

## Chapter 7. Monitoring Non-Native Plant Populations

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### INTRODUCTION

In Chapter 2 we defined two types of monitoring:

*Monitoring for Invasiveness*, in which a population could be considered invasive if it consistently increases in density or spatial extent, or is the source of new populations.

*Monitoring for Impact*; that is,

- the impact and effect of non-indigenous species on the surrounding vegetation and ecosystem relevant to the land management goals.
- the impact and effect of weed management practices on the target populations.
- the impact and effect of weed management practices on non-target species and ecosystems.

Impact is an evaluation of the effect of “something” on “something” else. What the “somethings” are to evaluate will relate to the land management goals. For example, one may evaluate the impact of an NIS on the surrounding vegetation; the impact/effect of the management treatment on the NIS, and also non-target species; and/or one may evaluate the impact of a NIS on the ecosystem function (e.g., soil properties, erosion, succession, etc.), though the latter type of impact monitoring is very complex.

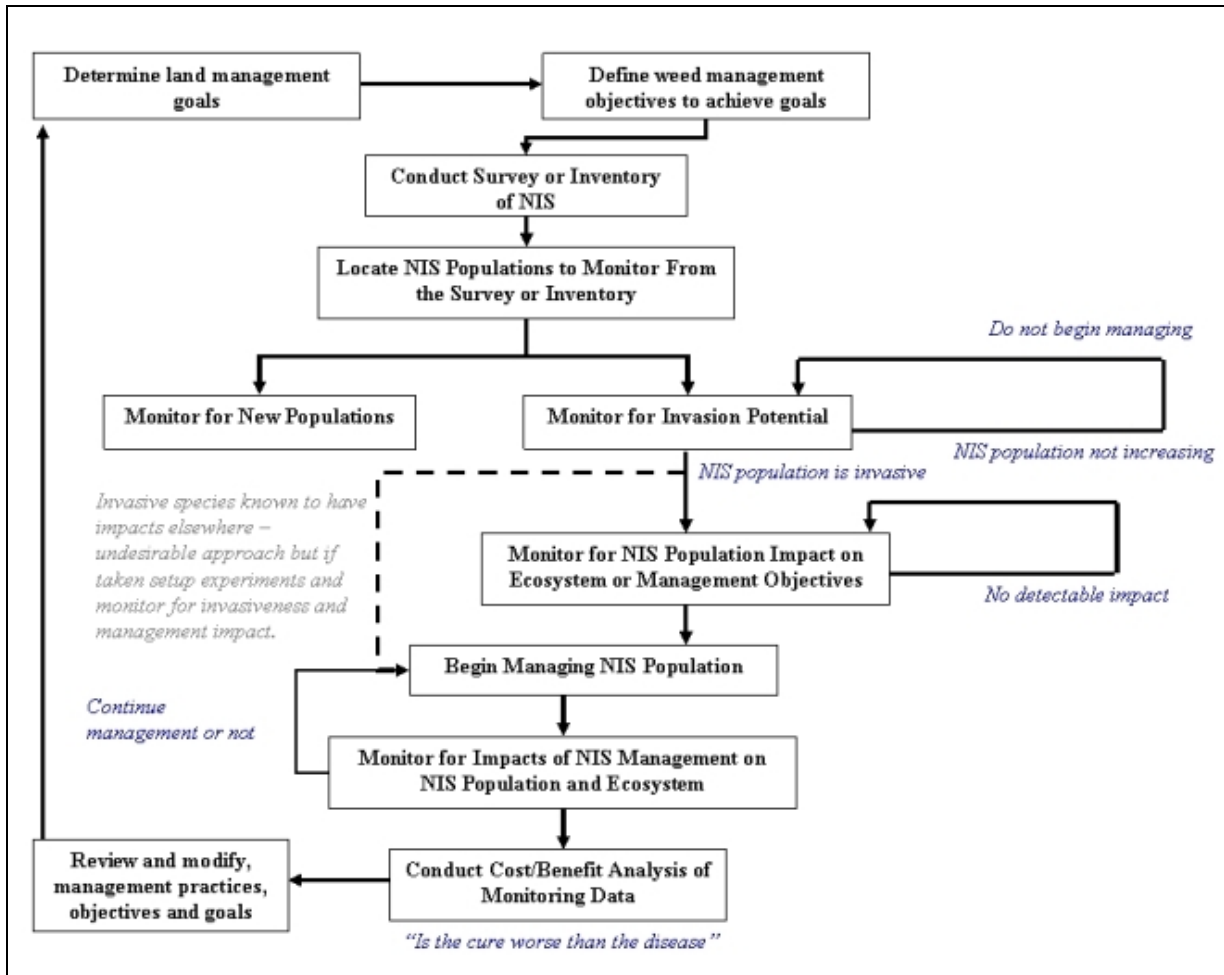
We argue that individual plant species should not be judged to be invasive, but populations of a species can be. Here we will address the first and last type of monitoring listed above. In terms of the flow diagram for ecologically based adaptive weed management (page 2; see also Chapter 2), addressing invasiveness comes prior to addressing impact; and monitoring for new populations should be performed alongside invasive monitoring. The methods can appear quite complicated but are really rather easy to perform. The first form of monitoring for invasiveness is monitoring for new colonies (populations) around a possible source population.

