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

By G. G. E. SCUDDER[1]

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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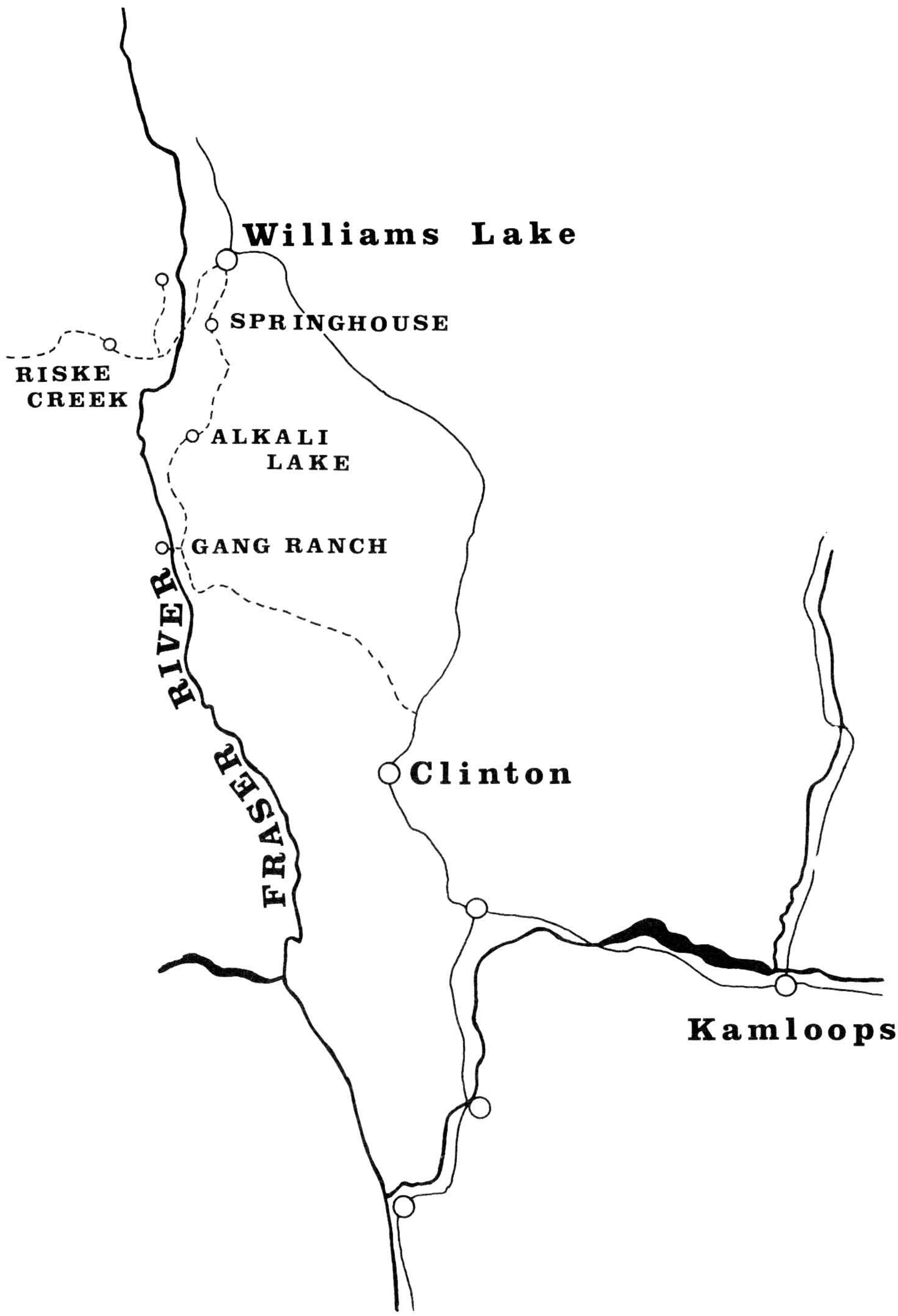

Fig. 1. Map of the Southern Interior Plateau region of British Columbia, showing localities mentioned in text.

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 (microhmos/cm at 25°C)	Mean surface pH	Main cation	Main anion	Distribution Cenocorixa bifida	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 water bodies.

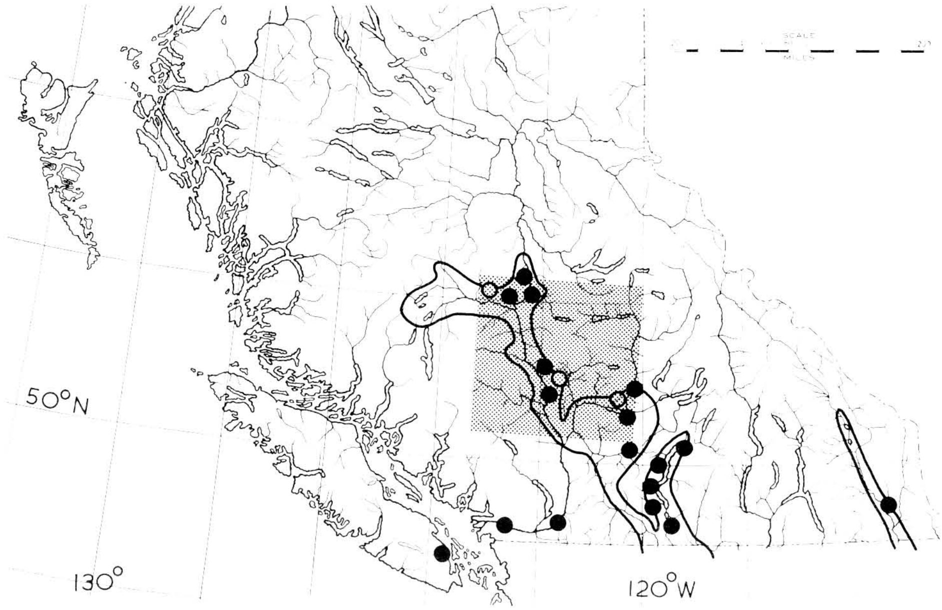

Fig. 2. Map of the southern half of British Columbia showing the known distribution of **Cenocorixa bifida** (closed circles) and **C. expleta** (open circles). Solid line shows area with a mean annual precipitation of 43.5 cm. or less, and stippled region represents area covered in Fig. 1.

