerraSync before copying.

Once TerraSync and the GPS file are closed successfully, from the Start menu, open File Explorer. Navigate to the My Device/My Documents/TerraSync folder.

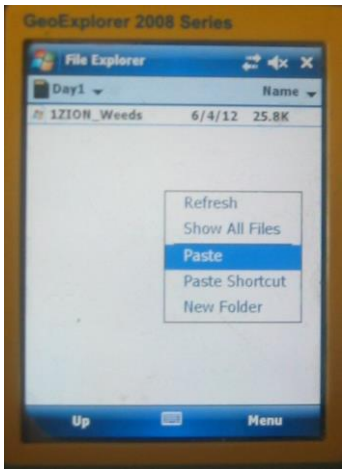




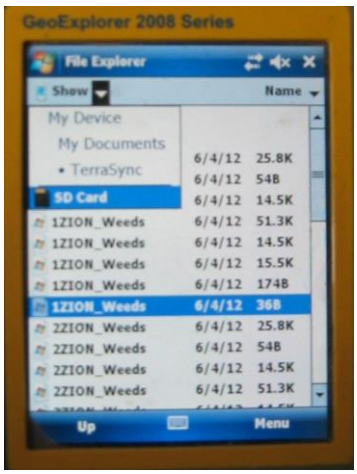
Each file you see inside TerraSync is made up of eight (8) files. In order to back these files up, each of those 8 files will need to be copied to the SD card.

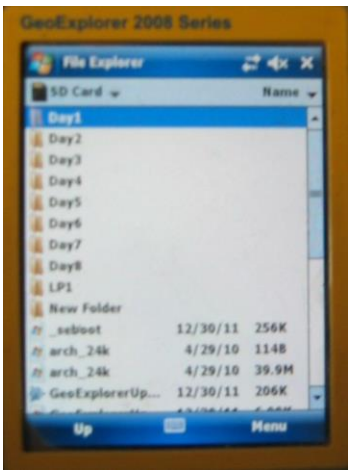


Tap and hold the stylus on a file piece, and a menu will come up. Choose Copy (unfortunately, each of the eight files will need to be copied and pasted individually).



Navigate to the SD card. Tap the arrow next to TerraSync and choose SD Card. The contents of the SD card will be displayed, showing a host of Day# folders. Navigate to the appropriate Day folder. Tap and hold the stylus on the screen, and choose Paste from the menu that appears. Repeat this for ALL 8 files.

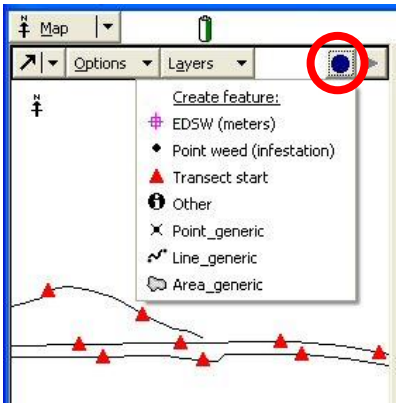




By copying (rather than cutting), you will still be able to use the file in TerraSync the next day.

Store the SD cards in a safe place (not inside the GPS unit) out of the sun and heat. Be sure to turn in both the GPS unit and SD card at the end of the field hitch.

A9. Other Tips

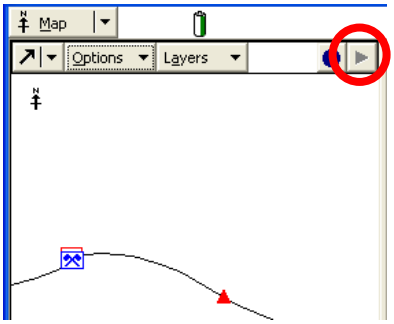


- When in the Map view on the GPS unit, to quickly choose another feature within the data dictionary, tap the blue dot in the upper right. A drop down list of the other features within the data dictionary will appear, allowing you to choose which feature you wish to log. Conversely, if there is a red square showing here, that will close (& save) the feature you have open.

- In Setup, make sure the Between Feature Point (BFP) interval is set to 20m before you begin a route.

- Log a point feature for a minimum of 10 “hits” (10 seconds).

- If TerraSync gives you the message, “Unable to append to a file over one week old”, close the file that’s too old, and open the next numerical file on the GPS unit.



- If you are not sure how large an infestation is, you can begin logging the point at the edge of the infestation for 5 seconds, then pause the GPS unit and walk through the infestation. When you reach the other side, allow the GPS to log for another 5 seconds. The GPS will average all 10 “hits” and place the point in the middle of the infested area.

- When viewing the Map Screen, on the very right upper corner, there is a toggle for turning the Between Feature Mapping on/off. Generally, this feature should be on, but if you're in camp, for instance, you can temporarily pause the collection of Between Feature points.

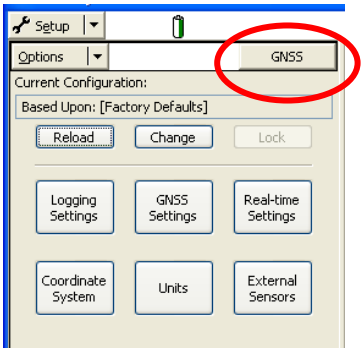
- Holding the power button down for 30 seconds will soft re-boot the XM GPS. Holding the power button down for 60 seconds will hard re-boot the XM GPS. Neither of these re-boots will lose any data, but you should recheck the coordinate system. You may also need to set the date and time on the GPS unit.

- To re-boot the Juno STs, there is a little hole on the top left side (next to the expansion card). Push that with the tip of the stylus to re-boot.

- To re-boot the Juno SBs, there is a small hole on the top right side (next to the camera zoom slider). Push that with the tip of the stylus to re-boot.

- To conserve battery life (generally 8 hours on XMs and 4+ hours on Junos), turn the unit off if you aren't using it to navigate. It is highly recommended that the GPS file and TerraSync be closed *prior* to turning off the unit.

- There is a sliding button near the power button. If it is slid down, this will "lock" the Juno ST off so it won't turn on while bouncing around in a backpack. Using this to turn the unit off (and on) seems to help conserve battery life.



- If the GPS gets disconnected, go to the Setup screen and tap the GNSS button on the upper right side.

- The NCPN has a copy of the TerraSync Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.

- Label the back (or case) of your GPS unit with your name on a piece of masking tape so you'll be able to use the same unit throughout a field stint.

- Report any idiosyncrasies with the Trimble GPSes to the NCPN data management staff with as much detail as possible.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #7
Data Management

Version 1.03
June 13, 2018

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.00	12/1/2012	H. Thomas	Minor edits to section 3.2	To reflect database changes made in 2012	1.01
1.01	3/2016	A.W. Biel H. Thomas	Minor editorial Edits made to several sections	Publication preparation To reflect current data management practices and changes to the database structure	1.02
1.02	6/2018	H. Thomas	Edits made to the *Database Design* and *Populating the IEP Database* sections, and appendices A-C	To reflect changes to the database structure needed to accommodate dead species and quadrats that are not sampled	1.03

This Standard Operating Procedure (SOP) describes data management procedures for all data derived from invasive exotic plant (IEP) monitoring in Northern Colorado Plateau Network (NCPN) park units. The procedures for data management given in this SOP follow guidelines and standards that are described in the NCPN Data Management Plan (Beer et al. 2005).

Definitions and Acronyms

BFP	Between Feature Position
EDSW	Effective Detection Swath Width
FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
GIS	Geographic Information Systems
GPS	Global Positioning System

I&M	Inventory & Monitoring Program of the National Park Service
IEP	Invasive Exotic Plants
NCPN	Northern Colorado Plateau Network
NPS	National Park Service
PDF	Portable Document Format
PDLC	Project Data Life Cycle
SOP	Standard Operating Procedure
Accepted data	Data that have undergone all QA and QC procedures as defined in the published protocol and associated SOPs.
Data products	Information that is derived from accepted project data.
Data Store	The NPS-wide repository for documents, publications, and data sets related to NPS natural and cultural resources (https://irma.nps.gov/DataStore).
Master database	Project-specific database that stores the full project data set and is used for viewing, summarizing, and analysis. Contains only accepted data.
Primary dataset	The dataset that is the most comprehensive and representative of the data associated with a project. This dataset can normally be used independently of other project datasets and is often distributed to external users. The primary dataset can be tabular or spatial. For most NCPN monitoring projects, the primary dataset will be either an MS Access database or a geodatabase.
Project level metadata	A metadata record associated with the primary project dataset that contains cross references to all project data products and is uploaded to the Data Store.
Quality assurance (QA) procedures	Procedures used to ensure collection of data with minimal errors.
Quality control (QC) procedures	Procedures used to flag or modify data to ensure that data meet established data quality standards.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by Microsoft (MS) Excel, MS Access, database, or statistical software, and managed as text, spreadsheet, or relational databases.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time).

Database Design

The primary dataset associated with the NCPN IEP monitoring project is a tabular dataset stored in a Microsoft (MS) Access database, referred to subsequently as the "IEP database." The IEP database runs using either Access 2007 or 2010. It has a frontend/backend file structure:

- *Invasives.accdb*: This frontend file contains all queries, forms, reports, and associated Visual Basic for Applications (VBA) application code.
- *Invasives_be.accdb*: This backend file contains the database tables.

The frontend/backend file structure allows multiple users to enter data in a network environment, and allows for easy backup and transfer of the data tables. Users typically launch the frontend file, and a utility will prompt them to establish a link to the backend file.

The IEP database was developed following the NPS Natural Resource Database Template (NRDT), which is based on a location record, one or more related event records, and observation data elements linked to each event. The database was modified in 2017 to accommodate the recording of dead species and quadrats that are not sampled. When these modifications were made, the tables storing transect data were redesigned to comply with the 2015 I&M database standards (Frakes et al. 2015). Figure 7-1 shows the relationships between the primary IEP database tables (all tables are not shown).

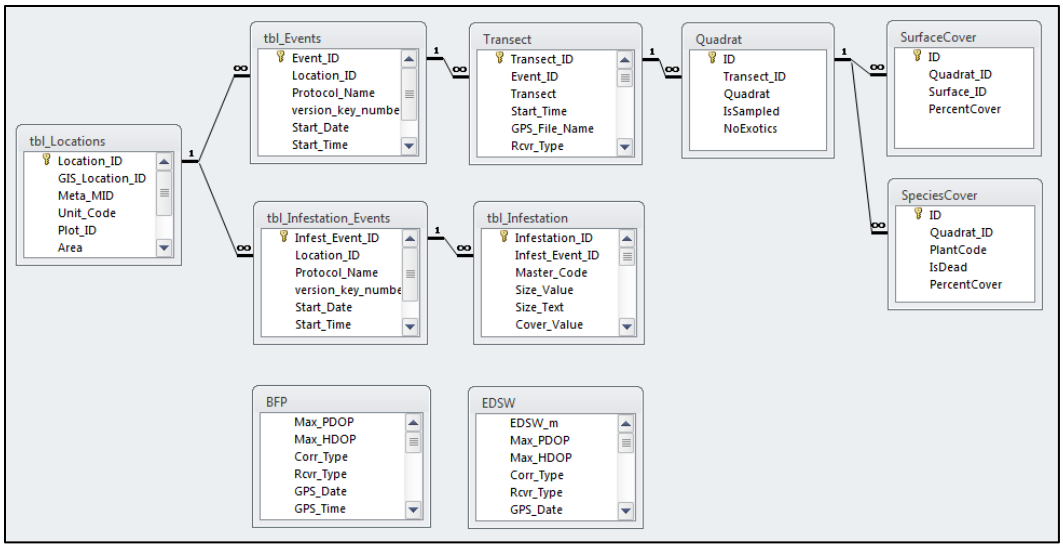


Figure 7-1. Data model for IEP database.

IEP monitoring is conducted along routes. Each route has a record in *tbl_Locations,* which stores basic information about the route (e.g., route name). Each route can have one or more events

associated with it, where an event corresponds to the collection of data for either an infestation or a transect.

- **Infestation**: For infestations, each unique combination of route and start date represents a sampling event and is stored in *tbl_Infestation_Events*. An infestation event can have one or more infestations associated with it. Each individual infestation has a record in *tbl_Infestation*, which stores details about the invasive plant species observed, along with the location of the infestation.

- **Transect**: For transects, each unique combination of route and start date represents a sampling event and is stored in *tbl_Events*. An event can have one or more transects associated with it. Each transect has a record in the *Transect* table, which stores details about the transect such as the location and the surveyor who completed the transect. Each transect has three quadrats associated with it. Quadrat information is stored in the *Quadrat* table, and includes the quadrat number and flags indicating whether the quadrat was sampled and whether any IEP species were present. Each quadrat can have species cover and microhabitat cover data associated with it. Species cover data are stored in the *SpeciesCover* table, while microhabitat cover data are stored in the *SurfaceCover* table.

Also stored in the IEP database are the between feature position points (*tbl_BFP*) and the effective detection swath width settings (*tbl_EDSW*) that are logged during monitoring. In addition, the priority or target lists of IEP species for each park and year are stored in *tbl_Target_Areas*, *tbl_Target_List*, and *tbl_Target_Species* (not shown in the figure).

Documentation of all tables and fields in the IEP database is provided in Appendix A.