### FINDING NEW COLONIES

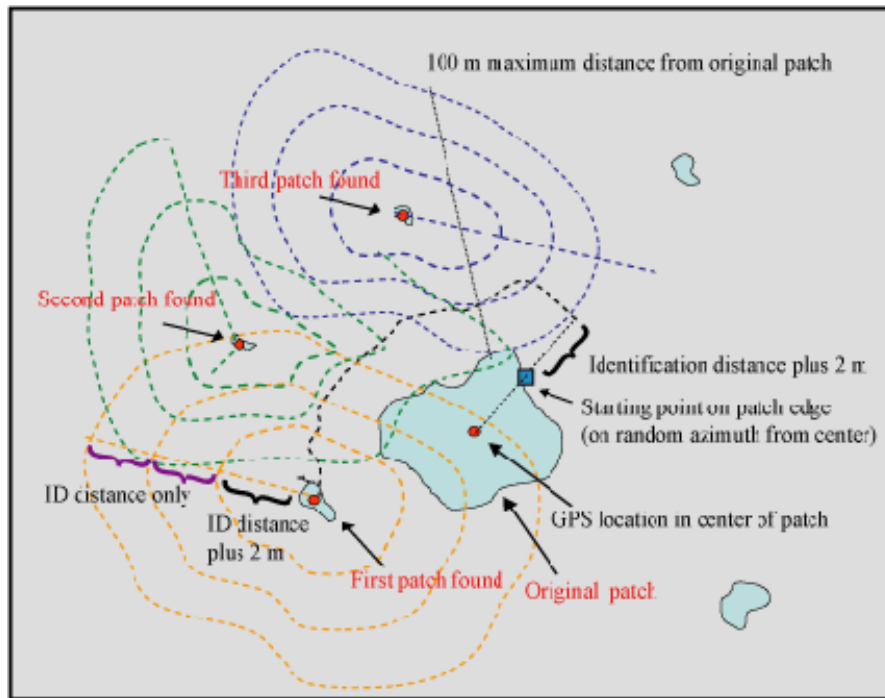
The most probable place to find new colonies of NIS is close to established patches. An adaptive sampling (Thompson and Seber 1996; Prather 2006) approach can be used to find new colonies or patches close to known populations. In addition, if you have access to fine scale (< 30 m) probability or risk maps of target species then the areas defined as more likely to contain those species could be sampled first. Adaptive sampling as defined here basically increases the time and efficiency of locating new colonies of the target species.

New colonies of NIS from 2 m to 100m around an existing patch may be efficiently identified using the adaptive sampling method described here. To use this method, the identification distance must first be determined; that is, the maximum distance within which one can detect a new colony (a few plants). This distance is determined according to the sampler’s knowledge of species dispersal and population dynamics. For example, 2 m may be an adequate distance for rhizomatous species, while a 10m or greater identification distance may be required for wind-dispersed species.

Once the identification distance is determined, three values between 1 and 360 are randomly selected. These values are azimuths that are used for the initial direction of travel. From the center of the patch, the sampler walks along one of the selected azimuths to the patch edge (**Figure 7-1**). From this patch-edge point, the sampler travels along the azimuth for the length of the identification distance plus 2 m. In our example, the identification distance is 3 m so an additional 2 m needs to be added. The added 2 m ensures that new plants are being identified rather than mistakenly including plants on the edge of the original patch. The sampler then turns so that he or she is now traveling parallel to the patch edge, maintaining the identification distance plus 2 m from the patch (a total of 5 m).



