RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A-018-IDA

WATER for IDAHO

Limnological Studies of Lentic Waters in Idaho

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Research Assistant R. C. Wissmar

Water Resources Research Institute
University of Idaho
Moscow, Idaho

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LIMNOLOGICAL STUDIES OF LENTIC WATERS IN IDAHO

(A Comparison of Crustacean Populations and Sampling Techniques in Four Mountain Lakes of Idaho)

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ABSTRACT

Standing crop of microcrustaceans were compared in four mountain lakes in northeast Idaho. Results over two summers indicated that the lower meadow lakes had higher densities of crustaceans than the headwall lakes. These findings were based on vertical plankton hauls. Four different field methods of collection together with various sample sizes were also compared. Reliability of data was possibly affected by small sample sizes and avoidance behavior of the crustaceans to the samplers. The four lakes had a similar species composition and low density of crustaceans. Fisher's coefficient of dispersion $S^2/\bar{X}$ was computed for all samples and used as a measure of horizontal dispersion. Mean total crustacean density and dispersion approximated taxa density and dispersion. Tables and graphs are included.

RABE, Fred W.

"Limnological Studies of Lentic Waters in Idaho (A Comparison of Crustacean Populations and Sampling Techniques in Four Mountain Lakes of Idaho)" Research Technical Completion Report Project A-018-IDA February 1969.

DESCRIPTORS Microcrustaceans*/ Standing crop/ Mountain lakes*/ Sampling/ Dispersion/ Plankton/ Limnology/

IDENTIFIERS Ecology/ Oligotrophy*/ Zooplankton*/ Limnology

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INTRODUCTION

Today there are relatively few natural bodies of water that are not polluted to some degree. Alpine Lakes offer the biologist an opportunity to investigate community structure in an undisturbed environment. Basic biological data from such ecosystems may someday be useful in establishing biotic baselines by which we could evaluate the changes that man has made and will continue to make in his environment. There are over one thousand high lakes in Idaho alone, however, little is known of their basic limnology.

Quantitative investigations of limnetic or open water crustacean population in high mountain lakes are usually made from a rubber raft with small volume plankton traps, two nets, and water bottles (Pennak, 1955; Reimers, et al, 1955: Rabe, 1964; and Sparrow, 1966). The remoteness of these lakes makes it difficult to transport a standard size boat and motor. Shallow lakes preclude the use of elaborate sampling equipment such as the Clark Bumpus metered tow net for large volume horizontal hauls. Another difficulty concerns the low zooplankton density in these nutrient poor waters where additional effort is required to obtain a large enough sample for statistical accuracy.

The objectives of this study were (1) to compare the horizontal distribution and density of crustaceans in four high lakes during the summer; (2) to compare field sampling techniques of the zooplankton in the lakes; and (3) to compare and evaluate sample size in the larger lake.

The study area is located in the Bitteroot Mountains of Idaho. The lakes are situated in cirque basins on a series of benches. Tin and Copper lakes are in meadows on the lowest bench (1751 meters) and are separated by a bedrock spur that extends up between Silver and Gold Lakes to the main headwall of the valley. Silver Lake is on the second bench (1800 meters) and south of the bedrock spur. Gold Lake is north on the third bench (1873 meters). Maximum depths in the above order are 2.1, 3.1, 12.8, and 3.7 meters. Total areas are 1.0, 1.6, 3.5 and 1.7 hectares respectively.

Substrates varied from soft organic mud in the meadow lakes to bedrock, talus, rubble, and gyttja in Silver and Gold Lakes. The chemical and physical characteristics of all of these waters was much the same during both summer seasons. The pH ranged from 6.1 - 6.9. Methyl orange alkalinity was 2.5 mg/l. Dissolved oxygen concentrations were above saturation. Water transparencies indicated the bottom visible at all times. Surface temperatures ranged from 16 C to 19 C.

METHODS

The sampling equipment consisted of a rubber reinforced tube as originally described by Pennak (1962), two liter Kemmerer and Van Doren water bottles, and a metered tow net. The rubber tube method made it possible to collect an entire "core" of water which was strained through no. 20 mesh bolting cloth attached at one end. The metered net was constructed as a modified Hardy sampler (Miller, 1961). It consisted of a plastic cylinder equipped with a flow meter, towing buckle, stabilizing fins, conical net and plankton bucket. Samples from the water bottles were filtered through a Wisconsin net and bucket (no. 20 mesh).

Standing crop of limnetic crustaceans were compared in 1966 by the use of the sampling tube. Each lake was sampled four times during the season. A comparison of plankton collection methods in 1966-67 involved both water bottle types and the rubber tube. Thirty liters were drawn from the Van Doren and Kemmerer bottles and 10 liters from the tube. A metered tow net (820 l), Kemmerer bottle (45 l) and Van Doren sampler (180 l) were used in sample size comparisons during 1966-67. The large volumes provided by the metered net made it possible to assess sample size differences.

