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Some Ecological Relations of Fairy Shrimps in Alkaline Habitats of Nebraska

D. BRUCE McCARRAHER
Nebraska Game and Parks Commission, Office of Limnology, Hastings College, Hastings, Nebraska 68901

ABSTRACT: Ecological studies on the distribution of fairy shrimps have been made from 246 sites in the sandhills region of Nebraska. New records for Nebraska have been established for *Artemia salina, Branchinecta campestris, B. lindahli, B. mackini* and *Cyzicus mexicanus.* Seasonal populations of shrimp have been located in habitats containing permanent fish populations. Water mineralization was the dominant environmental condition related to the distribution of phyllopods with sodium and potassium compounds predominating in the strongly alkaline lakes. Several of the *Artemia* lakes were classified as hydroxide sites. Many of the alkaline ponds, where *B. lindahli* and *B. campestris* flourish, are chemically different from the sodium chloride waters common throughout the western United States.

INTRODUCTION

The Nebraska Sandhill Region, an area of about 20,000 sq miles, is a plains environment that has been extensively modified by wind. It is a region of vegetated sandhills, sandy basins and valleys, with numerous exposed ground-water lakes and marshes of a permanent or seasonal nature (Fig. 1). An extensive limnological inventory of the aquatic habitats of the sandhills was undertaken between 1954 and 1961. This inventory was used to formulate a management program for sport fisheries (McCarraher, 1961). About 1640 lakes were investigated and an additional 850 permanent, smaller lakes less than 10 surface acres were recorded. In addition to permanent water, numerous seasonal pools were found. Periodic sampling of these permanent lakes

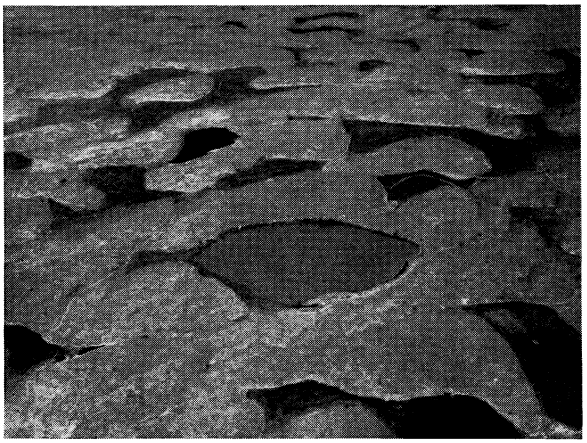

Fig. 1.—Typical lake area Nebraska Sandhill Region. Scale: 1:45,000

and numerous seasonal ponds was carried out during all months of the year over a 12-year period from 1954 to 1968.

This paper reports on the distribution of phyllopods in alkaline lakes of Nebraska and describes the quality of water and associated biota.

The inland mineral waters of arid regions of the western United States have been designated as saline since sodium chloride is the principal solute with a *p*H value normally less than 8.8. In Nebraska's alkaline waters chloride salts occur in insignificant quantities. For this reason the term "salinity," used in describing marine or inland chloride and sulfate waters, is employed here as a collective term for all dissolved ionic constituents, with concentrations expressed as parts per million (ppm).

Acknowledgments.—I am indebted to Dr. Ralph W. Dexter, Department of Biological Sciences, Kent State University, Kent, Ohio, for his identification of many of the phyllopods and for having been the source of encouragement for my interest in the fairy shrimps of Nebraska. The author also acknowledges the comments and manuscript suggestions of Dr. James E. Lynch.

METHODS

Collections of phyllopod shrimps were obtained either by dip-netting with fine-mesh nets, trawling with a beam trawl or by spot sampling with 5% liquid rotenone. Major collection sites are shown in Figure 2. Rotenone at a concentration of 0.125 ppm was used in sampling the larger ponds.

The recommendations of Lynch (1964) regarding the recent nomenclatural revision of species of *Branchinecta* were used.

Hydrochemical conditions were measured either directly in the field by the use of portable chemical kits, or by water samples collected and sent to the Nebraska Department of Health, Division of Laboratories, for analysis.