Flow Diagram for Ecologically Based Adaptive Weed Management



**Figure 7-1.** Hypothetical map showing NIS patches (solid blue areas), their boundaries (solid lines), and adaptive sampling walking paths (dashed lines) for finding new patches of the same species.

If no new colonies or plants are identified and the patch is fully circled, the sampler then continues moving away from the patch another increment of only the identification distance (3 m) and circles the patch again, parallel to the edge. This sampling path is continued until the sampler is 100m from the edge of the original patch. If no new colonies are found, the sampler repeats this process using the second (then the third if necessary) randomly selected azimuth.

If a new colony is encountered the process is started again from this new colony with the sampler randomly selecting new azimuths. The sampler is always keeping track not to exceed 100m from the edge of the original patch, and not to resample any colonies already located. When a new colony is located, a Global Positioning System (GPS) point is created in the center of the new colony and its area is estimated according to one of the methods described later in the chapter.

If information is collected along the sampling path about points where the NIS do not occur, and where the vegetative communities change, as well as where new colonies occur, the data can be used to estimate the probability of occurrence using the methods of Rew et al. (2006) and Rew et al. (2005).

## QUANTIFYING CHANGES IN POPULATIONS, OR MONITORING FOR INVASIVENESS OF POPULATIONS

Now let us consider monitoring for invasiveness. It would be impossible and indeed unnecessary to monitor every NIS population for invasiveness and impact. Instead one should select a number of populations for monitoring from the range of environments in which they have been observed in the inventory/survey. Selecting populations from the range of environments will provide a representative sample of the target species' invasiveness and impact. For example, survey data may show that a target NIS was only found in three habitats: Big sage/Idaho fescue, Big sage/bluebunch wheatgrass and Idaho fescue/bluebunch wheatgrass. Therefore, three patches should be selected in each of these habitats and the methods discussed below used to monitor for invasiveness and, either simultaneously or later, for impact. The results of the invasiveness monitoring may show that only the patches in the Idaho fescue/bluebunch wheatgrass are invasive, while the populations in the other habitats are stationary or declining.

We are defining invasiveness as consistently increasing in density and/or spatial extent. Not all populations are invasive, but certain populations or patches of a particular species can be invasive. To explain this in more detail, even for the most notorious "invasive species" there will always be variation in growth (density, spread, seed production etc.) of individual patches of the same plant species across the environments where it has become established; some of the patches will be invasive, others stable and some will be declining. The main point is that the focus for determination of invasiveness for management considerations should be placed on populations or metapopulations segregated by environments across their entire range of distribution within the management area.

Here we describe methods that allow an objective and quantitative assessment of the relative invasiveness of herbaceous plant populations. These methods would generally be used to as-

sess non-indigenous plant species (NIS) that are often thought to be invasive for a wide set of reasons and, that under a precautionary principle, may be best managed early in the invasion process (Simberloff 2003).

These methods could also be applied to indigenous and "rare" species. In fact, determining the relative invasiveness of a population of an indigenous species closely related to the non-indigenous species of interest in the same environment would be an excellent way to further discern the invasive potential of the non-indigenous species population. That is, if the quantitative methods allow a conclusion that the non-indigenous population is invasive, but has a lower invasive potential than the closely related indigenous species, then using the relative invasiveness conclusion to trigger management may be premature without further monitoring. The decision to manage will always be the result of assessing the balance between risk of invasion and subsequent impact of the population, cost of management, and the potential off-target impact of management.

Quantifying relative invasiveness allows land managers to prioritize management of populations based on the types of environments where they are found. The methods that we suggest were arrived at under two principal constraints.

- First, they must be simple and efficient enough to allow managers to conduct the measurements in the field within their time constraints, and to conduct the subsequent analysis without sophisticated computer software.
- Second, the metrics of invasiveness must be sensitive enough to rapidly identify potentially invasive populations so that managers may respond as quickly as possible to populations that are beginning to increase.

Monitoring for invasiveness is determining if representative populations/patches of a NIS (from across the environments where the species was found through an inventory or survey of the management area) are consistently in-

creasing in spatial extent or density. It is important to select populations from across the range of habitats where the target NIS was found in the inventory/survey to ensure a non-biased estimate of how invasive the species is across the whole management area. In addition, selecting a non-biased set of populations will improve the potential to observe the full variability in invasiveness of these species and improve the manager's ability to prioritize populations, or certain environments where populations reside, for management. A fundamental assumption behind this approach is that NIS may not be invasive in all the environments where they occur. And it may be best to target population in some environments and not others as part of an adaptive weed management plan.

