



UCBN and GRYN Sagebrush Steppe Vegetation Monitoring; Double Observer Study 2015

*Bighorn Canyon National Recreation Area, City of Rocks
National Reserve, and John Day Fossil Beds National
Monument-Clarno Unit*

Natural Resource Data Series NPS/UCBN/NRDS—2016/1052



ON THE COVER

Photograph of NPS biological technicians collecting sagebrush steppe vegetation data at City of Rocks National Reserve.
Photograph courtesy of the National Park Service)

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Natural Resource Data Series NPS/UCBN/NRDS—2016/1052

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Abstract

In June and July of 2015 the Upper Columbia Basin and Greater Yellowstone Inventory and Monitoring Networks conducted a double observer study of ocular cover class estimation in quadrats while engaged in annual sagebrush steppe (upland) vegetation monitoring. Both groups followed the same standard protocol (Yeo et al. 2009) for annual monitoring. While the goal of the double observer study was the same for both groups, slightly different field methodologies were adopted by each to best integrate with their standard work flow and field safety processes. The goal of this study was to determine the extent to which variation in visual estimation of plant cover between observers is influencing sagebrush vegetation monitoring data, and if there is a need to further develop data analysis techniques to account for this source of error. Our objectives were to: (A) determine how much visual estimation of cover and selection of cover classes varied between two independent observers within the same plot; (B) determine how significant the variation was; and (C) determine how much variability occurred in species detection (net species richness) between two independent observers within the same plot. In general, variability between observers in species detection was minimal, with most discrepancies occurring among species recorded at the lowest cover class. Discrepancies in cover class estimation between observers were generally less than 2 classes, with the largest amount of variability observed in the estimations of cover classes for bare ground, and for some non-native annual grasses. Potential issues with species identification were revealed in a small percentage of records where two different, but similar looking species were recorded by alternate observers at the same cover class in a double-observation plot. These findings suggest that a model-based approach to account for observation error may be helpful, but not urgent, given the relatively small amount of discrepancies found (interpreted as an indication of observer error) and the very large sample sizes that are routinely achieved in annual monitoring.

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Introduction

The Upper Columbia Basin Inventory and Monitoring Network (UCBN) Sagebrush Steppe Vegetation Monitoring Protocol (Yeo et al. 2009) is utilized in five National Park Units within the Upper Columbia Basin and at three park units within the Greater Yellowstone Network (GRYN), although Grand Teton and Yellowstone national parks are leading the monitoring programs in their respective parks. The protocol guides the monitoring of select indicators of ecological condition within the sagebrush steppe plant communities of Bighorn Canyon National Recreation Area (BICA), City of Rocks National Reserve (CIRO), Craters of the Moon National Monument and Preserve (CRMO), Hagerman Fossil Beds National Monument (HAFO), John Day Fossil Beds National Monument (JODA), and Lake Roosevelt National Recreation Area (LARO). Prior to the start of the field season, crews were trained on quality data collection methodologies. Nevertheless, we recognize that in spite of this training, observer variability remains a potential source of error in data collection. A double observer pilot study was conducted at BICA, JODA, and CIRO in order to determine the extent to which observer differences are influencing sagebrush vegetation monitoring data collection and if there is a need to further develop data analysis techniques to accommodate for this error.

This study examined variability in the visual estimation of plant cover, as well as variability in species detection and identification. A measure of pseudoturnover was used to address these latter inquiries. Lynch and Johnson (1974) presented the concept of pseudoturnover to deal with faulty or inconsistent data which can affect calculations of actual species turnover (e.g., in island biogeography) and a formula for calculating pseudoturnover was defined by Nilsson and Nilsson (1985). Calculating pseudoturnover is the same as for turnover, with one significant modification: turnover is calculated using species records taken from the same location at two distinctly different points in time, while pseudoturnover is calculated using species records taken from the same location at the same time by two different (independent) observers as in equation 1.

$$Pseudoturnover = \frac{(A+B)}{(S_A+S_B)} \times 100, \quad \text{eq. 1}$$

where A and B are the number of species found exclusively by observer 1 and observer 2, and S_A and S_B are the total number of species recorded by observer 1 and observer 2, respectively.

Determining what kind of variability is associated with our field methodologies and identifying where observer variability is most prevalent will provide invaluable information to both programs. The information in this study is meant to generate discussions among field crews and supervisors so that they can identify aspects of the monitoring effort that should be addressed in order to reduce observer variability or appropriately compensate for observer differences in the reporting of data as well as to help program leaders determine whether additional statistical methods are required to formally account for this source of error.

Methods

All field methods (including but not limited to plot navigation, plot set up, and field data entry) in this study follow the standard SOPs for the UCBN sagebrush steppe vegetation monitoring protocol (Yeo et al. 2009) except where otherwise noted. The Greater Yellowstone Network Upland Vegetation Monitoring Protocol (Tercek et al. 2015) was adapted from the UCBN protocol and in general follows the same field methods. Within each park unit sampling frame, 1m² square plots were located using the generalized random tessellation stratified (GRTS) spatially-balanced sampling design (Stevens and Olsen 2004). The GRTS approach provides for randomly located plots and good spatial dispersion across each site. Within each 1m² plot, we estimated cover of exposed bare ground and principal native plants and non-native invasive plants. Cover estimates were categorized into the following cover classes: 0, 1-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95-100% (Daubenmire 1959). Plant cover was defined as the natural spread of current year's growth outlined using a minimum convex polygon with small gaps included in the cover estimate. Exposed bare ground was defined as soil surface not overlain by plant cover, litter, and rock. The double-observer study took place in conjunction with the annual UCBN and GRYN sagebrush steppe vegetation monitoring field survey.

Study Areas and Selection of Sample Units

In each park unit, a subset of sample units was selected from the full (annual) panel of sample units and identified as double-observer plots. In order to preserve the spatially balanced distribution inherent in the GRTS sampling design, the subset of double-observed sample units began at the lowest GRTS rank order and continued sequentially until a sufficient number of plots were obtained (approximately ~30% of the full panel for each park unit). In BICA there are 15 distinct sample frames, 10 of which were scheduled for sampling in 2015. Within each of the 10 sample frames, double-observer surveys were conducted on the maximum number of sample units that could be surveyed in a 10 hour period (equal to one work day). Double-observer surveys progressed from the lowest number sample unit continuing sequentially through the work day (Table 1 and Figure 1). The Clarno Unit of JODA comprises a single sample frame. In order to obtain a proportionally significant number of units, double-observer sample units progressed uninterrupted from GRTS rank order 1 to 60 (Table 1 and Figure 2). In CIRO there are ten distinct sample frames. In order to include sample units from each sample frame, proportionally equal subsets were selected from each sample frame starting with the lowest number sample unit in a given frame and continuing sequentially until the desired number of sample units was obtained (Table 1 and Figure 3).

Table 1. Total number of plots sampled as part of the annual UCBN and GRYN monitoring effort, the number of plots which were subset out for double observation, and the proportion of double-observer plots to the total number of plots by location. *(Some plots in BICA were sampled by more than two observers resulting in a total of 400 paired-observations across 318 plots).

Park	Sample Frame	Total # of Plots	# of Double-Observer Plots	Percentage of Plots Visited Twice
BICA	Veg 20	52	24	46
	Veg 50	77	33	43
	Veg 60	52	25	48
	Veg 70	68	15	22
	Veg 80	50	50	100
	Veg 90	50	50	100
	Veg 100	65	13	20
	Veg 110	76	32	42
	Veg 120	53	25	47
	Veg 150	51	51	100
	BICA-Total	594	318*	54
CIRO	Bath Rock	55	20	36
	Circle Creek N	65	19	29
	Circle Creek S	55	20	36
	Castle Rock N	55	20	36
	Castle Rock S	55	20	36
	Castle Rock W	65	19	29
	Emery Canyon	75	21	28
	Kempton	60	21	35
	Tracy Lane	55	20	36
	Trail Canyon	65	21	32
	CIRO-Total	605	201	33
JODA	Clarno-Total	215	60	28

Bighorn Canyon National Recreation Area

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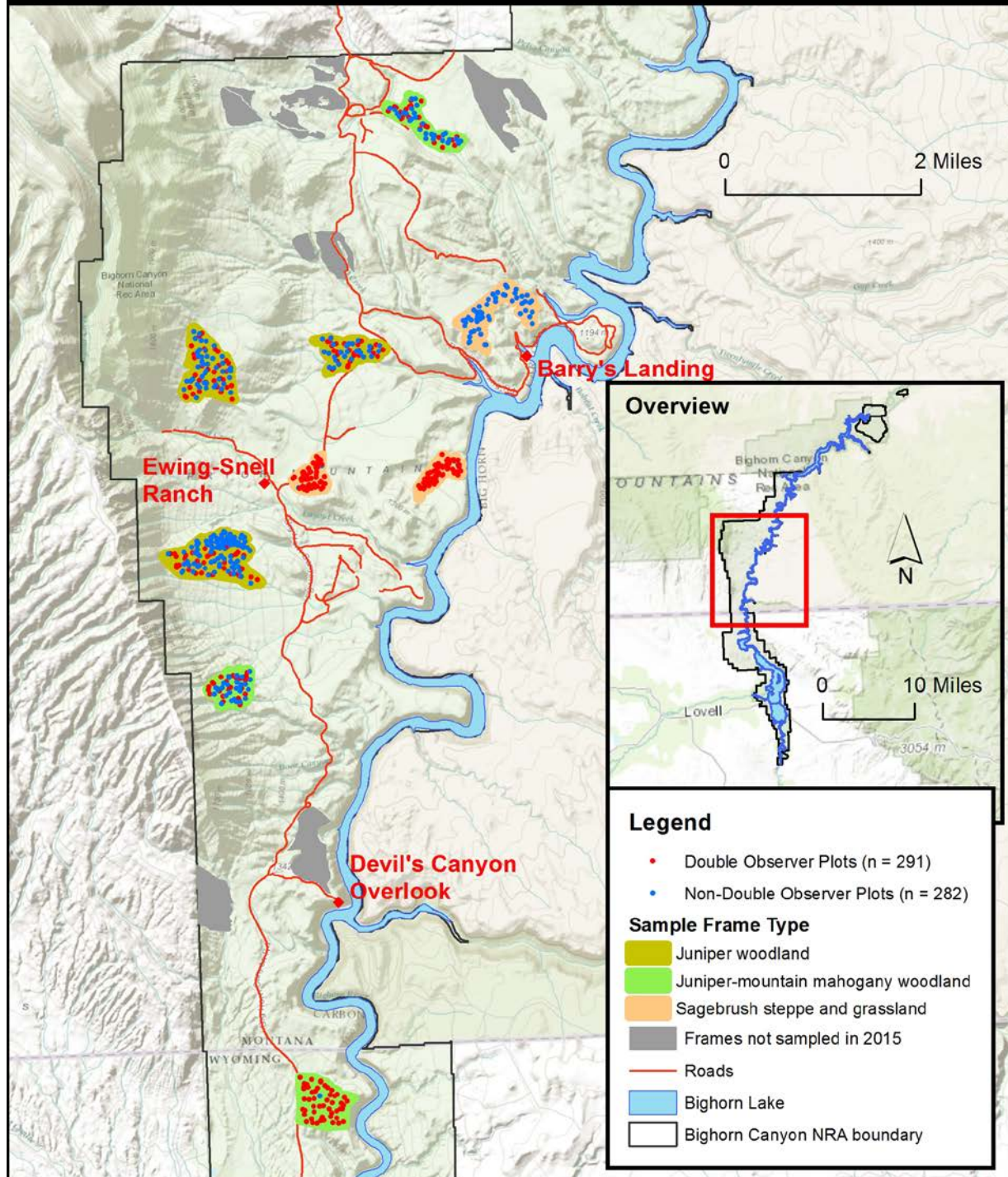


Figure 1. Bighorn Canyon NRA, showing locations of 2015 upland vegetation sampling plots and subset of double-observer plots.

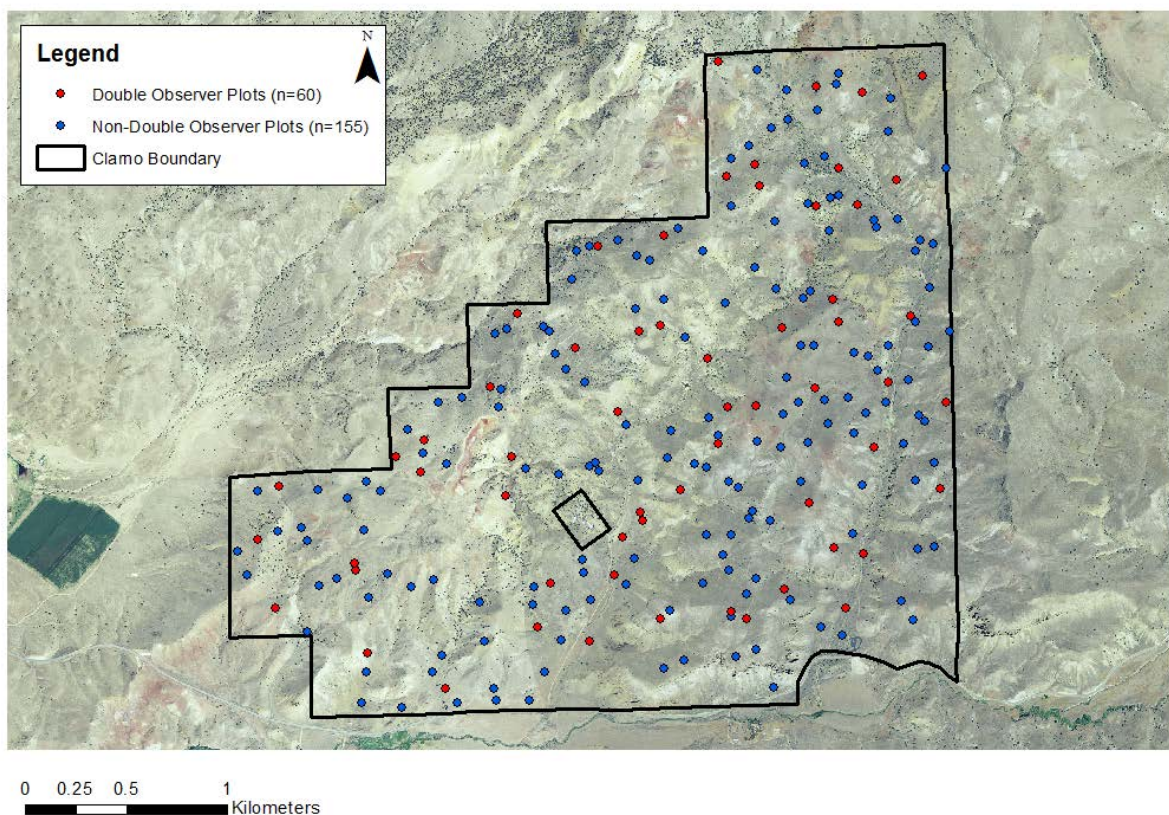


Figure 2. John Day Fossil Beds NM - Clarno Unit, showing locations of 2015 sagebrush vegetation sampling plots and subset of double-observer plots.

