THE DISTRIBUTION OF TWO SPECIES OF *CENOCORIXA* IN INLAND SALINE LAKES OF BRITISH COLUMBIA

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ABSTRACT

The distribution of **Cenocorixa bifida** (Hung.) and **C. expleta** (Uhler) in British Columbia is summarized. The distribution pattern in a series of inland saline lakes in the central interior of the Province is described. All water bodies are in the flight range of the two species, and seem to be colonized by them at random. However, **C. expleta** occurs and breeds only in saline waters, whereas **C. bifida** lives and breeds in fresh and moderately saline environments. **C. expleta** has been found only in waters with a conductivity between 3,900 and 29,000 micromhos/cm. (at 25°C): **C. bifida** occurs only in waters with a conductivity between 20 and 20,000 micromhos/cm. The distribution appears to be correlated with salinity and not with other features of the environment such as area of water body, mean depth, maximum depth, etc.

Seven species of *Cenocorixa* are recorded from British Columbia (Lansbury, 1960), but little is known about their distribution, abundance and biology. A comparative study has been started on two of the species *C. bifida* (Hung.) and *C. expleta* (Uhler). This paper describes the distribution of the two forms in the province of British Columbia, and further considers their occurrence in a series of saline water bodies in the Southern Interior Plateau region.

Materials and Methods

The general distribution of the species in the Province was determined from published records, from specimens in the Spencer Entomological Museum at the University of British Columbia and from personal collecting. Climatic data were taken from the B.C. Resources Atlas (Chapman *et al.*, 1956).

In the study of the lakes in the Southern Interior Plateau, a general survey was carried out in the period 1958-1960, and in 1961 a series of water bodies was selected for intensive study. The lakes were chosen so as to obtain as wide a range of salinity as possible, after the initial survey indicated that this was desirable. Those selected were chosen so that many other parameters of the environment were alike. Thus all water bodies were situated in the same general geographic area, on approximately the same latitude and longitude, were around 1000 m elevation, were situated in open grassland, were without fish as predators, but had cattle access and so were subject to disturbance and pollution.

The water bodies selected for special study are located in the Chilcotin and Cariboo Parklands biotic areas, but one lies within the Dry Forest area of Munro and Cowan (1947). Those named as lakes, e.g. White Lake, are to be found on maps. The others have local names or names used only in this project. Most are on Beecher's Prairie, just north of Riske Creek (Fig. 1). Others are distributed as follows: Westwick Lake, Boitano Lake and Rush are between Williams Lake and Springhouse, with the locality Sp. 6 a little way beyond Springhouse on the Alkali Lake road. White Lake and Long Lake are on the road between Clinton and Gang Ranch, the locality GR2 being about 10 miles west

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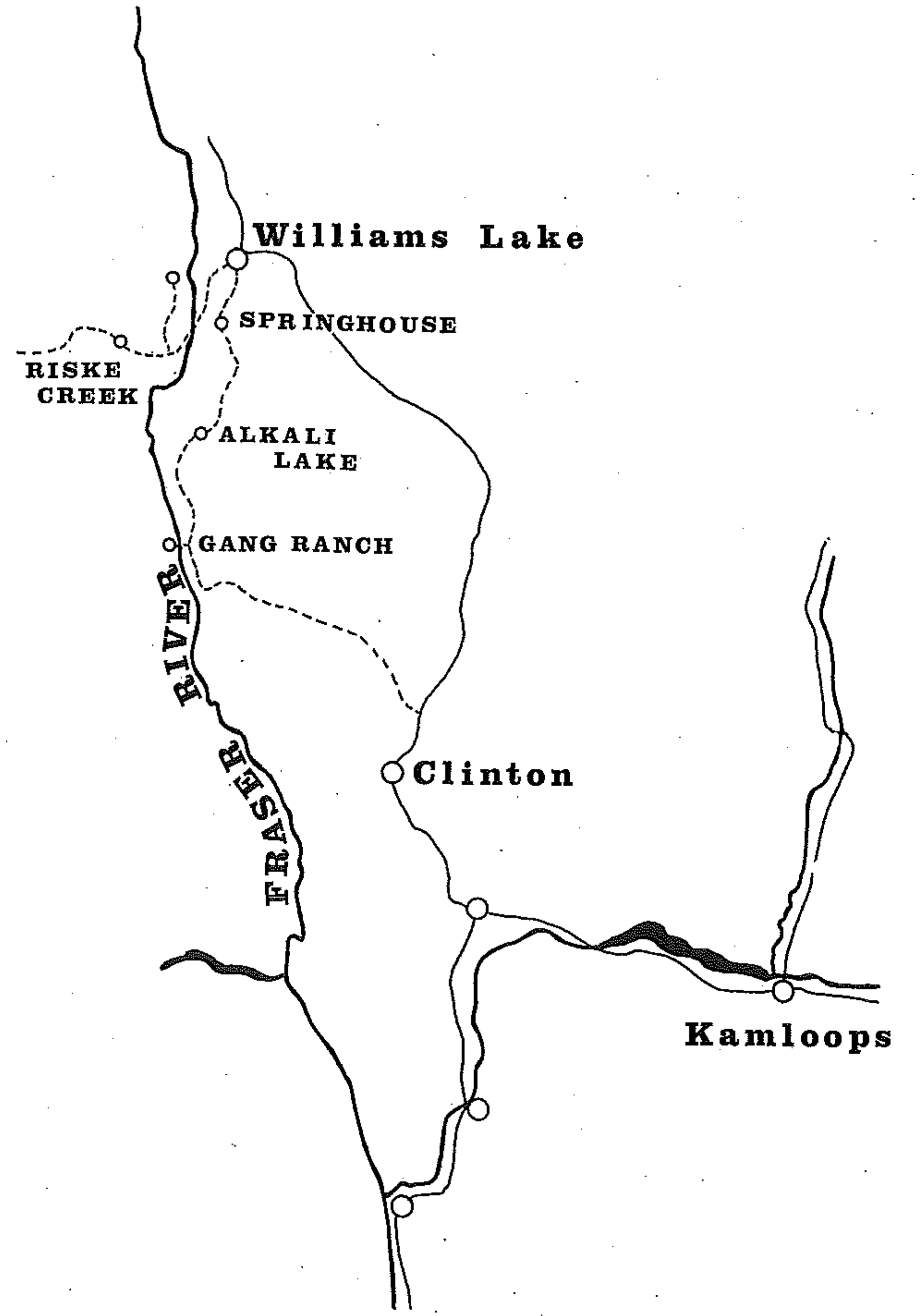

Fig. 1. Map of the Southern Interior Plateau region of British Columbia, showing localities mentioned in text.

of the Highway. Finally, the water body called LB2 is adjacent to Lac du Bois, near Kamloops, (Fig. 1).