LAKE CHARACTERISTICS

The sandhill lakes have been generally classified as "alkaline eutrophic of the sodium-bicarbonate group," with the strongly alkaline lakes resembling the "sodium-potassium-carbonate type" (McCarraher,

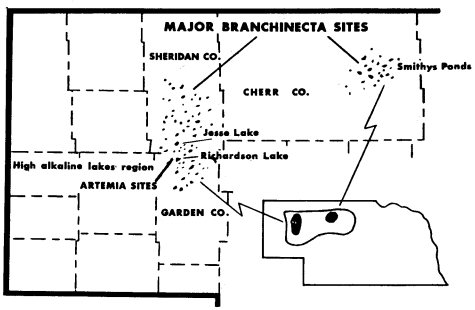

Fig. 2.—Major fairy shrimp collection sites, Nebraska Sandhill Lake Region.

1961). Carbonate, bicarbonate and sulfate anions predominate. Sodium and potassium are the major cations present. Many of the Nebraska alkaline lakes could be described as "Carbonate sodic" as designated by Wurtz and Simpson (1964) for carbonate alkaline lakes in Africa.

Annual surface evaporation from sandhill ponds has resulted in heavy deposition of alkaline salts in many basins. The greatest concentrations of alkaline lakes occur where ground water has slow underflow movement with no appreciable inflow or outward drainage of surface water. This trapped water becomes mineralized and precipitates of potassium and sodium compounds occur upon evaporation. It is speculated that compounds enter the lakes mostly as sulfates (Condra, 1912), which in the presence of organic matter and iron are reduced to sulfites and finally to monocarbonates. Consequently, the oldest mineralized sites, containing mostly sodium and potassium carbonate, are high in total alkalinity. The mineralized lakes may contain considerable concentrations of alkali deposits in layers of sand five to 20 ft beneath the lake basin. However, fresh water at varying depths appears to underlie most such deposits.

DISTRIBUTION OF PHYLLOPODS

Phyllopods were collected from 246 sites on 74 individual lakes, both temporary and permanent throughout the sandhills. The geographic ranges of *A. salina* (Leach), *B. campestris, B. lindahli* (Packard), *B. mackini* (Dexter), and *Cyzicus mexicanus* (Claus) have been extended into the sandhill region of Nebraska where they were previously unreported, with additional records established on the distribution of *Chirocephalopsis bundyi* (Forbes) and *Streptocephalus seali* (Ryder) (Table 1). I first noted the brine shrimp, *A. salina,* in the sandhill regions of Nebraska in 1962 from collections made by Mr. William Schoenecker. The complete range of this shrimp in the state has not been fully established. It has been collected from 12 lakes in Garden and Sheridan counties (Fig. 2).

WATER QUALITY FROM PHYLLOPOD COLLECTION SITES

Some publications on phyllopods present data on temperature, *p*H, and content of dissolved salts. However, most investigations are of a taxonomic nature and do not include reference to water quality.

In eastern Washington, Lynch (1960) collected specimens of *Branchinecta campestris* Lynch from alkaline sites having *p*H values ranging from 9.5 to 10.0. The specific gravity of several water samples was between 1.020 and 1.012%. Evidence here points to *B. campestris* as adapted to environments of high salinity. Moore (1958) recorded *Streptocephalus similis* Baird from alkaline habitats in Texas and Mexico. These waters had a *p*H range of 7.8 and 9.0 and a total alkalinity of 54 to 260 ppm, maximum chlorides of 82 ppm and sulfates of about 20 ppm. These distant geographical sites illustrate phyllopod environments considerably less alkaline than the majority of Nebraska sites (Table 1).

