

## **Quantitative Methods for Assessing NIS Populations for Invasiveness**

Bruce D. Maxwell and Lisa J. Rew

### **Introduction**

Plant species, as a taxonomic group can not be judged to be invasive. However, there are some plant species that have traits that allow a subset of their populations to be invasive. That is, there will always be variation in invasiveness of a plant species across the environments where it has become established regardless of its notoriety as an invasive species. In fact, there may be many environments where populations of notoriously invasive species are not at all invasive and may be going locally extinct following a rare establishment event. The main point is that the focus for determination of invasiveness for management considerations should be placed on populations or meta-populations segregated by environments rather than on species across their entire range of distribution.

Here we describe methods that allow an objective and quantitative assessment of the relative invasiveness of herbaceous plant populations thought to be invasive. We define an invasive plant population as one that at a minimum is consistently increasing in density or spatial extent. These methods would generally be used to assess non-indigenous plant species (NIS) that are often thought to be invasive for a wide set of reasons and under a precautionary principle may be best managed early in the invasion process. These methods could also be applied to indigenous 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 concluding 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.

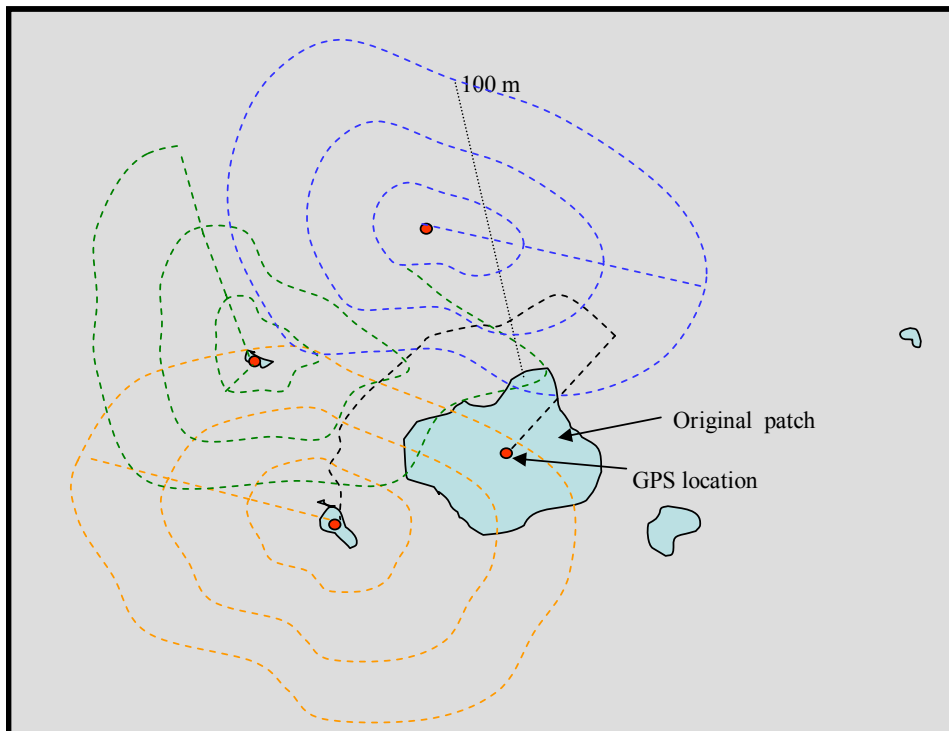
Quantifying relative invasiveness allows land managers to prioritize management of populations based on the types of environments where they are found. The methods that we suggest were arrived at under two principle constraints. First, they must be simple and efficient enough to allow managers to conduct the measurements in the field within their time constraints and be able to conduct the 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.

The methods are divided into 3 different approaches that assess local invasiveness of populations following an initial introduction. Thus, finding the new introductions is relegated as a separate issue and involves inventory or survey methods (Rew et al., 2004). The first method, discussed here, is focused on detecting new herbaceous NIS plant

colonies that become established at least 2 m away, but not more than 100 m away from a located source population. The second method quantifies the change in spatial extent of NIS populations (patches) using a range of simplified field measurements and automated approaches to analysis. The third method is focused on quantifying changes in population density and small scale changes in spatial occupation.

