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THE PLANKTON OF THE BEAR RIVER MIGRATORY WATERFOWL REFUGE, UTAH
SEASONAL DISTRIBUTION OF ORGANISMS

A Thesis

Presented to

The Committee on Graduate Work
Utah State Agricultural College

In Partial Fulfillment

of the requirements for the Degree
Master of Science in the School of

Agriculture

Department of Botany

By

George Piranian

May 1937

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1. Introduction

In the summer of 1932, an investigation of some biological, physical, and chemical conditions at the Bear River Migratory Waterfowl Refuge, Utah, was begun at the Utah State Agricultural College to determine some of the factors governing the biological productivity of brackish-water marshes. Unfortunately, lack of funds made it impossible to continue work beyond the first season.

In 1936, the Wild Life Experiment Station at the Utah State Agricultural College appropriated a fund for a cooperative project between the Station and the Department of Botany at the same institution. This project, planned to be continued by various graduate fellows over a period of several years, is an investigation of conditions existing at the Bear River Refuge and at some newer refuges of similar character.

It was believed that the micro-biota of the water at the Refuge is of importance in the study of general conditions, and consequently provisions were made to determine what organisms, exclusive of bacteria, compose the microscopic population of the waters at the Refuge, and what their seasonal and geographical distribution within the area is. This paper is a report on this particular phase of the investigation.

Acknowledgments are due to Dr. D.I. Baasmussen, who made the project possible by procuring the necessary financial support, to Professor Bassett Maguire, who directed the study, and to the personnel of the United States Biological Survey at the Bear River Refuge, who generously provided laboratory space, boats, and living quarters during periods of field activity.

2. Literature

No monograph of the aquatic microflora of the Western United States is available, but analyses have been published of the biota of single bodies of water and of the organisms of one or more taxonomic order occurring within one state by Fordyce⁹, Peares¹⁷, Elmore⁷, Maguire¹⁵), Edmondson⁵, Jewell¹², and Hanna and Grant¹⁰. The last three papers cited deal with the biota of alkaline waters. Two papers, one by Daniels⁵, and one by Patrick¹⁶, concerning the biota of Great Salt Lake in particular have come to the writers attention.

In 1923, Kennerer, Boverd, and Boorman¹⁴ gave an account of general investigations in northwestern lakes.

In 1924, Clark⁴ published a monograph on the mineral contents of various waters. His paper includes data concerning Great Salt Lake and its tributaries.

Methods of collecting and preserving plankton are discussed by Reighard in Ward and Whipple²³. Reighard describes the tow net, the cone dredge, the quantitative plankton net, three plankton pumps, methods of collecting nanno-plankton, and methods of making plankton-counts.

3. Description of the Area Studied

(a) Location and topography. The Bear River Migratory Waterfowl Refuge was created in 1928 by Act of Congress to further the conservation of North American waterfowl. The Refuge occupies a roughly semi-circular area of 64200 acres at the extreme end of the Bear River delta in Boxelder County, Utah. This area is so nearly level that the one-foot contour lines

*) This report included a qualitative and quantitative analysis of over four hundred plankton samples. These analyses constituted a major portion of the present writer's undergraduate work.

are generally between one and three miles apart, and consequently dikes of relatively small height suffice to impound water over nearly the entire refuge.

(b) Water supply. The source of water is the Bear River. In spring, there are generally two periods of maximum fresh water: first, when the tributaries to Bear River below Cutler Dam are high with the water of newly melted snow, and again during May and early June, when the snow melts in the higher portions of the water shed. Between the middle of June and early October, the river is diverted for irrigation, and no water reaches the refuge, except a relatively small amount of seepage and water from small tributaries below Cutler Dam. During this time, evaporation lowers the water level approximately one foot, and in some regions the soil is exposed and dries out.

In October, fresh water becomes available again until freezing temperatures set in. No consistent policy has hitherto been followed after ice formation occurs: during some winters, the water has been kept in the units until spring; during others, the entire area has been drained to prevent damage done to the dikes and spill-boxes when the ice breaks.

(c) Vegetation. According to individuals who have long been acquainted with the area, Distichlis spicata, Scirpus acutus, E. paludosus, Typha latifolia, Potamogeton pectinatus, Ruppia maritima, and Chara sp. occurred near the river channels at the time when construction began, while large portions of the area were barren salt flats. Since completion of the dikes in 1931, some of these previous salt flats have developed a cover of Chara, Ruppia, or Potamogeton.