TABLE 1.—Collection records and chemical conditions of some Nebraska fairy shrimp habitats

Locality	Date	Species	*p*H	(in ppm) HCO_3	CO_3	Cl	SO_4	Na + K	Specific conductance corrected to 25 C
Smithys Pond #2 Cherry Co.	4-20-60	*B. lindahli*	10.0	1,020	295	234	600	4,200	9,230
Smithys Pond #3 Cherry Co.	10-20-60	*B. lindahli*	9.6	633	254	25	108	700	1,312
Pool W of Ellsworth Sheridan Co.	3-27-61	*B. lindahli*	9.7	830	165	.....	.....	.....	1,960
Pool N of Antioch Sheridan Co.	3-27-61	*B. lindahli*	9.9	2,000	1,100	220	820	1,200	4,460
Hackberry Lake Pond #1, Cherry Co.	3-30-61	*B. lindahli*	9.3	1,256	221	150	.....	.....	2,550
Smithys Pond #4 Cherry Co.	4-20-61	*C. bundyi*	8.8	479	34	25	14	900	1,250
Pelican Lake Pond #1 Cherry Co.	4- 6-61	*C. bundyi*	9.0	374	84	15	42	.....	680
Big Alkali Lake Pond #2, Cherry Co.	6-17-65	*S. seali*	7.8	104	0.0	8	4	14	136
West Long Lake Pond #1, Cherry Co.	4-26-61	*B. lindahli*	9.5	1,230	34	.....	600	.....	3,420
By-Way-Ranch Pond Cherry Co.	5- 1-61	*B. lindahli*	10.3	7,055	2,975	700	1,400	940	9,280
Pond S of Lakeside Sheridan Co.	5-12-61	*B. lindahli*	9.5	3,366	1,054	135	200	.....	5,950
Alkali Lake Cherry Co.	4-20-61	*B. lindahli*	9.9	1,283	544	250	400	.....	2,736

Table 1.—(continued)

Locality	Date	Species	*p*H	HCO_3 (in ppm)	CO_3 (in ppm)	Cl (in ppm)	SO_4 (in ppm)	Na + K (in ppm)	Specific conductance corrected to 25 C
Pond 12 mi S, Smith Lake, Sheridan Co.	4-16-62	*B. lindahli*	10.0	.....	.....	1,040	5,000	9,460	36,342
Toms Lake, Cherry Co.	5- 1-62	*B. campestris*	9.9	4,292	1,675	5	55	1,800	5,130
Lakeside Pond Sheridan Co.	4-16-62	*B. campestris*	9.8	2,633	820	300	650	.....	5,557
Lakeside Pond #2, Sheridan Co.	4-16-62	*B. mackini*	9.3	889	306	150	115	.....	2,394
Richardson Lake Garden Co.	8-28-62	*A. salina*	10.6	15,215	23,358	1,550	1,300	7,500	31,816
Cook Lake Sheridan Co.	9- 4-62	*A. salina*	10.6	0.0	46,580	4,250	8,000	22,000	68,000
Jesse Lake Sheridan Co.	7-11-64	*A. salina*	10.2	26,800	21,200	4,100	13,800	21,600	77,976
Lily Lake Sheridan Co.	6- 7-63	*A. salina*	10.0	6,800	1,142	121	.....	4,960	26,622
Lake #29 Sheridan Co.	7-21-65	*A. salina*	10.0	21,600	18,000	3,250	10,200	33,400	70,374
Antioch Pond #6 Sheridan Co.	11-15-65	*A. salina*	10.1	23,000	64,000	6,500	13,900	70,000	135,640
Lake #2 Sheridan Co.	11-15-66	*A. salina*	10.0	35,700	14,300	3,000	6,800	23,700	67,280

B. lindahli was the only phyllopod species found in a small Sheridan Co. pond where the total dissolved solids were 36,342 ppm (36.3%). This locality represents the highest per cent solids for *B. lindahli* in North America.

Extreme *p*H values, above 10.0, appear to be tolerated by several species of shrimp during their normal life span. However, *p*H values outside this range and persisting for prolonged periods may be fatal to developing immature phyllopods.