### Finding New Colonies

Identifying new colonies of the NIS 2 m to 100 m around an existing population (patch) can be accomplished efficiently using adaptive sampling (Thompson, 200?). This method first must determine the maximum distance that one can detect a new colony (a few plants). This will be called the identification distance. Once the distance is determined 3 random patch edge points are identified by standing in the middle of the patch selecting random values between 1 and 360 and using the random number as an azimuth to travel along to the patch edge. From the random starting point, one travels the identification distance plus 2 m and turns so that he/she is traveling parallel to the patch edge maintaining the 2 m plus identification distance from the patch. If no new colonies or plants are identified and the patch is fully circled, then continue moving away from the patch another increment of the identification distance and circle the patch again parallel to the edge. Continue this sampling path until the sampler is 100 m from the edge of the original patch. If a new colony is encountered, then start the process again using the new patch like the original patch, but keeping track not to exceed 100 m from the edge of the original patch and not resampling any already located colonies. When a new colony is located, create a GPS location point in the center of the new colony and estimate its area. Estimates of area can be obtained by using the methods described below.



**Figure 1.** Hypothetical map showing NIS patch boundaries (solid lines) and adaptive sampling walking paths (dashed lines) for finding new colonies of the same species.  
Data Analysis

### **Quantifying Changes In Population (Patch) Spatial Extent**

Monitoring for invasiveness is determining if representative populations of a NIS (from across the environments where the species was found with a survey or inventory of the management area) are consistently increasing in spatial extent or density. It is important to select populations from across the habitats where it was found in the survey or inventory to ensure a nonbiased estimate of how invasive the species is across the management area. In addition, selecting a nonbiased 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 environments where they occur.

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. However, 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 a population and the ability to easily identify the patch edge. Measuring patch perimeters with a GPS has been promoted as an efficient way to estimate patch area (Roberts et al. 200?; Cooksey and Sheley?). However, with the standard GPS used by most government agencies, consultants and county weed supervisors, the mean horizontal accuracy is rarely less than 1.0 m 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. 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.

A second method that we have experimented with and shows promise of a higher degree of accuracy than the GPS method uses a compass and a tape measure. The tape measure patch radii methods (TMR4 and TMR8) determine change in spatial extent of each patch by remeasuring patch radii and calculating area of each patch each year.

Upon inspecting a patch and finding its borders, a tape measure line is run across the longest possible axis of the patch and the midpoint is marked or remarked (from previous

year) with a road hair. The first 2 patch radii ( $r_1$  &  $r_2$ ) are this longest possible diameter that you can find for the patch. Use the first patch diameter ( $r_1 + r_2$ ) to identify the center of the patch so that  $r_1 = r_2$ . This is not necessarily a geometric center of a patch, but simply serves as a reference starting point for more radii. Radii length is recorded in meters to the 0.01 m and azimuth in degrees. The base of plants at the edge of the patch are used to establish the ends of each radii. Using a compass while standing over the center point (roadhair), the azimuth ( $Az_1$ ) and the length of the first radii ( $r_1$ ) looking out toward the edge of the patch are recorded (Table 1). Turn and record the azimuth ( $Az_2$ ) and length of radii two ( $r_2$ ) along the longest axis ( $Az_2 = Az_1 \pm 180^\circ$ ). At approximately  $90^\circ$  to the first two radii place the tape measure to create a third radii from the center point to the patch edge. Measure the length of the  $r_3$  and record its azimuth ( $Az_3$ ). Radii 3 should always be clockwise from  $r_1$  so that  $Az_3 > Az_1$  unless  $Az_1$  is between  $270^\circ$  and  $360^\circ$  then  $Az_1 > Az_3$ . Keeping the azimuth in order will facilitate automatic calculation of areas using the included Excel Workbook. The fourth radii should then be placed approximately  $180^\circ$  from  $r_3$  and the azimuth ( $Az_4$ ) and length ( $r_4$ ) recorded. Thus, each time that a new radii is established it is as directly as possible opposite the previous numbered radii, across the patch staying within a  $45^\circ$  pie to maximize the distance to the edge of the patch. The 4 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 along the patch edge.

Patches that are highly irregular in shape having highly invaginated borders may require additional radii to increase the accuracy of the area estimate. The fifth radii ( $r_5$ ) is established to split the patch to the edge between  $r_1$  and  $r_3$  and  $r_6$  is oriented  $180^\circ$  from  $r_5$  to split  $r_2$  and  $r_4$ . In each case the radii length is measured and the azimuth from center to edge is recorded. The  $r_7$  and  $r_8$  radii are oriented to split  $r_3$  and  $r_2$ , and  $r_4$  and  $r_1$ , respectively.

