Proposal: October Working Group for Knowledge Network of Biocomplexity

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Introduction:

The nature of the relationship between species richness and productivity has been the subject of ongoing debate within the ecological literature, stimulating experimental research, theoretical considerations, and synthetic analyses. Species richness is often hypothesized to initially increase with productivity at low levels and then similarly decrease at higher levels of productivity, producing a unimodal (or hump-shaped) relationship. While there is empirical support for this hypothesis, it has not been universally observed. Positive linear, negative linear, and negative monotonic (or u-shaped) relationships have been observed within and across community types as well (Mittelbach et al. 2001). These observations suggest that the relationship is likely to be scale-dependent, at least spatially, and may change in form from local to regional to global scales (Gross et al. 2000). As such, a hump-shaped relationship may in fact emerge as a consequence of the aggregation of several consecutive linear patterns (which arise when limited ranges of productivity are examined). This "pattern accumulation hypothesis" has been suggested by several authors who assert that studies conducted over broad productivity ranges (a characteristic of analyses that include multiple community types) may be more likely to be hump-shaped in form because they capture greater variability than local scale analyses, which are constrained to a single community type (Rosenzweig 1995; Huston 1994; Grace 1999). If this is indeed the case, a logical next step is to address variability in the relationship across temporal scales and to identify the time frame in which such a pattern may be evinced. Given that most analyses to date have focused on species richness and productivity for a single year, this type of analysis is an important and novel contribution to our understanding of productivity-richness relationships.

As part of the May 2002 Knowledge Network for Biocomplexity (KNB) working group, a group of graduate students proposed the following research question: Does the pattern accumulation hypothesis explain the diversity/productivity relationship across time and space? Because climate is a primary driver of variability in species richness and ANPP (at least independently), the general objectives of our analysis will be: (1) to characterize patterns of the relationship at the local scale (individual years within a site) and regional scales (the aggregation of sites and years) and (2) to use both mean values and ranges in precipitation and temperature (the chief components of climate) to explain the observed patterns. Briefly, the data model includes regression analyses with climate parameters versus ANPP and richness within sites in addition to logistic regression, which will be used to look for evidence of "pattern accumulation" both within and across sites. While the statistical analyses themselves have been conducted at home institutions, we request the opportunity to have a October 17-19, 2002 working group at NCEAS to discuss results, conduct several new analyses, and continue manuscript writing.

Outline of Methods:

I. Data collection:
   a. Plant species richness, annual net primary productivity, and climatic data were obtained for herbaceous community types from five North American LTER network sites.
      1. Species richness and biomass were scaled to a common grain (1 m^2) when necessary using species-area relationships and data re-sampling techniques as in Gross et al. 1999.
      2. Woody species, mosses, fungi, and dead litter were excluded from all of the sites' biomass and species richness estimates.
      3. The Konza site had estimates of ANPP and species richness in four disturbance regimes (1, 2, 4, and 20 year fire intervals), and these data were considered separately.
      4. Missing climatic data for KBS was obtained from a National Weather Service Station near the KBS site.

II. ANPP/richness relationship characterization (analyses conducted in SAS v. 8)
   a. Stepwise linear regression was used for each year within a site and for all years within a site pooled together to test for a significant (alpha=0.1) linear (positive/negative) or quadratic relationship between species richness (dependent variable) and ANPP (independent variable). If the relationship was curvilinear, we performed a MOS test to determine whether the maximum or minimum of the curve occurred within the range of productivity observed (as in Mittelbach et al. 2001).

Table 1. Data pooled at LTER sites for ANPP-species richness regressions.

LTER Site	Years	Number of Replicate Plots Per Year
Cedar Creek (CDR)	1988-1991	52
	1992-1994	56
	1995	57
	1996	55
Jornada (JOR)	1991-1998	294
W. K. Kellogg Biological Station (KBS)	1989-1990	6
	1991	27
	1992	26
	1993	29
	1994	12
	1995, 1997, 1999-2001	30
	1996	18

Konza Praire (KNZ)	1993-1996	360
	1997-1998	400
Short Grass Steppe (SGS)	1983-1985, 1991	15
	1986	11
	1987-1990	12
	1992-1998	18

III. Climatic data (calculations performed in SAS v.8)
   a. For each site, the following was calculated:
      1. Mean temperature and precipitation were calculated for the entire year.
      2. Mean temperature and precipitation were calculated for the growing season.
      3. Standard deviation of monthly temperature and precipitation means were calculated.
      4. Degree days were calculated for the entire year.
      5. Degree days were calculated for the growing season.