4. Methods

To prevent excessive expenditure of time and money for transportation, the investigation was limited to three of the five units composing the Bear River Refuge. From six to twelve quadrates were established in each of these three units; seven additional stations were established at spill-boxes, and one at the gates near headquarters. Since the study reported in this paper is merely one phase of a broader project, it was impossible to base the choice of sites for stations on expediency in plankton investigation.

Beginning July, 1936, the stations were visited, at intervals of a few weeks, for the work pertaining to the general program which need not be discussed in this paper. Observations were continued until winter temperatures made field activities prohibitively difficult; in April, 1937, work was resumed.

At the time of each visit to the stations within the units, plankton samples were taken, where possible, by drawing a No. 20 silk bolting Wisconsin plankton net horizontally through the water; at the spill-boxes and near headquarters, samples were taken by holding the net in the path of the water for several minutes. No attempt was made to obtain rigorously quantitative data concerning plankton, and the length of the hauls was somewhat variable; generally, it was of the magnitude of a hundred feet. Since the diameter of the net constituted an appreciable fraction of the depth of the water, a plankton pump would have been necessary to obtain data concerning the vertical distribution of the organisms. In some cases, insufficient depth of the water made it impossible to take plankton hauls; in four of the thirty-three stations, samples could never be taken. In the fall,

temperatures far below freezing prevented the taking of samples without damaging the plankton net.

No work was done with the nanno-plankton.

The organisms were preserved in formaldehyde and kept until the winter months when they were examined and the species listed for each station and date of collection. Limited time, experience, equipment, and literature made it impossible to identify all organisms specifically. Representative samples from the collection have been sent to specialists and verifications of identifications are now pending.

The occurrences of each species were recorded, in chronological order of the collections, on index cards. No attempt was made to estimate the absolute frequency of the organisms, but for each collection, each species present was classed as rare, frequent, common, or abundant.

For the study of geographical distribution, a table was prepared to show the relative frequency, at each of the stations, of the seventy most abundant organisms. The discussion (in section 6. of this paper) of seasonal and geographical distribution is based on a study of the index cards and this table.

List I is based on identifications by means of the following publications:

- Smith^{17, 18} (algae in general, incl. flagellates)
- Tilden²⁰ (blue green algae)
- Taylor¹⁹ (Anabaenopsis)
- Boyer¹ (diatoms)
- Ward and Whipple²² (Protozoa, Cladocera, Copepoda)

Leidy¹³ (Rhizopoda)

Herrick and Turner¹¹ (Cladocera and Copepoda)

Eyferth--Schoenichen⁸ (rotifers)

List II was prepared by Dr. Frank J. Myers of Ventnor, N.J., who was kind enough to examine eleven samples. In Dr. Myers' list, the discarded synonyms are given in parentheses. In the writer's own list, the organisms are designated by the names current in less up-to-date literature, since the author found himself unable, in many cases, to establish the relationship between the organisms seen by him and the names listed by Dr. Myers.

An artificial key to the common green and blue-green algae, to the Copepoda, and to the Cladocera collected will be found in the appendix.

5. Results

List I

Organisms collected at the Bear River Refuge, Utah*)

(A) Cyanophyceae

1. *Anabaena variabilis* Kuetz.
Only one record; July.
2. *Anabaena*.
Very rare, July.
3. *Anabaenopsis Arnoldii* Aptek fa. (Philippine form)
Common in August-October; rare in Nov.; does not occur in shallow stations of Units 1 and 2.
4. *Aphanocapsa*.
Very rare; July, Sept. in unit 2.
5. *Aphanothece*.
Very rare in Clear Lake, May.
6. *Calothrix* sp.
Rare, July.
7. *Chroococcus*.
Rare, July.
8. *Gloetrichia natans* (Hedw.) Rab.
Common July-August; akimetes occur throughout the season.

*) Where no specific name follows a generic name in this list, the expression "sp." indicates that the organisms probably belong to one species, and "sp.", that they belong to two or more species, while the simultaneous absence of both expressions indicates that the author does not know whether he is dealing with one or with several species of the genus.

9. *Lyngbya*.
Very rare.
10. *Oscillatoria* spp. (sensus lato).
Frequent throughout the season, becoming increasingly abundant towards fall.
11. *Merismopedia*. sp.
Only one record; August.
12. *Microcoleus lacustris* (Nab.) Farlow.
Only one record; July.
13. *Nodularia Harveyana* (Thwaites) Thuret.
Frequent, July-September.
14. *Nodularia sphaerocarpa* Bornet & Flahault.
Only one record; July; on soil; water highly alkaline (620 p.p.m. Ca CO₃), chloride concentration 0.049 M, Oxygen 3 p.p.m.
15. *Nostoc*. sp.
Frequent at one station; July.
16. *Spirulina major* Kuets.
Very rare.