In all 20 lakes were included in the detailed study, the physical and chemical limnology of which will be described elsewhere (Topping and Scudder, in prep.). Faunal samples were obtained from each habitat at approximately monthly intervals during the ice-free period from April to November, in the years 1958-1968 inclusive. At the same time, water temperature and surface conductivity were measured using a Yellowsprings Portable Solubridge: pH and conductivity were also measured in the laboratory using Radiometer apparatus.

Information on dispersal was obtained by the use of light traps and horizontal reflection traps of the type described by Fernando (1958). These were set up adjacent to Westwick Lake and the Corixidae captured were noted.

The behaviour of insects in waters of varying salinity and temperature was observed in the laboratory. Insects were placed in 250 ml beakers containing 150 ml of water of known salinity. Experiments were carried out in constant temperature cabinets at 5°C, 15°C and 25°C. Each beaker was contained in a covered plastic box. The number of insects leaving the beaker and found in the box was recorded.

Results

1) General distribution

Fig. 2 summarizes in a general manner, the known distribution of the two species in British Columbia. Records available are as follows: new locality records are in italics.

Cenocorixa bifida (Hung.): Peachland, Vernon, Oliver, Nulki L., Kamloops, (Hungerford, 1948). Chilcotin, Nicola, Malahat, Vernon, 6 mi. S. Clinton, 149 mile L., Soda Cr., Milner, Westwick L., Riske Cr., Boitano L., Peachland, Nulki L., Westbank, Summerland, Oliver, Hope Mts., Jesmond, Minnie L., Nicola (Lansbury, 1960). McIntyre L. (Scudder, 1961). Horseshoe L. (Sparrow, 1966). *Lyons L.* (G. Halsey); *White L.* (G. G. E. Scudder); *Long L.* (G. G. E. Scudder); *Doctor's L.* (G. G. E. Scudder); *Pavilion L.* (G. G. E. Scudder); *Beaverdam L.* (G. G. E. Scudder); *Bower's L.* (G. G. E. Scudder).

Cenocorixa expleta (Uhler): Kamloops, 6 mile S. Clinton, Riske Cr. (Lansbury, 1960). *White L.* (G. G. E. Scudder); *Long L.* (G. G. E. Scudder); *Bower's L.* (G. G. E. Scudder); *Lyons L.* (G. Halsey).

Superimposed on this map is the area of the province that has a mean annual precipitation of around 43.5 cm, (15 in.), and in which the known saline lakes in the province are situated. It is seen that in general the records of both species lie within this climatological boundary.

ii) Detailed distribution

Table 1 lists the water bodies selected for special study and summarizes the most important environmental data required for the present discussion. It also shows in a general manner, the occurrence of the two species of *Cenocorixa*. *C. bifida* is found in waters with a mean surface conductivity between 38.6 and 14,848 micromhos/cm (at 25°C), while *C. expleta* has a narrower range. In British Columbia the two species have been found sympatric in ten water bodies, six of which are listed in Table 1. Allopatric populations of *C. bifida* occur in the fresh waters, while to date no allopatric population of *C. expleta* has been discovered. The data show no obvious correlation of distribution of the species with water body

Water body	Area (ha)	Mean depth (m)	Max. depth (m)	Mean surface conductivity (micromhos/cm at 25°C)	Mean surface pH	Main cation	Main anion	Distribution *Cenocorixa bifida*	Distribution *Cenocorixa expleta*
GR2	15.35	0.8	1.5	42,590	10.15	Na	CO_3	-	x
LB2	3.08	1.1	2.5	14,848	9.63	Na	CO_3-SO_4	o	*
Long L.	33.50	2.2	4.5	12,388	9.41	Na	SO_4	ø	*
Box 4	17.20	2.0	4.5	10,473	9.50	Na	HCO_3-CO_3	*	*
Phalerope	30.84	2.6	6.2	6,883	9.31	Na	HCO_3-CO_3	*	*
Box 20-21	46.50	2.8	5.4	6,074	9.30	Na	HCO_3-CO_3	*	*
White L.	127.68	5.0	15.5	5,540	9.50	Na	HCO_3-CO_3	*	*
Boitano L.	80.70	2.7	4.5	4,728	9.00	Na	HCO_3-SO_4	*	-
Rush	19.59	1.1	2.5	3,994	8.74	Na	HCO_3-SO_4	*	-
Nr.Op.Box 4	5.83	1.4	2.3	3,231	8.81	Na-Mg	SO_4	*	-
Box 89	15.18	1.0	2.3	1,803	9.08	Na	HCO_3	*	-
Rock	34.60	1.1	2.5	1,698	9.21	Na	HCO_3	*	-
Westwick L.	58.32	1.3	4.5	1,515	8.72	Mg	HCO_3-CO_3	*	-
Nr. Phalerope	5.06	1.3	3.0	1,457	8.64	Na	HCO_3	*	-
Nr.Op.Cr.	6.88	1.4	3.3	827	8.98	Mg	HCO_3-CO_3	*	-
Box 17	2.67	1.1	3.3	782	9.00	Mg	HCO_3-CO_3	*	-
Op.Box 4	4.53	0.7	2.2	720	9.27	Mg	HCO_3-CO_3	*	-
Racetrack	27.03	1.9	6.5	541	8.52	Na	HCO_3	*	-
Sp.6	0.85	0.6	1.5	254	8.80	Mg	HCO_3-CO_3	*	-
Box 27	4.30	0.5	1.5	38.6	6.86	Mg	HCO_3-CO_3	*	-

Table 1. List of water bodies studied with certain environmental data plus the distribution of C. bifida and C. expleta: * = one or two generations produced each year; o = first generation produced, but second unsuccessful; ø = first generation produced, second generation successful only some years; x = overwintered adults recorded, but no breeding detected in these waters; - = species never taken in these waters.