IV. Relationships between abiotic variables, richness, and ANPP (analyses conducted in SPSS v. 10)
   a. Within each site, Pearson's correlations were used to test for significant relationships between:
      1. abiotic variables
      2. abiotic variables and species richness
      3. abiotic variables and ANPP
   b. The data points in these correlations represent the value of an abiotic variable in a given year plotted versus ANPP/SR/other abiotic variable for that year.

V. Logistic Regression (analyses conducted in SAS v. 8)

Reasoning

The pattern accumulation hypothesis suggests that species richness is unimodally related to productivity and that positive and negative patterns result from examining a limited portion of the curve. Thus, the probability of finding a positive relationship between diversity and productivity should be higher at low levels of productivity. Likewise, negative relationships should be more common at high productivity levels. Furthermore, unimodal patterns should have a higher probability of occurrence at large ranges in productivity.

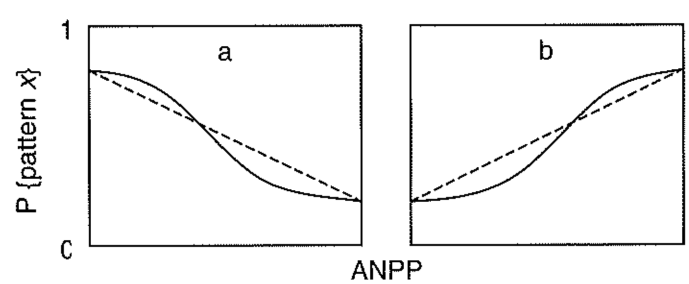

Figure 1. Expected relationships between ANPP and the probability of finding a positive (a) and negative (b) pattern between ANPP and species richness. Solid lines represent potential sigmoidal responses and dashed lines represent possible linear responses.

Logistic regression provides a way to predict the probability of an occurrence (e.g., P{unimodal relationship}, P{positive relationship}, P{negative relationship}) in response to a continuous predictor variable (ANPP). Using logistic regression, we were able to address the following hypotheses: 1) the likelihood of finding a positive relationship declines as ANPP increases (Figure 1a); 2) the likelihood of finding a negative relationship increases as ANPP increases (Figure 1b); and the likelihood of finding a unimodal relationship increases as range in ANPP increases (Figure 2).

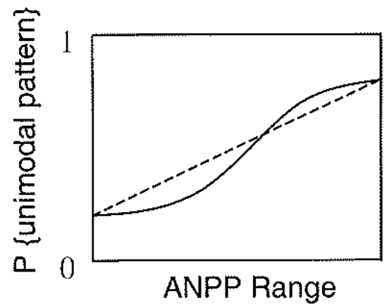

Figure 2. Expected relationship between range of ANPP and the probability of finding a unimodal relationship between ANPP and species richness. Solid line represents a potential sigmoidal response and dashed line represents possible linear response.

VI. Planned analyses:

a. If the logistic regressions described above reveal that mean ANPP or range of ANPP predict the shape of the ANPP-species richness relationship, we will try to identify climate/abiotic factors that influence mean/range ANPP (using regression analysis). (Really the only new analyses would be those using range in ANPP)

b. We intend to select years of data within sites at random, and pool SR and ANPP data across sites to construct cross-site SR-ANPP relationships. We will perform many iterations of this procedure and then ask if a single iteration represents the mean of many iterations. The purpose is to evaluate the appropriateness of using investigator selected, site-specific "representative year" as has been done in the past (Gross et al 2001).

c. Finally, we will plot ANPP-SR for all sites and all years, to see if a long-term regional pattern emerges. This will extend the scale of investigation of these patterns, so all four corners of a spatial scale by temporal scale matrix have been covered. (i.e. short term-within site scale, long term-within site scale, short term-continental scale, long term-continental scale).