Populating the IEP Database

Prior to each field season, the working database for the IEP monitoring protocol is prepared for the upcoming field season's data entry. The working database is initially an "empty" database; that is, it contains no observation data, just populated lookup tables. The working database is used for data entry, verification, and validation for a given field season. After the dataset in the working database is quality checked, it is merged into the master IEP database.

For the remainder of this document, the term "IEP database" refers to the working database. The IEP database will be populated via a combination of data import and data entry.

Data import

Because most IEP monitoring data is collected via GPS units, most of the data in the IEP database will be populated by importing it from GPS data files. These GPS data files are created by the GIS specialist, who processes (e.g., corrects, verifies) the raw GPS data and converts it to a spreadsheet format. The GPS data file for each park contains a worksheet for each of the

following datasets: transects, infestations, between feature positions (BFPs), effective detection swath width (EDSW) points, route area, and route length.

Data management staff uses custom-developed tools to import these datasets into the IEP database. Below is an outline of the steps required to import the data:

1. Link data files: Link the park GPS data file containing the data to be imported to the IEP backend database file. Also link the NCPN master plants table.

2. Open main menu form: Run frm_Menu.

3. Import monitoring routes: Click the "Load Routes and Events" button. Select the worksheet corresponding to transects as the input table and click the "Load Routes" button. Data will be loaded into *tbl_Locations*.

4. Import monitoring transect events: On the *Load Routes/Events* form, select the worksheet corresponding to transects as the input table and click the "Load Events" button. When prompted for the event type, choose "transect events". Data will be loaded into *tbl_Events*.

5. Import monitoring transects: On the main menu, click the "Import Infestation and Transect Data" button. Select the worksheet corresponding to transects as the input table and click the "Import Transect Data" button. Data will be loaded into the *Transect* table.

6. Import infestation routes: On the main menu, click the "Load Routes and Events" button. Select the worksheet corresponding to infestations as the input table and click the "Load Routes" button. Data will be loaded into *tbl_Locations*.

7. Import infestation events: On the *Load Routes/Events* form, select the worksheet corresponding to infestations as the input table and click the "Load Events" button. When prompted for the event type, choose "infestation events". Data will be loaded into *tbl_Infestation_Events*.

8. Import infestations: On the main menu, click the "Import Infestation and Transect Data" button. Select the worksheet corresponding to infestations as the input table and click the "Import Infestation Data" button. Data will be loaded into *tbl_Infestation*.

9. Import BFP data: On the main menu, click the "Load BFP and EDSW Data" button. Select the worksheet corresponding to BFPs as the input table, select park, and click the "Load BFP Records" button. Data will be loaded into *tbl_BFP*.

10. Import EDSW data: On the *Load BFP/EDSW Records* form, select the worksheet corresponding to EDSW points, select park, and click the "Load EDSW Records" button. Data will be loaded into *tbl_EDSW*.

11. Import route areas, lengths, and types: On the main menu, click the "Load Route Length/Area/Type" button. Select the worksheet corresponding to Area data as the input table, select park and year, and click the "Load Route Areas" button. Select the worksheet corresponding to Length data as the input table, select park and year, and click the "Load Length Records" button. Then click the "Load Route Types" button. Data will be loaded into tlu_Route_Statistics.

Before any data entry can begin, the monitoring routes and associated events/transects must be present in the database. Thus, steps 1–5 above must be completed prior to data entry.

Data entry

Only a small portion of data in the IEP database will be populated via data entry. Before field work begins, the priority IEP species lists are entered in the database. A tool has been developed to help automate this process and to allow reporting of these lists. After field work is completed, data collected on paper field sheets are entered in the database. Table 7-1 lists these database fields. Field definitions are provided in Appendix A.

Table 7-1. Database fields entered manually (table names are given in parentheses).

Sampling event-related fields (tbl_Events):
Observer
Comments
Transect-related fields (Transect):
Start_Time
Observer
Comments
Quadrat-related fields (Quadrat):
IsSampled
NoExotics
Microhabitat-related fields (SurfaceCover):
PercentCover (for each of the 15 microhabitats defined in SOP #3)
Species-related fields (SpeciesCover):
PlantCode
IsDead
PercentCover

Data entry should occur as soon as possible after data collection is completed, before the next observation occurs, and by the person who collected the data or someone who is familiar with

the project and data. The primary goal of data entry is *to record data in digital form with 100% accuracy.*

Detailed data entry instructions are provided in the user's guide in Appendix B. The user's guide is also available as a standalone document in the same folder location as the working copy of the IEP database:

X:\Active_Monitoring_Projects\Invasives\Data\Database\Current

The project manager ensures that persons performing data entry are familiar with the user's guide and understand how to enter data and follow the protocols. Data-entry technicians are responsible for becoming familiar with the field-data forms, database software, database structure, and any standard codes for data entry. The data manager, in conjunction with the project manager, will ensure that the user's guide is kept current as new features are implemented in the database and/or as data entry procedures change.

QA/QC measures for data entry have been built into the database to automatically validate data where possible. Data entry forms maximize the use of auto-filled fields, range limits, pick lists, and spelling checks. Error messages will alert the operator to correct mistakes. Any errors or omissions that become apparent during data entry should be resolved as soon as possible. In such cases, the data entry technician should contact the person who collected the data for clarification. The appropriate modifications should then be made to the field sheets or documented in a log according to the instructions provided in the Data Verification and Validation section of this document.

Data Verification and Validation

To ensure that IEP monitoring data are of the highest possible quality, verification and validation of IEP monitoring data will be performed according to the procedures described in the NCPN Quality Assurance and Quality Control Guidance Document (NCPN 2008). *Data verification* checks that data entered into a secondary (i.e., electronic) format match the source data, while *data validation* checks that the data make sense.

Data verification

Data verification immediately follows data entry and involves checking the accuracy and completeness of the computerized records against the hard copy field records and identifying and correcting any errors. The following verification methods will be used to verify IEP data:

1. **Visual review at data entry**. The person doing data entry verifies each and every record after input and immediately corrects any errors.

2. **Visual review after data entry**. All records are compared to the original data source. Each data field on the corresponding electronic data entry form is compared with the

original values from the hard copy, preferably by a second person who did not perform the data entry. Any errors that are discovered are corrected in the database as soon after data entry as possible.

3. **Summary queries and tallies**. Queries are run that detect broad errors, such as duplicate or omitted records. Examples of such queries for IEP data are given below. A more complete set of queries is provided in Appendix C (QA/QC Procedures).

    a. Listing and count of the monitoring transects visited by park/route/year.

    b. Listing and count of the infestations observed by park/route/year.

    c. Listing and count of the monitoring transects with species occurrences by park/route/year.

4. **Visual review of spatial data**. Using GIS, IEP monitoring data are visually inspected for accuracy. This review will take place at the end of the field season.

Detailed verification procedures are provided in Appendix C (QA/QC Procedures).

Data validation

While many errors are prevented by including validation routines that function during data entry, additional review of the data by the project manager is needed to detect generic and specific errors that fall outside the scope of automated validation.

Invalid data commonly consist of slightly misspelled names, the wrong date, or out-of-range errors in parameters with well-defined limits (e.g., elevation). Other errors consist of unreasonable metrics or associations. For example, a questionable species observation might indicate a species identification error. These types of logic errors (or potential errors) can be challenging to resolve, and in some cases it may not be possible to resolve them during the current year. Such questionable data will be flagged for future resolution.

Validation queries will be of two types. One type will present tabular data in ways that records can be reviewed for content and context. The other type will perform specific calculations or routines to detect logic or range errors. Corrections to errors detected during validation require notations in the *original paper field records* about how and why the data were changed. Modifications to the field records should be clear and concise while preserving the original data entries or notes. Validation efforts should also include a check for the completeness of a data set because field sheets or other sources of data could easily be overlooked.

Detailed validation procedures are provided in Appendix C (QA/QC Procedures).

Data quality review and communication

The project manager and any personnel involved in data collection or entry will meet several times during the field season to discuss data quality problems and issues. Procedures may need revision if verification and validation processes reveal an unacceptable level of data quality. Quality checks may also reveal the need to modify field or computer forms if data transcription or entry errors are frequent.

Once validation has been completed, metadata will be created for the IEP dataset. An important part of this metadata is data quality documentation, which consists of the verification and validation results (see Appendix C for QA/QC documentation procedures). This data quality documentation, along with the data quality assessment form, will be used to notify end users and other project personnel of project data quality. For example, any questionable data that have been flagged will be identified. The data quality assessment form will be completed by the project manager to indicate that the data have undergone all QA/QC procedures and are documented and ready for archiving, posting and distribution. The data quality assessment form can be found in the NCPN Project Data Life Cycle Guidance Document (NCPN 2007a). The data quality documentation and assessment form will be stored in the IEP project archive folder.

Version Control

Version control is the process of managing copies of changing files over the course of a project. Change includes any alteration to the structure or content of the files, which should not be made without the ability to fully recover a dataset as it existed before changes were made. NCPN uses several techniques to help ensure proper version control: data archiving (refer to the Data Archiving Section), directory structure conventions, backup procedures (refer to the user's guide in Appendix B), and database versioning.

Directory structure conventions

NCPN has adopted directory structure conventions for I&M project folders (NCPN 2007b). Based on these conventions, each project has an active folder for storing all current or working project files and an archive folder for storing archived project files. In general, the active project folder stores only the most recent project files (e.g., data and reports from current year, current protocol version). All active project folders are stored on the NCPN shared drive (X:). The active IEP project folder is in the following location:

X:\Active_Monitoring_Projects\Invasives

The structure of the active project folder is as follows (all folders are not shown):

- **Data**:
    - **Database**: Contains the working and master databases.

  - **Field_Forms**: Contains scanned field forms for current year.
  - **GPS_Downloads**: Contains corrected GPS data for current year.
- **Field_Crews**: Contains files used by field crews, such as plant lists and trip reports.
- **NCPN_Working_Files**: Contains miscellaneous files used internally, such as database requirements documentation.
- **Project_Life_Cycle**: Contains files related to project data life cycle tracking for current year, e.g., data quality assessment form, data quality documentation .
- **Protocol**:
  - **PDF**: Contains PDF of current version of protocol.
  - **Native_Format**: Contains source files for current version of protocol.
- **Protocol_Review**: Contains current documents associated with protocol reviews.
- **Reports**:
  - **PDF**: Contains PDF version of current annual project reports and any other reports produced during current year.
  - **Native_Format**: Contains source files used to create current year reports.

For additional details on NCPN directory structure conventions, refer to the NCPN Directory Structure Guidance Document (NCPN 2007b).

Database versioning

Database versioning refers to the process of tracking modifications to the database structure or application code, which can occur independently of modifications to the data. NCPN uses a version numbering scheme to track database modifications, in which modifications are grouped into software releases. Major releases are those involving significant changes to the database and are designated with the next whole number (e.g., version 2.0, 3.0, 4.0). For releases with only minor database changes (e.g., bug fixes), version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02). Database version information is maintained within the database, and can be viewed by choosing the **About** tab on the IEP main menu page, and then choosing **View release history**. Whenever a database version change occurs, copies of the database files are placed in the appropriate archive location (refer to Data Archiving Section).

Data Archiving

Archiving is a critical step in ensuring the long-term preservation of data. IEP data will be archived on an annual basis, after the current year's data have been quality checked and the annual report completed. Archiving of certain data may occur more frequently; for example, if a protocol version change occurs. Archiving will be done for both digital and hard copy data.

Digital data archiving

All digital IEP data will be archived on the NCPN read-only shared drive (R:) in the IEP archive folder (R:\Monitoring_Archive\Invasives). Table 7-2 lists the IEP monitoring digital data files that require archiving, along with their respective archive folder locations. The digital files listed in Table 7-2 will also be burned onto an archival-standard CD or DVD and sent to the Western Archeological and Conservation Center (WACC) according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN 2010).

Table 7-2. IEP digital data archiving summary.

Data Product(s)/File(s)	**Archive Location**[1]	**Comments**
Database	Data\<*year*[2]>\Database\	Contains archived database files for a given year
Field forms	Data\<*year*>\Field_Forms\	Contains digital field forms (PDF) for a given year
GPS data	Data\<*year*>\GIS_Data\ GPS_Data\	Contains both uncorrected and corrected GPS data files for a given year
Field crew files	Field_Crews\<*year*>\	Contains archived field crew files (e.g., trip reports) for a given year
Project data life cycle files	Project_Life_Cycle\<*year*>\	Contains archived files related to project data life cycle tracking for a given year
Protocol	Protocol\<*version*[3]>\	Contains archived protocol files (PDF and source files) for a given version
Protocol review	Protocol_Review\<*year*>\	Contains archived protocol review documents for a given year
Reports	Reports\<*year*>\	Contains archived report files (PDF and source files) for a given year

Hard copy data archiving

All hard copy IEP data will be archived at WACC according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN 2010). Table 7-3 lists the IEP monitoring hard copy data files that require archiving, along with a summary of archiving procedures.

[1] Archive location is relative to R:\Monitoring_Archive\Invasives unless stated otherwise.

[2] <*year*> indicates year in yyyy format.

