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Evaluating plant biodiversity measurements and exotic species detection in National Resources Inventory Sampling protocols using examples from the Northern Great Plains of the USA

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ABSTRACT

Native plant biodiversity loss and exotic species invasions are threatening the ability of many ecosystems to maintain key functions and processes. We currently lack detailed plant biodiversity data at a national scale with which to make management decisions and recommendations based on current conservation challenges. We collected plant biodiversity and exotic species richness data from 4 sites in the Northern Great Plains using the modified Whittaker (MW) and Natural Resources Inventory (NRI) methods to evaluate any major differences between indicators generated from these methods and offer recommendations based on findings. Our data indicated that the NRI protocols underestimated both total plant species richness and exotic species richness compared with the MW approach. More importantly, however, results show that biodiversity indicators from the two methods showed similar trends. Increasing time spent on making species richness measurements and implementing a more systematic approach to detecting species within a plot could improve biodiversity inventory and monitoring efforts in NRI while also providing a link between existing long-term data and any new information collected. These adjustments would ultimately help those interested in adopting NRI methods and using plant biodiversity data to increase the amount and quality of information collected.
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1. Introduction

Native plant biodiversity loss and exotic species invasions are threatening the ability of many ecosystems to maintain key ecological functions and processes (Hooper et al., 2012). Plant biodiversity data (IPCC, 2007) are needed to make conservation and management decisions and recommendations (Mack et al., 2007; Hooper et al., 2012; Symstad and Jonas, 2011). The National Resources Inventory (NRI) is an inventory of land use and natural resources on U.S. non-Federal lands (Nusser and Goebel, 1997), which provides indicators to estimate plant biodiversity among others. The NRI effort is led by the US Department of Agriculture, Natural Resources Conservation Service (NRCS) but the US Department of Interior, Bureau of Land Management, has also adopted NRI protocols for national implementation through the Assessment, Inventory and Monitoring strategy (Toevs et al., 2011). There is a need for determining how accurate plant biodiversity and exotic species data from NRI methods are, due to their increased adoption and the potential for indicators from these methods to be used for large-scale management decisions.

The NRI biodiversity measurement and exotic species detection methods consist of a combination of line point intercept data and a 15 min timed search in which all species encountered within circular 1642 m^2 plot are recorded. The modified Whittaker plot technique is a multiscale plot sampling approach with nested plot sizes and no specified time limitations (Stohlgren et al., 1995).

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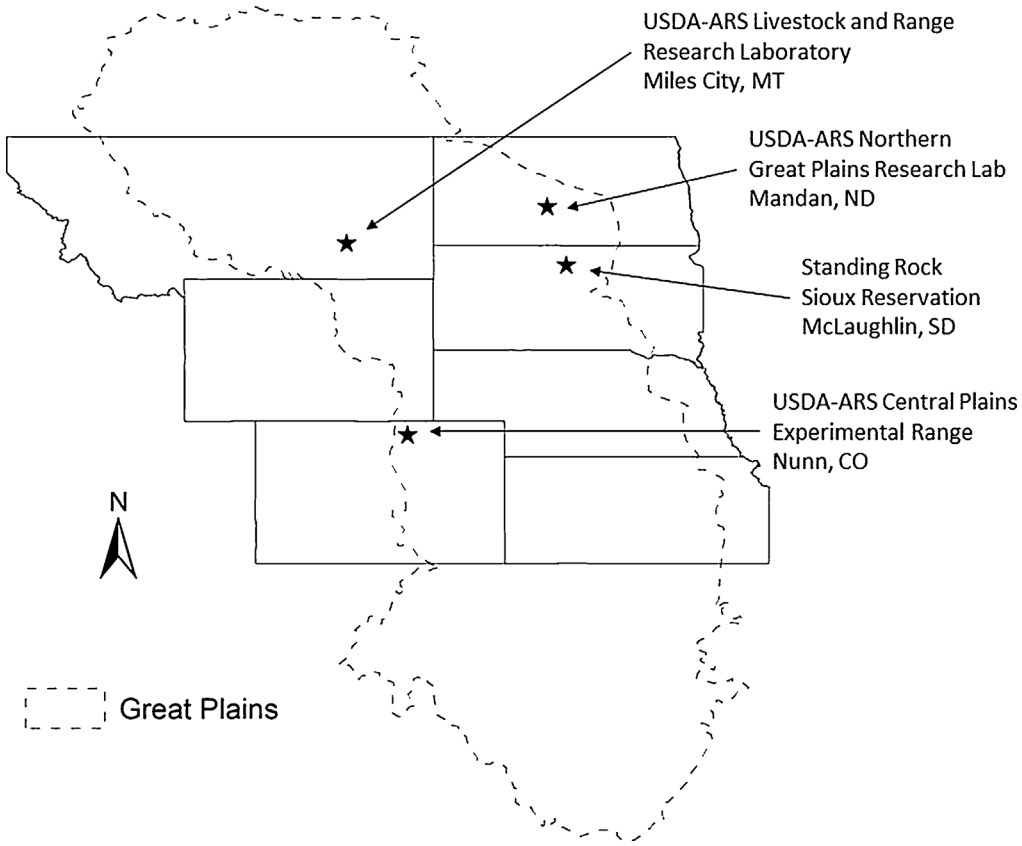

