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Composition, Biomass, and Protein Content of a Lemna trisulca L., Invertebrate Community in a Prairie Wetland

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COMPOSITION, BIOMASS, AND PROTEIN CONTENT OF A *LEMNA TRISULCA* L.-INVERTEBRATE COMMUNITY IN A PRAIRIE WETLAND

BY

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LEMNA TRISULCA L.-INVERTEBRATE COMMUNITY IN A PRAIRIE WETLAND

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Wildlife and Fisheries Sciences

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Abstract

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Samples of star duckweed (Lemna trisulca L.) were collected from a South Dakota prairie wetland during the summer 1981. Amphipods and gastropods were the dominant macroinvertebrates found within samples of duckweed in terms of biomass and density. Cladocera were the dominant microinvertebrates found in association with star duckweed. Significant variability was found in the biomass and densities of specific invertebrates with respect to sampling dates.

Crude protein values of star duckweed-invertebrate community samples ranged from 7.6 to 18.5% and were found to correlate significantly with protein levels of the duckweed. Crude protein values for star duckweed ranged from 7.1 to 17.0%. Highest protein values were detected during the early part of the sampling period. Protein values for amphipods, gastropods, and Odonata were found to be substantially higher than that of duckweed.

Significant associations were found between the biomass and protein content of duckweed and the biomass and densities of specific invertebrates. Amphipoda, Pleidae, Cladocera, Copepoda, Ostracoda, and Hydrazoa were among the invertebrates found associated with star duckweed.

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INTRODUCTION

The prairie potholes have long been known for their production of waterfowl (Smith et al. 1964, Bellrose 1979). With increasing wetland destruction, suitable habitat for prairie ducks has declined (Salyer 1945, Allen and Leedy 1970). An understanding of the biology of waterfowl and the ecosystems to which they belong is of utmost importance in the management of prairie potholes for duck production.

Food habits of prairie ducks have been investigated by a number of researchers (Dirschl 1969, Sugden 1973, Siegfried 1976, Krapu and Swanson 1975) and the importance of invertebrates and other high protein foods in the diets of breeding hens and juvenile waterfowl is well established (Moyle 1961, Sugden 1973, Swanson et al. 1974, Kaminski and Prince 1981). Kaminski and Prince (1981) found that breeding dabbling ducks (*Anas* spp.) concentrate their foraging efforts in areas with abundant invertebrate prey species. Swanson and Meyer (1973) estimated that the proportion of invertebrates contained in the diets of female Anatinae during the breeding season averaged 76%. They reported that invertebrate food intake in male dabblers ranged from 24% in gadwalls (*Anas strepera*) to 85% in blue-winged teal (*Anas discors*). It was further noted that an average of 89% of the diet of Anatinae ducklings was composed of invertebrates.

Star duckweed (*Lemna trisulca* L.) is a submersed aquatic plant utilized as a food source by many species of waterfowl within the prairie pothole region (Metcalf 1931, McAtee 1939, Sugden 1973).

During the growing season of the plant, a large number of invertebrates can be found in association with star duckweed (Pirnie 1935, McAtee 1939). Although the star duckweed-invertebrate association is common, little literature exists on the composition or nutritive value of the community (Krull 1970, Kobuszewska 1973).

The objectives of this study were to examine the composition, biomass, and protein content of star duckweed-invertebrate communities in a prairie wetland and to see how each of these factors varied throughout the peak brood rearing period for ducks.

STUDY AREA

Paul L. Errington Memorial Marsh was selected as the study area. This 89 hectare marsh is located in the glaciated prairie pothole region of eastern South Dakota. The marsh is surrounded by an uncultivated upland on a Waterfowl Production Area owned by the U.S. Fish and Wildlife Service and a Game Production Area owned by South Dakota Department of Game, Fish and Parks. Errington Marsh is a Class IVB (Stewart and Kantrud 1971) or large semipermanent marsh located in northwestern Brookings County (section 25, T112N, R52W).

