MACROBENTHIC COMMUNITIES IN THE COEUR D'ALENE LAKE SYSTEM

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ABSTRACT

Benthic invertebrates were sampled and identified from four depths in four areas of the Coeur d'Alene Lake system over a 7-month period. I identified 23 genera of chironomids. Oligochaetes were the most common taxa collected in Lake Chatcolet and Round Lake, which were nutrient-enriched waters containing large macrophytic populations. Chironomids were the most common taxa in Lake Coeur d'Alene where aquatic vegetation and enrichment were less. Sixty percent of the organisms were found in samples from 2 m, but wide variation was observed.

The concentrations of five heavy metals in the lake sediments were measured to determine the extent of contamination by mine and smelter wastes in the lake system and any possible effect on benthic communities. Zinc concentrations were 627-7,320 ppm in Lake Coeur d'Alene and 10-105 ppm in Chatcolet and Round Lakes. Numerical distribution of chironomids and oligochaetes did not appear to be substantially affected by metal concentrations.

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INTRODUCTION

Lake Coeur d'Alene, with a surface area of 120 km^2, is the second largest lake in Idaho and an important vacation and recreation area. The lake is drained by the Spokane River at Coeur d'Alene and fed by two major streams, the Coeur d'Alene and the St. Joe Rivers, both draining the west slopes of the Bitterroot Mountains (Fig. 1).

Since 1890, the Coeur d'Alene River has received mine, industrial, and domestic wastes. Kemmerer *et al.* (1923) reported that rock flour could be traced far out into the clear water of the lake in 1911. The mines switched to a new process in 1927, which crushed the ore into particles so fine that a considerable portion became a colloidal suspension. These were carried greater distances in the drainage system. The river depth has been decreased by siltation, and large volumes of rock flour have been deposited in the lake.

Metal concentrations in the lake and river have been documented by Mink *et al.* (1971). Ellis (1932) observed the river to be almost devoid of fish and benthic invertebrates. Savage (1970) noted a decrease in the depth of the silt covering the original substrate, an increase in attached forms of algae, and a slight increase in benthic invertebrates in 1968, after construction of settling ponds by the mining companies. Sappington (1969) obtained 96-hour TLm values of 0.62, 0.27, and 0.09 ppm zinc for cutthroat trout in a static system. These values are well within the range of concentrations found in the Coeur d'Alene River.

Minter (1971) studied the plankton population structure in the Coeur d'Alene River and Lake. Parker (1972) divided the lake into three trophic areas according to primary production, plankton community structure, and nutrients. He concluded that some of the nutrients in the southern portion of the lake are added by the Coeur d'Alene and St. Joe Rivers. Wissmar (1972) determined some of the effects of zinc, copper, and cadmium on primary production in the lake and river. Except for a preliminary study by Ellis (1932) and a fish food study in Round Lake (Marcuson 1966), the benthos of the Coeur d'Alene Lake system has not been investigated.

Benthic macroinvertebrates play an essential role in recycling nutrients from the sediments and are the main source of food for most fish in at least their early stages. They are excellent indicator organisms because many species are extremely sensitive to changes in water quality and are relatively sedentary. Also, bottom fauna usually have a complex life cycle of a year or more, and thus their presence or absence may reflect physical or chemical changes in the water over a lengthy time period.

Stations were selected at four depths in four areas of the lake at 6-8-mile intervals along the north-south axis of the lake. Samples were collected for benthic invertebrates, heavy metals, and organic carbon analysis. The pH, temperature, and dissolved oxygen were measured at each station.

The following objectives were established:

1. To measure pH, temperature, and dissolved oxygen in the water and organic carbon content and heavy metals in the lake sediments;
2. To collect and identify the benthic macroinvertebrates and determine their distribution in the lake; and

3. To attempt to relate any effect of heavy metals in the sediments and nutrients in the water on the distribution of the macro-invertebrates.

METHODS

Chatcolet, Harrison, Carlin Bay, and Cougar Bar were selected in the lake and four stations established in each area at depths of 2, 5, 10, and greater than 20 m. No deep-water station was located in the Chatcolet area. The 15 stations were situated as follows (Fig. 1):

Station 1A, in the NW end of Round Lake, approximately 100 m ENE from the end of the St. Joe River levy which extends NW to Lake Coeur d'Alene. 2 m.

Station 1B, in Chatcolet Lake directly east of the Park Hotel and approximately 100 m south of the southernmost piling marking the entrance to the St. Joe River from Chatcolet Lake. 5 m.

Station 1C, in Chatcolet Lake between Chatcolet and Rocky Point in line between the railroad drawbridge and the Chicago, Milwaukee, St. Paul, and Pacific Railroad trestle east of Hawley's Landing. 10 m.

Station 2A, 15 m east of the north levy of the Coeur d'Alene River. 2 m.

Station 2B, 5 m north of the last group of piling of the northwest of the Coeur d'Alene River mouth. 5 m.

Station 2C, approximately 1 km southwest of station 2B in line with the piling at the mouth of the Coeur d'Alene River. 10 m.

Station 2D, approximately 1/2 km from the west side of the lake between Spokane Point and Gasser Point in line with the piling in the Coeur d'Alene River. >20 m.

Station 3A, in Carlin Bay approximately 15 m west of the small bridge over Carlin Creek. 2 m.

Station 3B, approximately 250 m west of station 3A and directly north of the first large house on the south shore of the bay. 5 m.

Station 3C, approximately 1.25 km east of station 2A, centered between the bay shores and in line with the northeast shore of the lake. 10 m.

Station 3D, in the middle of the lake between McDonald Point and station 3C. >20 m.

