Autecology of Purple Coneflower on the Northern Mixed Grass Prairie

Llewellyn L. Manske PhD
Research Professor of Range Science
North Dakota State University
Dickinson Research Extension Center
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The autecology of Purple Coneflower, *Echinacea angustifolia*, is one of the prairie plant species included in a long ecological study conducted at the NDSU Dickinson Research Extension Center during 67 growing seasons from 1946 to 2012 that quantitatively describes the changes in growth and development during the annual growing season life history and the changes in abundance through time as affected by management treatments for the intended purpose of the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains. The introduction to this study can be found in report DREC 16-1093 (Manske 2016).

Purple Coneflower, *Echinacea angustifolia* DC., is a member of the aster (sunflower) family, Asteraceae, syn.: *Brauneria angustifolia* (DC) Heller, and is a native, perennial, warm season, dicot, herb. The first North Dakota record is Stevens 1940. Early aerial growth consists of a rosette of basal petioled leaves 5-30 cm (2.0-11.8 in) long, 1-4 cm (0.4-1.6 in) wide with blade narrowly elliptic to lanceolate or oblong arising from a perennating crown (caudex). Annual aerial growth has one to a few erect stiff stems 30-60 cm (11.8-23.6 in) tall. Stem (cauline) leaves are few, alternate, sessile, 5-20 cm (2.0-7.9 in) long, that are progressively smaller upward with blades elongated lanceolate. Short, stiff hairs cover stem and leaves. The root system has a thick, black, woody taproot that can descend vertically from the crown to 1.5-2 m (4.7-6.5 ft) deep with a few branches at lower depths. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the subterranian crown and there is evidence that sprouts can develop from buds on the taproot. Inflorescence is a terminal solitary head on a nearly bare stem 5-8 cm (2.0-3.1 in) wide. Flowers are perfect, ray florets are rose to light purple appearing during mid June to late July. Pollination is by insects. Fruit is a yellowish white achene with no pappus. The dark prickly cone of the flower head remains on the stem dispersing seed gradually from early fall to early summer. Aerial stems are rarely eaten by livestock or wildlife. Fire top kills aerial parts. Sprouts develop from surviving crown and taproot following defoliation by grazing, fire, or harvest. This summary information on growth development and regeneration of Purple coneflower was based on the works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Groen 2005, Stevens 2006, and Johnson and Larson 2007.

Procedures

The 1955-1962 Study

Purple Coneflower plant growth in height was determined by measuring ungrazed stems from ground level to top of leaf or to the tip of the inflorescence of an average of 10 plants of each species at approximately 7 to 10 day intervals during the growing seasons of 1955 to 1962 from early May until early September. Dates of first flower (anthesis) were recorded as observed. These growth in height and flower data were reported in Goetz 1963.

The 1969-1971 Study

The range of flowering time of Purple Coneflower was determined by recording daily observations of plants at anthesis on several prairie habitat type collection locations distributed throughout 4,569 square miles of southwestern North Dakota. The daily observed flowering plant data collected during the growing seasons of 1969 to 1971 from April to August were reported as flower sample periods with 7 to 8 day duration in Zaczkowski 1972.

The 1984-1985 Study

Purple Coneflower plant growth in height was determined by measuring stems from ground level to top of stem or leaf or to the tip of the inflorescence of 12 ungrazed specimens randomly selected on each of the three replications of grazed sandy, shallow, silty, and clayey ecological sites biweekly during June, July, and August of the growing seasons of 1984 and 1985. Phenological growth stage of each specimen was recorded as vegetative, budding, anthesis, seed developing, seed shedding, or mature. Percentage of stem dryness of each specimen was recorded as 0, 0-2, 2-25, 25-50, 50-75, 75-98, or 100 percent dry. Mean stem weight

was determined by clipping at ground level 25 specimens at typical phenological growth stages at biweekly sample dates on separate grazed areas of the sandy, shallow, silty, and clayey ecological sites. Clipped stems at each sample site were placed in separate labeled paper bags of known weight, oven dried at 62° C (144° F), and weighed in grams.