[3] <*version*> indicates protocol version key number, e.g., Version_Key_1

Table 7-3. IEP hard copy data archiving summary.

Data Product(s)/File(s)	Comments
Field forms	Original field forms stored in NCPN archives at WACC. Digital copies retained in NCPN office.
Reports	Archival copies stored in NCPN archives at WACC. Hard copies retained in NCPN office.
Protocol	Archival copies stored in NCPN archives at WACC. Hard copies retained in NCPN office.
Protocol review	Archival copies stored in NCPN archives at WACC. Digital copies retained in NCPN office.
Data/metadata printouts	Archival copies of project-level metadata stored in NCPN archives at WACC. Hard copies retained in NCPN office. Above applies to any other data/metadata printouts deemed critical to long-term IEP monitoring.
Project data life cycle files	Archival copies stored in NCPN archives at WACC. Digital copies retained in NCPN office.

Metadata

Metadata, which is defined as structured information about the content, quality, condition, and other characteristics of data, is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. Metadata can take many different forms, including formal FGDC-compliant metadata, Data Store References, and protocol version information.

To comply with NPS metadata requirements, metadata for IEP datasets will be created following NCPN metadata procedures (NCPN 2007c):

- A metadata record will be created for the IEP database (since it is considered the *primary dataset* for the IEP monitoring project), and uploaded to the Data Store. The Data Store metadata record, also referred to as the project-level metadata, will be updated annually.
- All other IEP datasets and data products (see **Dataset/Data Product** column in Table 7-4) will be documented as cross-reference citations in the project level metadata record.

Another type of metadata specific to NCPN is the Project Data Life Cycle (PDLC) checklist, which helps to ensure that all data management activities (e.g., data verification/validation, metadata, archiving) are completed each year for monitoring projects. In accordance with this requirement, a PDLC checklist will be completed each year for IEP monitoring data. For further details related to the PDLC checklist, refer to the NCPN Project Data Life Cycle Guidance Document (NCPN 2007a).

Table 7-4 summarizes the metadata tasks required for IEP monitoring datasets and data products, and Table 7-5 describes the tasks and provides references where more detailed procedures are described.

Table 7-4. Summary of metadata tasks for IEP monitoring data.

Dataset/ Data product	Data Store dataset	X-Ref citation	PDLC checklist	Data Store ref	MVT	DB doc
Database	X		X			X
GIS Data		X	X			
Report(s)		X	X	X		
Protocol		X	X	X	X	
Field Forms		X	X			

Table 7-5. Metadata task descriptions.

Metadata Task	Metadata Task Description	Reference(s)
Data Store Dataset	A Data Store Reference (Tabular Dataset type) is created and then updated annually.	Metadata Guidance Document (NCPN 2007c), https://irma.nps.gov/Content/DataStore/Help/
X-Ref Citation	A cross reference citation is added to the project level metadata record.	Metadata Guidance Document (NCPN 2007c)
PDLC Checklist	The PDLC checklist is completed, which includes adding product records to the NCPN Project Tracking Database.	Project Data Life Cycle Guidance Document (NCPN 2007a)
Data Store Ref	A Data Store Reference (usually Published Report type) is created.	https://irma.nps.gov/Content/DataStore/Help/
MVT	The Master Version Table is updated as needed.	Protocol Versioning Guidance Document (NCPN 2009)
DB Doc	Database table and field documentation is updated as needed.	Appendix A

The complete protocol for this project (protocol narrative and SOP #s 1–10) is an integral component of the project metadata. All narrative and SOP version changes are noted in a Master Version Table (MVT), which is maintained in SOP #10. Any time the narrative or an SOP version change occurs, the MVT is updated to reflect the date of the change and the versions of the narrative and SOPs in effect. Refer to the NCPN Protocol Versioning Guidance Document (NCPN 2009) for detailed protocol versioning procedures.

References

Beer, M., E. Nance, A. Wight, M. Powell, and R. DenBleyker. 2005. Northern Colorado Plateau Network data management plan. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah. 86 pp plus appendices.

Frakes B., S. Kingston, and M. Beer. 2015. Inventory and Monitoring Division database standards: September 11, 2015. Natural Resource Report NPS/NRSS/NRR—2015/1035. National Park Service, Fort Collins, Colorado.

Northern Colorado Plateau Network (NCPN). 2007a. Project data life cycle guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

——. 2007b. Directory structure guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

——. 2007c. Metadata guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

——. 2008. Quality assurance and quality control guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

——. 2009. Protocol versioning guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

——. 2010. Archiving guidance document, version 2.00. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

Appendix A. Documentation of Database Tables

The table and field definitions in this appendix correspond to version 2.00 of the invasive exotic plant (IEP) monitoring database.

Data Tables

Table Name: Quadrat
Description: Quadrat level sampling visit measurements

Field Name	Field Description	Field Type	Field Width
ID	Autogenerated unique identifier (PK)	dbLong	4
Transect_ID	Transect identifier (FK, Transect)	dbText	50
Quadrat	Quadrat number (1, 2, or 3)	dbInteger	2
IsSampled	Whether the quadrat was sampled during this event (0-not sampled, 1-sampled)	dbInteger	2
NoExotics	Whether no exotic species were present on the quadrat (0-exotics were present on the quadrat, 1-no exotics were present on the quadrat)	dbInteger	2

Table Name: SpeciesCover
Description: Table containing species percent cover information

Field Name	Field Description	Field Type	Field Width
ID	Autogenerated identifier (PK)	dbLong	4
Quadrat_ID	Quadrat identifier (FK, Quadrat)	dbLong	4
PlantCode	Master PLANT code (FK, tlu_NCPN_Plants)	dbText	50
IsDead	Species alive or dead flag (0-alive, 1-dead).	dbInteger	2
PercentCover	Percent cover value for the species	dbDouble	8

Table Name: SurfaceCover
Description: Quadrat percent cover for surface materials

Field Name	Field Description	Field Type	Field Width
ID	Autogenerated identifier (PK)	dbLong	4
Quadrat_ID	Quadrat identifier (FK, Quadrat)	dbLong	4
Surface_ID	Surface (microhabitat) identifier (FK, Surface)	dbLong	4
PercentCover	Percent cover value for the surface/microhabitat	dbSingle	4

Table Name: tbl_BFP
Description: Table of between feature position (BFP) points

Field Name	Field Description	Field Type	Field Width
BFP_ID	Unique record identifier - primary key	dbText	50
Unit_Code	Park code	dbText	4
Route	Route	dbText	255
GPS_File_Name	GPS file name	dbText	50
Rcvr_Type	GPS unit type	dbText	50
Elevation	Elevation in meters	dbInteger	2
Easting	UTM east of transect	dbDouble	8
Northing	UTM north of transect	dbDouble	8
UTM_Zone	UTM zone (UTM_Zone)	dbInteger	2
Datum	Datum of mapping ellipsoid (Datum)	dbText	5
Max_PDOP	Horizontal accuracy	dbDouble	8
Corr_Type	Correction type	dbText	25
GPS_Date	Recording date	dbDate	8
GPS_Time	Recording time	dbDate	8
Update_Status	Update status	dbText	25
Feat_Name	Feature name	dbText	50
Unfilt_Pos	Unfiltered position	dbInteger	2
Vert_Prec	Vertical precision	dbDouble	8
Horz_Prec	Horizontal precision	dbDouble	8
Std_Dev	Standard deviation	dbDouble	8

Table Name: tbl_EDSW
Description: Table of effective detection swath width (EDSW) measurements

Field Name	Field Description	Field Type	Field Width
Unit_Code	Park code	dbText	4
Route	Route name	dbText	255
Northing	UTM N	dbDouble	8
Easting	UTM E	dbDouble	8
GPS_Date	Date	dbDate	8
GPS_Time	Time	dbDate	8
EDSW_m	Effective Detection Swath Width in meters	dbDouble	8
Max_PDOP	Horizontal accuracy	dbDouble	8
Corr_Type	Correction type	dbText	255
Rcvr_Type	GPS unit type	dbText	255
Update_Sta	Update status	dbText	255
Feat_Name	Feature name	dbText	255
Datafile	GPS data file name	dbText	255
Unfilt_Pos	Unfiltered position	dbDouble	8

Field Name	Field Description	Field Type	Field Width
GPS_Height	Elevation in meters	dbDouble	8
Vert_Prec	Vertical precision	dbDouble	8
Horz_Prec	Horizontal precision	dbDouble	8
Std_Dev	Standard deviation	dbDouble	8

Table Name: tbl_Events
Description: Table of monitoring transect events

Field Name	Field Description	Field Type	Field Width
Event_ID	Event identifier (Event_ID)	dbText	50
Location_ID	Link to tbl_Locations (Loc_ID)	dbText	50
Protocol_Name	The name or code of the protocol governing the event (Protcl_Nam)	dbText	100
version_key_number	Master protocol version key	dbLong	4
Start_Date	Starting date for the event (Start_Date)	dbDate	8
Start_Time	Starting time of the sampling event; derived from the GPS data upon import by taking the earliest GPS time for the event	dbDate	8
Comments	Plot/transect visit comments	dbMemo	0
Observer	Plot/transect visit observer	dbText	50

Table Name: tbl_Infestation
Description: Table of infestations observed

Field Name	Field Description	Field Type	Field Width
Infestation_ID	Infestation identifier	dbText	50
Infest_Event_ID	Foreign key to event ID	dbText	50
Master_Code	Master plant species code	dbText	10
Size_Value	Numeric size code	dbSingle	4
Size_Text	Size text	dbText	25
Cover_Value	Numeric code for cover percentage	dbSingle	4
Cover_Text	Text cover description	dbText	25
Pulled	Was weed pulled	dbBoolean	1
Growth_Stage	Growth stage of trees	dbText	15
Prior_Treatment	Was area previously treated	dbBoolean	1
Disturbance	Disturbance at site	dbText	50
Surveyor	Person surveying the route	dbText	50
PSR	Patch separation resolution	dbInteger	2
GPS_File_Name	GPS file name	dbText	50
Rcvr_Type	GPS unit type	dbText	50

Field Name	Field Description	Field Type	Field Width
Elevation	Elevation in meters	dbInteger	2
E_Coord	UTM east of infestation	dbDouble	8
N_Coord	UTM north of infestation	dbDouble	8
UTM_Zone	UTM zone (UTM_Zone)	dbInteger	2
Datum	Datum of mapping ellipsoid (Datum)	dbText	5
Max_PDOP	Horizontal accuracy	dbDouble	8
Corr_Type	Correction type	dbText	25
GPS_Time	Recording time	dbDate	8
Update_Status	Update status	dbText	25
Feat_Name	Feature name	dbText	50
Unfilt_Pos	Unfiltered position	dbInteger	2
Vert_Prec	Vertical precision	dbDouble	8
Horz_Prec	Horizontal precision	dbDouble	8
Std_Dev	Standard deviation	dbDouble	8
Comments	Notes	dbMemo	0

Table Name: tbl_Infestation_Events
Description: Table of infestation events

Field Name	Field Description	Field Type	Field Width
Infest_Event_ID	Event identifier (Event_ID)	dbText	50
Location_ID	Link to tbl_Locations (Loc_ID)	dbText	50
Protocol_Name	The name or code of the protocol governing the event (Protcl_Nam)	dbText	100
version_key_number	Master protocol version key	dbLong	4
Start_Date	Starting date for the event (Start_Date)	dbDate	8
Start_Time	Starting time	dbDate	8
Comments	Infestation comments	dbMemo	0
Observer	Infestation observer	dbText	50

Table Name: tbl_Locations
Description: Location/route definition table

Field Name	Field Description	Field Type	Field Width
Location_ID	Location identifier (Loc_ID)	dbText	50
GIS_Location_ID	Link to GIS feature, equivalent to NPS_Location_ID (GIS_Loc_ID)	dbText	50
Meta_MID	Link to NR-GIS Metadata Database (Meta_MID)	dbText	50
Unit_Code	Park code	dbText	4
Plot_ID	Route name	dbText	255

Field Name	Field Description	Field Type	Field Width
Area	Area (applicable to GOSP only)	dbText	50
Observer	Person establishing route	dbText	50
Plot_Directions	Directions to route	dbMemo	0
Updated_Date	Date of entry or last change (Upd_Date)	dbDate	8

Table Name: tbl_Target_Areas
Description: Target area information (Invasives Target List Tool)

Field Name	Field Description	Field Type	Field Width
Target_Area_ID	PK for target areas	dbLong	4
Target_Area	Description of target area (Cub Creek, etc.)	dbText	255

Table Name: tbl_Target_List
Description: Target List information - park, year, create & last modified dates (Invasives Target List Tool)

Field Name	Field Description	Field Type	Field Width
Tgt_List_ID	Autogenerated target list ID	dbLong	4
Park_Code	Standard park code (CANY, FOBU, etc.)	dbText	4
Target_Year	Year (4-digit)	dbInteger	2
Created	List created timestamp	dbDate	8
Last_Modified	Last modified timestamp	dbDate	8

Table Name: tbl_Target_Species
Description: Species included in target lists (Invasives Target List Tool)