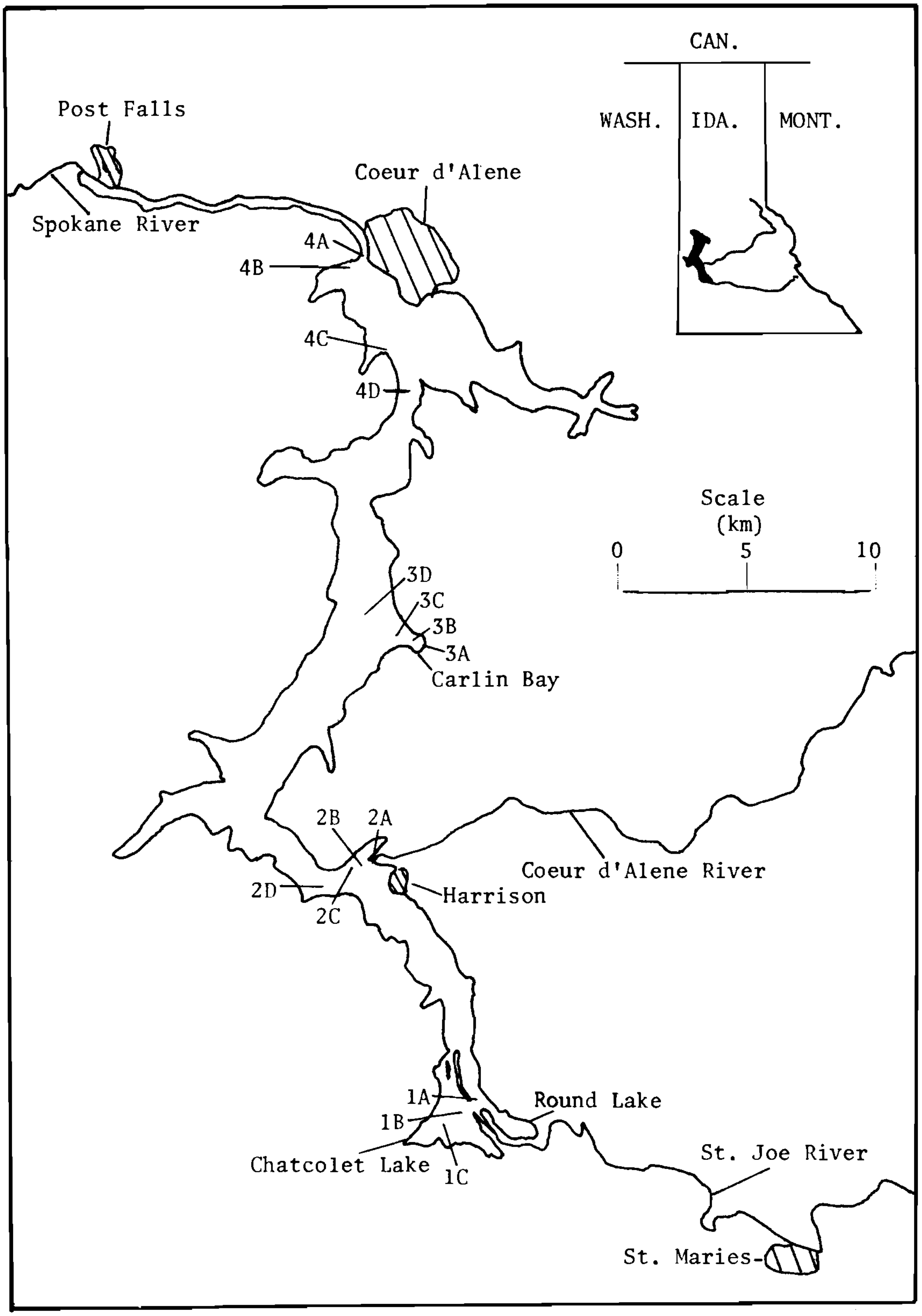

Fig. 1.--Coeur d'Alene Lake and station locations.

Station 4A, near old piling on the west bank in the mouth of the Spokane River. 2 m.

Station 4B, 10 m southeast of the multiple piling at the mouth of the Spokane River and near the entrance to the Texaco Marina. 5 m.

Station 4C, approximately 15 m off the North Cape, midway between Kid Island and Stevens Point. 10 m.

Station 4D, in the middle of the lake east of Three-Mile Point. >20 m.

Water and benthic samples were collected July 26-30, 1971, September 25-October 1, 1971, and March 25-27, 1972. Four benthic samples were obtained from each station on the first date and two from each station on the second and third dates. Sediments for heavy metal analysis by neutron activation and atomic absorption were collected on September, 1971, and March, 1972, respectively. Sediment for organic content analysis was collected on July, 1971, and March, 1972.

Dissolved oxygen was determined with a model 51 oxygen meter (Yellow Springs Instrument Co., Yellow Springs, Ohio) and temperature with an electronic thermometer (Applied Research Assoc., Austin, Texas). A Hellige Pocket Comparator was employed to estimate pH. A Van Dorn water bottle was used to obtain water for pH measurements and DO measurements below 16 m.

Samples for organic content and heavy metal analysis were carefully collected with an Eckman dredge to minimize disturbance of the substrate surface. Sediment from the top 3 cm was placed in glass jars and stored on ice. Samples were homogenized by stirring with a glass rod before sub-samples were removed for analysis. Organic carbon content was estimated by drying approximately 12 g of wet sediment to a constant weight and measuring the weight loss after ashing at 550 C.

The metal analysis on the sediments collected in September was performed by neutron activation at the Radiation Center at Washington State University. Analysis of the samples collected in March was performed by atomic absorption in the Sanitary Engineering Lab at WSU. The atomic absorption method (Lagerwerff and Specht 1970) resulted in lower values for zinc than those obtained by neutron activation possibly because of incomplete digestion of the sediment. Only zinc concentrations were obtained on both dates.

Benthic samples were collected with a 15.24 by 15.24 cm standard Eckman dredge at all stations except 4A and 4B in Cougar Bay, where a Peterson dredge was used. Samples were not accepted unless a complete square at least 3 cm deep was obtained. A standard 30-mesh seive was placed under the dredge before lifting it from the water to prevent loss of organisms. The samples were strained through the seive and preserved in 70% isopropyl alcohol. Organisms were separated from the debris under a dissecting microscope. Counts were multiplied by 43 and reported as no./m^2.

Chironomid larvae were soaked for 24 hours in 9% KOH, rinsed for 2 hours in distilled water, transferred to absolute alcohol for 1 hour, and mounted on a slide ventral side up in Euparal (GBI Labs Limited, Dendon, England). Light pressure on the coverslip helped expose parts necessary for identification. Keys by Mason (1968) and Johannsen (1969) were used to identify Chironomidae and Ceratopagonidae; by Usinger (1968) for Trichoptera, Ephemeroptera, Odonata, and Coleoptera; and by Pennak (1953) for Hirudinea and miscellaneous organisms.

RESULTS

Water Chemistry

Lake Coeur d'Alene was stratified in July with the thermocline at 9 m (Fig. 2). The temperature was 25 C at the surface and 5 C near the bottom at a depth of 50 m. Temperature in Chatcolet Lake ranged from 25 C at the surface to 11 C off the bottom. In September, a weak thermocline remained at 13 m in Coeur d'Alene Lake with temperatures from 14-6.5 C. Chatcolet Lake was homothermous in September, and both lakes were homothermous in March at 6.5 C.

Dissolved oxygen was similar at all stations in the Coeur d'Alene Lake. It ranged from 7.8-4.0 mg/l in July, 9.8-4.5 mg/l in September, and 8.0-11.8 mg/l in March, 1972 (Fig. 3). The dissolved oxygen in Chatcolet Lake ranged from 7.8-1.0 mg/l in July, 8.2-10.0 mg/l in September, and 11.6 mg/l in March (Fig. 3).

The pH ranged from 7.5 at the surface to 6.2 near the bottom of all stations over 20 m depth in Coeur d'Alene Lake and 10 m depth in Chatcolet Lake. In September and March, the pH was 6.8-7.2 in both lakes.

Sediment Chemistry

The highest percentage of organic carbon in the sediments was 17.7 in Cougar Bay and the lowest 5.7 in samples from the Chatcolet area (Table 1). The organic content increased with depth and was slightly higher in March than July.