(B) Bacillariaceae

17. *Amphora coffaeiformis* (Ag.) Kuets.
Only one record.
18. *Amphora ovalis* Kuets.
Rare, mostly in Unit 2.
19. *Amphiprora*. spp.
Frequent throughout season, especially July, Sept. and October.
20. *Asterionella formosa* Hass.
Rare; Sept. and Nov.
21. *Biddulphia levis* Ehr.
Very rare, November, May, April; specimens observed in spring are not fossil.
22. *Campylodiscus hibernicus* Ehr.
Rare, July, Aug., Nov., May. Clear Lake in May, August.
23. *Chaetoceros*. sp.
Frequent in August; nearly all records from Unit 2.
24. *Cocconeis*. sp.
Rare, mostly in Unit 1. Clear Lake in May.
25. *Cyclotella*.
Frequent throughout season, mostly in Unit 2.
26. *Cymatopleura elliptica* (Breb.) W. Smith.
Rare; throughout season.
27. *Cymatopleura solea* (Breb.) W. Smith.
Rare; Nov., April, May.
28. *Cymbella* spp.
Frequent throughout season, except while vegetation is scarce. Clear Lake, in May.
29. *Diatoma hiemale* (Lyngb.) Heiberg.
Frequent in Clear Lake, May.
30. *Diatoma vulgare* Bory
Rare, Nov., April, May; Clear Lake, in August.
31. *Epithemia argus* (Ehr.) Kuets.
Only one record, July.

32. *Epithemia sorax* Kuetz.
Only two records; July.
33. *Epithemia turgida* (Ehr.) Kuetz.
Rare, throughout season.
34. *Epithemia zebra* Kuetz.
Rare, throughout season; only one record from Unit 3.
35. *Fragilaria* sp.
Rare; April, May. Abundant in Clear Lake; May, Aug.
36. *Comphonema* spp.
Frequent, July-August
37. *Nentzschia amphioxys* (Ehr.) Grun.
Very rare.
38. *Nastogloia Smithii* Thw. Var. ?
Very rare.
39. *Melosira*
Rare, throughout the season, sporadically frequent in May.
40. *Navicula* sp. (sensus lato)
Rare, throughout the season.
41. *Nitzschia* spp.
Rare, through the season.
42. *Pleurosigma* sp.
Frequent throughout season, esp. Aug., Oct.
43. *Rhoicosphenia curvata* (Kuetz.) Grun.
Very rare.
44. *Rhopalodia gibba* (Ehr.) O. Muell.
Very Rare.
45. *Rhopalodia ventricosa* (Kuetz.) O. Muell.
Frequent throughout the season.
46. *Scelionleura peisonis* Grun.
Frequent in Unit 1 and in northwest portion of Unit 2.
47. *Surirella Baileysana* MacKay.
Common throughout Refuge, occurs in 80% of the collections.
48. *Surirella ovata* Kuetz.
Frequent throughout the Refuge.
49. *Surirella* spp.
Rare.
50. *Synedra* spp.
Frequent throughout the Refuge
51. *Terpeinoe musica* Ehr.
One specimen seen, May.
52. *Tetracyclus lacustris* Ralfs.
Rare in Clear Lake, August.

(c) Chlorophyceae

53. *Bulbochaeta* sp.
Very rare, July.
54. *Cladophora*.
Frequent as pioneer on barren areas.
55. *Closterium* sp.
Very rare.