**Table 1.** Example data table for TMR4 method.

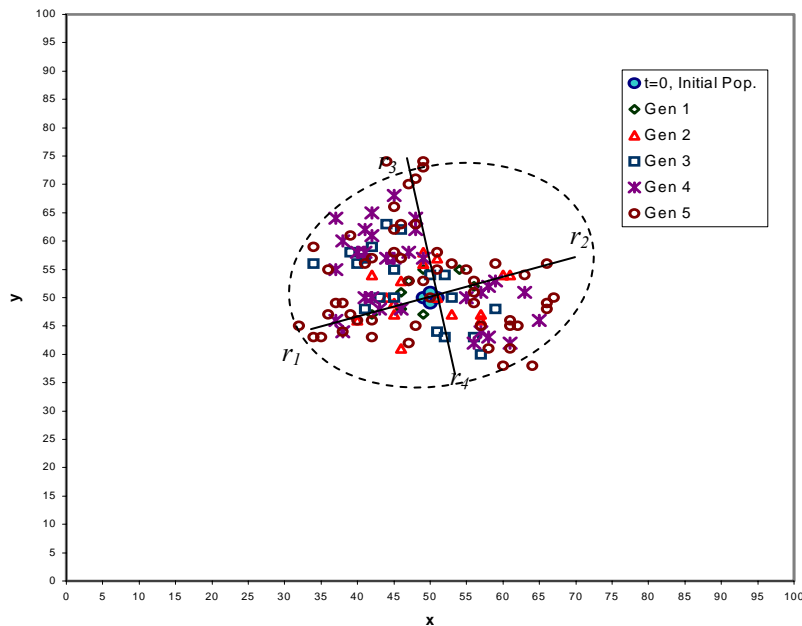
Species	Patch	Diam. 1		Azimuth	r <sub>3</sub>		r <sub>4</sub>	
		radii 1	radii 2	1	radii 3	Azm 3	radii 4	Azm 4

TMR4 Area Calculations:

The area of the patch can be calculated in  $m^2$  using the measurement of the first 4 radii (TMR4). 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  $r_1$  and  $r_2$  are the 2 radii of the ellipse.

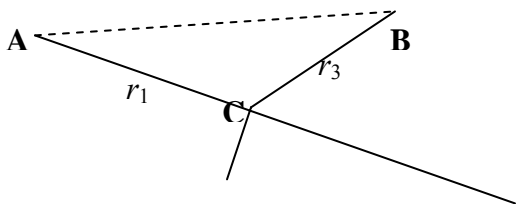


**Figure 2.** Simulated patch of plants(each symbol = one plant) with different symbols indicating different generations (year) of a single herbaceous population invading a plant community (considered an homogenous background).

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. If  $r_3$  and  $r_4$  are exactly perpendicular to  $r_1$  and  $r_2$  then the simplest case calculation is:

$$A = 2[0.5(r_1r_3) + 0.5(r_1r_4)]$$

where  $r_i$  are the radii measured from the intersection of the two patch diameters to the ends. If  $r_3$  and  $r_4$  are not perpendicular to  $r_1$  and  $r_2$  then a slightly more complicated method is required for calculating the area of triangles using simple geometric rules.



In order to calculate the area of triangle ACB ( $A_1$ ) the geometric rule for the area of a triangle is used where

$$Area = 0.5(AC \times BC \times \sin \angle ACB) \quad \text{in our case} \quad A_1 = \frac{AC \cdot BC \cdot \sin \angle ACB}{2}$$

where AC is the length of radii  $r_1$  and BC is the length of radii,  $r_3$ , and we get angle in degrees from subtracting the azimuth of  $r_1$  from  $r_3$  or  $r_3$  from  $r_1$  whichever one gives a positive number. Then the areas of the 4 triangles can be added together to estimate the area of the patch.

TMR8 Area Calculation:

Calculate the area of the patch in  $m^2$  using the measurement of 8 radii (TMR8). The new radii are added between the first 4 radii and are placed so that they pass through the patch center (roadhair) to further capture irregular patch shapes. Make sure that  $r_5$  is between  $r_1$  and  $r_3$ ,  $r_7$  is between  $r_3$  and  $r_2$ ,  $r_6$  is between  $r_2$  and  $r_4$  and  $r_8$  is between  $r_1$  and  $r_4$ . If one remains consistent with the sequence of measurement of the radii it will be easy to automate the calculations of area in Excel.