Field Name	Field Description	Field Type	Field Width
Tgt_Species_ID	Autogenerated target species ID	dbLong	4
Tgt_List_ID_FK	FK to target list ID (tbl_Target_List)	dbLong	4
Master_Plant_Code_FK	FK to plant master code (tlu_NCPN_Plants.Master_Species)	dbText	20
Species_Name	Target Species name (ITIS species name from tlu_NCPN_Plants.Master_Species)	dbText	255
LU_Code	Standard Species code lookup (tlu_NCPN_Plants.LU_Code, usually 6-letters)	dbText	20
Priority	Park priority (1 - , 2- , 3- , 4- , 5-)	dbInteger	2
Transect_Only	Should species be checked on transects only? (0-no, 1-yes)	dbByte	1
Target_Area_ID	FK to target area for invasives monitoring (tbl_Target_Areas.Tgt_Area_ID) (0 = no targeted area)	dbInteger	2
Comments	Record comments	dbText	255

Table Name: Transect
Description: Table of transect information

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number	dbInteger	2
Start_Time	Starting time for sampling transect as recorded by the surveyor on the data sheet	dbDate	8
GPS_File_Name	GPS file name	dbText	50
Rcvr_Type	GPS unit type	dbText	50
Elevation	Elevation in meters	dbInteger	2
E_Coord	UTM East of Transect	dbDouble	8
N_Coord	UTM North of Transect	dbDouble	8
UTM_Zone	UTM Zone (UTM_Zone)	dbInteger	2
Datum	Datum of mapping ellipsoid (Datum)	dbText	5
Max_PDOP	Horizontal accuracy	dbDouble	8
Corr_Type	Correction type	dbText	25
GPS_Time	Starting time for sampling transect as recorded by the GPS unit	dbDate	8
Update_Status	Update status	dbText	25
Feat_Name	Feature name	dbText	50
Unfilt_Pos	Unfiltered position	dbInteger	2
Vert_Prec	Vertical precision	dbDouble	8
Horz_Prec	Horizontal precision	dbDouble	8
Std_Dev	Standard deviation	dbDouble	8
Comments	Notes	dbMemo	0
Stop_Time	Ending time for sampling transect; not currently used but may be in legacy data	dbDate	8
Observer	Name of person surveying the monitoring route	dbText	50
Recorder	Name of person recording observations	dbText	50

Lookup Tables

Table Name: QuadratPosition
Description: Lookup table of position of species cover sampling per quadrat starting at a sampling year (current sampling positions are the latest records for a quadrat)

Field Name	Field Description	Field Type	Field Width
SamplingYear	Year the position usage began (usage is replaced vs. concurrent for the same quadrat)	dbInteger	2

Field Name	Field Description	Field Type	Field Width
Quadrat	Quadrat number (1,2,3)	dbInteger	2
Position_m	Position of quadrat placement along transect in meters; 0, 4.5, and 9.5 (centered at 0.5, 5, and 10); 3, 8, 13 used in 2009, n/a for 2008 (macroplots used instead of transects)	dbSingle	4

Table Name: Surface
Description: Lookup table of surface materials assessed for percent cover

Field Name	Field Description	Field Type	Field Width
ID	Autogenerated identifier (PK)	dbLong	4
Surface	Brief description of surfaces / substrates (microhabitats) which are assessed for percent cover	dbText	25
Description	Long description for surface / substrates (microhabitats)	dbText	255
ColName	Temp name for column	dbText	25

Table Name: tlu_Contacts
Description: Contact data for project-related personnel

Field Name	Field Description	Field Type	Field Width
Contact_ID	Contact identifier (Contact_ID)	dbText	50
Last_Name	Last name (Cnt_Last)	dbText	50
First_Name	First name (Cnt_First)	dbText	50
Middle_Init	Middle initial (Cnt_MI)	dbText	4
Organization	Organization or employer (cntorg)	dbText	50
Position_Title	Title or position description (cntpos)	dbText	50
Address_Type	Address (mailing, physical, both) type (addrtype)	dbText	50
Address	Street address (cntaddr)	dbText	50
Address2	Address line 2, suite, apartment number (Cnt_Addr2)	dbText	50
City	City or town (city)	dbText	50
State_Code	State or province (state)	dbText	8
Zip_Code	Zip code (postal)	dbText	50
Country	Country (country)	dbText	50
Email_Address	E-mail address (cntemail)	dbText	50
Work_Phone	Phone number (cntvoice)	dbText	50
Work_Extension	Phone extension (Work_Ext)	dbText	50
Contact_Notes	Contact notes (Cnt_Notes)	dbMemo	0

Table Name: tlu_Cover_Code
Description: Quadrat cover class lookup table

Field Name	Field Description	Field Type	Field Width
Cover_Code	Cover code to be stored in database	dbSingle	4

Table Name: tlu_Cover_Value
Description: Table to cross reference cover percent descriptions to numeric values

Field Name	Field Description	Field Type	Field Width
Cover_Description	Cover percentage description	dbText	25
Cover_Value	Cover percentage number value	dbSingle	4

Table Name: tlu_Disturbance
Description: Lookup table of disturbance types

Field Name	Field Description	Field Type	Field Width
Disturbance	Disturbance type	dbText	50

Table Name: tlu_NCPN_Plants
Description: Table containing plant species information for Northern Colorado Plateau Network parks

Field Name	Field Description	Field Type	Field Width
Master_Family	Master family	dbText	50
Master_PLANT_Code	Master species code; primary key (USDA PLANTS Database)	dbText	20
Master_Species	Master species name (Integrated Taxonomic Information System)	dbText	50
UT_Family	Utah family	dbText	50
CO_Family	Colorado family	dbText	50
WY_Family	Wyoming family	dbText	50
Utah_PLANT_Code	Utah species PLANTS code	dbText	20
Utah_Species	Utah species name (Welsh et al 2003)	dbText	50
Co_PLANT_Code	Colorado species PLANTS code	dbText	20
Co_Species	Colorado species name (Weber & Wittmann 2001)	dbText	50
Wy_PLANT_code	Wyoming species PLANTS code	dbText	20
Wy_Species	Wyoming species name (Dorn 2001)	dbText	50
Add_Synonyms	Additional synonyms	dbMemo	0
Taxonomic_Notes	Taxonomic notes	dbMemo	0
Master_Common_Name	Master common name	dbText	50
ARCH	Park presence descriptor for ARCH	dbText	15

Field Name	Field Description	Field Type	Field Width
BLCA	Park presence descriptor for BLCA	dbText	15
BRCA	Park presence descriptor for BRCA	dbText	15
CANY	Park presence descriptor for CANY	dbText	15
CARE	Park presence descriptor for CARE	dbText	15
CEBR	Park presence descriptor for CEBR	dbText	15
COLM	Park presence descriptor for COLM	dbText	15
CURE	Park presence descriptor for CURE	dbText	15
DINO (UT)	Park presence descriptor for DINO - Utah	dbText	15
DINO (CO)	Park presence descriptor for DINO - Colorado	dbText	15
FOBU	Park presence descriptor for FOBU	dbText	15
GOSP	Park presence descriptor for GOSP	dbText	15
HOVE (UT)	Park presence descriptor for HOVE - Utah	dbText	15
HOVE (CO)	Park presence descriptor for HOVE - Colorado	dbText	15
NABR	Park presence descriptor for NABR	dbText	15
PISP	Park presence descriptor for PISP	dbText	15
TICA	Park presence descriptor for TICA	dbText	15
ZION	Park presence descriptor for ZION	dbText	15
Lifeform	Lifeform derived from USDA PLANTS	dbText	255
Duration	Duration derived from USDA PLANTS	dbText	255
Nativity	Nativity derived from USDA PLANTS	dbText	255
Trinomial	True if species code represents a trinomial name	dbBoolean	1
Unique_Species	True if species code represents a genus and species designation	dbBoolean	1
LU_Code	Shorthand (a.k.a. 6-letter) lookup code	dbText	25
Wetland_Code	Code identifying wetland designation (see http://plants.usda.gov/wetinfo.html#categories)	dbText	20
Wetland_Code_Info_Source	Information source used to determine wetland classification	dbText	50
Photosynthetic_Pathway	Photosynthetic pathway designation (source: Osborne et al. 2014, doi: 10.1111/nph.12942)	dbText	5
ProtectedStatusID	Foreign key to protected status lookup table (Lkup_ProtectedStatus – not implemented for IEP database)	dbLong	4
ProtectedStatusNotes	Notes about the protected status designation	dbText	255

Table Name: tlu_Parks
Description: Look-up table of parks in the Northern Colorado Plateau Network

Field Name	Field Description	Field Type	Field Width
ParkCode	Four-letter abbreviation for park code	dbText	5
ParkName	Full name of park where data were collected	dbText	50

Field Name	Field Description	Field Type	Field Width
ParkState	State code	dbText	2

Table Name: tlu_Route_Statistics
Description: Table of monitoring route statistics used for reporting

Field Name	Field Description	Field Type	Field Width
Unit_Code	Park code	dbText	4
Route	Route name	dbText	255
Visit_Year	Year of data collection (yyyy)	dbInteger	2
Route_Length_k	Length of route in kilometers	dbDouble	8
Route_Area_h	Area of route in hectares	dbDouble	8
Route_Length_m	Length of route in miles	dbDouble	8
Route_Area_a	Area of route in acres	dbDouble	8
Route_Type	Type of route	dbText	50

Table Name: tlu_Size_Value
Description: Table to cross reference infestation size descriptions to numeric values

Field Name	Field Description	Field Type	Field Width
Size_Description	Infestation size description	dbText	25
Size_Value	Size number value	dbInteger	2

Appendix B. NCPN Invasive Exotic Plant Database User's Guide

1 Introduction

This document provides instructions for using version 2.00 of the NCPN Invasive Exotic Plant (IEP) Monitoring database. The database was written to store IEP monitoring data for NCPN network parks. It was written using the draft version of the NRDT version 3.1 database template. The current version of the database runs using Access 2007 or 2010 and consists of the following files:

- *Invasives.accdb*: This frontend file contains all data entry forms, queries, reports, and associated Visual Basic for Applications (VBA) application code.
- *Invasives_be.accdb*: This backend file contains the database tables.

All of the above files are located in the following folder on the NCPN I&M network drive (i.e., the X drive):

X:\Active_Monitoring_Projects\Invasives\Data\Database\Current

This folder will be referred to subsequently as the Current folder. It contains the *working database* (i.e., the database used to enter data for the current season). The working database does not contain data from previous years; such data are stored in the *master database*. The master database contains the full, accepted project dataset and is located on the read-only Archive drive. To allow convenient access to the master database, there is a read-only copy in the following location in the invasives project folder (location below). This folder will be referred to subsequently as the Master folder.

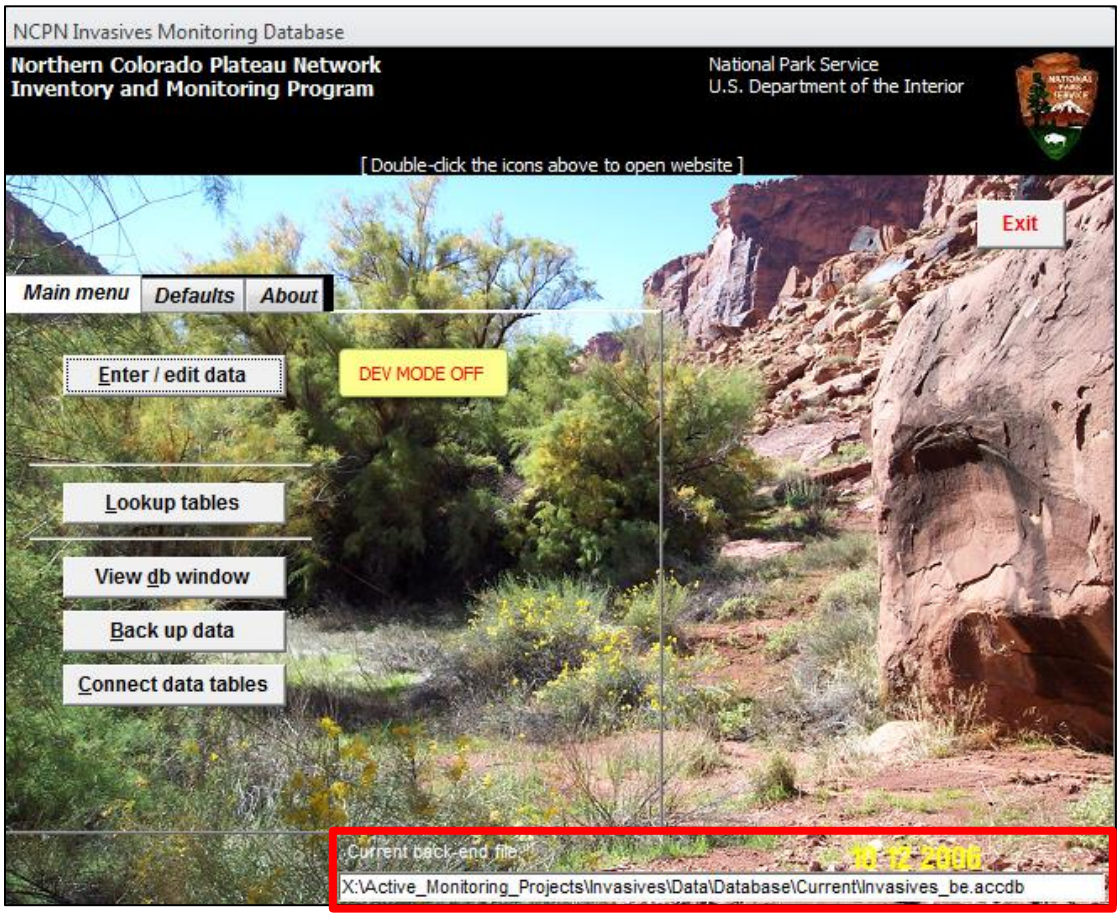
X:\ Active_Monitoring_Projects\Invasives\Data\Database\Master