Fig. 1. Map of the Northern Great Plains region marking study locations.

Although the NRI biodiversity protocols have not been specifically compared with other methodology, Stohlgren et al. (1998) suggested that less intensive, single scale plant biodiversity measurements may miss a relatively large number of species, many of them exotic invasive species in their initial stages of colonization, and many (if not most) rare species. Methods such as the modified Whittaker plot can be time consuming and require a very location-specific set of plant ID skills. However, the quality of the species richness indicators gathered from this method and its ability to detect invasive or exotic species before they become a problem make it a cost-effective method (Stohlgren, 2007; pp.132–135). Our objective is to compare NRI methods used for biodiversity data collection with biodiversity data from the modified Whittaker method. We will compare these two methods to determine if NRI is accurately measuring indicators related to plant species richness and presence of exotic species across the Northern Great Plains and to determine the degree of precision around NRI species richness estimates.

2. Methods

2.1. Study areas

This study included 4 different locations in the Northern Great Plains region of the USA: The Standing Rock Sioux Reservation (SRSR, $n = 12$), the USDA–ARS Northern Great Plains Research Lab (NGPRL, $n = 15$), the USDA–ARS Central Plains Experimental Range (CPER, $n = 8$), and the USDA–ARS Livestock and Range Research Laboratory (LRRL, $n = 8$) (Fig. 1). Study locations represented four different prairies with a variety of vegetation compositions and structures (Table 1). A variety of sites were subjectively chosen within each location to encompass as much within-site variation as possible. At each site within each location a modified Whittaker plot was measured and then an NRI plot was superimposed as described below (Fig. 2). To avoid having parts of a plot or transect being on different ecological sites and potentially confounding our results, care was taken during plot layout to ensure all

Table 1
Study location, historically dominant vegetation, number of plots per location, primary ecological site, average precipitation and geographic position of locations sampled for NRI and modified Whittaker method comparison.

Study location	Historically dominant vegetation	Plots	Primary ecological site	Average precipitation (mm)	Latitude	Longitude	Elev. (m)
Standing Rock Sioux Reservation	*Pascopyrum smithii, Bouteloua gracilis, Nassella viridula*	12	Thin Claypan and loamy	411	45.445530	-100.3978	549
USDA – ARS Northern Great Plains Research Lab	*Pascopyrum smithii, Nassella viridula*	15	loamy	411	46.77887	-100.9064	591
USDA – ARS Central Plains Experimental Range	*Pascopyrum smithii, Heterostipa comata, Koeleria macrantha*	8	loamy	340	40.822588	-104.7115	1626
USDA – ARS Livestock and Range Research Lab	*Nassella viridula, Pascopyrum smithii*	8	silty	353	46.405394	-105.9544	820