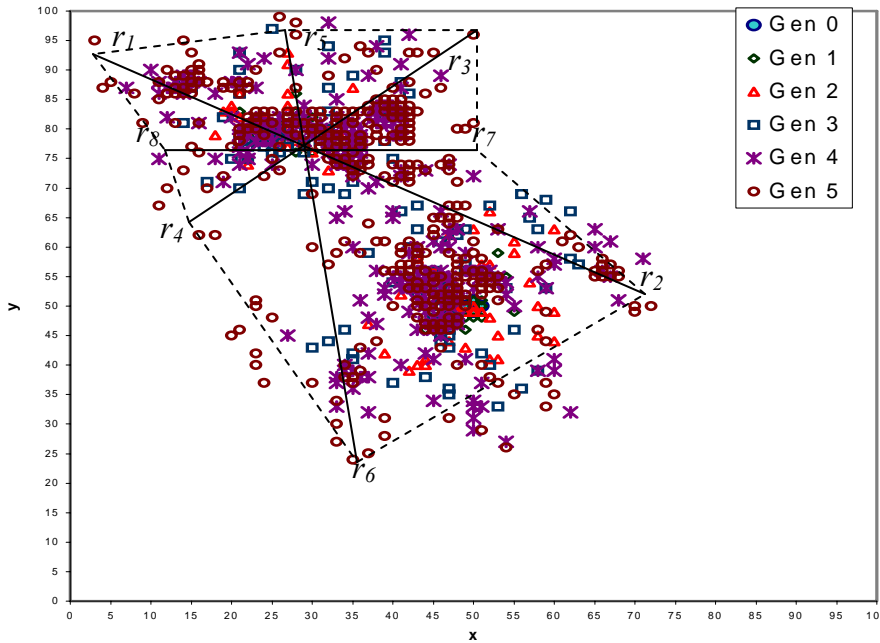


Figure 3. Simulated patch of plants(each symbol = one plant) with different symbols indicating different generations (year) of a single herbaceous population invading a plant community (considered an homogenous background).

In this case the patch is broken into a set of 8 triangles and the same sin rule for area of a triangle can be implemented as explained above. Then the areas of the 8 triangles can be added together to estimate the area of the patch.

**Table 2.** Example data table for additional radii associated with TMR8 method.

Species	Patch	Radii 5		Radii 6		Radii 7		Radii 8	
		radii 5	Azm 5	radii 6	Azm 6	radii 7	Azm 7	radii 8	Azm 8

**Table 3.** Area calculations sing data from Tables 1 and 2:

Species	Patch	Year	Ellipse	TMR4	TMR8

SKW = spotted knapweed  
 SCF = sulfur cinquefoil  
 SmB = smooth brome

## Quantifying Changes in Population Density

### Definitions:

Invasive population is one that is consistently increasing in density and/or spatial extent. Plant population growth can be characterized in many ways, but we have chosen two ways that are sensitive to detecting growth, are simple to gather the data, and require a minimum amount of data and thus are time efficient.

Density is the number of plants per unit area. Many perennial species have vegetative shoots (ramets) thus density is the number of shoots per unit area.

Temporal population growth rate is the change in population density ( $N$ ) over the change in time ( $t$ ) =  $\delta N / \delta t$  thus  $\delta N = N_{t+1} - N_t$

Spatial population growth rate is the change in the number of subsampled areas occupied by NIS plants within and surrounding the population from  $t$  to  $t + 1 = \delta n / \delta t$  thus  $\delta n = n_{t+1} - n_t$

### Sampling:

An inventory or stratified survey of potentially invasive species within a management area must be conducted to identify populations or metapopulations to monitor. Stratification must be used to insure that populations are found across the widest possible set of environments where they have become established. A random sample of the populations identified, stratified by environments thought to produce the widest amplitude in growth conditions for a particular species, then can be selected for monitoring.

Once a population is identified for monitoring, 1 m<sup>2</sup> sample areas must be chosen to make density counts of the species of interest. Here, we suggest two methods to minimize bias in sampling a population or metapopulation depending on whether the population is highly diffuse and difficult to identify edges (metapopulation) and those that are distinctively patchy with easily identifiable edges.

#### *Sampling within a metapopulation:*

A straight line transect can be intentionally placed to approximately bisect a metapopulation. Some number (usually 5 to 10) of random, non-overlapping, distances can be chosen along the length of the baseline transect. At each random distance, one can travel perpendicular to the transect along an azimuth using a compass until the first plant of the species of interest is intersected. At this point a 1 m<sup>2</sup> plot will be placed so that it extends along the same azimuth away from the baseline transect. Only one plot is established on each of the perpendicular azimuths.