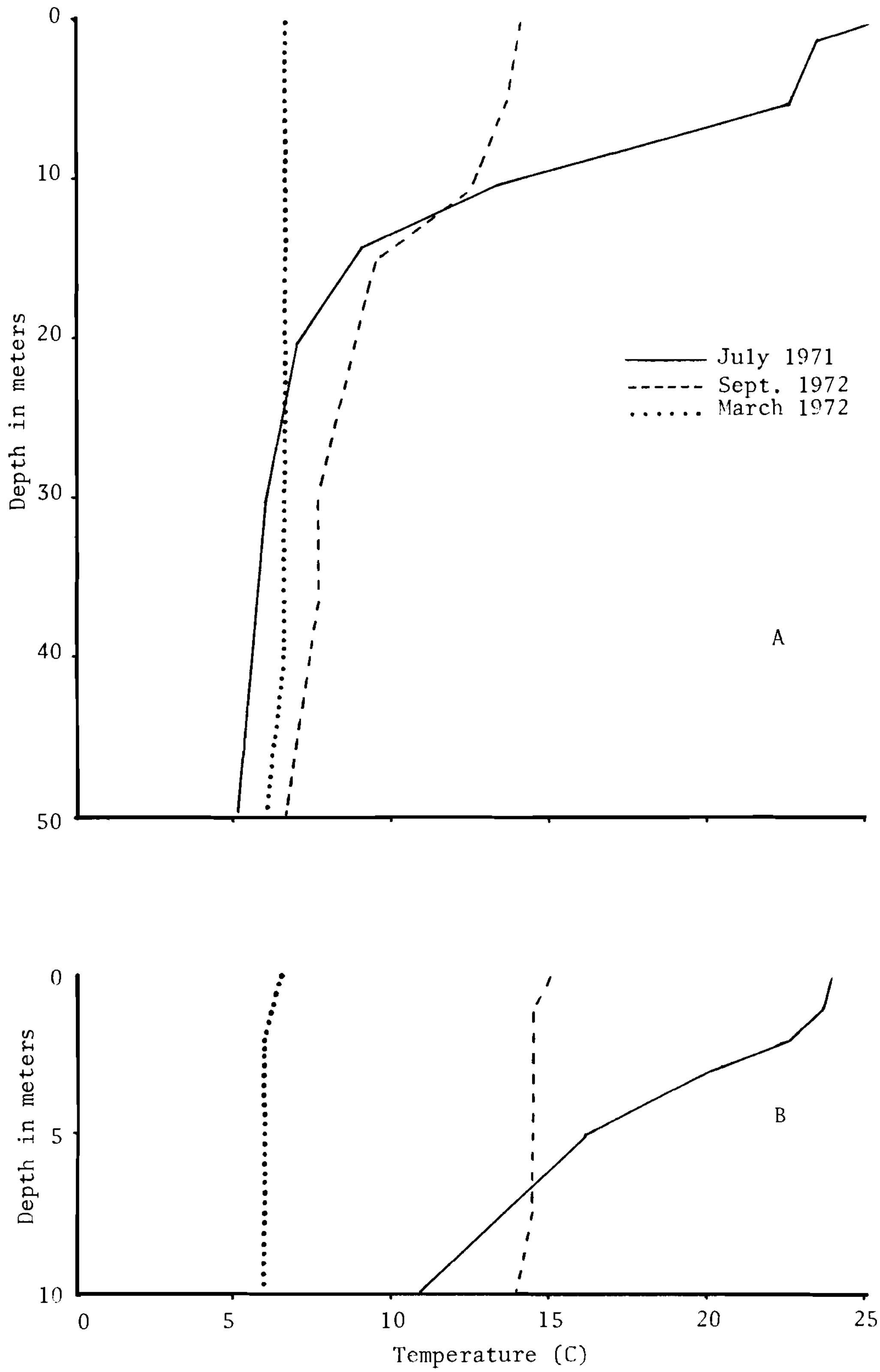

Fig. 2.--Temperature curves for Lake Coeur d'Alene (A) and Chatcolet Lake (B).

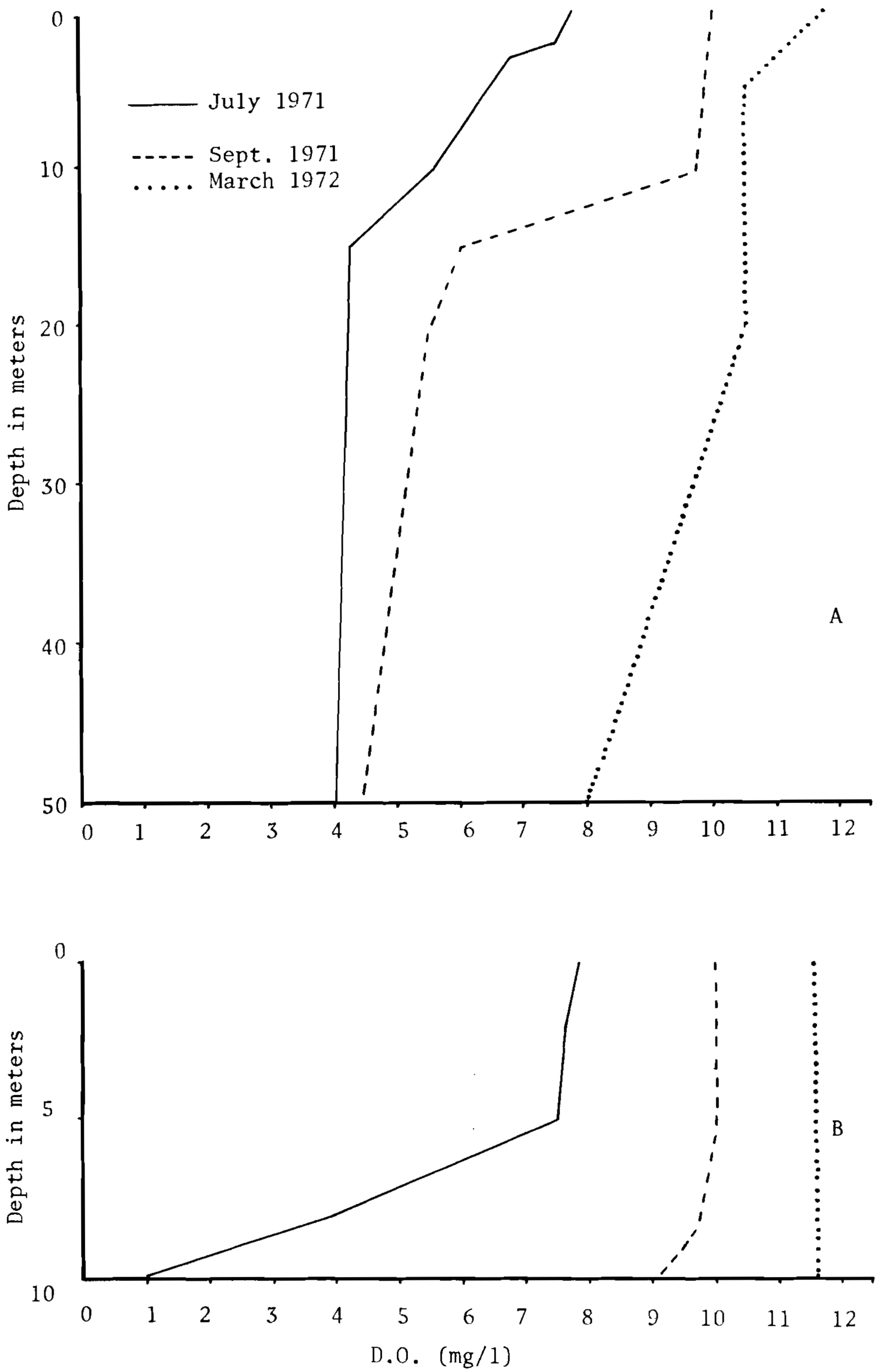

Fig. 3.--Dissolved oxygen curve for Coeur d'Alene Lake (A) and Chatcolet Lake (B) for each date sampled.