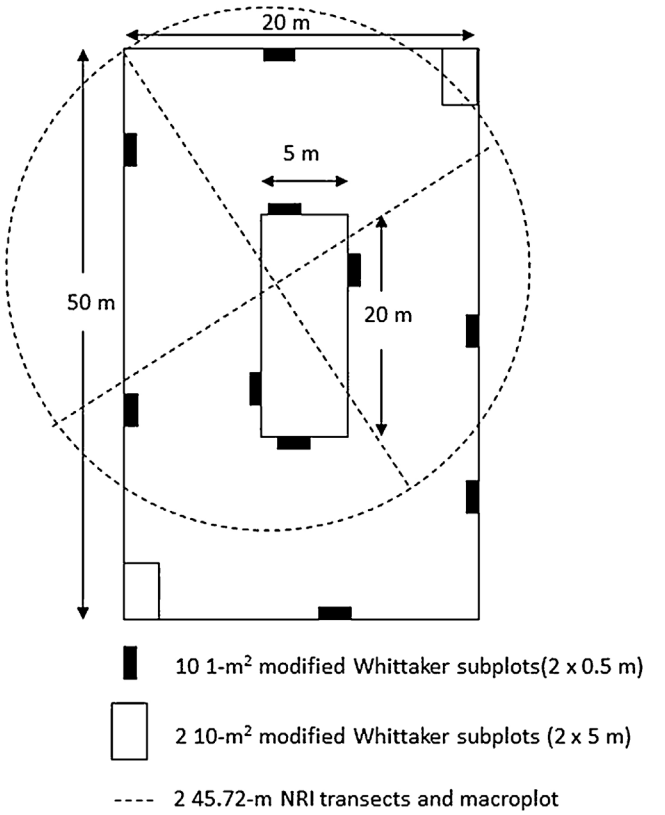

Fig. 2. Layout of NRI plot (dashed lines) and modified Whittaker plot (solid lines). Modified Whittaker plot layout based on Stohlgren et al. (1995); and plot layout of NRI based on NRI protocols.

measurements fell within the same landscape position. A soil pit was also dug and characterized near the center of the NRI plot and verification soil cores were systematically taken at 17 different locations within the MW plot.

2.2. Modified Whittaker (MW)

The modified Whittaker plot technique is a multiscale plot sampling approach with plot sizes of 1,10,100 m^2, and 1000 m^2 (Stohlgren et al., 1995; Stohlgren, 2007; Tracy and Sanderson, 2004; Goslee and Sanderson, 2010; Fig. 2). Within this multiscale plot, plant species cover and richness were estimated visually by systematically searching for all species in each plot. Sites were selected in three different topographic positions: top, mid and toe slope at the North and South Dakota sites. At the Colorado and Montana sites, one modified Whittaker plot was established in each of four pastures and at one pre-existing exclosure within each of those pastures.

At each of the 1 m^2 (0.5 m × 2 m) quadrats, the presence and canopy foliar cover of all species present were visually estimated. Species richness but not canopy foliar cover was estimated for 10 m^2 (2 m × 5 m) plots, the 100 m^2 (5 by 20 m) plot and for the entire 1000 m^2 (20 m × 50 m) plot. Once the MW measurement was completed, NRI transects were superimposed over the MW plot (Fig. 2).

2.3. National Resources Inventory (NRI)

A circular macroplot of 45.72 m in diameter and an area of 1642 m^2 was established following USDA–NRCS rangeland National Resource Inventory (NRI) plot protocols (Spaeth et al., 2003; NRCS, 2009; Fig. 2). To avoid observer bias, MW and NRI plots within a given location were measured by different teams of observers. The NRI plot included two 45.7 m transects that intersected at 22.9 m on each transect. Within each NRI macroplot, we used the line-point intercept, plant height and plant census methods described in NRI protocols (Spaeth et al., 2003; NRCS, 2009) to quantify vegetation attributes. For the purpose of this paper and indicator comparisons, we focus on the data from the line-point intercept, plant height and plant census methods.

For line-point intercept, measurements were started at the 0.0 end of transect 1 and measurements were repeated at 0.9 m intervals. Measurements were made at each point by vertically dropping a wire pin flag to the ground and recording every plant species that the pin flag intercepted. Once transect 1 was measured, observers moved to transect 2. For plant height, height of the tallest living or dead plant within a projected 30.5 cm diameter vertical cylinder was measured at 3.0 m intervals. Plant height measurements were relevant because plant species recorded are counted in species richness estimates. For the plant census method, a timed search of 15 min was used to identify all plants encountered in the NRI macroplot (circular area 45.72 m in diameter centered on NRI transects intersection). Species richness for the NRI macroplot is calculated by summing all species identified in the NRI protocols.