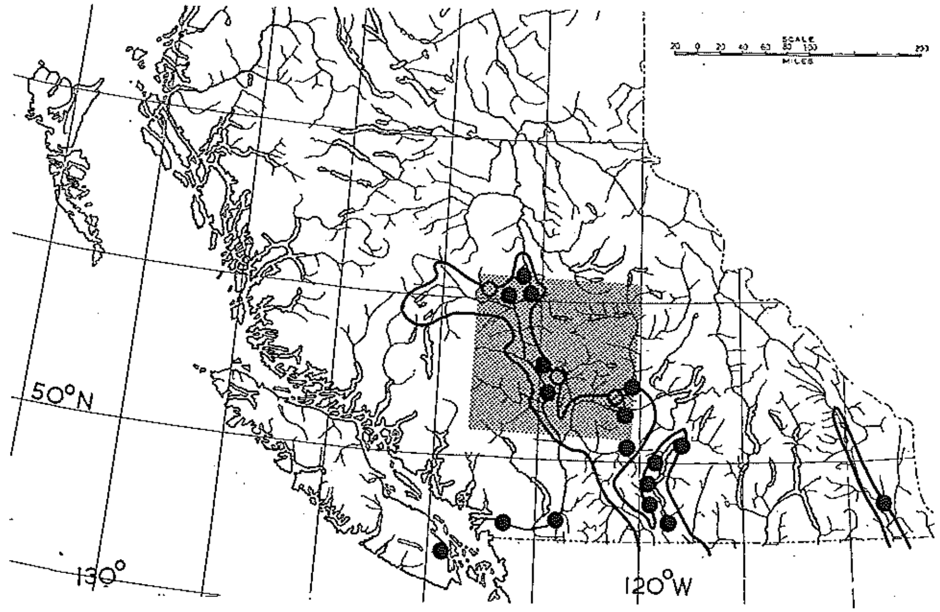

Fig. 2. Map of the southern half of British Columbia showing the known distribution of **Cenocorixa bifida** (closed circles) and **C. expleta** (open circles). Solid line shows area with a mean annual precipitation of 43.5 cm. or less, and stippled region represents area covered in Fig. 1.

area, mean depth, maximum depth, pH, main cation or main anion; there is a correlation with conductivity.

iii) Temporal changes in the distribution.

Comparisons have been made of the detailed distribution of the two species in the above lakes, comparisons being made of the patterns of distribution for spring, summer and fall for each of the ten years 1958-1968. While there has been no substantial change in the occurrence of the species in the lakes at the lower end of the salinity range, this is not the case at higher salinities. Here the distribution of *C. expleta* and *C. bifida* varies with seasonal and annual changes in surface conductivity of the water. There may be a three-to four-fold change in surface conductivity during any one year, and a two-to three-fold change from year to year. At times of substantial change, there occur changes in the distribution of the breeding populations of *Cenocorixa*.

Seasonal changes in distribution can be illustrated by considering the occurrence of the two species in the two localities Long Lake and LB2. Each year overwintered adults of both species occur in Long Lake and LB2. LB2 on 23 May 1966 had a surface conductivity of 9080 micromhos/cm. at 15.5°C and on 5 May 1968 the conductivity was 4680 micromhos/cm and the temperature 11°C. A first generation of larvae was produced in both species in the spring of the years 1966 to 1968, but while *C. expleta* was able to produce a second or summer generation in this habitat, this apparently did not occur in *C. bifida*. Larvae of the latter were not found in the LB2 locality in mid summer in any of the three years, a time when the conductivity had risen considerably. Thus both species are present in the spring,

but only *C. expleta* occurs in this water body in middle and late summer: the habitat is evidently recolonized each fall by *C. bifida* from neighbouring less saline habitats.

Similarily, in 1963, Long Lake like most of the other water bodies in the area at this time, had a conductivity well above the average. In May 1963 a first generation of *C. bifida* and *C. expleta* was produced with the conductivity at 13,200 micromhos/cm at 8°C. In the summer of 1963, there was a second generation of *C. expleta* reared, but not of *C. bifida*. The conductivity at this time had risen to 27,260 micromhos/cm at 22°C. Thus in 1963, and indeed in the previous two years, *C. bifida* appeared to die out in the Long Lake habitat in the summer and recolonize the lake in the fall, similar to LB2 above.

However, in the past few years there has been a marked change in the salinity of the most concentrated waters. This has evidently been due to the relatively colder and wetter years since 1963 and in the Long Lake locality also, attempts by a local rancher to divert a neighbouring creek into the lake and use the water for irrigation purposes. Thus in Long Lake in 1966, the water level was higher and the conductivities lower than in the period 1961-1963. These salinity changes have been accompanied by changes in the distribution pattern of the Corixidae. Instead of *C. bifida* in this habitat producing only a spring generation and then dying out as in 1963, in 1966, 1967 and 1968 this species produced both a spring and a summer generation similar to *C. expleta*. At no time in these three years did the surface conductivity in Long Lake go above 12,000 micromhos/cm at 25°C. Thus in these years there was a distribution pattern that differed from previous years.

We have not found any Corixidae breeding in the water body GR2 and so assume that they cannot do so.

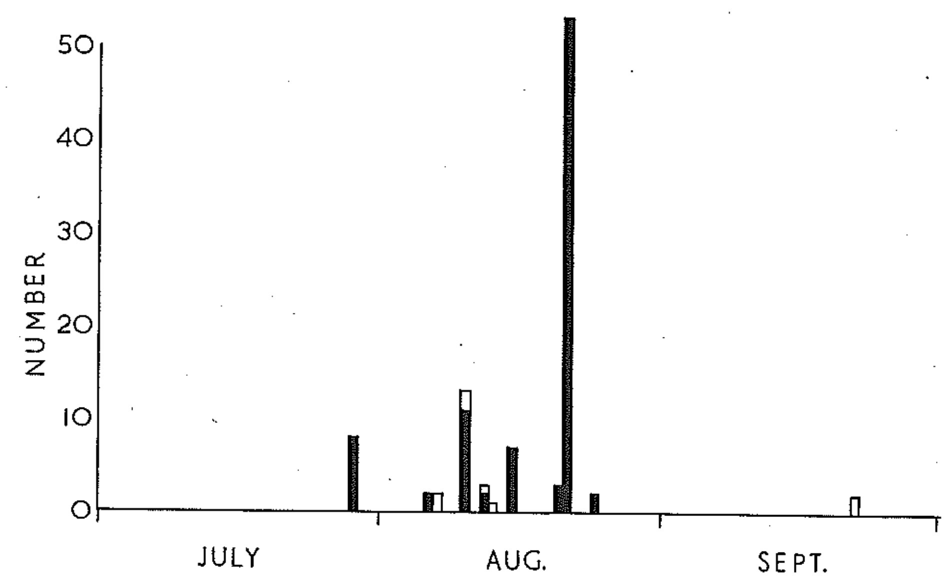

Fig. 3. Diagram showing flight period of **Cenocorixa bifida** in Westwick Lake area in 1964 (Data from Simpson, 1968). Solid columns represent light trap captures; open, horizontal reflection trap captures.