TABLE 1.--Estimated percentage organic carbon in the sediments of the Coeur d'Alene Lake system for July, 1971, and March, 1972

Area	Date	Depth in m			
		2	5	10	>20
Chatcolet	July, 1971	6.4	6.7	7.1	....
	March, 1972	5.8	6.6	7.9	....
Harrison	July, 1971	8.1	6.7	8.4	8.1
	March, 1972	8.6	7.5	7.4	8.0
Carlin Bay	July, 1971	7.3	7.3	9.5	9.7
	March, 1972	9.7	6.5	6.7	8.8
Cougar Bay	July, 1971	7.1	13.3	17.7	11.8
	March, 1972	3.0	10.6	8.9	9.6

Zinc constituted 0.45-0.73% of the top 3 cm of the sediment collected in September, 1971, in the direct flow of the lake north of Harrison but decreased to 0.06% in the east end of Carlin Bay and was not detected in the sediments of Chatcolet or Round Lakes (Table 2). Approximately 10% of the sediment in the Harrison area was iron, which represented 3.0-7.5% at all other stations. Iron concentrations increased with depth and were lower in Chatcolet and Round Lakes than in Lake Coeur d'Alene. Antimony in the sediments varied from 1-120 ppm and was higher in Lake Coeur d'Alene than in Chatcolet Lake.

In sediments collected in March, 1972, the copper concentrations were 3-6 ppm in Chatcolet Lake and 6-87 ppm in Coeur d'Alene Lake (Table 3). Magnesium varied from 180-362 ppm in Chatcolet and 160-660 ppm in Coeur d'Alene Lake. Concentrations of zinc and lead decreased with distance south of the Coeur d'Alene River delta (Fig. 4). Sediment from the St. Joe River, 5.25-9.5 miles from the mouth of the Coeur d'Alene River, was low in zinc and lead. Concentrations increased to 2,000-4,000 ppm between Conkling Park and the Coeur d'Alene River. The general flow of the lake is south to north, but wind and currents have carried heavy metals south as far as Conkling Park.

Benthos

Sixty-two taxa were counted and identified. They consisted of 26 species of Chironomidae, 9 Hydracarina, 9 Trichoptera, 5 Ceratopagonidae, and 14 miscellaneous invertebrates (Table 4). Chironomids made up 51-74.5% and oligochaetes 25.5-49% of the total number of organisms collected (Table 5). The 2-m station in Chatcolet contained the highest number of oligochaetes collected.

TABLE 2.--Metal concentrations in lake sediments (ppm) by neutron activation collected September, 1971

Station	Depth (m)	Concentration (ppm)		
		Zn	Fe	Sb
Chatcolet				
1A	2	ND[a]	31,700	1
1B	5	ND	44,900	23
1C	10	ND	53,000	1
Harrison				
2A	2	...[b]	20,800	32
2B	5	6,760	111,300	101
2C	10	5,140	95,100	77
2D	>20	6,200	100,000	93
Carlin Bay				
3A	2	627	35,900	3
3B	5	4,640	53,430	43
3C	10	4,100	55,100	43
3D	>20	6,700	75,100	120
Cougar Bay				
4A	2	1,430	48,800	5
4B	5	7,320	54,800	107
4C	10	7,220	75,700	63
4D	>20	...	...	...

[a]ND = not detected.

[b]....= no data.

TABLE 3.--Metal concentrations in lake sediments (ppm) by atomic absorption collected March, 1972

Station	Depth (m)	Concentration (ppm)		
		Zn	Cu	Mg
Chatcolet				
1A	2	10	5	362
1B	5	10	3	375
1C	10	105	6	180
Harrison				
2A	2	635	20	350
2B	5	640	22	362
2C	10	1,120	48	385
2D	>20	1,225	61	435
Carlin Bay				
3A	2	588	6	160
3B	5	1,405	33	325
3C	10	3,400	87	450
3D	>20	3,400	68	660
Cougar Bay				
4A	2	1,400	10	225
4B	5	3,475	67	612
4C	10	5,125	64	425
4D	>20	5,050	49	485

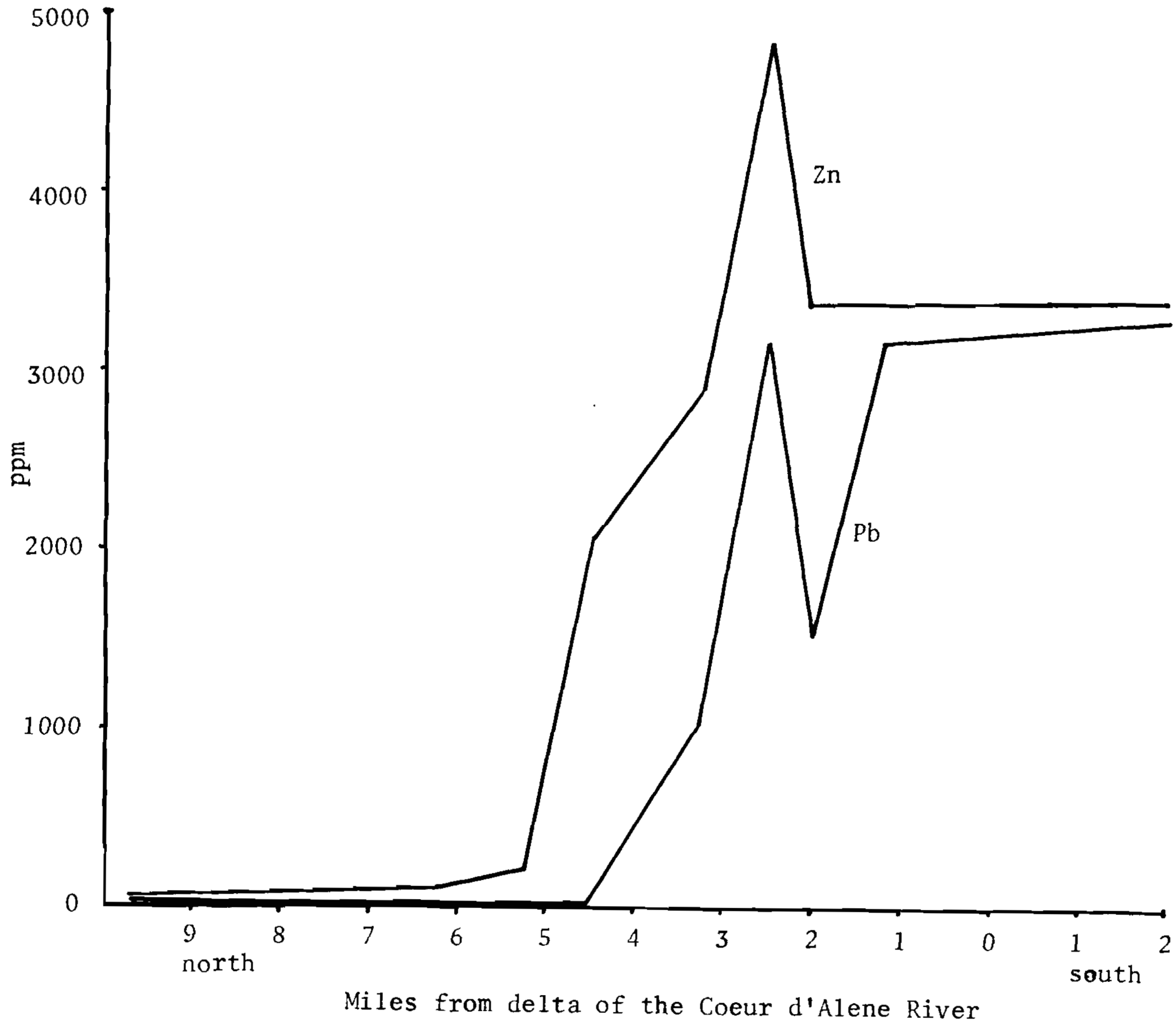

Fig. 4.--Metal concentrations in the sediments around Coeur d'Alene River delta.