56. *Cosmarium* spp.
Frequent in July; rare in August.
57. *Eudorina elegans* Ehr.
Occasionally present throughout season; sporadically frequent in spring.
58. *Mougeotia* sp.
Rare, Clear Lake in May.
59. *Cedogonium* spp.
Frequent July, Sept. present throughout season.
60. *Pandorina morum* Bory
Frequent; July, August.
61. *Pediastrum Boryanum* (Turp.) Menegh.
Frequent throughout the season.
62. *Pediastrum duplex* Meyen.
Frequent in November, rare in May.
63. *Pediastrum duplex* Meyen var. *clathratum* (A. Brown) Lagerh.
Frequent throughout season, except very rare July and August.
64. *Pediastrum duplex* Meyen var. *gracillimum* V. & G.S. West.
Rare, July-August.
65. *Pediastrum duplex* Meyen var. *reticulatum* Lagerheim.
Common throughout season, except in west-end of Unit I, and during September and early October, when this variety was not found at all.
66. *Pediastrum integrum* Naegeli.
Rare. October, November, all collections from Unit 3.
67. *Pediastrum tetras* (Ehr.) Ralfs.
Only one record, July.
68. *Scenedesmus bijuga* (Turp.) Lagerh.
Very rare.
69. *Scenedesmus dimorphus* (Turp.) Kuetz.
Only one record.
70. *Scenedesmus quadricauda* (Turp.) DeBreb.
Rare, occurring through the season.
71. *Scenedesmus* sp.
Very rare.
72. *Schroederia* sp. ?
Rare, mostly in Sept.-Oct.
73. *Spyrogyra*.
Rare; common in Clear Lake; May, August.
74. *Staurastrum* sp.
Very rare, Aug.-Nov.
75. *Stigeoclonium* sp.
Abundant on wooden stake, July.
76. *Ulothrix* sp.
Rare, Nov., May.
77. *Volvox* sp.
One specimen seen, May.

(D) Protozoa.

78. *Ceratium hirundinella* (O.F.M.) Schrank.
Very rare, Oct., Nov., early spring.
79. *Derepoxis* ?
Attached to *Marshia* only, rare.

80. *Diffugia* ?
Very rare, throughout Refuge in November, April, May.
81. *Dinobryon sertularia* Ehr.
Very rare, Oct.-Nov., May.
82. *Euglena* sp.
Rare in spring and fall, sporadically abundant in summer,
forming green or red blooms.
83. *Glenodinium* ?
Very rare; October
84. *Peridinium*.
Very rare; October, April; Clear Lake in August.
85. *Centropyxis aculeata* Stein.
Rare; July, Nov.
86. *Vorticella*.
Only two records.

(2) *Rotatoria*.

87. *Anuraea aculeata* Ehr.
Present throughout season; very abundant Sept., Nov.,
especially in regions distant from headquarters.
88. *Anuraea cochlearis* Gosse.
Frequent throughout season.
89. *Arthroglena Lustkeni*? Bergdl.
Only one record.
90. *Asplanchna* spp.
Rare.
91. *Brachionus Bakeri* var. ?
Very rare.
92. *Brachionus pala amphiceros* Ehr.
Frequent, except in Unit. 1.
93. *Brachionus pala* var. ?
Frequent; spring, until July.
94. *Brachionus urceolaris* O. F. Muell.
Common July-Oct.; occurs in Clear Lake.
95. *Brachionus* spp.
Frequent, July-Oct.
96. *Cathypna luna* Ehr.
Frequent, May-Aug.
97. *Cathypna unguolata* Gosse.
Only one record.
98. *Colurus leptus* Gosse.
Rare; July, Sept.
99. *Distyla* sp.
Only one record.
100. *Euchlanis* spp.
Very rare; spring and summer.
101. *Parcularia forficula* ? Ehr.
Only one record.
102. *Lepadella acuminata* (Ehr.)
Only one record.
103. *Lepadella patella* (O.F.M.)
Frequent; July-August.

104. *Lepadella* sp.
Rare.
105. *Monostyla lunaris* Ehr.
Only one record.
106. *Monostyla quadridentata* Ehr.
Common; July - Aug.
107. *Monostyla* spp.
Common; July- Sept.
108. *Noteus militaris* Ehr.
Common; July, August; frequent in May; perhaps sensitive to salts.
109. *Notholca striata* Ehr.
Common; April
110. *Notholca striata acuminata* Ehr.
Abundant, Oct.- Nov.; common, April- May.
111. *Notommatia* spp.
Rare.
112. *Pedalion* sp.
Common, July- Sept. Very rare. Oct., Nov., May.
Clear Lake in August.
113. *Polyarthra platyptera* Ehr.
Common July, Aug. frequent Oct., Nov., April-May.
Clear Lake, in August.
114. *Rattulus*.
Frequent in August.
115. *Salpina brevispina* Ehr.
Very rare.
116. *Salpina ventralis* Ehr.
Very rare.
117. *Synchaeta* spp.
Common; Oct., Nov.
118. *Triarthra longiseta* Ehr.
Common July- Sept. Very rare October, Nov., April, May.

(F) Cladocera.