The 1983-2012 Study

A long-term study on change in abundance of Purple Coneflower was conducted during active plant growth of July and August each growing season of 1983 to 2012 (30 years) on native rangeland pastures at the Dickinson Research Extension Center ranch located near Manning, North Dakota. Effects from three management treatments were evaluated: 1) long-term nongrazing, 2) traditional seasonlong grazing, and 3) twice-over rotation grazing. Each treatment had two replications, each with data collection sites on sandy, shallow, and silty ecological sites. Each ecological site of the two grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure. The sandy, shallow, and silty ecological sites were each replicated two times on the nongrazed treatment, three times on the seasonlong treatment, and six times on the twice-over treatment.

During the initial phase of this study, 1983 to 1986, the long-term nongrazed and seasonlong treatments were at different locations and moved to the permanent study locations in 1987. The data collected on those two treatments during 1983 to 1986 were not included in this report.

Abundance of Purple Coneflower was determined with plant species stem density by 0.1 m^2 frame density method and with plant species basal cover by the ten-pin point frame method (Cook and Stubbendieck 1986).

The stem density method was used to count individual stems of each plant species rooted inside twenty five 0.1 m^2 quadrats placed along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure. Stem density per 0.1 m^2 quadrat, relative stem density, percent frequency, relative percent frequency, and importance value were determined from the stem density data. Plant species stem density data collection was 1984, 1986 to 2012 on the twice-over treatment and was 1987 to 2012 on the long-term nongrazed and seasonlong treatments. However, stem density data was not collected during 1991, 1993 to 1997 on the sandy, shallow, and silty ecological sites of all three management treatments, stem density data was not collected during 1992 on the sandy ecological site of all three management treatments, and stem density data was not collected during 1999 on the sandy and silty ecological sites of the long-term nongrazed treatment.

The point frame method was used to collect data at 2000 points along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure. Basal cover, relative basal cover, percent frequency, relative percent frequency, and importance value were determined from the ten-pin point frame data. Point frame data collection period was 1983 to 2012 on the twice-over treatment and was 1987 to 2012 on the long-term nongrazed and seasonlong treatments. However, point frame data was not collected during 1992 on the sandy ecological sites of all three treatments.

During some growing seasons, the point frame method or the stem density method did not document the presence of a particular plant species which will be reflected in the data summary tables as an 0.00 or as a blank spot.

The 1983-2012 study attempted to quantify the increasing or decreasing changes in individual plant species abundance during 30 growing seasons by comparing differences in the importance values of individual species during multiple year periods. Importance value is an old technique that combines relative density or relative basal cover with relative frequency producing a scale of 0 to 200 that ranks individual species abundance within a plant community relative to the individual abundance of the other species in that community during a growing season. Density importance value ranks the forbs and shrubs and basal cover importance value ranks the grasses, upland sedges, forbs, and shrubs in a community. The quantity of change in the importance values of an individual species across time indicates the magnitude of the increases or decreases in abundance of that species relative to the changes in abundance of the other species.

Results

Purple coneflower resumed growth in spring as rosettes of petioled basal leaves arising from a perennating crown (caudex). One or a few erect stiff stems develop from the crown. A single composite head develops atop each stem. On the fall grazed pasture of the 1955-1962 study, the earliest first flowers appeared 18 June, the mean first flowers occurred on 25 June, and the flower period, from the

1969-1971 study, extended from mid June through the third week in July (table 1) (Goetz 1963, Zaczkowski 1972). A mean mature stem height of 30.0 cm (11.8 in) with an annual variance in height from 26.0 cm (10.2 in) to 35.0 cm (13.8 in) was reached during July (table 2) (Goetz 1963). The reported normal mature stem height in the Northern Plains ranged from 30 cm to 60 cm (11.8-23.6 in) tall, the mean mature stem height of 30.0 cm (11.8 in) was at the short end of the range of normal height. The lower heights of Purple coneflower on the 1955-1962 study was not caused directly by grazing effects but was caused by low quantities of available mineral nitrogen below the threshold levels of 100 lbs/ac in the soil as a result of detrimental effects from traditional management practices.