However, on 3 May 1964 a single female *C. expleta* was captured swimming in the water, and so the lake is not outside the flight range of the species.

iv) Dispersal of Corixidae

In an attempt to obtain some information on the dispersal of these Corixidae, light traps and horizontal reflection traps were run through the season at Westwick Lake. The results of this trapping are shown in Fig. 3. Flying *C. bifida* were taken between July 28 and September 25. A single female *C. expleta* was also taken on 12-13 September 1964. These results show that *C. bifida* has a pronounced tendency to disperse in late summer and fall: this is the time that adult insects are found to reappear in such saline waters as LB2 and further, at this time the water temperature also is beginning to drop.

v) Flight behaviour of *C. bifida* in waters of various salinity and temperature.

Experiments were carried out with natural lake water of varying salinities: the experimental temperatures were 5°C, 15°C and 25°C, the lower temperature approximating the normal environmental temperature in early spring, 25°C being around the highest temperature recorded in the study area in the summers.

A standard one hour period was used for each experiment, 20 insects being used in each test. The results (Table II) show that *C. bifida* has a pronounced tendency to leave water at a temperature of 25°C. Such behaviour was less evident at 15°C and was not seen at 5°C. There was little difference with waters of different salinity.

Discussion

The records in the literature and the detailed study of the two species of *Cenocorixa* in British Columbia indicate that they both generally occur in areas with a mean annual precipitation of under 43.5 cm (15 inches). In the area studied *C. expleta* occurs only in saline waters, whereas *C. bifida* lives and breeds only in fresh and moderately saline water. *C. expleta* has been found only in waters with a conductivity between 3,900 and 29,000 micromhos/cm (at 25°C). *C. bifida* was taken only from waters with a conductivity between 20 and 20,000 micromhos/cm.

Elsewhere within the range of these species, they appear to occur in similar relatively dry areas. *C. bifida* has a wider range than does *C. expleta*, the latter being confined to western North America (Hungerford, 1948). *C. expleta* seems to occur in saline water also elsewhere (Brooks

TABLE II. Proportion of **C. bifida** (flying form) leaving waters of different salinity and temperature in one hour

Source of Water	5°C		15°C		25°C	
	Conduct	% leaving	Conduct	% leaving	Conduct	%leaving
Sp.6	16.2	0	21.6	0	27	35
Boitano L.	438	0	584	0	730	35
White L.	2,850	0	3,800	10	4,750	40
Long L.	7,320	0	9,760	5	12,200	40
GR2	19,800	0	26,400	0*	33,000	30**

* 15% died in water
** 20% in addition died in water

& Kelton, 1967). Edmondson (1966) reports *C. expleta* from Soap Lake in the Grand Coulee area of Washington, and this has a surface TDS of between 21,200 and 37,112 ppm. He notes that in the years since the salinity has started to go down due to irrigation projects, *C. expleta* has become much more abundant than formerly when the salinity was high. I have also taken *C. expleta* together with *C. bifida* from the adjacent Lenore Lake on 23 March 1968 when the conductivity was 2899 micromhos/cm (at 25°C). Similarly, Hungerford (1948) records *C. expleta* from Redberry Lake in Saskatchewan. This lake is saline and according to Rawson & Moore (1944) has a TDS of 13,000-14,000 ppm.

The field results suggest that the two species differ in their salinity tolerance. The fact that *C. bifida* was eliminated from Long Lake in the years 1961 to 1963 and from LB2 over the years this water body has been studied, indicates that there is a certain upper lethal combination of temperature and salinity for *C. bifida*. There must be a similar upper lethal level for *C. expleta*, but no lake among those studied, attained this level. The upper level for *C. expleta* would appear to be higher than that for *C. bifida*, but must be below the levels that exist in GR2.

The fact that both species have been obtained in terrestrial trapping research and the fact that *C. expleta* has been taken in GR2 alive, shows that the species have an innate tendency to disperse, something that has been noted for other Corixidae (Macan, 1939, 1962; Fernando, 1959; Johnson, 1966). Since the water bodies are in the same general area, one can assume that they are all potential environments for these two insects. On the Beecher's Prairie area with the many lakes close together, it would be difficult to deny that all of the water bodies are potential habitats for *C. expleta*, yet it has been found only in four of the twenty or more larger habitats located there. Further, since the species are attracted to the shiny surface of the horizontal traps, they must be attracted at random to any shiny surface. Presumably they are thus attracted to all bodies of water, randomly, irrespective of their other characteristics.

Laboratory experiments have shown that *C. bifida* (and presumably also *C. expleta*) tend to fly from water when it is at 15°C or above: the higher the temperature, the greater the flight response. The species cannot survive more than one-half hour at 30°C and above, and live for a few days only at 25°C. These lethal temperatures evidently are related among other things to the transition point of the cuticular waxes, which for *C. expleta* is 29.5°C (Oloffs and Scudder, 1964). While the insects tend to leave waters at a temperature above 15°C, they rarely take flight at lower temperatures. Even when they are placed in water salinities that are lethal, they do not atempt to leave.

This suggests that once an insect lands in a body of water, provided the temperature is below 15°C, the insect will remain and not leave; presumably since most water bodies have areas that are cool even when surface waters may be warm, the insect will tend to remain once it enters them. Thus all waters would seem to have an equal chance of colonization at the time of random dispersal.

Studies on two other Corixids *Callicorixa audeni* (Hung.) and *Hesperocorixa laevigata* (Uhler) have shown that these have a flight period that coincides in time with that in *C. bifida* (Simpson, 1968). Further, these two species are known to colonize most water bodies each fall, but rare-

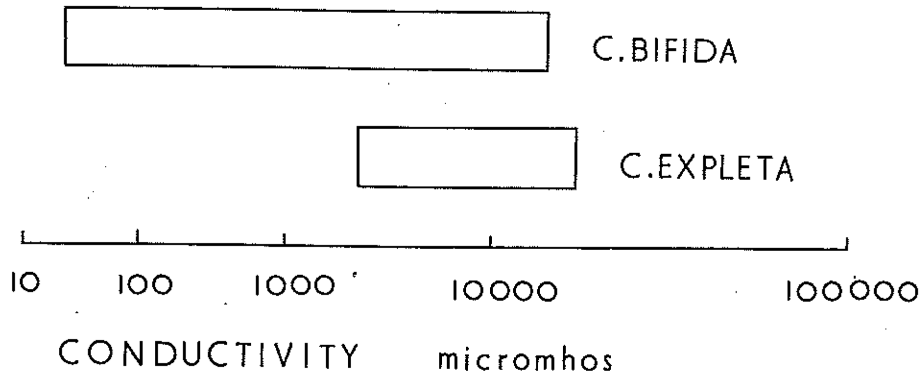

Fig. 4. Diagram showing field distribution of **Cenocorixa bifida** and **C. expleta** in British Columbia, with respect to the conductivity of the environment.

ly do they breed in them in the succeeding year (Scudder, 1969). All of the water bodies in the area have an equal chance of colonization by Corixidae.