The marsh can be characterized as having a cover type 2 as classified by Stewart and Kantrud (1971). Dominant emergent plants were cattail (*Typha* spp.). Common submergents and floating plants were star duckweed, sago pondweed (*Potamogeton pectinatus* L.), coontail (*Ceratophyllum demersum* L.), bladderwort (*Utricularia vulgaris* L.), and common duckweed (*Lemna minor* L.). Star duckweed beds were located in open areas sheltered by cattails within the shallow marsh zones of the wetland.

METHODS

Sampling began on 15 June 1981 and continued through 17 August 1981. Samples were collected during the morning hours at least once every 10 days. A canoe was used to make a reconnaissance of the marsh prior to each sampling period in order to select 3 star duckweed communities as sampling sites. Samples were drawn from the water using a sampler designed by McCrady (1982). Seven samples were collected at each site.

Upon return to the laboratory, 3 of the 7 samples were combined and sorted into star duckweed, other species of aquatic vegetation, macroinvertebrates (based on order or family), and detritus and microinvertebrates. Microinvertebrates were subsampled using a Hensen-Stemple pipette. All samples were sorted manually with the aid of a variable power (1.0 - 7.0x) dissecting scope. Manuals by Fasset (1957) and Pennak (1978) were used to identify plant and animal taxa, respectively. Sorted constituents were dried in a gravity convection oven at 80 C to constant weight, weighed, and ground into a fine powder using a mortar and pestle.

Three of the remaining samples were combined (with vegetation other than star duckweed removed), dried, and weighed. These samples were designated community samples since invertebrates were not separated from the duckweed. Community samples were dried to constant weight, weighed, and ground.

Macroinvertebrates (Amphipoda, Gastropoda, and Odonata) were sorted from the remaining sample to obtain an estimate of their contribution to the protein content of the duckweed community. These macroinvertebrates were also oven dried and ground for protein analysis.

The Tecator Kjeltec System I was used to analyze the crude protein content of the samples. Kjeltec System I procedures for protein determinations (Tecator, P.O. Box 405, Herdon, Virginia 22070) were followed with adjustments made in the quantity of reagents used to allow for semi-micro Kjeldahl analysis. Samples of $\geq$ 2.5 g dry weight were necessary for crude protein determinations.

Analysis of variance was used to test differences among sampling dates for composition, biomass, and protein values of star duckweed-invertebrate communities. Linear correlation was used to test relationships between biomass and protein values of star duckweed and community samples. Associations between star duckweed and the invertebrates found within community samples were determined through multiple regression.

RESULTS AND DISCUSSION

Community Composition and Biomass

Among the macroinvertebrates, Amphipoda and Gastropoda were the dominant orders in the star duckweed community (Table 1). Amphipods and gastropods made up 68.6% and 22.2% of the total number of macroinvertebrates in the community samples. Hydracarina, Pleidae, Diptera, and Corixidae each contributed less than 2.5% of the total macroinvertebrate density. Ephemeroptera, Hirudinea, Odonata, Coleoptera, Notonectidae, Mesoveliidae, Veliidae, and Nematoda collectively made up 2.4% of the total number of invertebrates in the community.

Of the microinvertebrates found associated with star duckweed, Cladocera contributed an average of 74.1% to the total microfauna density (Table 1). Copepoda contributed an average of 13.7%, Ostracoda 11.8%, and Hydrazoa 0.4% of the microinvertebrate density.

Krull (1970) found Amphipoda, Gastropoda, Odonata, Pleidae, Belostomatidae, Corixidae, Coleoptera, and Diptera associated with star duckweed in New York. Kobuszewska (1973) investigated the fauna associated with Lemnaceae in Poland and found Ephemeroptera, Diptera, Oligochaeta, Trichoptera, and Gastropoda in the star duckweed community. In both locations gastropods were commonly associated with duckweed.