Sampling stations were assigned at random in lakes but kept uniform as to bottom depth and level sampled. All samples were replicated vertical series or columns.

Samples were made up to 50 ml and four aliquots enumerated. Each enumeration was in a separate mount of a 1 ml Sedgewick-Rafter counting cell under 60X magnification. Appropriate calculations were made to determine the number of individuals per liter. All values were normalized by a square root transformation of the form $\sqrt{X + 0.5}$.

The units used in comparisons were densities and horizontal dispersions of crustaceans. The density was based on $\bar{X}$ and compared using the "F" test. Fisher's coefficient of dispersion, $S^2/\bar{X}$, was utilized to examine horizontal dispersion where S^2 was the variance and $\bar{X}$ was the mean of the population. Horizontal dispersions were examined for homogeneity.

Limnetic crustaceans (open water forms) were the only zooplankton with counts fitting the assumptions of the "F" test. The variation of rotifer counts was too large. Copepods were enumerated collectively as total copepodids and total copepodid nauplii, cladocerans as Daphnia and Holopedium and all crustaceans as total crustaceans. Separate "F" test of the above groups were impractical because of low density estimates. It was assumed that by combining all the crustaceans and therefore increasing counts within samples that data variances could be used in "F" tests. This assumption was justified by not assessing niche requirements of the plankters.

Horizontal dispersion of crustaceans in these lakes was thought to be uniform due to similar environmental conditions. Ricker (1938) found that choosing a central station to represent the whole pelagic region was generally satisfactory because plankton were reasonably uniform over the entire offshore area. He stated that vertical net hauls have a random distribution in the horizontal plane.

Cassie (1962) relates that plankton can be distributed as a Poisson series which may be described by a single parameter, the mean $\bar{X}$. The Poisson model is only a special case of the general binomial model. Tests for Poisson are mainly tests for randomness. Plankton dispersions can be examined on the basis of the relationship between the variance and the mean.

The deviations of $S^2/\bar{X}$ (Fisher's Coefficient) from one corresponds to three types of dispersion. Less than one is equated with infradispersion (more evenly spaced than random), one is random (Poisson) and greater than one is superdispersion (grouped). The significance of the deviation of $S^2/\bar{X}$ from one can be tested by the equation: $X^2 = (N-1)\ S^2/\bar{X}$, where N is the number of counts. Comita and Comita (1957) used this coefficient to show that uncrowded plankton populations had such distributions.

Horizontal dispersions for Daphnia, Holopedium, total copepodids, total copepodid nauplii and total crustaceans indicated high probabilities for infradispersion and low probabilities for superdispersion. An estimate of total crustacean dispersion was necessary to determine if they represented distributions of their components. If dispersions were similar, they may support the assumption of using total crustacean mean densities in "F" test comparisons.

RESULTS AND DISCUSSION

The four lakes were similar in that they had a simple species structure and low density of zooplankton. The principle zooplankton were two copepods, Diaptomus lintoni, S. A. Forbes 1893 and Cyclops sp.; and two cladocerans, Daphnia rosea, Sars 1862 amend. Richard 1896, and Holopedium amazonicum, Stingelin 1904. Holopedium amazonicum was only found in samples from Silver and Gold Lakes in 1966 and also in Copper Lake in 1967. Rotifers included Conochilus sp. with occasional observations of Keratella sp. and Trichotria sp.

A. Comparison of Lakes

The density and composition of microcrustaceans was similar from July - September, 1966 (Fig. 1). The mean number of taxa for all the sampling dates appear to represent those of each sampling date. It was then assumed that total crustaceans can be used as density estimates of the taxa.

The horizontal distributions of the comparison of lakes data are indicated in Table 1. All components and total crustaceans have high probabilities for infradispersion and low probabilities for superdispersion. All crustaceans were infradispersed except total copepodid nauplii in Gold and Tin Lakes. The superdispersion in Gold Lake was attributed to total copepodid nauplii density on August 25 (Fig. 1). This increase may have been due to counting errors caused by clumping during preservation or too rapid growth in one of the many developmental stages.

Total copepodid nauplii from Tin Lake were superdispersed with the highest density occurring on August 10. Abundance and subsequent maturation of these nauplii was indicated by total copepodid increase on August 25 and September 10. Comita and Comita (1957) found that nauplii can be superdispersed because developmental stages are of different sizes and coexist in microhabitats where competition for food is less. Infradispersion occurs when stages are considered separately and there appears to be a preference for similar grazing spaces.