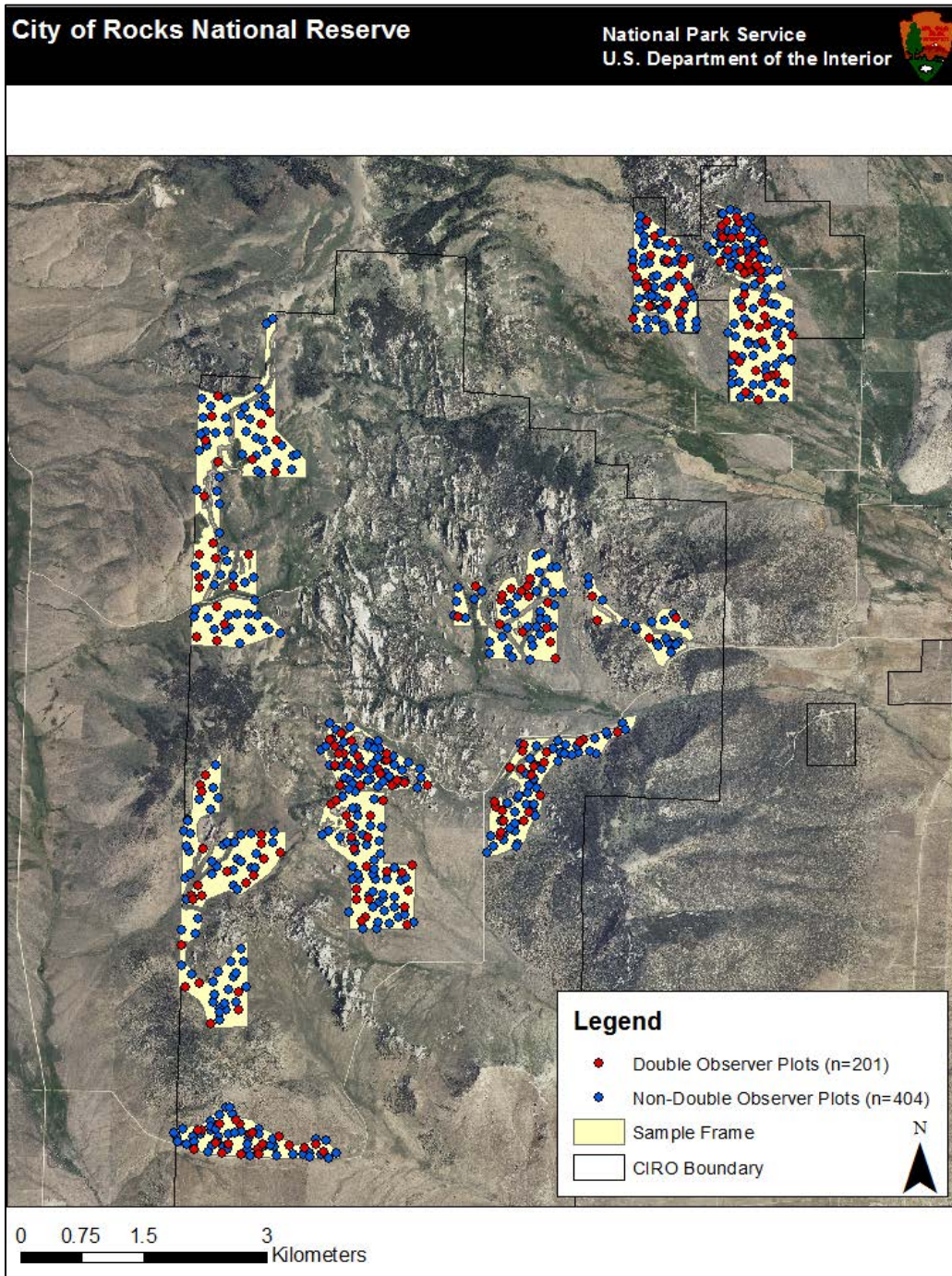


Figure 3. City of Rocks NR, showing locations of 2015 sagebrush vegetation sampling plots and subset double-observer plots.

Sample Unit Set-Up and Data Collection (BICA)

Teams of two observers navigated to each double-observer sample unit simultaneously. Once located, a 1m² plot was marked with two folding rulers. The first observer would independently collect data following the GRYN upland vegetation monitoring protocol and Standard Operating Procedures (Tercek et al. 2015, Jean et al. 2015) while the second observer stood several meters from the plot facing in the opposite direction. After the first observer completed data collection on the plot, the second observer would step in to independently survey the plot while the first observer moved several meters away. Plant cover was recorded following Daubenmire (1959) cover classes as described in the protocol. Data were recorded by one observer on an electronic tablet while the second observer used a paper data sheet. All data recorded on paper were entered into the electronic tablet upon completion of survey in each sample frame.

Sample Unit Set-Up and Data Collection (JODA and CIRO)

First Observer

The number of double-observer sample units was first divided equally between observers (single-person teams). Each observer would then independently navigate to a sample unit, and establish a 1m² plot using two folding rulers. Once the plot was established, a pin flag was inserted into the ground at each corner. Plant cover was then recorded following Daubenmire (1959) cover classes and the UCBN sagebrush steppe vegetation monitoring protocol (Yeo et al. 2009).

Second Observer

Once all double-observer plots had been located, marked with pin flags and surveyed by the first observers, a second observer then navigated (typically on the following day) to the plot to conduct a second estimation process. Sample units were equally reallocated among observers such that a) no one observer would sample a plot they had already visited and b) each observer was assigned the same number of second observer plots as plots they had established. The manner in which plots were divided among observers varied depending on the number of observers and their availability in each park unit. In JODA, a total of 60 plots were divided among three crew members (observers A, B, and C, 20 plots each) for first observation and plot establishment. Then, observer A was assigned 10 plots each from observers B and C (20 plots total) to relocate and record second observations. Similar assignments were made to observers B and C. In CIRO, the majority (~69%) of double-observer data was recorded by two observers (A and B) due to crew deployment logistics. An additional 63 plots (~31% of double-observed plots) were divided between three observers in a similar fashion to the method used in JODA.

After plots had been reallocated, each crew member would individually relocate a plot (previously established by another observer) mark the plot boundaries with folding rulers (using the pin flags as guides for corner placement) and record plant cover. Once the second observer had finished their data collection, they removed the pin flags and proceeded to the next plot.

Data Analysis

For each pair of observers (two individuals who made independent observations at the same plot locations), the difference in recorded cover class for each species (including bare ground) per plot was calculated. Then, the results were pooled in order to obtain a list comprised of the total number

of double-observed plots showing the magnitude of difference in recorded cover class (0-6) for each species, in each plot. For each species, the proportion of occurrence of each magnitude of difference was then calculated across all double-observed plots. Species were then subset by group (shrubs, native grasses, non-native grasses, native forbs, non-native forbs, and bare ground) and the average proportion of occurrence of each magnitude of difference was calculated across species groups and reported. The number of species recorded (plot richness) and the sum of cover classes recorded were compared between observer pairs using a correlation coefficient (r) and paired t -tests. Pseudoturnover was then used as a measure to examine the discrepancies between species recorded by each paired observer (Lynch and Johnson 1974, Nilsson and Nilsson 1985, Kercher et al. 2003). Paired t -tests were used to compare paired observer's records for select species of interest.

Results

To preserve the anonymity of observers, each individual was assigned a letter ID designation. It is important to note that letter designations (i.e., observer IDs) are only consistent within a single park across all of the frames sampled within that park, but are not consistent between parks.

Bighorn Canyon National Recreation Area

At BICA, recorded cover classes between observers typically had no difference for most vegetation groups (Table 2 and Figures 4 and 5). Two notable exceptions were observed in bare ground (~34% of plots with ≥ 1 difference in cover class) and litter and soil crust (~33% of plots with ≥ 1 difference in cover class). Differences in recorded cover class between observers rarely exceeded 1. A comparison of 3,854 total records collected by five observers across 400 double-observed plots, revealed only 120 pairings (~3%) which exceeded 1 difference in cover class.

Table 2. Proportion (%) of double-observed plots (n=400)* in BICA where recorded cover class differed between observers. *(Some plots were sampled by more than two observers resulting in a total of 400 paired-observations across 318 plots).

Species Group	0 Difference	1 Difference	2 Differences	3 Differences
Native Grasses	94	6	0	0
Native Forbs	94	6	1	0
Non-native Grasses	98	2	0	0
Non-native Forbs	98	2	0	0
Bare Ground	67	30	4	0
Litter and Soil Crust	67	27	5	1
Shrubs	96	3	0	0
Trees	95	3	1	1

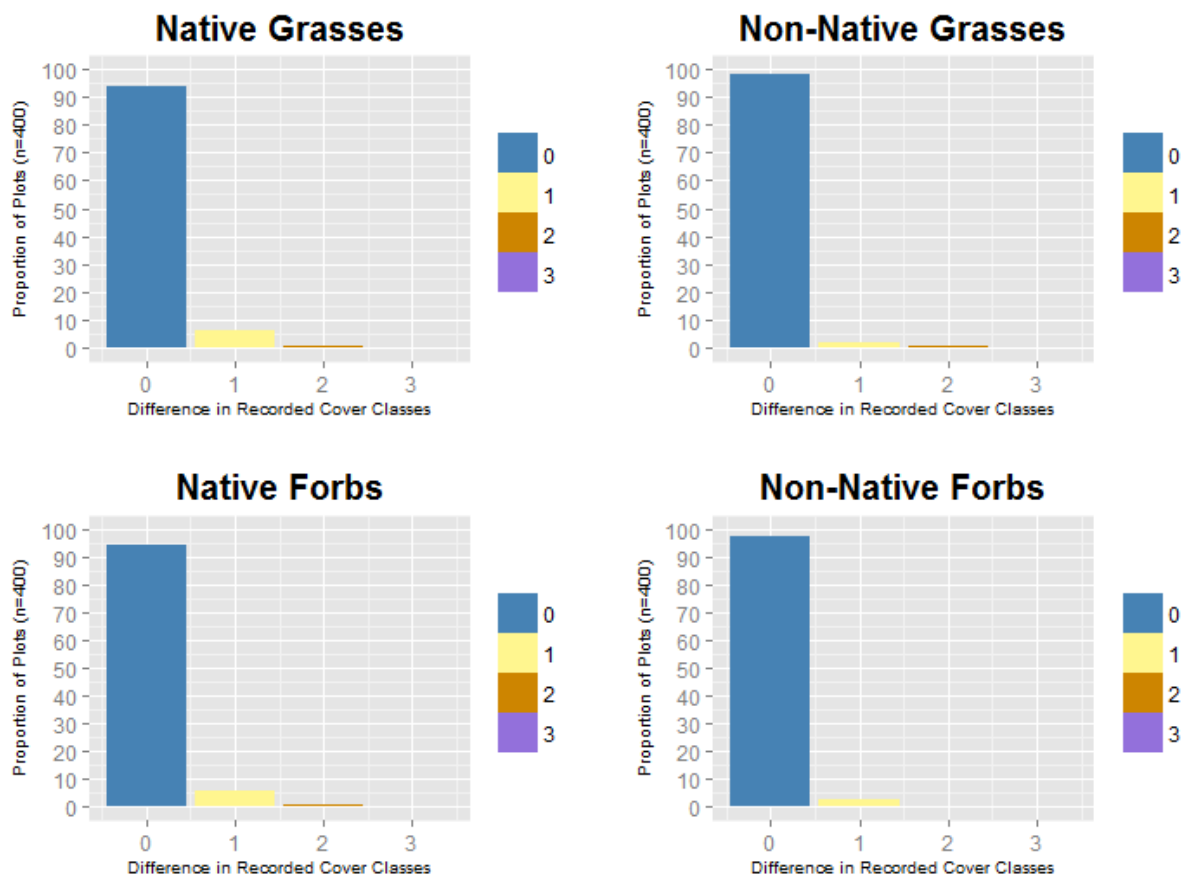


Figure 4. Proportion (%) of double-observed plots in BICA (n=400)* with differences in recorded cover class between observers by species group. *(Some plots were sampled by more than two observers resulting in 400 paired-observations across 318 plots).

