Autecology of Longheaded Coneflower on the Northern Mixed Grass Prairie

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The autecology of Longheaded coneflower, *Ratibida columnifera,* 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).

Longheaded coneflower, *Ratibida columnifera* (Nutt.) Woot. & Standl., is a member of the aster (sunflower) family, Asteraceae, and is a native, perennial, warm-season, dicot, herb that is tolerant of weakly acidic to moderately alkaline soils and weak saline soil and has weak shade tolerance. The first North Dakota record is Bolley 1891. Annual aerial growth has one to a few erect stems branched above, 30-60 cm (11.8-23.6 in) tall arising from a perennating woody crown (caudex). Stem (cauline) leaves are alternate, 5-10 cm (2.0-3.9 in) long, deeply pinnately divided unequally into 5 to 9 linear or oblanceolate segments. Stems and leaves are covered with stiff flattened (strigose) hairs. The extensive root system has a stout prominent taproot descending from the woody caudex to 1.1 m (3.5 ft) deep. Numerous fibrous lateral roots arise from the taproot, extend horizontally with a radial spread of 30.5 cm (12 in) then turning downward forming branches and descending to 1.1 m (3.5 ft) deep. The root segments in the top 30 cm (12 in) of soil have little or no absorption. Regeneration is by vegetative and sexual reproduction. Vegetative growth is by annual sprouts from the subterranian crown. Inflorescence is solitary, terminal heads on peduncle arising from leaf axils with few to several per stem. The floral disk is columnar 3-5 cm (1.2-2.0 in) long, 1 cm (0.4 in) across. Ray florets form ring at bottom of floral disk, yellow corollas appear during late June to early August. Pollination is mostly by bees. Fruit is small, gray-black achene with pappus reduced to 1-2 awn-teeth. Aerial parts are not eaten by livestock and are top killed by fire. Sprouts develop from surviving crown. This summary information on growth development and regeneration of longheaded coneflower was based on works of Weaver 1958, Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, Walsh 1994, Favorite 2003, Larson and Johnson 2007, and Stubbendieck et al. 2011.

Procedures

The 1955-1962 Study

Longheaded 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 Longheaded 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

Longheaded 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 48 ungrazed specimens randomly selected on 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 8 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 Longheaded 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 Longheaded 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 the 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 value 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

Longheaded coneflower resumed growth as erect stems arising from a perennating subterranian woody caudex with a stout deep taproot and an extensive lateral root system that has little or no absorption in the top 30 cm (1 ft). Inflorescence are solitary, terminal columnar heads with yellow ray florets forming a ring at the bottom. On the fall grazed pastures of the 1955-1962 study, the earliest first flowers appeared 14 July, the mean first flowers occurred on 22 July, and the flower period extended from late June to late July on the 1969-1971 study (table 1) (Goetz 1963, Zaczkowski 1972). The mean mature stems height of 28.7 cm (11.3 in) with an annual variance in height from 18.0 cm (7.1 in) to 43.0 cm (16.9 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 28.7 cm (11.3 in) was below the short end of the range of normal height. The shorter heights of longheaded 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 2,715 Longheaded coneflower stems were sampled during this study with, 682 stems (25.1%) from the sandy sites, 739 stems (27.2%) from the shallow sites, 768 stems (28.3%) from the silty sites, and 526 stems (19.4%) from the clayey sites. Longheaded coneflower can grow on sandy, shallow, silty, and clayey ecological sites; it appears to grow better on the shallow and silty sites. Mean mature stem height reached during July was, 26.4 cm (10.4 in) from the sandy sites, 23.7 cm (9.3 in) from the shallow sites, 26.1 cm (10.3 in) from the silty sites, and 25.2 cm (9.9 in) from the clayey sites. The measured mature stem heights from the 1984-1985 study were not significantly different and were all shorter than the reported low normal stem heights. The reduced stem height of Longheaded coneflower on the 1984-1985 study was caused by low available mineral nitrogen below the threshold quantities of 100 lbs/ac that resulted from traditional management practices conducted prior to the start of the study. The mean stem weights were 1.58 g on the sandy sites, 0.73 g on the shallow sites, 1.39 g on the silty sites, and 0.81 g on the clayey sites, and were not significantly different.

Most of the aerial stems produced flowers, only 10.7% of the stems remained vegetative. Anthesis phenological growth stage was reached by 0.33% of the stems by late June, 66.1% of the stems by early July, 69.3% of the stems by late July, and 93.5% of the stems by early August.