Our measurements of notoriously invasive species populations distributed over different environments indicated highly variable rates of invasion (Bauer 2006; Repath 2005). Thus, there is great potential for using monitoring to prioritize populations for management (i.e., focusing first on managing populations in the environments where they were found to be fast growing).

### **Quantifying Changes in Spatial Extent**

In order to rapidly determine if a population or metapopulation is increasing in spatial extent, a measure is needed that will accurately quantify the area of occupation so that the change in area can be detected from one generation (year) to the next. It is quite possible that populations may show increases in area occupied in one year, but not other years. The frequency of increasing generations relative to declining or no-change generations will determine the degree of invasiveness. The degree of invasiveness that will trigger management or monitoring for ecosystem impacts will be the decision of the manager. The adaptive management approach will really help here. However, experimentation will generally show that only the most non-invasive forms of management should be used on slowly advancing or stable NIS populations.

There are several methods for estimating the area of a NIS patch. Different methods may be more appropriate depending on the density of plants in the patch and the ease of identifying the patch edge. In all cases it will be important to sample at the same time each year.

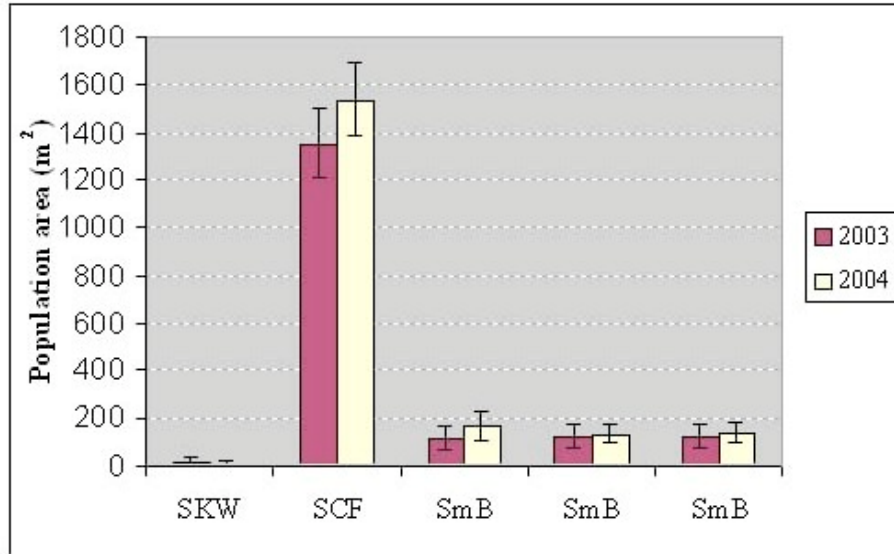
### ***Method using Global Positioning Systems.***

Measuring patch perimeters with a GPS has been promoted as an efficient way to estimate patch area (Roberts et al. 1999). However, with the standard GPS used by most government agencies, consultants, and county weed supervisors, the mean horizontal accuracy is rarely less than 1.0m error. Therefore, at the rate that most populations (patches) spread, it would take a minimum of 4 to 5 years to be certain that the area of a patch was actually increasing, even at a consistent maximum spread per year.

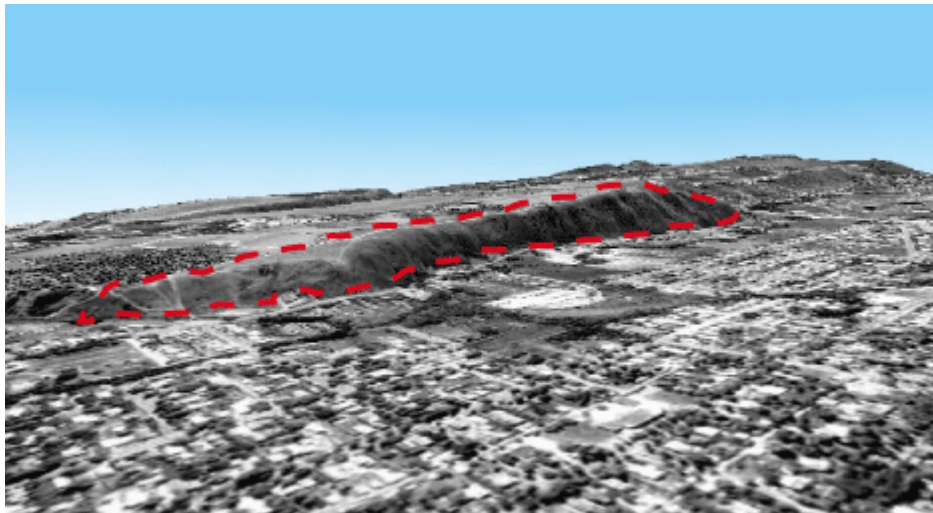
The example data shown in **Figure 7-2** (collected from our Burke Park, Bozeman, MT study site) indicates that one could not conclude invasiveness of any of the NIS populations measured with GPS in 2003 and 2004. If the GPS method is employed, there is certainly no reason to return to a patch to determine change in area for at least 4 years.