Changes in phenological growth stages from the 1984-1985 study are summarized on tables 3, 4, 5, and 6. A total of 3,128 Purple coneflower stems were sampled during this study with, 919 stems (29.38%) from the sandy sites, 943 stems (30.15%) from the shallow sites, 793 stems (25.35%) from the silty sites, and 473 stems (15.12%) from the clayey sites. Purple coneflower can grow on the sandy, shallow, silty, and clayey ecological sites, but it appears to grow better on the shallow and sandy sites, and grow poorly on the clayey sites. The mean mature stem height reached during July and the percent of the reported low normal height of 30.0 cm (11.8 in) was, 26.1 cm (87.1%) on the sandy sites, 22.2 cm (74.0%) on the shallow sites, 24.2 cm (80.7%) on the silty sites, and 25.1 cm (83.5%) on the clayey sites. The mean mature stem heights for Purple coneflower during July on each of the four ecological sites were all shorter than the reported low normal stem height. The reduced stem height of Purple coneflower on the 1984-1985 study was caused by low available mineral nitrogen below the threshold quantities of 100 lbs/ac that resulted from the traditional management practices conducted prior to the start of this study.

During the growing season, most of the Purple coneflower stems remained at early growth stages of vegetative and budding stages with, 60.2% on the sandy sites, 73.9% on the shallow sites, 73.2% on the silty sites, and 67.4% on the clayey sites (tables 3, 4, 5, and 6). A few stems were at the anthesis (flower) stage during late July and early August on all four ecological sites.

Mean Purple coneflower stem weights were not significantly different on the four ecological sites. Stem weights were heaviest on the sandy site at 1.83 g, and were lighter on the shallow sites at 1.11 g, on the silty sites at 1.06 g, and on the clayey sites at 1.03 g (tables 3, 4, 5, and 6).

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes in individual plant species abundance was followed for 30 growing seasons during the 1983-2012 study. The number of documented Purple coneflower plants on the silty ecological sites of the three management treatments was insufficient to describe the changes in abundance patterns and were not included in this report.

On the sandy site of the nongrazed treatment, Purple coneflower was present during 83.3% and 56.0% of the years that density and basal cover data were collected, with a mean 0.57 stems/m^2 density and a mean 0.06% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present during 100.0% and 80.0% of the years, with a mean 1.30 stems/m^2 density and a mean 0.16% basal cover. During the later period (1998-2012), Purple coneflower was present during 78.6% and 60.0% of the years, with a mean 0.36 stems/m^2 density and a mean 0.03% basal cover, respectively. Both the stem density and basal cover decreased on the sandy sites of the nongrazed treatment over time (tables 7, 8, and 9).

On the sandy sites of the seasonlong treatment, Purple coneflower was present on the ungrazed sandy site during 47.4% and 23.1% of the years, with a mean 0.29 stems/m^2 density and a mean 0.04% basal cover, and was present on the grazed sandy site during 42.1% and 40.0% of the years that density and basal cover data were collected, with a mean 0.25 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present on the ungrazed sandy site during 100.0% and 80.0% of the years, with a mean 0.80 stems/m^2 density and a mean 0.09% basal cover. During the later period (1998-2012), Purple coneflower was present on the ungrazed sandy site during 60.0% and 40.0% of the years, with a mean 0.15 stems/m^2 density and a mean 0.02% basal cover, respectively. Both the stem density and basal cover decreased on the ungrazed sandy site of the seasonlong treatment over time. During the early period (1983-1992), Purple coneflower was present on the grazed sandy site during 100.0% and 80.0% of the years, with a mean 0.80 stems/m^2 density and a mean 0.09% basal cover. During the later period (1998-2012), Purple coneflower was present on the

grazed sandy site during 26.7% and 26.7% of the years, with a mean 0.10 stems/m^2 density and a mean 0.006% basal cover, respectively. Both the stem density and basal cover decreased on the grazed sandy site of the seasonlong treatment over time. During the early period (1983-1992), stem density and basal cover of Purple coneflower were similar on the ungrazed and grazed sandy sites; stem density and basal cover decreased during 1988 but recovered rapidly. During the later period (1998-2012), stem density and basal cover of Purple coneflower decreased on both the ungrazed and grazed sandy sites. The decrease was greater on the grazed sandy site, resulting in slightly greater stem density and basal cover values on the ungrazed sandy site of the seasonlong treatment (tables 7, 8, and 9).