Thus the distribution of the two species of *Cenocorixa* in the inland saline lakes in central British Columbia seems to depend on the species tolerance to the salinity, and is not clearly correlated with other characteristics of the habitats; the species' food appears to be the same. The two species occur in the same area, but have different salinity ranges, although they do overlap.

Fig. 4 summarizes the findings with respect to this correlation of distribution and the conductivity of the environment. The species appear to differ quite markedly. Only experimental studies will reveal the basis for these differences in tolerance, survival and distribution.

Acknowledgments

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The fauna of saline lakes on the Fraser Plateau in British Columbia

G. G. E. SCUDDER

With 7 figures and 4 tables in the text

In a study of the saline lakes on the Fraser Plateau in British Columbia, some 33 water bodies have been examined. These have a range of conductivity from 27 micromhos/cm (at 25° C) to 68,000 micromhos/cm (at 25° C). They occur close together at a height of about 1,000 metres in an area with 25—37.5 cm annual precipitation, and average January and July temperatures of — 10° C and 15° C, respectively. The terrain is a rolling savanna type upland. The water bodies usually lack inlet and outlet streams, lack fish predators, but are subject to pollution by cattle.

The research has involved morphometric and chemical analyses, plus studies on the fauna of the water bodies. The full chemical data will be found in TOPPING & SCUDDER (1968). Suffice it to mention here the fact that the waters of the Fraser Plateau area differ widely in chemical composition, and in particular, do not have a single cation predominant throughout (Tab. 1). Further, the faunal data show that the occurrence of species in the most saline waters is apparently dependent on the predominant cation. For example, *Hyalella azteca* (SAUSSURE) occurs only up to 12,000 micromhos/cm in sodium predominant lakes, but up to 22,000 micromhos/cm in magnesium predominant waters.

Tab. 1. List of 14 saline water bodies on the Fraser Plateau, British Columbia, to show differences in chemical composition.

Water body	Recorded Range of Surface Conductivity (micromhos/cm at 25° C)	Recorded range of surface pH	Main Cation	Main Anion
Polygon	13,300—77,900	8.2— 9.0	Na-Mg	SO_4
Ironmask Lake	13,600—72,300	8.1— 9.1	Na-Mg	SO_4
One Mile	35,500—65,000	8.1— 8.5	Mg	SO_4
GR2	19,000—60,500	10.1—10.3	Na	CO_3
Long Lake	4,750—29,000	9.0— 9.6	Na	SO_4
Three Mile	9,280—28,000	8.1— 8.5	Mg	SO_4
Bowers Lake	10,900—22,175	8.2— 8.6	Mg	SO_4
LB2	2,720—20,580	9.2— 9.7	Na	CO_3—SO_4
Box 4	3,000—20,000	9.3— 9.7	Na	HCO_3—CO_3
LB1	13,750—14,750	8.7— 8.8	Mg	SO_4
Box 20—21	1,100—12,000	9.1— 9.6	Na	HCO_3—CO_3
Phalerope	2,820— 9,000	9.2— 9.3	Na	HCO_3—CO_3
Boitano Lake	4,000— 9,000	8.8— 9.2	Na	HCO_3—SO_4
White Lake	3,200— 9,000	9.1— 9.6	Na	HCO_3—CO_3

In order to simplify the following discussion of salinity and distribution of fauna on the Fraser Plateau, only the sodium predominant highly saline lakes will be considered. Tab. 2 presents the list of water bodies to be discussed, and gives some additional data on the waters.

Tab. 2. List of water bodies studied on the Fraser Plateau, British Columbia, in connection with determination of faunal distribution patterns.

Water body	Recorded Range of Surface Conductivity (micromhos/cm at 25° C)	Recorded Surface pH range	Major Cation	Major Anion	Area (ha)	Mean Depth (m)	Max. Depth (m)
GR2	19,000—60,500	10.1—10.3	Na	CO_3	15.35	0.8	1.5
LB2	2,720—20,580	9.2— 9.7	Na	CO_3—SO_4	3.08	1.1	2.5
Long L.	4,750—29,000	9.0— 9.6	Na	SO_4	33.50	2.2	4.5
Box 4	3,000—20,000	9.3— 9.7	Na	HCO_3—CO_3	17.20	2.0	4.5
Phalerope	2,820— 9,000	9.2— 9.3	Na	HCO_3—CO_3	30.84	2.6	6.2
Box 20—21	1,100—12,000	9.1— 9.6	Na	HCO_3—CO_3	46.50	2.8	5.4
White L.	3,200— 9,000	9.1— 9.6	Na	HCO_3—CO_3	127.68	5.0	15.5
Boitano L.	4,000— 9,000	8.8— 9.2	Na	HCO_3—SO_4	80.70	2.7	4.5
Rush	3,000— 4,750	8.5— 9.1	Na	HCO_3—SO_4	19.59	1.1	2.5
Nr. Op. Box 4	1,725— 3,730	8.6— 9.3	Na—Mg	SO_4	5.83	1.4	2.3
Box 89	1,400— 2,200	8.4— 9.5	Na	HCO_3	15.18	1.0	2.3
Rock	1,485— 2,600	8.6—10.5	Na	HCO_3	34.60	1.1	2.5
Nr. Phalerope	770— 1,790	8.1— 9.1	Na	HCO_3	5.06	1.3	3.0
Westwick L.	640— 2,200	8.1— 9.1	Mg	HCO_3—CO_3	58.32	1.3	4.5
Nr. Op. Cr.	710— 940	8.6— 9.7	Mg	HCO_3—CO_3	6.88	1.4	3.3
Box 17	660— 950	8.3— 9.2	Mg	HCO_3—CO_3	2.67	1.1	3.3
Op. Box 4	625— 750	8.6—10.1	Mg	HCO_3—CO_3	4.53	0.7	2.2
Racetrack	400— 600	7.8— 9.7	Na	HCO_3	27.03	1.9	6.5
Sp. 6	145— 330	7.7— 9.5	Mg	HCO_3—CO_3	0.85	0.6	1.5
Box 27	27— 75	5.5— 7.0	Mg	HCO_3—CO_3	4.30	0.5	1.5

The distribution of 29 of the commonest invertebrates in this series of lakes is shown in Figs. 1—2. The species can be divided into two groups, firstly those that occur in the fresh and lower salinity lakes (Fig. 1) and secondly, those that are restricted to the highly saline waters (Fig. 2).

