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

Standard Operating Procedure (SOP) 1*:* Field Work Preparation

Version 1.03 (June 2015)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	12/11	K. Lund	Updates to equipment list	Needed equipment	1.01
1.01	9/13	D. Perkins	Comments from peer review	Clarity	1.02
1.02	6/15	K. Lund	Updates to equipment list	Needed equipment	1.03

I. Procedures

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

2. The project manager provides 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 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 back-country camping permits, where necessary. A preliminary schedule should be approved by the PI. Upon approval, resource staff of park units being visited should be notified (via an email message) of the dates the invasive field crew will be in their parks. Just prior to the time the field crew enters a park unit, the resource staff of the park is to be provided with the actual dates 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:

Item	Number needed	Description	Notes
General Equipment - *Necessary for all SOPs*			
GPS with data dictionaries and extra batteries	2 per person	Trimble GeoXM or more accurate	Includes back-up GPS
GPS car charger	1 per vehicle		
GPS Memory Cards	1 per GPS		To back-up GPS
Digital Camera	1 per person		
Extra battery for digital camera	1 per camera		
Camera charger	1 per vehicle		for charging camera batteries
Inverter	1 per vehicle	plugs into vehicle	charge electronic equipment
2-Way Radios	1 per person + 1 back-up		crew communication, includes spare & lanyards on each radio; bring extra for boatmen if monitoring large water body/river and as back-ups
Spare batteries for radios	min. 15	AA alkaline, 3 per radio	1.5 sets per radio per day
Data sheets	variable		at least 25% on rite-in-the-rain paper
Unknown Plant Specimen Forms	12		at least 25% on rite-in-the-rain paper
Monitoring Maps	1 per person		Contains routes, plots and extra area searches
Waterproof Topo Map of park	1 per person		Display search units or line transects
Permit	1 per vehicle plus 1 per person		one on dashboard, one with crew
SOPs	1 per person		
Access documents	1		Specific to park
Target species lists	1 per person		
Previous trip reports	1		
Park Herbaria list	1 per person		
Invasive Plant Guides	1 per person		To identify exotic plants, including photographs of plants and similar species
Clipboard/Binder	1 per person	lightweight with interior storage	
Field notebook	1 per person	small, Rite-in-the-Rain©	To record field notes
Pencils	5 - 10		
Sharpies	5		

Item	Number needed	Description	Notes
Hand Lens	1 per person		
Compass	1 per person		
Clinometer	1 per person		
2 m folding engineer's ruler	1 per person		
Plant Press	1		
Backpacks	1 per person		
Laser Rangefinders	1 per person		
Binoculars	1 per person		
Calculators	1 per person		
Plant Taxonomic Keys	1		
Plant Dissection Kits	1		
Unknown Plant Kit	1 per person	2 gallon or larger resealable bags, masking tape, permanent marker, trowel	
Transect tapes (m)	1 per person		10 m tape
Chaining Pins	2 per person		To hold transect tapes
Safety Equipment - *Necessary for all SOPs*			
First aid kit	1 per 2 people (or 1 per person if working independently)		content list in NCPN Field Safety Plan
Satellite phone	1 per 2 people (or 1 per person if working independently)		
Satellite phone charger	1 per phone		
SPOT	1, use if sat phone is not available		
NCPN Field Safety Plan	1 per person		
NCPN Accident Report Logs	1 per person		found in NCPN Field Safety Plan
NCPN Medical Information Forms	1 per person		found in NCPN Field Safety Plan

Item	Number needed	Description	Notes
Orange safety vest	1 per person		If monitoring next to a road
Survey Crew Ahead Road Signs	2		Includes sign, stand, and cross bars. Use if monitoring next to a road

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

Standard Operating Procedure (SOP) 2*:* Observer Training

Version 1.01 (September 2013)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	9/13	D. Perkins	Editorial changes from peer review.	Clarity	1.01

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 collect are reviewed below.

I. 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 exercise the use of 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.

II. 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. Training field botanists should include:

A. Provide exotic plant priority 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. Training in actual detection with known infestations or placement of replicas.

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

C. Provide 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.

III. 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.

A. 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.
B. 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.
C. 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.
D. Encourage observers to memorize the cover class scale
E. Practice estimating cover for different plant-forms, such as forbs, grasses, and shrubs.
F. Throughout the sampling season, review foliar cover estimation. Early in the field season, observers should calibrate themselves daily. Weekly calibration is recommended thereafter.
G. Ensure good communication among the crew about observer patterns of cover estimation.
H. As vegetation dies back, 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.

IV. 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 1.09 (June 2015)

Revision History Log:

Prev. 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

This SOP gives step by step methods for the collection of field data for invasive 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.

I. 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 of Invasive Exotic Plants (IEP) 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.

II. Determine Settings

A. *Determine the Park Priority Invasive List.* NCPN will work with park staff and other local cooperators to develop a target species list of 20-30 invasive plant species for each park 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. Since these surveys are designed to be rapid, they will be much more effective if the 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 that are new to the area are added (SOP #11).

B. *Determine the Minimum Detection Target Size (MDTS)*. 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.

C. *Determine Effective Detection Distance (EDD).* The 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 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 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 detection swath widths as narrow as 2 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater.

D. *Determine Effective Detection Swath Width (EDSW)*. 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 3.1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90 percent 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.

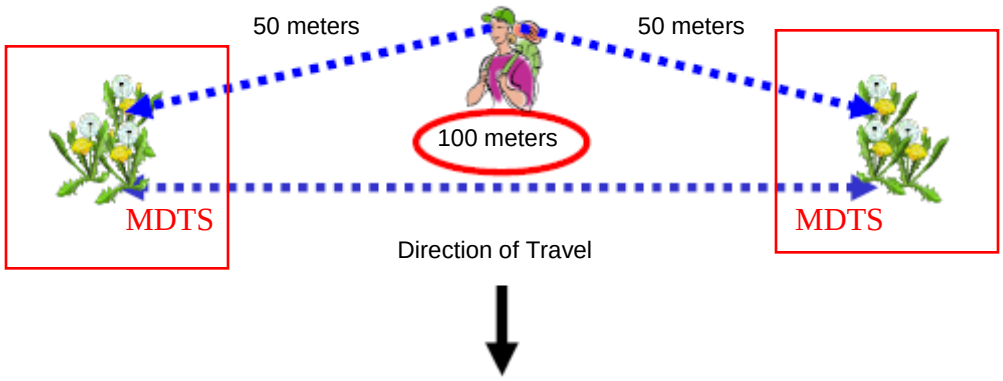


Figure 3.1. If the maximum Effective Detection Distance (EDD) for this MDTS is 50 meters, the actual Effective Detection Swath Width would be 100 meters (From Anderson and Dewey 2007).

E. *Determine Patch Separation Resolution (PSR):* The 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. 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.

F. *Set the Between Feature Position (BFP) Setting*. 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 the 20 m. This needs to be set in the GPS under Settings every time a new route is started.

III. Conducting a Monitoring Route

A. *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, and streams and washes less than 1 m across (wetted width), the surveyor should walk directly down the wash, trail, or road, so 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 Park Priority Invasive 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 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 percent of the time spent walking through a search area must be devoted to looking down at one's feet, 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.

B. *Determine the EDSW*. Determine the EDSW 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. 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 1m across, the EDSW will equal the EDD plus the distance away from the edge of the road/stream.

C. 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 Using GPS for more information). Point features reflect a distinct location described as a single position coordinate (Figure 3.2).

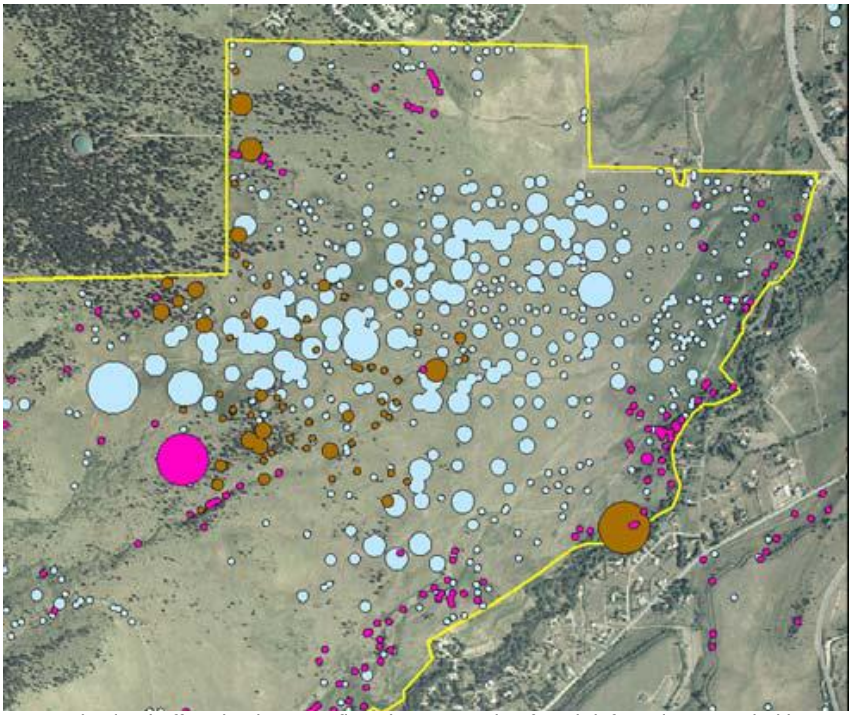


Figure 3.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors (From Anderson and Dewey 2007).

1. 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 below for Estimating Size of Infestation)*	Infestation size • 1 to few plants • few plants – 40m^2 • 40 – 400m^2 • 400 – 1000m^2 • 1000 -2000m^2
CanopyCover *(visually estimated; see below 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
Disturbance	Disturbances 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 SOP #3 section 2,C for further explanation)
PSR	Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#3, sec 2,D)

Notes	Any comments regarding the site (can contain species name if “other”)

- If several species are present with similar distributions, 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.

- 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 (i.e. size, cover, etc.) in the GPS unit, noting the corresponding letter or number in the Comments section (see SOP 6).

- Generally, only the invasive species on the Park Priority 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 a 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.). Avoid pulling plants unless one has 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).

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).

Table 3.1. 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
1000	0.25	1,120	17.9	18.9	35.7	37.8
2000	0.5	2,420	25.3	27.8	50.1	55.5

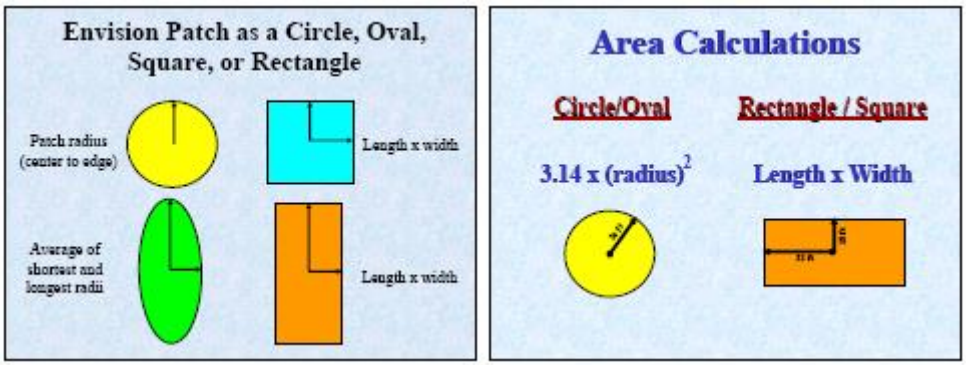


Figure 3.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right) (From Anderson and Dewey 2007).

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 40 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 4 hectares, with a very low density or canopy cover designation (Figure 3.4).

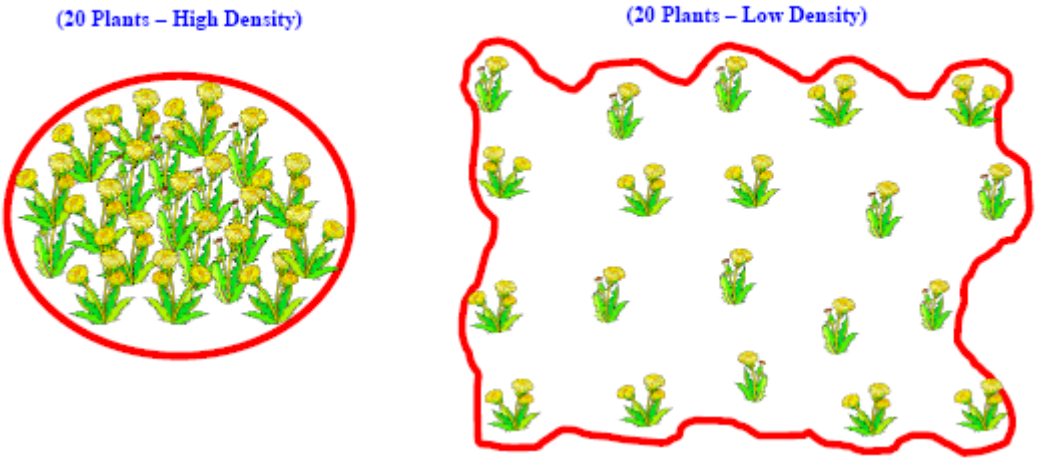


Figure 3.4. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 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.

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

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

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

A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 3.5). To estimate canopy cover the surveyor first considers the midpoint value between 0 and 100 percent, and asks the question “Is the percent cover greater or less than 50 percent?” If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question “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.

Figure 3.5. The percent canopy cover is estimated from within the perimeter of the actual infested area (From Anderson and Dewey 2007).

D. *Invasion on Inaccessible Land:* 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, 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, 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.

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.

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, the weed point's placement on a map will be incorrect (placed further away from the observer than was actually the case).

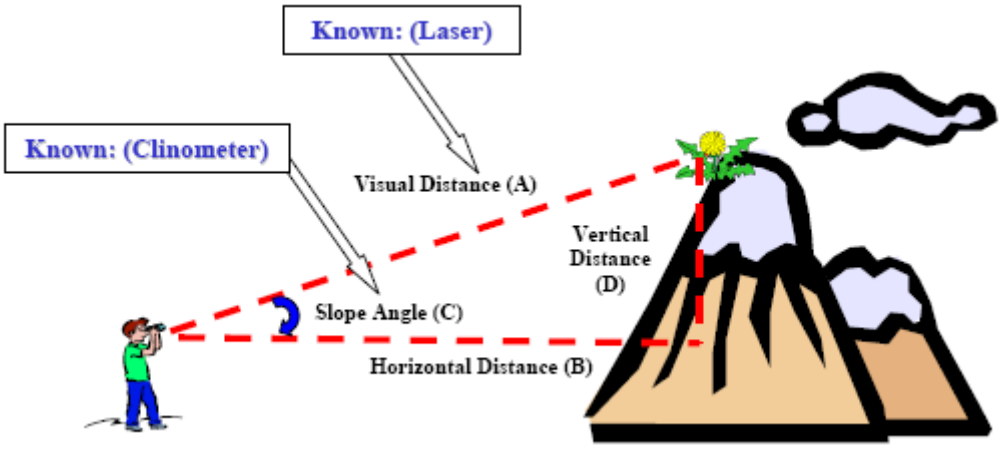


Figure 4.7. The visual distance between the observer and the weed (A) as measured by a laser rangefinder is greater than the true horizontal distance (B). Simple trigonometry can be used to calculate the horizontal distance and the vertical distance (D) (From Anderson and Dewey 2007).

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) x 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. 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 equation (see Figure 4.7):

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

IV. 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, models the patches of missed and less sampled non-native species, and a method for understanding which habitats and sites are being invaded.

Transects with 3 vegetation quadrats are established every 500 m along monitoring routes.

A. *Establishing the Transect and Vegetation Quadrats*

1. *Establishing the Transect*: The 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 update the file by logging ten points, see SOP 6) in the GPS and extending measuring tape perpendicular from the monitoring route (see Fig.4.8).

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, and streams and washes less than 1 m across (wetted width): establish transects on alternating sides. If one side cannot be sampled, establish the transect on the same side. 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.
- If the transect location cannot be reached (i.e. cliff wall), establish the transect in the closest location possible. Efforts should be taken to not skip transects.

2. *Establishing the Quadrats*: Establish 3 vegetation quadrats (1x1m) along the transect at 0, 4.5, and 9.5m (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 (Figure 4.8). .

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

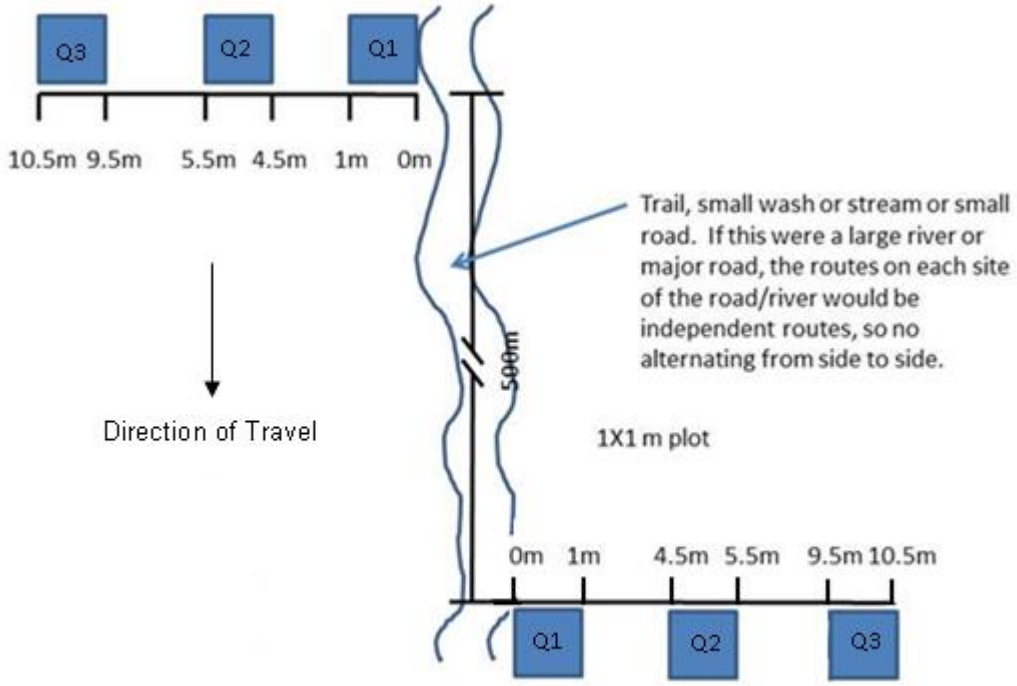


Figure 4.8. Location of 1X1 m plots along a monitoring route.

B. *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 Invasive Plant Priority List as well as park requested widespread invasives (i.e. 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, etc….100%. Only estimate cover on plants or portion of plant that falls 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.

2. Identify dominant microhabitats (see Table 2.1) and estimate percent cover using the above classes within the 1-m^2 quadrat. The total percent cover for the microhabitats should be close to 100%. With the invasive cover, there will often be overlap of plant species and microhabitats. Therefore, your total cover for a quadrat may exceed 100%.

Table 2.1. Microhabitat Variables Table

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 forest mineral soil (<10 cm diameter).
Live root / bole	Living roots at the base of plants or trees or exposed at the surface of the forest floor or soil and cross-sectioned area of tree boles at the ground line.
Dead root / bole	Dead roots at the base of plants or trees or exposed at the surface of the forest floor or soil and cross-sectioned area of tree boles at the ground line.
Mineral soil / Sediment	Physically weathered soil parent material that may or may not also be chemically and biologically altered.
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.
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%, etc.) 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.

V. 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 on following 2 pages.

Park: **Route:** **Transect:** **Date:** **Obs:**

Microhabitat	% cover		
	Q1@0m	Q2@4.5m	Q3@9.5m
Dead wood (>10 cm diameter)			
Dung			
Fungus			
Lichen			
Litter/Duff			
Live root/Bole			
Dead root/Bole			
Mineral soil/Sediment			
Moss			
Biological Soil Crust			
Road			
Rock			
Standing water/flooded			
Stream			
Trash/junk			

Cover Classes	
0	10
<1	20
1	30
2	40
3	50
4	60
5	70
6	80
7	90
8	100
9	

Species	% Cover		
from Invasive Plant Priority List	Q1@0m	Q2@4.5m	Q3@9.5m

Park: **Route:** **Transect:** **Date:** **Obs:**

Microhabitat	% cover		
	Q1@0m	Q2@4.5m	Q3@9.5m
Dead wood (>10 cm diameter)			
Dung			
Fungus			
Lichen			
Litter/Duff			
Live root/Bole			
Dead root/Bole			
Mineral soil/Sediment			
Moss			
Biological Soil Crust			
Road			
Rock			
Standing water/flooded			
Stream			
Trash/junk			

Keep original spacing of quadrats along transects.

Do not move quadrats to new locations.