***Tape-measure patch-radii method.*** A second, experimental, method using a compass and tape measure shows promise of a higher degree of accuracy than the GPS method. Through the tape-measure patch-radii methods, TMR4 and TMR8, the changes in spatial extent of each patch can be determined by re-measuring patch radii and calculating the area of each patch each year. The calculations have been added to an Excel macro to improve utility of the method.

***TMR4 Measurements*** Start by inspecting a patch and determining its borders. We use the rule that a patch boundary plant must be within 2 m of another plant (ramet) of the same species to be considered within the patch. Thus, if there are more plants of the same species in the area, but they are more than 2 m in any direction from a patch boundary plant, they are considered part of a separate patch.



**Figure 7-2.** Patch area using patch perimeter length recorded with a GPS with an average horizontal error of 1.12m on spotted knapweed (SKW), sulfur cinquefoil (SCF) and smooth brome (SmB) patches at Burke Park, Bozeman, MT.

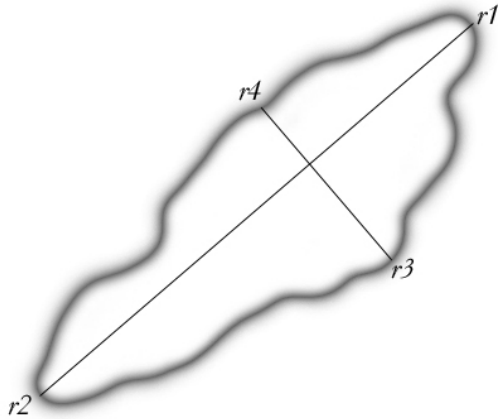


*Burke Park Study Site, Bozeman, MT*

(This is the same as the identification distance and may need to be increased for some species.) Run a tape measure line along the longest possible axis of the patch (**Figure 7-3**). This first patch diameter defines the first two radii,  $r_1$  and  $r_2$ . (The bases of plants at the edge of the patch are used to establish the ends of each radius.) Mark the midpoint of the patch along the diameter (now the length of  $r_1$  = the length of  $r_2$ ), or re-mark it from the previous year with a roadhair. This midpoint is not necessarily a geometric center of a patch, but

simply serves as a reference starting point for more radii.

Using a compass while standing over the center point (roadhair) and looking out toward the edge of the patch, record the azimuth ( $Az_1$ ) and the length of the first radii ( $r_1$ ) (**Table 7-1**). Record radius length in meters to an accuracy of 0.01m and azimuth in degrees. Turn and record the azimuth ( $Az_2$ ) and length of radius two  $r_2$  along the longest axis ( $Az_2 = Az_1 \pm 180^\circ$ ).



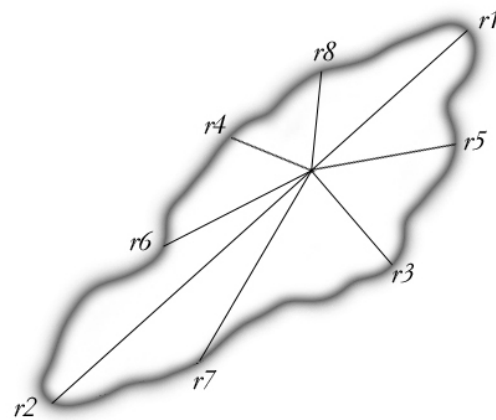
**Figure 7-3.** Simulated patch demonstrating the four radii to be measured for the TMR4 method. Azimuths must be measured from the center.