119. *Alona costata* Sars.
Sporadically frequent throughout the season.
120. *Bosmina*.
Rare throughout season. Unit 2 and west end of Unit 3.
121. *Ceriodobbia* sp.
Very rare.
122. *Chydorus sphaericus* (O.F.M.)
Rare; July, Aug., May. Clear Lake in May.
123. *Daphnia longispina* (O.F.M.)
Rare; July, Nov., May.
124. *Diaphanosoma brachyurum* (Lieven)
Frequent; second half of July.
125. *Diaphanosoma Leuchtenbergianum* Fischer.
Only one record; July.
126. *Dunhevedia setigera* (Birge).
Very rare; July.
127. *Kursia latissima* (Kurz).
Only one record; April

128. *Latonopsis* sp.
Rare.
129. *Leydigia quadrangularis* (Leydig).
One record; Nov., 1932.
130. *Macrothrix laticornis* (Jurine).
Rare; Nov., May.
131. *Macrothrix rosea* (Jurine).
Very rare; July.
132. *Moine affinis* Birge.
Common; May; abundant in shallow water, east end of
Unit 3.
133. *Pleuroxus*.
Very rare.
134. *Simocephalus*.
Very rare.

(c) Copepoda.

135. *Canthocamptus* sp.
One specimen seen; May.
136. *Cyclops phaleratus* Koch.
Frequent at one station; July.
137. *Cyclops serrulatus* Fischer.
Sporadically frequent July, Aug., April, May. Clear Lake
in May.
138. *Cyclops signatus* Koch.
Only one record; Nov., 1932
139. *Cyclops viridis* Jurine.
Abundant in spring; this species is probably responsible
for most of the records of unidentified *Cyclops*.
140. *Cyclops* spp.
Frequent throughout the season.
141. *Diaptomus Judeyi* March.*)
Common throughout the season; very abundant west end of
Unit 1 in Nov.; probably the organism of most or all the
unidentified *Diaptomus*.
142. *Diaptomus novamexicanus* Herrick.
Frequent at one station; July.
143. *Diaptomus nudus* Marsh.
Frequent at one station, August.
144. *Diaptomus sicilis* Forbes.
Only one specimen, May.
145. *Diaptomus signicauda?* Lilljeborg.
Only one record, November.
146. *Diaptomus* spp.
147. *Marshallia albuquerquensis* Herrick
Rare throughout season, but frequent in most collections
from Unit 1, Quad. 1, and from spill-box 3-4/3. Females
bearing ovisacs in May.
148. *Marshallia brevicaudata* Herrick.
Rare in August, frequent in May. Not recorded from Unit 1,
Clear Lake in May.

*) Identification confirmed by Dr. Charles E. Wilson of Westfield, Mass.

(H) Miscellaneous.

149. *Chaetonotus enormis* ? Stokes.
One record only.
150. Ostracoda.
Frequent in shallow water throughout the season.
151. Phyllopora (*Anostraca*).
Two females collected in Unit 1, Station 1, April.
152. Nematodes.
Present throughout season; frequent in spring.
153. *Tribonema* sp. ?
Present October-November; rare in May.

LIST II

Rotifers identified by Dr. F.J. Myers

1. *Asplanchna seiboldi* Leydig.
2. *Asplanchna silvestrii* Daday.
3. *Asplanchnopus hyalinus* Harring.
4. *Asplanchnopus multiceps* (Schrank).
(*Asplanchnopus myrmeleo*)
5. *Brachionus angularis* Gosse.
6. *Brachionus calyciflorus amphiceros* Ehrenberg.
(*Brachionus amphiceros*)
7. *Brachionus angularis caudatus* (Barrios and Daday).
8. *Brachionus budapestinensis* Daday.
9. *Brachionus capsuliflorus entzii* (France).
(*B. bakerii entzii*)
10. *Brachionus patulus* Mueller.
(*Brachionus militaris*)
11. *Brachionus plicatilis* Mueller.
(*B. muellerii*)
12. *Brachionus urceus* Linnaeus.
(*B. urceolaris*)
13. *Cephalodella gibba* (Ehrenberg).
(*Diaschiza gibba*)
14. *Dicranophorus forcipatus* (Mueller).
(*Diglena forcipata*)