Species	% Cover in Classes		
from Invasive Plant Priority List	Q1@0m	Q2@4.5m	Q3@9.5m

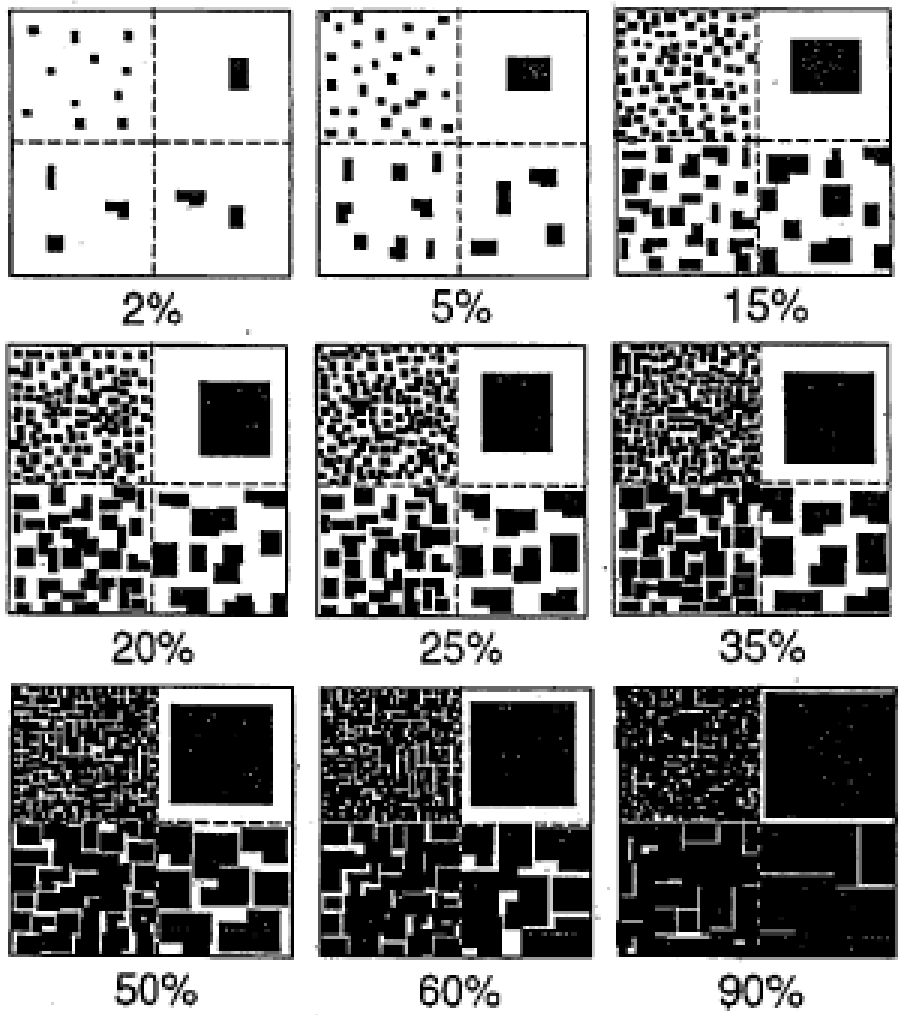
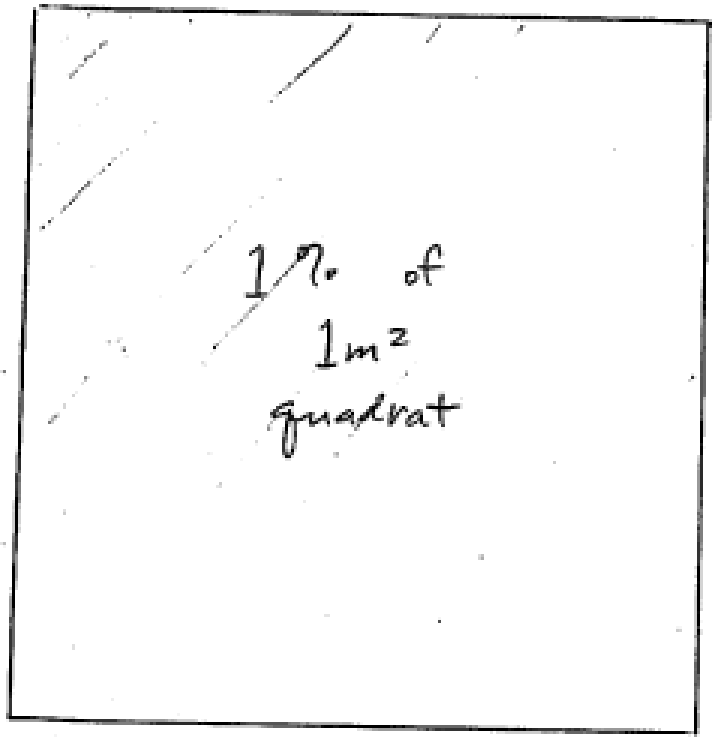


Figure 5. Guide for estimating percent of area covered (from Schoeneberger et al. 2002).



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

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

Version 1.01 (December 2010)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	12/2010	D. Perkins	Editorial	Clarity	1.01

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 towards extra-areas. Extra-areas are somewhere where park personnel determine that an invasive plant survey is of utmost importance. Examples could be a new burn, 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 the efforts on the Colorado Plateau and their expertise in this area.

I. Determine the Species and Area to Be Searched and Method of Search

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

B. *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.

C. *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 search swath width and repeats the process in the opposite direction. This creates a series of parallel contiguous search swaths, which 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 he/she 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.

II. Initiating the Search

A. *Determine the Minimum Detection Target Size (MDTS).* 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 1 meter^2 (approximately 20 x 20 ft) for all invasive species, unless otherwise noted.

B. *Determine Effective Detection Distance (EDD).* The 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 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.

C. *Determine Effective Detection Swath Width (EDSW).* 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 4.1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90 percent of all target weed patches 1 meter^2 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).

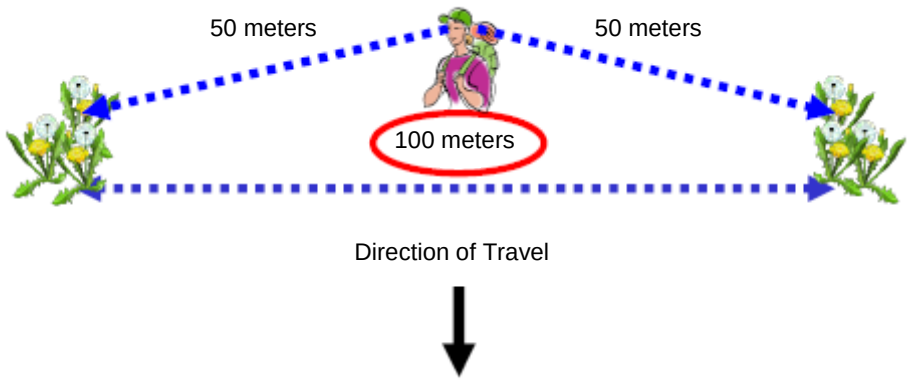


Figure 4.1. If the maximum Effective Detection Distance (EDD) for this MDTS is 50 meters, the actual Effective Detection Swath Width would be 100 meters (From Anderson and Dewey 2007).

D. *Determine the Patch Separation Resolution (PSR).* The 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 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.

E. *Set the Between Feature Position (BFP) Setting.* 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. Use the distance setting for these positions. Use the EDSW as the setting for the BFP. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. Each time a surveyor walks the equivalent of "one effective detection swath width", the Trimble GPS unit creates a point. So, at the beginning of each day, and whenever moving to significantly different terrain or vegetative cover, each surveyor must adjust the GPS Between-Feature Position (BFP) distance setting to correspond to the average EDSW for that new area.

F. *Initiate Survey Route:* 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 percent of the time spent walking through a search area must be devoted to looking down at one's feet, 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.

G. *Determine the Spacing of Survey Routes:* In most cases the areas will be surveyed comprehensively. In this case transects will be placed on EDSW apart so that the entire extra area is covered. In some cases, park staff may only want a quick look to determine if additional surveys should be completed. In this case the spacing of transects would be determined in cooperation with the pertinent park staff.

III. Recording Invasive Plants

Once a weed patch/infestation from the Invasive Plant Priority list has been discovered, a mapping crew must record : 1) the survey unit, 2) the number of the invasion per survey unit, 3) dimension of a point, and 4) estimate canopy cover. It is important to note that not all non-native species that are 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 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 a separate point.

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. Point Dimensions - The size of each infestation is recorded as a point feature that is estimated visually and placed in the size category most closely matched to its actual area: 1) 1 to a few plants, 2) few plants to 40 meters^2 (48 yards^2 or 0.01 acres), 3) 40 square meters to 400 square meters (48 yards^2 to 478 yards^2 or 0.01 to 0.10 acres), 4) 400 meters^2 to 1000 meters^2 (0.1 acre to 0.25 acre), 5) or 1000 m^2 to 2000 m^2 (0.25 acre to 0.5 acre) (see table 3.1). "1 to few plants" is used for isolated single plants or very small patches (2 meters x 2 meters) or less (Table 4.1).

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, 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 (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
1000	0.25	1,120	17.9	18.9	35.7	37.8
2000	0.5	2,420	25.3	27.8	50.1	55.5

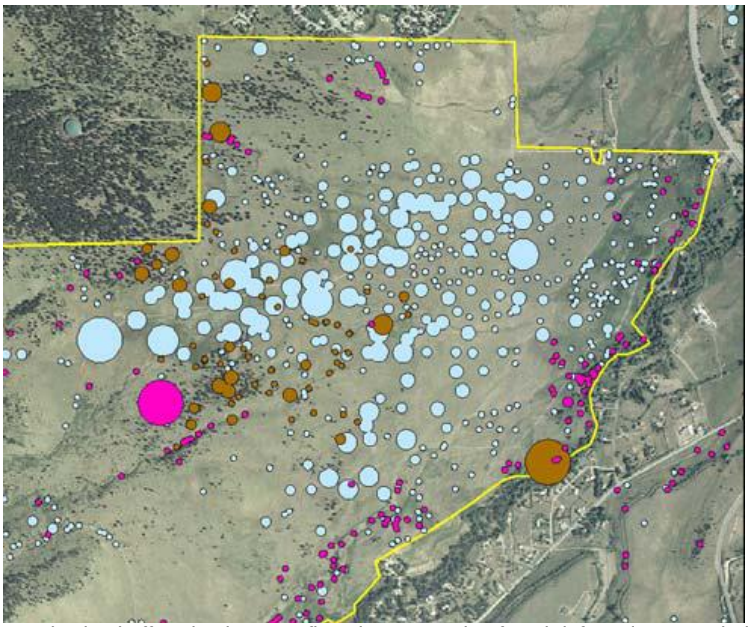


Figure 4.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors (From Anderson and Dewey 2007).

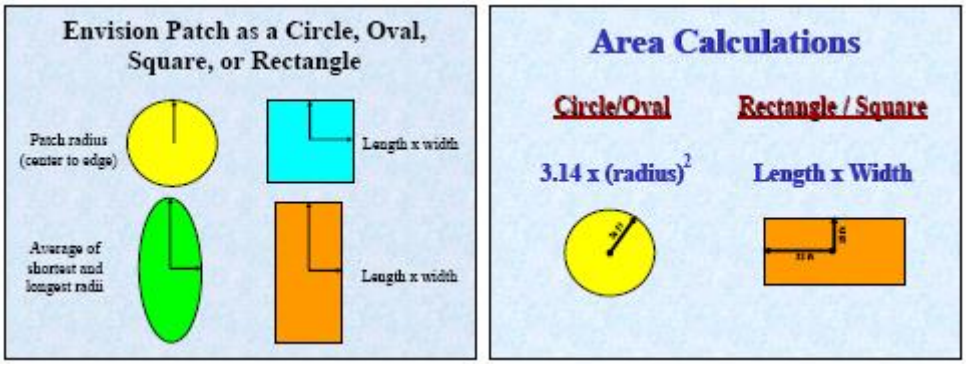


Figure 4.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right) (From Anderson and Dewey 2007).

D. *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 40 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 4 hectares, with a very low density or canopy cover designation (Figure 4.4).

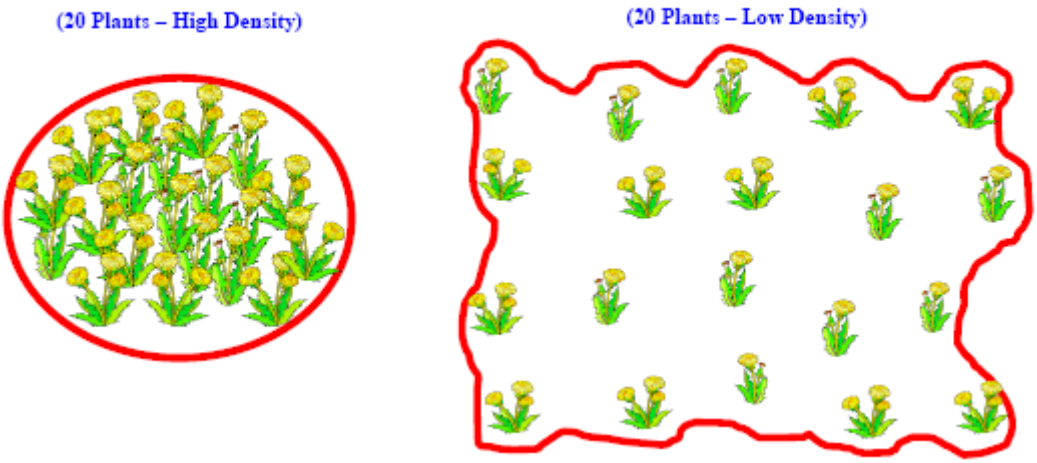


Figure 4.4. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 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 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50, or majority = 51 to 100 percent. 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 the question “Is the percent cover greater or less than 50 percent?” If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question “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.

Figure 4.5. The percent canopy cover is estimated from within the perimeter of the actual infested area (From Anderson and Dewey 2007).

E. *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 a 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. If there are several small invasions then that should be left for park control personnel to control. In the vast majority of cases invasions will require response commitments from parks and EPMTs. Note whether the species was pulled.

F. *Ancillary 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).

IV. Additional Situations

A. *Invasion on Inaccessible Land:* 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.

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, 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.

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.

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, the weed point's placement on a map will be incorrect (placed further away from the observer than was actually the case).

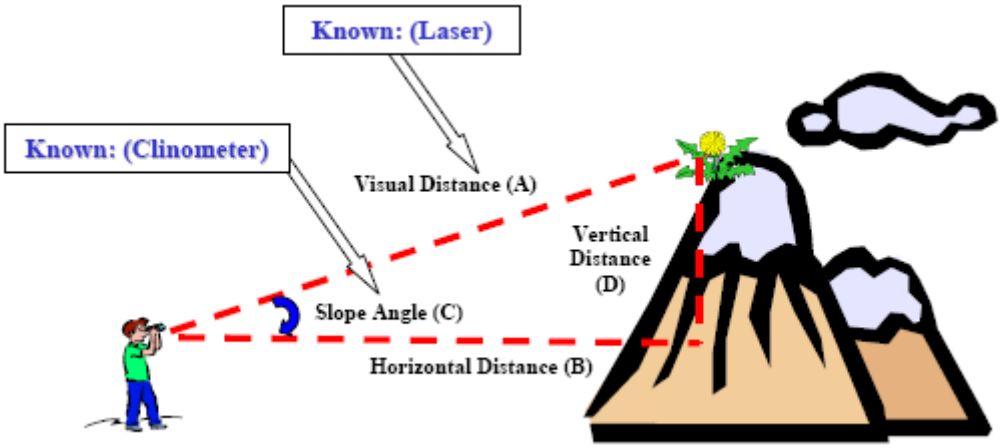


Figure 4.7. The visual distance between the observer and the weed (A) as measured by a laser rangefinder is greater than the true horizontal distance (B). Simple trigonometry can be used to calculate the horizontal distance and the vertical distance (D) (From Anderson and Dewey 2007).

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) x 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. 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 equation (see Figure 4.7):

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

B. *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.

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).

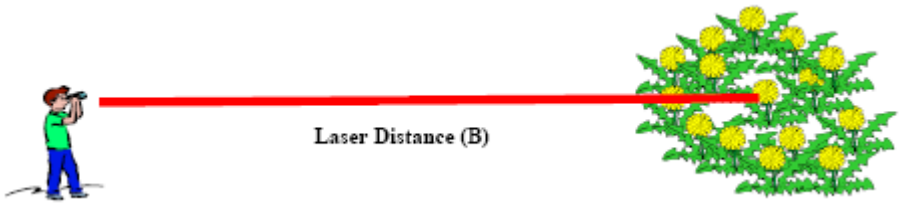


Figure 4.8. Side view of the surveyor determining the laser distance (B) to the center of a remote weed patch (From Anderson and Dewey 2007).

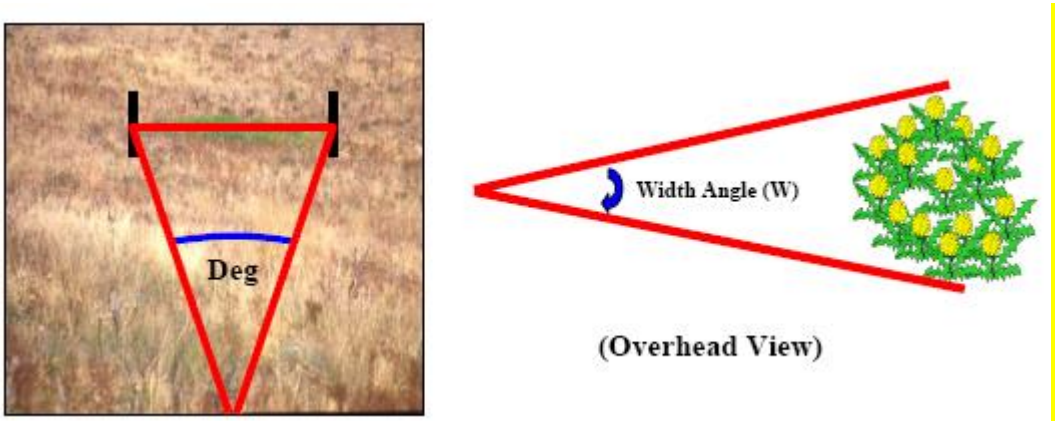


Figure 4.9. To determine the width angle, the surveyor must find the compass bearings of the left and right edges of the patch. The difference between the two bearings is the width angle (W). For example, if the left edge bearing is 88 degrees and the right edge bearing is 100 degrees, the width angle (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) x B = D

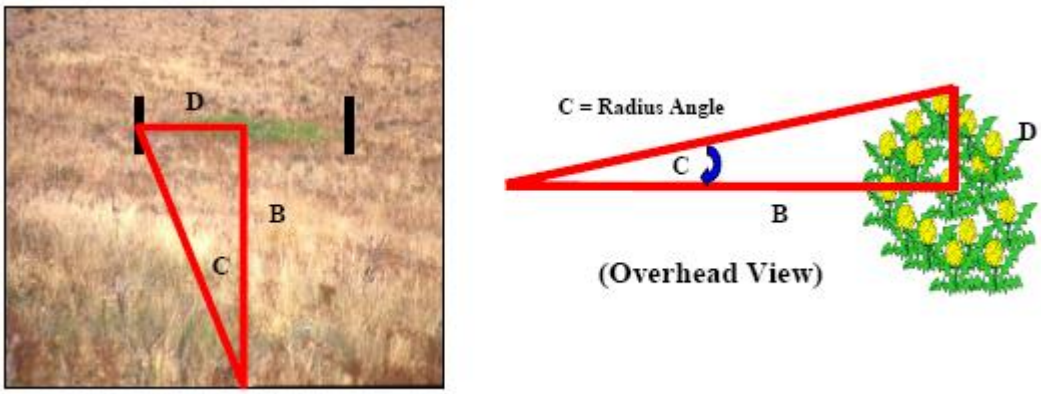


Figure 4.10. The radius angle (C) is equal to one half of the width angle (W in Figure 4.9). If the width angle of this leafy spurge patch was determined to be 12 degrees, the radius angle would be 6 degrees (From Anderson and Dewey 2007).

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

V. 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.

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

Standard Operating Procedure (SOP) 5*:* Monitoring Lite

Version 1.00 (May 2008)
Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

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 that 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 1997). In several cases large portions of the text have been lifted directly from their handbook. We are grateful for the efforts on the Colorado Plateau and their expertise in this area.

I. 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 less 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 was not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps are converted to digital format.

II. Definitions

A. *Determine the Minimum Detection Target Size (MDTS).* 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 1 meter^2 (approximately 20 x 20 ft) for all invasive species, unless otherwise noted.

B. *Determine Effective Detection Distance (EDD).* The 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.

C. *Determine Effective Detection Swath Width (EDSW):* 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 percent of all target weed patches 1 meter^2 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 per monitoring route. 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).

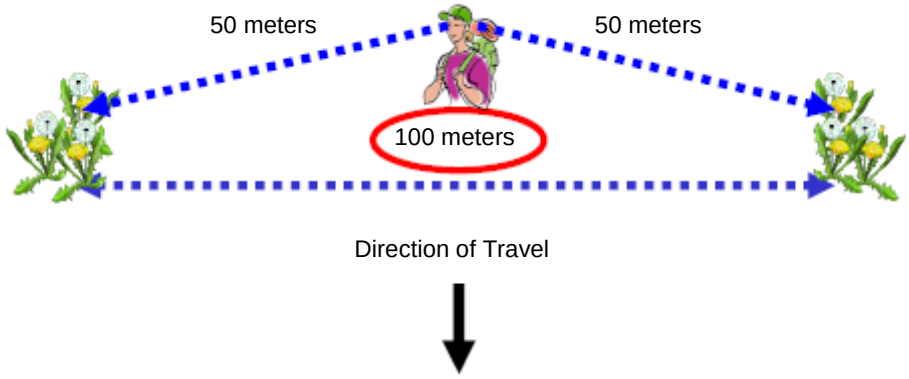


Figure 5.1. If the maximum Effective Detection Distance (EDD) for this MDTS is 50 meters, the actual Effective Detection Swath Width would be 100 meters.

D. *Determine Patch Separation Resolution (PSR):* The 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 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.

E. *Set the Between Feature Position (BFP) Setting.* 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. Use the distance setting for these positions. Use the EDSW as the setting for the BFP. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. Each time a surveyor walks the equivalent of "one effective detection swath width", the Trimble GPS unit "beeps" and creates a point. So, at the beginning of each day, and whenever moving to significantly different terrain or vegetative cover, each surveyor must adjust the GPS Between-Feature Position (BFP) distance setting to correspond to the average EDSW for that new area.