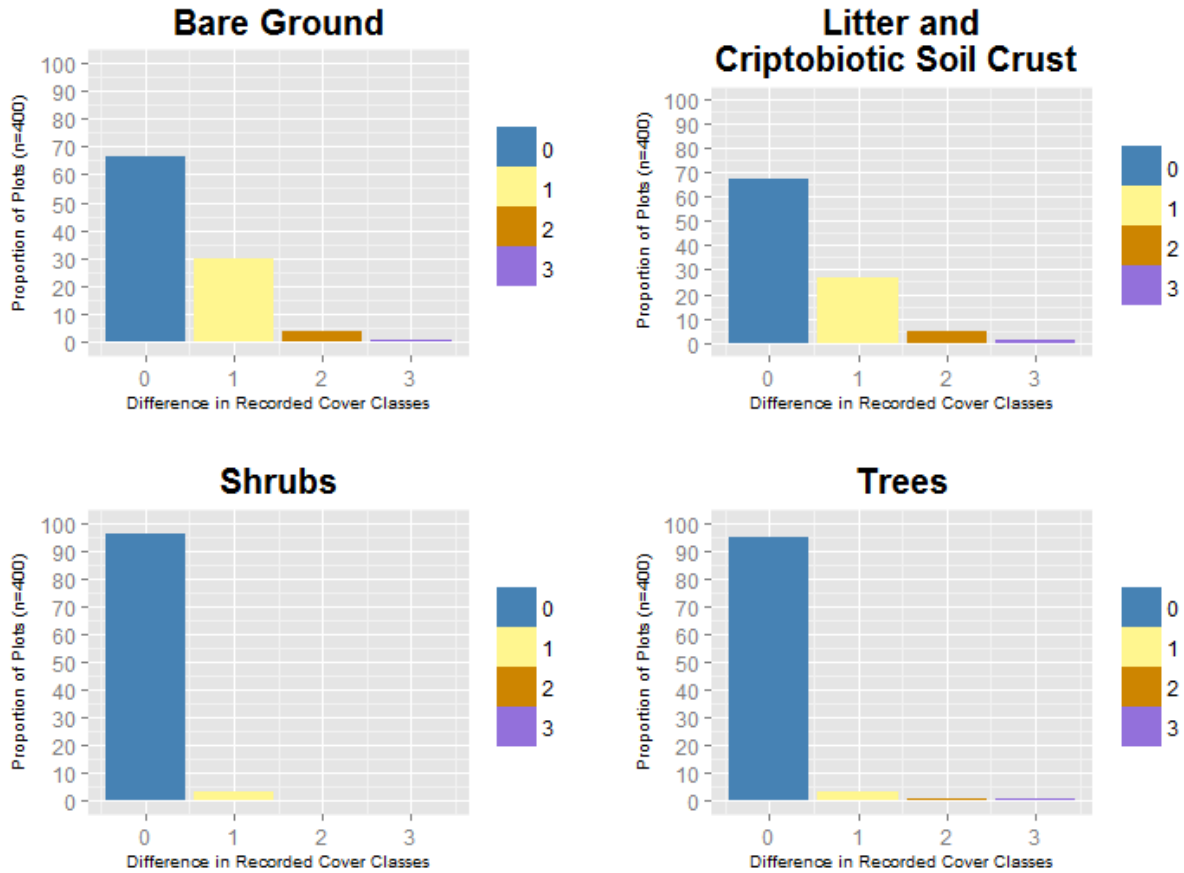


Figure 5. Proportion (%) of double-observed plots in BICA (n=400)* with differences in recorded cover class between observers by species group. *(Some plots were sampled by more than two observers resulting in 400 paired-observations across 318 plots).

Species Richness and Sum of Cover Classes

Species richness recorded by observers A and B was highly correlated ($r = 0.76$) and 42% of plots sampled (n=174) had no difference in species richness (Figure 6). A paired t -test produced no evidence of a difference in the number of species recorded by observers A and B (mean difference = 0.04 ± 0.17 , $p=0.63$, $df=173$). A large proportion of plots (75%) had some pseudoturnover, with a mean pseudoturnover of 36.1% across all plots for observers A and B. The sum of cover classes by plot were also highly correlated ($r = 0.70$) with 32% of plots having no difference (Figure 6). There was no evidence for a difference in the sum of cover classes between observers A and B (paired t -test, mean difference = 0.13 ± 0.24 , $p=0.3$, $df=173$).

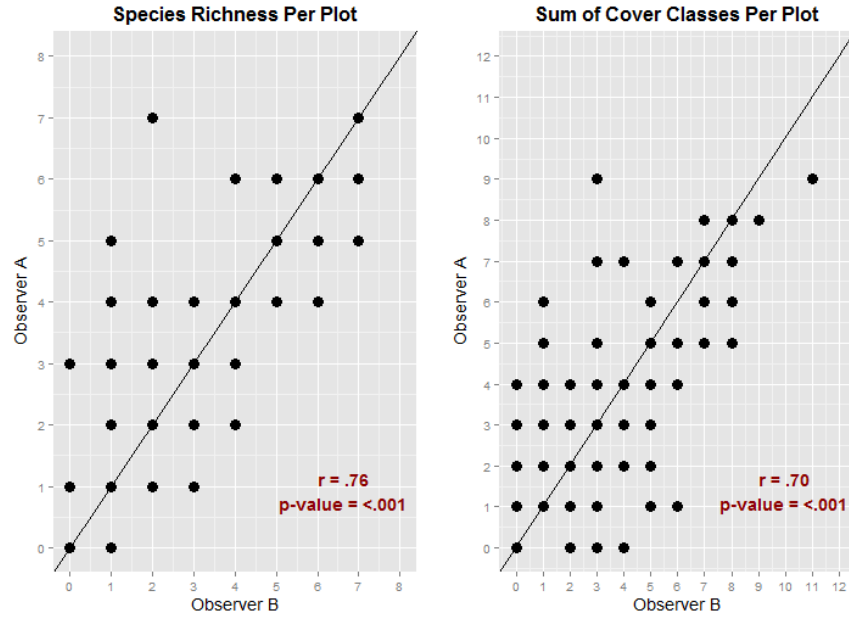


Figure 6. Comparison of observers A and B for species richness (left) and sum of cover classes (right) per double-observed plot (n=174). Points on the line indicate no difference.

Species richness recorded by observers C and D was highly correlated ($r = 0.86$) and 56% of plots sampled (n=140) had no difference in species richness (Figure 7). A paired t -test produced no evidence of a difference in the number of species recorded by observers C and D (mean difference = -0.07 ± 0.17 , $p=0.41$, $df=139$). Approximately half of the plots (56%) had some pseudoturnover, with a mean pseudoturnover of 20% across all plots for observers C and D. The sum of cover classes by plot were also highly correlated ($r = 0.85$) with 36% of plots having no difference (Figure 7). There was no evidence for a difference in the sum of cover classes between observers C and D (paired t -test, mean difference = 0.13 ± 0.25 , $p=0.3$, $df=139$).

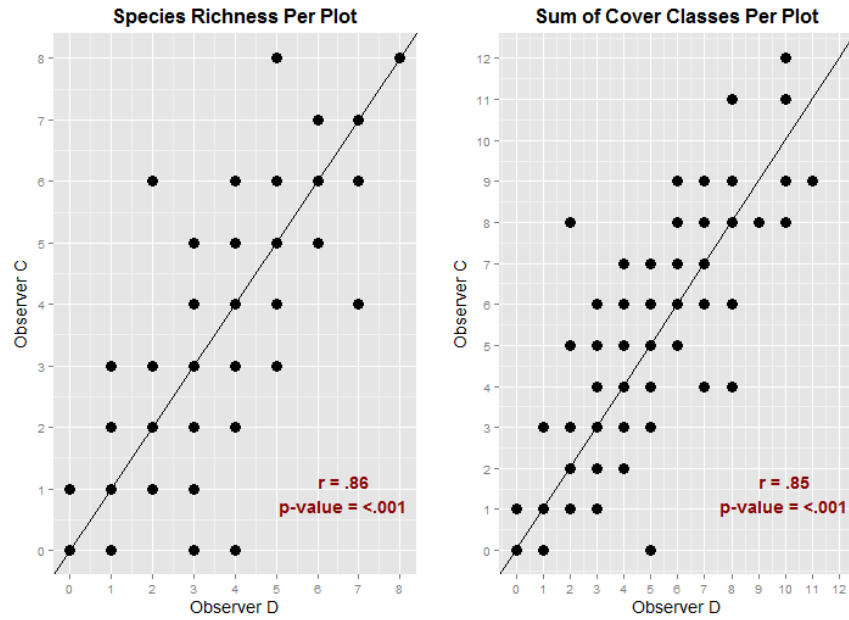


Figure 7. Comparison of observers C and D for species richness (left) and sum of cover classes (right) per double-observed plot (n=140). Points on the line indicate no difference.

Species richness recorded by observers E and A was somewhat correlated ($r = 0.40$) and 49% of plots sampled (n=45) had no difference in species richness (Figure 8). A paired t -test produced no evidence of a difference in the number of species recorded by observers E and A (mean difference = 0.18 ± 0.26 , $p=0.17$, $df=44$). A large proportion of plots (69%) had some pseudoturnover, with a mean pseudoturnover of 44% across all plots for observers E and A. The sum of cover classes by plot were slightly negatively correlated ($r = -0.02$) with 38% of plots having no difference (Figure 8). There was no evidence for a difference in the sum of cover classes between observers E and A (paired t -test, mean difference = -0.11 ± 0.49 , $p=0.65$, $df=44$).

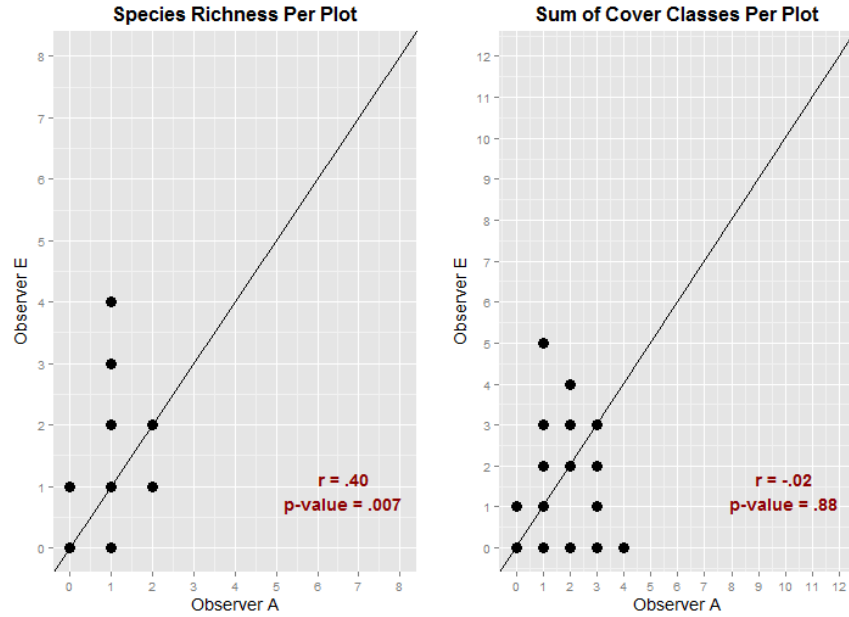


Figure 8. Comparison of observers E and A for species richness (left) and sum of cover classes (right) per double-observed plot ($n=45$). Points on the line indicate no difference.

Species richness recorded by observers E and B was somewhat correlated ($r = 0.49$) and 37% of plots sampled ($n=41$) had no difference in species richness (Figure 9). A paired t -test produced some evidence of a difference in the number of species recorded by observers E and B (mean difference = -0.27 ± 0.28 , $p=0.06$, $df=40$). More than half of the plots (66%) had some pseudoturnover, with a mean pseudoturnover of 40% across all plots for observers E and B. The sum of cover classes by plot were also somewhat correlated ($r = 0.21$) with 39% of plots having no difference (Figure 9). There was no evidence for a difference in the sum of cover classes between observers E and B (paired t -test, mean difference = -0.37 ± 0.48 , $p=0.13$, $df=40$).

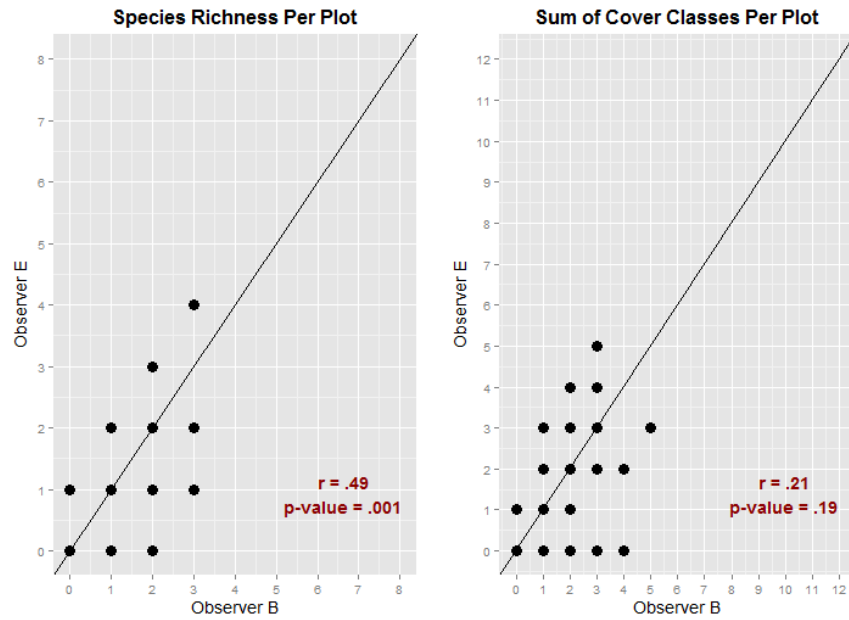


Figure 9. Comparison of observers E and B for species richness (left) and sum of cover classes (right) per double-observed plot ($n=41$). Points on the line indicate no difference.

Individual Species Records

Paired t -tests were used to examine significant differences between observers for recorded cover classes of select species (Table 3). Corresponding boxplots are shown below (Figures 10-17).

Table 3. Results of t -tests between paired observers for recorded cover class of select species.

Observers	Species	Mean Difference	Plus or Minus	p-value	d.f.
AB	Bare ground	-0.30	0.10	<0.001	173
CD	Bare ground	0.00	0.09	1	139
EA	Bare ground	0.62	0.21	<0.001	44
EB	Bare ground	0.22	0.17	0.011	40
AB	Litter	0.09	0.11	0.112	173
CD	Litter	-0.04	0.09	0.448	139
EA	Litter	0.76	0.23	<0.001	44
EB	Litter	0.68	0.30	<0.001	40
AB	Soil crust	0.14	0.10	0.008	173
CD	Soil crust	0.09	0.10	0.057	139
EA	Soil crust	-0.36	0.28	0.014	44
EB	Soil crust	-0.05	0.24	0.688	40
AB	<i>B. tectorum</i>	0.02	0.03	0.319	173
CD	<i>B. tectorum</i>	0.06	0.07	0.131	139
EA	<i>B. tectorum</i>	0.02	0.02	0.323	44
EB	<i>B. tectorum</i>	0.02	0.05	0.323	40

Table 3 (continued). Results of t-tests between paired observers for recorded cover class of select species.