On the sandy sites of the twice-over treatment, Purple coneflower was present on the ungrazed sandy site during 81.0% and 58.6% of the years, with a mean 0.16 stems/m^2 density and a mean 0.04% basal cover, and was present on the grazed sandy site during 95.2% and 65.5% of the years that density and basal cover data were collected, with a mean 0.40 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present on the ungrazed sandy site during 100.0% and 75.0% of the years, with a mean 0.32 stems/m^2 density and a mean 0.08% basal cover. During the later period (1998-2012), Purple coneflower was present on the ungrazed sandy site during 73.3% and 46.7% of the years, with a mean 0.10 stems/m^2 density and a mean 0.008% basal cover, respectively. Both stem density and basal cover decreased on the ungrazed sandy site of the twice-over treatments over time. During the early period (1983-1992), Purple coneflower was present on the grazed sandy site during 100.0% and 88.9% of the years, with a mean 0.78 stems/m^2 density and a mean 0.07% basal cover. During the later period (1998-2012), Purple coneflower was present on the grazed sandy site during 93.3% and 53.3% of the years, with a mean 0.25 stems/m^2 density and a mean 0.011% basal cover, respectively. Both the stem density and basal cover decreased on the grazed sandy site of the twice-over treatment over time. Stem density and basal cover increased during the low precipitation period of 1988 to 1992 on both the ungrazed and grazed sandy sites. During the early period (1983-1992), Purple coneflower stem density was greater on the grazed site than that on the ungrazed sandy site and basal cover was slightly higher on the ungrazed site than that on the grazed sandy site. When growing season precipitation returned to normal after 1992, stem density and basal cover of Purple coneflower decreased on both the ungrazed and grazed sandy sites of the twice-over treatment (tables 7, 8, and 9).

During the 30 year period of the 1983-2012 study, on the sandy sites, the greatest stem density of 0.57 stems/m^2 and the greatest basal cover of 0.06% were on the nongrazed treatment.

On the shallow site of the nongrazed treatment, Purple coneflower was present during 36.8% and 50.0% of the years that density and basal cover data were collected, with a mean 0.24 stems/m^2 density and a mean 0.06% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present during 20.0% and 50.0% of the years, with a mean 0.20 stems/m^2 density and a mean 0.16% basal cover. During the later period (1998-2012), Purple coneflower was present during 42.9% and 46.7% of the years, with a mean 0.26 stems/m^2 density and a mean 0.02% basal cover, respectively. Stem density increased slightly and basal cover decreased on the shallow sites of the nongrazed treatment over time (tables 7, 8, and 9).

On the shallow sites of the seasonlong treatment, Purple coneflower was present on the ungrazed shallow site during 30.0% and 7.7% of the years, with a mean 0.25 stems/m^2 density and a mean 0.01% basal cover, and was present on the grazed shallow site during 55.0% and 30.8% of the years that density and basal cover data were collected, with a mean 0.27 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present on the ungrazed shallow site during 80.0% and 16.7 % of the years, with a mean 0.62 stems/m^2 density and a mean 0.06% basal cover. During the later period (1998-2012), Purple coneflower was present on the ungrazed shallow site during 40.0% and 6.7% of the years, with a mean 0.13 stems/m^2 density and a mean 0.002% basal cover, respectively. Both the stem density and basal cover decreased on the ungrazed shallow site of the seasonlong treatment over time. During the early period (1983-1992), Purple coneflower was present on the grazed shallow site during 80.0% and 66.7% of the years, with a mean 0.62 stems/m^2 density and a mean 0.04% basal cover. During the later period (1998-2012), Purple coneflower was present on the grazed shallow site during 46.7% and 13.3% of the years, with a mean 0.15 stems/m^2 density and a mean 0.003% basal cover, respectively. Both the stem density and basal cover decreased on the grazed shallow site of the seasonlong treatment over time.

During the 1983-2012 study, stem density and basal cover were similar on the ungrazed and grazed shallow sites, with slightly more stem density and basal cover on the grazed shallow site of the seasonlong treatment (tables 7, 8, and 9).