III. Conducting a Monitoring Route

A. *Set the Effective Detection Swath Width (EDSW):* 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.)

B. *Set the Between Feature Position:* The same distance as the EDSW.

C. *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.

D. *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 percent of the time spent walking through a search area must be devoted to looking down at one's feet, 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.

E. *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) estimate canopy cover. It is important to note that not all non-native species that are found will be mapped. For example cheatgrass that is dominant across a park or a portion of the park will not be individually mapped, however it will be recorded in the quantitative plots. These species are to be identified prior to the initiation of a monitoring route.

1. Record the monitoring route.

2. All invasions will be recorded as buffered points. If several species are present with similar distributions, 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 (Zamora and Petroff 1985) - 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 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).

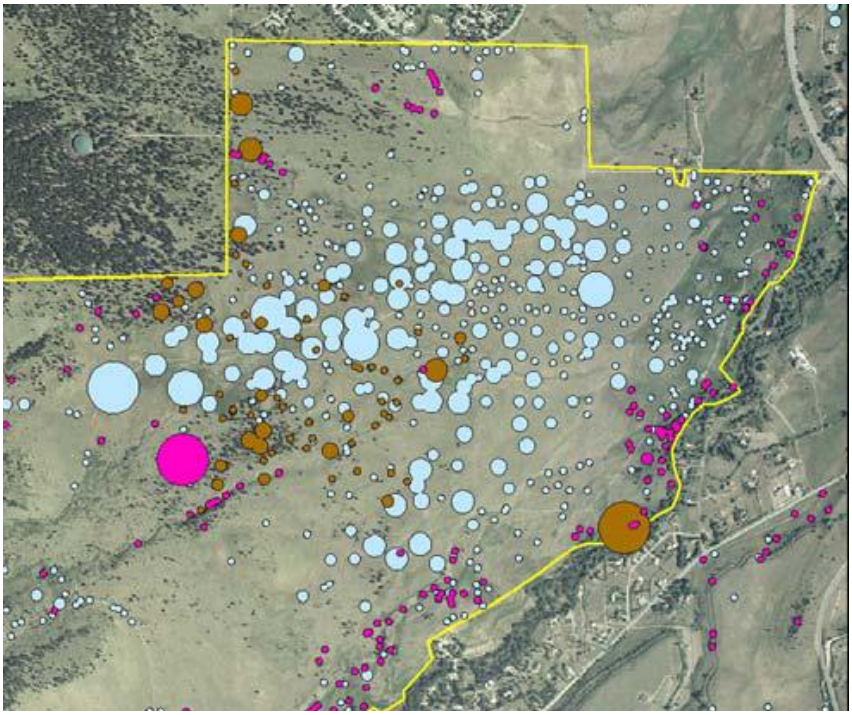


Figure 5.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors.

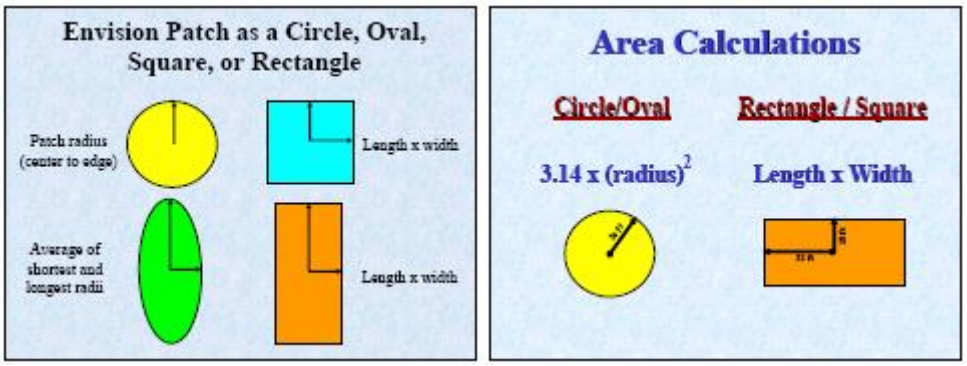


Figure 5.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right).

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 to a few plants, 2) few plants to 40 meters^2 (48 yards^2), 3) 40 square meters to 400 square meters (48 yards^2 to 478 yards^2), 4) 400 meters^2 to 1000 meters^2 (0.1 acre to 0.25 acre), 5) or 1000 m^2 to 2000 m^2 (0.25 acre to 0.5 acre) (see table 5.1). "1 to few plants" is used for isolated single plants or very small patches (2 meters x 2 meters) or less.

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
1000	0.25	1,120	17.9	18.9	35.7	37.8
2000	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.

If the length or overall size of a linear infestation is considered too great to represent as a single point, 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, 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.

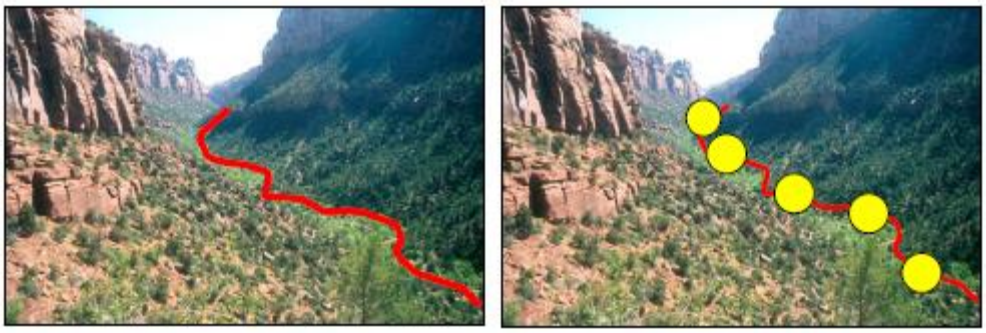


Figure 5.5. To map a linear infestation as a series of points, the surveyor begins by estimating the average width of the nfestation, deciding upon the appropriate point size category, calculating the necessary patch segment length based upon that size category, and then placing a new point each time an infested area of that distance is walked.

If several species are present with similar distributions, 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.

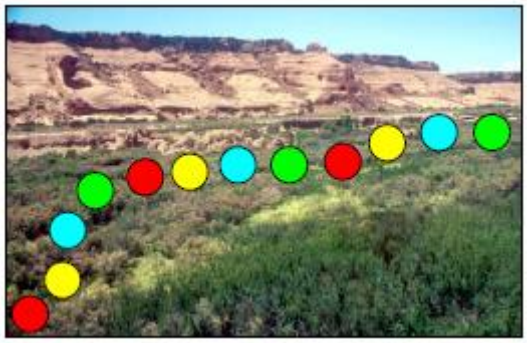


Figure 5.6. Continuous linear infestations of four intermixed weed species mapped as staggered point features. Each point of the same color represents a 0.1-hectare segment of a continuous line of that species.

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 40 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 4 hectares, with a very low density or canopy cover designation (Figure 5.7).

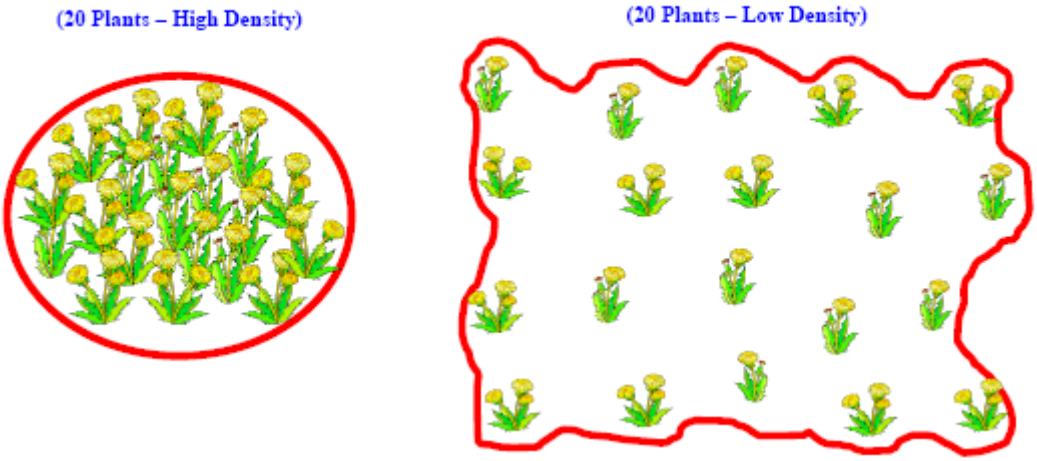


Figure 5.7. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 hectares in size.

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 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50, or majority = 51 to 100 percent. 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 the question “Is the percent cover greater or less than 50 percent?” If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question “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.

Figure 5.8. The percent canopy cover is estimated from within the perimeter of the actual infested area.

4. Qualified surveyors may remove small populations if under a threshold size (*i.e.*, 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)

IV. Field Data Processing

At the end of each day, field crews will mark and date all monitored areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions that are recorded each day are used for reference when marking the topographic maps. Each crew member will keep a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Data are downloaded from GPS units onto a laptop computer each day using Pathfinder Office GIS software. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders are established within the main project folder on the computer hard drive. These are for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consists of rover files that are transferred directly from GPS units to the computer, and stored without any editing or modification. They are named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files are created from raw files that are viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations that are added in the editing process are noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under the differential correction section. Notes are sometimes expanded during the editing process to

include more detailed information about the surrounding habitat. Gross area features are added during this process. File names are changed after editing to avoid confusion with the raw files. Edited files are named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files are then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the monitoring area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension "cor" rather than "ssf". Example: May19-A2.cor.

Shapefiles are created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles are created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photopoint shapefile, and between-feature point shapefile. Three kinds of files are created from each ".cor" file. These are ".shp", ".shx", and ".dbf." Example: pt-weed.shp, pt-weed.shx, ptweed.dbf.

Appendix A: Invasive 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.

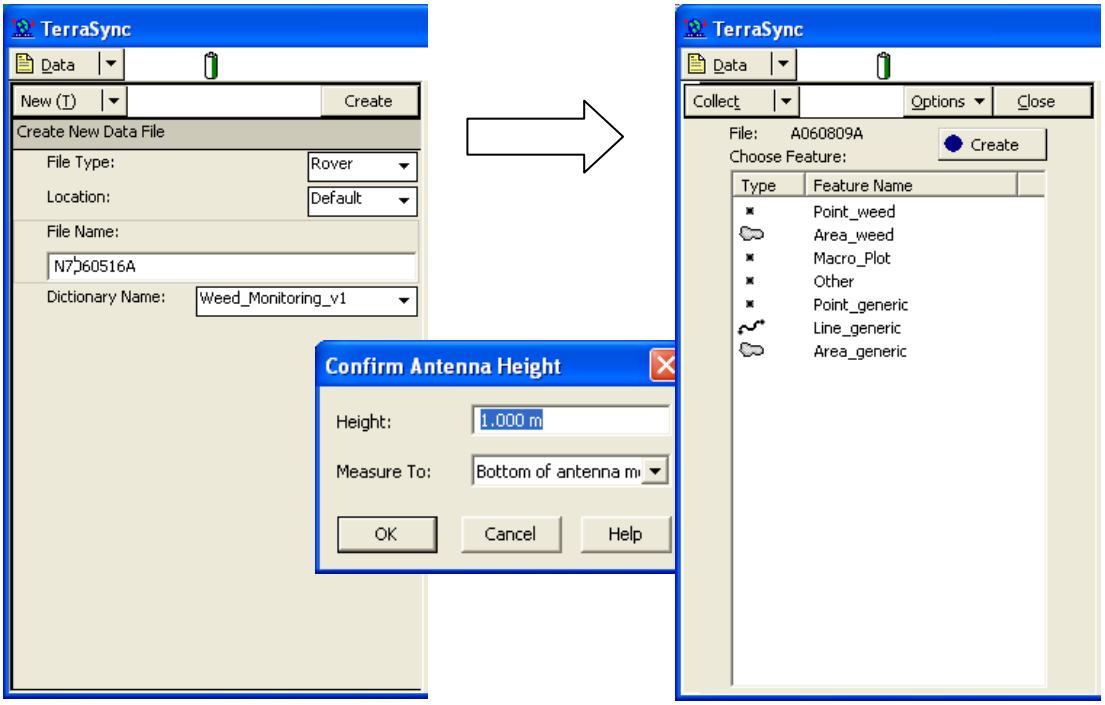
When multiple species are noted within one area (within the PSR, see SOP#5, section 2D) and you are mapping these locations as point features, collect the data for species #1, then walk a step or two, and collect the data for species #2 and continue until one point per species is collected. If mapping 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	Nume ric
PSR	Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#5, sec 2,D)	Entry permitted in the field	Nume ric

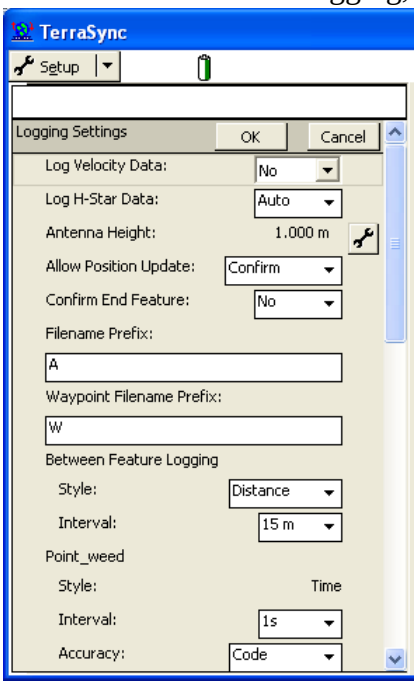
Notes	Any comments regarding the site (can contain species name if "other")	Entry permitted in the field	Text – Optional

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.

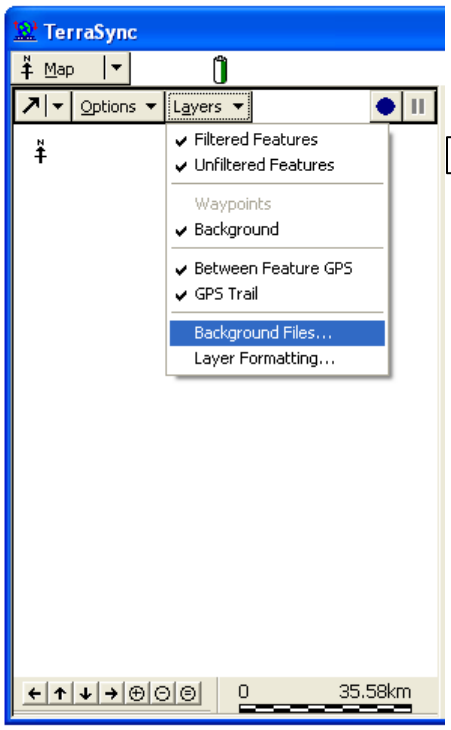


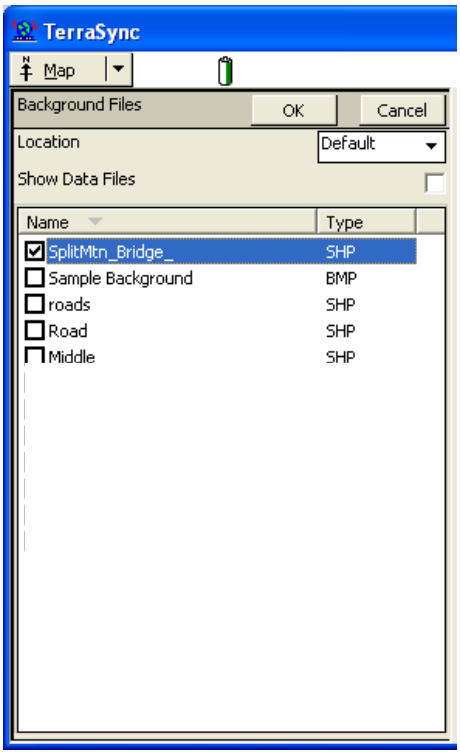
Once a file has been created, you'll need to determine what the EDSW (Effective Detection Swath Width) and then set the Between Feature Logging to that distance. To set the Between Feature Logging, tap the down arrow next to **Data**, and select **Setup**.

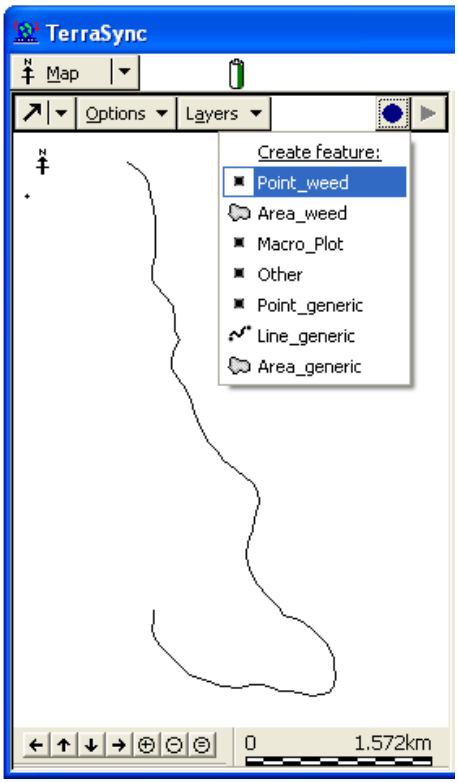


On the **Setup** menu, choose Logging Settings. On the logging settings screen, scroll down until you see Between Feature Logging. For Style, choose Distance and for Interval, type in your EDSW. Tap OK. This sets the Between Feature distance for the file, so you won't have to change it again, unless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

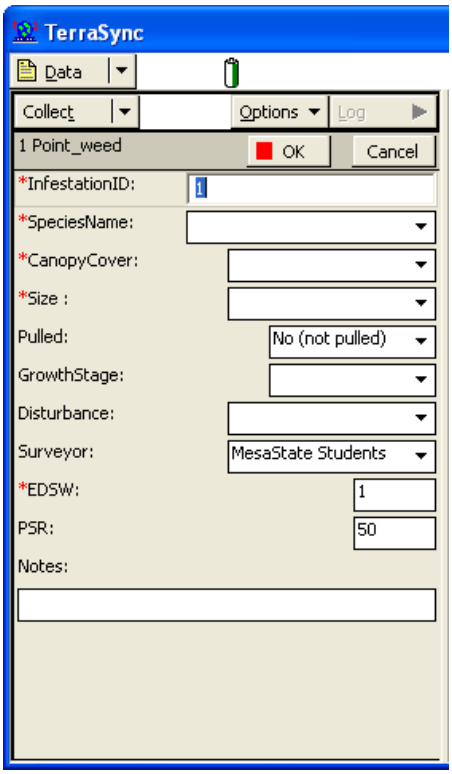






As you begin walking the route, and you come across a species of weed which you need to log, tap the blue dot and your data dictionary will appear. The majority of the time, you'll be using the Point_Weed feature.

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).

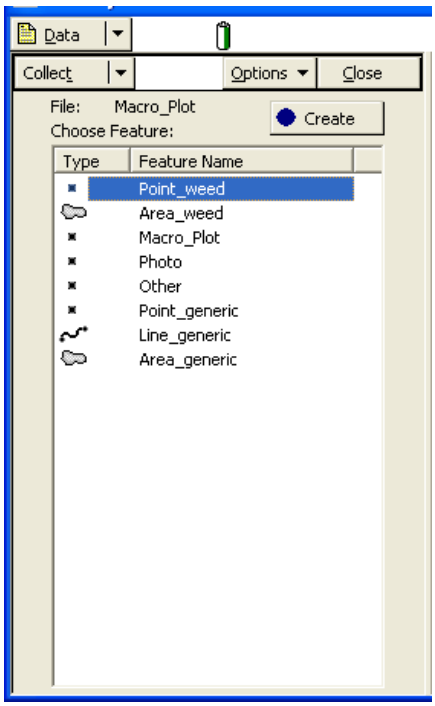
Cancel:
If you began to collect (log) a point and have decided not to, tap the Cancel button while in the data dictionary, and tap Yes to Abandon feature.

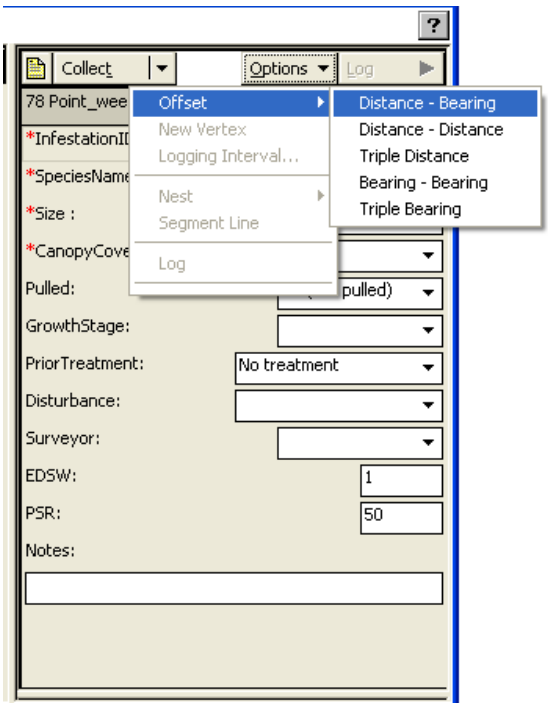
When you've finished recording the data, tap the OK button.

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.