2 Installation

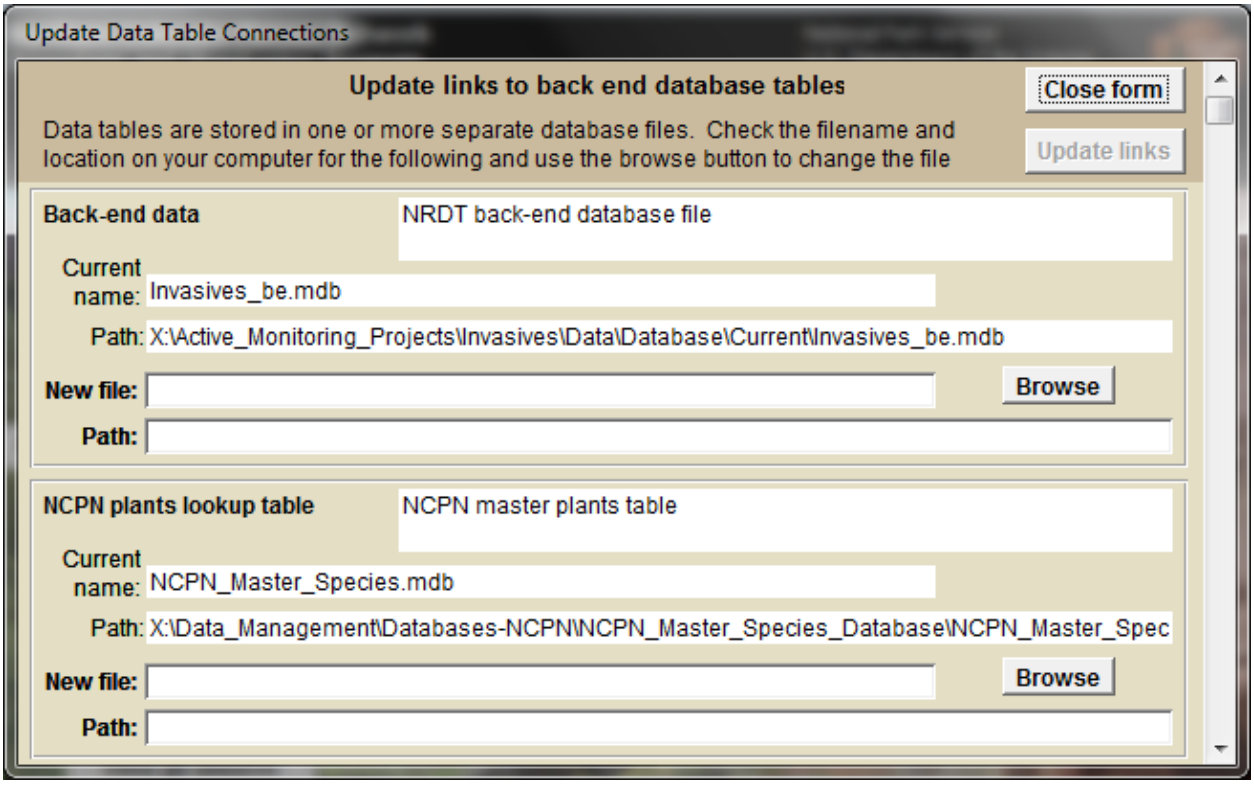
Data management staff will ensure that the frontend file (*Invasives.accdb*) is installed on NCPN computers. The backend database file, *Invasives_be.accdb*, is the database that contains the data and thus, should be kept on the X drive. Keeping the backend database file on the X drive allows multiple frontends to link to it so that multiple data entry sessions can be conducted concurrently, and also ensures that the database is backed up regularly.

3 Getting Started

To start the IEP database, use the Microsoft Access Application shortcut named Invasives, located on the desktop. **It is important that your frontend database be linked to the correct copy of the backend database**. The location of the current linked backend database can be viewed at the bottom of the main menu page (see the **Current back-end file** box below). ***Before starting a data-entry session, always check the location of the backend database to make sure you are entering data into the correct backend file.***



If the backend file is not correct, then you will need to change it. Click on “Connect data tables,” and a form opens that allows you to define the locations of the backend data tables.



There are two locations to set for the backend table locations:

1. The location of the IEP database backend (the first location above, labeled "Back-end data"): The location of the backend database file is below, so browse to that location and select the file *Invasives_be.accdb*.

   X:\Active_Monitoring_Projects\Invasives\Data\Database\Current

2. The location of the plants lookup table (the second location above, labeled "NCPN plants lookup table"): The location of the NCPN shared plants table is below, so browse to that location and select the file *NCPN_Master_Species.accdb*.

   X:\Data_Management\Databases-NCPN\NCPN_Master_Species_Database

After making these selections, click "Update links", and the database will link to all the tables in the new locations. You will then see the message box: "Update complete!" Click "OK" to close this box.

The Main Menu form contains a tab control with three tabs. The first tab contains navigation buttons for the primary database functions:

- The "Enter / edit data" button provides access to the data entry functions.

- The “Lookup tables” button allows editing of lookup tables associated with the pick lists in the database.
- The “View db window” button displays the Access database window.
- The “Back up data” button provides a convenient interface for making backup copies of the backend data files.
- The “Connect data tables” button will bring up the Update Data Connections form to allow you to change back-end databases.

The second tab displays the current database default settings. The Project Name, Current User, Park Code, Datum, and Zone are shown and can be changed by clicking the “Change” button. If this is your first time using the database, you may not be listed in the user pick list. Contact data management staff to have your information added to this list. There are also checkboxes on the tab to select optional automated functions which are available.

The third tab displays information about the database. You should see “Version 2.00” (or a higher number) displayed at the top of this tab. The “View release history” button allows you to view the version history of the database which details enhancements and upgrades. If you encounter a bug in the database, you can email data management staff the details.

4 Backing Up the Database

A backup can be created from within the database by clicking the “Back up data” button on the main menu. Backups are named as follows:

> *Invasives_be_yyyymmdd_hhmm.accdb*, where *yyyymmdd* represents the current date and *hhmm* the current time (e.g., *Invasives_be_20101130_1250.accdb*).

The “Back up data” button will name the backup file using the above-given naming convention.

- <u>Location</u>**: Backup** folder (in X:\ Active_Monitoring_Projects\Invasives\Data\Database). Data management staff, in consultation with the project manager, will periodically review the **Backup** folder and remove any unnecessary backup files. Note that if multiple users click the “Back up data” button simultaneously, an Access “write conflict” error may occur. Thus, if there are multiple users doing data entry at the same time, only one user should make a backup.
- <u>Frequency:</u> Once per day (unless there is no data entry on a given day).

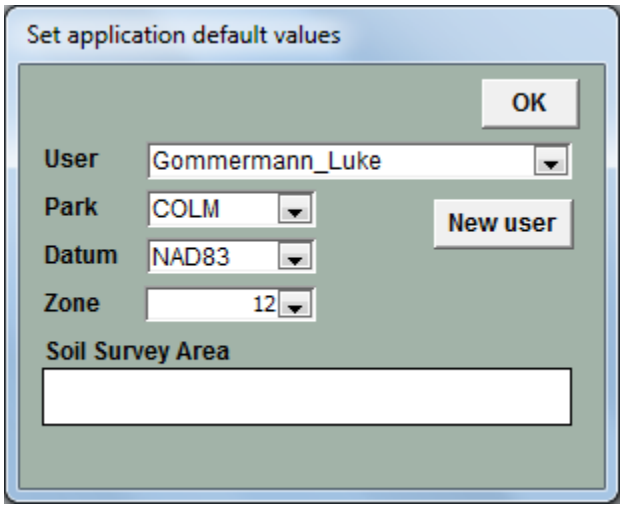
5 Data Entry

Before entering data, it may help to sort the data sheets by route, visit date, and then transect. Note that records for routes, visits, and transects must be loaded into the database prior to data entry. Thus,

if you do not find the route, visit, or transect you are looking for, contact data management staff for assistance.

5.1 Setting Application Default Values

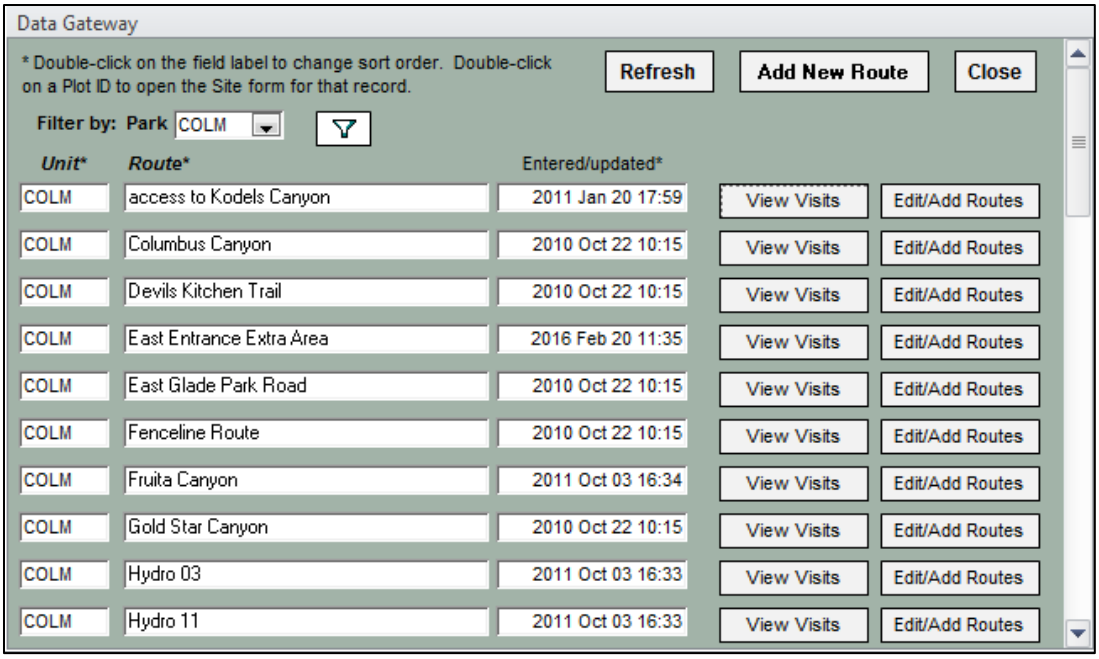
To begin data entry, click the “Enter / edit data” button on the Main Menu tab. You will see this pop-up form:



Select your name in the User pick list and verify that the application defaults are correct. Change any values as needed. If you are a new user and not listed in the User pick list, contact data management staff to have your information added to the database. Once all application defaults are correct, click the “OK” button and the Data Gateway form appears.

5.2 Data Gateway Form

The Data Gateway form displays routes by park:



Double-clicking on a column header (e.g., Route) will sort by that column. By default, the Data Gateway lists only the routes for your default park. To see routes for a different park, select another park in the "Filter by park" drop-down. To see routes for all parks, click the filter button next to the "Filter by park" drop-down. The filter button is a toggle, so clicking the filter button again and selecting a park in the drop-down will display routes for only that park.