Plant species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. The plant species composition on all management treatments changed after a few growing seasons. Longheaded coneflower decreased greatly on the sandy ecological sites. Patterns in the changes in individual plant species abundance was followed for 30 growing seasons during the 1983-2012 study on the shallow and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 7, 8, and 9).

On the shallow site of the nongrazed treatment, Longheaded coneflower was not present where basal cover data were collected and was present during 26.3% of the years that density data were collected with a mean 0.13 stems/m^2 density during the total 30 year period. During the early period (1983-1992), Longheaded coneflower was not present on the shallow site of the nongrazed treatment. During the later period (1998-2012), Longheaded coneflower was present during 33.7% of the years density data were collected with a mean 0.17 stems/m^2 density. The percent present and stem density increased on the shallow site of the nongrazed treatment over time (tables 7, 8, and 9).

On the shallow site of the ungrazed seasonlong treatment, Longheaded coneflower was not present where basal cover data were collected and was present during 5.0% of the years that density data were collected with a mean 0.01 stems/m^2 density. During the early period (1983-1992), Longheaded coneflower was not present on the shallow site of the ungrazed seasonlong treatment. During the later period (1998-2012), Longheaded coneflower was present during 6.7% of the years that density data were collected with a mean 0.01 stems/m^2 density. The percent present and stem density increased on the shallow site of the ungrazed seasonlong treatment over time (tables 7, 8, and 9).

On the shallow site of the grazed seasonlong treatment, Longheaded coneflower was present during 35.0% and 7.7% of the years that density and basal cover data were collected with a mean 0.10 stems/m^2 density and a mean 0.003% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 40.0% and 16.7% of the years with a mean 0.18 stems/m^2 density and a mean 0.01% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 33.3% and 6.7% of the years with a mean 0.07 stems/m^2 density and a mean 0.001% basal cover, respectively. The percent present, stem density, and basal cover all decreased on the shallow site of the grazed seasonlong treatment over time (tables 7, 8, and 9). The percent present, stem density, and basal cover were greater on the shallow site of the grazed seasonlong treatment than those on the shallow site of the ungrazed seasonlong treatment.

On the shallow site of the ungrazed twice-over treatment, Longheaded coneflower was present during 81.8% and 55.2% of the years that density and basal cover data were collected with a mean 0.62 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 57.1% and 44.4% of the years with a mean 0.79 stems/m^2 density and a mean 0.02% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 93.3% and 66.7% of the years with a mean 0.55 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present increased and the stem density and basal cover decreased on the shallow site of the ungrazed twice-over treatment over time (tables 7, 8, and 9).

On the shallow site of the grazed twice-over treatment, Longheaded coneflower was present during 86.4% and 46.7% of the years that density and basal cover data were collected with a mean 0.41 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 71.4% and 50.0% of the years with a mean 0.57 stems/m^2 density and a mean 0.03% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 93.3% and 40.0% of the years with a mean 0.33 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present for the density data increased and the percent present for the basal cover data decreased. The stem density and basal cover decreased on the shallow site of the grazed twice-over treatment over time (tables 7, 8, and 9). The percent present and the basal cover were similar on the ungrazed and grazed twice-over treatments. The stem density was greater on the shallow site of the ungrazed twice-over treatment than those on the shallow site of the grazed twice-over treatment.

On the silty site of the nongrazed treatment, Longheaded coneflower was present during 21.1% and 3.9% of the years that density and basal cover data were collected with a mean 0.23 stems/m^2 density and a mean 0.01% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was not present on the silty site of the nongrazed treatment. During the later period (1998-2012), Longheaded coneflower was present during 28.6% of the years density data were collected with a mean 0.31 stems/m^2 density and it was not present where basal cover data were collected. The percent present and stem density increased on the silty site of the nongrazed treatment over time (tables 7, 8, and 9).

On the silty site of the ungrazed seasonlong treatment, Longheaded coneflower was present during 30.0% and 23.1% of the years that density and basal cover data were collected with a mean 0.21 stems/m^2 density and a mean 0.02% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 20.0% and 33.3% of the years with a mean 0.42 stems/m^2 density and a mean 0.04% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 33.3% and 20.0% of the years with a mean 0.11 stems/m^2 density and a mean 0.004% basal cover, respectively. The percent present of the density data increased and percent present of the basal cover data decreased. The stem density and basal cover decreased on the silty site of the ungrazed seasonlong treatment over time (tables 7, 8, and 9).