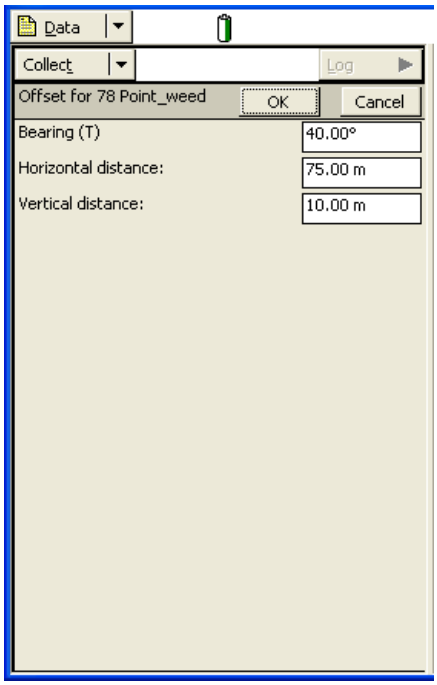
Point Offset

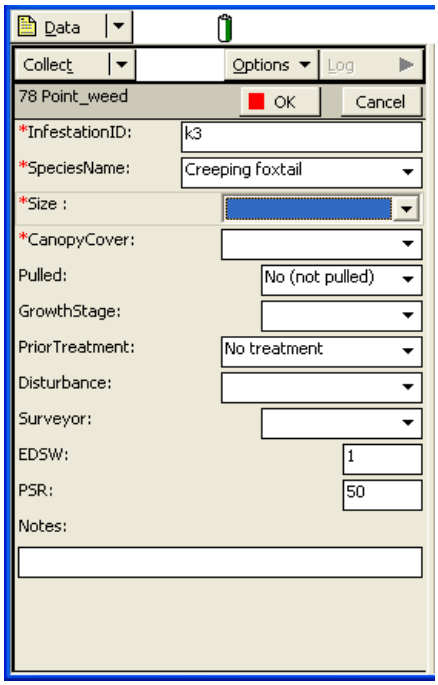
If a weed population is noted in a difficult location (such as across a drainage/river), but you'd like to log the species you see there, you can do that with the Offset feature. Create the Point_Weed feature and tap the Options dropdown menu. Select Offset/Distance – Bearing.





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.

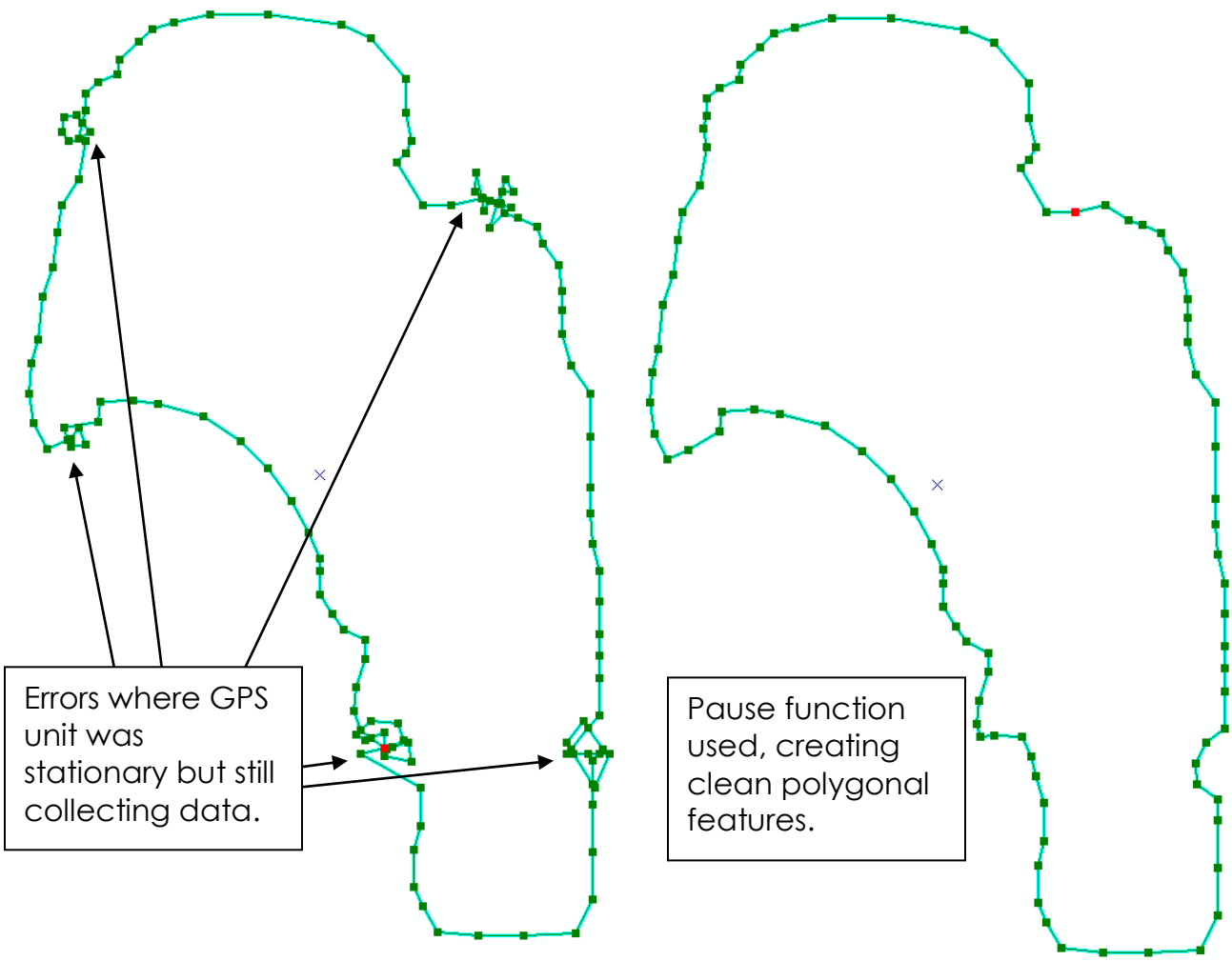




There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (the location of your vehicle, an archaeology site, etc.), use the Other feature point, and type in a comment regrading that location.

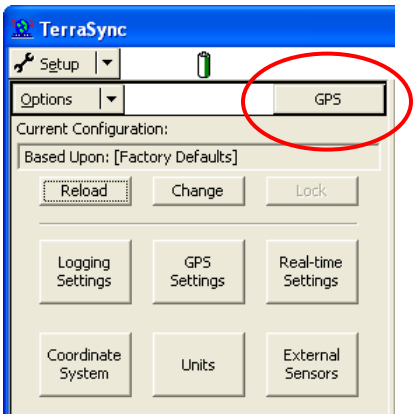
GPSing Areas

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.

Invasive Exotic Plants Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 6

Using Global Positioning System (GPS) Units

Version 1.04 (June 2013)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	7/8/2009	Wight	Macroplot to transect	Methodology changed	1.01
1.01	6/29/2010	Wight	Added EDSW feature, deleted Area_weed feature, other minor edits	Need for tracking EDSW	1.02
1.02	6/4/2012	Wight	Updated App A, and added SD card data backup instructions	Software changes	1.03
1.04	6/6/2013	Wight	Added instructions for data collection when satellites not available.	Catching infestation data in data dictionary when GPS can't see satellites	1.04

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 compliment, 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 as well as 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 these invasive exotic infestation 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 (such as Leica etc.).

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 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	NAD 1983 (Conus) CORS96

Name	Definition	Standard
	point on the earth's surface to the ellipsoid.	
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 as well as assuring 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:

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

EDSW (Effective Detection Swath Width) Feature

This feature point is used to record the EDSW (Effective Detection Swath Width) 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 (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

Point_Weed Feature

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 PSR, see SOP#3, section 2E) 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
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 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

Point_weed	Attribute Explanation	Entry	Type
Disturbance	Disturbances noticed at the site: • Grazing Impact • Livestock • Tamarisk beetle • Insect disturbance • Flooding • Hiking trails • Human occupation • Recreation use • Roads/OHV Trails • Prehistoric occupation • 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
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

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, section 4, A). 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

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, as well as allowing 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 section 4, A). 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 layer necessary 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 do 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 infestation, it's time to collect the GPS locations necessary (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 (i.e. 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. If this method was necessary, be sure to pass on your field maps to the GIS technician so those populations can be added to the final data.

Each crew member will keep a daily log of where they traversed what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. This data will be used when QC-ing the data.

At the end of each field day, each GPS unit used should be backed up using SD cards to prevent loss of data. 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 App. A, 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. Table 2 indicates the attributes to capture while exporting the corrected GPS data into a GIS data format ("turn on" in Pathfinder Office).

Table 2 GPS Auto-generated Attributes to Capture

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

Data should be exported using the same coordinate system used in the field (UTM, NAD83 (Conus) CORS96, 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 downloaded and differentially corrected field data will be QA/QC'd by the project lead and GIS technician at the end of each field excursion to catch any edits or additions necessary (ex. areas drawn on field maps when satellite reception was not possible).

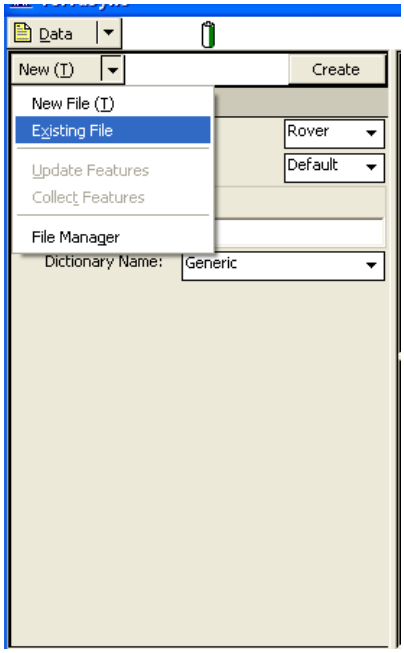
1.7 Uploading to the working Invasive Database

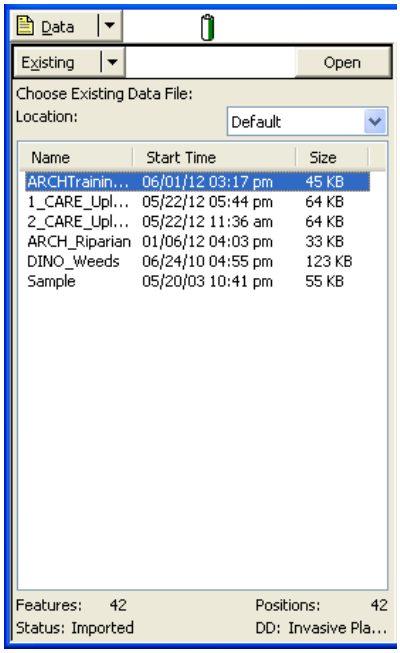
Once the GPS field data is validated and verified (GPS points given a visual review, additions added, attributes checked and corrected if necessary) in ArcMap, the data is ready to be uploaded into the working Invasive Database. The GPS data is exported from ArcMap into an Excel spreadsheet for importing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

2 Appendix A

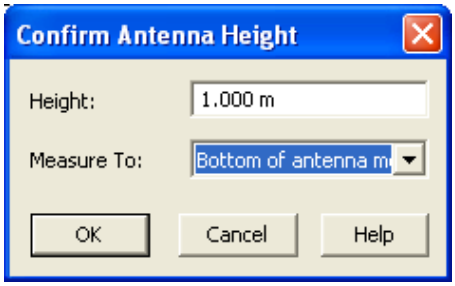
2.1 Beginning Invasive Exotic Plant GPSing

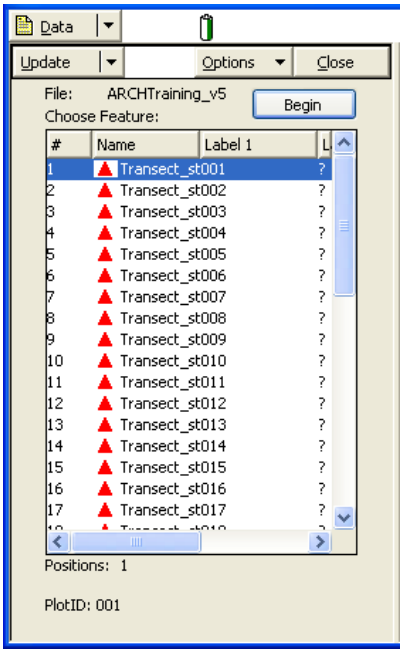
Open TerraSync. To open the transect start points, from the opening satellite status screen, choose Data/Existing File. Choose the file ("ARCHTraining", in this example) and tap the Open button.



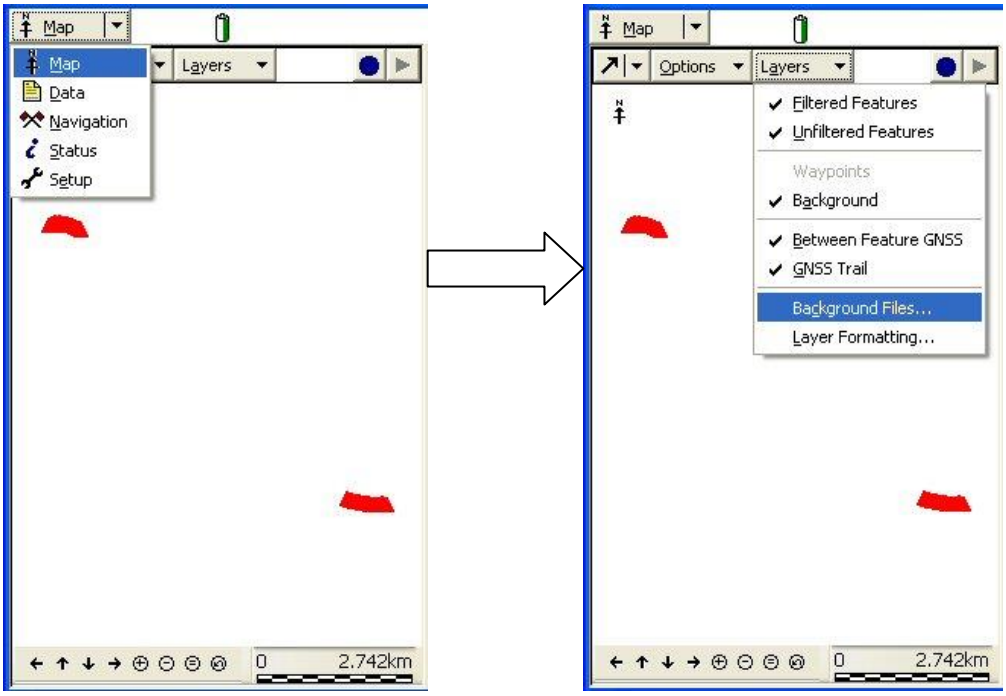


The Confirm Antenna Height window will appear, enter 1.000 m for Height, and choose "Bottom of antenna mount" for the Measure To: portion. Once you've set this, most of the time you can merely OK this window. A list of all the predetermined locations of transects will then appear.

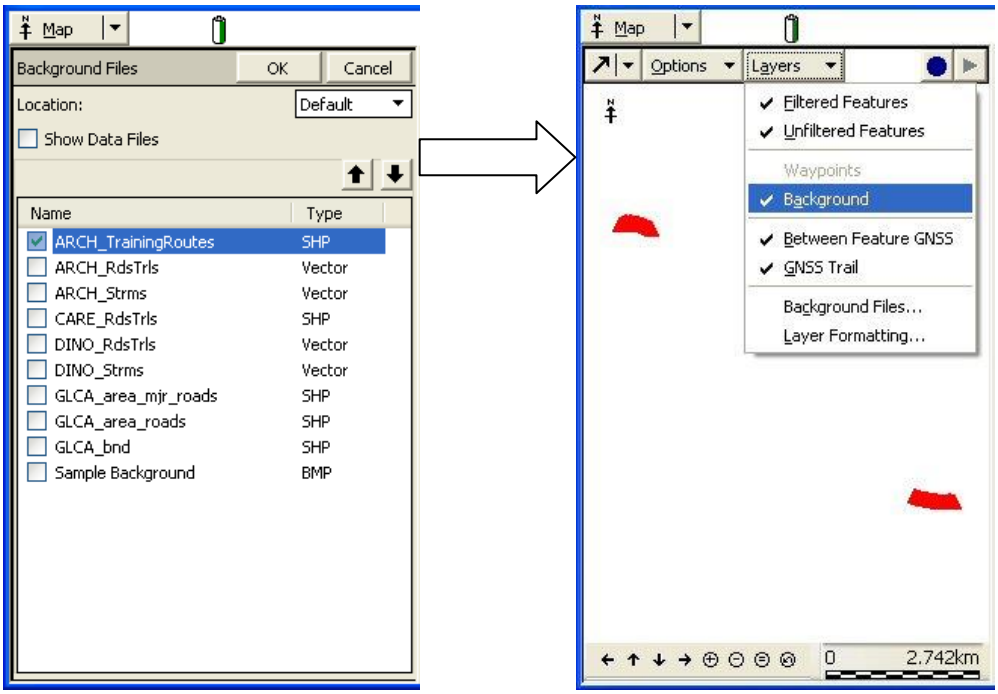




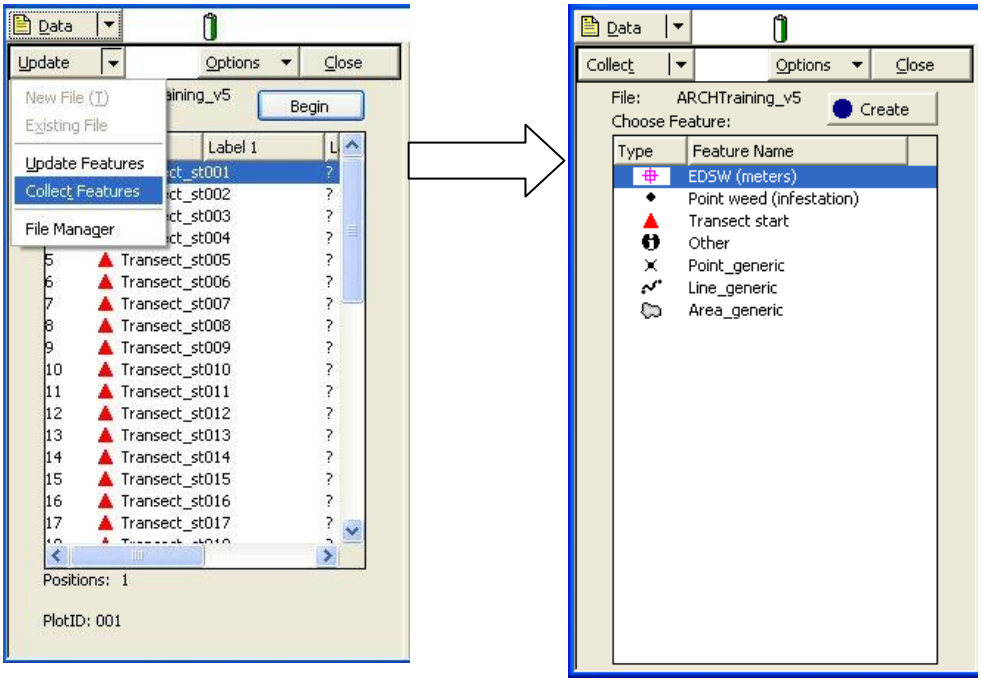
To set up the background layers to assist in navigation, choose Map from the upper left menu button. Then tap on the Layers menu button, and choose Background Files:



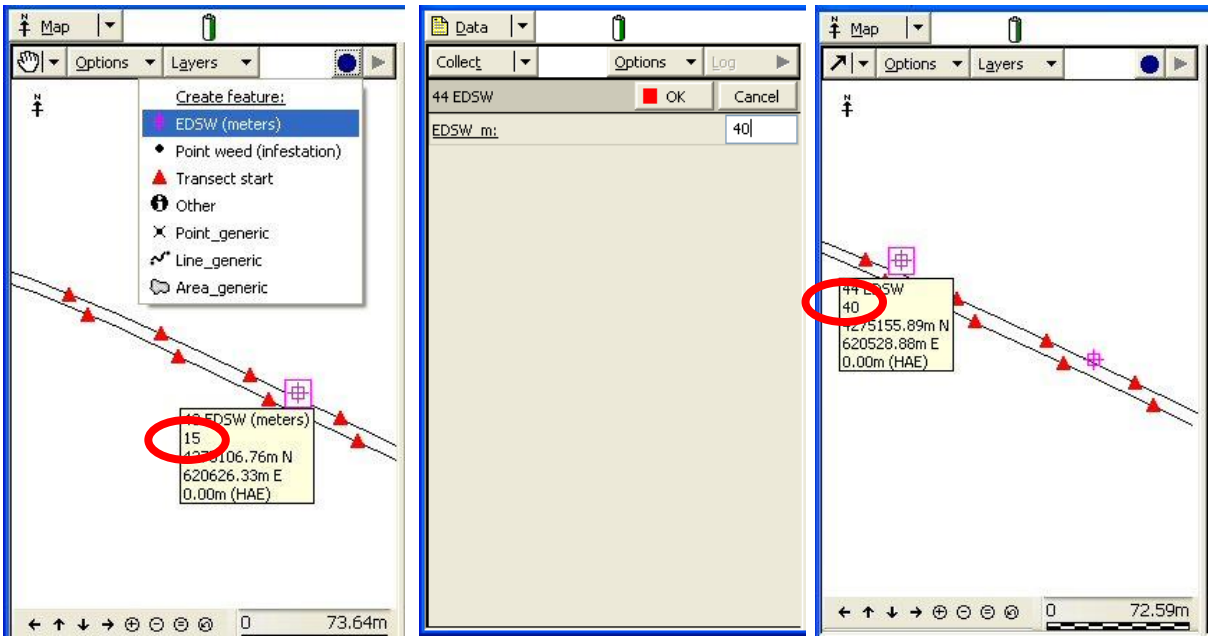
Check the check box next to the layer file(s) you need displayed and click OK. Make sure on the Layers menu that Background is checked; if not, merely tap it to check it. Then your background layer(s) will appear on your map screen:



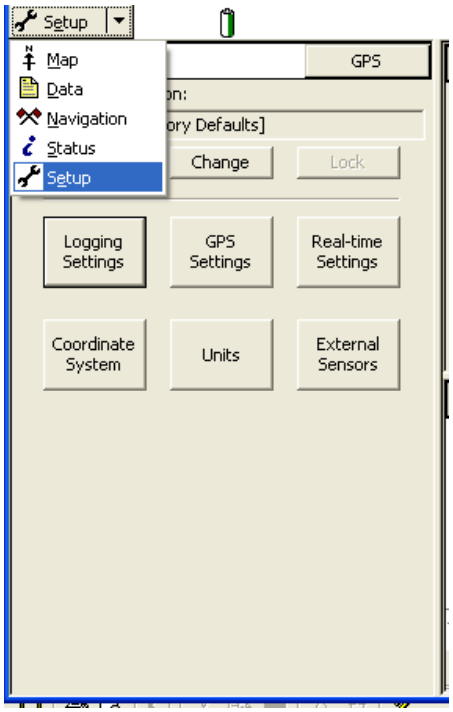
Tap the Data screen, and the list of transects appears. Change the function from Update to Collect features (the drop down list under the top left button). This will change the screen to display the features in the Invasive Data Dictionary:

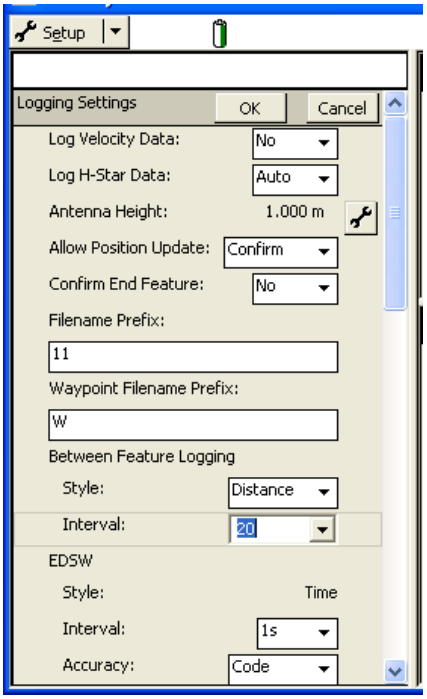


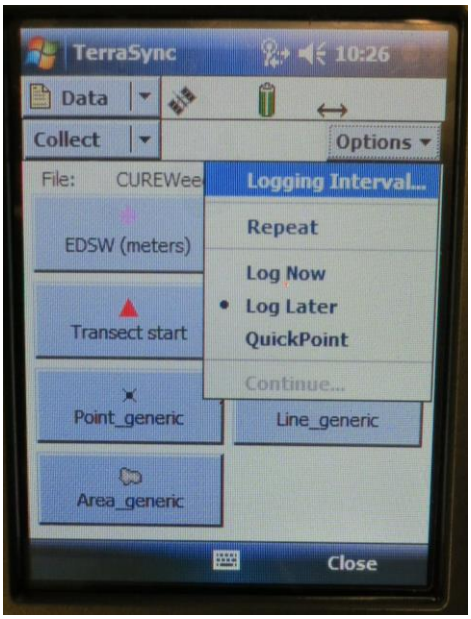
The first feature listed in the data dictionary is an EDSW feature point. When you begin your weed monitoring route, create and log a point. Within the data dictionary, merely type in the EDSW (in meters) for the route. As you traverse along a given route, whenever the EDSW changes, log a quick EDSW 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.



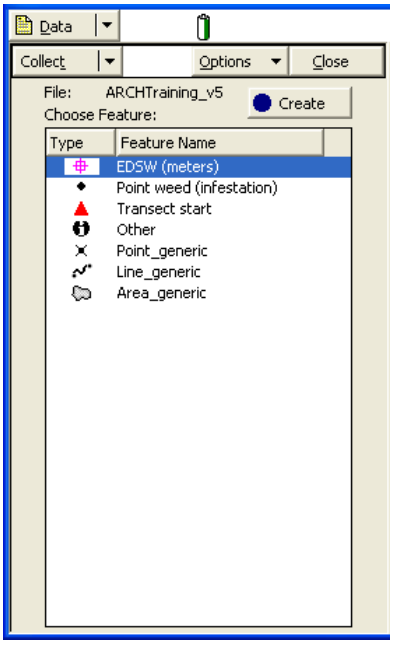




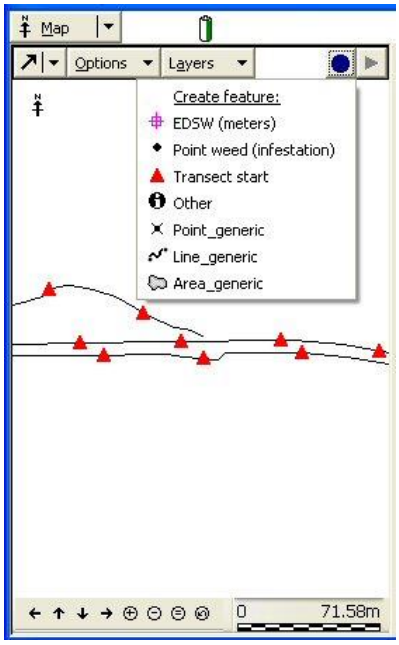
To toggle between logging as soon as the feature from the data dictionary is tapped (Log Now) to needing to tap the Log button (Log Later), choose the Data Screen/Collect. Then from the Options button, you can choose your preferred method of data collection. This is also where you can turn On and Off the Repeat function.

2.2 Collecting Point Weed features

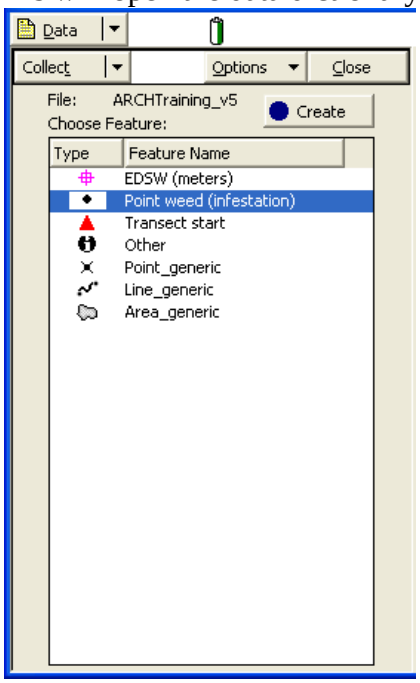
Now you're ready to collect GPS data. A lot of the data you'll be collecting will be Point_Weed data. There are two ways to reach the data dictionary – you can choose Collect Features from the Data screen, or use the blue dot/circle on the Map screen.

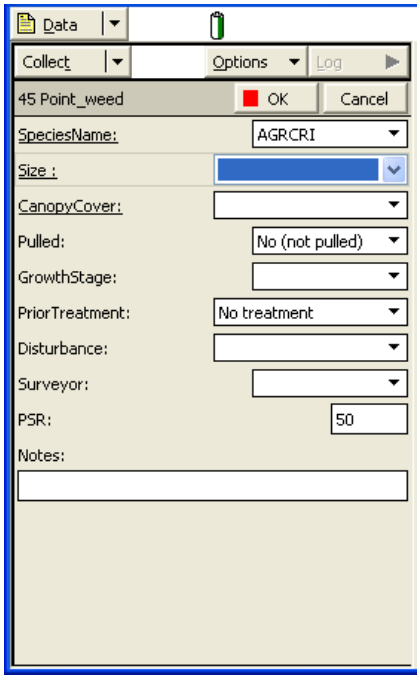


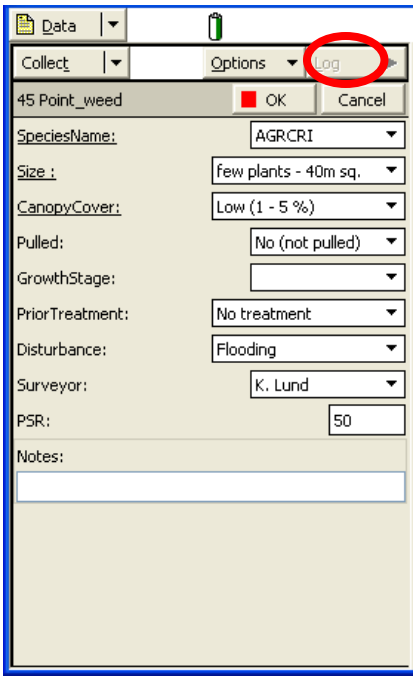
OR



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





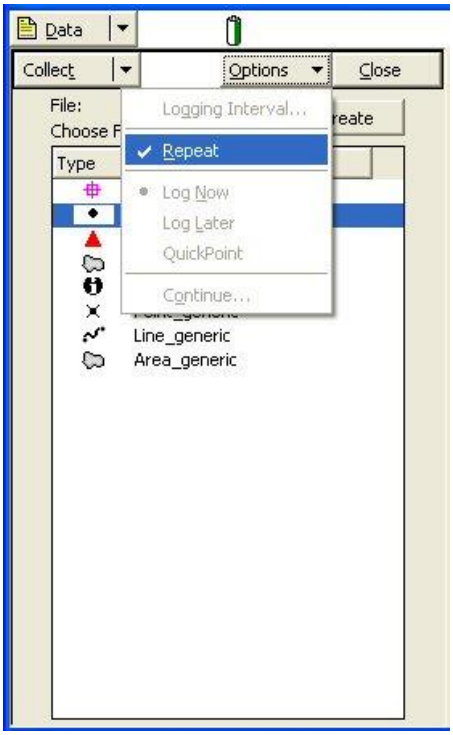


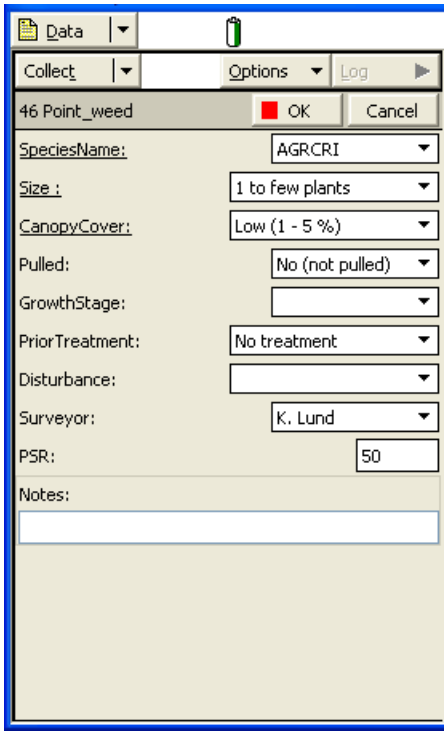
Please note that the items which are required are displayed as underlined; this means that you **must** fill in *at least* those items before TerraSync will allow you to close the feature and move on.

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.)

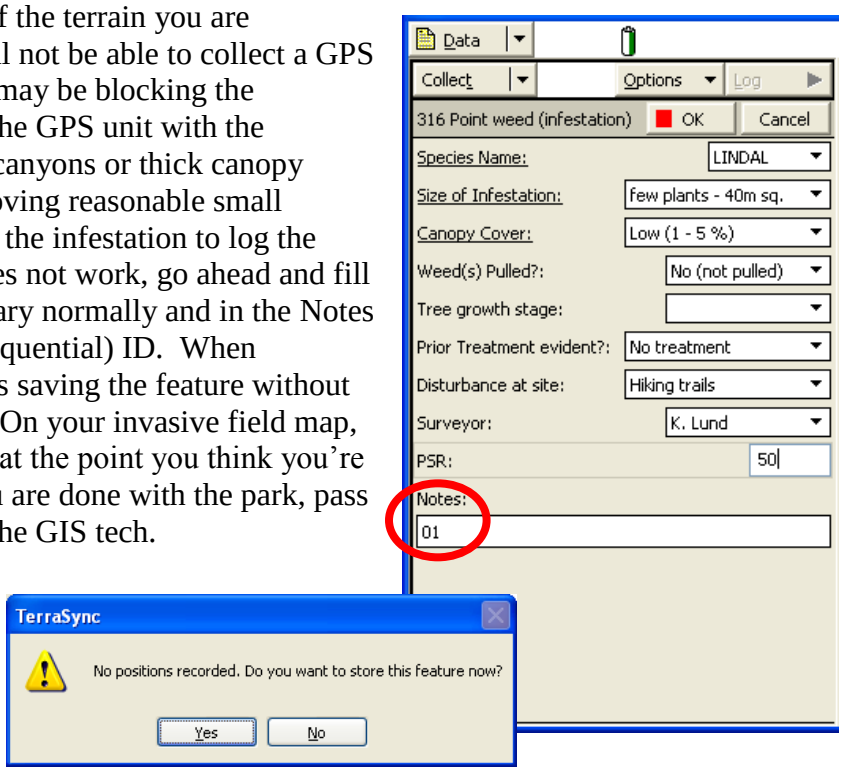
If TerraSync gives you the message "Unable to append to a file over one week old", close the file and open the next numerical file contained on the GPS (something like 2DINO_weeds).

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.



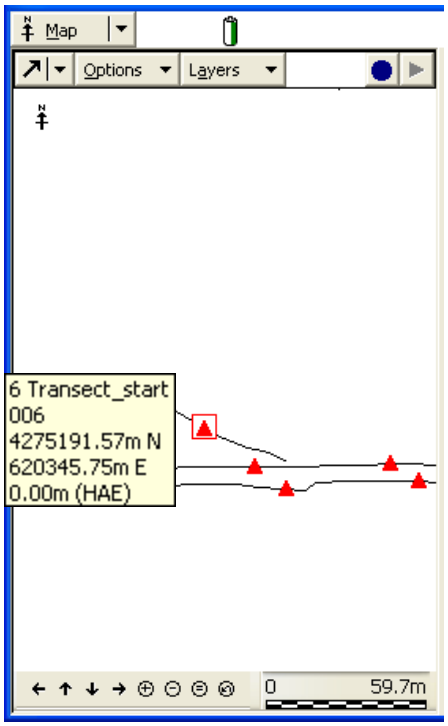


At times, because of the terrain you are monitoring, you will not be able to collect a GPS point as the terrain may be blocking the communication of the GPS unit with the satellites (i.e. tight canyons or thick canopy cover). First try moving reasonable small distance away from the infestation to log the location. If that does not work, go ahead and fill out the data dictionary normally and in the Notes section, add in 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 you think you're located. When you are done with the park, pass your field maps to the GIS tech.

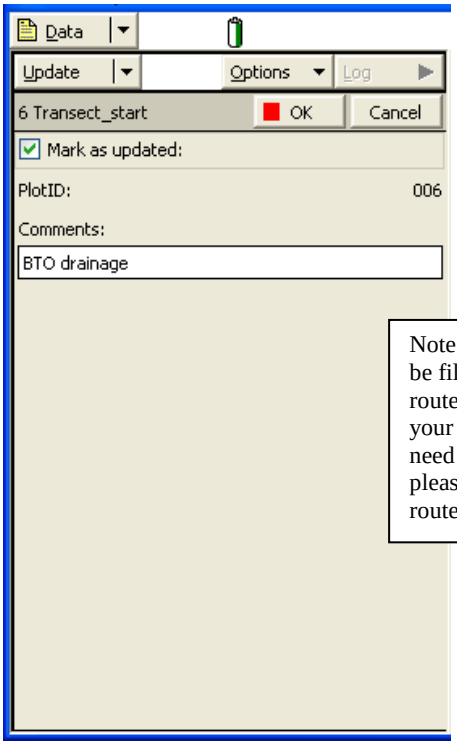


2.3 <u>Logging Transect Starts</u>

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 for which you collect field data, 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:' check 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.

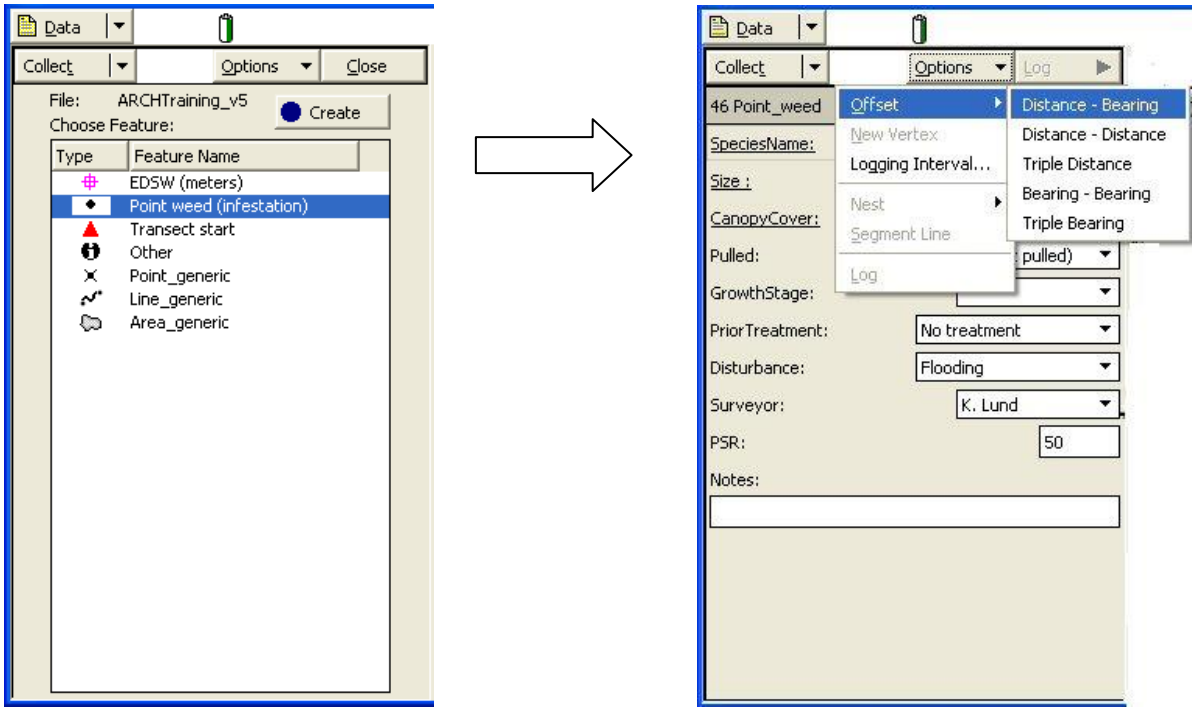
Note: The Comments field may be filled in with the monitoring route name. This data is here for your benefit, but if you feel you need to write in a comment, please do so. Maintaining the route names is not necessary.

2.4 Other Data Dictionary Features

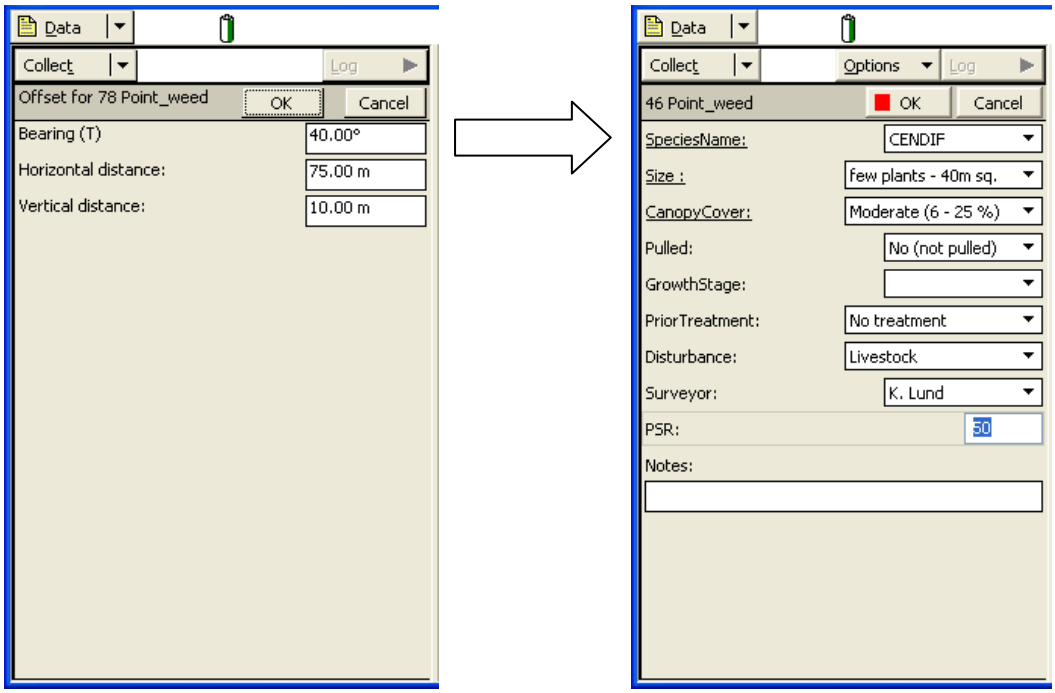
There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (the location of your vehicle, an archaeology site, etc.), use the Other feature point.

2.5 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.