Lynch (pers. comm., 1962) states that the phyllopod Crustacea of western United States may occur in alkaline ponds of opaque water of white, gray or yellow-green color. Alkaline ponds with transparent water seldom occur. These same water colors are also common throughout the Nebraska sandhills. An exception to colored and opaque water may be found in the *Artemia* sites where 10 of the 12 lakes contained clear water with good light transmission. Both *B. lindahli* and *B. campestris* were taken in extremely dark brown or dark gray waters from a small, strongly alkaline pond with water the color of black ink (Toms Lake, Table 1). The dark color was due to suspended matter which had not precipitated or settled out. Per cent transmission of light, measuring the percentage of light absorbed in traversing a 10-cm path of water, was 4% during May 1962. Sunlight transmission did not increase until early winter when a reading of 62% was recorded.

All collections of *C. bundyi* and *Eubranchipus ornatus* (Holmes) were from slightly alkaline, transparent waters with little suspended material. The *p*H for these shrimp sites did not exceed 9.0 with total alkalinity values below 550 ppm.

The brine shrimp *A. salina* was collected from several sites. Data on water quality indicate that Nebraska *Artemia* lakes (Table 1) contain considerably higher proportions of carbonate, bicarbonate, hydroxide and potassium ions than are found in the Great Salt Lake and chemically similar western saline lakes. The *p*H values were also consistently higher, whereas chlorides and sulfates were proportionately less than in other recorded *Artemia* habitats. Annual water level fluctuations are severe most years. Average lake depths of 30 inches occur most winters with maximum depths seldom exceeding 4 ft during the spring. Bottom deposits are sand and flocculent silt. Submergent vegetation does not appear in these lakes whereas three-square bulrush, *Scirpus americanus,* hardstem bulrush, *Scirpus acutus* and salt grass, *Distichlis stricta,* are dominant plants along the shoreline (Fig. 3).

PHYLLOPODS AND ASSOCIATED FAUNA

Seldom have investigators found phyllopods and established fish populations within the same lake or pond basins. Lynch (pers. comm., 1961) indicates that phyllopods are normally absent from permanent lakes with a resident population of fish. However, there are a few noteworthy exceptions. Large shallow lakes which have a heavy

growth of aquatic plants along the border may contain a population of *Conchostraca* in the mats of vegetation. In regions of irregular rainfall, a small lake with fish life may, after a prolonged period of rains, spread out over an area many times larger than its usual size. In such a case phyllopods may hatch from eggs in the area and temporarily inhabit both the lake and adjacent flooded regions. Pennak (1953) states that phyllopods are of no importance in the diet of fish since they are found in waters too small, too alkaline or too temporary to support fish life. I first observed a migratory population of northern pike, *Esox lucius,* and the anostracan, *C. bundyi,* together in an 8-acre pond in 1957. Spawning adult pike had ascended the Big Alkali Lake inlet drainage and deposited eggs in the pond. Fingerling pike 2.5-3.5 inches in length were found actively feeding on the recently hatched shrimps (McCarraher, 1959). The waters of the Big Alkali Lake drainage are slightly alkaline to alkaline (*p*H from 8.3-8.8).

The fathead minnow, *Pimephales promelas,* and the fairy shrimp, *B. lindahli,* were found in abundance in a 5-acre alkaline lake during the spring of 1961. The shrimps occurred as an immature population on 20 April and disappeared 25 May 1961. The water was distinctly alkaline, having 70.2% of the ionic composition in bicarbonates and monocarbonates. Other hydrochemistry data are given in Table 1. The permanency of this small lake depends directly on the groundwater table and runoff from nearby meadows. During cyclic dry years the lake will be completely dry. However, the alkali lake has contained a permanent water pool for the past ten years. Maximum