2.4. Data analysis

Indicators calculated for method comparison from the modified Whittaker and NRI protocols include: species richness, canopy foliar cover, and number of rare species (species with less than 1% cover). For the MW method, canopy foliar cover values were obtained from the 1 m^2 plots and species richness values were obtained for each scale at each site. Additionally, we calculated the Shannon-Weaver index, the Simpson's reciprocal index and the Sørensen index, which are commonly used diversity indices (Krebs, 1999, pp. 410–451). We used SPSS to perform an analysis of covariance to test whether the relationship between the MW and NRI indices differed among locations. We then performed paired comparison *T*-tests to obtain test for differences between the means of indicators and correlation coefficients (*R*-values) at each location. Precision estimates for species richness and canopy foliar cover for each location were estimated by calculating coefficients of variation (Godínez-Alvarez et al., 2009) and paired comparison *t*-tests were used to determine whether there were significant differences in the coefficients of variation between the NRI and the MW methods.

3. Results

Analyses of covariance showed that there was an absence of interaction for location effects for all indicators, except percent canopy foliar cover ($F = 8.40$; $P = 0.0002$). However, we provide results by location to better address our specific objective of determining accuracy and precision around NRI biodiversity estimates.

Sample means for MW indicators tended to be numerically larger than those of NRI indicators (Table 2), but so did the standard deviation values. Despite the larger spread, most differences in values between methods were statistically significant. The MW captured greater species richness (native + exotic) as well as greater richness of exotic species than the NRI at all locations, although differences in exotic species richness estimates were only statistically significant at the LRRL. Both the MW and NRI showed similar species richness trends across locations. Richness of exotic species within locations did not display similar trends as evidenced by the low *R*-values for these indicators. Precision of species

Table 2
Paired comparison *T*-test results for modified Whittaker and NRI data for a set of cover and biodiversity indicators at each location.

Study location	Indicator/index	MW[a]	NRI[a]	Diff.	*R*
SRSR	Species richness	42.42 (12.84)	29.16 (6.73)	13.25	0.82
	Exotic species richness	5.42 (1.38)	5.00 (1.95)	0.42[b]	0.24
	Shannon–Weaver	11.21 (5.24)	6.27 (2.06)	4.93	0.60
	1/Simpson's	7.99 (4.26)	4.89 (1.67)	3.10	0.53
	Canopy cover (%)	81.25 (20.47)	68.75 (24.42)	12.51	0.93
	# Species with <1% cover	29.58 (8.32)	22.00 (5.44)	7.58	0.84
NGPRL	Species richness	44.40 (11.53)	32.80 (8.82)	11.60	0.88
	Exotic species richness	7.93 (1.79)	7.07 (3.61)	0.87[b]	-0.05
	Shannon–Weaver	9.70 (4.46)	4.84 (2.08)	4.87	0.77
	1/Simpson's	6.57 (3.20)	2.97 (1.16)	3.60	0.73
	Canopy cover (%)	80.37 (9.61)	97.60 (2.69)	17.23	-0.13
	# Species with <1% cover	33.40 (8.18)	22.40 (7.50)	11.00	0.59
CPER	Species richness	29.37 (6.99)	24.37 (6.65)	5.00	0.74
	Exotic species richness	0.87 (1.13)	0.50 (0.76)	0.37[b]	0.75
	Shannon–Weaver	6.32 (1.84)	4.46 (1.76)	1.86	0.83
	1/Simpson's	4.65 (1.86)	5.55 (6.53)	0.90[b]	0.36
	Canopy cover (%)	58.42 (6.63)	68.12 (11.05)	9.70[b]	0.08
	# Species with <1% cover	29.37 (6.99)	18.62 (6.93)	10.75	0.79
LRRL	Species richness	33.12 (9.73)	25.75 (4.95)	7.37	0.86
	Exotic species richness	8.37 (2.45)	5.25 (1.28)	3.12	0.60
	Shannon–Weaver	8.36 (2.39)	5.96 (1.19)	2.40	0.85
	1/Simpson's	6.65 (2.55)	4.47 (1.17)	2.18	0.90
	Canopy cover (%)	62.39 (11.17)	85.75 (8.75)	23.36	0.71
	# Species with <1% cover	23.62 (9.33)	17.00 (4.75)	6.62	0.70

