Beyond North American Weed Management Association Standards

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The North American Weed Management Association (NAWMA) system for mapping non-native plant species provides a standard that will coordinate and synchronize efforts to control and prevent plant invasions. The system creates a standardized format for the collection and mapping of non-native plant species that allows for information to be shared and transferred across boundaries. Sharing information will promote coordinated control efforts, and systems for early warning and detection. The exchange of distribution and abundance information on invasive species is an essential component of containing them. The standards established have been adopted by the US Forest Service, the National Park Service, the US Fish and Wildlife Service, and many other public and private organizations.

The authors of the NAWMA standards repeatedly stress that these standards represent a minimum of what should be collected when inventorying and mapping non-native plant species on the landscape. Incorporating these standards into an inventory and monitoring plan or research project will yield data comparable to non-native plant surveys while serving other purposes and increasing the utility of the combined information. While we applaud the effort to create a standard that will ease the distribution and comparability of data across landscapes, the minimum standards should include methods that incorporate quality assurance and levels of uncertainty.

It is not the object of this document to discuss or describe the existing standards in detail. More information can be found about the current standards by visiting the NAWMA website (www.NAWMA.org). However, a brief description of the required fields serves as a useful starting point to outline additions to the minimum NAWMA standards. The system collects the following variables:

- **Date**
- **Examiner**
- **Plant Name**
- **Common Name** (optional)
- **Plant Codes**
- **Infested Area** (with units) – area of land containing a single weed species

- **Gross Area** (with units, optional) – intended to show general location and population information, contains infested area and significant parcels of land that are not occupied by the weed species.
- **Canopy Cover –** variety of methods are acceptable: the percent the 'gross area' covers the infested area, ocular estimates, Daubenmire classes, Greater Yellowstone Area system, or 10 point codes
- **Ownership**
- **Source of the Data**
- **Country**
- **State or Province**
- **County or Municipality**
- **Hydrologic Unit Code** – required for aquatic species only
- **Location** – legal, Latitude and Longitude, UTMs
- **Quad Number** – (optional)
- **Quad Name** – (optional)

In the sections below, we outline steps that include some simple study design suggestions and field methods that will make the NAWMA standards more statistically sound, and increase the power of the data collected by allowing for greater inference across unsampled areas.

Location

The **gross area** of as many patches as practical should be recorded with a GPS unit by actually walking and delimiting the perimeter of the patch of weeds. This provides a patch size and a location that will be more useful than simply documenting the center as suggested in the required **location** field. The US Forest Service weed mapping effort already implemented this technique (Bill Cheatum, pers. comm.). If the infestation is smaller than 5-m in diameter then the center of the patch should be recorded with the GPS unit.

Area Searched

It is equally important to record the regions searched that did not contain non-native plant species. This provides a general understanding of the locations that may be resistant to invasion, provides an estimation of the extent of invasions, and allows examination of areas searched so gaps in searched area and habitats can be assessed.

Ancillary Data

Recording information about the site of the non-native species occurrence is another way to make data more comparable and complete and is essential for including a predictive component to invasive species containment efforts. Funding constraints and the size of vulnerable landscapes often prohibit field sampling and location of non-native plant species on more than a very small portion of a landscape. The ancillary data collected at sampled points can be related to remote sensing data, topographic data, and other abiotic variables (e.g. soil type, topographic position, notable disturbance such as fire) to create spatial predictive models that estimate distribution and concentration of non-native species across much larger unsampled regions. These predictive maps can be used to identify gaps in an inventory effort, direct control efforts, and help formulate predictions of the future potential distribution and spread of invasive species. We are not the first and only group to stress the importance of these variables. The National Park Service also highly recommends (but does not require) the collection of these variables ("abiotic") in weed mapping efforts (Pamela Benjamin, pers. comm.).

Ancillary data is easy to collect and should be recorded every time a non-native individual or patch is encountered. The following variables should be recorded:

- **slope, aspect, and elevation.** These variables can be obtained from digital elevation models, but field measurements provide more accurate information.

- **geologic features.** Soil descriptions and collection (color and texture descriptions, collect if have means), topography (hillside, distance to road, wetland, or stream, etc.)