Star duckweed constituted a seasonal average of 91.12% of the Errington community biomass (Table 2). Star duckweed-invertebrate community biomass was found to correlate significantly ($P < 0.05$)

Table 1. Seasonal mean number of invertebrates found per liter of water in association with star duckweed in Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

	Occurrence of individuals per liter		
Taxa	Number	SD	Percent of total
Macroinvertebrates			
Amphipoda	30.90	14.86	68.6
Gastropoda	9.99	4.97	22.2
Hydracarina	1.04	0.63	2.3
Pleidae	0.74	0.97	1.6
Diptera	0.73	2.60	1.6
Corixidae	0.54	0.90	1.2
Ephemeroptera	0.37	0.73	0.8
Hirudinea	0.28	0.30	0.6
Odonata	0.15	0.16	0.3
Coleoptera	0.13	0.27	0.3
Notonectidae	0.10	0.17	0.2
Nematoda	0.02	0.03	-
Mesoveliidae	0.02	0.06	-
Veliidae	0.01	0.04	-
Microinvertebrates			
Cladocera	384.62	261.03	74.1
Copepoda	71.14	42.41	13.7
Ostracoda	61.43	34.98	11.8
Hydrazoa	1.81	3.85	0.4

Table 2. Seasonal mean biomass of star duckweed-invertebrate community components in Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Taxa	Biomass per liter		
	mg/l	SD	Percent of total
Star duckweed	591.01	181.20	91.12
Gastropoda	9.12	4.88	1.41
Amphipoda	6.65	2.63	1.03
Odonata	2.54	6.13	0.39
Hirudinea	0.48	0.54	0.07
Corixidae	0.40	0.52	0.06
Notonectidae	0.24	0.61	0.04
Hydracarina	0.13	0.11	0.02
Pleidae	0.11	0.11	0.02
Ephemeroptera	0.09	0.09	0.01
Diptera	0.05	0.20	0.01
Coleoptera	0.02	0.05	-
Detritus and microinvertebrates[a]	38.13	14.87	5.88

[a]Although detritus is not living matter, it was included in biomass calculations.

with values of star duckweed yielding a correlation coefficient of 0.8883. Gastropods (1.41%) and amphipods (1.03%) were the dominant macroinvertebrates in terms of biomass. Remaining macroinvertebrates associated with star duckweed contributed 0.62% of the community biomass. Detritus combined with microinvertebrates averaged 5.88% of the biomass during the period of sampling. (Although detritus is not living matter it was included in biomass calculations.)

The density and biomass of the invertebrates associated with star duckweed can be related to the food habits of ducks. Swanson et al. (1979) stated that during late spring and early summer gadwalls start their first nests and many other dabblers have begun to renest. During the period of this study, dabblers were rearing their broods. Ducklings depend a great deal on invertebrate food especially immediately after hatching (Sugden 1973). Krull (1970) reported star duckweed as possessing the largest seasonal mean weight of invertebrates per unit mass of plant matter when compared with other submersed plants. Coontail exceeded star duckweed in the seasonal mean number of animals found per 100 grams of plant material. McCrady (1982) found coontail-star duckweed communities to be more productive in terms of biomass when compared to communities dominated by sago pondweed, coontail and cattail, and cattail alone. Thus, star duckweed may provide a concentrated source of invertebrate foods for ducklings.

Analysis of variance revealed significant differences ($P < 0.05$) between densities and sampling periods of amphipods and gastropods (Table 3). Highest densities for these macroinvertebrates occurred at different times during the sampling period with gastropods revealing

Table 3. Analysis of variance of the numbers of Gastropoda and Amphipoda associated with star duckweed per liter of water versus sampling date, Errington Marsh, Brookings County, South Dakota, 1981.

Source	Degrees of freedom	Mean square	F value
Gastropoda			
Date	8	80.51	3.26*
Error	18	24.72	
Total	26		
Amphipoda			
Date	8	972.80	4.41**
Error	18	220.72	
Total	26		

*Indicates a significant difference at $P < 0.05$.

**Indicates a significant difference at $P < 0.01$.

a peak in early July and amphipods a peak in late August (Table 4). Nematode densities also varied significantly ($P < 0.05$) but were never found in quantities greater than 0.1 per liter of water. Densities of other macroinvertebrates in the samples (Table 1) did not vary significantly between sampling periods.

Densities of microinvertebrates varied significantly ($P < 0.05$) over time (Table 5). Highest densities recorded for copepods and cladocerans occurred during late July, ostracods during mid July and early August and hydras in mid June (Table 6).