In this study, frequent occurrence of infradispersion was due to the extreme low density of crustaceans. Zooplankton commonly forage on nannoplankton which were not observed in any great abundance. The poor productive capacity of these lakes is apparently due to the low quantity of available inorganic nutrients which form the basic materials for structure and growth of living organisms. In-

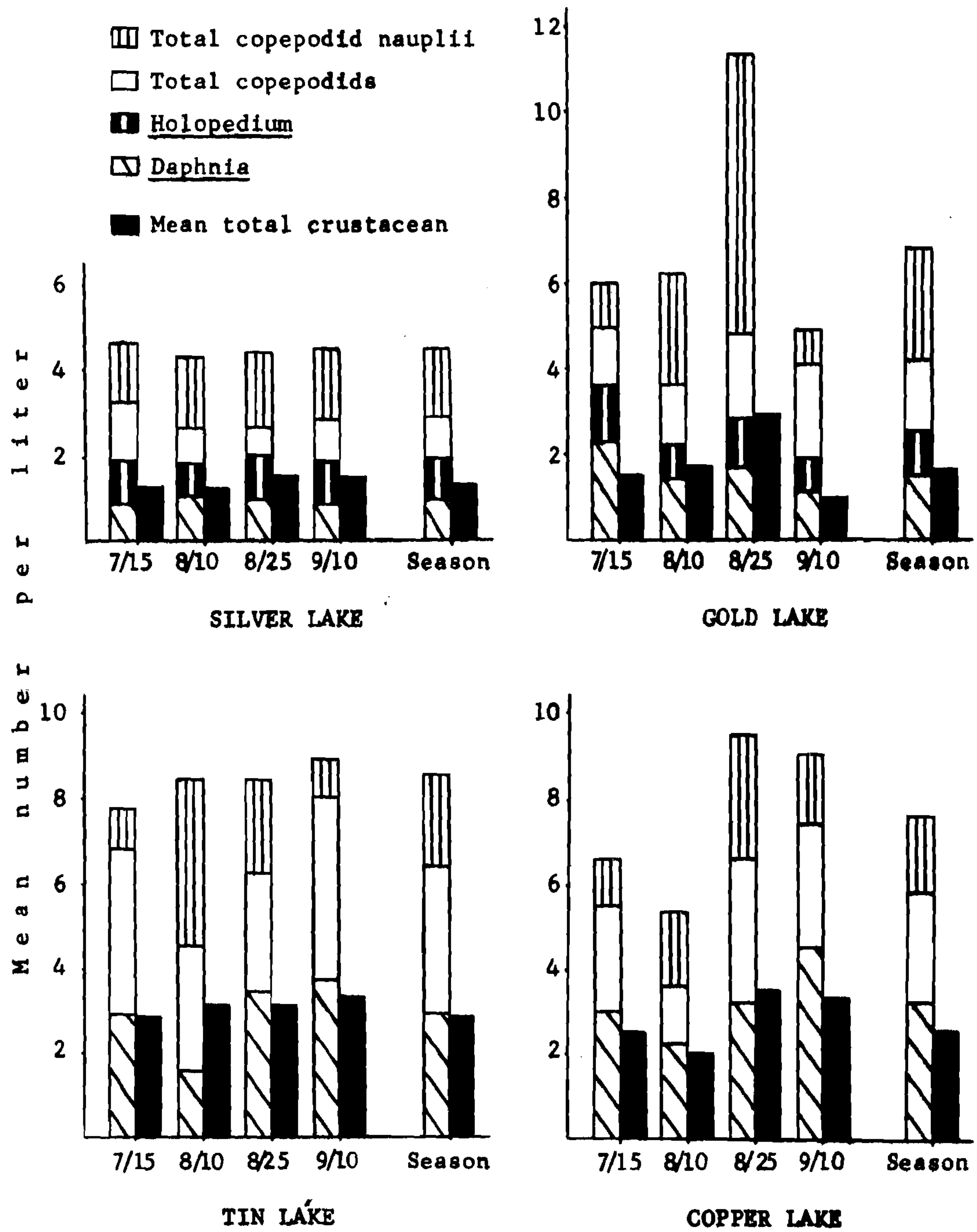

Fig. 1 Comparison of Zooplankton density in four lakes, 1966.

Table 1. Types of horizontal dispersion for mean number of taxa and total crustaceans per liter, 1966.
I = Infradispersion, R = Random, S = Superdispersion