TABLE 4.--A list of the macrobenthic taxa collected from Lake Coeur d'Alene, Chatcolet Lake, and Round Lake

Turbellaria
  Tricladida
    Planariidae ?[a]

Oligochaeta

Hirudinea
  Rhynchobdellida
    Glossiphosiidae
      Helobdella stagnalis

Crustacea
  Amphipoda
    Gammaridae
      Gammarus sp.

Arachnoidea
  Hydracarina
    Limnesiidae
      Limnesia sp.
    Hygrobatidae
      Hygrobates sp.
    Libertiidae
      Libertia sp.
    Unionicolidae
      Neumania sp.
      Unionicola sp.
    Pionidae
      Piona sp.
      Unk.
    Protziidae
      Calonys sp.
    Arrenuridae
      Arrenurus sp.

Insecta
  Ephemeroptera
    Heptigeniidae
      Epeorus sp.[b]
    Baetidae
      Ephemerella serrata levis
      Caenis sp.
  Odonata
    Coenagrionidae
      Enallagma sp. (possibly *E. clausam*)
  Plecoptera
    Perlodidae
      Isoperla sp.[b]

TABLE 4--Continued

Trichoptera
  Rhyacophiladae
    Rhyacophila sp.
    Glossosoma sp.
    Agapetus sp.
  Leptoceridae
    Mystacides sp.
  Hydroptilidae
    Agraylea sp.
    Dibusa sp.
  Hydropsychidae
    Hydropsyche[b]
  Limnophilidae
    Unk.
  Psychomyiidae[b]
    Unk.
Coleoptera
  Elmidae
    Zaitzevia sp.[b]
  Cicindelidae
    Megacephala sp.[c]
Diptera
  Ceratopagonidae
    Palpomyia group (four spp.)
  Chaoboridae
    Chaoborus sp.
  Tipulidae
    Tipula sp.
  Rhagionidae
    Athrix variagata
  Chironomidae
    Procladius (two spp.)
    Psectrotanypus sp.
    Guttipelopia ? sp.
    Thienemannimyia grp, one sp.
    Protanypus sp.
    Odontomesa sp.
    Psectrocladius sp.
    Heterotrissocladius sp.
    Cricotopus sp.
    Corynoneura sp.
    Chironomus (three spp.)
    Paratendipes sp.
    Cryptochironomus fulvus
    Cryptochironomus (two spp.)
    Polypedilum sp., Tripodura grp.
    Paracladopelma sp.
    Phaenopsectra sp.
    Endochironomus sp.
    Einfeldia sp.
    Glyptotendipes sp.

TABLE 4--*Continued*

Stictochironomus sp.
Tanytarsus sp.
Micropsectra sp.
Gastropoda
Planorbidae
Unk.
Pelecypoda
Pisidum sp.

[a] ? = unconfirmed.

[b] Probable drift from river or stream.

[c] Terrestrial.

TABLE 5.--Density estimates of chironomids and oligochaetes collected from the Coeur d'Alene Lake system on three dates

Station	Depth (m)	Chironomidae/m^2				Oligochaeta/m^2			
		July	Sept.	March	Average	July	Sept.	March	Average
Chatcolet									
1A	2	2,776	1,657	8,845	4,426	22,682	10,050	1,033	11,255
1B	5	905	495	1,291	897	603	86	2,066	918
1C	10	646	22	430	366	2,335	839	1,313	1,496
Harrison									
2A	2	108	22	0	43	22	0	0	7
2B	5	667	1,636	366	890	108	1,291	65	488
2C	10	2,001	947	1,442	1,463	194	1,506	258	652
2D	>20	108	1,011	323	481	0	108	0	36
Carlin Bay									
3A	2	5,703	6,869	1,141	4,571	1,076	5,100	1,958	2,711
3B	5	839	344	667	617	581	194	43	273
3C	10	237	387	387	337	22	0	0	7
3D	>20	22	0	43	22	0	0	0	0
Cougar Bay									
4A	2	5,703	689	258	2,216	0	0	0	0
4B	5	108	495	452	352	237	430	430	366
4C	10	108	215	968	352	22	22	108	51
4D	>20	194	2,647	2,958	1,933	753	624	1,313	897

Samples from a 2-m depth contained the greatest diversity and number of organisms amounting to approximately 60% of the total collected. However, only four species and 11 organisms were collected at the 2-m station in the Harrison area. Samples from station 4A, in the mouth of the Spokane River, comprised a large number of organisms in July, but 85% were Tanytarsus or Micropsectra. Few organisms were collected at this station in September and March.

Stations at a 10-m depth consisted mostly of Procladius and Chironomus. Macroinvertebrate numbers showed a wide variation at the three deep stations exceeding 20 m. Station 2D, near Harrison, contained only 172 Chironomus, 904 Micropsectra, and 904 turbellarians/m^2 in July, September, and March, respectively. Station-3D samples contained turbellarians and a few Micropsectra. I found a few turbellarians and 2,582-3.012 Chironomus sp. A/m^2 in station-4D samples.

Distribution of Common Species

Chironomidae

Seventy-three percent of the chironomids collected were in the sub-family Chironominae. Micropsectra was the most numerous and Chironomus the most commonly collected (Table 6). Tanytarsus and Micropsectra occurred in large numbers in water less than 5 m in depth. Chironomus sp. C and C. sp. B occurred most commonly at 2-10 m, and C. sp. A was collected only at station 4D, the deepest station. Endochironomus was most frequently collected at 2 m, and 6,327/m^2 were found at station 3A, in Carlin Bay, in March. Cryptochironomus was most commonly observed at 5 m or less. Procladius (sub-family Tanypodinae) was found at stations less than 10 m

TABLE 6.--Density estimates of each genus of the sub-family Chironominae collected in the Coeur d'Alene Lake system

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
1A	2	Chironomus	1,119	86	1,679
		Cryptochironomus	43	732	43
		Polypedilum	818	43	430
		Endochironomus	174	...	6,328
		Glyptotendipes	...	129	...
		Paratendipes	387	...	...
		Micropsectra	...	...	43
		Dicrotendipes	...	...	86
1B	5	Chironomus	129	344	86
		Cryptochironomus	43	...	43
		Endochironomus	...	43	43
		Glyptotendipes	129	43	517
		Micropsectra	43	...	...
1C	10	Chironomus	86	...	387
		Glyptotendipes	...	43	...
2A	2	...	...	...	...
2B	5	Chironomus	172	430	86
		Cryptochironomus	43	43	43
		Polypedilum	...	86	43
		Endochironomus	43	258	...
		Glyptotendipes	...	43	...
		Micropsectra	43	...	...
2C	10	Chironomus	1,248	775	86
		Cryptochironomus	...	...	43
		Polypedilum	344	...	344
		Endochironomus	...	...	43
		Micropsectra	172	...	129
2D	>20	Chironomus	172	43	...
		Polypedilum	...	...	86
		Endochironomus	...	43	...
		Micropsectra	...	904	129
3A	2	Chironomus	172	43	43
		Cryptochironomus	301	1,335	258
		Polypedilum	...	344	43
		Endochironomus	43	344	43