Preliminary Results:

I. Relationships between abiotic variables, richness, and ANPP (Tables 5-9; the interpretation of these results will be discussed in the upcoming conference call).

II. Logistic Regression

Logistic regression results verified only one of our hypotheses. The probability of finding a negative relationship between ANPP and species richness increased as mean ANPP increased (Table 2). The likelihood of finding a positive relationship decreased with ANPP, however the logistic model was not significant (Table 3). The probability of finding a hump-shaped pattern increased with range in ANPP as expected, but this model also lacked statistical significance (Table 4). These results were produced using PROC LOGISTIC in SAS. It is important to note that these results differ from previous analyses in SPSS and S-Plus. We are in the process of trying to determine why this was the case; these results are therefore preliminary and should be interpreted with caution.

Table 2. Results from logistic regression of occurrence of positive relationships and mean ANPP.

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	4.0108	1	0.0452
Score	4.4290	1	0.0353
Wald	3.8819	1	0.0488

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-2.8064	0.7594	13.6587	0.0002
meananpp	1	0.00476	0.00242	3.8819	0.0488

Table 3. Results from logistic regression of occurrence of negative relationships and mean ANPP.

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	1.7880	1	0.1812
Score	1.4241	1	0.2327
Wald	1.2727	1	0.2593

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.3448	0.8570	2.4623	0.1166
meananpp	1	-0.00574	0.00509	1.2727	0.2593

Table 4. Results from logistic regression of occurrence of hump-shaped relationships and range in ANPP.

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	1.1472	1	0.2841
Score	1.4815	1	0.2235
Wald	1.3071	1	0.2529

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-4.3240	1.3384	10.4379	0.0012
ranganpp	1	0.00219	0.00192	1.3071	0.2529

Potentially Relevant Literature

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*Literature from the KNB Seminar

Time Line

Group will review analyses to date, suggestions/improvements made as needed.

- September ~26, 2002—Conference call to discuss the results of completed analyses as well as methods for future analyses and the outline of the manuscript. During this time the agenda for the October working group will be formalized.
- October 17-19, 2002—KNB working group at NCEAS
    - The results of all analyses completed since the May working group will be presented and discussed.
    - The "Planned Analyses" described in this proposal will be conducted.
    - Discussion/selection of relevant figures and results for a manuscript (followed by figure preparation).
    - Re-visit issue of order of authorship and individual responsibilities for writing and submitting a manuscript. A first draft will be generated.
- November 10, 2002—2nd draft of manuscript circulated to group members.
- November 25, 2002—Feedback and revisions from group members.

- December 10, 2002—final draft circulated to group members.

Goal for submission—January 1, 2003

Table 5. Correlations for Cedar Creek.