	d.f.	$\overline{X}$	S^2	$S^2/\overline{X}$	X^2	P	DISPERSION
Silver L.							
Daphnia	15	0.8	0.1	0.1	1.5	~.995	I
Holopedium	15	1.0	0.3	0.3	4.5	~.995	I
Total Copepodids	15	1.0	0.1	0.1	1.5	~.995	I
Total Copepodid Nauplii	15	1.6	0.4	0.3	4.5	~.995	I
Total Crustaceans	63	1.1	0.3	0.3	16.4	~.995	I
GOLD L.							
Daphnia	15	1.5	0.4	0.3	4.5	~.995	I
Holopedium	15	0.9	0.2	0.3	4.5	~.995	I
Total Copepodids	15	1.7	0.5	0.3	4.5	~.995	I
Total Copepodid Nauplii	15	2.7	10.0	3.7	56.3	~.005	S
Total Crustaceans	63	1.7	3.1	1.8	114.7	~.005	S
Tin L.							
Daphnia	15	2.8	2.1	0.8	12.0	~.750	R>I
Total Copepodids	15	3.5	2.0	0.6	9.0	~.900	I
Total Copepodid Nauplii	15	1.9	2.7	1.4	21.0	~.200	S
Total Crustaceans	47	2.7	2.4	0.9	41.8	~.750	R>I
Copper L.							
Daphnia	15	3.1	1.5	0.5	7.5	~.750	I
Total Copepodids	15	2.5	1.0	0.4	6.0	~.975	I
Total Copepodid Nauplii	15	1.8	0.8	0.4	6.0	~.975	I
Total Crustaceans	47	2.5	1.1	0.4	20.2	~.995	I

addition, the shortened growing season limits production at these higher elevations. It is then assumed that total crustaceans were infradispersed. Similarities of dispersion help justify analyses based on total crustacean densities.

The crustacean density in the lakes was compared by analysis of variance and results indicated a significant difference at the .01 probability level (Table 2). The highest standing crops occurred in Copper and Tin Lakes respectively. Standing crop in Gold Lake was greater than in Silver Lake. These results were based on a multiple range test of means (Duncan, 1955). The small differences were in agreement with the dispersion estimates. The data shows that there are no tendencies of organisms being exclusively random or superdispersed which is indicative of higher densities (Table 1). There was not enough evidence to indicate why the meadow lakes had the greatest biomass of zooplankton. These lakes are located at lower elevations and the substrata is composed of a greater percentage of organic matter than exists in the rocky lakes. Water chemistries however are essentially similar in the four lakes.

The dispersion and densities of total crustaceans were also analyzed for variation between lakes and sampling dates. Horizontal dispersions are presented in Table 3; infradispersion was predominant. Superdispersion in Gold Lake on August 25 was caused by a high total copepodid nauplii count. This particular pulse made total copepodid nauplii appear superdispersed for the entire season (Table 1). The randomness of total crustaceans in Tin Lake on July 15 and September 10 was attributed to high counts of Daphnia and total copepodids.

The density of total crustaceans in each lake was tested for variations between sampling dates. Silver and Tin Lakes showed no significant difference for total crustaceans. Gold Lake showed a significant difference at the .05 probability level. The multiple range test indicated that total crustaceans density only varied on August 25 when total copepodid nauplii counts were high (Table 4). Copper Lake had a significant difference between dates at the .01 probability level. The multiple range test indicated that highest total crustacean density occurred on August 25 and September 10 (Table 4). An increase in Daphnia and total copepodids seemed to cause this increase (Figure 1).

The density of total crustaceans for each sampling date was tested for variations between lakes. On any of the four dates, at least one of the lakes

Table 2. Comparison of mean total crustaceans per liter in the four lakes, 1966.

A. Analysis of Variance

Source of Variation	d.f.	S.S.	M.S.	"F"
Among Lakes	3	93.8	31.3	18.1**
Within Lakes	220	381.1	1.7	
	223	474.9		

B. Duncan's Multiple Range Test

Silver L.	Gold L.	Tin L.	Copper L.
1.1	1.7	2.5	2.7

Table 3. Types of horizontal dispersion for sampling dates of lakes.*
I = Infradispersion, R = Random, S = Superdispersion.

		SILVER LAKE	GOLD LAKE	TIN LAKE	COPPER LAKE
	d.f.	15	15	11	11
JULY 15	$\bar{X}$	1.1	1.4	2.7	2.4
	S^2	0.2	0.4	3.1	0.9
	$S^2/\bar{X}$	0.2	0.2	1.1	0.4
	X^2	3.0	3.0	16.5	6.0
	P	~.995	~.995	~.425	~.975
	DISPERSION	I	I	R	I
AUG. 10	$\bar{X}$	1.0	1.5	3.0	1.9
	S^2	0.2	1.0	1.7	1.0
	$S^2/\bar{X}$	0.2	0.7	0.6	0.5
	X^2	3.0	10.5	9.0	7.5
	P	~.995	~.825	~.850	~.950
	DISPERSION	I	R > I	I	I
AUG. 25	$\bar{X}$	1.1	2.7	3.0	3.4
	S^2	0.4	9.5	1.9	0.4
	$S^2/\bar{X}$	0.3	3.5	0.6	0.1
	X^2	4.5	5.2	9.0	1.5
	P	~.995	~.990	~.850	~.995
	DISPERSION	I	S	I	I
SEPT. 10	$\bar{X}$	1.3	1.2	3.2	3.2
	S^2	0.3	0.6	3.5	2.0
	$S^2/\bar{X}$	0.2	0.5	1.1	0.6
	X^2	3.0	7.5	16.5	9.0
	P	~.995	~.950	~.425	~.850
	DISPERSION	I	I	R	I

* Expressed as mean number of total crustaceans per liter.