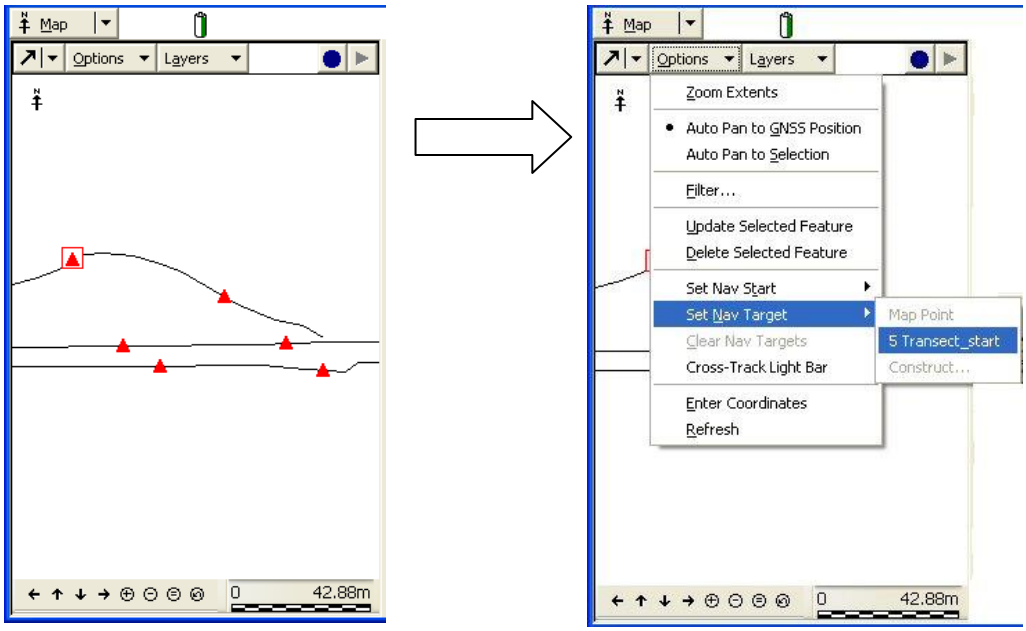


The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location.

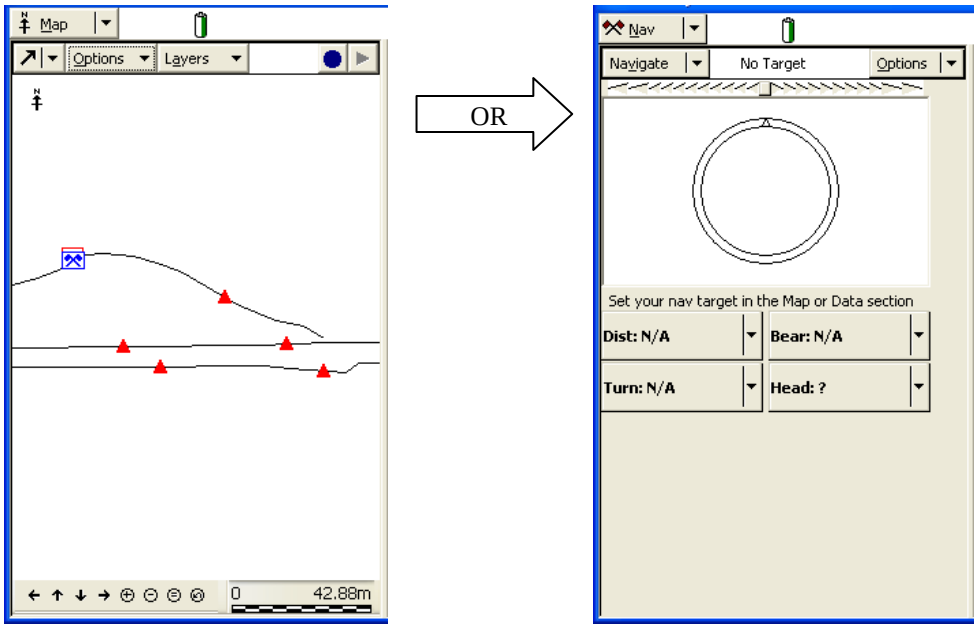


2.6 Navigation

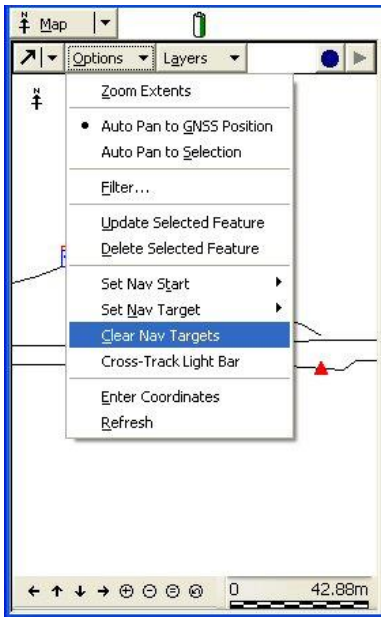
As you traverse along a monitoring route, knowing where to stop to collect the transect and quadrat data is important. Locations 500 meters apart have been generated in the office to assist you in knowing where to collect the transect data.
From the map screen, select (note square box around point) the 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 5ish meters), an alarm will sound (if you have the sound turned on) and the screen will change from a compass to a bullseye map.



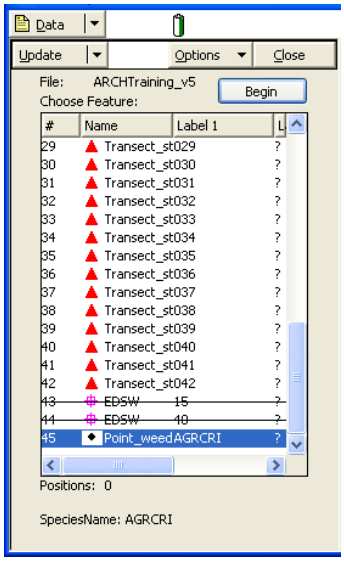
To clear the navigation target, tap the Options button, then tap Clear Nav Target. Now you are ready to set a new navigation target.

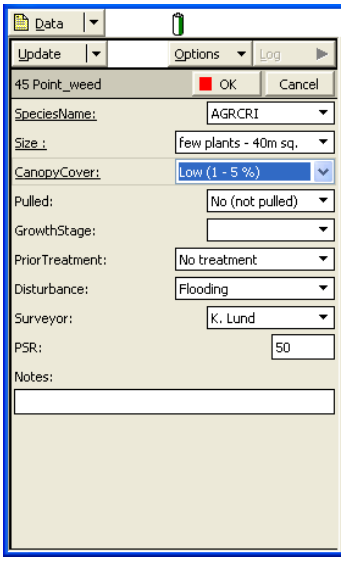


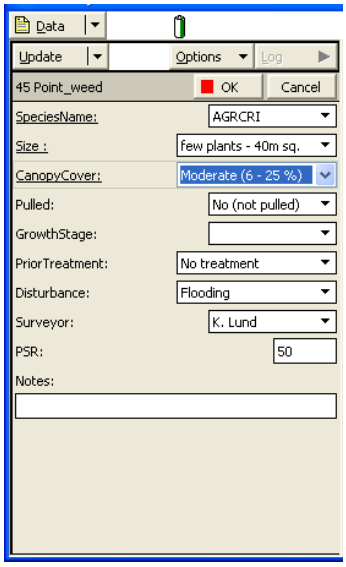
> **TIP:** When viewing the map screen, if you tap and hold on a point, a menu will appear, allowing you to Update, Delete or Set Target. If used to Set Target, you will still need to clear the target under the Options menu.

2.7 Editing a feature

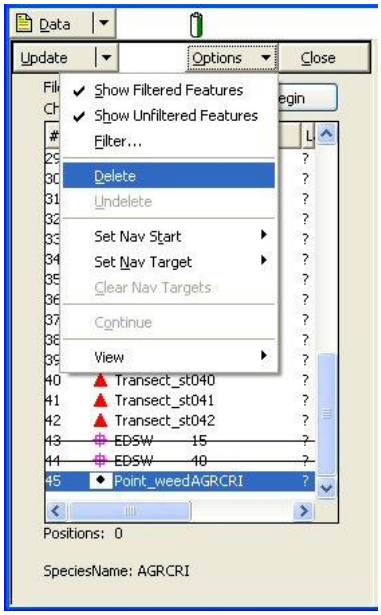
If you need to edit a point that you've already GPSed and closed, you may do so by "Updating" the feature. On the dropdown menu in the upper left, choose Data. In the menu right below, choose Update. A list of the features logged will show up. Double tapping a feature will open the data dictionary, allowing 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.

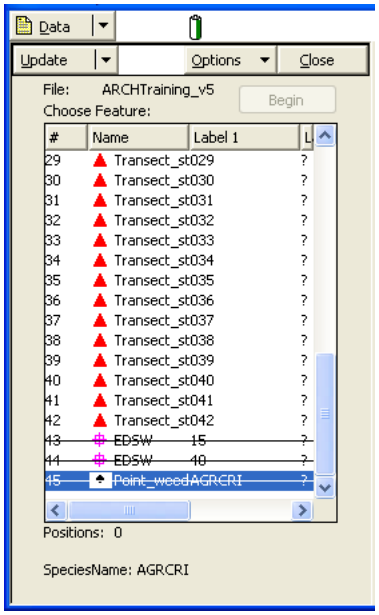






You may also like to delete a point, which is possible from the Update menu as well. Tap Options Menu and choose Delete. The feature will have a line through it, and the deleted feature will not appear on the Map screen. You may also Undelete a feature as well.

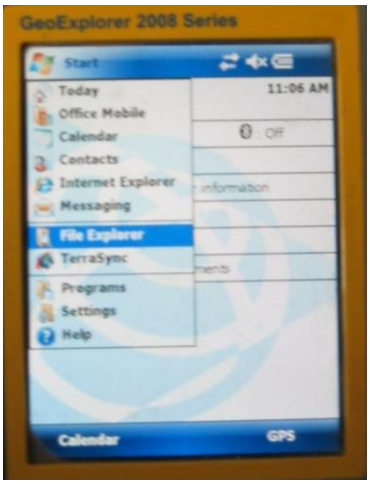


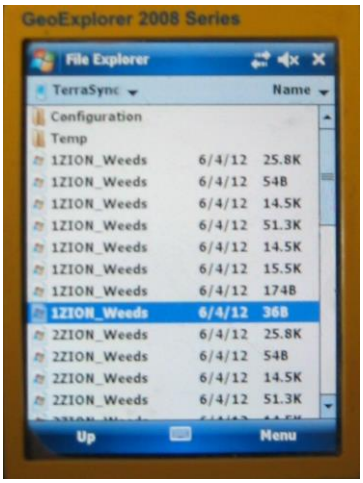


2.8 Backing up GPS data

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.

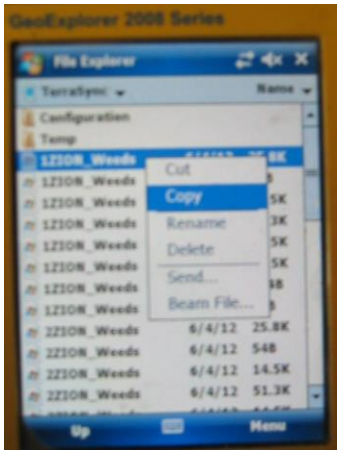
Once TerraSync and the GPS file are closed successfully, from the Start menu, open File Explorer. Navigate to the My Device/My Documents/TerraSync folder.



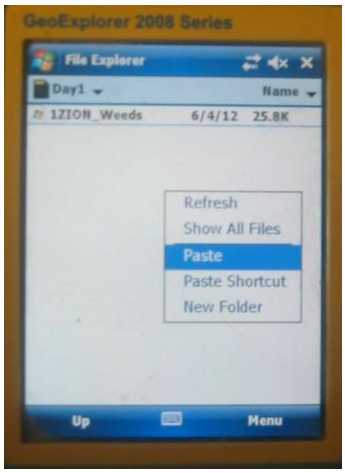


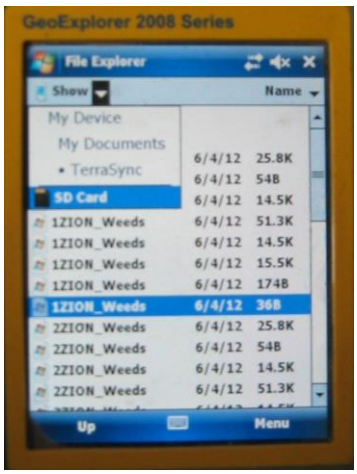
You will see that each file you see inside TerraSync is made up of eight (8) files. In order to back these files up, **each of those 8 files will need to be copied to the SD card**.

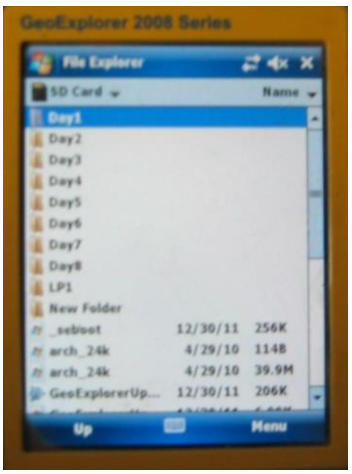
Tap and hold the stylus on a file piece, and a menu will come up. Choose Copy (unfortunately, each of the eight files will need to be copied and pasted individually).



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.



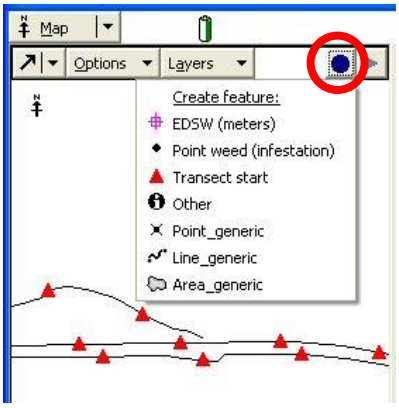




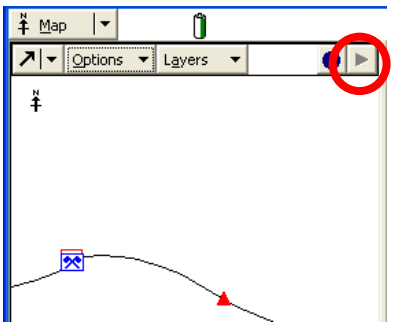
By copying (rather than cutting), you will still be able to use the file in TerraSync the next day.

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.

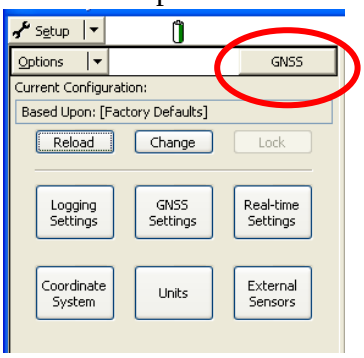
2.9 <u>Other Tips:</u>



- 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 do 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, walk through the infestation, and 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 on/off the Between Feature Mapping. Generally, the Between Feature feature should be on, but if you're in camp or something, 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 loose 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 the Juno.
- 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 on 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 or something. 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.

Invasive Exotic Plant Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 7

Data Management

Version 1.01 (December 2012)

Revision History Log:

Prev. 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

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).

1 Definitions and Acronyms

NPS	National Park Service
NCPN	Northern Colorado Plateau Network
I&M	Inventory & Monitoring Program of the National Park Service
SOP	Standard Operating Procedure
GIS	Geographic Information Systems
GPS	Global Positioning System
IEP	Invasive Exotic Plants
BFP	Between Feature Position
EDSW	Effective Detection Swath Width
PDF	Portable Document Format
TIFF	Tagged Image File Format
JPG	Joint Photographic Experts Group File Format
DLL	Dynamic Link Library
FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
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.
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.
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.
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.
Certified data	Finalized project data, i.e., data that have undergone thorough quality assurance and screening as well as complete documentation.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time). This might be the only database for short-term projects where there is no need to distinguish working data for the current season from the full set of validated project data.
Master database	Project-specific database for storing the full project data set, used for viewing, summarizing, and analysis. Only used to store certified data.
Data products	Information that is derived from certified project data.
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 Natural Resource Information Portal (NRInfo).
Quality assurance (QA) procedures	Procedures used to maintain a defined level of quality throughout all stages of data development.
Quality control (QC) procedures	Procedures used to monitor or evaluate the quality of data products.

2 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 XP or Access 2003 (it has not yet been tested with Access 2007). It has a frontend/backend file structure:

- *Invasives.mdb*: This frontend file contains all queries, forms, reports, and associated Visual Basic (VB) application code.
- *Invasives_be.mdb*: 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 invasives 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. Figure 1 shows the relationships between the primary IEP database tables (all tables are not shown).

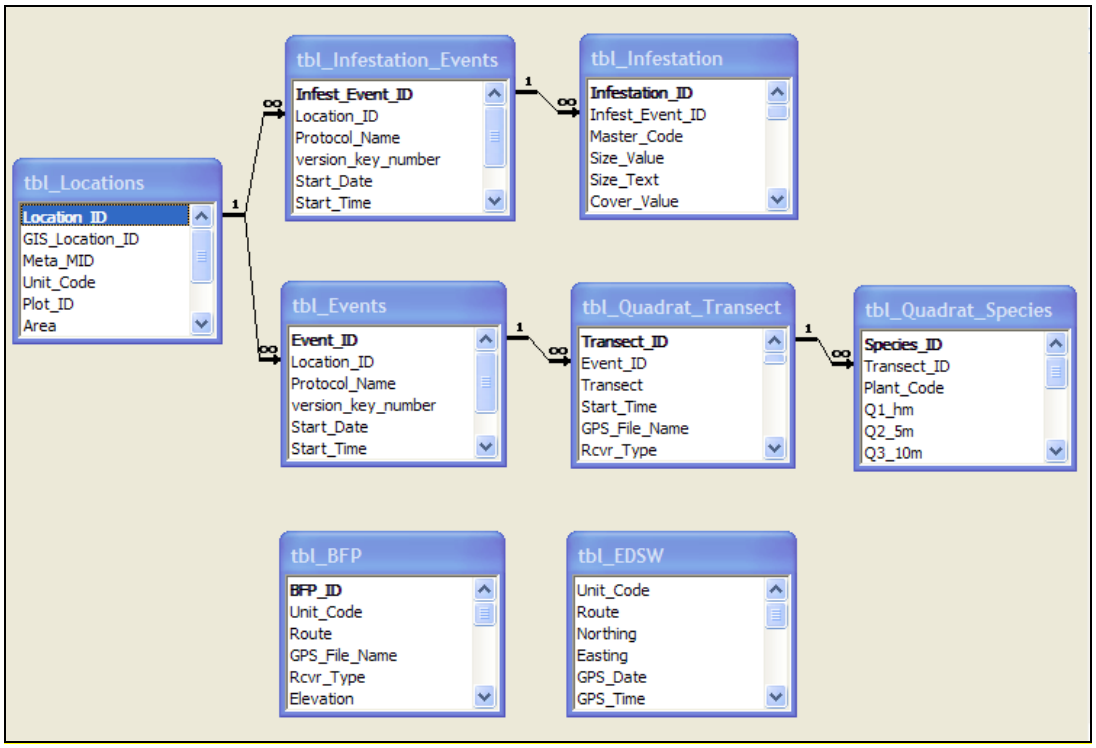


Figure 1 Data Model for IEP Database

IEP monitoring is conducted along routes, and 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 monitoring transect:

- **Infestation**: For infestations, each unique combination of route and start date represents an 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.
- **Monitoring Transect**: For monitoring transects, each unique combination of route and start date represents an event and is stored in *tbl_Events*. An event can have one or more transects associated with it. Each transect has a record in *tbl_Quadrat_Transect*, which stores the measurements recorded on the transect (e.g.,

microhabitat data), along with the location of the transect. Each transect can have one or more invasive plant species associated with it. Each invasive plant species has a record in *tbl_Quadrat_Species*, which stores the percent cover information for the species.

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. Furthermore, each event is linked to tables *tbl_master_verison* and *tbl_SOP_version* (not shown in the figure), which together define the narrative and suite of SOP versions in effect at the time of the site visit.

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

3 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, i.e., 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 certified, 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.

3.1 Data Import

Since 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), and effective detection swath width (EDSW) points.

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

1. Link park GPS data file: Link the park GPS data file containing the data to be imported to the IEP backend database file.
2. Import monitoring routes: Run frm_Load_Route_Event. Select worksheet corresponding to transects as input table and click "Load Routes" button. Data will be loaded into *tbl_Locations*.
3. Import monitoring transect events: Run frm_Load_Route_Event. Select worksheet corresponding to transects as input table and click "Load Events" button. When prompted for the event type, choose "transect events". Data will be loaded into *tbl_Events*.

4. Import monitoring transects: Run frm_Data_Import. Select worksheet corresponding to transects as input table and click "Import Transect Data" button. Data will be loaded into *tbl_Quadrat_Transect*.
5. Import infestation routes: Run frm_Load_Route_Event. Select worksheet corresponding to infestations as input table and click "Load Routes" button. Data will be loaded into *tbl_Locations*.
6. Import infestation events: Run frm_Load_Route_Event. Select worksheet corresponding to infestations as input table and click "Load Events" button. When prompted for the event type, choose "infestation events". Data will be loaded into *tbl_Infestation_Events*.
7. Import infestations: Run frm_Data_Import. Select worksheet corresponding to infestations as input table and click "Import Infestation Data" button. Data will be loaded into *tbl_Infestation*.
8. Import BFP data: Run frmLoadBFPEDSW. Select worksheet corresponding to BFPs as input table, select park, and click "Load BFP Records" button. Data will be loaded into *tbl_BFP*.
9. Import EDSW data: Run frmLoadBFPEDSW. Select worksheet corresponding to EDSW points, select park, and click "Load EDSW Records" button. Data will be loaded into *tbl_EDSW*.

Before any data entry can begin, the monitoring routes and associated events/transects must be present in the database. Thus, steps 1-4 above must be completed prior to data entry.

3.2 Data Entry

Only a small portion of data in the IEP database will be populated via data entry. Table 1 lists these database fields.