There are two buttons associated with each route:

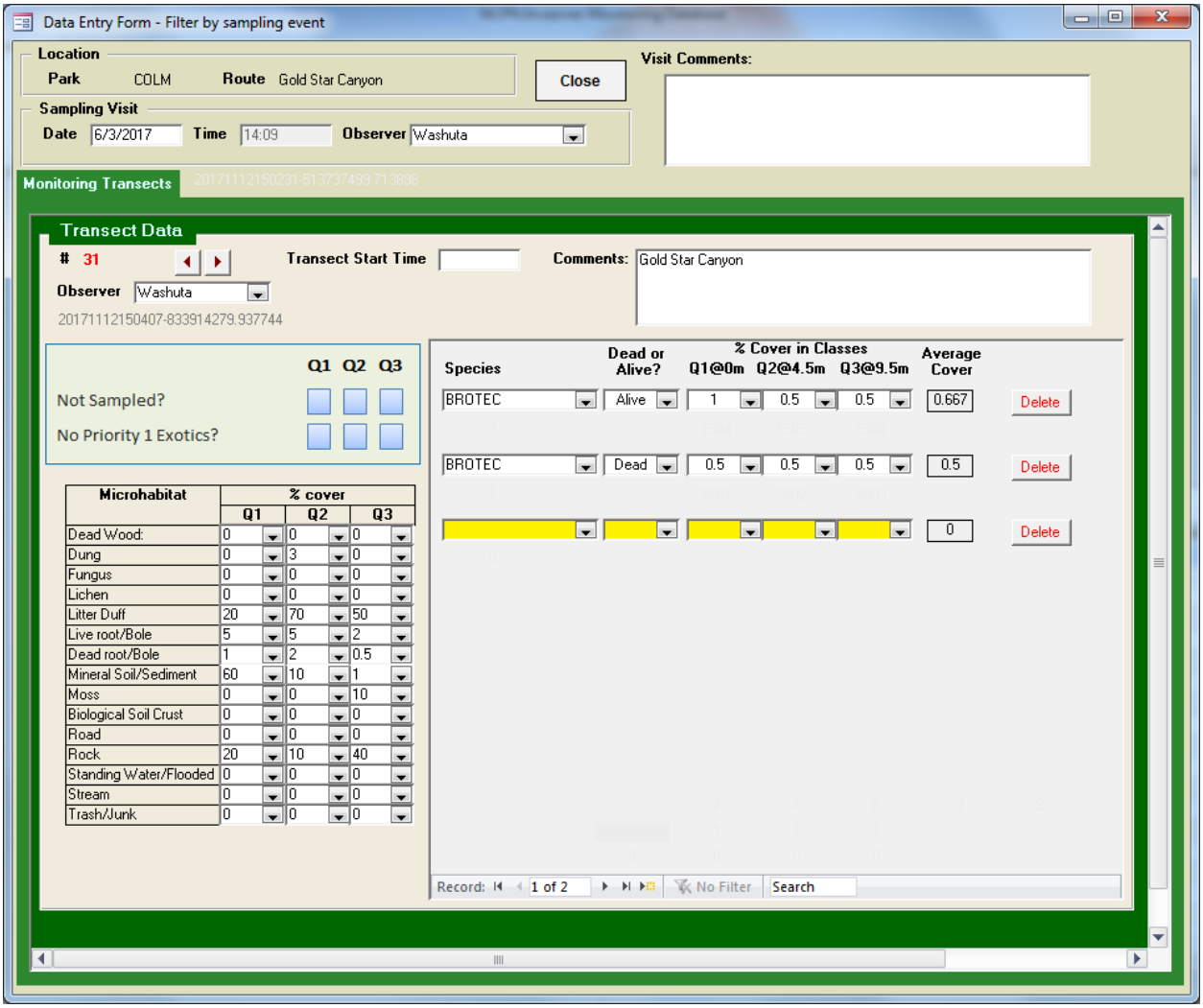
- Use "View Visits" to enter/edit/view transect data. The "Select a Visit" form will display the visits for the selected route (in descending order by visit date). Click the "Edit Visit" button next to the visit you would like to enter/edit/view. This will open the main data entry form (see Section 5.3). If you cannot find the visit you are looking for, contact data management staff for assistance.

- The "Edit/Add Routes" button can be used to add/edit route information. However, since route information is loaded into the database prior to data entry, this button will not normally be used and it is primarily intended for data management staff. Thus, contact data management staff for assistance with updates to route information.

If you do not see a record for your route on the Data Gateway form, contact data management staff for assistance.

5.3 Main Data Entry Form

The main data-entry form allows you to enter new and edit existing transect data.



The top of the form displays location information (Park and Route) and sampling visit information (Date, Time, Observer, and Visit Comments). Only the Observer and Visit Comments can be entered/edited in this section. If there are multiple observers, you can use the Observer field at the top to record one of them.

All fields on the Transect Data section of the form can be entered/edited.

- Observer should always be entered.
- Enter Transect Start Time and Comments if they are recorded on the data sheet.
- Use the Not Sampled quadrat checkboxes to indicate any quadrats that were not sampled. When this box is checked for a quadrat, the associated species and microhabitat percent cover fields are disabled.

- Use the No Priority 1 Exotics quadrat checkboxes to indicate any quadrats that had no priority exotics recorded. When this box is checked for a quadrat, the associated species percent cover fields are disabled.

- For microhabitat percent cover and species percent cover, enter 0.5 for "<1".

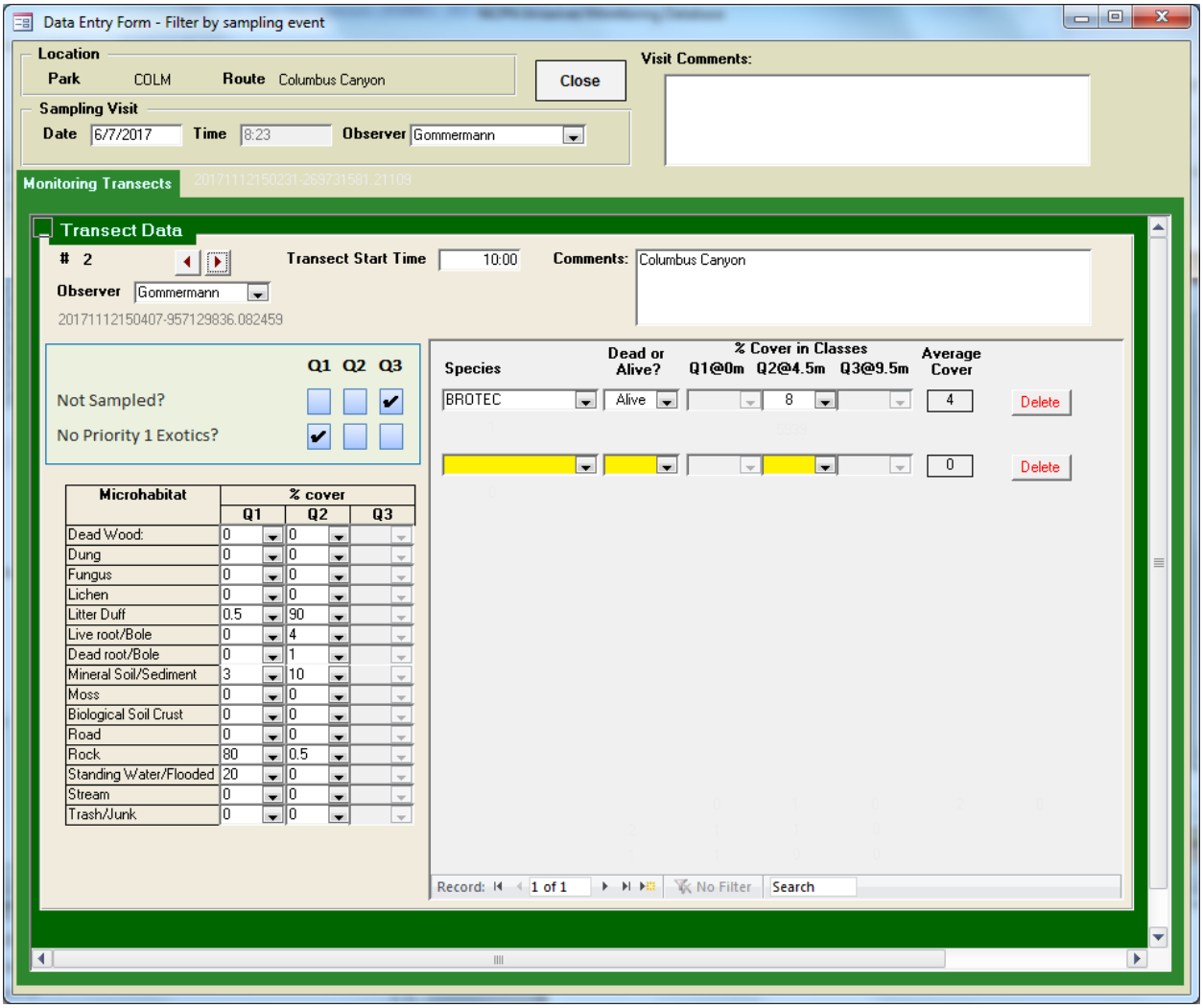
- All species in the species pick list are sorted by shorthand codes (aka 6-letter codes), which are formed by concatenating the first three characters of the genus and species names. By clicking on the dropdown arrow, you can view the entire genus and species name for the entry you've selected.

- Select the appropriate entry in the Dead or Alive dropdown box for each species. The same species can be recorded no more than twice for a quadrat, once alive and once dead.

When you finish entering data for a transect, be sure to fill in the "Entered By" box on the paper data sheet. Use the navigation buttons to move to a different transect. Transects may be navigated in sequence either forward or backward. If a transect number is colored in red, this indicates that it is either the first or last in the sequence. Navigating forward from the last transect will take you to the first transect. Similarly, navigating backward from the first transect will take you to the last transect.

To navigate to a transect on a different date or route, close the data entry form to return to the Data Gateway form.

The screen capture below shows an example of a transect with a quadrat that had no priority exotics (Q1) and a quadrat that was not sampled (Q3). Notice that the corresponding species and microhabitat percent cover fields are disabled.


Data Entry Form - Filter by sampling event
Location
Park COLM Route Columbus Canyon
Close
Visit Comments:
Sampling Visit
Date 6/7/2017 Time 8:23 Observer Gommermann
Monitoring Transects
Transect Data
2
Transect Start Time 10:00
Comments: Columbus Canyon
Observer Gommermann
20171112150407-957129836.082459
Q1 Q2 Q3
Not Sampled?
No Priority 1 Exotics?
Microhabitat
% cover
Q1 Q2 Q3
Dead Wood: 0 0
Dung 0 0
Fungus 0 0
Lichen 0 0
Litter Duff 0.5 90
Live root/Bole 0 4
Dead root/Bole 0 1
Mineral Soil/Sediment 3 10
Moss 0 0
Biological Soil Crust 0 0
Road 0 0
Rock 80 0.5
Standing Water/Flooded 20 0
Stream 0 0
Trash/Junk 0 0
Species
Dead or Alive?
% Cover in Classes
Q1@0m Q2@4.5m Q3@9.5m
Average Cover
BROTEC Alive 8 4 Delete
0 Delete
Record: 1 of 1 No Filter Search

Appendix C. Quality Assurance (QA)/Quality Control (QC) Procedures

This appendix describes the QA/QC procedures used to check invasive exotic plant (IEP) monitoring data for errors.

QA/QC Documentation and Folder/File Locations

QA/QC documentation should provide a record that the procedures described in this document were followed. The tables throughout the document provide columns to indicate that a particular condition was checked ("*Complete?*" column) and allow for any associated comments ("*Comments*" column). Comments can be stored in a separate, linked file. QA/QC documentation is stored in the locations below:

Current year: X:\Active_Monitoring_Projects\Invasives\Project_Life_Cycle\Data_Quality

Previous years: R:\Monitoring_Archive\Invasives\Project_Life_Cycle*YYYY*\Data_Quality

The queries referenced in this document can be found in the IEP QA/QC database:

X:\Active_Monitoring_Projects\Invasives\Project_Life_Cycle\Data_Quality\Invasives_QAQC.accdb

The QA/QC database should be linked to the IEP database backend file and the NCPN master plants table:

X:\Active_Monitoring_Projects\Invasives\Data\Database\Current\Invasives_be.accdb

X:\Data_Management\Databases-NCPN\NCPN_Master_Species_Database\NCPN_Master_Species.accdb

The remainder of this document is organized into the following sections, based on the different types of IEP data that are collected: Transect Data, Infestation Data, Location-specific Data (location-related attributes common to transect and infestation data), EDSW Data, BFP Data, and Species-related Data.

Transect Data

This section focuses on the transect data that are entered into the database manually from paper field sheets. These data are first verified during data entry by the individual entering the data. A second verification is done after data entry, by an individual who did not enter the data. After completing the second verification, the individual fills in the "Proofed by" box on the field sheet.

After all verification has been completed, the procedures in Table 7C-1 are performed. These steps are performed jointly by data management staff and the project manager (or designee). Note that the data-entry forms in the database contain logic to validate most of the data that is entered. Thus, the procedures in Table 7C-1 are designed to supplement the built-in database validation.

Table 7C-1. Transect data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Missing transect records	tbl_Events, Transect	QC_MoTr_Missing_Recs, QC_MoTr_Missing_Recs _GPS	Compare listing/counts of monitoring transects visited by park/route/year with GPS data files.		
Logical start dates	tbl_Events: Start_Date	QC_MoTr_Start_Dates	Check for dates outside monitoring period. Note: Database ensures dates are valid, but dates can still be entered incorrectly (e.g., wrong year).		
Valid microhabitat percent cover[4]	SurfaceCover: PercentCover	QC_MoTr_Valid_Microhab_Cov	Check for missing values. Ensure each microhabitat percent cover value is valid (0, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).		
Valid species percent cover[4]	SpeciesCover: PercentCover	QC_MoTr_Valid_Sp_Cov	Check for missing values. Ensure each species percent cover value is valid (0, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).		
Valid observer	Observer (tbl_Events, Transect)	QC_MoTr_Valid_Observer	Check for missing values. Ensure Observer is a valid name (see tlu_Contacts).		
Orphan observers	Observer (tbl_Events, Transect)	QC_MoTr_Orphan_Event_Obs, QC_MoTr_Orphan_Transect_Obs	Queries list observers that are not in table tlu_Contacts. Run after appending data to the master database.		
Misspellings in comments	Comments (tbl_Events, Transect)	QC_MoTr_Spellchk_Comments	Use spellcheck to find and correct spelling errors (select column while in query datasheet view and choose Spelling from Access ribbon).		