Analysis of variance revealed significant differences ($P < 0.05$) between biomass values of the star duckweed-invertebrate communities with respect to sampling date (Table 7). Variability was also detected among star duckweed samples with respect to sampling date (Table 7). The highest biomass for community samples and duckweed samples appeared in mid August (Table 8). Kobuszewska (1973) found peak biomass values for star duckweed samples collected in Poland to occur in July. Gastropod, amphipod, ephemeropteran, and corixid biomass also varied significantly ($P < 0.05$) with sampling dates (Table 7). The highest gastropod biomass occurred in early July (Table 8). Donaldson (1976) also found fluctuations in gastropod biomass and density within a marsh dominated by star duckweed and *Cladophora* sp. The highest biomass values recorded for amphipods occurred in mid August, ephemeropterans in late June, and corixids in early August (Table 8). No other macroinvertebrate family or order (Table 2) varied significantly ($P < 0.05$) between sampling periods.

Table 4. Mean numbers of Amphipoda and Gastropoda associated with star duckweed per liter of water in Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Date	Gastropoda no.	Amphipoda no.
June 15	5.90[a]	33.80
24	8.27	18.50
July 2	14.37	10.20
9	20.83	10.20
16	6.20	18.83
23	13.57	37.73
30	5.57	37.60
Aug. 8	7.70	47.83
17	7.47	63.30

[a]Mean value for 3 sample sites for each sampling period.

Table 5. Analysis of variance of the number of microinvertebrates associated with star duckweed per liter of water versus sampling date, Errington Marsh, Brookings County, South Dakota, 1981.

Source	Degrees of freedom	Mean square	F value
Cladocera			
Date	8	4.34×10^5	7.97*
Error	18	5.45×10^4	
Total	26		
Copepoda			
Date	8	1.17×10^4	6.50*
Error	18	1.80×10^3	
Total	26		
Ostracoda			
Date	8	4.21×10^3	3.44**
Error	18	1.22×10^3	
Total	26		
Hydrazoa			
Date	8	39.72	2.68**
Error	18	14.82	
Total	26		

*Indicates a signficant difference at $P < 0.01$.

**Indicates a significant difference at $P < 0.05$.

Table 6. Mean number of microinvertebrates associated with star duckweed per liter of water in Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Date	Cladocera[a] no.	Copepoda no.	Ostracoda no.	Hydrazoa no.
June 15	231.1	33.0	0.0	16.5
24	56.3	8.2	38.0	2.7
July 2	63.3	12.7	53.2	2.5
9	45.7	13.7	59.6	0.0
16	405.7	63.3	114.1	0.0
23	295.3	167.3	37.7	0.0
30	1,210.0	165.7	47.3	0.0
Aug. 8	629.0	77.5	116.2	0.0
17	631.3	98.4	77.0	0.0

[a]Mean value of 3 sample sites for each sampling period.

Table 7. Analysis of variance of the biomass (mg/l) of the star duckweed-invertebrate community and its components versus sampling date, Errington Marsh, Brookings County, South Dakota, 1981.

Source	Degrees of freedom	Mean square	F value
Community			
Date	8	1.40×10^5	4.61*
Error	18	3.03×10^4	
Total	26		
Star duckweed			
Date	8	1.45×10^5	4.41*
Error	18	3.28×10^4	
Total	26		
Gastropoda			
Date	8	125.29	5.27*
Error	18	23.77	
Total	26		
Amphipoda			
Date	8	23.24	3.37**
Error	18	6.89	
Total	26		

Table 7. Continued

Source	Degrees of freedom	Mean square	F value
Ephemeroptera			
Date	8	0.019	2.56**
Error	18	0.008	
Total	26		
Corixidae			
Date	8	0.73	2.71**
Error	18	0.27	
Total	26		

*Indicates a significant difference at P < 0.01.

**Indicates a significant difference at P < 0.05.

Table 8. Mean biomass of star duckweed-invertebrate community and its components between 15 June and 17 August 1981, Errington Marsh, Brookings County, South Dakota.