At approximately 90° to the first two radii, place the tape measure to create a third radius from the center point to the patch edge. It does not have to be exactly 90° — but you want to measure to the furthest distance close (within 45°) to the 90° line. Measure the length of  $r_3$  and record its azimuth ( $Az_3$ ).  $R_3$  should always be clockwise from  $r_1$  so that  $Az_3 > Az_1$  unless  $Az_1$  is between 270° and 360° when  $Az_1 > Az_3$ . Keeping the azimuth in order will facilitate automatic calculation of areas using an Excel spreadsheet. The fourth radius should then be placed approximately 180° from  $r_3$  and the azimuth ( $Az_4$ ) and length ( $r_4$ ) recorded. Thus, each time that a new radius is established, it is directly opposite (insofar as possible) the previous numbered radius, and should stay within a 45° segment (pie-shaped wedge) to maximize the distance to the edge of the patch. The four radii can then be used to calculate an area for the patch. The TMR4 method should be effective for patches that are roughly circular or elliptic

without a lot of invaginations (folds) along the patch edge. Patches that are highly irregular in shape with highly invaginated borders may require additional radii to increase the accuracy of the area estimate and will be discussed below in TMR8.

If the patch is more irregular then it is best to collect another four radii and azimuths.

**TMR8 Measurements** The new radii are added between the first four radii and are placed so that they pass through the patch center (road-hair) to further capture irregular patch shapes. For example, a fifth radius ( $r_5$ ) is established to split the patch to the edge between  $r_1$  and  $r_3$ , and  $r_6$  is oriented 180° from  $r_5$  to split  $r_2$  and  $r_4$  (**Figure 7-4**). In each case the radii length is measured and the azimuth from center to edge is recorded. If one remains consistent with the sequence of measurement of the radii it will be easy to automate the calculations of area in Excel. Results using the TMR8 method are given in **Table 7-2**.



**Figure 7-4.** Simulated patch demonstrating the eight radii to be measured for the TMR8 method. Azimuths must be measured from the center point towards the outside ( $r_1$ , etc.).

**Table 7-1.** Example data table for TMR4 method applied on patches in Burke Park, Bozeman, MT. Radius in meters; azimuths = Az in degrees; SKW = spotted knapweed; SCF = sulfur cinquefoil; SmB = smooth brome.

Species	Patch	Radius1	Az1	Radius2	Az2	Radius3	Az3	Radius4	Az4
SKW	1	3.5	243	3.5	63	2.20	332	1.1	173
SCF	1	21.5	27	215	207	22.54	120	15.38	309
SmB	1	7.20	327	7.20	147	6.85	50	7.35	230

**Table 7-2.** Example data table for additional radii associated with TMR8 method. Radius in meters; azimuths = Az in degrees; SKW = spotted knapweed; SCF = sulfur cinquefoil; SmB = smooth brome.

Species	Patch	Radius5	Az5	Radius6	Az6	Radius7	Az7	Radius8	Az8
SKW	1	1.95	253	0	—	2.4	25	0	—
SCF	1	19.39	83	41.5	265	33.5	172	21.66	27
SmB	1	5.47	15	6.64	208	7.92	104	5.54	270

**Area Calculations** The area calculations have been included into our Excel macros so that if the data are collected as explained above the areas will be calculated for you. The calculations use geometry that we all learnt in school and most of us then forgot. We have two types of calculations, one which assumes each section is a triangle and the other which assumes ellipses or pieces of pie.

The geometry used in the macro is explained below for the four radii method (TMR4), but is essentially the same for the TMR8 methods. The area of the patch can be calculated in m<sup>2</sup> using the measurement of the first four radii. The measured diameters can each be split into radii and thus used to calculate the area of an ellipse using the following equation:

$$A = \pi \cdot r_1 \cdot \left( \frac{r_3 + r_4}{2} \right)$$

where A is area of the ellipse and r<sub>1</sub> and r<sub>2</sub> are the two radii of the ellipse.

The second approach for estimating the area of the patch using the radii lengths and azimuth measurements is to calculate the area of triangles created by the radii. A method is required for calculating the area of triangles using simple geometric rules.



In order to calculate the area of triangle ACB (A<sub>1</sub>) the geometric rule for the area of a triangle is used where:

Area = 0.5(AC x BC x sin ACB); in our case:

$$A_1 = \frac{AC \cdot BC \cdot \sin \angle ACB}{2}$$

where AC is the length of radius r<sub>1</sub> and BC is the length of radius r<sub>3</sub>, and we get angle in degrees from subtracting the azimuth of r<sub>1</sub> from r<sub>3</sub> or r<sub>3</sub> from r<sub>1</sub>, whichever gives a positive number. Then the areas of the four triangles can be added together to estimate the area of the patch.