[a] Values represent means and standard deviation (in parentheses).
[b] Not statistically significant at $\alpha = 0.05$.

richness estimates varied by study location. At the NGPRL and CPER, precision was significantly higher for the MW method while precision at the LRRL and SRSR was significantly higher for the NRI method (Table 3).

Differences for the Shannon–Weaver and Simpson's reciprocal index were significant at all locations except for the CPER where the difference between both methods was not significant for the Simpson's reciprocal index. Differences in the Shannon–Weaver index were large and statistically significant for all locations. The Simpson's reciprocal index calculated using MW and NRI methods does not follow similar trends across locations.

Differences in number of species with less than 1% canopy foliar cover were large and statistically significant, with the MW consistently capturing greater richness of species with less than 1% canopy foliar cover than the NRI protocols. However, the trends for both methods were consistent between locations with the LRRL having the least number of species with less than 1% canopy foliar cover, followed by the CPER, SRSR and NGPRL. When comparing the number of species with less than 1% canopy foliar cover with overall species richness, it is evident that species with less than 1% cover make up a large proportion of the overall species richness and highlights the importance of the appropriateness of methods for detecting these species.

Differences in canopy foliar cover indicators are large and statistically significant at all locations except for the CPER. Based on differences in cover, we looked at the 5 most dominant species for each method. We used the Sørensen index, also known as the Sørensen's similarity coefficient, which uses presence–absence

Table 3
Species richness, canopy foliar cover and precision for the MW and NRI methods at 4 different study locations. Values are mean and 95% confidence intervals in parentheses and coefficient of variation (CV).

Indicators	Modified-Whittaker		National Resources Inventory	
	Mean	CV	Mean	CV
SRSR				
Species richness	42.4 (34.3–50.6)	30.3[A]	29.2 (24.9–33.4)	23.1[B]
Canopy foliar cover %	81.3 (68.3–94.3)	25.2[A]	68.7 (53.2–84.3)	35.5[B]
NGPRL				
Species richness	44.4 (38.0–50.8)	25.9[A]	32.8 (27.9–37.7)	26.9[B]
Canopy foliar cover %	80.4 (75.0–85.7)	11.9[A]	97.6 (96.1–99.1)	2.8[B]
CPER				
Species richness	29.4 (23.5–35.2)	23.8[A]	24.4 (18.8–29.9)	27.3[B]
Canopy foliar cover %	58.4 (52.8–63.9)	11.3	68.1 (58.9–77.4)	16.2
LRRL				
Species richness	33.1 (25.0–41.3)	29.4[A]	25.7 (21.6–29.9)	19.2[B]
Canopy foliar cover %	62.4 (53.0–71.7)	17.9[A]	85.7 (78.4–93.1)	10.2[B]

Table 4
Top five species based on canopy cover for both the modified Whittaker and NRI method (MW canopy cover was based on 101-m^2 quadrats and NRI canopy cover was based on 100 line-point intercept points). A subset of plots was selected for illustration purposed based on Sørensen's index of community similarity. The plots in which communities displayed the greatest similarities were selected for display. Canopy cover can add to more than 100% because it takes into account total canopy foliar cover for each species, including those whose canopies overlap.