Date	Community[a] mg/l	Star duckweed mg/l	Gastropoda mg/l	Amphipoda mg/l	Ephemeroptera mg/l	Corixidae mg/l
June 15	308.33[b]	241.92	6.60	9.47	0.06	0.06
24	351.39	360.61	4.67	6.83	0.26	0.04
July 2	530.22	445.82	17.07	6.21	0.00	0.37
9	540.51	502.46	19.75	3.51	0.04	0.11
16	716.10	646.47	5.65	2.39	0.05	0.11
23	799.05	653.61	15.79	6.76	0.04	0.70
30	760.93	726.30	3.88	7.22	0.10	0.74
Aug. 8	933.11	868.75	5.34	6.49	0.16	1.49
17	800.28	873.17	3.33	11.72	0.08	0.00

[a]Community samples were not sorted and contain _Lemna trisulca_, invertebrates, and detritus.

[b]Mean value of 3 sample sites for each sampling period.

Sugden (1973) found that ducklings seek diversity in their diets. The bills of newly hatched ducklings are not specialized for selective feeding (Sugden 1973). As the bird ages its bill becomes more specialized and a change in the duckling's feeding behavior and diet results (Sugden 1973). Invertebrate abundance and diversity appear to be of prime importance to ducklings. Collias and Collias (1963) found duckweed (*Lemna* spp.) and bladderwort (*Utricularia* spp.) to harbor large numbers of invertebrates. They recorded that ducklings of blue-winged teal and mallard (*Anas platyrhynchos*) actively captured amphipods within a bed of duckweed. They found that distribution of ducklings during their first week after hatching was correlated with invertebrate abundance. Krull (1970) found that star duckweed had the greatest level of both seasonal and weekly diversity of invertebrates followed by waterweed (*Elodea canadensis* Michx.), coontail, and water milfoil (*Myriophyllum spicatum* L.). Star duckweed-invertebrate communities appear to be an excellent food base for ducklings. The variability in the biomass and densities of associated invertebrates indicate the presence of a constant supply of a variety of potential food items.

Crude Protein Content of Star Duckweed and Associated Invertebrates

Percent crude protein levels of the star duckweed-invertebrate community ranged from 7.59% to 18.46% (Table 9). Analysis of variance revealed a significant ($P < 0.01$) difference for protein levels among sampling dates for both the community and star duckweed samples (Table 10). Crude protein levels of the community samples correlated significantly

Table 9. Mean crude protein content (based on dry weight) and weight of protein per liter of sample for star duckweed-invertebrate community and star duckweed samples in Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Date	Community[a]		Star duckweed	
	%	mg/1[b]	%	mg/1
June 15	18.46[c]	56.12	16.79	41.05
24	10.29	36.16	9.59	34.58
July 2	7.59	40.24	7.09	31.61
9	8.17	44.16	7.42	37.28
16	7.69	55.07	7.32	47.32
23	7.74	61.85	7.75	50.65
30	8.14	61.94	7.84	56.94
Aug. 8	9.71	90.61	8.97	77.93
17	7.96	63.70	8.01	69.94

[a] Community samples were not sorted and contained star duckweed, invertebrates, and detritus.

[b] Percent crude protein values multiplied by biomass values found in Table 8.

[c] Mean value of 3 sample sites for each sampling period.

Table 10. Analysis of variance of crude protein content (based on dry weights) of the star duckweed-invertebrate community and star duckweed versus sampling date, Errington Marsh, Brookings County, South Dakota, 1981.

Source	Degrees of freedom	Mean square	F value
Community[a]			
Date	8	36.36	21.08*
Error	18	1.72	
Total	26		
Star duckweed			
Date	8	28.78	23.02*
Error	18	1.25	
Total	26		

[a]Community samples were not sorted and contain star duckweed, invertebrates, and detritus.

*Indicates a significant difference at $P < 0.01$.