[4] This condition is validated by the database via the data entry forms. The check is included here because it is possible (though not likely) that an inadvertent edit could be made to the backend table that could violate this condition (the backend table is constrained to a number type, but not the specific numbers listed since these values may have changed over time). This check may be dropped later if it is subsumed by a summary or other similar query used for analysis/reporting purposes.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Transects without species occurrences	tbl_Events, Transect, Quadrat, SpeciesCover	QC_MoTr_Trans_without_Sp	Query provides a listing of monitoring transects with no species occurrences by park/route/year (mostly for informational purposes, since no species is a valid condition).		
Transects with duplicate species	tbl_Events, Transect, Quadrat, SpeciesCover	QC_MoTr_Duplicate_Species	Query lists all transects having quadrats with duplicate species. The same species can be recorded no more than twice for a quadrat, once alive and once dead.		
Quadrats not sampled having zero PercentCover records in SurfaceCover table	Quadrat, SurfaceCover	QC_MoTr_Quadrats_Not_Sampled	Query lists all quadrats having surface cover sums = 0. Confirm that quadrats were not sampled and then use query QC_MoTr_SurfaceCover_Delete_Skipped_Quadrats to delete[5].		
Quadrats with microhabitat cover sums <100 or ≥130	SurfaceCover: PercentCover	QC_MoTr_SurfaceCover_Sums_Extremes	Query lists all quadrats having microhabitat surface cover sums that are <100 or ≥130. Check data sheet for data entry errors. If unable to resolve, document in Transect table Comments.		
Records in SpeciesCover table having zero PercentCover	SpeciesCover	QC_MoTr_SpeciesCover_Delete_Zero_Cover	Query deletes any records in SpeciesCover table with PercentCover = 0[6].		

Infestation Data

All infestation data are collected via GPS units. GIS staff performs QA/QC on these data, and then generates a GPS data file (in spreadsheet format) for each park. Data management staff performs some basic QA/QC on the GPS data file (e.g., resolving duplicate route names) and then uploads the data to

[5] These zero percent cover records are inserted by the data entry interface initially. When a quadrat is not sampled, however, there is currently no automated method for removing the records with zero percent cover, so these queries are used instead.

[6] These zero percent cover records are inserted by the data entry interface initially. There is currently no automated method for removing them, so this query is used instead.

the IEP database. After these data are uploaded, the procedures in Table 7C-2 are performed. These steps are performed jointly by data management staff and the project manager (or designee).

This section focuses on QA/QC of the infestation data that are not location-specific. Note that the data dictionary in the GPS units is designed to validate most of the data that is collected. Thus, the procedures in Table 7C-2 are designed to supplement the GPS unit validation and ensure that the data has not been inadvertently altered.

Table 7C-2. Infestation data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Missing infestation records	tbl_Infestation_Events, tbl_Infestation	QC_Inf_Missing_Recs, QC_Inf_Missing_Recs_GPS	Compare counts of infestations observed by park/route/year with GPS data files.		
Logical start dates	tbl_Infestation_Events: Start_Date	QC_Inf_Start_Dates	Check for dates outside monitoring period. Note: Database ensures dates are valid, but dates can still be entered incorrectly (e.g., wrong year).		
Valid infestation size	tbl_Infestation: Size_Value, Size_Text	QC_Inf_Valid_Size	Check for missing Size_Value, Size_Text. Try to recover any missing values, but leave blank otherwise (it is unlikely that missing values can be recovered since there is no paper record). Ensure Size_Value is a valid size category midpoint (1, 20, 220, 700, 1500).		
Valid canopy cover	tbl_Infestation: Cover_Value, Cover_Text	QC_Inf_Valid_Canopy_Cover	Check for missing Cover_Value, Cover_Text. Try to recover any missing values, but leave blank otherwise. Ensure Cover_Value is a valid cover category midpoint (0.5, 3, 15, 38, 75).		
Valid surveyor	tbl_Infestation: Surveyor	QC_Inf_Valid_Surveyor	Check for missing values. Try to recover any missing values, but leave blank otherwise. Ensure Surveyor is a valid name (see tlu_Contacts).		
Valid patch	tbl_Infestation:	QC_Inf_Valid_PSR	Ensure PSR = 50.		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
separation resolution (PSR)	PSR				
Valid growth stage of trees	tbl_Infestation: Growth_Stage	QC_Inf_Valid_Growth_Stage	Ensure Growth_Stage is populated for tree species. Try to recover any missing values, but leave blank otherwise.		
Misspellings in comments	Comments (tbl_Infestation_Events, tbl_Infestation)	QC_Inf_Spellchk_Comments	Use spellcheck to find and correct spelling errors (select column while in query datasheet view and choose Spelling from Access ribbon).		
Routes with no infestations and/or transects	tbl_Infestation_Events, tbl_Events	QC_MoTr_Events_without_Inf_Events, QC_Inf_Events_without_MoTr_Events, QC_Inf_Events, QC_Mo_Tr_Events	Compare infestation events and monitoring transect events. Add infestation events as needed.		

Location-specific Data

This section focuses on QA/QC of the location-specific attributes common to transect and infestation data (e.g., coordinates, route names). GIS staff performs QA/QC on the GPS data prior to generating a park GPS data file, including correcting the coordinates, visually reviewing the points to verify their locations (e.g., within park), and resolving any issues identified. The procedures in Table 7C-3 are performed after the GPS data file has been uploaded to the database. These steps are performed jointly by data management staff and GIS staff, and are intended to supplement the QA/QC done prior to upload and ensure that the data has not been inadvertently altered.

Table 7C-3. Location-specific data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Valid route names	tbl_Locations: Plot_ID	QC_Loc_Valid_Routes	Sort by park code and route. Check for missing route names and potential duplicate names (e.g., “Bullpen Two Track” vs. “Bullpen 2-track”).		
Valid UTMs	E_Coord, N_Coord (Transect, tbl_Infestation)	QC_Loc_MoTr_UTMs, QC_Loc_Inf_UTMs	Run query to generate table of UTMs for monitoring transects (MoTr) or infestations (Inf). Display UTM table in ArcMap. Visually inspect points to verify		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
			their locations (e.g., within park).		
Valid UTM zone	UTM_Zone (Transect, tbl_Infestation)	QC_Loc_MoTr_UTM_Zone, QC_Loc_Inf_UTM_Zone	Check for missing values. Ensure UTM zone = 12 (13 for BLCA/CURE).		
Valid datum	Datum (Transect, tbl_Infestation)	QC_Loc_MoTr_Datum, QC_Loc_Inf_Datum	Check for missing values. Ensure Datum = NAD83.		
Valid elevation	Elevation (Transect, tbl_Infestation)	QC_Loc_MoTr_Elevation, QC_Loc_Inf_Elevation	Check for missing values. Try to recover any missing values, but leave blank otherwise (it is unlikely that missing values can be recovered since there is no paper record). Check for valid ranges: BLCA (1600, 2770) CARE (1175, 2740) COLM (1380, 2180) CURE (1900, 2910) DINO (1400, 2800) FOBU (1990, 2500) GOSP (1300, 1640) ZION (1080, 2700)		

EDSW Data

Effective detection swath width (EDSW) points are collected via GPS units. GIS staff visually reviews the points to verify their locations (e.g., within park), resolves any issues identified, and adds route names. A GPS data file (in spreadsheet format) is then generated for each park and uploaded to the IEP database. The procedures in Table 7C-4 are performed after the GPS data file has been uploaded to the database. These steps are performed jointly by data management staff and GIS staff, and are intended to supplement the QA/QC done prior to upload and ensure that the data have not been inadvertently altered. Because the EDSW data are stored mainly for backup purposes and not reported on directly, minimal data quality checking is done on these data.

Table 7C-4. EDSW data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Missing EDSW	tbl_EDSW	QC_EDSW_Missing_Recs, QC_EDSW_Missing_Recs_GPS	Compare counts of EDSW records by park/route/year		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
records			with GPS data files.		
Valid EDSW	tbl_EDSW: EDSW_m	QC_EDSW_Valid_EDSW	Check for values between 0 and 200. Values > 200 may be valid, but are unlikely.		

BFP Data

Between feature position (BFP) points are collected via GPS units. GIS staff visually reviews the points to verify their locations (e.g., within park), resolves any major issues identified (e.g., BFP points that are logged inadvertently while not monitoring may be removed), and adds route names. A GPS data file (in spreadsheet format) is then generated for each park and uploaded to the IEP database. The procedures in Table 7C-5 are performed after the GPS data file has been uploaded to the database. These steps are performed jointly by data management staff and GIS staff, and are intended to supplement the QA/QC done prior to upload and ensure that the data has not been inadvertently altered. Because the BFP data are stored mainly for backup purposes and not reported on directly, minimal data quality checking is done on these data.

Table 7C-5. BFP data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Missing BFP records	tbl_BFP	QC_BFP_Missing_Recs, QC_BFP_Missing_Recs_GPS	Compare counts of BFPs by park/route/year with GPS data files.		

Species-related Data

All species recorded for each park are compared to the current park priority list. Any species not on the park priority list are discussed with the crew leader and project manager to determine whether any action is needed (e.g., notifying the park of a new invasive exotic plant). All species recorded for each park are also compared to the current park species list in NPSpecies. This check will identify any updates that need to be made to park species lists and may also identify questionable species. Any species errors or questionable species should be resolved before proceeding with any updates to park species lists.

Table 7C-6. Species data quality checks.

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Species not on park priority list	tbl_Infestation: Master_Code, SpeciesCover:	QC_Inf_Species, QC_MoTr_Species, QC_Species_Priority,	Update QC_Inf_Species, QC_MoTr_Species, and QC_Species_Priority to the		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
	PlantCode	QC_Species_NonPriority	desired park and year. Run QC_Species_NonPriority to get a list of species not on priority list.		
Species not on park species list	tbl_Infestation: Master_Code, SpeciesCover: PlantCode	QC_Inf_Species, QC_MoTr_Species, QC_NPSpecies_Not_on_List, QC_NPSpecies_Not_Present	Download park vascular plant list from NPSpecies in Excel format and link it to IEP QA/QC database as "NPSpecies". Update QC_Inf_Species and QC_MoTr_Species to the desired park and year. Run QC_NPSpecies_Not_on_List to find species not on park list. Run QC_NPSpecies_Not_Present to find species on park list that are not present.		

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #8
Data Analysis and Reporting

Version 1.01
March 22, 2016

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	3/2016	A.W. Biel	Minor editorial and formatting	Publication preparation	1.01

This SOP details the analysis and reporting procedures for data collected in the NCPN Invasive Exotic Plant Monitoring Protocol. Analytical and reporting procedures in this SOP are relatively basic. Enhancements are expected over time, as experience working with uplands data accumulates and as the full suite of potentially supporting data provided by other NCPN vital signs monitoring (e.g., land condition) becomes available. The procedures described in this version, however, provide a solid basis for future enhancements.

Park Communication

Within 30 days (preferably sooner) of monitoring, the park weed manager will be notified of particularly important or significant new invasions (e.g., species with high invasive potential found in a canyon that was formerly weed-free). Prior to each year's sampling, NCPN staff will communicate with park staff to review the Priority Invasive Exotic Plant List (see SOP #9), determine if there are any extra-area weed searches desired (see SOP #4), and confirm plans for that year's monitoring routes.

Monitoring and Park Briefs

A monitoring brief will be prepared annually that provides an overview of invasive exotic plant monitoring throughout the network. A park brief will also be prepared annually that provides an overview of all NCPN activities (including invasive exotic plants) that took place over the past year. These briefs are designed to quickly give a status of the resource at the park.

Annual Reports

Annual monitoring reports will be submitted to the parks. These reports summarize monitoring data collected during the year and provide an update on the status of invasive plants in selected areas. Reports will be prepared and distributed by May of the next calendar year following data collection.

A. Template. The report template for regional natural resource technical reports should be followed (http://www.nature.nps.gov/publications/NRPM/index.cfm). Natural resource technical reports are the designated medium for disseminating high-priority, current natural resource management information with managerial application. The natural resource technical reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission.

B. Information and Estimates to Be Included in Annual Reports. The annual reports will focus on reporting the locations and cover of species during the most recent field work and the amount of change since previous sampling.

1. Monitoring Routes and Extra Areas. Reports will include the time spent surveying and kilometers and hectares covered. Summary statistics will include number of invasives per 100 m along monitoring routes, size and canopy cover of each invasion, tree size when appropriate, maps with locations and presence/absence of species by monitoring route. Weed-free areas will be noted.

2. Monitoring Plots. Summary statistics will include percent cover of invasive exotic plant species by monitoring route. When applicable, correlations between percent cover of invasive exotic plants and other plot variables will be conducted.

3. Evaluate operational aspects of the monitoring program, such as whether any sampling locations need to be eliminated or moved due to access problems, and whether the sampling period remains appropriate (e.g., the optimal sampling season could conceivably change over time in response to climate change).

C. Long-term Trends. After sufficient time has passed, long-term trends for some species may be estimated in annual reports.