Table 4. Comparison of sampling dates for each lake, 1966.*

GOLD LAKE			
September 10	July 15	August 10	August 25
1.2	1.4	1.5	2.7

COPPER LAKE			
July 10	August 10	August 25	September 10
2.4	1.9	3.4	3.2

* Expressed as mean number of total crustaceans per liter.

showed a significant difference in total crustacean density (.01 and .05 probability levels). This was confirmed by multiple range tests (Table 5). The tests support the estimate of highest densities of total crustaceans in Tin and Copper Lakes for 1966. Differences in density for each taxon explain variations of lakes (Fig, 1).

The comparison of lakes was based on densities (mean total crustaceans $\overline{X}$) and horizontal distributions (coefficient of dispersion $S^2/\overline{X}$) of limnetic crustaceans. Comita and Comita (1957) proposed that their data was randomly distributed when the population was low and superdispersed when the population was high. This was examined by plotting the population density against the coefficient of dispersion for all developmental stages of copepodids. Their results indicated that there may be a linear relationship between the population density and the coefficients of dispersion.

It appears that the data may have been likewise randomly distributed. Total crustaceans density was plotted against its coefficient of dispersion for the four lakes and there was an indication that a linear relationship existed. The correlation coefficient for $\overline{X}$ and $S^2/\overline{X}$ was found to be 0.6109, which was significantly different from zero at the .05 level, (Fig. 2).

B. Comparison of Methods

The Pennak, Kemmerer and Van Doren plankton samplers were used to compare methods of collection. The highest densities of total crustaceans for the two years were in Tin and Copper Lakes (Fig. 3).

The types of horizontal dispersion of total crustaceans were considered for the three methods in the four lakes (Table 6). Silver and Gold Lakes were infradispersed supporting the low density estimates. Tin and Copper Lakes had essentially random distributions which indicated higher densities. Superdispersion in Tin Lake had low probabilities and were considered as random.

The three methods in Tin and Copper Lakes indicated no significant difference at the .05 probability level. There was a significant difference at the .05 probability level for Silver and Gold Lakes. A multiple range test indicated similarity of methods except in Gold Lake (Table 7). Samples using Pennak's rubber tube method exhibited higher counts for taxa, but the magnitude of the differences were not considered significant. Similar total crustacean counts were collected by the three methods in each lake.

Table 5. Comparison of lakes for each sampling date, 1966.*

JULY 15			
Silver L.	Gold L.	Copper L.	Tin L.
1.1	1.4	2.4	2.7

AUGUST 10			
Silver L.	Gold L.	Copper L.	Tin L.
1.0	1.5	1.9	3.0

AUGUST 25			
Silver L.	Gold L.	Copper L.	Tin L.
1.1	2.7	3.4	3.0

SEPTEMBER 10			
Silver L.	Gold L.	Copper L.	Tin L.
1.3	1.2	3.2	3.2

* Expressed as mean number of total crustaceans per liter.