**Table 7-3.** Area calculations using data from Tables 7-1 and 7-2. SKW = spotted knapweed; SCF = sulfur cinquefoil; SmB = smooth brome.

Species	Patch	Year	Ellipse	Triangles	Triangles
			TMR4	TMR4	TMR8
SKW	1	2004	18.14	11.32	7.39
SCF	1	2004	1280.6	4440.6	6835.4
SmB	1	2004	160.60	101.48	126.64

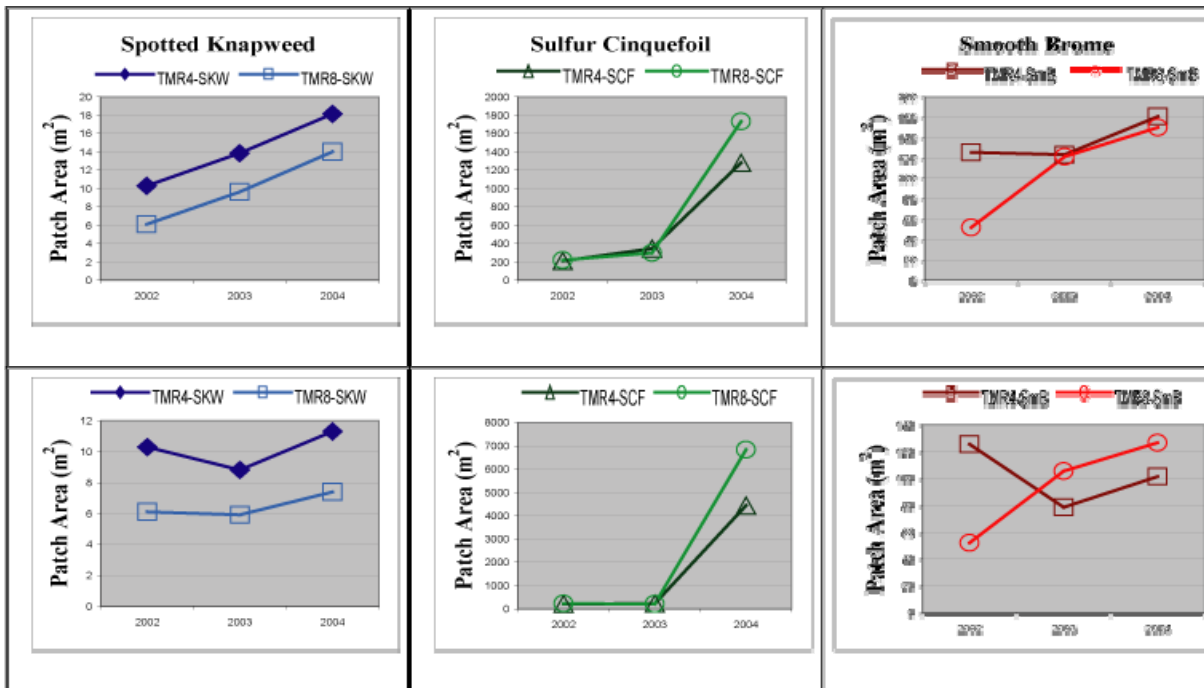
One may conclude from the plots below (**Figure 7-5**) that the patches are generally increasing in area, particularly when eight radii were used in the area calculation. Thus, these populations may be invasive based on measurements of spread. However, it is possible for the boundaries of a patch to expand while at the same time the density within the patch is declining (e.g., spotted knapweed in the Burke Park case) which would lead one to believe that there may be more measurements to take into account before concluding that a population (patch) is invasive.

We should state that we have been collecting data using these different methods for the last 3 to 5 years in order to determine the accuracy and efficiency of them. **Table 7-4** demonstrates that each of the methods have their strengths and weaknesses but measurements with a tape are more accurate, particularly the triangle method, than using the GPS. The tape measurements have also proved to provide more repeatable results.

### QUANTIFYING CHANGES IN POPULATION DENSITY

Another way to quantify change is to record density. We won't go into this monitoring method in detail here, it is a bigger time commitment than the methods we have described above. However, it is important to know that such methods exist—we recommend performing density counts within and at the edge of the patch so that the extremes of population variation are being recorded. At least four quadrats should be counted and permanently marked at the edge (basically spanning the patch to outside patch area) and also in the main part of the patch. We use a 1-m<sup>2</sup> quadrat which is subdivided into 16 and record the location and growth stage of each ramet so that we can record population dynamic changes from one time to the next. From such data it is possible to calculate an invasiveness index.