15. *Diurella brachyura* Gosse.
16. *Diurella dixon-nuttalli* Jennings.
17. *Diurella Tigris* (Mueller).
18. *Euchlanis dilatata* Ehrenberg.
19. *Euchlanis pyriformis* Gosse.
20. *Filinia longiseta* (Ehrenberg).
(*Triarthra longiseta*)
21. *Eosphora ehrenbergi* (Ehrenberg).
22. *Keratella cochlearis* Gosse.
(*Anuraea cochlearis*)
23. *Keratella cochlearis* v. *tecta* (Lauterborn).
(*Anuraea tecta*)
24. *Keratella quadrata* f. *divergens* (Voight).
(*Anuraea aculeata divergens*)
25. *Keratella valga* (Ehrenberg).
(*Anuraea valga*)
26. *Keratella valga* f. *brehmi* Klausner
27. *Keratella valga* f. *monstrosa* (Apstein-Barrios and Daday).
28. *Lecane luna* (Mueller).
(*Cathypna luna*).
29. *Lepadella patella* (Mueller).
(*Metopidia patella*).
30. *Monostyla bulla* Gosse.
31. *Monostyla closterocerca* Schmarda.
32. *Monostyla cornuta* (Mueller).
33. *Monostyla quadridentata* Ehrenberg.
34. *Monostyla thalera* Harring and Myers.
35. *Mytilina ventralis* (Ehrenberg).
(*Salpina ventralis*)
36. *Notholca striata* (Mueller)
37. *Notholca striata acuminata* (Ehrenberg).
(*Notholca acuminata*)
38. *Polyarthra trigla* Ehrenberg.
(*Polyarthra platyptera*)

39. *Pleurotrocha petromyzon* Ehrenberg.
40. *Pedalia fennica* v. *oxyrus* (Sernov).
(*Pedalion oxyure*)
41. *Rotaria rotatoria* Pallas.
(*Rotifer vulgaris*)
42. *Synchaeta littoralis* Rousselet
43. *Synchaeta pectinata* Ehrenberg.
44. *Synchaeta tremula* (Mueller).
45. *Testudinella patina* (Hermann).
(*Pterodina patina*)
46. *Testudinella patina intermedia* (Anderson).
(*Pterodina intermedia*)
47. *Trichocerca cristata* Harring.
(*Rattulus carinatus*)
48. *Trichocerca pusilla* (Jennings).
(*Rattulus pusillus*)

Chemistry

The following data concerning the chemistry of the water are included for the sake of interest; the methods by which they were obtained will be reported in a later account. Correlation between data on chemistry and data on plankton must necessarily await the collection of further information.

The water at the Bear River Refuge generally has a pH of 8.0 or higher, except in a few places where aquatic vegetation is scarce and the alkalinity high. The highest pH recorded with assurance of accuracy is 10.1; other data lead the author to believe, however, that the pH often approaches and sometimes reaches 11. The pH is highest during periods of photosynthetic activity.

At headquarters, the total alkalinity varies between 268 and 317 parts per million, expressed as calcium carbonate. Within the units it varies between 100 and 400 parts per million, except in very shallow water of high salt content. Low alkalinity is generally associated with dense vegetation, high pH, and high oxygen concentration.

The alkalinity to phenolphthalein varies between zero and 79 parts per million. In general, the higher the total alkalinity, the lower is the alkalinity to phenolphthalein.

The chloride concentration varies between 0.005 N and 0.2 N, although, in exceptional cases, a concentration of 1 N may be approached.

The alkalinity, pH, and salinity relationships are in accordance with the findings of Buehrer and Williams³ and of Breazeale², whose experiments indicate that the presence of chlorides increases the solubility of calcium carbonate, but decreases the extent of its hydrolysis.

The oxygen concentration in the surface water is usually near saturation or higher. The temperature of the water seldom exceeds 27° C. The maximum recorded is 35° C.

6. Discussion

It is of interest to note that the following organisms, which the writer has found to be common in this geographical region, were seldom, or not at all, found at the Bear River Refuge: Conochilus unicornis, Notholca longispina, Daphnia longispina, D. pulex, Coelosphaerium spp., Anabanto-menon flos-aquae, Dinobryon spp., Tabellaria spp., Fragilaria spp., Asterionella formosa, Rhopalodia gibba (replaced at the Bear River Refuge by R. ventricosa), Cosmarium spp., Staurastrum spp., and Ceratium hirundinella.

The following organisms are more or less peculiar to the refuge: Anabaenopsis Arnoldii, Biddulphia levis, Chaetoceros sp., Cyclotella, Scolionleura neisonis, Surirella Baileyana, S. ovata. Biddulphia levis is typical of inland salt waters. Chaetoceros is a marine genus; one fresh water species is reported from Devil's Lake, North Dakota (Elmore). Scolionleura neisonis, according to Boyer,¹ is peculiar to salt lakes.