Observers	Species	Mean Difference	Plus or Minus	p-value	d.f.
AB	<i>S. tragus</i>	0.01	0.03	0.656	173
CD	<i>S. tragus</i>	0.03	0.03	0.045	139
EA	<i>S. tragus</i>	0.00	0.00	NA	44
EB	<i>S. tragus</i>	0.00	0.00	NA	40
AB	<i>P. spicata</i>	0.00	0.07	1	173
CD	<i>P. spicata</i>	0.04	0.06	0.227	139
EA	<i>P. spicata</i>	0.02	0.18	0.800	44
EB	<i>P. spicata</i>	0.12	0.20	0.230	40
AB	<i>P. secunda</i>	-0.06	0.06	0.027	173
CD	<i>P. secunda</i>	-0.04	0.07	0.202	139
EA	<i>P. secunda</i>	0.02	0.10	0.660	44
EB	<i>P. secunda</i>	-0.05	0.07	0.160	40
AB	<i>H. comata</i>	-0.09	0.07	0.019	173
CD	<i>H. comata</i>	0.06	0.06	0.049	139
EA	<i>H. comata</i>	0.24	0.13	0.000	44
EB	<i>H. comata</i>	-0.15	0.15	0.057	40

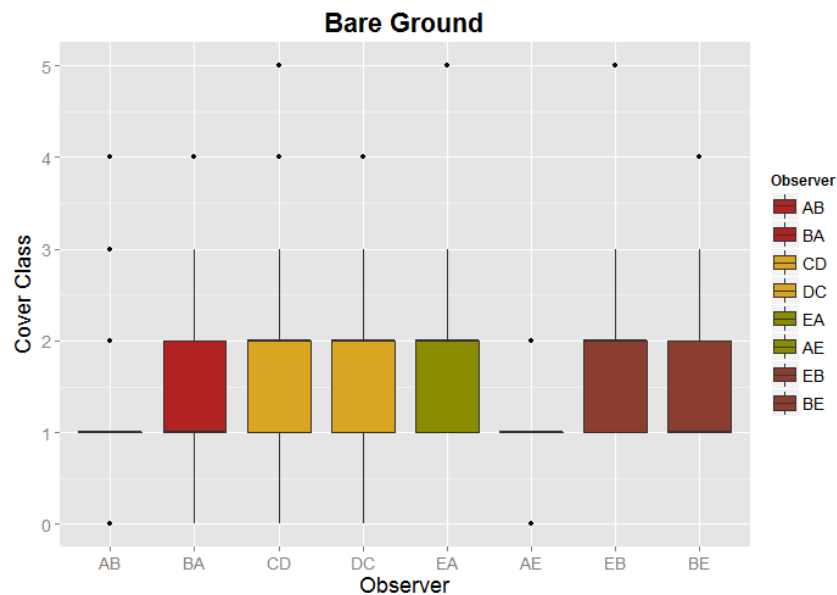


Figure 10. Box plots of the subset of bare ground observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

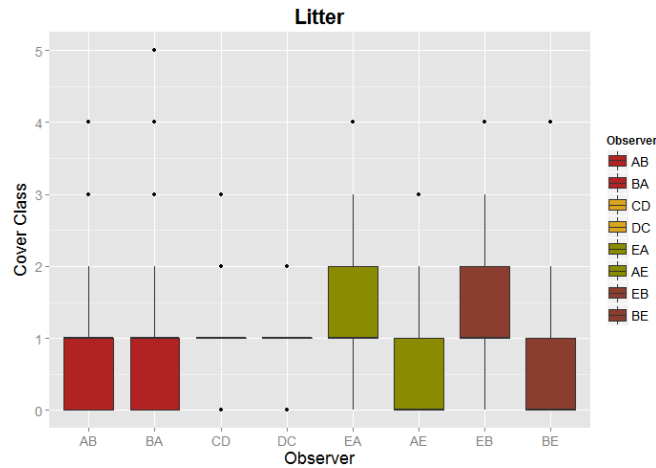


Figure 11. Box plots of the subset of litter observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

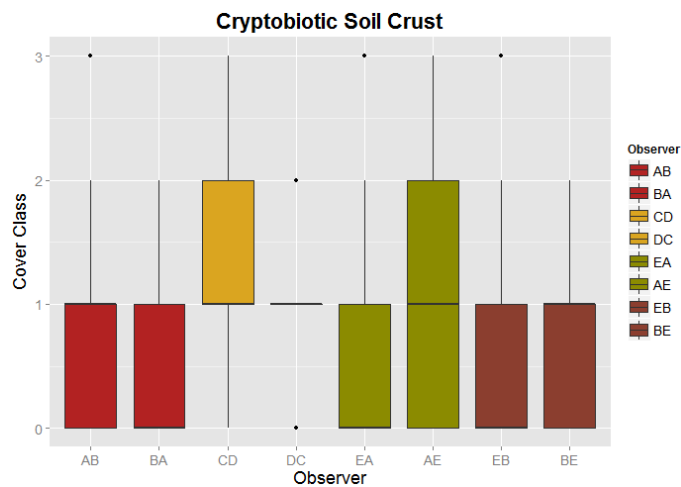


Figure 12. Box plots of the subset of soil crust observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

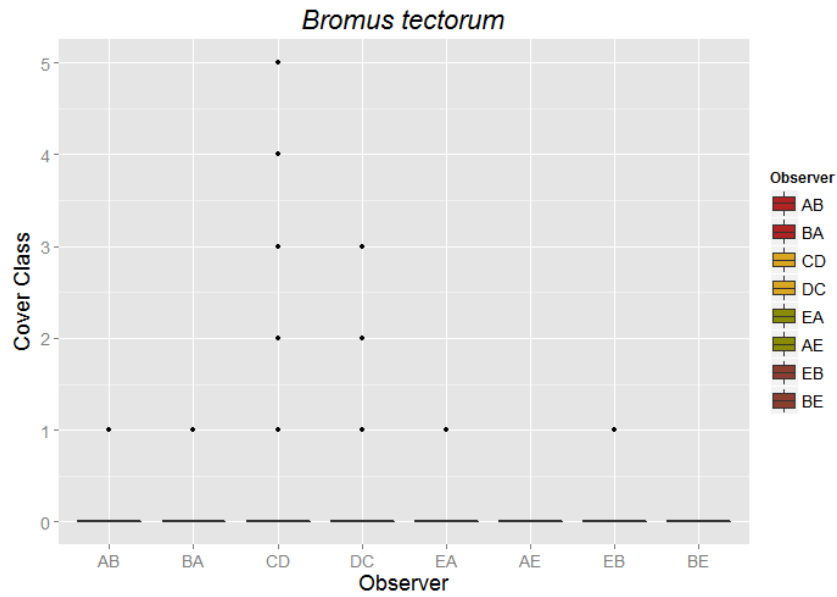


Figure 13. Box plots of the subset of *B. tectorum* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

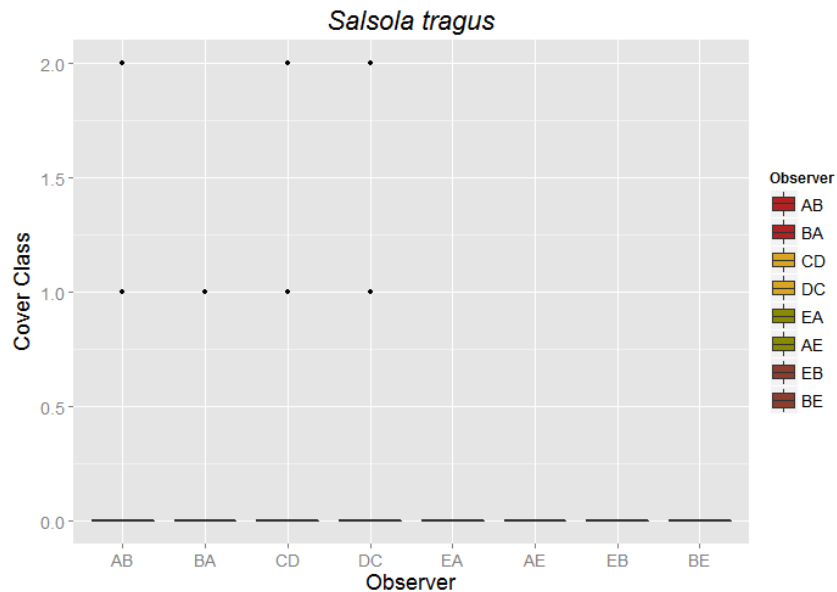


Figure 14. Box plots of the subset of *S. tragus* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

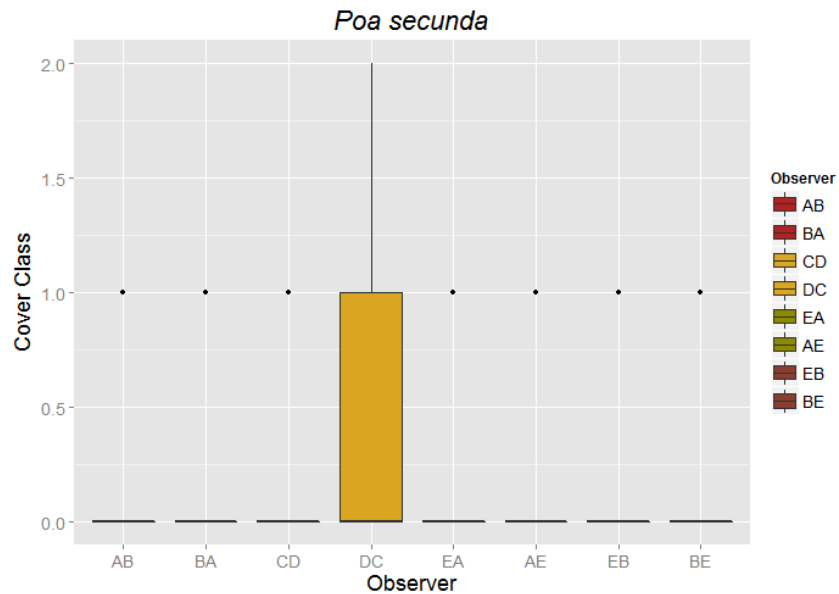


Figure 15. Box plots of the subset of *P. secunda* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

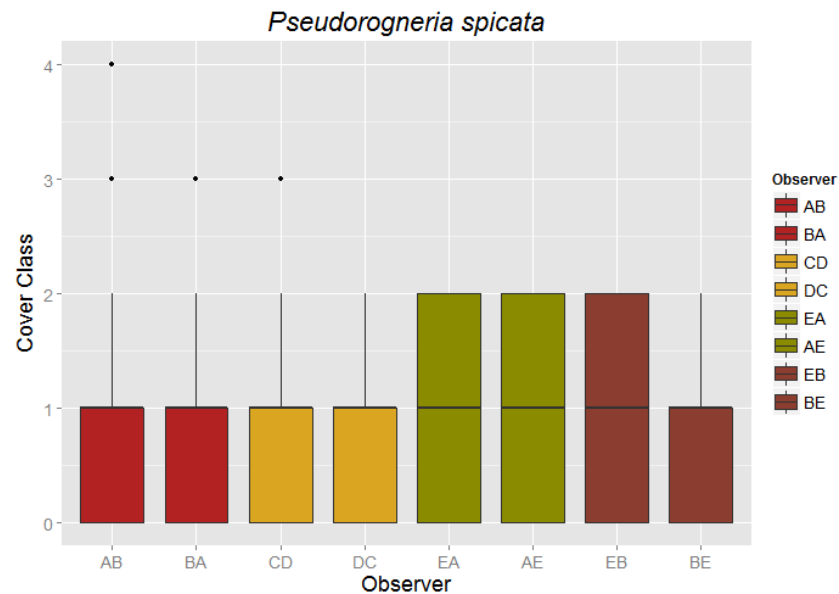


Figure 16. Box plots of the subset of *P. spicata* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

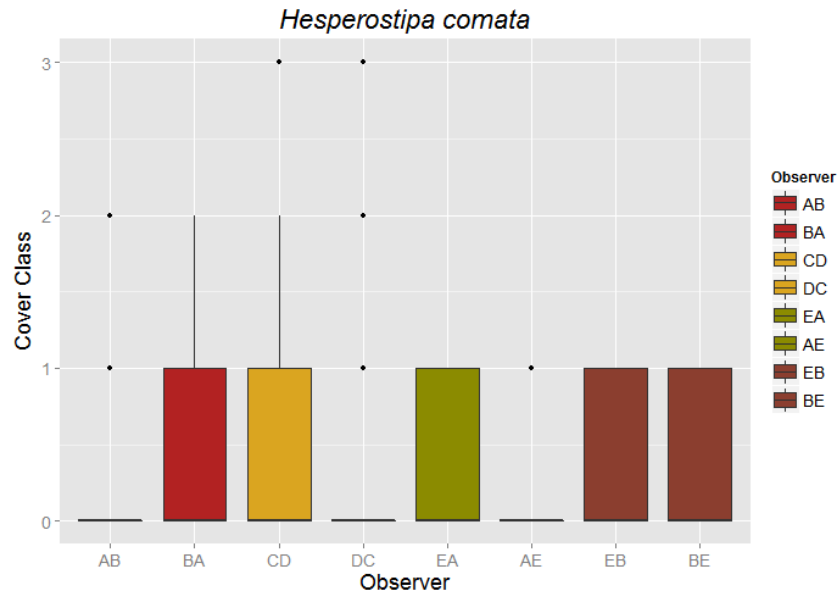


Figure 17. Box plots of the subset of *H. comata* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

John Day Fossil Beds National Monument – Clarno Unit

At JODA, recorded cover classes between all three observers typically had no difference for most vegetation groups (Table 4 and Figure 18). Two notable exceptions were observed in non-native grasses (~24% of plots with ≥ 1 difference in cover class) and bare ground (~47% of plots with ≥ 1 difference in cover class).