On the shallow sites of the twice-over treatment, Purple coneflower was present on the ungrazed shallow site during 100.0% and 89.7% of the years, with a mean 1.13 stems/m^2 density and a mean 0.10% basal cover, and was present on the grazed shallow site during 100.0% and 86.7% of the years that density and basal cover data were collected, with a mean 0.72 stems/m^2 density and a mean 0.06% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Purple coneflower was present on the ungrazed shallow site during 100.0% and 77.8% of the years, with a mean 1.44 stems/m^2 density and a mean 0.16% basal cover. During the later period (1998-2012), Purple coneflower was present on the ungrazed shallow site during 100.0% and 93.3% of the years, with a mean 0.94 stems/m^2 density and a mean 0.05% basal cover, respectively. Both stem density and basal cover decreased on the ungrazed shallow site of the twice-over treatments over time. During the early period (1983-1992), Purple coneflower was present on the grazed shallow site during 100.0% and 90.0% of the years, with a mean 0.70 stems/m^2 density and a mean 0.12% basal cover. During the later period (1998-2012), Purple coneflower was present on the grazed shallow site during 100.0% and 93.3% of the years, with a mean 0.73 stems/m^2 density and a mean 0.03% basal cover, respectively. Stem density increased slightly and basal cover decreased on the grazed shallow site of the twice-over treatment over time. Stem density and basal cover during the early period and the later period were greater on the ungrazed shallow site than those on the grazed shallow site of the twice-over treatment (tables 7, 8, and 9).

During the 30 year period of the 1983-2012 study, on the shallow sites, the greatest stem density of 1.13 stems/m^2 and the greatest basal cover of 0.10% were on the ungrazed site of the twice-over treatment.

The stem abundance of Purple coneflower followed a similar pattern on the sandy and shallow sites of the three management treatments. Stem abundance was relatively high during the years before 1988. Stem abundance greatly increased during the low precipitation period of 1988 to 1991, then it decreased to relatively high levels until 1995. The stem abundance was relatively low during 1998 to 2012. Purple coneflower has a hefty taproot than can descend down to 2 m (6.5 ft) deep permitting plants to survive and increase during the low precipitation period of 1988 to 1992. As grass plant density recovered and increased after growing season precipitation returned to normal, Purple coneflower stem abundance reached an equilibrium level with the quantity of available soil resources of water and essential elements and the competition for those resources from the grass plant population.

Discussion

Purple coneflower, *Echinacea angustifolia*, is a late succession forb that is commonly present on healthy mixed grass prairie plant communities. Purple coneflower can grow on sandy, shallow, silty, and clayey ecological sites, however, it grew better on the shallow and sandy sites, it did not grow well on the silty sites, and it grew poorly on the clayey ecological sites. Annual aerial growth resumed in spring from crowns (caudexes) atop a deep hefty taproot as a rosette of basal petioled leaves. Stiff erect stems arise from the rosette and produce a single terminal head with a first flower date on 18 June (1955-1962 study), with a five week flower period from mid June to third week in July (1969-1971 study), and with a seven week flower period from mid June to early August (1984-1985 study). Erect aerial stems reached maximum mature height during July. The mean mature stem heights collected during the 1955-1962 study were 30.0 cm tall and during the 1984-1985 study were 24.4 cm tall. These collected mean stem heights were at the short end of the reported normal mature stem height of 30-60 cm because the soils of both studies had mineral nitrogen available at less than the threshold quantity of 100 lbs/ac which resulted from the detrimental effects caused by the traditional management practices on the ecosystem biogeochemical processes and soil microorganism biomass of the prairie plant communities. During the 1984-1985 study, only about 32% of the plants measured that were growing on grazed prairie developed to the anthesis and mature phenological growth stages. Purple coneflower stems are not eaten by livestock and thus the effects from partial defoliation by grazing do not directly cause annual changes in stem abundance. The hefty taproot can descend deeply into the soil giving access to soil water and essential elements that most forbs cannot reach, however, the limited length of the lateral roots restricts the volume of soil that can be explored. Stem abundance depends on the level of available soil water and nutrients and the degree of competition for those resources.