A few species occur commonly throughout most or all of the season, as, for example, Surirella Baileyana, S. ovata, and Amurea cochlearis. Most species, however, exhibit more or less marked periodicity, as Anabaenopsis Arnoldii (common in August and October; rare in November; not observed at other times), Nodularia Harveyana (frequent in July and September), and Cathynna luna (frequent in May and August). Amurea aculeata and Marisia albuquerquensis occur throughout the season, but show a marked increase in number, the first as the temperature drops below 20° C. in fall, the latter in spring. The abundance of Gloeotrichia natans

C. Key to the Copepoda common at
the Bear River Refuge

1. Separation into cephalothorax and abdomen distinct ---- 4
1. Separation into cephalothorax and abdomen indistinct -- 2
 2. Antennae of 8 segments -----Seathocamptus
 2. Antennae of 6 segments ----- Marshallia 3
3. Caudal setae fused at base -----M. albuquerquensis
3. Caudal setae not fused at base -----M. brevicaudata
 4. Antennae of 24 or 25 segments ----- Diantoma
 4. Antennae of 17 or fewer segments ----- Cycolona 5
5. Antennae of 17 segments; furcae without row of spines--C. viridis
5. Antennae of 12 segments; furcae externally with a
fine row of spines -----C. serrulatus

coincides with the presence of aquatic vegetation, which serves as mechanical support, and with high temperatures. The ekinetes of this species are well distributed throughout the refuge at all times.

Pedalion sp., very common in late July, was not collected within the refuge earlier than May 16, (temperature 29°C.), nor later than October 4 (temperature 17°C.). One later occurrence at the head gates is recorded for this species (November 1, temperature 8°C.). Notolca striata acuminata made its appearance on September 22 (temperature 22°C. at time of collection, 3 p.m.; average temperatures on that day well below 20°C.), one week before the autumnal fresh water supply was available. It is of interest to note that, as the season progressed, this rotifer approached more and more a form intermediate between the variety and N. striata proper.

The seasonal and geographical distribution of Notona militaris is worthy of particular attention. Only once was this species collected in Unit 3 (chloride concentration 0.031N), and once in Unit 1 (chlorides 0.044N). From Unit 2, the organism was recorded nine times. All but one of these collections had been from water with a chloride concentration of 0.031 N or less. At the exceptional station, the chloride concentration had risen from 0.008 N on July 24 to 0.073 N on August 22. On July 24, Notona militaris had been very numerous; a few individuals were still present on August 22. It should be worth while to study the behavior of this organism, since it is easily recognized and may, therefore, be a useful indicator in the study of brackish inland waters.

Diantonus Judayi is rare in the spring and summer. During October, its number experiences a very remarkable increase. On October 25, the

author, visiting an area in the northeast portion of unit 1 (depth 9 inches, temperature 13.5°C, chloride concentration 0.083 M), estimated the frequency of this organism to be of the order of magnitude of fifty individuals per liter of water.

The fact that the micro-biota of the Bear River Refuge is an aggregate developing within the area and is not merely "washed down" by the river is evident from the differences between collections from the river at headquarters and collections from the other stations. Asterionella formosa occurs more commonly near headquarters than at any other station. Surirella Baileyana, E. ovata, and Brachionus ucaolaris are absent from headquarters at times when they occur within the refuge. The following organisms were never observed at headquarters, although collections were made at such times that, should the organisms originate before the waters enter the refuge, they could not have escaped attention: Anabaenopsis Arnoldii, Modularia Harveyana, Compyodiscus hibernicus, Gomphonema, Rhopalodia ventricosa, Scolionleura neisonis, Galyona luna, Alona costata, and Marshia albuquerquensis.

Most species that occur with any degree of frequency were found throughout the area studied. A remarkable exception is Anabaenopsis Arnoldii, which, being very common over a period of several weeks, was never collected at certain stations.

Excepting the gates at headquarters, no single station or group of stations can be set apart as different from the others in the qualitative composition of its plankton with respect to more than one species. Species that are recorded as rare, however, are more likely to occur in the central and eastern portion of Unit 2 and in the west end of Unit 3 than elsewhere.

This indicates that most of the common organisms at the Bear River Refuge are able to succeed under a wide range of conditions, but that the environment presents threshold values of salinity or alkalinity to the rarer organisms. Evidence for this is also offered by the facts that many of the organisms rare at the Refuge are common in other waters of the geographical region, and that the areas noted for absence of the rarer species also show a poor cover of aquatic vegetation.

7. Summary and Conclusions

The answer to the question "What are the microscopic organisms occurring at the Bear River Refuge?" cannot well be given in a form more condensed than that of Lists I and II on pages 8 and 15, resp. The following statements merely present a summary of additional facts determined more or less incidentally, during the course of the investigation.