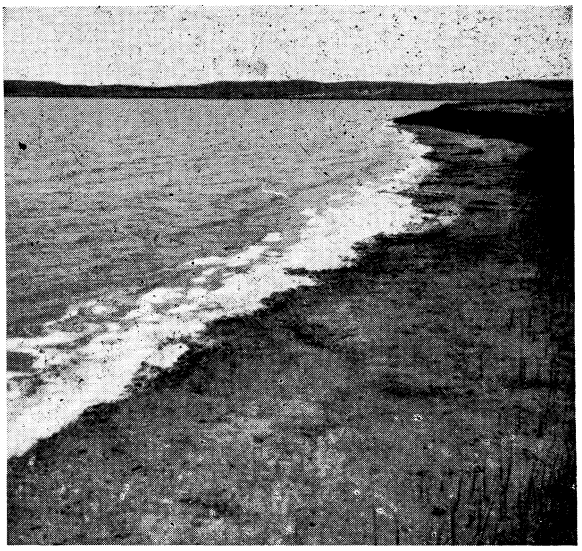

Fig. 3.—A permanent sandhill lake in Garden County where *Artemia salina* specimens were collected for the first time in 1962.

depth has been recorded at 4.5 ft. The water remains greenish and turbid throughout the year. The bottom is about 85% sand and 15% organic silt. Water level fluctuation normally varies from about 1.5 to 2.5 ft a year. *P. promelas* was introduced into the lake some years ago by the landowner in order to establish a bait-minnow source for fishing. This euryionic minnow is tolerant of alkaline environments and has been able to survive most years (McCarraher and Thomas, 1968).

Anostracan shrimp have been observed entering Watts Lake, a 230-acre sandhill lake in Cherry Co., from adjacent sloughs. Several phyllopods were collected during April 1959 in about 4 ft of water, some 100 ft from the Watts Lake shoreline. During the spring months the Watts Lake drainage sloughs produce not only phyllopods but young northern pike, *Esox lucius,* and yellow perch, *Perca flavescens.*

The occurrence of *C. bundyi* in ephemeral rearing ponds has been recorded at the Valentine State Fish Hatchery in Nebraska. The shrimps hatched, matured and died several days before pike fingerlings were able to utilize them for food. By delaying the filling of the ponds with water each spring it should be possible to regulate the shrimp hatch so that this forage will be available for the production of fish.

The notostracan, *Lepidurus couesii* (Packard), has been collected from the alkaline waters of Hudson Lake in Cherry Co. (*p*H 8.8-9.5). This is a 130-acre lake which annually varies in dissolved solutes in direct proportion to the amount of drainage flowing into the lake. The resident fish fauna consists of *P. promelas* and the Sacramento perch, *Archoplites interruptus. L. couesii* enters the lake during periods of drainage and is seldom encountered more than 50 ft from shore. The adjacent meadow pools where the shrimps hatch are an environment chemically less alkaline than the lake into which *L. couesii* enters during periods of high water. Chemical and physical differences between the two sites are manifest, with the lake about 72% higher in total solutes, and with total alkalinity between 400-750 ppm during the spring months.

Lynch (1966) describes the occurrence of the minnow, *Siphateles obesus* with notostraca and anostraca shrimp in Honey Lake, Washington. Johnson (1962) examined stomachs of 191 lake trout, *Salvelinus namaycush,* from Greiner Lake on Victoria Island, Northwest Territory, Canada, and found 33.5% contained *Lepidurus arcticus.* Although not found in trout stomachs, *Branchinecta paludosa* was also reported to be a common seasonal resident of the lake. Greiner Lake was described by Johnson as very slightly alkaline, having a total dissolved solid content of 156 ppm and a *p*H of 7.4.

Phyllopods are apparently common in lakes in the lower reaches of the Yenisei River, USSR. Zhadin and Gerd (1961) have established that the genera *Lepidurus* and *Branchipus* are important food items for the whitefishes, *Coregonus sardinella,* in the region.

The occurrence of the topsmelt, *Atherinops affinis,* in two of the Alviso salt ponds, California, together with *A. salina,* presented an

interesting relationship according to Carpelan (1957). *Atherinops,* although not surviving for an extended period, did feed on *Artemia* eggs, young and adults for brief periods of time. The average mean annual salinity for the two salt ponds was calculated at 6350 ppm and 9400 ppm. The *p*H was nearly constant at 8.1.