On the silty site of the grazed seasonlong treatment, Longheaded coneflower was present during 60.0% and 34.6% of the years that density and basal cover data were collected, with a mean 0.47 stems/m^2 density and a mean 0.03% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 40.0% and 33.3% of the years, with a mean 0.76 stems/m^2 density and a mean 0.06% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 66.7% and 33.3% of the years, with a mean 0.37 stems/m^2 density and a mean 0.01% basal cover, respectively. The percent present of the density data increased and the percent present of the basal cover data remained the same. Stem density and basal cover decreased on the silty site of the grazed seasonlong treatment over time (tables 7, 8, and 9). The percent present, stem density, and basal cover were greater on the silty site of the grazed seasonlong treatment than those on the silty site of the ungrazed seasonlong treatment.

On the silty site of the ungrazed twice-over treatment, Longheaded coneflower was present during 86.4% and 65.5% of the years that density and basal cover data were collected with a mean 0.43

stems/m^2 density and a mean 0.05% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 57.1% and 44.4% of the years with a mean 0.54 stems/m^2 density and a mean 0.07% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 100.0% and 80.0% of the years with a mean 0.37 stems/m^2 density and a mean 0.04% basal cover, respectively. The percent present increased and the stem density and basal cover decreased on the silty site of the ungrazed twice-over treatment over time (tables 7, 8, and 9).

On the silty site of the grazed twice-over treatment, Longheaded coneflower was present during 86.4% and 66.7% of the years that density and basal cover data were collected with a mean 1.32 stems/m^2 density and a mean 0.06% basal cover during the total 30 year period, respectively. During the early period (1983-1992), Longheaded coneflower was present during 57.1% and 50.0% of the years with a mean 0.93 stems/m^2 density and a mean 0.08% basal cover, respectively. During the later period (1998-2012), Longheaded coneflower was present during 100.0% and 80.0% of the years with a mean 1.50 stems/m^2 density and a mean 0.05% basal cover, respectively. The percent present and stem density increased and basal cover decreased on the silty site of the grazed twice-over treatment over time (tables 7, 8, and 9). The percent present and basal cover were similar on the silty site of the ungrazed and grazed twice-over treatment. The stem density was greater on the grazed twice-over treatment than those on the ungrazed twice-over treatment.

On the shallow sites during the 30 year period, Longheaded coneflower abundance increased on the nongrazed treatment and decreased on the ungrazed and grazed seasonlong and ungrazed and grazed twice-over treatments. Stem density and basal cover on the shallow sites were greater on the ungrazed and grazed twice-over treatments.

On the silty sites during the 30 year period, Longheaded coneflower abundance increased on the nongrazed and grazed twice-over treatments and decreased on the ungrazed and grazed seasonlong and ungrazed twice-over treatments. Stem density and basal cover on the silty sites were greater on the grazed twice-over treatment.

Longheaded coneflower was not present during the 1988 growing season on the shallow and silty sites of the nongrazed treatment and was not present on the shallow site of the ungrazed seasonlong treatment. Longheaded coneflower was present during the 1988 growing season on the shallow and silty sites of the grazed seasonlong and ungrazed and grazed twice-over treatments and was present on the silty site of the ungrazed seasonlong treatment.

Discussion

Longheaded coneflower, *Ratibida columnifera*, is a native late succession warm season perennial forb of the aster family that is commonly present on healthy mixed grass prairie plant communities. Longheaded coneflower can grow on sandy, shallow, silty, and clayey ecological sites. It appears to grows best on the shallow and silty ecological sites. Annual aerial growth consists of one to a few erect stems arising from a perennating woody caudex with a stout prominent taproot and an extensive deep root system. The inflorescence are solitary, terminal columnar heads on a peduncle. Yellow ray florets form a ring at the bottom of the head. The mean first flower date is 22 July (1955-1962 study) with a five week flower period extending from late June to late July (1969-1971 study) and with a seven week flower period extending from late June to early August (1984-1985 study). Mean flower stalk height was 28.7 cm (11.3 in) (1955-1962 study) and 25.4 cm (10.0 in) (1984-1985 study). Mean stem weight was 1.13 g (1984-1985 study). Longheaded coneflower was present on the shallow sites during 46.9% and 21.9% of the years density and basal cover data were collected with a mean 0.25 stems/m^2 density and a mean 0.01% basal cover. Longheaded coneflower was present on the silty sites during 56.8% and 38.8% of the years that density and basal cover data were collected with a mean 0.53 stems/m^2 density and a mean 0.03% basal cover. Stem density and basal cover were greater on the silty sites.