Table 1 Database fields entered manually

Event-related fields (tbl_Events):
Observer
Comments
Transect-related fields (tbl_Quadrat_Transect):
Start_Time
Observer
Comments
Microhabitat fields (percent cover):
Dead_Wood_Q1… Dead_Wood_Q3
Dung_Q1… Dung_Q3
Fungus_Q1… Fungus_Q3
Lichen_Q1… Lichen_Q3
Litter_Duff_Q1… Litter_Duff_Q3
Root_Bole_Q1… Root_Bole_Q3
Dead_Root_Bole_Q1… Dead_Rood_Bole_Q3
Mineral_Soil_Sediment_Q1… Mineral_Soil_Sediment_Q3
Moss_Q1… Moss_Q3
Cryptogram_Q1… Cryptogram_Q3
Road_Q1… Road_Q3

Rock_Q1… Rock_Q3
Standing_Water_Flooded_Q1… Standing_Water_Flooded_Q3
Stream_Q1… Stream_Q3
Trash_Junk_Q1… Trash_Junk_Q3

Species-related fields (tbl_Quadrat_Species):
Plant_Code
Species fields (percent cover)[1]:
Q1_hm
Q2_5m
Q3_10m

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 makes certain 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 forms 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 Section 4.

4 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-NPS 2008a). *Data verification* checks that data entered into a secondary (i.e.,

[1] Although not listed here, a different set of percent cover fields is maintained for each year prior to 2010 since measurements were recorded differently. Refer to Appendix A for a complete list of database fields. Refer to the 2008 and 2009 versions of the protocol for details related to the methods used in those years.

electronic) format match the source data, while *data validation* checks that the data make sense.

4.1 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).

4.2 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 since field sheets or other sources of data could easily be overlooked.

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

4.3 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 (refer to Section 7 for details on metadata). 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 project data certification 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 project data certification form will be completed by the project manager to indicate that the data are complete, they have passed quality assurance checks, and they are documented and ready for archiving, posting and distribution. The data certification form can be found in the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a). The data quality documentation and data certification form will be stored in the IEP project archive folder.

5 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 Section 6 for data archiving details), directory structure conventions, backup procedures (refer to the user's guide in Appendix B), and database versioning.

5.1 Directory Structure Conventions

NCPN has adopted directory structure conventions for I&M project folders (NCPN-NPS 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**:
    - **Backup**: Contains one or more backup copies of database files made during data entry (not retained permanently).
    - **Current**: Contains the working database (current year data) and user's guide.
    - **Master**: Contains a copy of the master database (complete data record) to be used for analysis and reporting (the master database is stored in the invasives archive folder).
  - **Field_Forms**: Contains scanned field forms for current year.
  - **GPS_Downloads**: Contains corrected GPS data for current year.
  - **GIS_Data**: Contains GIS 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 certification form, data quality documentation (refer to Section 7 for more details on the project data life cycle).
- **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 operational 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-NPS 2007b).

5.2 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, etc). 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 Section 6).

6 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 data have been certified and annual report completed. Archiving of certain data may occur more frequently, e.g., if a protocol version change occurs. Archiving will be done for both digital and hard copy data.

6.1 Digital Data Archiving

All digital IEP data will be archived on the NCPN read-only shared drive (R:) in the IEP archive folder (R:\Archive\Monitoring_Archive\Invasives\). Table 2 lists the IEP monitoring digital data files that require archiving, along with their respective archive folder locations. The digital files listed in Table 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-NPS 2010).

Table 2 IEP Digital Data Archiving Summary

Data Product(s)/ File(s)	Archive Location[2]	Comments
Database	Data\<*year*[3]>\Database\	• Contains certified database files for a given year, master database files, and metadata
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*[4]>\	• 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

6.2 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-NPS 2010). Table 3 lists the IEP monitoring hard copy data files that require archiving, along with a summary of archiving procedures. Digital copies of applicable items in Table 3 are also provided to parks for their working files.

[2] Archive location is relative to R:\Archive\Monitoring_Archive\Invasives\ unless stated otherwise.
[3] <*year*> indicates year in yyyy format.
[4] <*version*> indicates protocol version key number, e.g., Version_Key_1

Table 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 and provided to parks as working copies.
Reports	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office and provided to parks included in IEP monitoring project.
Protocol	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Digital copies provided to parks included in IEP monitoring project.
Protocol review	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.
Photos	• Slides or selected prints stored in NCPN archives at WACC. • Digital copies retained in NCPN office and provided to parks included in IEP monitoring project.
Data/metadata Printouts	• Archival copies of project-level metadata stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Digital copies provided to parks included in IEP monitoring project. • 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. • Hard copies retained in NCPN office. • Digital copies provided to parks included in IEP monitoring project.

7 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, NRInfo References, and protocol version information.

To comply with NPS metadata requirements, metadata for IEP datasets will be created following NCPN metadata procedures (NCPN-NPS 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 NRInfo Reference Application. The NRInfo 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 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-NPS 2007a).

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

Table 4 Summary of Metadata Tasks for IEP Monitoring Data

Dataset/ Data Product	NRInfo Dataset	Dataset Catalog	X-Ref Citation	PDLC Check-list	NRInfo Ref	MVT	Photo DB	DB Doc
Database	X	X		X				X
GIS Data			X	X				
Report(s)			X	X	X			
Protocol			X	X	X	X		
Photos			X	X			X	
Field Forms			X	X				

Table 5 Metadata Task Descriptions

Metadata Task	Metadata Task Description	Reference(s)
NRInfo Dataset	An NRInfo Reference (Dataset type) is created and then updated annually.	Metadata Guidance Document (NCPN-NPS 2007c), NRInfo Reference Application Documentation & Help Manual
Dataset Catalog	A Dataset Catalog record is created.	Dataset Catalog Guidelines (Appendix C, Beer et al 2005)
X-Ref Citation	A cross reference citation is added to the project level metadata record.	Metadata Guidance Document (NCPN-NPS 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-NPS 2007a), Project Tracking Guidance Document (NCPN-NPS 2008b, in development)
NRInfo Ref	An NRInfo Reference (usually Published Report type) is created.	NRInfo Reference Application Documentation & Help Manual
MVT	The Master Version Table is updated as needed.	Protocol Versioning Guidance Document (NCPN-NPS 2009)
Photo DB	Photo records are added to the NCPN Photo Database.	Photo Management Guidance Document (NCPN-NPS 2008c)
DB Doc	Database table and field documentation is updated as needed.	Appendix A

A metadata questionnaire has been developed to assist in gathering the information needed for metadata creation (see the NCPN Metadata Guidance Document (NCPN-NPS 2007c)).

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, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The Version Key number is essential for project information to be properly interpreted and analyzed. *The protocol narrative, SOPs, and data should not be distributed independently of this table.* Refer to the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009) for detailed protocol versioning procedures.

8 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, UT. 86 pp plus appendices.
- NCPN-NPS 2007a. Project Data Life Cycle Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007b. Directory Structure Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007c. Metadata Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
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- NCPN-NPS 2008c. Photo Management Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2010. Archiving Guidance Document, Version 2.00. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

Appendix A Documentation of Database Tables

The table and field definitions in this appendix correspond to version 1.00 of the invasive exotic plant (IEP) monitoring database.

Data Tables

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	50
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	50
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	GSP data file name	dbText	255
Unfilt_Pos	Unfiltered position	dbDouble	8
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	Start time from GPS	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
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

Field Name	Field Description	Field Type	Field Width
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	50
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_Quadrat_Species
Description: Table of invasive plant species observed for a monitoring transect

Field Name	Field Description	Field Type	Field Width
Species_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_Quadrat_Transect	dbText	50
Plant_Code	Plant code from lookup table	dbText	50
Q1_hm	Percent cover Q1 @ 0.5m	dbSingle	4
Q2_5m	Percent cover Q2 @ 5m	dbSingle	4
Q3_10m	Percent cover Q3 @ 10m	dbSingle	4
Average_Cover	Average cover percentage	dbSingle	4
Q1_3m	Percent cover Q1 @ 3m (used in 2009)	dbSingle	4
Q2_8m	Percent cover Q2 @ 8m (used in 2009)	dbSingle	4
Q3_13m	Percent cover Q3 @ 13m (used in 2009)	dbSingle	4
Avg_Cover_2009	Average cover percentage (2009)	dbSingle	4
Q1	Percent cover Q1 (used in 2008)	dbSingle	4
Q2	Percent cover Q2 (used in 2008)	dbSingle	4
Q3	Percent cover Q3 (used in 2008)	dbSingle	4
Avg_Cover_2008	Average cover percentage (2008)	dbSingle	4

Table Name: tbl_Quadrat_Transect
Description: Table of measurements recorded for a monitoring transect

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	Start time of this transect's observations - defaults to GPS time, but can be overwritten by data entry	dbDate	8

Field Name	Field Description	Field Type	Field Width
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	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
Stop_Time	Stop time - 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
Dead_Wood_Q1	Dead wood cover percentage quadrat 1	dbSingle	4
Dead_Wood_Q2	Dead wood cover percentage quadrat 2	dbSingle	4
Dead_Wood_Q3	Dead wood cover percentage quadrat 3	dbSingle	4
Dung_Q1	Dung cover percentage quadrat 1	dbSingle	4
Dung_Q2	Dung cover percentage quadrat 2	dbSingle	4
Dung_Q3	Dung cover percentage quadrat 3	dbSingle	4
Fungus_Q1	Fungus cover percentage quadrat 1	dbSingle	4
Fungus_Q2	Fungus cover percentage quadrat 2	dbSingle	4
Fungus_Q3	Fungus cover percentage quadrat 3	dbSingle	4
Lichen_Q1	Lichen cover percentage quadrat 1	dbSingle	4
Lichen_Q2	Lichen cover percentage quadrat 2	dbSingle	4
Lichen_Q3	Lichen cover percentage quadrat 3	dbSingle	4
Litter_Duff_Q1	Litter/Duff cover percentage quadrat 1	dbSingle	4
Litter_Duff_Q2	Litter/Duff cover percentage quadrat 2	dbSingle	4
Litter_Duff_Q3	Litter/Duff cover percentage quadrat 3	dbSingle	4
Root_Bole_Q1	Root/Bole cover percentage quadrat 1	dbSingle	4
Root_Bole_Q2	Root/Bole cover percentage quadrat 2	dbSingle	4
Root_Bole_Q3	Root/Bole cover percentage quadrat 3	dbSingle	4
Dead_Root_Bole_Q1	Dead root/bole cover percentage quadrat 1	dbSingle	4
Dead_Root_Bole_Q2	Dead root/bole cover percentage quadrat 2	dbSingle	4
Dead_Root_Bole_Q3	Dead root/bole cover percentage quadrat 3	dbSingle	4
Mineral_Soil_Sediment_Q1	Mineral Soil/Sediment cover percentage quadrat 1	dbSingle	4
Mineral_Soil_Sediment_Q2	Mineral Soil/Sediment cover percentage quadrat 2	dbSingle	4
Mineral_Soil_Sediment_Q3	Mineral Soil/Sediment cover percentage quadrat 3	dbSingle	4
Moss_Q1	Moss cover percentage quadrat 1	dbSingle	4
Moss_Q2	Moss cover percentage quadrat 2	dbSingle	4
Moss_Q3	Moss cover percentage quadrat 3	dbSingle	4
Cryptogram_Q1	Cryptogram cover percentage quadrat 1	dbSingle	4
Cryptogram_Q2	Cryptogram cover percentage quadrat 2	dbSingle	4

Field Name	Field Description	Field Type	Field Width
Cryptogram_Q3	Cryptogram cover percentage quadrat 3	dbSingle	4
Road_Q1	Road cover percentage quadrat 1	dbSingle	4
Road_Q2	Road cover percentage quadrat 2	dbSingle	4
Road_Q3	Road cover percentage quadrat 3	dbSingle	4
Rock_Q1	Rock cover percentage quadrat 1	dbSingle	4
Rock_Q2	Rock cover percentage quadrat 2	dbSingle	4
Rock_Q3	Rock cover percentage quadrat 3	dbSingle	4
Standing_Water_Flooded_Q1	Standing Water/Flooded cover percentage quadrat 1	dbSingle	4
Standing_Water_Flooded_Q2	Standing Water/Flooded cover percentage quadrat 2	dbSingle	4
Standing_Water_Flooded_Q3	Standing Water/Flooded cover percentage quadrat 3	dbSingle	4
Stream_Q1	Stream cover percentage quadrat 1	dbSingle	4
Stream_Q2	Stream cover percentage quadrat 2	dbSingle	4
Stream_Q3	Stream cover percentage quadrat 3	dbSingle	4
Trash_Junk_Q1	Trash/Junk cover percentage quadrat 1	dbSingle	4
Trash_Junk_Q2	Trash/Junk cover percentage quadrat 2	dbSingle	4
Trash_Junk_Q3	Trash/Junk cover percentage quadrat 3	dbSingle	4

Table Name: tbl_Target_Plant_Lists
Description: Table of target (high priority) invasive plants for each park and year

Field Name	Field Description	Field Type	Field Width
Year	Year of data collection (yyyy)	dbInteger	2
Unit_Code	Park code	dbText	4
Priority	Priority of target species determined by park	dbInteger	2
Report_Scientific_Name	Scientific name used in annual report (retained for historical purposes)	dbText	50
Report_Common_Name	Common name used in annual report (retained for historical purposes)	dbText	50
Master_Plant_Code	Master plant species code from tlu_NCPN_Plants	dbText	20
Comments	Any comments about the record	dbMemo	0

Lookup Tables
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

Field Name	Field Description	Field Type	Field Width
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: Contains all NCPN master plant species

Field Name	Field Description	Field Type	Field Width
Master_Family	Master_Family	dbText	50
Master_PLANT_Code	Master Species PLANTS Code	dbText	20
Master_Species	Master Species (ITIS)	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 (Welsh et al 2003)	dbText	50
Co_PLANT_Code	Colorado Species PLANTS Code	dbText	20
Co_Species	Colorado Species (Weber & Wittmann 2001)	dbText	50
Wy_PLANT_code	Wyoming species PLANTS code	dbText	20
Wy_Species	Wyoming Species (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
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

Field Name	Field Description	Field Type	Field Width
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
New_Record	Is it a new record?	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

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
ParkState	State code.	dbText	2

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

Table Name: tlu_Species
Description: Table to cross reference plant common names to master plant codes

Field Name	Field Description	Field Type	Field Width
Species_Name	Common name as used by field crews	dbText	50
Master_PLANT_Code	Master Plant Code	dbText	10

Metadata Tables

Table Name: tbl_master_version
Description: Table of protocol version information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
version_key_number	Protocol version key number	dbLong	4
version_key_date	Date of protocol version key number	dbDate	8
narrative_version	Version of protocol narrative	dbDecimal	16
version_comments	Comments regarding version, if any	dbMemo	0

Table Name: tbl_SOP_version
Description: Table of SOP version information

Field Name	Field Description	Field Type	Field Width
version_key_number	Protocol version key number	dbLong	4
SOP_number	SOP number	dbLong	4
SOP_version_number	SOP version number	dbDecimal	16
active_flag	Yes indicates SOP is active	dbBoolean	1

Table Name: tlu_projects
Description: Table of NCPN project information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
project_name	Project name	dbText	50
project_linkfile	Path and file name of project database	dbText	255
project_include_flag	True indicates project is to be included in query results	dbBoolean	1
project_comments	Comments regarding project, if any	dbMemo	0

Table Name: tsys_App_Releases
Description: Application table - Application release history

Field Name	Field Description	Field Type	Field Width
Release_ID	Unique identifier for the release	dbText	50
Release_date	Date of the release	dbDate	8
Database_title	Title of the database	dbText	100
Version_number	Version control number	dbText	20
File_name	Filename, used to identify older versions of the database	dbText	50
Release_by	Person who made the release	dbText	50
Release_notes	Release notes, which may include a summary of revisions	dbMemo	0
Author_phone	Phone number of application author	dbText	50
Author_email	Email address of application author	dbText	50
Author_org	Organization (NPS Unit code) for the author's place of work	dbText	10
Author_org_name	Name of organization for author's place of work	dbText	100

Appendix B NCPN Invasive Exotic Plant Database User's Guide

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1 Introduction

This document provides instructions for using version 1.02 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.mdb*: This frontend file contains all data entry forms, queries, reports, and associated Visual Basic (VB) application code.
- *Invasives_be.mdb*: 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, certified 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

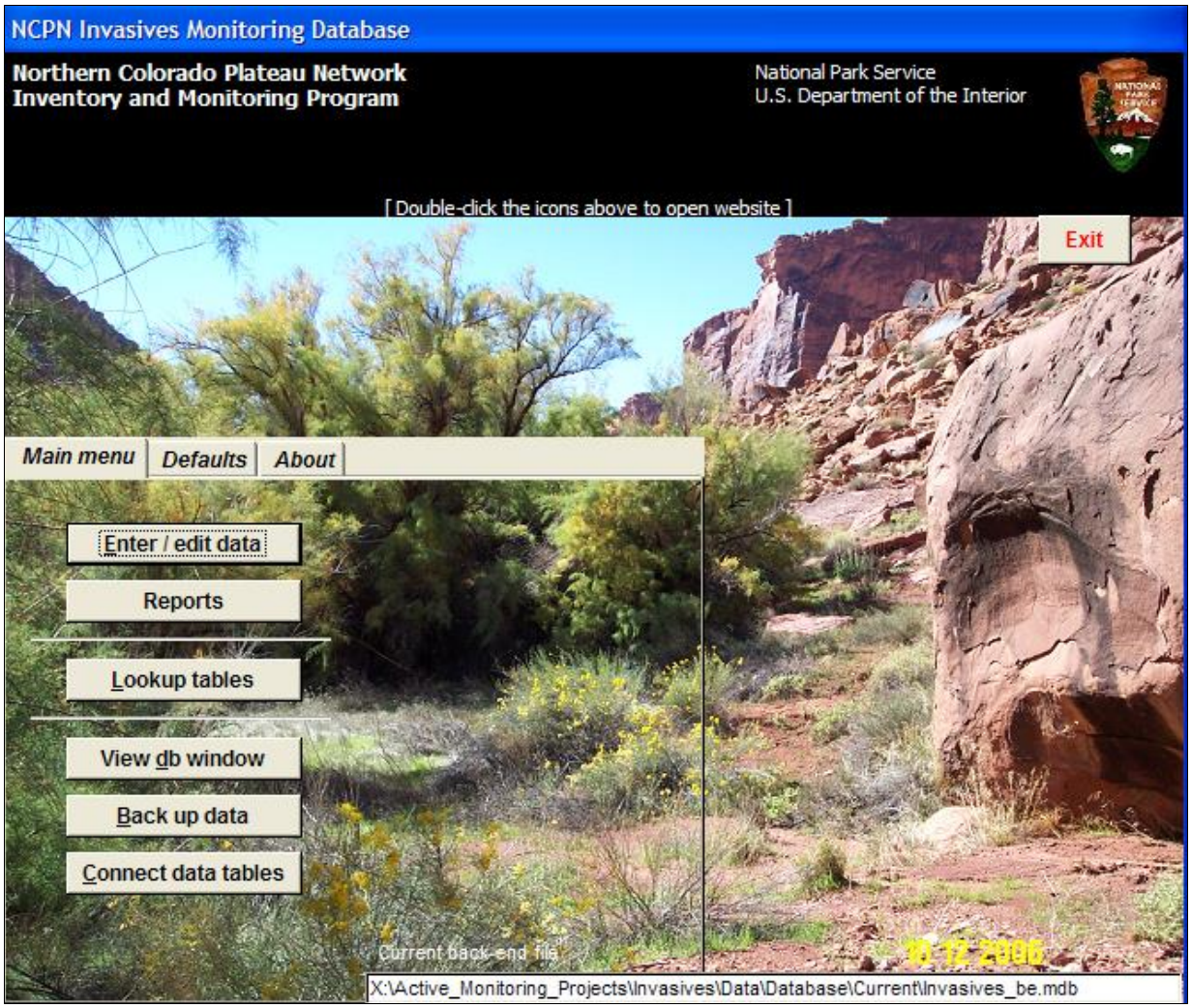
2 Installation

Data management staff will ensure that all the files needed to run the database application are installed on your machine. This will normally include the frontend file (*Invasives.mdb*). The backend database file, *Invasives_be.mdb*, 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.