- **disturbance features** (e.g., recent fire, flood, small mammal disturbance)

Cover

The methods for assessing **cover** by the NAWMA standards are not adequate. The use of a classification system for cover (e.g. 0-5 % or 75-100%) does not provide useful information for detecting change over time. An actual estimate of cover should be used (i.e. 1-m^2 plots nested in larger plots, Appendix 1). Methods that measure small areas, such as Daubenmire plots, for assessing cover are not reliable or complete (see Stohlgren et al 1998). To make data comparable with national plot monitoring standards (e.g. Forest Health Monitoring, Forest Inventory and Analysis, USGS Modified-Whittaker technique and others) we recommend the use of a circular 168 m^2 plots with three 1-m^2 nested quadrats (see Appendix 1 for details). We understand that this technique requires a greater time investment than any of the other methods suggested for measuring cover, however, **the described plot does not have to be placed at every sampling location.** The plot only needs to be measured in every fifth or tenth polygon measured. Cover at other sampling locations should be estimated using ocular estimates and, if appropriate using the infested proportion of the gross area (see NAWMA methods). Sampling with this combination of techniques provides a tool for assessing actual cover, calibrating ocular and other cover estimates, modeling the patches of missed and less sampled non-native species, and a method for understanding which habitats and sites are being invaded. The system allows managers to be more pro-active rather than re-active in the effort to contain invasive species.

Proposed Sample design

Current NAWMA standards are based on 100% subjective sampling by well-trained and less-trained individuals. To be credible, it is important to quantify (1) the spatial bias of investigation, (e.g. were only roadways, flat terrain, and regions close to facilities searched?); (2) the accuracy of observations (e.g., Did they get the species taxonomy correct 20% of the time or 80% of the time? Did they record location data accurately?); (3) an estimate of the abundance and distribution of invasive plants in unsampled areas (i.e. predictive modeling of polygon and plot data with remotely sensed data and derived variables). We recommend the following procedures to augment the NAWMA standards, using about 10% of the total resources allocated to collecting the NAWMA data. That is, instead of collecting NAWMA data with 100% of the available resources, use 90% of the resources (time or effort, or funding) to collect the minimum standards, and 10% of the resources for the quality control, quality assurance, and accuracy assessments described below.

Patches of non-native plant species should be mapped, measured and located in the following ways:

1. **NAWMA** mapping standards (~90% of resources), including the additions we outlined above, should be used to map weed polygons across the landscape. This includes the use of a circular plot every fifth to tenth time a weed polygon is mapped. Every time a polygon is encountered, the surrounding area should be searched (and mapped) for occurrence of other infestations.

2. **A stratified random design** (~5% of resources) can be used to assess the spatial bias of the NAWMA mapping standards. At least 5 circular plots (if costs allow) are placed in each stratum (cover types, condition class, etc.) with rare and common cover types included in the stratification process. Sampling locations should be selected from randomly selected stratum.

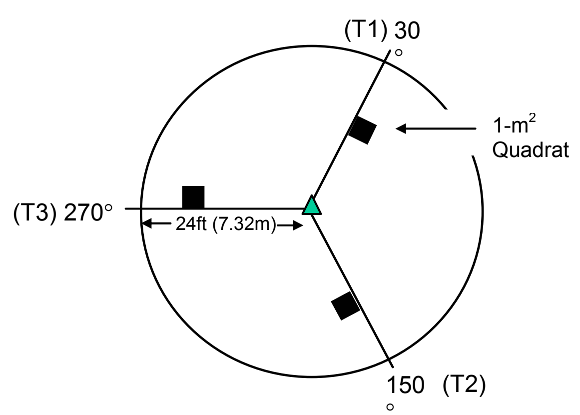
This method will also record locations where weeds do not exist. This is important on the broad scale as previously noted (where weeds were not found; see '**Area Searched**') as well as at the smaller plot scale. As an alternative to the randomized design, a circular plot could be placed on the landscape in an area adjacent to a weed polygon. If this technique is used, the circular plot should be paired (same slope, aspect, elevation) with circular plots placed in the weed polygons (see #1 above and #3 below). Evaluations of areas without weeds provide an understanding about the locations and habitat types that might be resistant to weed establishment, vulnerable habitats, and the rate of spread, all important components of predicting weed invasion and increasing our ability to contain weed establishment. This is the first step in an iterative process.