Table 4. Proportion (%) of double-observed plots (n=60) in JODA where recorded cover class differed between observers.

Species Group	0 Difference	1 Difference	2 Differences	3 Differences
Native Grasses	92	8	0	0
Native Forbs	97	3	0	0
Shrubs	98	2	0	0
Non-native Grasses	76	21	3	0
Non-native Forbs	96	4	0	0
Bare Ground	53	45	2	0

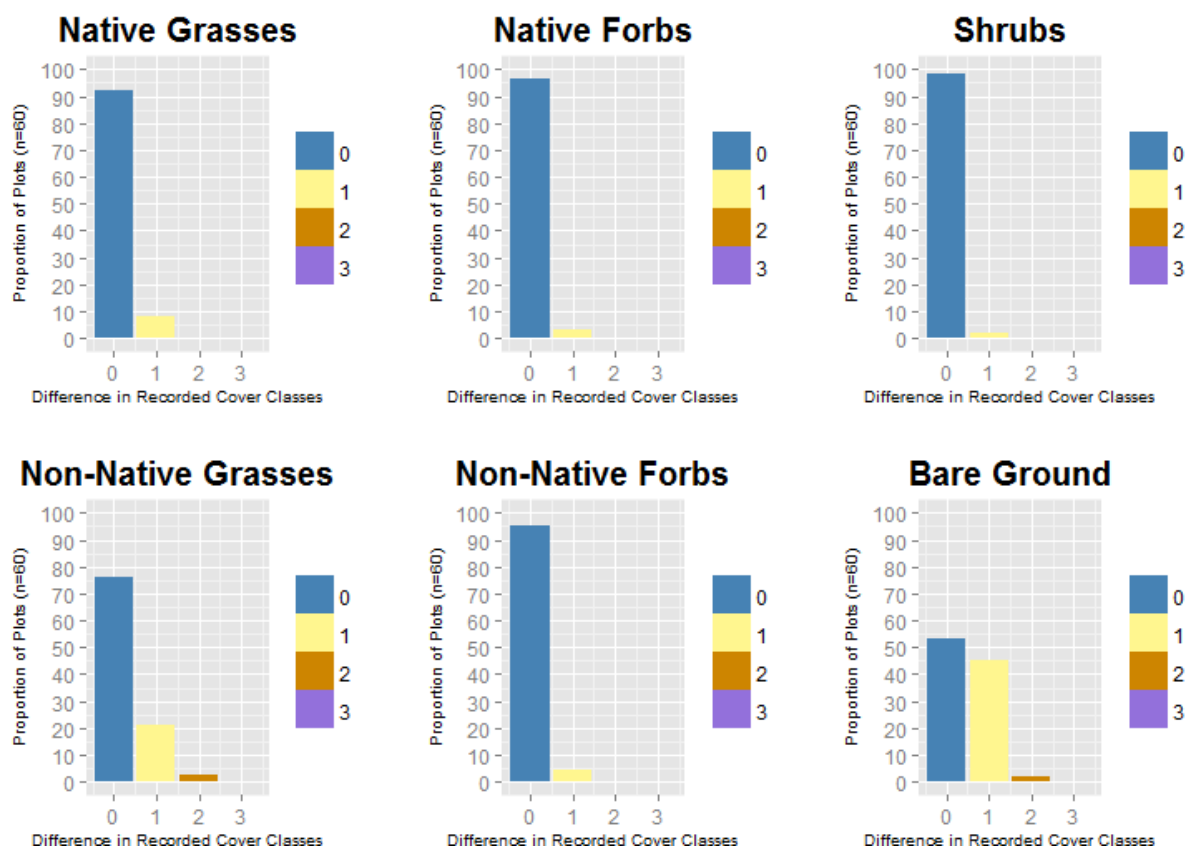


Figure 18. Proportion (%) of double-observed plots in JODA (n=60) with differences in recorded cover class between observers by species group.

Differences in recorded cover class between observers rarely exceeded 1. A comparison of 707 total records collected by three observers across 60 double-observed plots, revealed only 10 pairings (~2%) which exceeded 1 difference in cover class (Table 4). Four of the 10, were cases of one observer recording a non-native species with a cover class ≥ 2 where the other observer had not recorded the species as present. Three of the 10 were cases where the same non-native species was recorded by both observers but with greater than 1 difference in cover class. One of the 10 was a case of the same native species recorded by both observers but with greater than 1 difference in cover class. One of the 10 was a case of two different, but similar native species being recorded (one spp. each/observer). When the cover classes of the two species were compared the difference was less than 2. One of the 10 was a case of greater than 1 difference in recorded bare ground.

Table 5. Number of JODA double-observations where the difference in cover class was >1, organized by specific discrepancies, and their proportion (%) of all double-observation records (n=707).

Discrepancies with >1 Difference in Cover Class	# of Paired Records	% of Total Records
Bare Ground Record	1	0.1
Non-native species recorded by only one observer	4	0.6
Same native species recorded by both observers	1	0.1
Same non-native species recorded by both observers	3	0.4
Two different, but similar native spp recorded; resulting difference =1	1	0.1

Species Richness and Sum of Cover Classes

Species richness recorded by observers A and B was highly correlated ($r = 0.82$) and 50% of plots sampled (n=20) had no difference in species richness (Figure 19). A paired t -test produced no evidence of a difference in the number of species recorded by observers A and B (mean difference = -0.15 ± 0.46 , $p=0.51$, $df=19$). A large proportion of plots (80%) had some pseudoturnover, with a mean pseudoturnover of 10.5% across all plots for observers A and B. The sum of cover classes by plot were also highly correlated ($r = 0.83$) with 50% of plots having no difference (Figure 19). There was no evidence for a difference in the sum of cover classes between observers A and B (paired t -test, mean difference = -0.05 ± 0.62 , $p=0.87$, $df=19$).

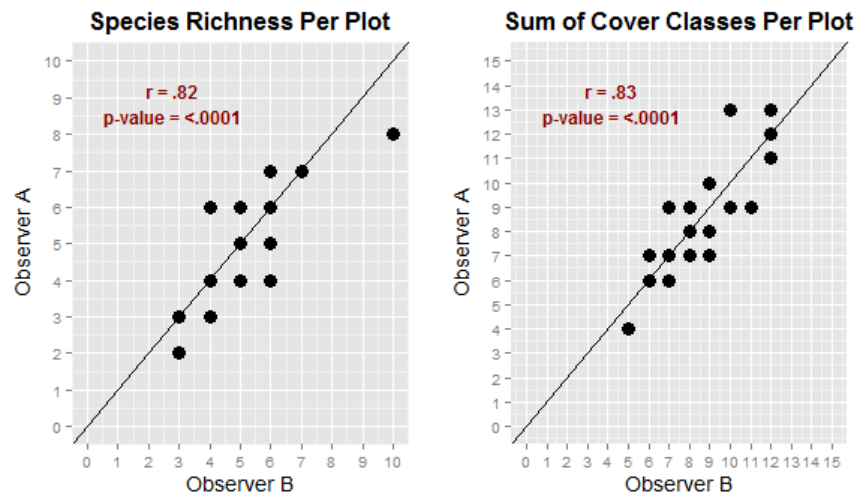


Figure 19. Comparison of observers A and B for species richness (left) and sum of cover classes (right) per double-observed plot (n=20). Points on the line indicate no difference.

Species richness recorded by observers A and C was highly correlated ($r = 0.85$) and 50% of plots sampled (n=20) had no difference in species richness (Figure 20). However, a paired t -test produced some evidence of a difference in the number of species recorded by observers A and C (mean difference = -0.65 ± 0.46 , $p<0.05$, $df=19$). A large proportion of plots (85%) had some pseudoturnover, with a mean pseudoturnover of 13.1% across all plots for observers A and C. The

sum of cover classes by plot were also highly correlated ($r = 0.77$) but with only 15% of plots having no difference (Figure 20). There was no evidence for a difference in the sum of cover classes between observers A and C (paired t -test, mean difference = -0.55 ± 0.8 , $p=0.16$, $df=19$).

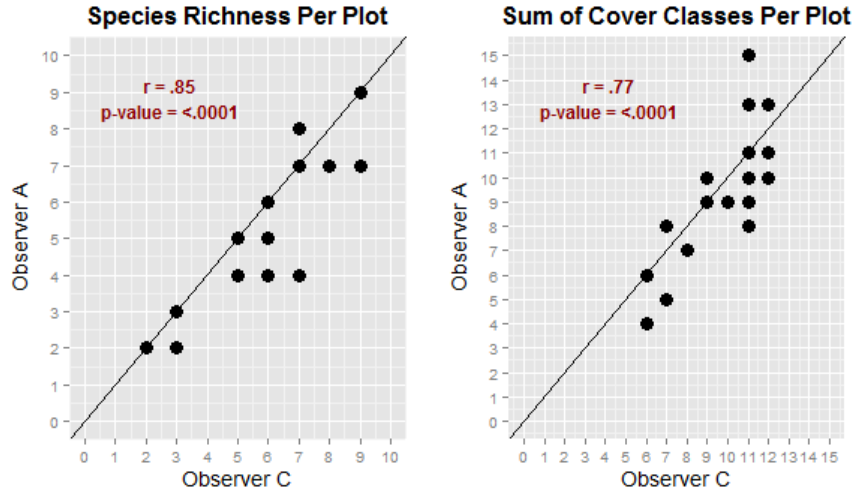


Figure 20. Comparison of observers A and C for species richness (left) and sum of cover classes (right) per double-observed plot ($n=20$). Points on the line indicate no difference.

Species richness recorded by observers B and C was highly correlated ($r = 0.80$) and 35% of plots sampled ($n=20$) had no difference in species richness (Figure 21). A paired t -test produced no evidence of a difference in the number of species recorded by observers B and C (mean difference = -0.4 ± 0.56 , $p=0.14$, $df=19$). A large proportion of plots (85%) had some pseudoturnover, with a mean pseudoturnover of 18.3% across all plots for observers B and C. The sum of cover classes by plot were also highly correlated ($r = 0.83$) with 55% of plots having no difference (Figure 21). However, there was some evidence of a difference in the sum of cover classes between observers B and C (paired t -test, mean difference = -0.7 ± 0.57 , $p=0.02$, $df=19$).

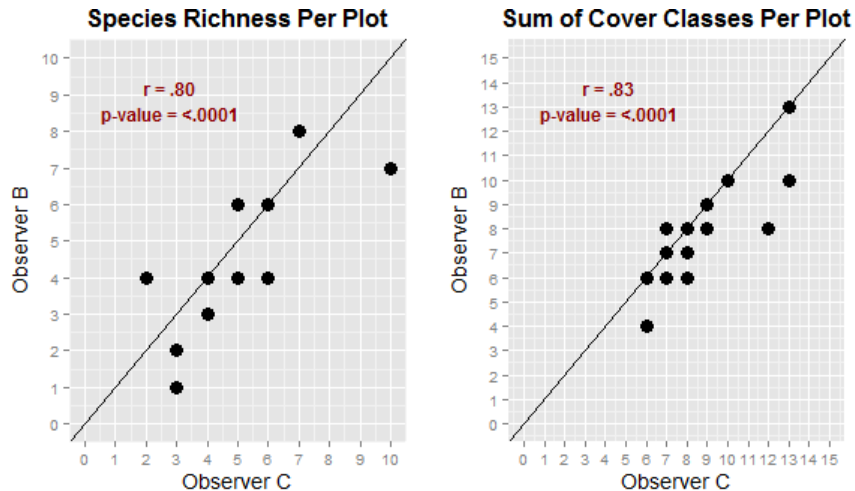


Figure 21. Comparison of observers B and C for species richness (left) and sum of cover classes (right) per double-observed plot ($n=20$). Points on the line indicate no difference.

Individual Species Records

Paired *t*-tests were used to examine significant differences between observers for recorded cover classes of select species (Table 6). Corresponding boxplots are shown below (Figures 22-26).

Table 6. Results of *t*-tests between paired observers for recorded cover class of select species.