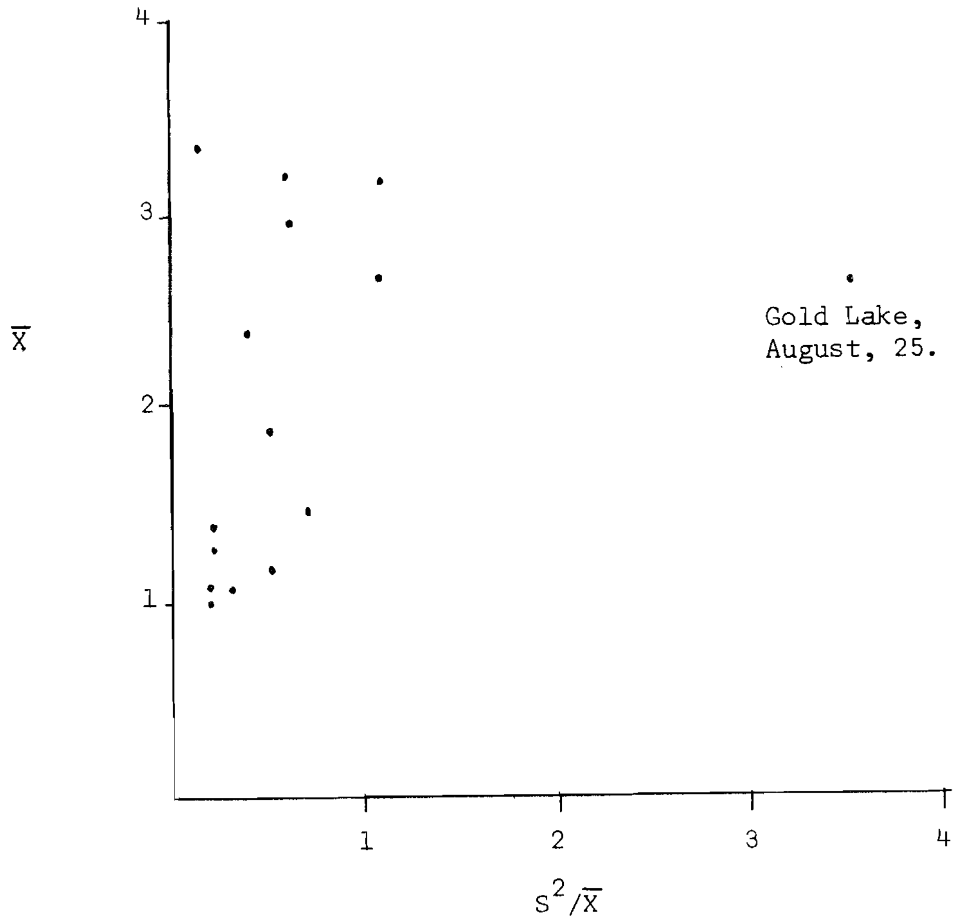

Fig. 2. Population densities plotted against Fisher's coefficient of dispersion for sampling dates of lakes. Expressed as mean number of total crustaceans per liter.

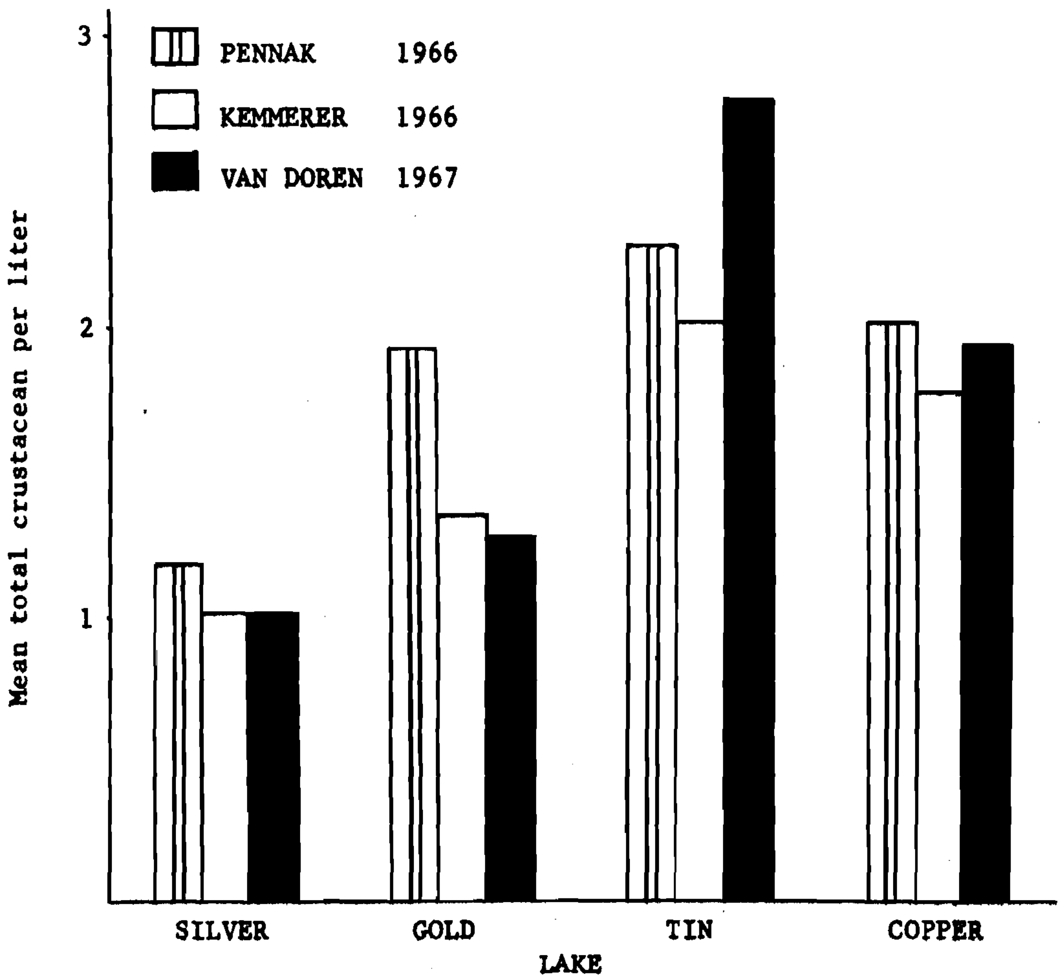

Fig. 3. Comparison of three zooplankton collection methods.

Table 6. Types of horizontal dispersion for methods in lakes.*
I = Infradispersion, R = Random, S = Superdispersion.