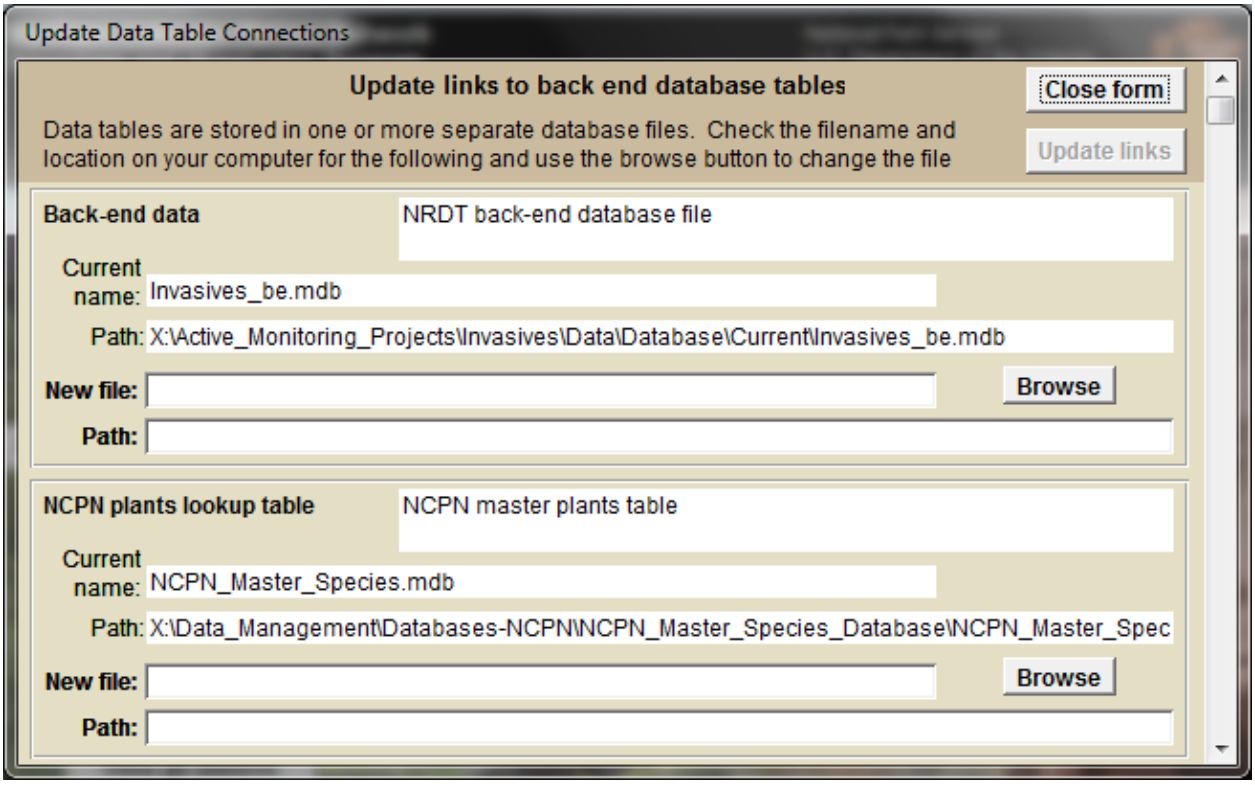
3 Getting Started

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, 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 invasives 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.mdb*.
   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.mdb*.
   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.

Note: If the database backend file has "HOLD" appended to it (e.g., *Invasives_be_HOLD.mdb)*, this means that the database is locked. This usually occurs when data management staff needs to perform maintenance on the database. In such cases, you should **not** start a data entry session! You may view the records in the database, but do not make any changes as they may be lost.

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 "Reports" button opens the Reports menu. Reports for IEP monitoring are currently under development.
- 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 1.01" (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. In the unlikely event that you encounter a bug in the database, you can email data management staff the details. The "SOP Version Admin" button provides functionality related to managing the protocol SOP history of this database. ***This button is for data management staff only.*** Procedures for this process are detailed in the *NCPN Protocol Versioning Guidance Document* (NCPN-NPS 2009). The current master SOP version key for this protocol is stored in each new visit event record added to the database.

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

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

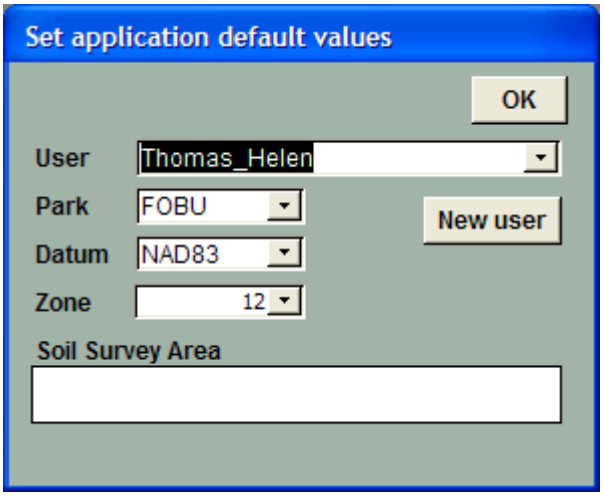
- Location**: Backup** folder (in X:\ Active_Monitoring_Projects\Invasives\Data\Database). Data management staff, in consultation with the project manager, will periodically review the **Backup** folder and remove any unnecessary backup files. Note that if multiple users click the "Back up data" button 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.
- Frequency: 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

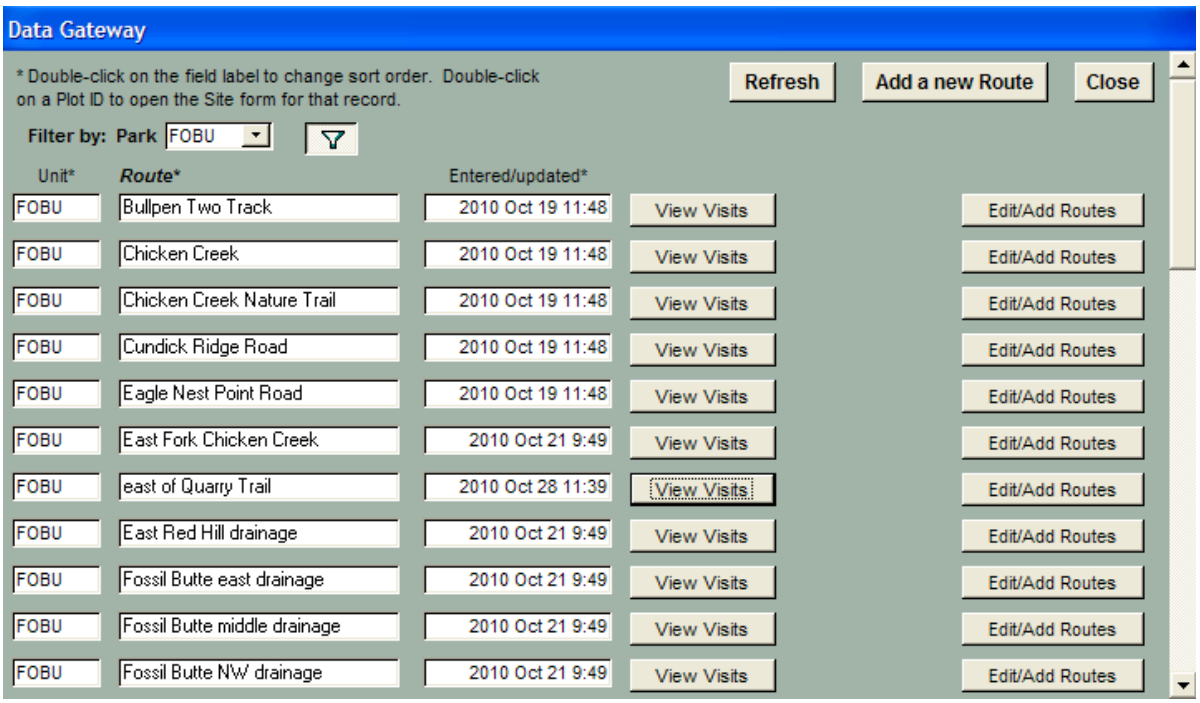
To begin data entry, click the "Enter / edit data" button on the Main Menu tab. You will see this pop-up form:



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.

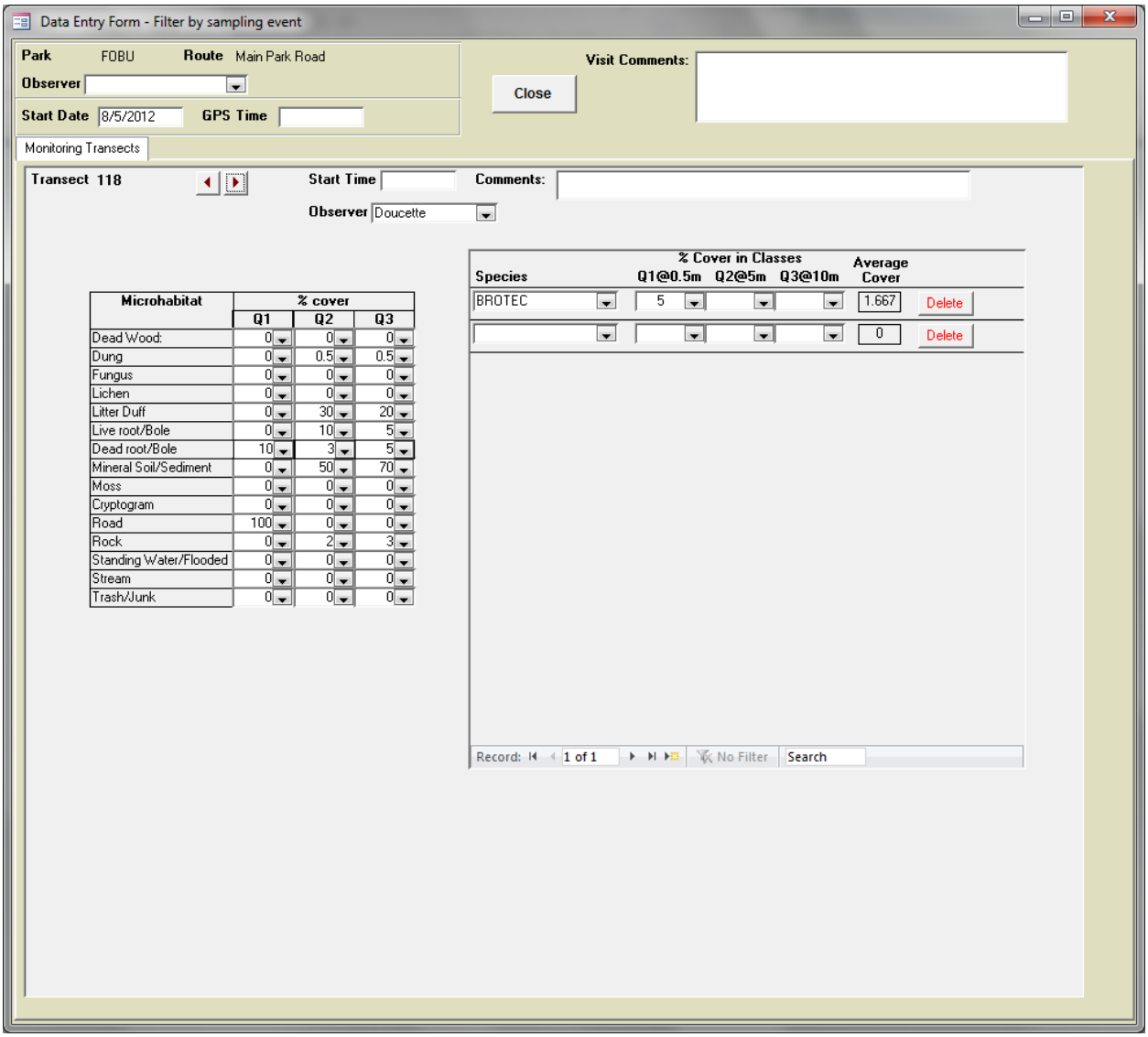
There are two buttons associated with each route:

- Use "View Visits" to enter/edit/view monitoring 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 monitoring transect data. The top of the form shows the Park, Route, Observer, Start Date, GPS Time, and Visit Comments. The latter four fields can be edited. If there are multiple observers, you can use the Observer field at the top to record one of them.



Enter all fields on the monitoring transect part of the form.

- For microhabitat % cover and species % cover, enter 0.5 for “<1”.
- All species in the species pick list are sorted by shorthand codes (a.k.a. 6-letter codes), which are formed by concatenating the first three characters of the Genus and Species names. Some species could not be assigned codes using this 6-letter format because they would result in duplicate codes. Codes for these species are listed in Section 5.4.

When finished with a transect, use the navigation button to move to the next transect, or close the form to return to the Data Gateway form. Be sure to fill in the “Entered by” box on the paper data sheet.

5.4 Species Shorthand (a.k.a. 6-Letter) Codes

Use the 6-letter codes (first 3 letters of Genus + first 3 letters of species) for all plant species on data forms. By clicking on the dropdown arrow, you can view the entire genus and species name for the entry you've selected.

Using this method turned up some duplicate 6-letter codes. Refer to the list below for codes outside of the standard 6-letter format.

1) First 3 letters of Genus + entire species name (e.g. ASTSABULONUM)

2) Hybrids- "X" between genus and species (e.g. POPXCAN)

3) General unknowns

UNK	unknown species (unknown life form)
UNKAF	unknown annual forb
UNKAG	unknown annual graminoid
UNKF	unknown forb
UNKG	unknown graminoid
UNKH	unknown herb (forb or grass)
UNKPF	unknown perennial forb
UNKPG	unknown perennial graminoid
UNKS	unknown shrub
UNKT	unknown tree

4) Trinomials- additional letter for the first letter of the variety (e.g. ARAHOLF for Arabis holboellii var. fendleri). Do not use trinomial codes.

6 References

- NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

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

This appendix describes the QA/QC procedures used in certifying invasive exotic plant (IEP) monitoring data. These procedures are focused on data collected during the 2010 field season and beyond. Due to changes in the IEP monitoring protocol in 2010, the exact same set of checks may not be applicable to data collected prior to 2010. Thus, additional queries may be needed to perform data quality checking for data collected during 2008 and 2009.

1 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 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:\Archive\Monitoring_Archive\Invasives\Project_Life_Cycle*YYYY*\Data_Quality

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

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

The QA/QC database should be linked to the invasives backend database file:

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

The remainder of this document is organized into the following sections, based on the different types of IEP data that are collected: monitoring transect (Section 2), infestation (Section 3), location-specific (location-related attributes common to monitoring transect and infestation data, Section 4), effective detection swath width (EDSW, Section 5), between feature position (BFP, Section 6), and species-related (Section 7).

2 Monitoring Transect Data

This section focuses on the monitoring transect data that is entered into the database manually from paper field sheets. This data is first verified during data entry by the individual entering the data. A second verification is then 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 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 1 are designed to supplement the built-in database validation.

Table 1 Monitoring transect data quality checks

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
Missing transect records	tbl_ Events, tbl_Quadrat_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[1]	tbl_Quadrat_Transect: Dead_Wood_Q1…Q3 Dung_Q1…Q3 Fungus_Q1…Q3 Lichen_Q1… Q3 Litter_Duff_Q1…Q3 Root_Bole_Q1…Q3 Dead_Root_Bole_Q1 …Q3	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).		

[1] 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
	Mineral_Soil_Sediment_Q1…Q3 Moss_Q1…Q3 Cryptogram_Q1…Q3 Road_Q1…Q3 Rock_Q1…Q3 Standing_Water_Flooded_Q1…Q3 Stream_Q1…Q3 Trash_Junk_Q1…Q3				
Valid species percent cover[1]	tbl_Quadrat_Species: Q1_hm, Q2_5m, Q3_10m	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, tbl_Quadrat_Transect)	QC_MoTr_Valid_Observer	• Check for missing values. • Ensure Observer is a valid name (see tlu_Contacts).		
Misspellings in comments	Comments (tbl_Events, tbl_Quadrat_Transect)	QC_MoTr_Spellchk_Comments	• Use spellcheck to find and correct spelling errors (select column while in query datasheet view and choose Tools-Spelling from Access main menu).		
Transects without species occurrences	tbl_ Events, tbl_Quadrat_Transect, tbl_Quadrat_Species	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).		

3 Infestation Data

All infestation data is collected via GPS units. GIS staff performs QA/QC on this data (see Section 4), 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 the IEP database. After this data is uploaded, the procedures in Table 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 is 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 2 are designed to supplement the GPS unit validation and ensure that the data has not been inadvertently altered.

Table 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		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
			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 separation resolution (PSR)	tbl_Infestation: PSR	QC_Inf_Valid_PSR	• Ensure PSR = 50.		
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 Tools-Spelling from Access main menu).		

4 Location-specific Data

This section focuses on QA/QC of the location-specific attributes common to monitoring 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 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 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 (tbl_Quadrat_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 their locations (e.g., within park).		
Valid UTM zone	UTM_Zone (tbl_Quadrat_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 (tbl_Quadrat_Transect,	QC_Loc_MoTr_Datum, QC_Loc_Inf_Datum	• Check for missing values. • Ensure Datum = NAD83.		

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
	tbl_Infestation)				
Valid elevation	Elevation (tbl_Quadrat_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 (1400, 2180 CURE (1900, 2910) DINO (1400, 2800) FOBU (1990, 2500) GOSP (1300, 1640)		

5 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 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 has not been inadvertently altered. Since the EDSW data is stored mainly for backup purposes and not reported on directly, minimal data quality checking is done on this data.

Table 4 EDSW data quality checks

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

Condition Checked	Table Name: Field Name(s)	Query Name	Instructions	Complete?	Comments
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.		

6 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 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. Since the BFP data is stored mainly for backup purposes and not reported on directly, minimal data quality checking is done on this data.

Table 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.		

7 Species-related Data

A check for newly added plant species should be done so that any new species records can be added to the NCPN master species table. This is done by comparing tlu_NCPN_Plants in the IEP database with the master version of this table (see NCPN_Master_Species.mdb, located in R:\Archive\NCPN_Databases_Archive\NCPN_Master_Species_Database*yyyy*\). This task is done jointly by data management staff and ecologists (or other designated staff having plant expertise).

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

Standard Operating Procedure (SOP) 8*:* Data Analysis and Reporting

Version 1.0 (May 2008)
Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

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 the upland data accumulates and as the full suite of potentially supporting data provided by other vital signs monitoring (e.g., land condition) of the NCPN become available. The procedures described in this version, however, provide a solid basis for future enhancements.

I. Park Communication

Within 30 days (preferably sooner) of monitoring, the park weed manager will be notified of particularly important or significant new invasions (i. e. 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 1 invasive exotic plant list, determine if there are any extra area weed searches desired and confirm plans for that year's monitoring routes.

II. Vital Sign and Park Briefs

A vital sign brief will be prepared annually that gives a brief overview of invasive exotic plant monitoring throughout the network. A park vital sign brief will also be prepared annually which gives 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.

III. Annual Reports

On annual basis monitoring reports will be submitted to the park. 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 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 the 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 on maps.
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, whether the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change), etc.

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. Place network results within the larger context of established invasive plant species population changes throughout the Pacific, 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 is 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.

IV. 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 habitats prone to invasion. Data from the vegetation monitoring protocol will also be useful for these analyses.

Due to the complications of many plots with no IEPs present and removal of IEPs for control reasons, 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 actual quadrat data. 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 were created. These ranged from fairly simple designs at small parks such as monitor all roads, trails, and riparian corridors in the park every two years to more complicated re-visit 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-yrs 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.

Frequentists Survey-Design 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, 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 Assessment of Trends

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 listed in Table 1 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 et al. (2000) provide in-depth explanations of the underlying mathematics of various analytical methods. In short, a Likelihood distribution is generated from the sample data which provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which 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.

V. References

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

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 List of Priority 1 Invasive Exotic Plants

Version 1.0 (May 2008)
Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

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 broad list of Priority 1 non-native species occurring at each park that observers will be trained on for the monitoring routes. Additional species will be on the list for consideration for future years. The list will be evaluated each year a park is monitoring.

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 designated weed lists for targeted state(s) for possible species that may be moving into the area of the park.

There are several ways to find this information, however, one of the better resources for this information is the Invaders Database System, (http://invader.dbs.umt.edu/Noxious_Weeds/), housed at University of Montana – Missoula. In many cases, such as in CO, a state will categorize or prioritize weeds on its list to guide coordinate state and county efforts and it may even provide management recommendations or directives for individual species (eradication, containments, suppression, etc.). 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://weedcenter.org/inv_plant_info/invasive_info.htm)

The federal site Invasivespecies.gov also provides state list information at:
http://invasivespecies.gov/geog/main.shtml

The most updated sources for weed information, should lists change, will likely be the state's websites (accessed 4/2/2010):

Arizona: http://www.azda.gov/PSD/quarantine5.htm
Colorado: http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1174084048733
Utah: http://www.utahweed.org/weeds.htm
Wyoming: http://www.wyoweed.org/

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 to find contact information for a particular county or counties:

Arizona:
- State Weed Coordinator's Office: 602-542-3309
- http://www.land.state.az.us/programs/natural/conservation_021004.htm

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/addresses.html

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 list of Priority Species. The Priority IEP 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 (i.e. tamarisk beetle) could then be evaluated over time.

8. Re-evaluate the 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.

Invasive Plant Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 10

Revising the Protocol Narrative and SOPs

Version 1.07 (April 2016)

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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

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 one of the SOPs need to follow these procedures in order to eliminate confusion on how data are collected and analyzed. All observers conducting the 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-NPS 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 and experts outside of the Park Service 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, etc.) 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 a narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The VK number increments by whole integers (e.g., 1, 2, 3, 4, 5). Updates to the MVT also must be provided to the NCPN Data Manager for inclusion in the master version table database. *The protocol narrative, SOPs, and data should not be distributed independently of this table*.

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

Invasive Plant Monitoring, Northern Colorado Plateau Network
Master Version Table

Version Key #	Date of Change	Narrative	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	SOP 8	SOP 9	SOP 10
VK1	5/1/2008	1.00	n/a	n/a	1.00	1.00	1.00	1.00	n/a	1.00	1.00	1.00
VK2	7/8/2009	1.00	n/a	n/a	1.01	1.00	1.00	1.01	n/a	1.00	1.00	1.01
VK3	12/15/2010	1.00	1.00	1.00	1.03	1.01	1.00	1.02	1.00	1.00	1.00	1.02
VK4	12/1/2011	1.00	1.01	1.00	1.04	1.01	1.00	1.02	1.00	1.00	1.00	1.03
VK5	12/1/2012	1.00	1.01	1.00	1.04	1.01	1.00	1.03	1.01	1.00	1.00	1.04
VK6	9/20/2013	1.01	1.02	1.01	1.06	1.01	1.00	1.04	1.01	1.00	1.00	1.05
VK7	5/11/2015	1.01	1.02	1.01	1.07	1.01	1.00	1.04	1.01	1.00	1.00	1.06
VK8	4/8/2016	1.01	1.03	1.01	1.09	1.01	1.00	1.04	1.01	1.00	1.00	1.07

References

NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.