		ANPP	SR	DAY_TEMP	STD_TEMP	DEG_DAY	PRECIP	GS_TEMP	GS_SDTMP	GS_DGDAY	GS_PRCP
ANPP	Pearson Corr.	1	0.882912	-0.4160712	-0.0015853	-0.3075683	0.561262	-0.2918847	0.16454379	-0.22241	0.4317709
	Sig. (2-tailed)	.	0.00161	0.26533968	0.99702752	0.4207421	0.115862	0.445992	0.69700387	0.565174	0.2458488
	N	9	9	9	8	9	9	9	8	9	9
SR	Pearson Corr.	0.882912	1	-0.32752	-0.3511791	-0.5858642	0.610393	-0.6088322	0.08056898	-0.4955647	0.5780801
	Sig. (2-tailed)	0.00161	.	0.3895833	0.39367343	0.0973733	0.080853	0.0818486	0.84958565	0.1749048	0.103013
	N	9	9	9	8	9	9	9	8	9	9
DAY_TEMP	Pearson Corr.	-0.41607	-0.32752	1	-0.3551265	0.4834445	0.013734	0.3811063	-0.2662701	0.314032	0.1266059
	Sig. (2-tailed)	0.26534	0.389583	.	0.38800317	0.1873534	0.972026	0.3115522	0.52383976	0.4105277	0.7455009
	N	9	9	9	8	9	9	9	8	9	9
STD_TEMP	Pearson Corr.	-0.00159	-0.35118	-0.3551265	1	0.618393	-0.241832	0.7114256	0.43028548	0.697221	-0.3809187
	Sig. (2-tailed)	0.997028	0.393673	0.38800317	.	0.1022006	0.563934	0.0478255	0.28726541	0.0545894	0.3518587
	N	8	8	8	8	8	8	8	8	8	8
DEG_DAY	Pearson Corr.	-0.30757	-0.58586	0.48344451	0.61839295	1	-0.26832	0.9804834	0.12514777	0.9211421	-0.0913017
	Sig. (2-tailed)	0.420742	0.097373	0.18735342	0.10220061	.	0.485125	3.355E-06	0.76778649	0.0004195	0.8152889
	N	9	9	9	8	9	9	9	8	9	9
PRECIP	Pearson Corr.	0.561262	0.610393	0.01373374	-0.241832	-0.2683199	1	-0.284164	0.14281157	-0.4293696	0.4968785
	Sig. (2-tailed)	0.115862	0.080853	0.97202624	0.5639336	0.4851249	.	0.4586584	0.73584686	0.2487786	0.1735846
	N	9	9	9	8	9	9	9	8	9	9
GS_TEMP	Pearson Corr.	-0.29188	-0.60883	0.3811063	0.71142559	0.9804834	-0.284164	1	0.21783209	0.8938776	-0.1856054
	Sig. (2-tailed)	0.445992	0.081849	0.31155219	0.0478255	3.355E-06	0.458658	.	0.60430129	0.0011539	0.6325749
	N	9	9	9	8	9	9	9	8	9	9
GS_SDTMP	Pearson Corr.	0.164544	0.080569	-0.2662701	0.43028548	0.1251478	0.142812	0.2178321	1	0.1448883	0.3117444
	Sig. (2-tailed)	0.697004	0.849586	0.52383976	0.28726541	0.7677865	0.735847	0.6043013	.	0.7321124	0.4522461
	N	8	8	8	8	8	8	8	8	8	8
GS_DGDAY	Pearson Corr.	-0.22241	-0.49556	0.31403204	0.69722098	0.9211421	-0.42937	0.8938776	0.14488834	1	0.0537917
	Sig. (2-tailed)	0.565174	0.174905	0.41052772	0.05458939	0.0004195	0.248779	0.0011539	0.73211241	.	0.8906804
	N	9	9	9	8	9	9	9	8	9	9
GS_PRCP	Pearson Corr.	0.431771	0.57808	0.12660593	-0.3809187	-0.0913017	0.496878	-0.1856054	0.31174439	0.0537917	1
	Sig. (2-tailed)	0.245849	0.103013	0.74550088	0.35185867	0.8152889	0.173585	0.6325749	0.45224605	0.8906804	.
	N	9	9	9	8	9	9	9	8	9	9

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 6. Correlations for Jornada.