Table 1. First flower and flower period of Echinacea augustifolia, Purple coneflower.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest			18			
Mean			25			
Flower Period						
1969-1971			XX	XX X		

First Flower data from Goetz 1963.
Flower Period Data from Zaczkowski 1972.

Table 2. Autecology of Echinacea augustifolia, Purple coneflower, with growing season changes in mature height.

				Percent of Mature Height Attained					
Data Period	Minimum Annual Mature Height cm	Maximum Annual Mature Height cm	Mean Mature Height cm	Apr %	May %	Jun %	Jul %	Aug %	Sep %
1955-1962	26.0	35.0	30.0		24.4	63.7	100.0		

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for, Echinacea augustifolia, Purple coneflower, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	72.7	52.1	53.5	41.8	45.0	47.2
Bud	27.3	39.7	17.6	4.3		
Anth		8.2	16.4	9.9	1.5	
Seed Dev			12.6	31.2	26.0	8.1
Seed Shed				12.8	23.7	42.3
Mat					3.8	2.4
Mean Height (cm)						
Veg	9.5	5.0	5.3	8.2	8.6	8.1
Bud	13.8	17.9	16.3	19.1		
Anth		7.3	25.9	32.5	26.2	
Seed Dev			23.9	26.6	27.4	26.5
Seed Shed				21.7	23.9	27.2
Mat					28.1	18.8
% Dryness						
Veg	1.8	4.4	11.3	24.7	27.6	34.9
Bud	3.7	7.1	7.5	13.8		
Anth		7.3	7.2	21.0	13.5	
Seed Dev			18.2	29.4	30.4	39.8
Seed Shed				58.0	49.1	52.8
Mat					55.0	41.7
Mean Weight (g)	0.58	2.10	2.21	1.74	2.50	1.86

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 4. Phenological growth stage changes during the growing season for, Echinacea augustifolia, Purple coneflower, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	96.1	73.3	70.7	61.0	65.0	60.3
Bud	3.9	25.5	10.2	3.3		
Anth			14.3	9.1	0.7	
Seed Dev		1.2	3.4	20.1	22.6	2.2
Seed Shed			1.4	5.8	10.9	35.3
Mat				0.6	0.7	2.2
Mean Height (cm)						
Veg	6.7	4.2	4.7	6.5	6.8	6.8
Bud	9.0	14.3	15.1	20.2		
Anth			22.7	21.3	21.2	
Seed Dev		24.6	19.7	21.1	22.6	21.6
Seed Shed			26.2	16.6	21.5	22.1
Mat				15.6	18.1	17.3
% Dryness						
Veg	3.0	3.0	21.6	30.8	34.8	37.2
Bud	12.5	4.1	8.1	11.2		
Anth			9.9	18.0	25.0	
Seed Dev		1.0	50.0	28.3	38.8	20.8
Seed Shed			62.5	55.3	49.7	59.5
Mat				25.0	50.0	33.3
Mean Weight (g)	0.55	0.41	1.40	1.88	1.51	0.91

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 5. Phenological growth stage changes during the growing season for, Echinacea augustifolia, Purple coneflower, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	72.2	71.8	56.0	58.5	61.6	57.3
Bud	27.8	27.3	22.6	5.7	5.1	
Anth		0.9	12.5	13.8	1.0	
Seed Dev			8.9	18.7	14.1	5.5
Seed Shed				3.3	18.2	33.6
Mat						3.6
Mean Height (cm)						
Veg	5.6	4.7	6.3	7.8	8.6	6.9
Bud	14.9	17.8	16.1	20.7	28.6	
Anth		23.1	26.6	27.5	22.1	
Seed Dev			21.5	26.0	24.3	32.3
Seed Shed				19.5	21.2	22.8
Mat						23.4
% Dryness						
Veg	0.7	9.1	25.6	28.3	34.3	32.6
Bud	2.3	5.4	14.1	4.4	40.0	
Anth		2.0	5.0	12.7	2.0	
Seed Dev			33.6	35.0	41.1	62.5
Seed Shed				74.5	59.7	58.9
Mat						50.0
Mean Weight (g)	0.42	0.10	1.49	1.16	1.77	1.44