1. Reporting will focus on trends in species distributions: spread rates by habitat type and trends in number of detections. Because some portions of parks will only be sampled infrequently (e.g., every five years), statistical analyses in which sample size is equivalent to number of years (e.g., regression) should only be done after enough data points are obtained to allow sufficient statistical power.

2. Reporting will place network results within the larger context of established invasive plant species population changes throughout the Colorado Plateau, as measured by regional efforts.

3. Two complicating issues will present challenges to long-term trend analyses. First, invasive exotic plants—and plant cover in general—are quite low in many NCPN parks, resulting in many 0s in plots and low percent cover (<1% cover of IEPs). Second, managers will likely act to reduce the densities of a number of the invasive species. These actions are likely to vary both spatially and temporally within parks and among parks. Unless the histories of such management actions are documented and made available to the analyst, interpretation of observed long-term patterns may prove difficult.

Analyses

Data summary routines that will be undertaken include (1) maps for invasive plant distribution and infestation sizes in portions of each park sampled, (2) summary statistics and correlation analyses from plot-based samples, and (3) changes in invasive species distribution and abundance over time in re-sampled units. Additional analyses that can be undertaken with the data include spatial interpolation and other modeling to help predict which habitats may be prone to invasion. Data from the vegetation monitoring protocol will also be useful for these analyses.

Because many plots will have no IEPs present and some IEPs will be removed in control efforts, long-term trend analysis will prove challenging. When IEPs are present in low densities at a park or a particular monitoring route, we may be able to examine long-term trends from the monitoring data by examining the actual number of infestations along a monitoring route, as opposed to using the quadrat data. However, this method will prove problematic when IEP densities increase, because the methods are to be rapid and are therefore qualitative and somewhat subjective. Therefore, when densities increase for IEPs, we can use quadrat data for analyses.

Sampling designs

Sampling designs for each NCPN park unit range from fairly simple designs at small parks, such as monitoring all roads, trails, and riparian corridors in the park every two years, to more complicated revisit designs at larger parks. The sampling design for each park unit with invasive plant monitoring is documented in a separate report. These reports should be consulted to determine the proposed sampling objective of the current sampling design for each park unit.

It is important to examine the realized levels of variance components after at least 5 years of monitoring to evaluate the efficacy of the extant sampling design. The recommended frequency of assessments thereafter will vary. Variance assessment is based on all data collected to date, not just observations of the current monitoring event. The utility of this assessment will depend on the number of plots with observations and the number of revisits. However, periodic checking of the assumptions of the sampling design affords timely opportunity to invoke enhancements to meet the original monitoring and sampling objectives. Even well-researched estimates can become obsolete over time due to substantive changes in system conditions, such as those resulting from climatic change.

Frequentist status and trend assessments

Trend assessments of complex survey designs are performed using a mixed-effects ANOVA model (Larsen et al. 1995) or using repeated-measures ANOVA. Time is treated as a fixed effect, while site and year are random effects. Site refers to the plot and year is the same as time. Both site and year are treated as categorical variables; time is treated as a continuous variable. The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend at least at the alpha level used to assess significance. Trend assessments are performed separately for each invasive pathway type (road, trail, riparian) in a park unit. This may also be further stratified by management unit in larger parks. Regression analyses could also be employed to estimate rates of change or the trajectory of change (i.e., linear or nonlinear).

Status is the condition of the attribute and is derived in two ways. If the trend slope is not significantly different from zero, then mean and variance of status is simply the mean and variance of all measures of the attribute up to the current time period. If the slope is significant, then status is the solution of the regression model for the latest time period of the data used to generate the trend line.

Geostatistical temporal modeling (Kyriakidis and Journel 1999) and general linear models (Manley 2001) may also be used to identify whether or not the spatial patterns are changing over time. Interpretation of trends will require assessment by park managers of any park management actions that may have affected invasive species abundance in areas surveyed.

Bayesian trend assessments

Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000; Wade 2000) given the observed data. This differs from frequentist methods, which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other attributes of this protocol likely will be considerably much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

The technical calculations of Bayesian methods are beyond the scope of this SOP. Wade (2000) provides a readable overview, and Gelman and others (2000) provide in-depth explanations of the underlying mathematics of various analytical methods. In short, a Likelihood distribution is generated from the sample data that provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution that is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters. In the absence of such knowledge, a non-informative distribution can be used, which essentially is a uniform distribution across the range of the Likelihood distribution. In subsequent analysis, the posterior distribution of previous assessments is used as the prior distribution. The posterior distribution allows assessments of the probability of user-selected parameter values. The probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even though conventional statistics may not reveal a significant trend, relatively high probabilities (e.g., >0.70) of trends with a Bayesian method may warrant special attention.

Bayesian methods for trend assessments are recommended, but exact guidelines are not provided. As data become available for trend assessments, Bayesian procedures should be developed. With experience, specific guidelines for Bayesian analysis of trend should be documented in this section of the SOP.

References

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2000. Bayesian Data Analysis. New York: Chapman and Hall.

Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. Water Resources Bulletin 31:117–140.

Wade, P. R. 2000. Bayesian methods in conservation biology. Conservation Biology 14:1308–1316.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #9
Developing a Priority Invasive Plant List

Version 1.01
March 22, 2016

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.0	3/2016	A.W. Biel	Minor editorial and formatting	Publication preparation	1.01

This SOP explains the process of gathering and compiling invasive species lists to use in subsequent profiling and prioritization/ranking exercises. The final product will be a list of target invasive exotic plant species occurring at each park that observers will be trained to identify on monitoring routes. Additional species will be on the list for consideration for future years. The list will be evaluated each year monitoring is conducted in a park.

Procedures

1. Create a "master" table in a word processing or spreadsheet/database application to organize the species, source, and occurrence information that will be compiled. A master list should include all non-native species known to be present within a park, as well as any species that are not known to be present but are known to be invasive and are on local, county, or weed management area lists that include the park.

2. Consult state and federal invasive plant lists for targeted state(s) for possible species that may be moving into the area of the park.

   Although there are several ways to find this information, one of the better resources is the Invaders Database System (http://invader.dbs.umt.edu/Noxious_Weeds/), housed at the University of Montana–Missoula. In many cases, such as in Colorado, a state will categorize or prioritize weeds on its list to guide coordinate state and county efforts,

and may even provide management recommendations or directives for individual species (e.g., eradication, containments, suppression). The Invaders Database System is one of the few web resources that provides this information. The Center for Invasive Plant Management also has state weed lists for all western states and Canadian provinces: http://www.weedcenter.org/resources/state.html.

3. Contact county weed-management staff to determine if particular counties of interest have their own weed list (many do). Most county weed lists will be a selection of species from the state weed list, but many also include species not found on state lists, such as species of local concern. County weed managers may also be able to comment on countywide occurrence and distribution information, as well as on species that should be flagged for early detection (watch list).

   Most states do not have a centralized location on the internet for county weed management offices and phone numbers, and employees are subject to change over time. Local park resource managers are often the best source of information. The following resources may also help you find contact information for a particular county or counties:

State	Contact
Arizona	State Weed Coordinator's Office: 602-542-3309
Colorado	Troublesome Weeds of the Rocky Mountain West (weed identification booklet distributed by the Colorado Weed Management Association) State Weed Coordinator's Office: 303-239-4182 http://www.cwma.org/
Utah	Noxious Weed Field Guide for Utah (weed identification booklet distributed by USU and county weed control management) State Weed Coordinator's Office: 801-538-7183 http://www.utahweed.org/cwma.htm
Wyoming	State Weed Coordinator's Office: 307-777-6585 Weed and Pest Council/Districts: http://www.wyoweed.org/about/district-offices#Table

4. Review park datasets and maps from any vegetation community and/or invasive species mapping projects for park-specific presence data.

5. Present the list to park staff for their review. (Ideally, the park staff is involved throughout this process.)

6. Develop the Park Priority Invasive Exotic Plant List . This list should include existing IEPs and potential IEPs of high management concern. The monitoring methods were designed to be rapid; therefore, field crews are only able to be trained for a maximum of 25–30 species per park. This enables them to develop a focused search image on the

target 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.

7. Develop a list of additional species to be monitored within the quadrats. There may be a desire for some widespread species (i.e., cheatgrass, tamarisk) to be monitored in the monitoring transects. These are generally species that are too widespread to be mapped, but parks may want to follow trends in these species or establish a baseline. Future changes in management practices or the introduction of a biological control agent (e.g., tamarisk beetle) could then be evaluated over time.

8. Re-evaluate the Park Priority Invasive Exotic Plant List annually. Compare monitoring results to target list and re-check the list with state, local, and park staff to ensure invasive exotic plant needs have not changed.

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #10
Revising the Protocol Narrative and SOPs

Version 1.10
January 21, 2021

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.00	7/8/2009	H. Thomas	Updated MVT	To reflect changes based on 2008 field work	1.01
1.01	12/15/2010	H. Thomas	Updated MVT	To reflect changes based on 2009 field work	1.02
1.02	12/1/2011	H. Thomas	Updated MVT	To reflect changes based on 2010/2011 field work	1.03
1.03	12/1/2012	H. Thomas	Updated MVT	To reflect changes based on 2012 field work	1.04
1.04	9/20/2013	H. Thomas	Updated MVT	To reflect changes based on peer review comments	1.05
1.05	5/11/2015	H. Thomas	Updated MVT	To reflect changes based on 2014 field work	1.06
1.06	4/8/2016	H. Thomas	Updated MVT	To reflect changes based on 2015 field work	1.07
1.07	11/16/2016	A.W. Biel H. Thomas	Minor editorial Updated MVT	Publication preparation To reflect changes based on 2016 field crew training	1.08
1.08	6/13/2018	H. Thomas	Updated MVT	To reflect changes based on 2017 field work and major modifications to database	1.09
1.09	1/21/2021	H. Thomas	Updated MVT	To reflect changes based on 2018/2019 field work	1.10

This Standard Operating Procedure (SOP) explains how to make and track changes to the narrative and standard operating procedures for the Northern Colorado Plateau Network (NCPN) Invasive Plant Monitoring Protocol. Individuals editing the protocol narrative or any SOP

need to follow these procedures in order to eliminate confusion on how data are collected and analyzed. All observers conducting monitoring should be familiar with this SOP in order to identify and use the most current methods. The procedures in this SOP are based on the NCPN Protocol Versioning Guidance Document (NCPN 2009).

Procedures

1. Modifications must be reviewed for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by NCPN Inventory and Monitoring staff. An outside review is required for substantive changes in methods. Regional and national staff of the National Park Service (NPS) and experts outside the NPS with familiarity in vegetation and soil monitoring and data analysis will be used to review major changes.

2. Record all changes to a protocol document (protocol narrative or SOP) in the document's revision history log, even minor edits like fixing typos or formatting changes. It is not necessary to record the specific edits made—rather, just the fact that typos were fixed or formatting changes were made. For minor edits, record the same document version number in the revision history log. For actual protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, and the reason for the changes, along with the new version number (if applicable).

3. Narrative and SOP updates may occur independently. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The NCPN tracks the narrative and SOP version numbers in a Master Version Table (MVT), which is maintained in this document (SOP #10). Any time the narrative or an SOP version change occurs, the MVT is updated to reflect the date of the change and the versions of the narrative and SOPs in effect.

4. New versions of the protocol narrative and SOPs must be posted on the NCPN website. Older versions of the protocol narrative and SOPs must be archived in the NCPN Invasive Plant Protocol Library: (R:\Monitoring_Archive\Invasives\Protocol).

Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

Master Version Table[1]

Effective Date	Narrative	1-Field Work Preparation	2-Training Observers	3-Monitoring Route Methods	4-Extra-Area Search Methods	5-Monitoring Lite	6-Using GPS Units	7-Data Management	8-Data Analysis & Reporting	9-Priority Invasive Plant List	10-Revising the Protocol
1/1/2008	1.00	-	-	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00
1/1/2009	1.00	-	-	1.01	1.00	1.00	1.01	-	1.00	1.00	1.01
1/1/2010	1.00	1.00	1.00	1.03	1.01	1.00	1.02	1.00	1.00	1.00	1.02
1/1/2011	1.00	1.01	1.00	1.04	1.01	1.00	1.02	1.00	1.00	1.00	1.03
1/1/2012	1.00	1.01	1.00	1.04	1.01	1.00	1.03	1.01	1.00	1.00	1.04
1/1/2013	1.01	1.02	1.01	1.06	1.01	1.00	1.04	1.01	1.00	1.00	1.05
1/1/2014	1.01	1.02	1.01	1.07	1.01	1.00	1.04	1.01	1.00	1.00	1.06
1/1/2015	1.01	1.03	1.01	1.09	1.01	1.00	1.04	1.01	1.00	1.00	1.07
1/1/2016	1.02	1.04	1.02	1.11	1.02	1.01	1.05	1.02	1.01	1.01	1.08
1/1/2017	1.02	1.05	1.02	1.14	1.03	1.02	1.06	1.03	1.01	1.01	1.09
1/1/2018	1.02	1.06	1.02	1.15	1.04	1.02	1.06	1.03	1.01	1.01	1.10

References

Northern Colorado Plateau Network (NCPN). 2009. Protocol versioning guidance document, version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, Utah.

[1] A dash ("-") in a cell indicates that the narrative or SOP is not applicable during the corresponding time period.