Along with shrimp collections in Nebraska sandhill lakes, the genera of other pond invertebrates were recorded. A copepod (*Diaptomus* sp.) was found in 78% of alkaline shrimp pools larger than 1.2 acres. Two cladocerans (*Bosmina* sp. and *Daphnia* sp.) were common to abundant in about 45% of all shrimp ponds examined. The occurrence of copepods and cladocerans in most alkaline pools coincided with the occurrence of fairy shrimp populations. Many ponds supported an abundant fauna of relatively few species of crustaceans, such as species of *Daphnia,* ostracods, *Diaptomus* and also culicid and ephydrid larvae.

Populations of *Diaptomus* in inland mineral waters of Saskatchewan were recorded by Rawson and Moore (1944) where copepods and brine shrimp, *A. salina,* occurred together in a salinity of 120,000 ppm in Little Manitou Lake. Associated with *Artemia* in the Nebraska carbonate lakes are *Ephydra* larvae. Large numbers of *Ephydra* larvae and adults inhabit the lake perimeters during the early autumn months when populations of *Artemia* have disappeared. This faunistic association is also common in many chloride and sulfate mineral waters (Zhadin and Gerd, 1961); (Rawson and Moore, 1944); (McDonald, 1966). Tendipedidae were collected from 88% of the Saskatchewan alkaline habitats in 1961 and constituted a large percentage of the bottom organisms. Gastropoda were present only in the more permanent pools of Nebraska. The dominant genera were *Lymnaea* and *Physa* which occurred with anostraca shrimp in ponds having total alkalinities below 3400 ppm.

REFERENCES

ANDERSON, G. C. 1958. Some limnological features of a shallow saline meromictic lake. *Limnol. Oceanog.,* **3**(3):259-269.

CARPELAN, L. H. 1957. Hydrobiology of the Alviso salt ponds. *Ecology,* **38**:376-390.

JOHNSON, LIONEL. 1962. The relict fauna of Greiner Lake, Victoria Island, N. W. T., Canada. *J. Fish Res. Bd. of Canada,* **19**(6):1105.

LYNCH, J. E. 1958. *Branchinecta cornigera,* a new species of anostracan phyllopod from the state of Washington. *Proc. U.S. Nat. Mus.,* **108**(3342): 34-36.

———. 1960. The fairy shrimp *Branchinecta campestris* from northwestern United States. *Ibid.,* **112**(3347):559-560.

———. 1964. Packard's and Pearse's species of *Branchinecta:* analysis of nomenclatural involvement. *Amer. Midl. Natur.,* **71**(2):466-488.

———. 1966. *Lepidurus lemmoni* Holmes: A redescription with notes on variation and distribution. *Trans. Amer. Microsc. Soc.,* **85**(2):181-192.

MCCARRAHER, D. B. 1959. Phyllopod shrimp populations of the Big Alkali Lake drainage, Nebraska, and their relationship to young pike *Esox lucius. Amer. Midl. Natur.,* **61**(2):509-510.

———. 1961. Sandhill lakes survey. Job Completion Report F4R. 89.
——— AND R. THOMAS. 1968. Some ecological observations on the fathead minnow, *Pimephales promelas,* in the alkaline waters of Nebraska. *Trans. Amer. Fish. Soc.,* **97**(1):52-55.
MCDONALD, D. B. 1956. The effects of pollution upon Great Salt Lake, Utah. M. S. Thesis abstract, Univ. of Utah.
MOORE, W. G. 1958. On the occurrence of *Streptocephalus similis* in Mexico and the United States. *J. Wash. Acad. Sci.,* **48**(5):169-175.
PENNAK, R. W. 1953. Fresh-water invertebrates of the United States. Ronald Press Company, New York. 769 p.
RAWSON, D. S. AND J. E. MOORE. 1944. The saline lakes of Saskatchewan. *Can. J. Res.,* **22**:141-201.
WURTZ, A. G. AND H. C. J. SIMPSON. 1964. Limnological survey of Lake Rudolph (British East Africa). *Verhand Proc., Travaux,* **XV**(1):149.
ZHADIN, V. I. AND S. V. GERD. 1961. Fauna and flora of the rivers, lakes and reservoirs of the USSR. 626 p.

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