Study site	Plot	Modified-Whittaker		NRI		
		Top 5 species	Canopy cover (%)	Top 5 species	Canopy cover (%)	NRI vs. MW species richness Sørensen
SRSR	1	*Melilotus officinalis*	15.1	*Bouteloua gracilis*	35.3	0.79
		Bouteloua gracilis	12.7	*Melilotus officinalis*	34.3	
		Nassella viridula	12.4	*Bromus arvensis*[a]	12.7	
		Pascopyrum smithii	10.0	*Nassella viridula*	12.7	
		Hesperostipa comata[a]	9.4	*Pascopyrum smithii*	8.8	
	2	*Bassia scoparia*	18.5	*Bassia scoparia*	9.8	0.70
		Plantago patagonica	8.7	*Plantago patagonica*	6.9	
		Dyssodia papposa	5.2	*Pascopyrum smithii*	2.0	
		Pascopyrum smithii	1.7	*Dyssodia papposa*	1.0	
		Schedonnardus paniculatus	0.8	*Schedonnardus paniculatus*	1.0	
NGPRL	1	*Poa pratensis*	19.3	*Poa pratensis*	86.3	0.85
		Bromus inermis[a]	11.7	*Pascopyrum smithii*	7.8	
		Cirsium undulatum[a]	5.0	*Aristida purpurea*[a]	6.9	
		Pascopyrum smithii	4.7	*Nassella viridula*[a]	4.9	
		Artemisia ludoviciana	4.1	*Artemisia ludoviciana*	2.9	
	2	*Poa pratensis*	17.0	*Poa pratensis*	77.5	0.86
		Bromus inermis	15.0	*Pascopyrum smithii*[a]	17.6	
		Lactuca tatarica[a]	5.0	*Bromus inermis*	14.7	
		Hesperostipa comata[a]	3.9	*Schizachyrium scoparium*[*]	3.9	
		Helianthus pauciflorus	3.7	*Gaura coccinea*[a]	2.9	
CPER	1	*Bouteloua gracilis*	35.7	*Bouteloua gracilis*	51.0	0.84
		Pascopyrum smithii	11.0	*Pascopyrum smithii*	15.7	
		Opuntia fragilis[a]	7.4	*Opuntia polyacantha*[a]	7.8	
		Sphaeralcea coccinea	4.9	*Carex dudleyi*[a]	2.0	
		Cryptantha micrantha[a]	2.1	*Sphaeralcea coccinea*	2.0	
	2	*Bouteloua gracilis*	39.4	*Bouteloua gracilis*	52.9	0.84
		Opuntia fragilis[a]	6.7	*Bouteloua dactyloides*	8.8	
		Sphaeralcea coccinea	6.2	*Carex dudleyi*[a]	3.9	
		Vulpia octoflora[a]	4.8	*Sphaeralcea coccinea*	3.9	
		Bouteloua dactyloides	2.2	*Opuntia polyacantha*[a]	2.0	
–						
LRRL	1	*Carex filifolia*	16.1	*Hesperostipa comata*	31.4	0.75
		Hesperostipa comata	16.1	*Carex filifolia*	30.4	
		Pascopyrum smithii	9.4	*Pascopyrum smithii*	25.5	
		Bouteloua gracilis	7.4	*Bouteloua gracilis*	17.6	
		Sphaeralcea coccinea[a]	4.1	*Bouteloua dactyloides*[a]	6.9	
	2	*Hesperostipa comata*	10.4	*Pascopyrum smithii*	29.4	0.72
		Pascopyrum smithii	8.1	*Bouteloua gracilis*[a]	18.6	
		Agropyron cristatum	7.9	*Hesperostipa comata*	16.7	
		Poa secunda[a]	4.9	*Agropyron cristatum*	9.8	
		Bouteloua dactyloides[a]	4.6	*Aristida purpurea*[a]	3.9	

[a] Represents species that appeared dominant based on canopy cover for one method but where not captured by the other method.

data to compare the similarity of two samples (Table 4). We found that even for the most similar plots at each location, the most dominant species based on canopy foliar cover, varied between methods by two or three species per plot, further highlighting the difference between methods. Precision of canopy foliar cover estimates made with the NRI method was significantly higher than that of canopy foliar cover estimates made with the MW method at all locations except the SRSR (Table 3).