Observers	Species	Mean Difference	Plus or Minus	p-value	d.f.
AB	Bare	0.05	0.36	0.772	19
AC	Bare	0.1	0.37	0.577	19
BC	Bare	0.3	0.27	0.029	19
AB	<i>B. tectorum</i>	-0.35	0.27	0.015	19
AC	<i>B. tectorum</i>	-0.2	0.36	0.259	19
BC	<i>B. tectorum</i>	-0.3	0.31	0.055	19
AB	<i>T. caput-medusae</i>	-0.05	0.18	0.577	19
AC	<i>T. caput-medusae</i>	0.15	0.27	0.267	19
BC	<i>T. caput-medusae</i>	0.1	0.14	0.163	19
AB	<i>P. spicata</i>	0.2	0.19	0.040	19
AC	<i>P. spicata</i>	0	0	NA	19
BC	<i>P. spicata</i>	0.05	0.24	0.666	19
AB	<i>G. sarothrae</i>	0	0	NA	19
AC	<i>G. sarothrae</i>	0.1	0.14	0.163	19
BC	<i>G. sarothrae</i>	0	0	NA	19

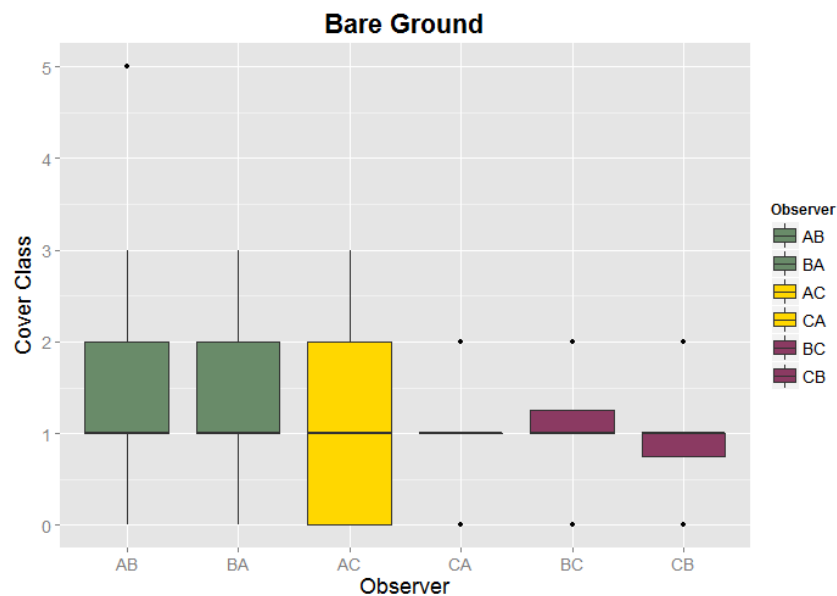


Figure 22. Box plots of the subset of bare ground observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

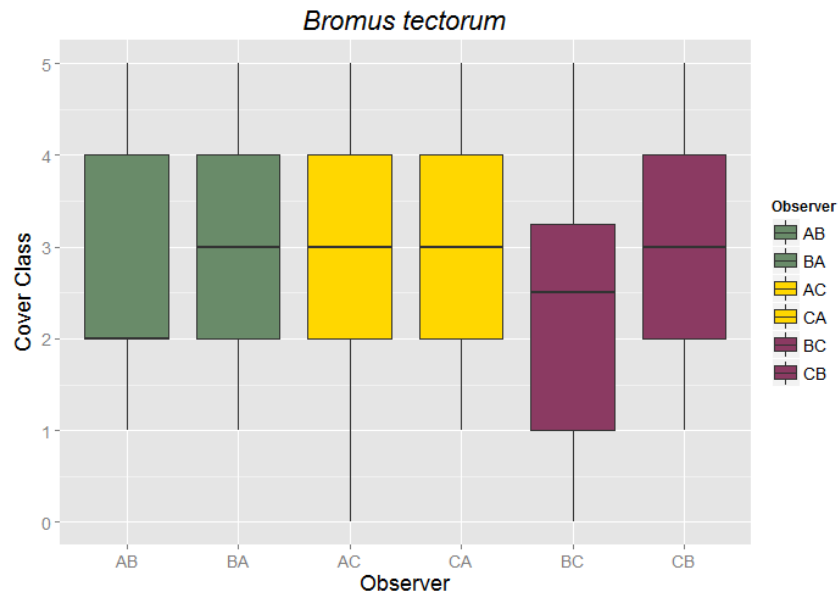


Figure 23. Box plots of the subset of *B. tectorum* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

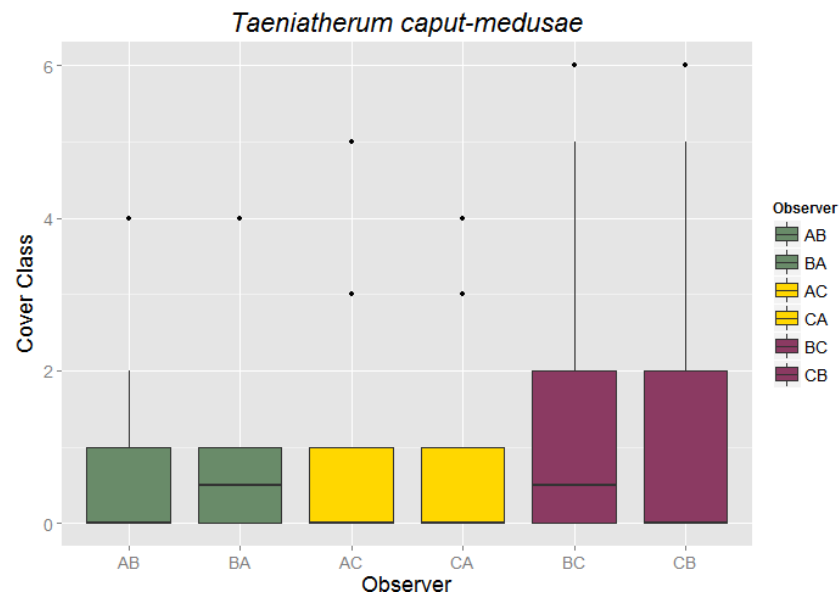


Figure 24. Box plots of the subset of *T. caput-medusae* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

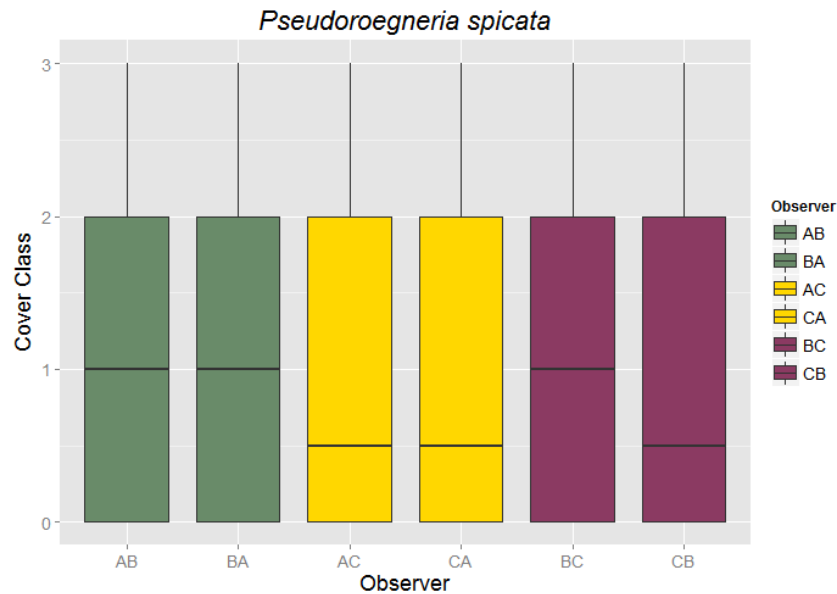


Figure 25. Box plots of the subset of *P. spicata* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

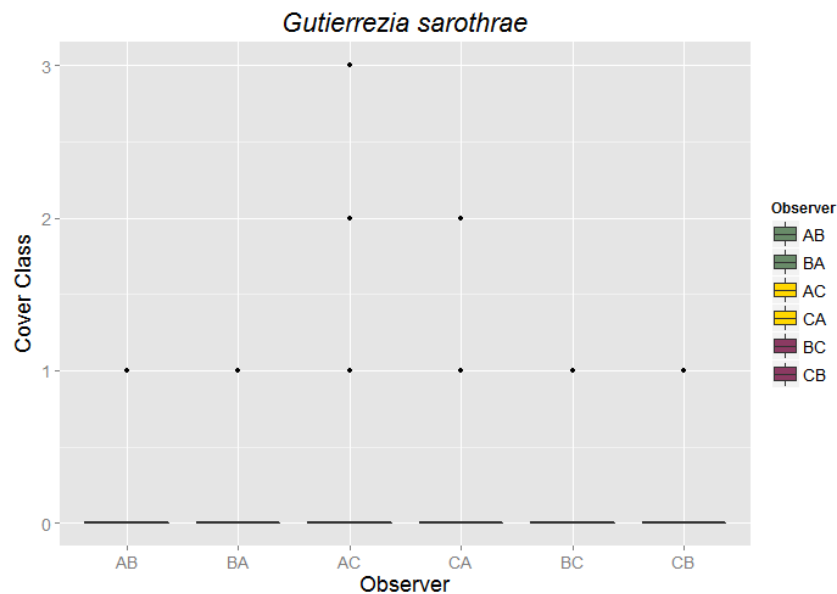


Figure 26. Box plots of recorded cover classes for *G. sarothrae* by observer. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations.

City of Rocks National Reserve

At CIRO, recorded cover classes between all three observers typically had no difference for most vegetation groups (Table 7 and Figure 27). The one notable exception was observed in bare ground (~49% of plots with ≥ 1 difference in cover class).

Table 7. Proportion (%) of double-observed plots (n=201) in CIRO where recorded cover class differed between observers.

Species Group	0 Difference	1 Difference	2 Differences	3 Differences
Native Grasses	93	6	1	0
Native Forbs	98	2	0	0
Shrubs	94	5	1	0
Non-native Grasses	88	11	1	0
Non-native Forbs	98	2	0	0
Bare Ground	51	39	10	1

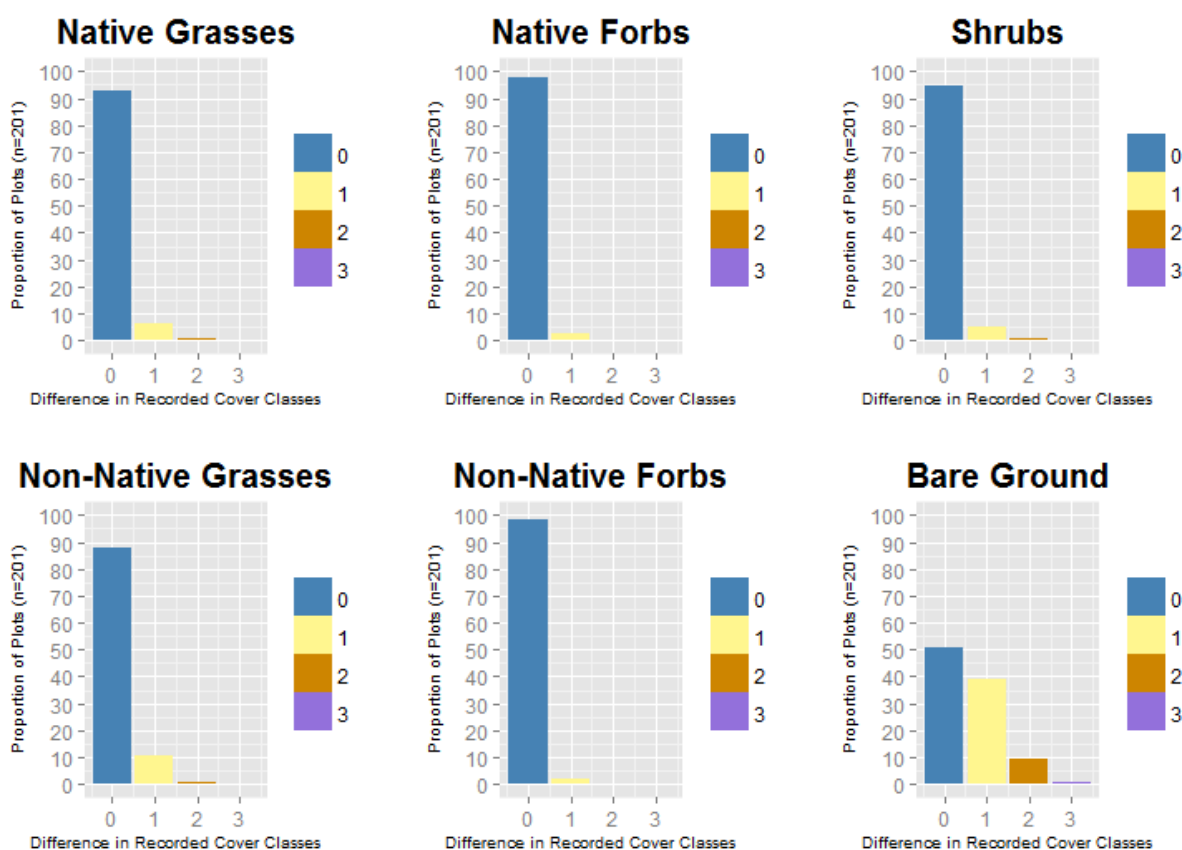


Figure 27. Proportion (%) of double-observed plots in CIRO (n=201) with differences in recorded cover class between observers by species group.

Differences in recorded cover class between observers rarely exceeded 1. A comparison of 3113 total records collected by three observers across 201 double-observed plots revealed only 73 pairings (~2%) which exceeded 1 difference in cover class (Table 8). Twenty-one of the 73 were cases of greater than 1 difference in recorded bare ground. Thirteen of the 73 were cases where a native species had been recorded by one observer with a cover class ≥ 2 while the other observer did not record the species as present. Nine of the 73 were cases of one observer recording a native species and the other observer recording a similar looking non-native species such that when the cover

records for the two species were compared the difference was <2 . Eight of the 73 were cases of each observer recording a different, but similar looking native species with a cover class ≥ 2 , such that when the records for the two species were compared the resulting difference was 0. Six of the 73 were cases where each observer recorded a different, but similar looking native species with a cover class ≥ 2 , such that when the records for the two species were compared the resulting difference was <2 . Five of the 73 were cases of the same native species being recorded by both observers but with ≥ 2 cover class differences. Three of the 73 were cases of the same non-native species being recorded by both observers but with ≥ 2 cover class differences. Lastly, 6 of the 73 were cases which when examined, provided no easily discernable explanation.

Table 8. Number of CIRO double-observations where the difference in cover class was >1 , organized by specific discrepancies, and their proportion (%) of all double-observation records ($n=3113$).

Discrepancies with >1 Difference in Cover Class	# of Paired Records	% of Total Records
Bare ground record	21	0.7
Native species recorded by only one observer	13	0.4
Non-native species recorded by only one observer	1	0.0
Same native species recorded by both observers with cover class difference >1	5	0.2
Same non-native species recorded by both observers with cover class difference >1	3	0.1
Two different, but similar native spp recorded; resulting difference = 0	8	0.3
Two different, but similar spp (one native & one non-native) recorded; resulting difference = 0	1	0.0
Two different, but similar native spp recorded; resulting difference = 1	6	0.2
Two different, but similar spp (one native and one non-native) recorded; resulting difference = 1	9	0.3
Undetermined	6	0.2

Species Richness and Sum of Cover Classes

Species richness recorded by observers A and B was correlated ($r = 0.65$) and 14% of plots sampled ($n=21$) had no difference in species richness (Figure 28). A paired t -test produced no evidence of a difference in the number of species recorded by observers A and B (mean difference = -0.62 ± 1.03 , $p=0.23$, $df=20$). All double-observed plots (100%) had some pseudoturnover, with a mean pseudoturnover of 18.3% across all plots for observers A and B. The sum of cover classes by plot were also somewhat correlated ($r = 0.34$) with only 10% of plots having no difference (Figure 28). There was no evidence for a difference in the sum of cover classes between observers A and B (paired t -test, mean difference = 0.10 ± 1.47 , $p=0.89$, $df=20$).