		ANPP	SR	DAY_TEMP	STD_TEMP	DEG_DAY	PRECIP	GS_TEMP	GS_SDTMP	GS_DGDAY	GS_PRCP
ANPP	Pearson Corr.	1	0.30573	-0.1140374	-0.1279044	0.0840877	0.41719	0.4538156	0.08018731	0.0627217	0.4969774
	Sig. (2-tailed)	.	0.461475	0.78802632	0.76278195	0.8430772	0.303793	0.2587059	0.85029205	0.8827048	0.210232
	N	8	8	8	8	8	8	8	8	8	8
SR	Pearson Corr.	0.30573	1	0.09359867	-0.8445355	-0.0283087	0.095251	0.3443463	-0.5658948	-0.1453656	0.5743643
	Sig. (2-tailed)	0.461475	.	0.82552479	0.0083324	0.9469495	0.822481	0.4035734	0.14371023	0.7312549	0.1364758
	N	8	8	8	8	8	8	8	8	8	8
DAY_TEMP	Pearson Corr.	-0.11404	0.093599	1	-0.3609099	0.9166835	-0.79288	0.7751867	-0.3542982	0.9207488	0.0556548
	Sig. (2-tailed)	0.788026	0.825525	.	0.37976092	0.001357	0.018905	0.0238316	0.38918998	0.0011716	0.8958626
	N	8	8	8	8	8	8	8	8	8	8
STD_TEMP	Pearson Corr.	-0.1279	-0.84454	-0.3609099	1	-0.2343418	0.094283	-0.5493776	0.76358202	-0.1477052	-0.5216173
	Sig. (2-tailed)	0.762782	0.008332	0.37976092	.	0.5764305	0.824264	0.1584139	0.02745487	0.7270545	0.1848918
	N	8	8	8	8	8	8	8	8	8	8
DEG_DAY	Pearson Corr.	0.084088	-0.02831	0.91668349	-0.2343418	1	-0.577357	0.7698228	-0.3794587	0.9731108	0.242103
	Sig. (2-tailed)	0.843077	0.94695	0.00135704	0.57643049	.	0.133969	0.0254669	0.35386209	4.763E-05	0.5634832
	N	8	8	8	8	8	8	8	8	8	8
PRECIP	Pearson Corr.	0.41719	0.095251	-0.79288	0.09428288	-0.5773571	1	-0.4785831	0.13198977	-0.6814048	0.3416358
	Sig. (2-tailed)	0.303793	0.822481	0.01890532	0.82426444	0.1339689	.	0.2302612	0.75537846	0.0627589	0.4075303
	N	8	8	8	8	8	8	8	8	8	8
GS_TEMP	Pearson Corr.	0.453816	0.344346	0.7751867	-0.5493776	0.7698228	-0.478583	1	-0.3670727	0.7882366	0.2890434
	Sig. (2-tailed)	0.258706	0.403573	0.02383159	0.15841391	0.0254669	0.230261	.	0.37106479	0.0201298	0.4874726
	N	8	8	8	8	8	8	8	8	8	8
GS_SDTMP	Pearson Corr.	0.080187	-0.56589	-0.3542982	0.76358202	-0.3794587	0.13199	-0.3670727	1	-0.270271	-0.681078
	Sig. (2-tailed)	0.850292	0.14371	0.38918998	0.02745487	0.3538621	0.755378	0.3710648	.	0.5173791	0.0629349
	N	8	8	8	8	8	8	8	8	8	8
GS_DGDAY	Pearson Corr.	0.062722	-0.14537	0.92074879	-0.1477052	0.9731108	-0.681405	0.7882366	-0.270271	1	0.0964164
	Sig. (2-tailed)	0.882705	0.731255	0.0011716	0.72705448	4.763E-05	0.062759	0.0201298	0.51737906	.	0.8203365
	N	8	8	8	8	8	8	8	8	8	8
GS_PRCP	Pearson Corr.	0.496977	0.574364	0.05565479	-0.5216173	0.242103	0.341636	0.2890434	-0.681078	0.0964164	1
	Sig. (2-tailed)	0.210232	0.136476	0.89586256	0.18489183	0.5634832	0.40753	0.4874726	0.06293489	0.8203365	.
	N	8	8	8	8	8	8	8	8	8	8

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 7. Correlations for KBS.