AND

A subset of plots (number and placement determined by field crews) are then subjectively placed (called "purposive sampling") to capture the "tails of the distributions" -- a wide variety of extreme - or near extreme environmental gradients. This allows field crews to catalogue non-native species not randomly located, and improves spatial interpolation when modeling the entire landscape of typical and atypical sites. Species overlap (Jaccards Coefficient) within and among strata, species-accumulation curves (Estimate-S) by strata, and the variation in environmental gradients are monitored and assessed routinely through the field season to see if more plots are needed. Low species composition overlap within a strata suggests the need to put more plots in that type. Very high overlap among strata suggests certain types may be combined. If species-accumulation curves are very steep (no leveling off after many plots are evaluated), more plots are needed in that type. If some elevation zone is missed (i.e. no plots landed between 1000m and 1500m, maybe more plots are needed there. If, after ploting the UTM coordinates of the plots, there are major gaps (holes) in coverage, perhaps additional plots are needed to fill the gaps.

3. **Quality control and quality assurance** (~5% of resources) are important to evaluate observer accuracy and spatial bias for the "minimum-standard" NAWMA polygon. The stratified-random design and purposive sampling design can be used to assess the spatial bias of NAWMA records. To evaluate observer bias and accuracy (taxonomy and location), a random subset of minimum standard polygons must be assessed by an independent field crew. The "audit" crew verifies the taxonomy and spatial location accuracy of the polygon. If the accuracy is low, additional audit polygons are necessary. The recorder's data should be noted as "validated" in the metadata, and the level of accuracy should be noted separately for taxonomy and location, with the sample site noted.

Appendix 1:
Methods for Assessing Cover and Vegetation Diversity of Non-native Species



layout for vegetation diversity measurements

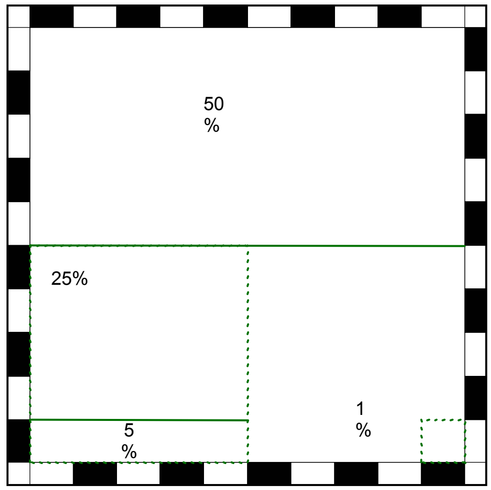
Locate the predetermined subplot, subplot center pins are inserted and flagged. Transect lines (T1, T2, T3) are located on the 30°, 150°, and 270° azimuths from subplot center, radiating out 24 ft (7.32m). Transects are flagged at the 24ft (7.32m) mark to delineate the perimeter of the subplot. Vegetation quadrats are located at 15ft and 18.3ft (4.57m and 5.57m) along transects. Flag all four corners of each quadrat to prevent trampling. Note: all distances are horizontal distance, therefore transect lines are corrected for slope. Place the quadrat frame to the right side of the transect line. Level quadrat if necessary by propping up quadrat corners.

Vegetation diversity and cover measurements are taken with a small 1-m^2 quadrat. On each quadrat, the following types of data are recorded: species identification and dominant microhabitat codes, and cover estimated to the nearest 1% for each plant species and microhabitat variable present. The botanist identifies each plant species in the quadrat and enters its corresponding standardized NRCS (Natural Resource Conservation Service) PLANTS database code (USDA, NRCS. 2001. The PLANTS Database, Version 3.1 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA). Percent cover to the nearest 1% is estimated for each species. Cover is then estimated to the nearest 1% for each ground variable listed in the Microhabitat Variables Table.