	Theromyzon rude	Hyalella azteca	Gammarus lacustris	Callibaetis	Enallagma	Cenocorixa bifida	Callicorixa audeni	Hesperocorixa laevigata	Cymatia americana	Notonecta kirbyi	Notonecta undulata	Rhantus frontalis	Enochrus diffusus	Coelambus unguicularis	Chaoborus	Aedes fitchii	Aedes flavescens	Chironomus tentans	Glyptotendipes barbipes
GR 2																			
LB 2																			
Long L					●	●						●	●	●	●				
Box 4				●	●	●				●		●	●	●	●	●			
Phalerope				●	●	●						●			●	●			●
Box 20 21		●	●	●	●	●				●	●	●	●	●	●	●			●
White L		●		●	●	●				●		●	●	●		●	●		●
Boltano L		●		●	●	●				●	●	●	●	●	●			●	●
Rush		●				●	●	●		●		●	●	●	●	●		●	●
Nr Op B4	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●
Box 89	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●
Rock	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●		●	●
Nr Phal		●	●	●	●	●	●	●	●	●		●			●	●	●	●	●
Westwick L	●	●		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●
Nr Op Cr	●	●	●		●	●	●	●	●	●	●	●		●	●	●	●	●	●
Box 17	●	●	●		●	●	●	●	●	●	●	●		●	●			●	●
Op Box 4	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Racetrack	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●
Sp 6	●			●	●	●	●	●	●	●	●	●	●		●	●	●	●	
Box 27	●				●	●	●	●	●	●	●	●			●	●		●	

Fig. 1. Distribution of some "fresh water and low salinity" species in water bodies of the Fraser Plateau, British Columbia.

Of note in Fig. 1 is the fact that the distribution pattern of all the species therein is not identical; certain species extend further into the upper salinity range than do others. Similarly in Fig. 2, the distributions are quite dissimilar, and differ both as to the upper and lower salinity limits.

That salinity in some species is important in the distribution, has been demonstrated by an experiment in the field, in which part of an environment (Boitano Lake) was changed. Boitano Lake was studied from 1959 until 1963 and over this period the conductivity remained between 4,500 and 5,000 micromhos/cm (at 25° C). At this time the species present were as shown in Figs. 1—2. In 1964 the north-east part of the lake was isolated from the rest by the construction of an earth-filled dam. This isolated part of the lake received much of the spring run-off from the surrounding terrain and as a result, the water was considerably diluted in the following two years, such that in the spring 1965, the conductivity was 1,000 micromhos/cm. A survey of the species present at the time showed that concomitant with a change in salinity, there was a change in fauna: species such as *Theromyzon rude* (Baird), *Callicorixa audeni* Hung. and *Hesperocorixa laevigata* (Uhler) characteristic of the fresh waters, were present and breeding, yet they

were not found in the main lake which retained a conductivity of 4,500—5,000 micromhos/cm.

The distribution patterns presented in Figs. 1—2 are based on data obtained in a ten year period. However, they do not show the details of seasonal and annual changes that occur. It is found that the patterns are not constant, but ever changing.

	Artemia salina	Branchinecta mackini	Diaptomus	Dasycorixa rawsoni	Cenocorixa expleta	Coelambus masculinus	Deronectes spenceri	Aedes campestris	Ephydra hians	Triaenodes grisea
GR 2	●	●				●		●	●	
LB 2		●			●	●				
Long L		●	●		●	●		●	●	
Box 4		●	●	●	●	●	●	●		●
Phalerope			●	●	●	●		●		●
Box 20 21		●		●	●	●	●	●		●
White L		●	●		●	●	●			●
Boitano L						●		●		
Rush								●		
Nr Op B4										
Box 89										
Rock										
Nr Phal										
Westwick L								●		
Nr Op Cr										
Box 17										
Op Box 4										
Racetrack										
Sp 6										
Box 27										

Fig. 2. Distribution of some "high" salinity species in water bodies of the Fraser Plateau, British Columbia.

This dynamic nature of the distributions has been studied extensively in the Corixidae, and Fig. 3 summarises the results to date. In most water bodies, all species succesfully pass through one or two generations each year. However, at the upper limits of the range, such is not the case. Overwintered adults may occur in certain waters, but be unable to breed there in the spring. For example, *Cenocorixa expleta* (Uhler) has been found in the water body GR2, and *Callicorixa audeni*, *Hesperocorixa laevigata* and *Cymatia americana* Hussey have been taken in a number of lakes in the spring, but never there have they produced a spring generation.

There is usually marked seasonal and annual variation in salinity in the surface waters where these insects live (Tab. 3 and 4). There may be a three to four fold increase in surface salinity during a year (Tab. 3) and a two or three fold change from year to year (Tab. 4). These salinity variations are evidently due to changes in the amount of and time of spring run-off, and the different amount of mixing of surface waters with the more saline layers beneath. The salinity changes are of such magnitude as to have a profound effect on the fauna.

Tab. 3. Seasonal variation in surface conductivity in six water bodies on the Fraser Plateau, B. C. (micromhos/cm at 25° C).

Date	Water body GR2	Long L.	Box 4.	White L.	Box 20—21	Boitano L.
7. IV. 1966	19,000	4,800	3,300	4,000	1,100	400
10. V. 1966	30,100	9,110	6,610	5,090	4,680	3,900
7. VI. 1966	33,000	9,440	9,440	4,720	5,380	4,000
3. VII. 1966	40,000	10,450	11,017	5,068	6,220	4,120
28. IX. 1966	45,000	12,200	11,350	4,750	6,020	4,200
16. II. 1967*	57,320	12,033	—	5,360	—	—
2. V. 1967	27,500	8,400	6,850	4,780	5,000	4,480
3. VI. 1967	37,000	10,200	9,550	4,780	6,000	4,130
24. VI. 1967	47,500	11,000	10,600	5,080	6,530	4,350
23. VII. 1967	48,300	11,150	11,850	5,750	6,650	4,350
9. IX. 1967	60,500	12,600	13,300	5,380	7,250	4,500
7. X. 1967	52,175	12,540	13,480	5,220	7,260	4,640

* Below ice cover.