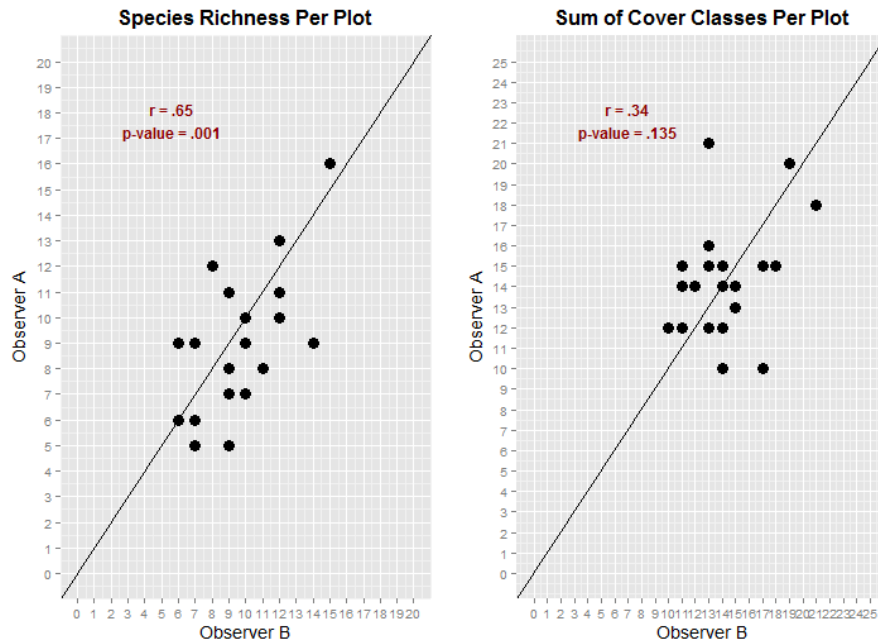


Figure 28. Comparison of observers A and B for species richness (left) and sum of cover classes (right) per double-observed plot ($n=21$). Points on the line indicate no difference.

Species richness recorded by observers A and C was highly correlated ($r = 0.90$) and 37% of plots sampled ($n=159$) had no difference in species richness (Figure 29). However, a paired t -test produced strong evidence of a difference in the number of species recorded by observers A and C (mean difference = -0.28 ± 0.18 , $p=0.003$, $df=158$). A large proportion of plots ($\sim 82\%$) had some pseudoturnover, with a mean pseudoturnover of 15.9% across all plots for observers A and C. The sum of cover classes by plot were also highly correlated ($r = 0.90$) with 28% of plots having no difference (Figure 29). There was no evidence for a difference in the sum of cover classes between observers A and C (paired t -test, mean difference = -0.07 ± 0.25 , $p=0.58$, $df=158$).

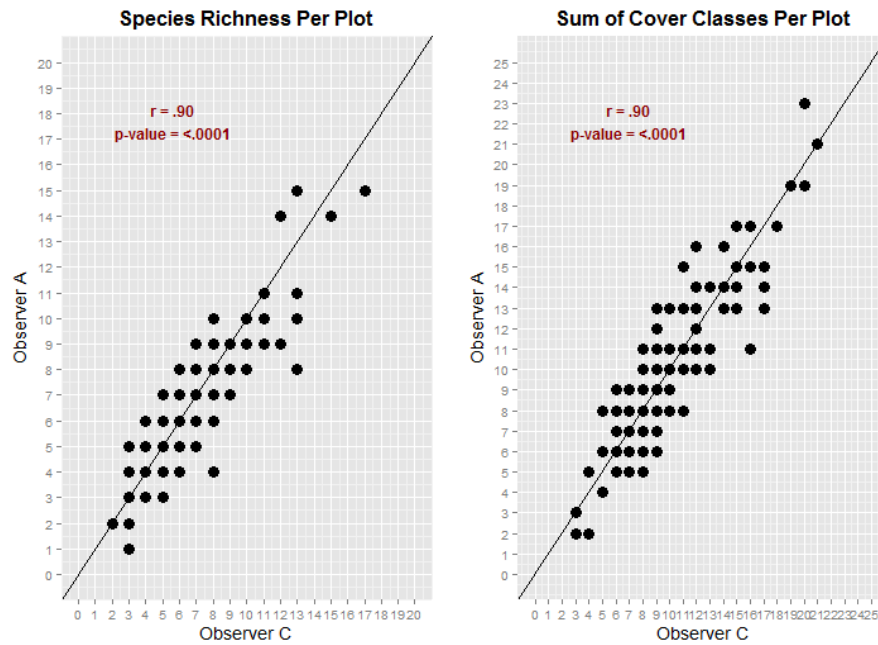


Figure 29. Comparison of observers A and C for species richness (left) and sum of cover classes (right) per double-observed plot ($n=159$). Points on the line indicate no difference.

Species richness recorded by observers B and C was highly correlated ($r = 0.83$) and 33% of plots sampled ($n=21$) had no difference in species richness (Figure 30). A paired t -test produced no evidence of a difference in the number of species recorded by observers B and C (mean difference = -0.05 ± 0.92 , $p=0.91$, $df=20$). A large proportion of plots (81%) had some pseudoturnover, with a mean pseudoturnover of 17% across all plots for observers B and C. The sum of cover classes by plot were also highly correlated ($r = 0.79$) but with 0% of plots having no difference (Figure 30). There was no evidence for a difference in the sum of cover classes between observers B and C (paired t -test, mean difference = -0.57 ± 1.35 , $p=0.39$, $df=20$).



Figure 30. Comparison of observers B and C for species richness (left) and sum of cover classes (right) per double-observed plot ($n=21$). Points on the line indicate no difference.

Individual Species Records

Paired t -tests were used to examine significant differences between observers for recorded cover classes of select species (Table 9). Corresponding boxplots are shown below (Figures 31-37).

Table 9. Results of t -tests between paired observers for recorded cover class of select species.

Observer	Species	Mean Difference	Plus or Minus	p-value	d.f.
AB	Bare	0.38	0.30	0.017	20
AC	Bare	0.52	0.13	<0.001	158
BC	Bare	0.29	0.21	0.010	20
AB	<i>B. tectorum</i>	0.10	0.32	0.540	20
AC	<i>B. tectorum</i>	-0.14	0.08	0.001	158
BC	<i>B. tectorum</i>	-0.24	0.28	0.096	20
AB	<i>P. pratensis</i>	-0.10	0.25	0.428	20
AC	<i>P. pratensis</i>	-0.17	0.08	<0.001	158
BC	<i>P. pratensis</i>	-0.05	0.10	0.329	20
AB	<i>A. cristatum</i>	-0.10	0.14	0.162	20
AC	<i>A. cristatum</i>	-0.08	0.05	0.003	158
BC	<i>A. cristatum</i>	0.00	0	NA	20
AB	<i>P. spicata</i>	-0.02	0.23	0.104	20
AC	<i>P. spicata</i>	0.02	0.07	0.603	158
BC	<i>P. spicata</i>	-0.10	0.20	0.329	20

Table 9 (continued). Results of t-tests between paired observers for recorded cover class of select species.

Observer	Species	Mean Difference	Plus or Minus	p-value	d.f.
AB	<i>P. secunda</i>	0.00	0.22	1	20
AC	<i>P. secunda</i>	0.25	0.12	<0.001	158
BC	<i>P. secunda</i>	-0.29	0.26	0.030	20
AB	<i>P. smithii</i>	0.24	0.25	0.056	20
AC	<i>P. smithii</i>	-0.09	0.11	0.092	158
BC	<i>P. smithii</i>	-0.05	0.17	0.576	20

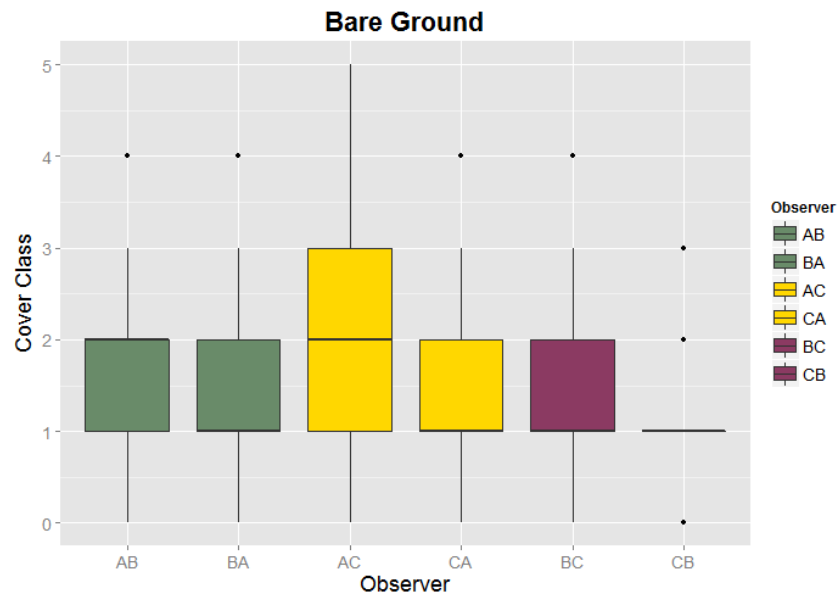


Figure 31. Box plots of the subset of bare ground observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

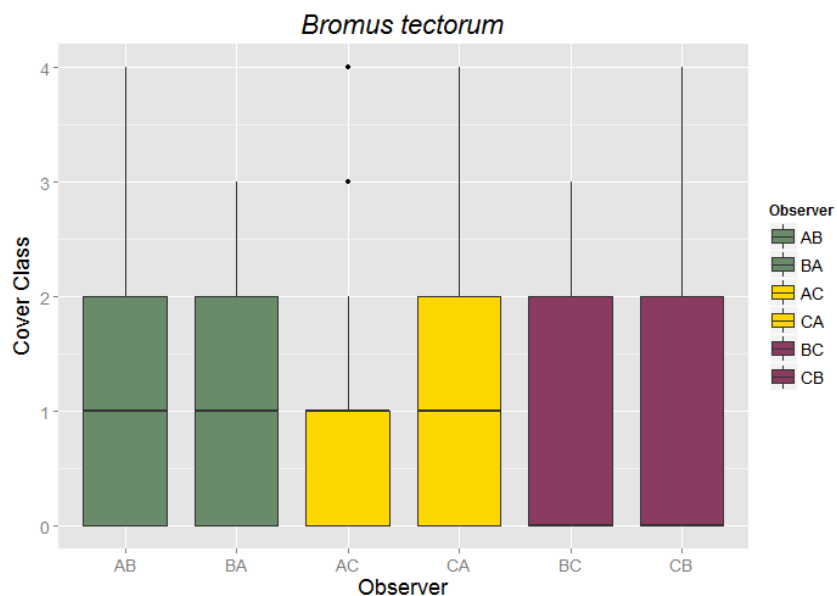


Figure 32. Box plots of the subset of *B. tectorum* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

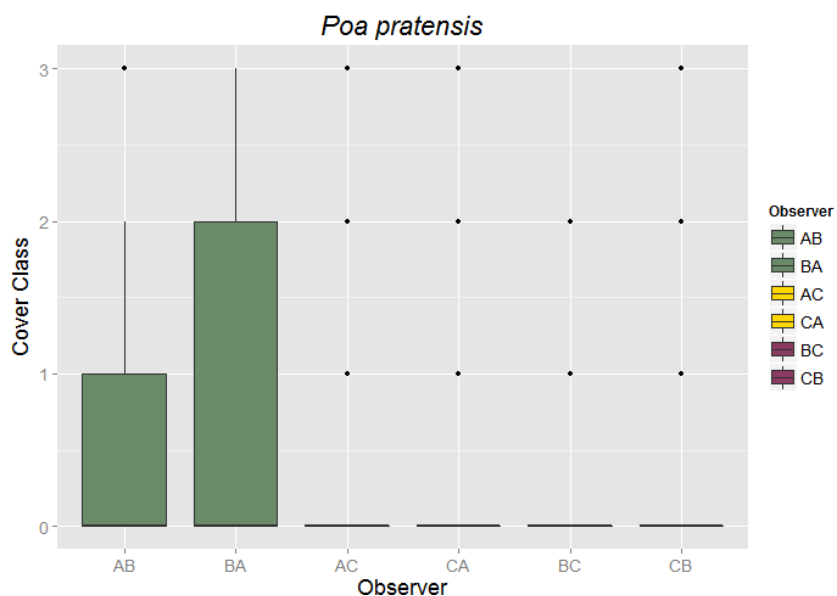


Figure 33. Box plots of the subset of *P. pratensis* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

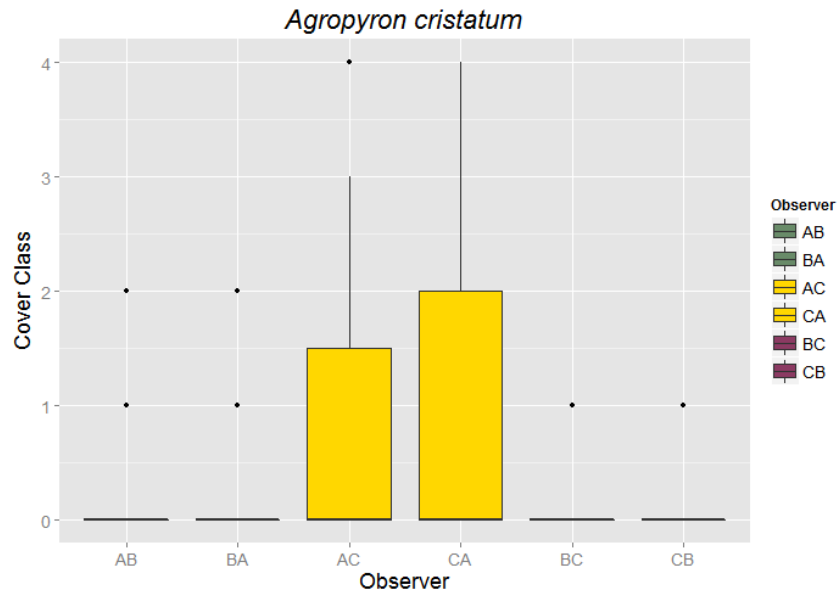


Figure 34. Box plots of the subset of *A. cristatum* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