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.

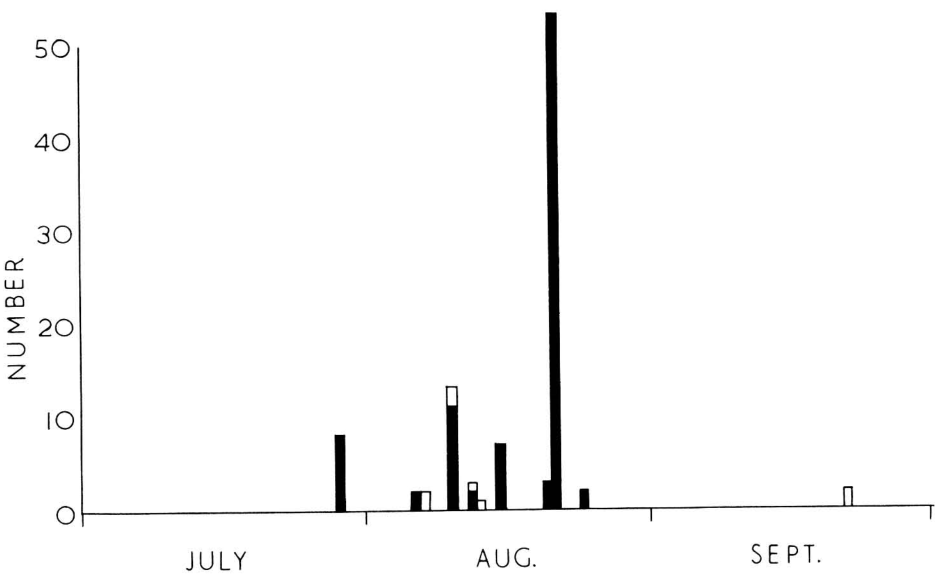

Fig. 3. Diagram showing flight period of **Cenocorixa bifida** in Westwick Lake area in 1964 (Data from Simpson, 1968). Solid columns represent light trap captures; open, horizontal reflection trap captures.

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-

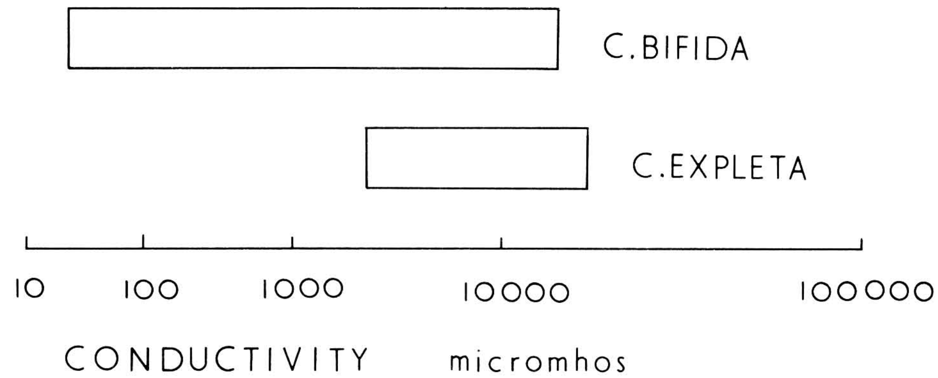

Fig. 4. Diagram showing field distribution of **Cenocorixa bifida** and **C. expleta** in British Columbia, with respect to the conductivity of the environment.

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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INFLUENCE OF TEMPERATURE INVERSION ON DEVELOPMENT OF SPRUCE BEETLE, *DENDROCTONUS OBESUS* (MANNERHEIM) (COLEOPTERA: SCOLYTIDAE)

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ABSTRACT

In the East Kootenay region of British Columbia, spruce logs infested by **Dendroctonus obesus** (Mannerheim) were placed beside thermographs at three sites. Throughout the summer, the mean and minimum air temperatures were higher on a mountain slope than in two valley bottoms at similar or lower elevations. Beetle development was faster on the mountain slope, where it continued until frost occurred in October, at which time 96% of the progeny were mature. In the lower valley bottom the minimum temperature fell 3.9 and 2.8°C (7 and 5°F.) below freezing on successive nights in August and larval development stopped. In the valley bottoms only 13 and 9% of the broods matured before winter. Temperature conditions that allow most broods of **D. obesus** to mature in one season may result in a critical addition to the normal number of beetles that mature after 2 years' development.

Introduction

Dendroctonus obesus (Mannerheim) is the most destructive bark beetle of mature spruce forests (Swaine, 1924; Woods, 1963). Endemic populations breed in wind-thrown trees and logging slash, but when the population is large the beetles frequently attack and kill the largest trees over extensive areas (Swaine, 1924; Massey and Wygant, 1954).

In spruce forests growing at northern latitudes and high elevations most spruce beetles require 2 years to reach maturity, but during hot summers and in warm locations many of the young mature in a single season (Watson, 1928; Massey and Wygant, 1954; Knight, 1961). In western North America, only the beetles that have passed the winter as adults reproduce the next summer (Massey

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