Microhabitat Variables

Code	Definition
1	Dead wood; log and slash (>10cm diameter), stump, branches and limbs
2	Dung
3	Fungus
4	Lichen
5	Litter / Duff; accumulation of organic matter over forest mineral soil.
6	Live root / bole; living roots at the base of trees or exposed at the surface of the forest floor or soil and cross-sectioned area of live tree boles at the ground line.
7	Mineral soil / Sediment; physically weathered soil parent material that may or may not also be chemically and biologically altered.
8	Moss
9	Road
10	Rock; a large rock or boulder or accumulations of pebbles or cobbles.
11	Standing water / flooded; ponding or flowing water that is not contained within banks.
12	Stream; body of flowing water contained within banks.
13	Trash / junk

Each 1-m^2 quadrat frame is calibrated (painted in 10 cm sections) to make cover estimates easier. Only estimate cover on plants or portion of plant that falls inside the quadrat frame. Visually group species together into a percent cover. Fine tune that estimate by subtracting out any spaces or gaps. Familiarize yourself with what certain cover estimates (e.g., 1%, 10%, 15%, 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. There will often be overlap of plant species. Therefore, your total cover for a quadrat may exceed 100%.



After completing the three quadrats, the botanist does a walking search of the entire subplot looking for and recording any new species that were not previously found on any of the quadrats. The botanist is adding species to the total species list.

The following ancillary data is collected:

1. UTM location of the center stake
2. Trees >10 cm at 2.3m above the ground: record dbh of trees by species (live and dead trees separately).
3. Tally trees <10cm: record dbh by species.
4. Total tree canopy cover (estimate to nearest 5%)
5. Topographic position (slope, aspect, elevation)
6. Distance to stream (or water), distance to road, and distance to crops if the distances are <100 m; and land use notes on disturbance, grazing intensity, small mammal mounds, etc, that make sense for a later synthesis of plots from many such studies.

Suggested add-on:

1. Collect soil samples after litter is removed -- Four soils samples, one at each point where transects meet the perimeter of the subplot and one in the center. Take samples with 2.5cm diameter core to a depth a 15cm and pool into one composite sample. Analyze for texture (%sand, silt, and clay), total N and C, other nutrients where appropriate.
2. Permanent stake -- copper top engraved survey stake -- for long-term monitoring if that is a study objective. Permanent pins may also be used to mark quadrat corners at the 15ft and 18.3ft (4.57m and 5.57m) points along transects.
3. Collect and store data using MS Access friendly software programs loaded onto handheld computers that interface with GPS units. Objective: Efficient movement of data from field to lab for analysis and modeling.

Example data sheet, blank data sheet follows.

Sample data sheet

		Q = QUAD
Botanist:	Joe Johnson	SS = SUBPLOT SEARCH (1 for presence)
Date:	4-22-02	TRAMPLING: 1 undisturbed, 2 moderate, 3 heavy
UTM:	455058 4471036	.01 indicates less than 1 percent cover
Plot Number	Aspen-23	1 indicates species presence in the subplot search column
Location:	Colorado	All cover estimates are to the closest 1%
		N/I Native or introduced

		Grnd Variables	**Q1**	**Q2**	**Q3**	
		dung	0	2	0	
		lichen	5%	0	.01	
		litter/duff	40%	51	33	
		moss	0	0	10	
		road	0	0	0	
		rock	10%	.01	15	
		root/bole	5%	12	20	
		soil	30%	10	10	
		stream	0	0	0	
		trash/junk	0	0	0	
		water	0	20	0	
		wood	15%	12	0	
		Condition Class				
		Trampling				
Comment	**N/I**	**Species**	**Q1**	**Q2**	**Q3**	**SS**
		CALI4	23		10	1
		KOMA		2		1
		POTR5	34		4	1
		POPR	5	50		1
		RICE	5		4	1
		ARTR2		23		
		AGSM	6		3	1
		ERRA3	13	4		
	I	POPR		25	45	1
		CHNA2	12			1
		STCO4			23	1
		ABCO				1
	I	BRIN2	30	40		1

Sample data sheet

	Q = QUAD
Botanist:	SS = SUBPLOT SEARCH (1 for presence)
Date:	TRAMPLING: 1 undisturbed, 2 moderate, 3 heavy
UTM:	.01 indicates less than 1 percent cover
Plot Number	1 indicates species presence in the subplot search column
Location:	All cover estimates are to the closest 1%
	N/I Native or introduced

		Grnd Variables	**Q1**	**Q2**	**Q3**	
		dung				
		lichen				
		litter/duff				
		moss				
		road				
		rock				
		root/bole				
		soil				
		stream				
		trash/junk				
		water				
		wood				
		Condition Class				
		Trampling				
Comment	**N/I**	**Species**	**Q1**	**Q2**	**Q3**	**SS**