	Dasycorixa rawsoni	Cenocorixa expleta	Cenocorixa bifida	Callicorixa audeni	Hesperocorixa laevigata	Cymatia americana
GR 2		X				
LB 2		●	○			
Long L		●	◐			
Box 4	●	●	●			
Phalerope	●	●	●		X	
Box 20 21	●	●	●		X	X
White L		●	●		X	X
Boitano L			●	X	X	
Rush			●	●	●	
Nr Op B			●	●	●	
Box 89			●	●	●	●
Rock			⊖	⊖	⊖	⊖
Nr Phal			●	●	●	●
Westwick L			●	●	●	●
Nr Op Cr			●	●	●	●
Box 17			●	●	●	●
Op Box			●	●	●	●
Racetrack			●	●	●	●
Sp 6			●	●	●	●
Box 27			●	●	●	●

Fig. 3. Distribution of six species of Corixidae in water bodies of the Fraser Plateau, British Columbia. Closed circles = one or two generations produced each year; open circle = first generation produced, but second unsuccessful; half circle = first generation produced, second generation successful only some years; X = overwintered adults present, but no breeding detected in these water bodies.

However, Kinne (1964) has shown in marine and brackish water animals, there is an important salinity-temperature effect, and so salinity should not be considered by itself. Fig. 4 presents a plot of the temperature record in Westwick Lake at 1.0 m in 1966 and shows that there is a marked seasonal variation, with a recorded maximum of about 22° C. Other data show that this surface plot for Westwick Lake is representative for all lakes studied.

Tab. 4. Annual variation in surface conductivity in six water bodies on the Fraser Plateau, B. C. (micromhos/cm at 25° C).

Water body	Year 1961	1962	1963	1966	1967	Range
May						
GR2		21,000	37,500	30,100	27,500	10,000
Long Lake		—	20,000	9,110	8,400	11,600
Box 4		—	12,000	6,610	6,850	5,390
White Lake		4,900	7,500	5,090	4,780	2,720
Box 20—21		—	5,750	4,680	5,000	1,070
Boitano Lake		4,000	4,500	3,900	4,500	600
September						
GR2	60,000	—	50,000	45,000	60,500	15,500
Long Lake	—	—	29,000	12,200	12,600	16,800
Box 4	20,000	10,000	14,000	11,350	13,300	10,000
White Lake	9,000	6,000	9,000	4,750	5,380	4,250
Box 20—21	12,000	5,100	8,500	6,020	7,250	6,900
Boitano Lake	—	5,000	9,000	4,200	4,500	4,800

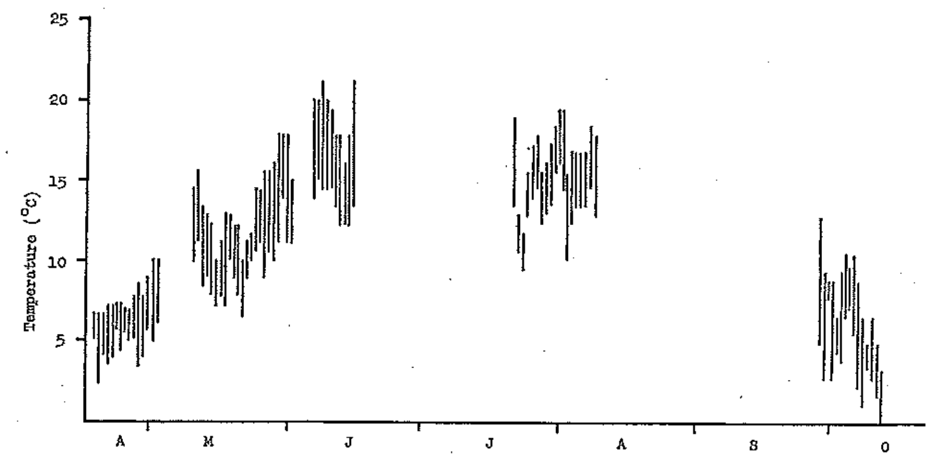

Fig. 4. Daily temperature range in Westwick Lake at 1.0 m (1966).

In order to investigate the effect of the salinity temperature interaction on the distribution of Corixidae, experiments were carried out on adult *Cenocorixa bifida* (Hung.) from White Lake and adult *C. expleta* (Uhler) from the water body called LB2. The waters used were both natural lake waters from a selected series of lakes and various concentrations of Long Lake water; the temperature selected for study were representative of the normal environmental temperatures, ranging from 5° C for spring and 25° C as the maximum summer temperature.

All experiments were carried out in controlled environment cabinets, with millipore filtered water in covered beakers. The insects were examined at regular intervals and time of death recorded: insects were not fed during the course of the experiment, but had fat réserves already accumulated in preparation for overwintering.

Initial experiments using the natural lake waters showed a low survival at

25° C, but better survival at 15° C and 5° C. Further, the effect of salinity, while not greatly evident at 25° C is distinct at 15° C and quite marked at 5° C. These results show that GR2 water (33,000 micromhos/cm at 25° C) is unsuitable for both species. Both species survive well at 5° C and 15° C in other waters. In a further experiment, in order to provide a wider range of salinity and also have the waters constant in ionic composition, a series of concentrations of Long Lake water was used. Figs. 5—6 present the data obtained on survival in these waters. The

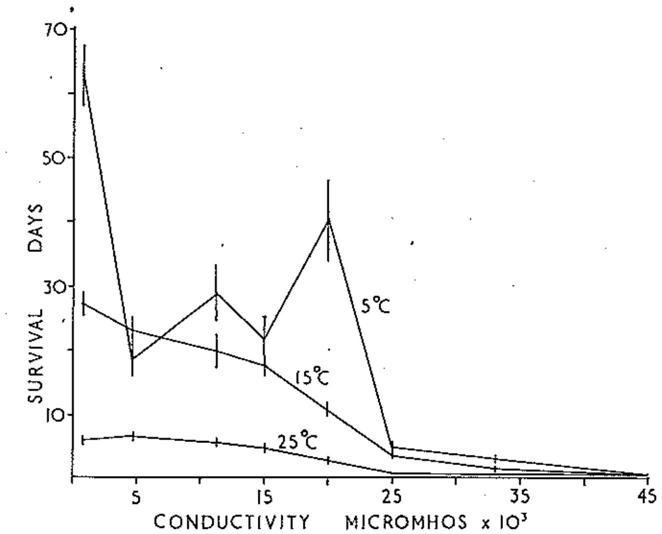

Fig. 5. Survival of *Cenocorixa bifida* in concentrations of Long Lake water.