		ANPP	SR	DAY_TEMP	STD_TEMP	DEG_DAY	PRECIP	GS_TEMP	GS_SDTMP	GS_DGDAY	GS_PRCP
ANPP	Pearson Corr.	1	0.488601	0.18154907	-0.182734	-0.0679964	0.041796	0.0116214	0.1482037	-0.085125	0.0014363
	Sig. (2-tailed)	.	0.107002	0.57228031	0.56973242	0.8336924	0.897383	0.9714055	0.64575213	0.7925235	0.9964653
	N	12	12	12	12	12	12	12	12	12	12
SR	Pearson Corr.	0.488601	1	-0.3177111	0.28090048	-0.28168	-0.595478	-0.0080788	0.11893424	-0.1002211	-0.1115788
	Sig. (2-tailed)	0.107002	.	0.31425297	0.37647505	0.3750956	0.041062	0.9801203	0.71276072	0.7566355	0.7299188
	N	12	12	12	12	12	12	12	12	12	12
DAY_TEMP	Pearson Corr.	0.181549	-0.31771	1	-0.2823761	0.7333983	0.22827	0.626157	-0.4881036	0.5885254	-0.1315875
	Sig. (2-tailed)	0.57228	0.314253	.	0.37386592	0.0066403	0.475485	0.0293856	0.10741399	0.0441074	0.6835321
	N	12	12	12	12	12	12	12	12	12	12
STD_TEMP	Pearson Corr.	-0.18273	0.2809	-0.2823761	1	0.3782902	-0.12406	0.4757635	0.13601325	0.5054289	0.4520088
	Sig. (2-tailed)	0.569732	0.376475	0.37386592	.	0.225319	0.700874	0.1179651	0.67339989	0.0936884	0.1401458
	N	12	12	12	12	12	12	12	12	12	12
DEG_DAY	Pearson Corr.	-0.068	-0.28168	0.73339826	0.37829015	1	0.140954	0.8842233	-0.2144438	0.9021779	0.0915431
	Sig. (2-tailed)	0.833692	0.375096	0.00664032	0.22531898	.	0.662147	0.0001345	0.50331491	5.974E-05	0.7772164
	N	12	12	12	12	12	12	12	12	12	12
PRECIP	Pearson Corr.	0.041796	-0.59548	0.22827004	-0.1240604	0.140954	1	-0.0420139	-0.2409707	-0.0745827	0.728116
	Sig. (2-tailed)	0.897383	0.041062	0.47548521	0.7008742	0.6621473	.	0.8968495	0.45056495	0.8178112	0.0072534
	N	12	12	12	12	12	12	12	12	12	12
GS_TEMP	Pearson Corr.	0.011621	-0.00808	0.62615697	0.47576351	0.8842233	-0.042014	1	-0.3170083	0.9808388	0.0322116
	Sig. (2-tailed)	0.971406	0.98012	0.02938565	0.1179651	0.0001345	0.896849	.	0.31538402	1.97E-08	0.9208388
	N	12	12	12	12	12	12	12	12	12	12
GS_SDTMP	Pearson Corr.	0.148204	0.118934	-0.4881036	0.13601325	-0.2144438	-0.240971	-0.3170083	1	-0.2237009	-0.1148895
	Sig. (2-tailed)	0.645752	0.712761	0.10741399	0.67339989	0.5033149	0.450565	0.315384	.	0.4846027	0.7221814
	N	12	12	12	12	12	12	12	12	12	12
GS_DGDAY	Pearson Corr.	-0.08513	-0.10022	0.58852536	0.50542886	0.9021779	-0.074583	0.9808388	-0.2237009	1	-0.0075547
	Sig. (2-tailed)	0.792523	0.756635	0.04410742	0.09368838	5.974E-05	0.817811	1.97E-08	0.4846027	.	0.9814097
	N	12	12	12	12	12	12	12	12	12	12
GS_PRCP	Pearson Corr.	0.001436	-0.11158	-0.1315875	0.45200881	0.0915431	0.728116	0.0322116	-0.1148895	-0.0075547	1
	Sig. (2-tailed)	0.996465	0.729919	0.68353215	0.14014576	0.7772164	0.007253	0.9208388	0.72218144	0.9814097	.
	N	12	12	12	12	12	12	12	12	12	12

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 8. Correlations for Konza.