($P < 0.05$) with protein levels in the duckweed with a correlation coefficient of 0.9867. Highest protein levels were detected during the early part of the sampling period (Table 9). On 15 June protein levels for star duckweed ranged from 15.24% to 18.65% and protein levels from early July through mid August averaged 7.77%. Lehman et al. (1981) found Lemna sp. protein per frond and root to increase with developmental stage until the plants were at least 2 generations old. It is suspected that the early high protein levels resulted from the presence of large quantities of new duckweed fronds. As the growing season progressed and the plants continued to age, the ratio of new fronds to old fronds decreased. Thus, we see a decline from high protein levels early in the growing season followed by a plateau or leveling off.

Although percent crude protein values in both community samples and star duckweed samples were found to be highest during the early part of the sampling period, the total amount of protein present per sample increased over time due to the increase in biomass (Table 8 and Table 9). The importance of this relationship to waterfowl can only be determined with information on the actual consumption rates of star duckweed and associated invertebrates.

Crude protein values for star duckweed ranged from 7.09 to 16.79% (Table 9). Amado et al. (1980) found that star duckweed protein levels in their samples from Germany ranged from 6.8 to 23.0%. Sugden (1973) recorded a crude protein value of 15.2% for star duckweed in Alberta, Canada. Allenby (1968) sampled star duckweed from different wetland types in England during May, August, and October and found that crude protein values ranged from 10.0 to 30.0%. Denton (1966) and Allenby (1968) noted that nitrogen levels within different aquatic habitats and the date of sampling may explain differences in protein values within a given species of plant.

Percent protein of aquatic invertebrates in the samples was substantially higher than that of star duckweed. Amphipod crude protein levels ranged from 37.60 to 41.74% (Table 11). Crude protein values for gastropods (shells included) ranged from 16.93 to 21.27%. Sugden (1973) reported crude protein content in amphipods as 47.0% and that of gastropods as 16.9%. Odonata separated from the samples taken over the sampling period were analyzed as 1 sample. A protein value of 71.70% was determined for Odonata. Sitaramaiah (1967) found protein levels in Odonata to range from 38.4 to 54.8%.

The value of high protein foods for breeding and laying waterfowl and ducklings cannot be overemphasized. Holm and Scott (1954) determined that wild ducklings required no more than 19% total protein in their diet. Optimal results were obtained when ducklings were fed diets containing 8% animal protein. Breeding and laying mallards required a diet containing 18.6% protein in order to achieve satisfactory egg production and hatching success (Holm and Scott 1954). Krapu and Swanson (1975) revealed that the amino acid composition of several invertebrates compared favorably with the amino acid content of a duck egg. They found that a deficiency in one or more essential amino acids may reduce the quantity of protein synthesized thereby causing a reduction in egg size. The level of methionine in the diet is known to affect egg weight (Leong and McGinnis 1952) and feather growth in juvenile chickens

Table 11. Average percent crude protein content (based on dry weights) of Amphipoda, Gastropoda, and Odonata, associated with star duckweed, Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Source	% crude protein[a]			
	June 15- Aug. 2	Aug. 9- Aug. 23	Aug. 30- Sep. 17	June 15- Sep. 17
Amphipoda	41.52	37.60	41.74	-
Gastropoda[b]	21.26	16.93	21.27	-
Odonata	-	-	-	71.70

[a]Samples were combined for these time periods prior to analysis.

[b]Includes shell.

(Sugden 1973). Sugden (1973) found chironomid larvae, corixids, and amphipods to provide the most complete range of amino acids for ducklings when based on the requirements of chickens. Culley and Epps (1973) determined that high concentrations of lysine and arginine in duckweeds were sufficient to be used as alfalfa substitutes in poultry feed. Thus, it appears that the star duckweed-invertebrate community contains protein levels high enough to serve as a food source for ducklings and laying hens.

Community Associations

Stepwise multiple regression was used to determine the existence of any associations between aquatic invertebrate densities, biomass, and the protein values of duckweed samples (Table 12). Density and biomass of amphipods were found to be significantly associated ($P < 0.05$) with both star duckweed biomass and protein content. McCrady (1982) also found amphipod biomass to be significantly associated with duckweed (*Lemna minor* and *Lemna trisulca*) biomass. Corixid biomass and pleid biomass were found to be significantly associated ($P < 0.05$) with star duckweed biomass. Densities of Odonata, Mesoveliidae, Veliidae, Pleidae, Cladocera, Copepoda, Hydracarina, and Ostracoda were found to associate significantly ($P < 0.05$) with star duckweed biomass. Hydra numbers were found to be associated with star duckweed protein content. A strong association between biomass values of *Lemna* spp. and zooplankton densities were also found by McCrady (1982).