TABLE 6--Continued

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
		Glyptotendipes	...	172	129
		Micropsectra	3,659	1,507	43
		Stictochironomus	474	...	43
3B	5	*Chironomus*	172	129	43
		Cryptochironomus	129	...	...
		Polypedilum	129	...	...
		Paratendipes	43	...	...
		Micropsectra	43	...	43
3C	10	*Micropsectra*	...	301	215
3D	>20	*Chironomus*	43	...	...
		Micropsectra	...	...	43
4A	2	*Cryptochironomus*	430	...	...
		Endochironomus	86	...	...
		Micropsectra	4,822	344	258
4B	5	*Chironomus*	...	344	430
		Cryptochironomus	43	...	...
		Micropsectra	43	86	...
4C	10	*Chironomus*	...	...	43
		Cryptochironomus	...	...	43
		Glyptotendipes	...	...	43
		Micropsectra	...	...	172
4D	>20	*Chironomus*	215	2,626	2,927

in depth (Table 7). *Psectrocladius* and *Cricotopus*, sub-family Orthocladinae, were common at 2-5 m and *Protanypus* at 10 m (Table 7).

Other Diptera

Ceratopagonids were collected infrequently at all depths. Four species of the group *Palpomyia*, which includes the genera *Bezzia*, *Probezzia*, and *Palpomyia*, were sampled. These larvae could not be separated because current keys do not list distinguishing characteristics. A few *Athrix variagata* were collected at the 2-m stations. One tipulid, probably drifting, was found at station 2B near Harrison.

Chaoborus was observed at station 1C in the Chatcolet area and 2B near Harrison.

Oligochaeta

I counted seven different forms of oligochaetes. However, more were probably present since 33 species have been reported from Lago Maggiore (Brinkhurst 1963) and 22 from Esrom Lake (Berg 1938). Because of the difficulty in preparation and identification, I did not separate them. The highest numbers occurred in shallow water, and they decreased with depth, with three exceptions. Stations 2A and 4A (2 m at Harrison and Cougar Bay) contained very few oligochaetes due to the gravel or hard substrate, and 4D in Cougar Bay contained 623-1312/m^2. Between 22,380 and 24,533/m^2 occurred in Round Lake in July, where they comprised 80% of the invertebrates.

Trichoptera

Glossosoma and an unknown limnophilid were found in low numbers throughout the lake system (Table 8). Hydroptilids, *Agraylea*, occurred

TABLE 7.--Density estimates of *Procladius* and *Psectrotanypus* (sub-family Tanypodinae), *Psectrocladius* (Orthocladinae), and *Protanypus* (Diamesinae) collected on three dates in the Coeur d'Alene Lake system

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
1A	2	*Procladius*	215	430	43
		Psectrotanypus	86	...	...
		Psectrocladius	43	215	...
1B	5	*Procladius*	560	86	430
		Psectrocladius	43	...	43
		Protanypus	43	43	...
1C	10	*Procladius*	43	...	43
		Psectrotanypus	560	...	...
		Psectrocladius	43	...	...
2A	2	*Procladius*	43	43	...
2B	5	*Procladius*	215	517	215
		Psectrocladius	215	43	...
2C	10	*Procladius*	129	172	732
		Psectrocladius	172	...	...
2D	>20	*Procladius*	...	...	43
		Psectrocladius	...	43	86
3A	2	*Procladius*	172	517	344
		Psectrocladius	...	215	...
3B	5	*Procladius*	344	172	517
		Psectrocladius	43	...	...
		Protanypus	86	...	43
3C	10	*Procladius*	86	...	...
		Psectrocladius	...	...	43
		Protanypus	172	129	129
3D	>20	...	...	...	...
4A	2	*Psectrotanypus*	43	...	...
		Psectrocladius	301	86	...
4B	5	*Psectrocladius*	43	...	...
4C	10	*Procladius*	43	172	...
		Protanypus	43	...	...
4D	>20	...	...	...	...

TABLE 8.--Density estimates of Trichoptera collected on three dates in the Coeur d'Alene Lake system

Station	Depth (m)	Taxon	Number Collected/m^2		
			July	Sept.	March
1A	2	Dibusa	430	...	...
		Limnephilidae	...	43	...
		Glossosoma	...	...	129
1B	5	Limnephilidae	43	...	...
		Glossosoma	...	...	129
1C	10	...	...	...	...
2A	2	Psychomyiidae	43	...	...
		Glossosoma	...	43	...
2B	5	Limnephilidae	...	...	43
		Glossosoma	86	172	...
		Rhyacophila	...	...	43
2C	10	Limnephilidae	...	...	474
		Glossosoma	...	...	43
		Rhyacophila	...	...	172
2D	>20	...	...	...	...
3A	2	Agraylea	215	990	...
		Agapetus	...	129	...
		Rhyacophila	...	43	...
3B	5	...	...	...	...
3C	10	...	...	...	...
3D	>20	...	...	...	...
4A	2	Mystacidaes	...	603	...
4B	5	Agapetus	...	43	...
		Rhyacophila	...	...	43
4C	10	Glossosoma	...	...	43
		Limnephilidae	...	...	86
4D	>20	...	...	...	...

at $989/m^2$ at station 3A (Carlin Bay) in September and Dibusa at $430/m^2$ in July at station 1A in Round Lake. Over 600 Mystacidaes/m^2 occurred at station 4A in the mouth of the Spokane River in September. One Psychomiidae and a Hydropsyche were collected in the Harrison area but were probably washed in from the Coeur d'Alene River.

Hydracarina

Nine species of Hydracarina occurred in the lakes. Eighty-five percent of the total number collected were found in 2-5 m (Table 9). Limnesia, the most common genus, occurred at $8600/m^2$ at station 3A in Carlin Bay.

Miscellaneous

A small turbellarian, probably a triclad, was collected from deep stations. Over $530/m^2$ were observed at station 3C (10 m), but most were collected at depths over 20 m. Two species of baetids, a heptageniid and a coenagrionid, were found at 1A or 3A, the shallow stations in Round Lake and Carlin Bay. Elmid beetles and a terrestrial tiger beetle larva, collected from station 2B, were probably carried there by the Coeur d'Alene River.

Pisidium and planorbid snails were observed at stations in the Chatcolet area and at station 3A in Carlin Bay.

TABLE 9.--Density estimates of each genus of Hydracarina collected on three dates in the Coeur d'Alene Lake system

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
1A	2	*Limnesia*	86	430	301
		Hygrobates	...	...	43
		Arrenurus	...	...	43
1B	5	*Limnesia*	...	...	43
		Arrenurus	43	43	43
		Piona	...	43	86
1C	10	*Limnesia*	43	...	...
		Unionicola	...	...	43
2A	2	...	...	...	...
2B	5	*Limnesia*	...	43	...
		Piona	...	43	...
2C	10	*Limnesia*	...	...	43
		Piona	...	43	...
		Pionidae	...	43	...
		Neumania	...	...	43
2D	>20	*Limnesia*	43	...	...
3A	2	*Limnesia*	...	43	...
		Pionidae	...	43	...
3B	5	*Limnesia*	86	129	86
		Arrenurus	...	172	...
		Libertia	...	43	...
		Hygrobates	...	...	43
3C	10	*Hygrobates*	...	43	86
3D	>20	...	...	...	...
4A	2	...	...	...	...
4B	5	*Limnesia*	...	43	...
		Hygrobates	...	43	...
4C	10	*Limnesia*	43	43	43
4D	>20	...	...	...	...