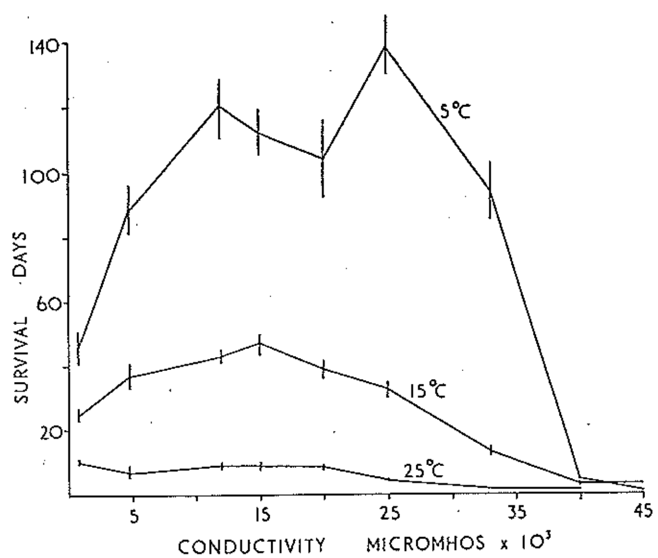

Fig. 6. Survival of *Cenocorixa expleta* in concentrations of Long Lake water.

results are in essential agreement with the data from the natural lake water experiment. Survival in all waters decreases as the temperature rises, or at any one temperature survival decreases with increase in salinity; the two species studied have differing survival curves.

It has been found (SCUDDER 1968) that acclimation to these waters takes 72 hours and this period can be used as a standard to compare the survival in the various experiments. The results show that in these sodium predominant waters, the upper limit for *C. bifida* is between 20,000 and 24,000 micromhos/cm and in *C. expleta* between 33,000 and 35,000 micromhos/cm (Fig. 7). These conductivity values can be obtained in a low salinity water at high temperature, or a high

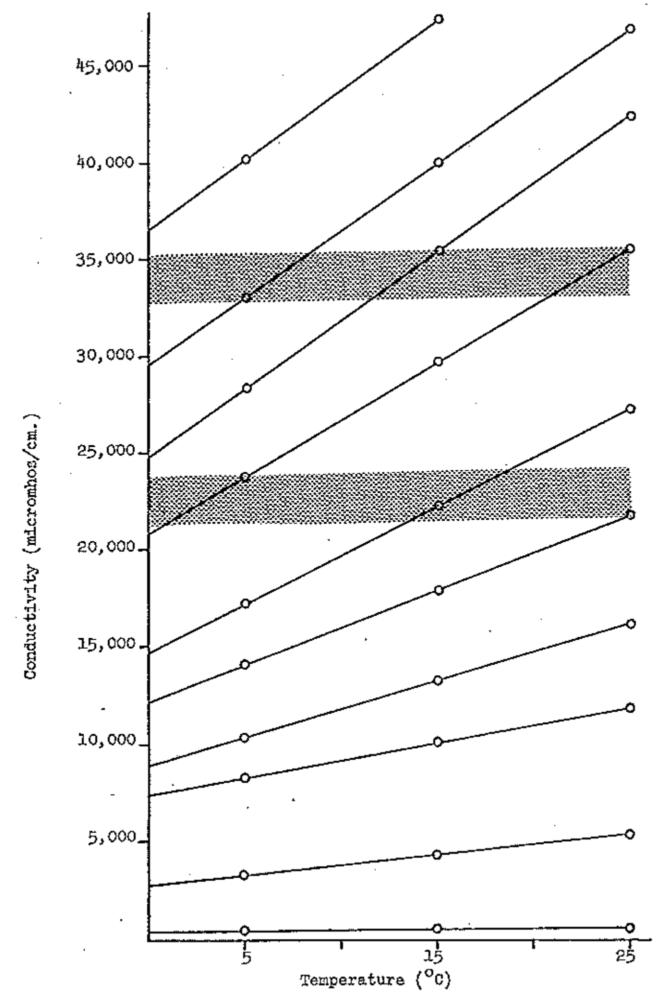

Fig. 7. Comparison of survival of *Cenocorixa bifida* and *C. expleta* in concentrations of Long Lake water. Lines on graph show the waters used; upper stippled area shows experimental survival limit for *C. expleta*, the lower that for *C. bifida*.

salinity water at low temperature, but the effect on the insects is the same. These results agree well with the field data.

C. bifida has been taken only in waters up to a conductivity of 20,000 micromhos/cm (at 25° C) and *C. expleta* in waters up to 30,000 micromhos/cm (at 25° C). Any time these conditions are exceeded in the environment, either by salinity and/or temperature increase, faunal changes occur. For example, in 1966 and 1967 in the Long Lake habitat, a spring and a summer generation were produced in both *C. bifida* and *C. expleta* and at no time in the year did the conductivity go above 12,000 micromhos/cm (at 25° C). But in 1963, such was not the case. In May 1963 a first generation of *C. bifida* and *C. expleta* was produced with the conductivity at 13,200 micromhos/cm at 8° C. In the summer of 1963 there was a second generation of *C. expleta* produced in this habitat, but not in *C. bifida* and at this time, the conductivity reached 27,260 micromhos/cm at 22° C. Similarly, each year overwintered adults occur in the water body listed as LB2. A first generation is produced in both species in the spring, but to date, we have not detected a second or summer generation in *C. bifida*, but there is one in *C. expleta*. It is seen that the changes in the distribution pattern of the Corixidae studied, can be explained by temporal changes in the physical-chemical environment of their habitats.

It is evident that the survival of these Corixid species is dependent upon the temperature and salinity of the waters in which they occur. The upper salinity limit of their distribution in a series of saline waters is dependent upon the species' individual tolerance to these environmental parameters. However, it is not certain that these same physical-chemical features limit the lower limit of the more saline tolerant species.

Tab. 2 shows that these species do not occur in the fresh and less saline waters, yet the experiments with *C. expleta* show that this species can survive in these waters. Preliminary experiments with other species show a similar picture. The absence of these saline forms in freshwater may not therefore be due to a failure to survive in these waters.

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Discussion

Fryer: What sort of geographical distribution do the forms have which frequent saline waters?

Scudder: I have only really looked at *Cenocorixa expleta* to date. This is confined to the western part of Canada and the western USA, whereas the related *C. bifida* is more widely distributed in North America.

Bayly: How did you determine the osmotic concentration of the body fluids?

Scudder: By the cryoscopic method of Ramsay & Brown (1955, *J. Sci. Instrum.* 32, 372—375).

Ruttner-Kolisko: How did you measure the conductivity, in natural samples or in diluted ones?

Scudder: In the particular experiments described, conductivity was measured in the experimental conditions, at the experimental temperature and without dilution.