#### *Sampling within a patch:*

There are two positions within a patch where population growth is apt to be different. First the interior of a patch will usually be older plants and often have higher density and thus higher density-dependent regulation of demographic processes. Patch edges will generally be at lower density, and be the place where new seedlings are likely to become established. Thus, we have found that stratifying samples to be in the interior or edge of plots will maximize the potential to characterize the true variance of population dynamics within a patch.

We have identified two ways to minimize bias in selecting placement of edge and interior plots and to maximize the potential to characterize the true variance in population growth metrics. The first, is more time consuming, but minimizes bias. It requires that an entire patch or portion of a large patch is superimposed with a grid with 1 m<sup>2</sup> cells and a random number of replicate 1 m<sup>2</sup> edge cells (where half or less of the cell is infested with the target species) are chosen and an equal number of 1 m<sup>2</sup> patch interior cells are randomly chosen. At least 3 replicate edge and 3 interior plots (1m<sup>2</sup> cells) should be chosen. The second approach for locating replicate edge and interior plots is to establish a patch dissecting diameter along the longest axis of the patch and establish edge plots with one edge of the plot along the diameter. Randomly choose the right or left side of the diameter and place plots at each end of the diameter (i.e. opposite edges of the patch). Locate the center of the long-axis diameter and choose a direction that is approximately perpendicular to the long-axis diameter and place the longest possible radius to the patch edge and establish a 3rd edge plot at the end of the radius. If more edge plots are desired then create another radius roughly perpendicular to the long-axis diameter in the opposite direction and establish a 4<sup>th</sup> plot at the end. Continue adding longest possible radii in directions that bisect the angles already created with each radii from the long-axis diameter center. Interior 1 m<sup>2</sup> plots can then be established immediately interior to each edge plot.

All 1 m<sup>2</sup> plots must be permanently marked on the corners so that they can be relocated for successive year stem census counts.

*Subsamples within plots:*

Each 1 m<sup>2</sup> plot can be divided into 1/16 m<sup>2</sup> cells to increase the accuracy of density counts and for estimating small-scale local changes in density from year to year.

Data:

The density data should be organized by species, environment, patch (population or metapopulation), patch position (interior or edge), plot, subsample cell and then by time (year). So a typical data file may look as follows:

**Stem Density = Number/1/16 m<sup>2</sup>)**

**Data File for Herbaceous Invasive Plant Monitoring**

Management Area \_\_\_\_\_ Observer ->

Species	Environment	Patch	Patch Position	Plot	Cell	Year 2001	Year 2002	Year 2003	Year 2004
<i>P. recta</i>	Burke Park	1	Interior	1	1	6	2	10	16
<i>P. recta</i>	Burke Park	1	Interior	1	2	9	14	2	9

<i>P. recta</i>	Burke Park	1	Interior	1	3	6	3	5	4
<i>P. recta</i>	Burke Park	1	Interior	1	4	0	3	5	3
<i>P. recta</i>	Burke Park	1	Interior	1	5	5	6	10	8
<i>P. recta</i>	Burke Park	1	Interior	1	6	5	6	15	10
<i>P. recta</i>	Burke Park	1	Interior	1	7	4	5	16	14
<i>P. recta</i>	Burke Park	1	Interior	1	8	10	5	15	4
<i>P. recta</i>	Burke Park	1	Interior	1	9	9	12	16	10
<i>P. recta</i>	Burke Park	1	Interior	1	10	3	12	7	14
<i>P. recta</i>	Burke Park	1	Interior	1	11	5	4	3	8
<i>P. recta</i>	Burke Park	1	Interior	1	12	0	8	7	17
<i>P. recta</i>	Burke Park	1	Interior	1	13	5	4	2	16
<i>P. recta</i>	Burke Park	1	Interior	1	14	4	5	13	13
<i>P. recta</i>	Burke Park	1	Interior	1	15	3	11	3	5
<i>P. recta</i>	Burke Park	1	Interior	1	16	1	10	4	9

The data for plot 1 (a patch interior plot) would be summarized as follows:

Plot	Cell	$dN/dt$		$dN/dt$
		2001-2002	2002-2003	2003-2004
1	1	-4	8	5
1	2	5	-12	7
1	3	-4	2	-2
1	4	3	2	-2
1	5	0	4	-2
1	6	1	9	-5
1	7	2	10	-1
1	8	-5	11	-12
1	9	4	3	-6
1	10	9	-5	7
1	11	-1	-1	5
1	12	8	-1	10
1	13	-1	-2	14
1	14	1	8	0
1	15	8	-8	2
1	16	9	-5	4