DISCUSSION

The variation in the genera represented in samples was caused by several factors. Jonasson (1955) states that the use of the bottom sampler, the process of seiving, and sorting largely determine the degree of accuracy obtained. I observed that an Eckman dredge will sink more deeply in gytja than in more coarse material as found near the Coeur d'Alene River. Since the Eckman dredge does not give realistic estimates of benthos in gravel and sand (Hamilton et al. 1970), I used the Peterson dredge at the shallow stations in Cougar Bay where the bottom was gravel or littered with bark and log chips. Samples with large amounts of debris require longer periods of time to strain and therefore may contain fewer small species such as Corynoneura and Micropsectra since more of them would pass through the seive. I could not permanently mark my stations. However, shallow stations were easy to locate, and I observed the substrate and community composition to be homogeneous in deep water.

Since bottom fauna is not always evenly distributed, there is a risk that erroneous conclusions about the benthic populations may be drawn from samples that are too few. There was considerable variation in the eight samples from each station; however, they do indicate general trends.

An important factor limiting benthic communities is the oxygen content of the water adjacent to the bottom (Ruttner 1963). This is not a critical factor in the northern portion of the lake because of the oligotrophic nature. The lowest concentration observed for this part of the lake was 4 mg/l in July, 1971. I measured 1.0 mg/l in Chatcolet, and Minter (1971) observed 0.5 mg/l near Harrison. Ellis indicated that, to maintain a varied fish fauna in good condition, the dissolved oxygen should remain at 5.0 mg/l or higher (1932). However, Berg and Jonasson (1965) found that the invertebrates _Chironomus anthracinus_, _Procladius_ sp., _Tubifex barbatus_, and _Pisidium casertanum_ survived 3-4 weeks in water that was practically oxygen-free. The organisms containing hemoglobin maintained a constant respiration rate as oxygen concentrations in the water decreased to 3 mg/l and then dropped rapidly. The respiration rate of _Procladius_ sp. and _Pisidium casertanum_ decreased steadily with a decrease in dissolved oxygen and dropped sharply as the oxygen concentration approached zero (Berg _et al_. 1962).

Uniform low temperatures influence the composition of the benthic community in the profundal zone (Ruttner 1963). Temperature at the deep stations in the Cougar Bay and Carlin Bay areas probably do not greatly exceed the 6.5 C measured in March. Because of their depth, the water column is cooled before mixing affects the profundal zone in the fall overturn. This biotope is an ideal habitat for cold stenothermal organisms but not necessarily restricted to them. Under such conditions, an organism no longer needs to maintain a high degree of tolerance to survive in an ever-changing environment. In Lake Coeur d'Alene, few macroinvertebrates are adapted to living in this cold dark habitat. _Chironomus_ sp. A and a turbellarian were found only in these deep cold stations where they apparently avoid competition for both food and space.

Within a given lake, there usually exists a high correlation between the nature of the substrate and the number of species and population density (Reid 1961). I measured 5100-6100 ppm zinc in the sediments of the

Harrison area. Sceva[1] (unpublished data) found 0.5 ppm zinc in the water near the bottom in the same locale, The pH was 6.4-7.0, and conductivity was less than 50 μmhos in the lake and 50-320 μmhos in the Coeur d'Alene River (Minter 1971). These conditions are fatal to most fish (Pickering 1932, Rudolfs et al. 1950, Jones 1938, Sappington 1969). However, fish have been reported in the Coeur d'Alene River by residents, and fish are commonly caught in the area of the lake around Harrison. The zinc may be in a complexed form that is not as toxic as dissolved zinc. Wissmar (1972) reported a decrease in the inhibitory effects of zinc and copper to carbon fixation by phytoplankton with an increase in concentrations of calcium, magnesium, sodium, potassium, and manganese. I found 180-660 ppm magnesium in the lake sediments (Table 3), and Maxfield (pers. comm.) reported magnesium concentrations more than twice the concentrations of zinc in the sediments of the Coeur d'Alene River delta. Although these elements must be in the water to have an antagonistic effect, it is assumed that there is an equilibrium between the water and the sediment.

In spite of the high zinc concentration and relatively soft water, chironomids, rhagionids, and elmids survive in the river (Savage 1969), and many chironomids, oligochaetes, and other invertebrates live in the lake. To evaluate the acute toxicity of heavy metals to aquatic insects, Warnick and Bell (1969) conducted static bioassays using a stonefly, *Acroneuria lycorias*, a mayfly, *Ephemerella subvaria*, and a caddisfly, *Hydropsyche betteni*. All three organisms survived beyond 96 hours in 64 mg/l zinc although copper, iron, cadmium, and mercury were more toxic, in that order. Jones (1938) also observed a diverse benthic community in

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[1] Jack E. Sceva, Geologist, FWPCA, Room 501, Pittock Block, Portland, Oregon 97205. Heavy metal data for Coeur d'Alene Lake, 1970.

a stream contaminated with zinc from abandoned mines. Flentje (1945) found that 50 ppm copper sulfate was ineffective in controlling midge larvae in water treatment facilities.

Ellis (1932) detected rock flour from the mines over practically the entire lake. I found high zinc concentrations in the top 3 cm of lake sediments from Conkling Park, south of the Coeur d'Alene River, to the city of Coeur d'Alene at the north end of the lake. Therefore, since the investigation by Ellis, the rock flour has not been buried by sedimentation, or it has been buried by more rock flour. Ellis noted several species of dipteran larvae in Lake Coeur d'Alene but few in number. He did not identify these. Although I collected few benthic organisms at the 1-m station near Harrison, 11 genera of Chironomidae, 4 Hydracarina, 4 Trichoptera, and 1 of Turbellaria were observed where zinc concentrations were greater than 4500 ppm in the sediments and 0.5 ppm in the overlying water.

Areas containing aquatic vegetation also contained the greatest numbers and diversity of benthic invertebrates. The aquatic plants, which supply food, shelter, and diverse habitat for the organisms, are found in shallow water where oxygen is always present. Few organisms were observed at station 2A, at the mouth of the Coeur d'Alene River, where rooted aquatic plants were not present. Large numbers of chironomids representing a few species were noted in the mouth of the Spokane River where very few macrophytic plants occurred. The substrate at stations 4B and 4C, which include a portion of Cougar Bay, was covered with bark and debris as a result of log storage. Bark may depress oxygen levels and create a physical barrier for the development and maintenance of a healthy benthic community (Hansen et al. 1971). Yet, dissolved oxygen was never below

6 mg/1 at these stations, probably because of the depth, low temperature, and a dilution effect. However, the bark-littered substrate contained fewer benthic organisms than the other stations at similar depth.

The organic content of the sediment was inversely related to the number of chironomids and oligochaetes, probably because sediment organic content increased with depth (Johnson and Matheson 1968). This is caused by the greater sedimentation of plankton in the open water, colder temperatures, slower rate of decay, and less eddy diffusion in the deep water (Odum 1971).