1. Collections of plankton taken at different times of the year at the Bear River Migratory Waterfowl Refuge were analyzed.
2. The distribution of the common plankton organisms at the Bear River Refuge is nearly homogeneous.
3. Some of the organisms collected are brackish-water species.
4. Some species occur throughout the season, others during a more or less limited period of time.
5. The presence of the rotifer Rotaria militaris in waters of the Bear River Refuge indicates that the chloride concentration of the water is probably below 0.05 N.
6. The plankton at the Bear River Refuge is qualitatively different from that of Bear River.

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Appendix

A. Key to the green and blue-green algae common
at the Bear River Refuge.

1. Cells with nuclei and plastids ----- Chlorophyceae 3
1. Cells without nucleus and plastids: color often
bluish-green ----- Cyanophyceae 2
 2. Filaments without heterocysts, cells cylindrical or disc-shaped ----- Oscillatoria
 2. Filaments tapering, with heterocysts at one end ----- Gloetrichia
 2. Filaments more or less straight, with intercalary heterocysts ----- Nodularia
 2. Filaments in circles or spirals, with one heterocyst at each end ----- Anabaenopsis
3. Single-celled ----- 9
3. Colonial ----- 6
3. Filamentous ----- 4
 4. Filaments branched ----- Gladophora
 4. Filaments simple ----- 5
5. Chloroplasts one to several spiral bands ----- Scenedesmus
5. Chloroplast reticular ----- Scolecium
 6. Cells 16 or more, in motile spherical colonies 8
 6. Cells four or eight, not forming a circular plate ----- Scenedesmus
 6. Cells usually 16 or more, forming a circular plate ----- Pediastrum 7
7. Plate entire ----- P. horvathii
7. Plate perforate ----- P. duplex
The segregation of this species into varieties depends on the size of the perforations: see Smith¹⁸.

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|---|--------------------|----|
| 8. Cells angular by mutual compression ----- | <u>Pandorina</u> | |
| 8. Cells spherical ----- | <u>Eudorina</u> | |
| 9. Cells arcuate, without constriction ----- | <u>Closterium</u> | |
| 9. Cells with constriction separating two symmetrical
semi-cells ----- | | 10 |
| 10. Semi-cells with processes ----- | <u>Staurastrum</u> | |
| 10. Semi-cells without processes ----- | <u>Coenacium</u> | |

B. Key to the Cladocera
collected at the Bear River Refuge

1. Both rami of the antenna 3-jointed ----- 5
1. Dorsal ramus of the antenna 4-jointed, ventral ramus
3-jointed ----- 3
 2. Abdominal claw with 3 spines ----- Leptanopsis
 2. Abdominal claw without spines ----- Bosmina
3. Shell with long terminal spine ----- Raphnia
3. Shell without long terminal spine ----- 5
 4. Antennules large, fixed. Valves with short
spine at lower posterior corner. ----- Bosmina
 4. Antennules small; if large, attached at ventral
side of head, freely movable ----- 5
5. Antennules small, covered by rostrum ----- Simoccephalus
5. Antennules small, not covered by rostrum; head
small, conspicuously depressed ----- Ceriodanobia
5. Antennules large, freely movable ----- Moine
 6. Post-abdomen straight and narrow; claws
with secondary tooth in middle ----- Kurzia
 6. Post-abdomen broad, with clusters of large
spines ----- Lepidocia
 6. Post-abdomen otherwise ----- 7
7. Animal circular in outline ----- Chydorus
7. Animal more or less elongate in outline ----- 8
 8. Rostrum exceeding the antennules markedly, claw
with two basal spines ----- Pleuroxus
 8. Rostrum not exceeding the antennules markedly-- 9
9. Valves with spine anterior to lower posterior corner Dunheviadia
9. Valves without such spine ----- Alopa

C. Key to the Copepoda common at
the Bear River Refuge

1. Separation into cephalothorax and abdomen distinct ---- 4
1. Separation into cephalothorax and abdomen indistinct -- 2
 2. Antennae of 6 segments ----- Caathocamptus
 2. Antennae of 6 segments ----- Marshia 3
3. Caudal setae fused at base ----- M. albuquerqueensis
3. Caudal setae not fused at base ----- M. brevicaudata
 4. Antennae of 24 or 25 segments ----- Diatomus
 4. Antennae of 17 or fewer segments ----- Cyclone 5
5. Antennae of 17 segments; furcae without row of spines-- C. viridis
5. Antennae of 12 segments; furcae externally with a
fine row of spines ----- C. serrulatus