Table 12. Significant associations of aquatic invertebrates with star duckweed biomass and protein content tested by stepwise multiple regression at the 95% confidence level, Errington Marsh, Brookings County, South Dakota, between 15 June and 17 August 1981.

Dependent variable	Independent variable	Intercept	Part. reg. coef. (b)	Cumulative R^2
Amphipoda biomass	*Lemna trisulca* protein		0.6305	0.1212
	Lemna trisulca biomass	-2.4337	0.0058	0.2598
Corixidae biomass	*Lemna trisulca* biomass	-0.1672	0.0010	0.1513
Pleidae biomass	*Lemna trisulca* biomass	-0.0960	0.0003	0.4855
Amphipoda no./liter	*Lemna trisulca* biomass		0.0697	0.3468
	Lemna trisulca protein	-40.9873	3.4318	0.5340
Hydracarina no./liter	*Lemna trisulca* biomass	0.4321	0.0010	0.1784
Odonata no./liter	*Lemna trisulca* biomass	-0.0520	0.0003	0.2598
Pleidae no./liter	*Lemna trisulca* biomass	-0.3969	0.0019	0.2531
Mesoveliidae no./liter	*Lemna trisulca* biomass	-0.0355	0.0001	0.1636
Veliidae no./liter	*Lemna trisulca* biomass	-0.0325	0.0001	0.1772
Cladocera no./liter	*Lemna trisulca* biomass	-159.3845	0.9788	0.3760
Copepoda no./liter	*Lemna trisulca* biomass	-19.7181	0.1537	0.3284

Table 12. Continued

Dependent variable	Independent variable	Intercept	Part. reg. coef. (b)	Cumulative R^2
Ostracoda no./liter	*Lemna trisulca* biomass	12.2330	0.0832	0.2175
Hydrazoa no./liter	*Lemna trisulca* protein	-6.3832	0.9107	0.3586

Few aquatic macroinvertebrates utilize plant tissue as a food source, however, certain species of amphipods and gastropods are known to consume Lemna spp. (Gaevskaya 1969). Rosine (1955) proposed that the association found among submersed plant and animal communities results primarily from periphyton occurring on the surface of the plant. Smock and Stoneburner (1980) found a relationship between the degree of decomposition of aquatic macrophytes and the densities of associated macroinvertebrates. Surface area and leaf dissection appear to be other factors determining the quantity of invertebrates associated with a given plant (Rosine 1955). Surface area, protein content, degree of decomposition, and the large concentration of fronds per given area may explain the positive association of aquatic invertebrates with star duckweed. The association of invertebrates with star duckweed strengthens the idea that star duckweed communities provide a valuable food base for waterfowl.

CONCLUSION

Star duckweed harbored a variety of invertebrates throughout the sampling period. Composition of the community changed during the sampling period with amphipods and gastropods as the dominant macroinvertebrates found within samples of star duckweed. Cladocerans were the dominant microinvertebrates. The biomass of the community was found to increase over the sampling period. A similar trend was found in the biomass of star duckweed. Densities and biomass of a variety of invertebrates also fluctuated during the sampling period. Percent crude protein values of community samples and star duckweed samples were found to be highest during the early part of the sampling period. Since juvenile ducks and laying hens require and utilize high protein foods, it is believed that star duckweed and the invertebrates associated with it may provide a valuable food base for such birds throughout the summer months. The nutritive value of the community is not restricted to ducks and may apply to other waterfowl, fish, amphibians, and mammals associated with prairie wetlands.

Additional research is needed to obtain information on the physical and chemical aspects of wetlands containing star duckweed in order to better understand the community. Special emphasis should be placed on comparisons between nitrogen levels in the aquatic habitat and star duckweed and invertebrate protein levels. Comparisons of star duckweed-invertebrate communities among different wetlands would also provide useful information.

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