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 6. Phenological growth stage changes during the growing season for, Echinacea augustifolia, Purple coneflower, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	88.6	69.6	61.0	47.1	50.0	53.4
Bud	11.4	30.4	19.5	4.3	1.7	
Anth			11.7	22.9	1.7	
Seed Dev			7.8	22.9	26.7	8.6
Seed Shed				2.9	16.7	37.9
Mat					3.3	
Mean Height (cm)						
Veg	6.8	5.3	5.5	6.1	8.2	7.3
Bud	11.4	12.3	17.1	28.0	10.1	
Anth			25.6	31.6	13.1	
Seed Dev			14.4	28.4	29.7	22.5
Seed Shed				25.3	25.1	28.9
Mat					22.4	
% Dryness						
Veg	2.2	1.3	15.0	23.1	38.0	31.7
Bud	0.5	10.6	2.6	9.7	25.0	
Anth			6.4	9.1	2.0	
Seed Dev			29.2	24.0	43.8	40.0
Seed Shed				50.0	44.8	60.0
Mat					98.0	
Mean Weight (g)	0.28	0.33	1.39	1.78	1.90	0.49

Phenological Growth Stages: Vegetative (Veg), Budding (Bud), Anthesis (Anth), Seed Developing (Seed Dev), Seed Shedding (Seed Shed), Mature (Mat).

Table 7. Autecology of Echinacea angustifolia, Purple coneflower, with growing season changes in density importance value, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	7.98	0.00	10.50	1.39	4.35
1988-1992	11.92	0.00	4.78	5.25	6.98
1993-1998	2.55	0.00	2.27	0.00	2.01
1999-2003	1.39	0.21	1.00	0.87	1.59
2004-2009	2.03	0.94	0.00	0.65	0.88
2010-2012	1.22	1.54	0.00	0.53	1.63
Shallow					
1983-1987	0.00	0.00	3.76	7.22	4.15
1988-1992	1.22	0.00	7.00	12.96	5.83
1993-1998	0.00	0.00	0.00	4.27	2.70
1999-2003	1.09	0.15	2.38	4.13	2.25
2004-2009	2.36	0.62	0.68	2.67	2.01
2010-2012	0.67	1.29	0.00	4.25	4.44
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 8. Autecology of Echinacea angustifolia, Purple coneflower, with growing season changes in basal cover importance value, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	1.46	0.00	0.73	0.19	0.32
1988-1992	1.40	0.00	0.72	1.01	1.09
1993-1998	0.41	0.00	0.24	0.67	0.11
1999-2003	0.54	0.09	0.00	0.15	0.16
2004-2009	0.35	0.32	0.11	0.04	0.05
2010-2012	0.08	0.05	0.00	0.00	0.05
Shallow					
1983-1987	0.00	0.00	0.28	0.58	0.60
1988-1992	2.06	0.29	0.59	2.13	1.47
1993-1998	0.67	0.00	0.40	1.13	0.41
1999-2003	0.20	0.00	0.05	0.57	0.15
2004-2009	0.17	0.05	0.02	0.40	0.17
2010-2012	0.00	0.00	0.00	0.36	0.24
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

Table 9. Autecology of Echinacea angustifolia, Purple coneflower, with growing season changes in density, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	0.10	0.00	0.13	0.02	0.07
1988-1992	0.14	0.00	0.06	0.05	0.08
1993-1998	0.06	0.00	0.03	0.00	0.03
1999-2003	0.04	0.01	0.02	0.01	0.03
2004-2009	0.04	0.02	0.00	0.01	0.02
2010-2012	0.02	0.02	0.00	0.01	0.03
Shallow					
1983-1987	0.00	0.00	0.07	0.21	0.10
1988-1992	0.03	0.00	0.06	0.10	0.05
1993-1998	0.00	0.00	0.00	0.10	0.09
1999-2003	0.06	0.00	0.03	0.14	0.08
2004-2009	0.02	0.02	0.02	0.07	0.06
2010-2012	0.01	0.02	0.00	0.09	0.09
Silty					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					

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