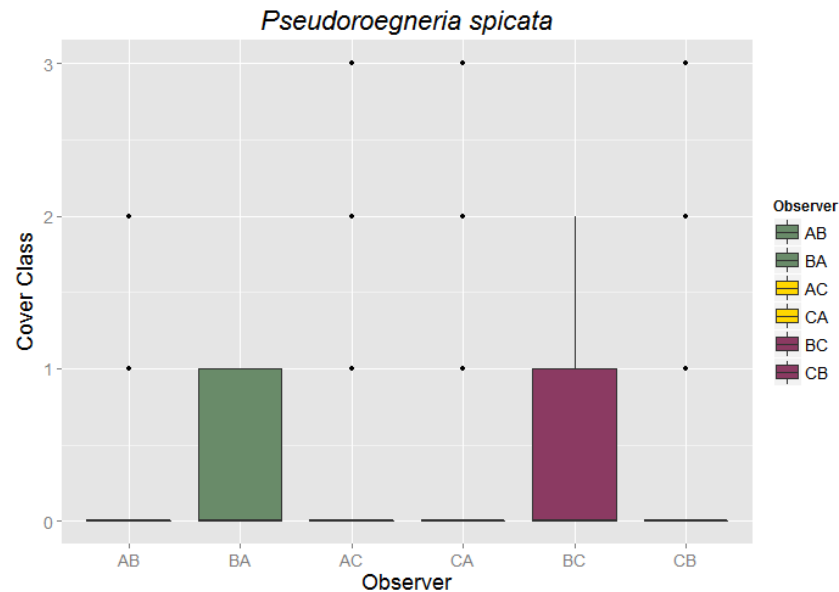


Figure 35. Box plots of the subset of *P. spicata* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

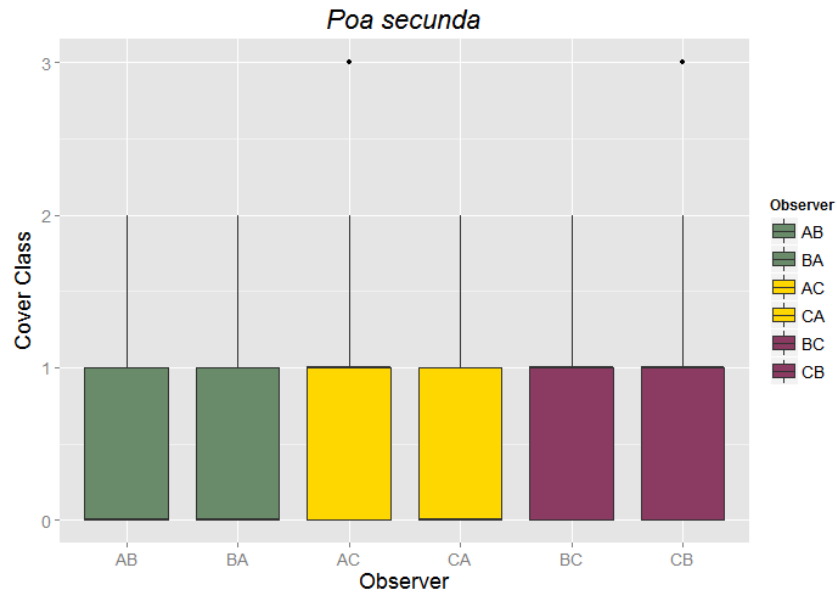


Figure 36. Box plots of the subset of *P. secunda* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

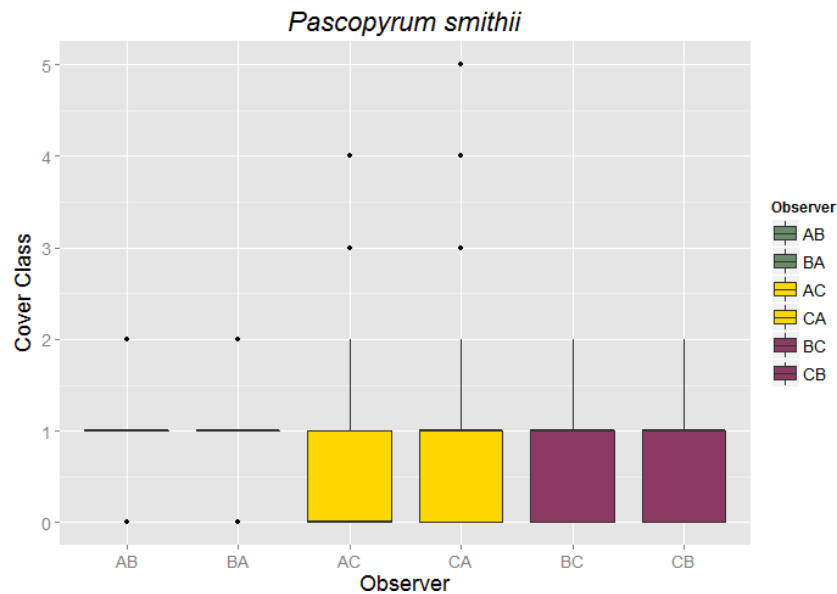


Figure 37. Box plots of the subset of *P. smithii* observations in which recorded cover classes differed between observers. Observer labels are comprised of two letters. The first letter indicates the observer whose records are being depicted, and the second letter indicates the observer whose plots were paired with these observations. First and 3rd quartiles bound the colored boxes (the interquartile range [IQR]), dots represent outliers (beyond 1.5 x the IQR).

Discussion

The quality and consistency of data collection is paramount to the goals of inventory and monitoring. The vegetation monitoring efforts of the Upper Columbia Basin and Greater Yellowstone Networks take place across expansive landscapes. Often, data is collected independently by multiple observers following a standard protocol. The use of multiple, independent observers ensures data collection is completed in a timely fashion. Having multiple field technicians working independently, but in close proximity to one another, also provides a degree of safety (when compared to a solo effort). Observers are selected based on similar (high to moderate) expertise in plant identification and familiarity of regional flora in order to minimize misidentification of plant species. Additionally, at the beginning of the sampling effort, observers perform calibration exercises as a group to improve inter-observer consistency of visual estimation of plant cover. However, despite these efforts variability between observers is inevitable. This study was performed in order to identify how much variability occurred between observers during the 2015 sagebrush steppe monitoring effort in multiple park units.

Differences in Recorded Cover Class

Differences in recorded cover classes between paired observers rarely exceeded 1 cover class. Most discrepancies between observer records occurred in the estimation of cover of bare ground, litter and soil crusts, and non-native grasses. Differences in recorded cover class for bare ground ≥ 1 ranged from 34-50% across all double-observed plots in the three parks in this study. Differences in recorded cover class ≥ 1 for non-native grasses ranged from 2-24% across all double-observed plots in the three parks in this study. Litter and soil crusts (recorded only in BICA) had 32% of records with greater than or equal to 1 difference in cover class between observers. Because Daubenmire (1959) cover classes define a range of cover values (Table 10), it is difficult to determine when a difference of 1 cover class between observers is significant.

Table 10. Daubenmire (1959) cover classes and range of values within each class.

Cover Class	Range
0	0%
1	1-5%
2	>5-25%
3	>25-50%
4	>50-75%
5	>75-95%
6	>95%

When the estimated cover of a species approaches the maximum value of one cover class and the minimum value of the next highest cover class (e.g. an estimated cover of ~25%) the observer needs to decide which cover class is most accurate. In these cases, one observer may record the lower cover class while a second observer may record the higher cover class. Conversely, a difference of 2 or more recorded cover classes between observers indicates a large discrepancy in estimation of cover.

The differences in recorded cover class which were greater than or equal to 2 cover classes for bare ground ranged from 2-10%, and only 0-3% for non-native grasses across all double-observed plots in the three parks in this study. Additionally, only 5% of litter and soil crust (recorded only in BICA) records had greater than or equal to 2 differences in cover class between observers.

The proportion of paired records with a difference of 2 cover classes was rare (~1-3%). These discrepancies were examined on a case by case basis (for JODA and CIRO), which revealed some cases where the actual discrepancy was indeed an instance of both observers recording the same species but with a difference of 2 or more cover classes. This indicates a true disagreement in cover estimation. Other cases, were instances where one observer recorded a species where the other observer did not, indicating a detection error. The rest of the discrepancies were cases of misidentification of species (or possibly errors in data entry). Some instances of misidentification revealed two similar looking species being recorded by separate observers at the same cover class. In these instances it is assumed that each observer was recording the same plant but identifying it differently. These records indicate agreement in visual estimation of cover but disagreement in species identification. Similar instances show records where two different but similar looking species were recorded by separate observers at different cover classes but, when compared, the difference in cover class is less than 2. In these instances we assume, as above, that each observer was recording the same plant but disagreed on the identification. While the cover classes are still different in these instances, they are only off by 1 cover class, which as previously discussed, is somewhat unavoidable. Misidentification of species (in JODA and CIRO) was seen predominantly in *Poa*, *Bromus*, and wheatgrass (*Pascopyrum* and *Pseudoroegneria*) species.

While discrepancies in the estimates of cover for bare ground and non-native grasses were the most prevalent in the study, *t*-tests revealed only two out of nine pairs of observers in this study with significant ($p < 0.05$) differences in estimated cover of non-native annual grass species. However, seven of the nine pairs had significant differences in estimated cover of bare ground. The predominance of discrepancies in estimated cover of bare ground, non-native annual grasses, litter (BICA only), and soil crusts (BICA only) may be due to the inherent difficulty of observers trying to visually aggregate and bin small and scattered coverage patterns in to an accurate total.

Species Detection and Estimation of Total Cover

In BICA, there were four pairs of observers who participated in the study. Within-pair correlation for (1) the number of species recorded per plot and (2) the sum of cover classes per plot varied considerably between observer pairs in BICA. The proportion of plots where the number of species recorded was equal between a pair of observers ranged from 37-56%. None of the four pairs produced any evidence of a significant difference in the number of species recorded per plot. The proportion of plots which contained some pseudoturnover ranged from 56-75% with the average pseudoturnover per plot ranging from 20-44% between observer pairs. The lowest pseudoturnover at BICA (20%) is almost twice that reported by Nilsson and Nilsson (1985) (11.4%) and Lepš and Hadincová (1992) (13%), but is comparable to the 19% found by Kercher et al. (2003), and to the 24% reported by Scott and Hallam (2002). However, the higher pseudoturnover rates (36-44%) at BICA are all much higher.

In JODA, there were three pairs of observers. Within pair correlation for (1) the number of species recorded per plot and (2) the sum of cover classes per plot was consistently high for all observer pairs in JODA. The proportion of plots where the number of species recorded was equal between a pair of observers was similar to the results in BICA and varied from 35-50%. One out of the three pairs appeared to differ significantly in the number of species recorded per plot. Most (80-85%) plots contained some amount of pseudoturnover with the average pseudoturnover per plot ranging from 11-18% between observer pairs. The amount of pseudoturnover at JODA is comparable to measurements of pseudoturnover found in other studies (e.g. Nilsson and Nilsson 1985; Lepš and Hadincová 1992; Scott and Hallam 2002; and Kercher et al. 2003).

In CIRO there were three pairs of observers. Within pair correlation for the number of species recorded per plot varied somewhat between observer pairs and within pair correlation for the sum of cover classes per plot varied considerably between observers at CIRO. One out of the three pairs of observers appeared to differ significantly in the number of species recorded per plot. Most (81-100%) plots contained some pseudoturnover with the average pseudoturnover per plot ranging from 16-18% between observer pairs. The amount of pseudoturnover at CIRO is slightly higher than that reported by Nilsson and Nilsson (1985), but is comparable to others (e.g. Lepš and Hadincová 1992; Scott and Hallam 2002; and Kercher et al. 2003).

Fortunately, most of the pseudoturnover (75-94% at BICA; 92-95% at JODA; and 87-95% at CIRO) was the result of species which were recorded as cover class 1 (1-5% cover). This indicates that most of the detection error suggested by pseudoturnover was the result of species which may have been sparse or inconspicuous within a plot. Additionally, in JODA and CIRO, plot boundaries were removed by the first observer and replaced by the second observer (using pin flags at the corners to guide placement). This removal and replacement may have resulted in some degree of species inclusion/exclusion along the edges of the plots.

Conclusions

This study has shown that the observers involved in the 2015 sagebrush steppe (upland) vegetation monitoring in the UCBN and GRYN varied in their ocular estimation of plant cover, species detection, and identification of species. Bare ground and non-native annuals appeared to be the most difficult categories for observers to estimate cover. Future training should focus more attention on inter-observer calibration of visually estimating cover which is widely dispersed within a plot. Some species misidentification was documented and it is recommended that project leaders and crew lead discuss these findings and how best to approach future monitoring in order to avoid misrepresenting actual species abundance measured. This may be achieved by (1) grouping species together by genus, or (2) identifying concrete key breaks to ensure a higher level of confidence in separating similar looking species. Of these two recommendations, the latter is preferable considering that many instances of species misidentification in this study involved either; similar looking native and non-native species (e.g. *P. secunda* and *P. pratensis*), or two native species of particular interest due to their value as indicators of health within these ecosystems (*P. spicata* and *P. smithii*). If these issues of species misidentification can be addressed, further modification in the interpretation of data collected following the UCBN sagebrush steppe vegetation protocol (Yeo et al. 2009) or GRYN

upland vegetation monitoring protocol (Tercek et al. 2015) may not be required. However, formal statistical modeling of the detection and identification error may be a worthwhile investment. With such tools, this kind of study could be repeated in order to assess the degree of bias that is present in estimates of important model parameters (e.g., trend) when field observation discrepancies are present between observers.

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