*Data Analysis:*

First one must consider the research question: Is the population consistently increasing or decreasing in density and/or spatial extent? We will first consider change in density over change in time ( $\delta N/\delta t$ ) or temporal dynamics in population growth. The null hypothesis will be that the population is, on average, stable with regard to density change so that there should be an equal number of cells increasing in density as there is decreasing in density and that the magnitude of those changes should be in equal proportions. That is, a frequency distribution of  $\delta N/\delta t$  should be centered on 0 and there should be equal proportions of  $\delta N/\delta t$  values on the negative side and positive side of the distribution. In addition, if one had a random set of densities and compared those with a second set of random densities from the same range their difference ( $\delta N/\delta t$ ) would be a normal distribution with a mean and median of 0. Thus, the specific interest of this analysis is to detect trends away from the normal distribution of  $\delta N/\delta t$  from samples within the population. This can be accomplished with a statistical test and a set of descriptive statistics for the  $\delta N/\delta t$  distribution that can be easily calculated in Excel.

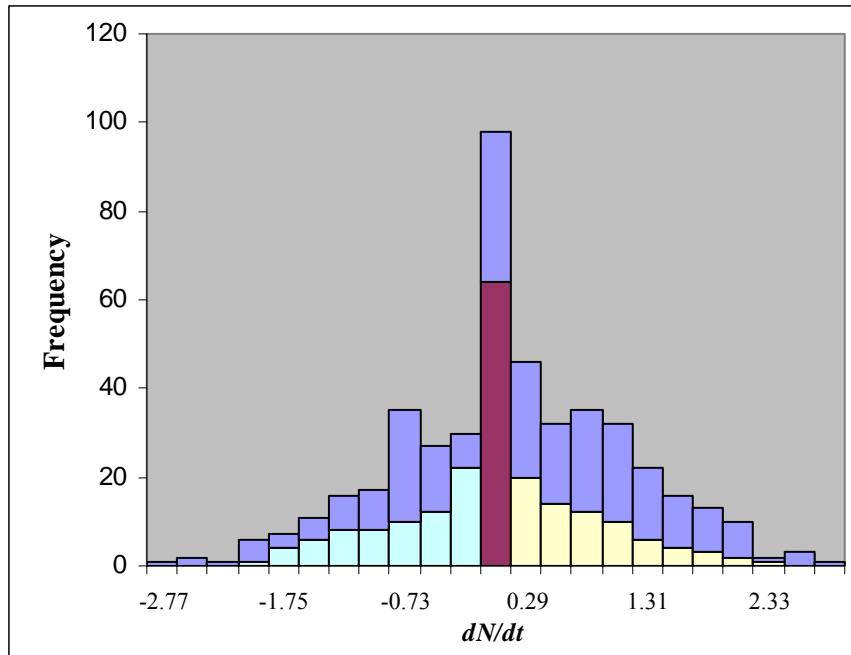
The first step is a  $\chi^2$  (CHITEST) test of difference between the observed  $\delta N/\delta t$  distribution and the expected (according to the null hypothesis) normal distribution of  $\delta N/\delta t$ . The expected normal distribution of  $\delta N/\delta t$  is based on a mean of 0 and the standard deviation of the observed distribution. If the CHITEST value is  $\leq 0.05$  then by convention one might conclude that the observed  $\delta N/\delta t$  is significantly different from the expected normal distribution and thus there is a significant trend in the population. An alternative statistical test of deviation from normality in the  $\delta N/\delta t$  distribution is the Kalmogorov-Smirnov goodness-of-fit test, but it will require a more advanced statistical software package. If the observed distribution is not different from the null (normal expected) distribution then one cannot conclude that the population is invasive. If the observed distribution is significantly different from the expected normal distribution then

the center of the distribution and the direction of the trend in the distribution can be quantified with the median ( $M$ ) and skew ( $sk$ ), respectively. If the skew is greater than 0 then the population is showing a trend or tail toward positive growth rates and alternatively if the skew is less than 0 then the population trend or tail is toward negative growth rates. Four additional characterizations of the  $\delta N/\delta t$  distribution can help identify invasiveness. The first is calculation of the proportion of cases that are  $\delta N/\delta t$  values greater than 0 ( $\alpha$ ) and the second is the proportion of  $\delta N/\delta t$  values that are less than 0 ( $\sigma$ ). The third characterization is the proportion of  $\delta N/\delta t$  values that are positive and originated from 0 (i.e.  $N_{t-1} = 0$  and  $N_t > 0$  = new colonization events) ( $\gamma$ ). The fourth characterization statistic is the proportion of  $\delta N/\delta t$  values that are negative and originating from values greater than 0 and changing to 0 (i.e.  $N_{t-1} > 0$  and  $N_t = 0$  = new extinction events) ( $\theta$ ). These descriptive statistics can be combined into an invasiveness index as follows:

$$\text{Invasiveness Index} = M + sk + \alpha - \sigma + \gamma - \theta$$

The invasiveness index is centered on 0 and values above 0 indicate an invasive population and values less than 0 indicate populations that are in density decline and thus cannot be interpreted as invasive for the  $\delta N/\delta t$  transition time period.

Some important considerations should be taken into account when selecting the data for the frequency distributions. First, when using the 1/16 m<sup>2</sup> subsample cell data from the edge plots in particular, there will be a number of cells with 0 density at  $t$  and  $t + 1$ . These should not be included for the calculation of  $\delta N/\delta t$  frequency distribution skew or the  $\chi^2$  test. Second, the  $\delta N/\delta t$  frequency distribution should group all of the 1/16 m<sup>2</sup> data from replicate plots in a patch to draw conclusions about the invasiveness of the population. For further refinement, one may want to divide the data by interior and edge plots to see if there is any difference in the conclusion based on that split. A third consideration, is to summarize the frequency data by cases for qualitative assessment of the  $\delta N/\delta t$  frequency distribution.



**Figure 1.**  $\delta N/\delta t$  frequency distributions

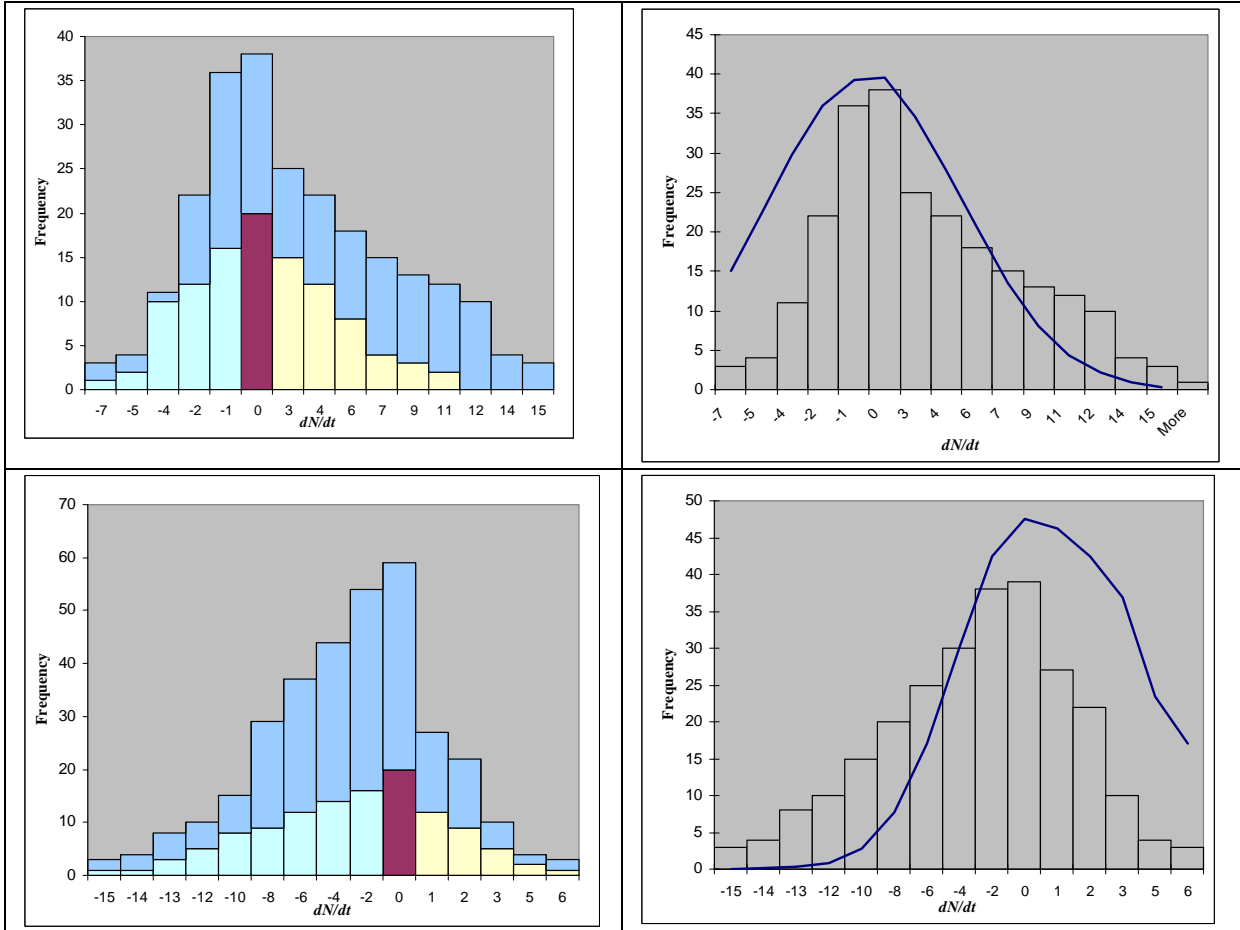
There are 6 cases for  $\delta N/\delta t$ :