		ANPP	SR	DAY_TEMP	STD_TEMP	DG_DAY	PRECIP	GS_TEMP	GS_SDTMP	GS_DGDAY	GS_PRCP
ANPP	Pearson Corr.	1	0.012771	-0.2026094	-0.1426344	0.0010165	0.60499	-0.1317459	0.24782634	-0.1762351	0.613184
	Sig. (2-tailed)	.	0.952773	0.34237169	0.50613166	0.996239	0.001736	0.5394468	0.2429644	0.4100764	0.001442
	N	24	24	24	24	24	24	24	24	24	24
SR	Pearson Corr.	0.012771	1	-0.7353997	-0.8273563	-0.7664646	-0.164525	-0.8202095	0.11815294	-0.8127612	0.2332272
	Sig. (2-tailed)	0.952773	.	4.2352E-05	6.1491E-07	1.257E-05	0.442349	9.273E-07	0.58241474	1.397E-06	0.2727316
	N	24	24	24	24	24	24	24	24	24	24
DAY_TEMP	Pearson Corr.	-0.20261	-0.7354	1	0.37993249	0.8421443	-0.270245	0.7869064	-0.1672437	0.8027585	-0.5050294
	Sig. (2-tailed)	0.342372	4.24E-05	.	0.06705814	2.47E-07	0.201541	5.09E-06	0.43473754	2.355E-06	0.011832
	N	24	24	24	24	24	24	24	24	24	24
STD_TEMP	Pearson Corr.	-0.14263	-0.82736	0.37993249	1	0.5533072	0.070751	0.7514223	-0.4233613	0.7427462	-0.2921019
	Sig. (2-tailed)	0.506132	6.15E-07	0.06705814	.	0.0050376	0.742521	2.313E-05	0.03926394	3.227E-05	0.1660416
	N	24	24	24	24	24	24	24	24	24	24
DG_DAY	Pearson Corr.	0.001016	-0.76646	0.84214434	0.5533072	1	0.005086	0.9489682	-0.4567587	0.9243023	-0.2465361
	Sig. (2-tailed)	0.996239	1.26E-05	2.4699E-07	0.00503764	.	0.981183	1.662E-12	0.02484909	1.132E-10	0.2455059
	N	24	24	24	24	24	24	24	24	24	24
PRECIP	Pearson Corr.	0.60499	-0.16452	-0.2702453	0.07075112	0.0050859	1	-0.1033204	0.37543303	-0.1378326	0.911251
	Sig. (2-tailed)	0.001736	0.442349	0.20154122	0.74252075	0.9811832	.	0.6309198	0.07063092	0.5206985	6.121E-10
	N	24	24	24	24	24	24	24	24	24	24
GS_TEMP	Pearson Corr.	-0.13175	-0.82021	0.78690641	0.75142226	0.9489682	-0.10332	1	-0.6010201	0.9900692	-0.38996
	Sig. (2-tailed)	0.539447	9.27E-07	5.0901E-06	2.3134E-05	1.662E-12	0.63092	.	0.00189629	3.049E-20	0.0595943
	N	24	24	24	24	24	24	24	24	24	24
GS_SDTMP	Pearson Corr.	0.247826	0.118153	-0.1672437	-0.4233613	-0.4567587	0.375433	-0.6010201	1	-0.6117032	0.3715032
	Sig. (2-tailed)	0.242964	0.582415	0.43473754	0.03926394	0.0248491	0.070631	0.0018963	.	0.0014918	0.0738685
	N	24	24	24	24	24	24	24	24	24	24
GS_DGDAY	Pearson Corr.	-0.17624	-0.81276	0.80275853	0.74274617	0.9243023	-0.137833	0.9900692	-0.6117032	1	-0.4117922
	Sig. (2-tailed)	0.410076	1.4E-06	2.355E-06	3.227E-05	1.132E-10	0.520699	3.049E-20	0.00149177	.	0.0455668
	N	24	24	24	24	24	24	24	24	24	24
GS_PRCP	Pearson Corr.	0.613184	0.233227	-0.5050294	-0.2921019	-0.2465361	0.911251	-0.38996	0.37150325	-0.4117922	1
	Sig. (2-tailed)	0.001442	0.272732	0.01183201	0.16604163	0.2455059	6.12E-10	0.0595943	0.07386847	0.0455668	.
	N	24	24	24	24	24	24	24	24	24	24

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 9. Correlations for Short Grass Steppe