The woody caudex, a stout taproot, and an extensive deep root system help Longheaded coneflower to persist during the conditions of the Northern mixed grass prairie.

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Table 1. First flower and flower period of Longheaded coneflower, Ratibida columnifera.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
1955-1962						
Earliest				14		
Mean				22		
Flower Period						
1969-1971			X	XX XX		

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

Table 2. Autecology of Longheaded coneflower, Ratibida columnifera, 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	18.0	43.0	28.7		26.4	64.7	100.0		

Data from Goetz 1963.

Table 3. Phenological growth stage changes during the growing season for Longheaded coneflower, Ratibida columnifera, 1984-1985.

Site Sandy	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	40.7	2.4	2.6	6.4		8.3
Bud	59.3	97.6	21.8	33.3	5.3	9.2
Anth			64.1	31.2	5.3	
Seed Dev			11.5	11.3	56.8	3.3
Seed Shed				17.0	27.3	63.3
Mat				0.7	5.3	15.8
Mean Height (cm)						
Veg	13.4	13.1	10.2	9.1		10.2
Bud	19.5	23.8	24.1	24.1	17.6	16.2
Anth			21.6	30.5	24.7	
Seed Dev			28.2	24.8	28.9	28.1
Seed Shed				27.0	25.3	27.7
Mat				20.8	26.4	23.7
% Dryness						
Veg	0.7	2.0	1.0	0.7		8.1
Bud	2.1	12.2	18.5	12.7	18.7	12.3
Anth			20.6	8.6	8.9	
Seed Dev			25.2	28.4	14.5	13.5
Seed Shed				34.3	32.2	32.8
Mat				100.0	25.6	28.2
Mean Weight (g)	0.83	0.81	1.85	2.66	2.06	1.25

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 Longheaded coneflower, Ratibida columnifera, 1984-1985.

Site Shallow	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	30.9	16.7	8.6	8.0	4.9	4.8
Bud	69.1	83.3	23.5	23.3	5.6	4.8
Anth			33.3	37.3	3.5	
Seed Dev			33.3	18.7	44.1	2.4
Seed Shed			1.2	10.7	35.7	67.5
Mat				2.0	6.3	20.6
Mean Height (cm)						
Veg	10.6	14.7	7.5	9.3	10.7	7.0
Bud	16.8	19.7	16.5	19.3	12.4	8.2
Anth			20.7	25.6	26.0	
Seed Dev			23.6	21.0	24.1	24.5
Seed Shed			28.1	22.9	22.6	23.7
Mat				23.9	20.4	23.8
% Dryness						
Veg	1.0	12.2	28.6	5.5	18.7	5.2
Bud	3.3	8.7	29.3	19.9	22.6	9.3
Anth			19.2	14.7	11.2	
Seed Dev			29.9	35.0	27.8	25.0
Seed Shed			25.0	43.8	40.4	34.3
Mat				33.3	49.8	40.6
Mean Weight (g)	0.34	0.34	0.95	1.33	0.45	0.94

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 Longheaded coneflower, Ratibida columnifera, 1984-1985.

Site Silty	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	41.7	20.8	4.8	2.9	4.3	2.2
Bud	58.3	77.9	27.7	26.8	5.8	3.7
Anth		1.3	27.7	34.1	8.6	
Seed Dev			39.8	14.5	41.7	4.4
Seed Shed				15.9	27.3	59.6
Mat				5.8	12.2	30.1
Mean Height (cm)						
Veg	12.8	12.3	13.0	12.0	12.2	8.2
Bud	18.5	22.9	21.6	23.3	16.0	12.0
Anth		52.3	25.5	32.1	22.7	
Seed Dev			23.4	18.6	28.7	29.3
Seed Shed				31.0	23.2	26.9
Mat				31.7	19.8	27.7
% Dryness						
Veg	1.6	13.3	62.0	26.0	12.7	17.3
Bud	0.9	13.9	27.6	20.9	31.1	25.8
Anth		25.0	34.9	14.0	13.2	
Seed Dev			32.6	59.1	32.3	17.3
Seed Shed				51.2	47.2	40.9
Mat				46.9	35.7	45.6
Mean Weight (g)	0.79	0.47	3.40	1.13	1.47	1.06

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 Longheaded coneflower, Ratibida columnifera, 1984-1985.