1.  $\delta N/\delta t = 0$ . Subsampled areas where there are 0 plants at time  $t$  and 0 plants at time  $t + 1$ . (purple bar above)
2.  $\delta N/\delta t = 0$ . Subsampled areas where there are  $>0$  plants at time  $t$  and the same number of plants at time  $t + 1$ . (blue portion of 0 bar)
3.  $\delta N/\delta t > 0$ . Subsampled areas where there are 0 plants at time  $t$  and  $>0$  plants at time  $t + 1$ . This case represents new colonization. (yellow bars)
4.  $\delta N/\delta t > 0$ . Subsampled areas where there are  $>0$  plants at time  $t$  and  $>N_t$  plants at time  $t + 1$ . (blue bars to the right of 0)
5.  $\delta N/\delta t < 0$ . Subsampled areas where there are  $>0$  plants at time  $t$  and 0 plants at time  $t + 1$ . This case represents local extinction. (light blue bars left of 0)
6.  $\delta N/\delta t < 0$ . Subsampled areas where there are  $>0$  plants at time  $t$  and  $<N_t$  plants, but  $>0$  plants at time  $t + 1$ . (blue bars left of 0)

First, the frequency distributions for  $\delta N/\delta t$  will often have a mode (highest frequency) of 0 due to many cells with 0 density that remain 0 density, particularly from patch edge plots. Second, most of the observed distributions that we have assessed appear close to a normal distribution like the one in Figure 1. When this distribution was tested with the  $\chi^2$  test it was found to be significantly different ( $P = 0.016$ ) from the null (expected) distribution allowing us to calculate the statistics and subsequent invasiveness index of this particular  $\delta N/\delta t$  distribution.

$$\begin{aligned} \text{Median } (M) &= 0.0655 & \text{Prop. + growth } (\alpha) &= 0.502 & \text{Prop. new colonies } (\gamma) &= 0.464 \\ \text{Skew } (sk) &= -0.122 & \text{Prop. - growth } (\sigma) &= 0.462 & \text{Prop. local extinct } (\theta) &= 0.471 \\ \text{Invasiveness Index} &= 0.0655 - 0.122 + 0.502 - 0.462 + 0.464 - 0.471 = -0.024 \end{aligned}$$

Therefore, one might conclude that the population with the sampled  $\delta N/\delta t$  distribution in Figure 1 is not invasive. It would follow that there is no evidence that management should be initiated on this population, but monitoring should continue. Sampled  $\delta N/\delta t$  values can be grouped from previous years to increase the data in the distributions and determine the consistency in the population growth trend.



**Figure 2.** Examples of possible extreme observed  $\delta N/\delta t$  distributions and the distribution compared with the expected normal distribution (line) centered on mean of 0 and with the standard deviation of the observed distribution.

Table ?. Invasiveness Index values for the  $\delta N/\delta t$  distributions in Figure 2.

$\chi^2$ test P-value	Median ( $M$ )	Skew ( $sk$ )	Prop. + growth ( $\alpha$ )	Prop. - growth ( $\sigma$ )	Prop. new colonies ( $\gamma$ )	Prop. local extinction ( $\theta$ )	<i>Invasive- ness Index</i>
<0.000	4.00	0.420	0.565	0.352	0.186	0.174	4.65
<0.000	-5.00	-0.421	0.277	0.643	0.439	0.451	-5.80

One would conclude that the top sampled  $\delta N/\delta t$  distribution was from a population that is invasive and management should be initiated immediately and the bottom distribution was sampled from a population that is locally in decline and there would be no reason to manage this population or even populations in similar environments.