		ANPP	SR	DAY_TEMP	STD_TEMP	DEG_DAY	PRECIP	GS_TEMP	GS_SDTMP	GS_DGDAY	GS_PRCP
MEANANPP	Pearson Corr.	1	0.40744	0.12745747	-0.1104792	0.2501863	0.202502	-0.0506273	0.18165865	0.0753654	0.3650163
	Sig. (2-tailed)	.	0.117247	0.63806918	0.68377281	0.3500207	0.451962	0.8522876	0.50073834	0.7814716	0.164482
	N	16	16	16	16	16	16	16	16	16	16
SR	Pearson Corr.	0.40744	1	0.05087289	0.06803419	-0.0550562	0.5365	0.0229403	0.55546342	-0.1610818	0.6328339
	Sig. (2-tailed)	0.117247	.	0.85157853	0.80231599	0.8395157	0.032152	0.9327957	0.02549618	0.5511925	0.0085119
	N	16	16	16	16	16	16	16	16	16	16
DAY_TEMP	Pearson Corr.	0.127457	0.050873	1	0.88215905	0.9514546	0.628555	0.9572342	0.54755228	0.9422321	0.4170433
	Sig. (2-tailed)	0.638069	0.851579	.	6.163E-06	1.498E-08	0.00911	6.264E-09	0.02813017	4.938E-08	0.1080357
	N	16	16	16	16	16	16	16	16	16	16
STD_TEMP	Pearson Corr.	-0.11048	0.068034	0.88215905	1	0.7981464	0.710595	0.9689228	0.61436351	0.8355048	0.4803684
	Sig. (2-tailed)	0.683773	0.802316	6.163E-06	.	0.0002107	0.002034	6.915E-10	0.01133781	5.59E-05	0.0596559
	N	16	16	16	16	16	16	16	16	16	16
DEG_DAY	Pearson Corr.	0.250186	-0.05506	0.95145461	0.79814642	1	0.519544	0.8839537	0.46423705	0.9756757	0.3155272
	Sig. (2-tailed)	0.350021	0.839516	1.4979E-08	0.0002107	.	0.039153	5.563E-06	0.07006361	1.267E-10	0.2338723
	N	16	16	16	16	16	16	16	16	16	16
PRECIP	Pearson Corr.	0.202502	0.5365	0.62855539	0.71059503	0.5195436	1	0.6831673	0.62379458	0.5178967	0.8847661
	Sig. (2-tailed)	0.451962	0.032152	0.00911049	0.00203403	0.0391527	.	0.0035327	0.00981517	0.0398892	5.308E-06
	N	16	16	16	16	16	16	16	16	16	16
GS_TEMP	Pearson Corr.	-0.05063	0.02294	0.95723422	0.96892278	0.8839537	0.683167	1	0.56922416	0.917315	0.4478162
	Sig. (2-tailed)	0.852288	0.932796	6.2637E-09	6.9148E-10	5.563E-06	0.003533	.	0.02136976	5.681E-07	0.0819555
	N	16	16	16	16	16	16	16	16	16	16
GS_SDTMP	Pearson Corr.	0.181659	0.555463	0.54755228	0.61436351	0.464237	0.623795	0.5692242	1	0.4257808	0.540807
	Sig. (2-tailed)	0.500738	0.025496	0.02813017	0.01133781	0.0700636	0.009815	0.0213698	.	0.100107	0.0305359
	N	16	16	16	16	16	16	16	16	16	16
GS_DGDAY	Pearson Corr.	0.075365	-0.16108	0.94223211	0.83550478	0.9756757	0.517897	0.917315	0.42578078	1	0.2821531
	Sig. (2-tailed)	0.781472	0.551193	4.9375E-08	5.5902E-05	1.267E-10	0.039889	5.681E-07	0.10010701	.	0.289706
	N	16	16	16	16	16	16	16	16	16	16
GS_PRCP	Pearson Corr.	0.365016	0.632834	0.41704332	0.48036841	0.3155272	0.884766	0.4478162	0.54080704	0.2821531	1
	Sig. (2-tailed)	0.164482	0.008512	0.10803568	0.05965592	0.2338723	5.31E-06	0.0819555	0.0305359	0.289706	.
	N	16	16	16	16	16	16	16	16	16	16

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).