**Figure 7-5.** Patch area estimates according to the ellipse (top row) and triangular (bottom row) area calculations using TMR4 and TMR8 measurements in the field from 2002 to 2004.



**Table 7-4.** Demonstrating the true area, calculated area and percentage error of known patch areas and shapes. Areas calculated using the ellipse and triangle methods with 8 radii given above, and averaged over 5 GPS walks of the patch perimeters.

Patch Shape	True Area	Area by			% Error		
		Ellipse	Triangle	GPS	Ellipse	Triangle	GPS
Square	16	16	16	27	0.2	0.0	65.9
Circle	17	17	15	22	0.0	-10.0	32.6
Rectangle	18	26	18	22	43.1	-0.1	19.3
Square	81	81	81	102	0.2	0.0	26.1
Circle	82	82	74	106	0.0	-10.0	29.2
Rectangle	84	133	81	94	58.8	-2.6	11.7
Square	310	310	442	91	0.2	0.0	11.7
Circle	314	314	554	322	0.0	-10.0	2.6
Rectangle	312	471	297	—	51.0	-4.7	—

**MONITORING FOR IMPACTS**

As explained in Chapter 2, experimentation is the key to adaptive management.

Monitoring for impact can be performed in many different ways and the precision with which it is done will depend on the land management goals. The key to monitoring for impact is the same as other monitoring practices, it has to be done over time—one assessment is not sufficient. Monitoring for impact should also be performed when prior monitoring has already defined invasive, stable, and declining non-native plant populations/patches. And, like monitoring for invasiveness, monitoring for impact should be performed on a small number of patches before treatments are applied to a large number of patches or metapopulations.

Assuming that invasive populations have been defined in particular environments and the decision has been made to manage . The most effective management strategy then needs to be evaluated. Using a simple example, only one management practice is to be evaluated, an herbicide applied at one rate. A number of

invasive patches should be selected, if the patches are small and in close proximity whole patches could be treated and others left untreated. If patches are large or spatially spread-out part of each selected patch should be treated and part left untreated.

Leaving untreated (control) areas is essential—it is only with them that we can truly evaluate how the treatment is working. The results of a treatment may be extremely variable, but if there are treated and untreated areas it should be possible to determine if there is a pattern in the data. For example, the treated data may show variable response but overall the densities may be declining significantly more than the control plots in which case it would be decided the treatment was effective and should be continued. Conversely the data may show that treated and untreated data are so similar that the treatment was not effective, or should be monitored for a longer period before the decision to treat a larger area was made.

Prior to applying the treatment each patch should be measured using the tape measure method described above. In addition density

and/or percent cover assessments should be made of the target species and non-target species. At least four quadrats using one quadrat size (between 0.1 and 1 m<sup>2</sup> is usual) should be assessed per treated and untreated area. The location of these quadrats should be permanently marked (with rebar). The measurements should then be sampled post treatment for a number of years.

As the number of different management options to be evaluated increases so too will the number of small scale experiments or treatments per experiment. The measurements we have suggested here will provide information, after a number of years, on whether the target species is increasing, not changing much or consistently, or declining and if the native species have been affected positively, negatively or no effect. In order to reach the land management goals it may be necessary to do further measures – for example to see if soil nutrients, litter, insect diversity etc. alter.

If monitoring for invasiveness has not been performed it can be completed at the same time as monitoring for impact, but this is much less desirable option. If, as may be preferable to managers who wish to prove to themselves that not all non-native populations are invasive everywhere the above approach can be extended and performed simultaneously with monitoring for invasiveness. Patches of target species should be selected from a range of different environments where the species occurs. Continuing with the simplest example above of evaluating one herbicide. A number of patches of the target species, from the range of environments that the species occurs in should be selected. Herbicide should be applied to part of each patch, leaving the rest unsprayed.

As above, areas of the patches should be monitored, ensuring that the area treated and untreated is known, and the density and/or percent cover of the target and non-target species recorded. After a number of years it will be possible to determine invasiveness; i.e., which patches (or parts of patches) in which environments are increasing, staying the same or declining (using the untreated data); in which

environments the herbicide treatment is being most effective through to least effective at reducing the target species (using the treated data); and, if the non-target species were affected by the herbicide (using treated and untreated data).

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