		1966 KEMMERER d.f. 15	1966 PENNAK d.f.15	1967 VAN DOREN d.f. 15
SILVER LAKE	$\bar{X}$	1.0	1.2	1.0
	S^2	0.3	0.2	0.1
	$S^2/\bar{X}$	0.3	0.2	0.1
	X^2	4.5	3.0	1.5
	P	~.995	~.995	~.995
	DISPERSION	I	I	I
GOLD LAKE	$\bar{X}$	1.4	1.9	1.3
	S^2	0.6	0.7	0.3
	$S^2/\bar{X}$	0.4	0.4	0.2
	X^2	6.0	6.0	3.0
	P	~.975	~.975	~.995
	DISPERSION	I	I	I
TIN LAKE	$\bar{X}$	2.0	2.3	2.7
	S^2	2.8	1.9	5.8
	$S^2/\bar{X}$	0.4	0.4	0.2
	X^2	21.0	12.0	31.5
	P	~.150	~.700	~.008
	DISPERSION	S	R>I	S
COPPER LAKE	$\bar{X}$	1.7	2.0	1.9
	S^2	1.7	1.2	1.6
	$S^2/\bar{X}$	1.0	0.6	0.8
	X^2	15.0	9.0	12.0
	P	~.450	~.850	~.700
	DISPERSION	R	R>I	R>I

* Expressed as mean number of total crustaceans per liter.

Table 7. Comparison of sampling methods *within* lakes, 1966 and 1967.*

SILVER LAKE			GOLD LAKE		
Van Doren	Kemmerer	Pennak	Van Doren	Kemmerer	Pennak
1.0	1.0	1.2	1.3	1.4	1.9

* Expressed as mean number of total curstaceans per liter.

The density and distributions of total crustaceans collected by the three methods in four lakes had a linear relationship. The correlation coefficient for $\overline{X}$ and $S^2/\overline{X}$ was found to be 0.897, which was significantly different from zero at the .05 level (Fig. 4).

C. Comparison of Sample Size

The relationship of sample size to density and coefficient of dispersion of total crustaceans was examined for variation. Silver Lake was selected because a larger volume could be taken from its deeper limnetic area. A metered tow net was used to collect large volumes of water from the upper ten meter stratum. This information was compared to small volume Kemmerer and Van Doren samples from shallow depths (Table 6).

The data for different sample sizes, methods and depths (Table 8) indicated that the coefficient of dispersion and density of total crustaceans remained constant as the sample size and depth changed. There was no significant difference in the densities of total crustaceans. Similarities of total crustacean densities and dispersion estimates from different sample volumes were attributed to the low crustacean density throughout the limnetic region of Silver Lake.

The low density of crustaceans indicated the need for larger sample volumes. The necessary sample size may be approximated by calculating the number of replications per station as described by Steel and Torrie (1960).

$$r \geq \frac{2\,(t_o + t_1)^2 S^2}{\delta^2}$$

The r is the number of replications per station; S^2 is an estimate obtained from the previous experiment; δ is the size difference necessary; t_o is the t value associated with Type II error. The t_1 equals tabulated t for probability 2(1-P) where P is the required probability of detecting δ.

When previous data were selected from two sample sizes of the Kemmerer method (Table 6), the variance of the two Kemmerer sample sizes was 0.4 based on 30 degrees of freedom. If a difference of 0.5 organisms per liter desired between two stations then the probability of Type I error equals 0.05 and Type II error 0.20. If 20 replications are required at each of the two stations, then error degrees of freedom are 39.2. If the volume of each replication is 110 liters (average of Kemmerer samples), 4,312.0 liters per station would be necessary to detect a difference of 0.5 organisms per liter. A difference of 1 organism per liter would require 985.6 liters per station.