4. Discussion

Our objectives for this study were to explicitly compare NRI biodiversity protocols with the modified Whittaker method to quantify how well NRI protocols capture information on plant species richness and to determine the degree of accuracy and precision around NRI species richness estimates. We found large differences between indicator values for both methods. Our data indicated that the NRI protocols underestimated both total plant species richness and exotic species richness compared with the more time and labor intensive MW approach. More importantly, however, *R*-values show that trends in the results of the two methods were qualitatively similar, which suggests that the NRI protocols generate data useful in identifying problem areas for further study. NRI protocols can provide a minimum estimate of species richness but do not provide an accurate representation of the total number of species in an area. In terms of precision, there was variation in species richness and canopy foliar cover values for each method but overall for canopy foliar cover, point-based methods were more precise. This is supported by previous studies which reported greater precision in point-based methods than ocular estimates (Hanley, 1978; Sykes et al., 1983; Floyd and Anderson, 1987; Bonham, 1989; Elzinga et al., 2001; Godinez-Alvarez et al., 2009). Precision in species richness estimates seems to vary depending on plant community but overall, the MW method provided greater accuracy. Since species richness is a count and not an estimate, we know that for a specific area, the method that finds the most species is also the most accurate making the MW a more accurate method for quantifying species richness. However, correlation values

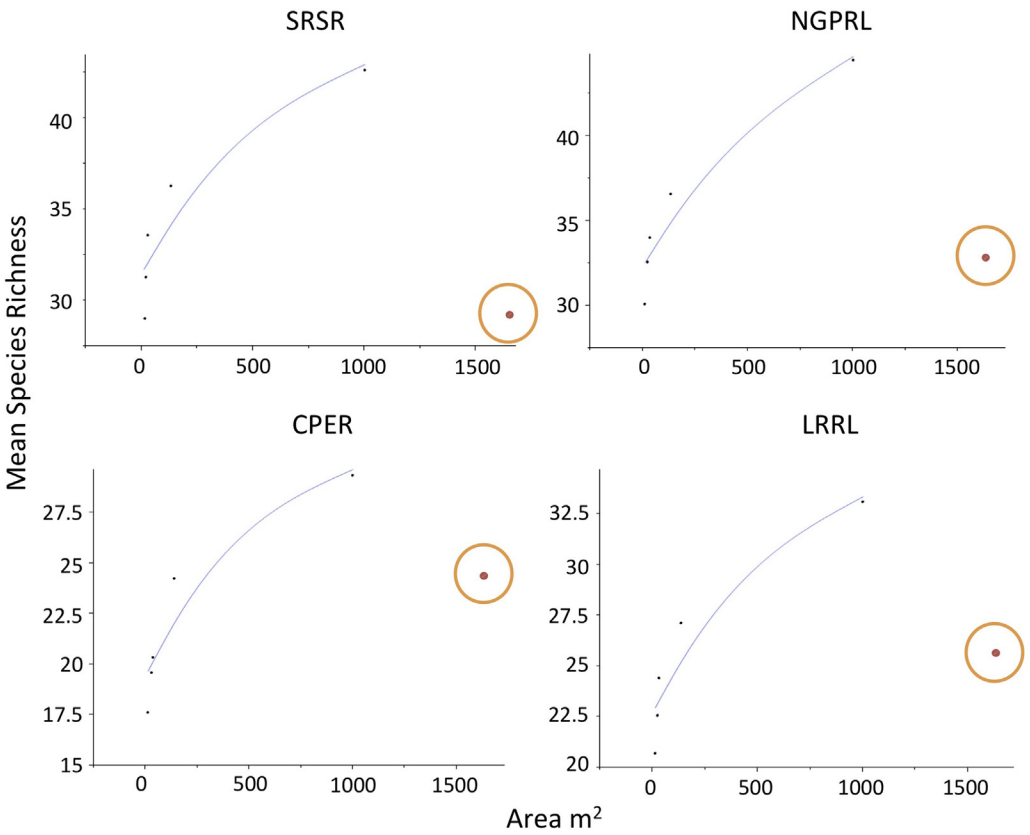

Fig. 3. Species area curve plotted using modified Whittaker data for all plots at each site and mean species richness based on NRI data represented by the highlighted dot.

corresponding to the paired comparisons having significant differences between mean measurements also suggest that greater accuracy and precision of NRI estimates could be developed with sufficient calibration efforts (Symstad et al., 2008).