Site Clayey	8 Jun	23 Jun	8 Jul	23 Jul	8 Aug	23 Aug
% Population						
Veg	48.9	17.6	1.7	1.1		3.2
Bud	51.1	82.4	45.0	20.7		6.4
Anth			28.3	31.0	3.0	
Seed Dev			25.0	29.9	50.5	3.2
Seed Shed				16.1	41.4	70.2
Mat				1.1	5.1	17.0
Mean Height (cm)						
Veg	10.0	16.8	19.3	9.4		11.2
Bud	14.9	20.5	19.4	19.7		10.2
Anth			24.4	31.3	18.8	
Seed Dev			24.1	22.9	29.3	19.8
Seed Shed				23.4	25.3	28.0
Mat				26.4	21.2	30.3
% Dryness						
Veg	0.8	3.4	50.0	2.0		0.0
Bud	5.1	7.0	21.0	20.3		9.3
Anth			10.1	9.7	2.0	
Seed Dev			27.2	41.9	26.6	17.3
Seed Shed				48.3	32.6	36.9
Mat				50.0	45.0	47.0
Mean Weight (g)	0.38	0.44	1.08	1.08	1.08	0.79

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

Table 7. Autecology of Ratibida columnifera, Longheaded 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	1.03	7.02	5.69
1988-1992	0.00	0.00	1.95	0.94	0.88
1993-1998	0.00	0.00	2.00	0.35	1.25
1999-2003	0.21	0.00	0.43	4.06	2.03
2004-2009	0.66	0.07	0.12	2.29	1.11
2010-2012	2.24	0.00	1.24	2.95	3.33
Silty					
1983-1987	0.00	6.33	11.69	9.21	12.80
1988-1992	0.00	0.00	0.64	0.87	0.64
1993-1998	0.00	0.92	1.37	18.27	7.14
1999-2003	0.00	0.61	3.22	21.17	11.48
2004-2009	3.24	0.35	0.58	13.34	9.18
2010-2012	3.38	0.82	1.40	4.03	16.88

Table 8. Autecology of Ratibida columnifera, Longheaded 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	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	0.00	0.30	0.40
1988-1992	0.00	0.00	0.07	0.10	0.04
1993-1998	0.00	0.00	0.00	0.12	0.07
1999-2003	0.00	0.00	0.00	0.16	0.05
2004-2009	0.00	0.00	0.02	0.06	0.08
2010-2012	0.00	0.00	0.00	0.02	0.07
Silty					
1983-1987	0.00	1.58	2.14	1.29	1.06
1988-1992	0.00	0.11	0.12	0.00	0.00
1993-1998	0.37	0.25	0.31	0.39	0.20
1999-2003	0.00	0.03	0.20	0.58	0.54
2004-2009	0.00	0.03	0.02	0.60	0.43
2010-2012	0.00	0.05	0.00	0.07	0.28

Table 9. Autecology of Ratibida columnifera, Longheaded coneflower, with growing season changes in density, 1983-2012.					
Ecological Site Year Period	Nongrazed	Seasonlong		Twice-over	
		Ungrazed	Grazed	Ungrazed	Grazed
Sandy					
1983-1987	Few Plants Present				
1988-1992					
1993-1998					
1999-2003					
2004-2009					
2010-2012					
Shallow					
1983-1987	0.00	0.00	0.01	0.17	0.12
1988-1992	0.00	0.00	0.02	0.01	0.01
1993-1998	0.00	0.00	0.01	0.01	0.02
1999-2003	0.01	0.00	0.01	0.09	0.04
2004-2009	0.01	0.00	0.00	0.03	0.02
2010-2012	0.06	0.00	0.01	0.05	0.05
Silty					
1983-1987	0.00	0.21	0.37	0.21	0.29
1988-1992	0.00	0.00	0.00	0.01	0.01
1993-1998	0.00	0.05	0.03	0.26	0.07
1999-2003	0.00	0.02	0.08	0.25	0.18
2004-2009	0.05	0.01	0.01	0.11	0.15
2010-2012	0.04	0.01	0.02	0.03	0.16

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