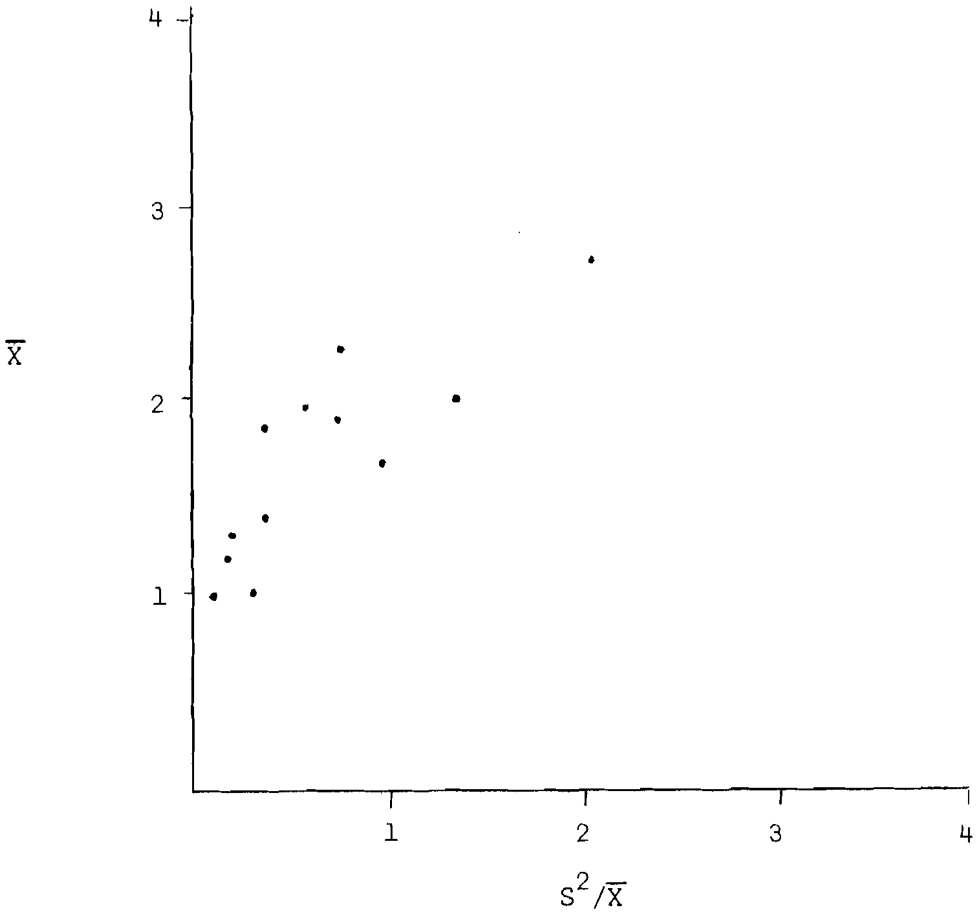

Fig. 4. Population densities plotted against Fisher's coefficient of dispersion for methods in lakes. Expressed as mean number of total crustaceans per liter.

Table 8. Types of horizontal dispersion in Silver Lake for sample sizes based on mean number of total crustaceans per liter.

Method	Sample Size* (liters)	Sample Depth (meters)	d.f.	$\bar{X}$	S^2	$S^2/\bar{X}$	X^2	P	DISPERSION
Pennak 1966	(120)	2	15	1.2	0.2	0.2	3.0	~.995	I
Kemmerer 1966	(40)	2	15	1.0	0.3	0.3	4.5	~.995	I
Van Doran 1967	(120)	2	15	1.0	0.1	0.1	1.5	~.995	I
Kemmerer 1966	(180)	11	15	1.4	0.5	0.4	6.0	~.975	I
Van Doran 1967	(720)	11	15	1.7	0.4	0.2	3.0	~.995	I
Metered Net 1967	(3280)	11	15	1.6	0.4	0.3	4.5	~.995	I

* Total sample volume for season.

The collection of large volumes for comparison of limnetic crustacean densities in these waters may be considered adequate when taken with replicate vertical samples where horizontal dispersions are essentially homogenous. Low density estimates to be used in "F" tests might be averaged and converted to number per 100 liters.

The recommended sampler for collecting limnetic crustaceans is a simple tow net with a coarse meshed net (No. 14-15), large aperture, offset towing bridle, and a large net surface area. The tow rates might then be increased without causing turbulence in front of the net and avoidance by crustaceans.

It should be noted that low density estimates may have been influenced by avoidance behavior of the crustaceans. Fleminger and Clutter (1965) state that when samplers are preceded by a towing line, crustaceans may react to tactile stimuli or pressure waves which are created ahead of the moving samplers. They found that relatively more animals were collected in denser populations. This suggests that interindividual inteference may be responsible for their restricted movements. The degree of avoidance is most likely related to behavior and locomotor capabilities characteristic of the species. In this study, avoidance may have been due to low crustacean density and high transparency of water which provides additional space for movement and increased visibility.

SUMMARY

1. Four subalpine lakes in northeast Idaho were studied during the summers of 1966 and 1967. These lake areas ranged from 1.0 to 3.5 hectares and from 2 to 13 meters in depth.
2. Limnetic crustaceans exhibited a simple species structure and low density.
3. Mean total crustacean density and horizontal dispersion appeared to approximate taxa density and horizontal dispersion.
4. Tin and Copper Lakes had higher densities of limnetic crustaceans than Silver and Gold Lakes, 1966 and 1967.
5. There was an indication that a positive linear relationship existed between total crustacean density and coefficient of dispersion when sampled by three methods in four lakes.
6. The similarities of total crustacean density and dispersion estimates from different methods and sample sizes was attributed to the low density in the limnetic region of these waters.
7. It is recommended that larger sample sizes are needed to increase the accuracy of density and dispersion estimates, and that sampling should be repeated by vertical hauls with simple tow nets.
8. Reliability of samples could have been affected by crustacean avoidance of samplers, which may be high in these waters having low plankton density and high transparency.

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