Our results suggest NRI is not capturing as much species richness and cover of rare species compared to the MW method, and is therefore underestimating plant biodiversity. Diversity indices calculated from both the NRI and MW methods have large enough differences to matter when making management or policy decisions regarding biodiversity. Diversity indices are important in management decisions because species richness or any single index of diversity alone is not an accurate measure of biodiversity (Purvis and Hector, 2000). The large differences in biodiversity indicators found in this study stress the importance of adequate method selection based on current and future conservation goals (Purvis and Hector, 2000; Pereira and Cooper, 2006).

Exotic species richness did not differ statistically between methods at most sites, which counters our expectations that the modified Whittaker method is better at capturing exotic species based on Stohlgren (1998). However, the exotic invasive species measured were, for the most part, conspicuous species such as Kentucky bluegrass (*Poa pratensis*), sweetclover (*Melilotus officinalis*), yellow salsify (*Tragopogon dubius*), prickly Russian thistle (*Salsola tragus*), and smooth bromegrass (*Bromus inermis*) that covered enough of an area that make capturing them with either method more feasible. In fact, a large percentage of the difference in species richness for both protocols at all sites was attributable to species with less that 1% canopy foliar cover and in all cases the modified Whittaker method did a much better job at detecting these species.

Our data and experience suggest that incorporation of an iterative measurement process in NRI species richness protocols would be appropriate. Even though we did not measure time, based on our field experience we believe that an adjustment to measurement time when making species richness measurements for NRI is needed. This time adjustment would promote detection of exotic species of concern and potentially rare and threatened species at levels of cover where management decisions could greatly alter the future eradication and or establishment of these species (Peters et al., 1996). Increasing the amount of time spent on making species richness measurements and implementing a more systematic approach to detecting species would improve current biodiversity inventory and monitoring efforts while also providing a link between existing long-term data and any new information collected. Additionally, location and objective specific modifications to current biodiversity measurement methodologies could provide enhanced data for the creation of quantitative goals and expectations for management and conservation of natural systems.

Table 5
Species richness measurements for MW and NRI methods at different scales illustrating that finding species is an iterative process whether in NRI or MW.

Location	# plots	Mean 1 m^2 (S. E.)	Mean 10 m^2 (S. E.)	Mean 100 m^2 (S. E.)	Mean 1000 m^2 (S. E.)	Mean NRI line-point species richness (S. E.)	Mean NRI species richness (S. E.)
SRRP	12	10.9 (1.16)	17.8 (1.72)	24.7 (2.85)	42.4 (3.71)	11.1 (1.16)	29.2 (1.94)
NGPRL	15	9.4 (0.69)	12.9 (1.21)	22.1 (1.97)	44.4 (2.98)	14.9 (1.45)	32.8 (2.28)
CPER	8	6.5 (0.45)	10.5 (0.89)	18.4 (1.43)	29.4 (2.47)	8.9 (0.90)	24.4 (2.35)
LRRL	8	7.7 (0.60)	13.7 (1.11)	19.0 (1.75)	33.1 (3.44)	11.8 (0.67)	25.8 (1.75)

Biogeographical principles suggest that more species should be found in the larger area encompassed by the NRI assessment (Rosenzweig, 1995). However, that was not the case in our study, highlighting the importance of method selection and method consistency. We used species area curves as a tool to illustrate our results since these curves have proven to be one of the most important tools available for describing and understanding species distributions in space (He and Hubbell, 2013). Our species area curves illustrate biodiversity and rare species detection are dependent of the methodology used and how intensively an area is sampled (Fig. 3; Table 5). The data presented show that finding new species is an iterative process and multi-scale sampling techniques provide greater opportunity for finding more species. Additionally, multiscale approaches could be used to adjust the scale of measurement to the scale at which management decisions for specific taxa are made (Bestelmeyer et al., 2003; Cash et al., 2006).

Increasing the value of the plant species richness indicators collected by NRI without sacrificing overall efficiency to current protocols could be achieved by separating the NRI macroplot into 4 sections delineated by transect locations (Fig. 2). Each of the 4 sections should be searched until the observer spends 1 min without finding any new species. This would reduce the time currently spent on species richness estimates for NRI in species poor areas and would allow greater flexibility for observers to thoroughly record species richness in species rich areas. Modifying NRI protocols slightly would increase overall efficiency by improving precision around NRI species richness estimates without having to increase the number of separate measurements taken.

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