A simplified food web of taxa based on collected data and observations is presented in Fig. 5. Trophic positions of the organisms were determined by gut content and previously reported food habits. Chironomus, Endochironomus, and Micropsectra consume large amounts of ooze or construct a net and devour it after it has trapped detritus (Walshe 1947). This was evident by the material in their guts. One species of Cryptochironomus contained only diatoms. Procladius fed on both diatoms and other chironomid larvae. Copepods and chironomid larvae were observed in the gut of Protanypus. Other predators collected included water mites, trichopterans, Helobdella stagnalis, ceratopagonids, and Chaoborus. Leaches and ceratopagonids have been reported to feed on chironomid larvae (Hilsenhoff 1963, Johannsen 1969). Chaoborus enters open water at night to feed on zooplankton (Pennak 1953).

Parker (1972) described area I, from the city of Coeur d'Alene south of East Point, as oligotrophic; area II, from Rockford Bay south to Conkling Park, as mesotrophic; and area III, from Conkling Park south including Chatcolet, Hidden, Round, and Benewah Lakes, as eutrophic. The high percentage of oligochaetes, large numbers of benthic invertebrates,

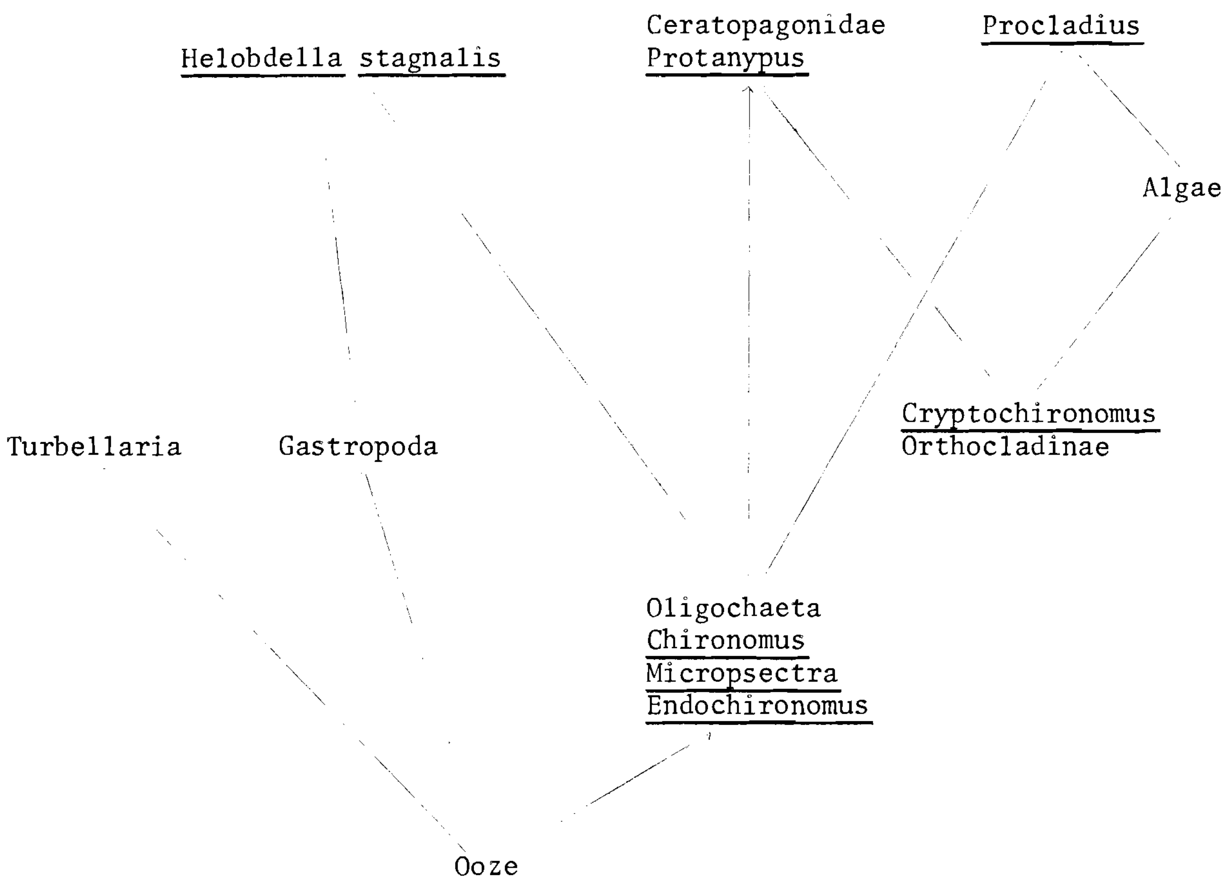

Fig. 5.--A simplified food web of taxa from Lake Coeur d'Alene based on collected data and observations.

and oxygen depletion in the Chatcolet area support these divisions. Shallow water, high temperature, and large areas covered with macrophytes present an excellent habitat for a wide variety of aquatic invertebrates.

Although Chatcolet and Round Lakes had large areas of aquatic plants and appeared eutrophic, the organic carbon in the sediment was low compared to the rest of the lake system (Table 2). In additional samples, high organic carbon was found at the mouth of the St. Joe River and at Conkling Park. The organic debris from decaying vegetation may be transported by the St. Joe River to the southern portion of the Coeur d'Alene Lake where it is deposited by decreased currents. The resulting nutrients released by decay may explain the high primary production found in that area by Parker (1972). Also, a portion of the aquatic plants may be carried out by the ice after spring thaw.

Goodnight and Whitley (1961) used the following percentages of oligochaetes to designate pollution areas: an unpolluted condition if less than 60%, doubtful if 60-80%, and highly polluted or eutrophic if over 80%. Lundbeck (1926) suggested that culturally eutrophied lakes showed a proliferation of oligochaetes and an increase in sphaeriids. Chatcolet samples contained, on an average, over 66% oligochaetes. *Pisidium* was common. Parker (1972) indicated that the nutrient enrichment of the southern portion of the lake was caused by domestic sewage from cottages and boats and fertilizer from surrounding farm land. These do add nutrients to the lake; however, low dissolved oxygen in the profundal zone, high blue-green algae counts, and abundant macrophytes reported by Ellis (1932) and Kemmerer *et al.* (1923) indicate that Chatcolet Lake has been eutrophic for at least 60 years.

Several physical, chemical, and biotic parameters are compared between Lake Washington and Lake Coeur d'Alene (Table 10). Lake Washington received large amounts of sewage until 1968 and was classified as eutrophic (Thut 1969). The lakes are similar in size, shape, and depth. Dissolved oxygen in the profundal zone was 0.2 mg/l in Lake Washington, 1.0 mg/l in the southern portion of Lake Coeur d'Alene, and 4.0 mg/l in the northern portion. The genus *Tanytarsus*, not collected in Lake Washington, was common in the northern portion of Lake Coeur d'Alene. This organism according to Ruttner (1953) was identified by Theinemann as characterizing the bottom fauna of an oxygen-rich oligotrophic lake. *Pontoporiea affinis*, associated with eutrophic lakes (Juday and Birge 1927), was collected in Lake Washington but not in Lake Coeur d'Alene. A leach, *Helobdella stagnalis*, and planorbid snails were observed in both lakes but occurred deeper and in greater number in Lake Washington. I believe that these data further support the division of Lake Coeur d'Alene into a eutrophic southern portion and an oligotrophic northern portion.

TABLE 10.--A comparison of some physical, chemical, and biological characteristics of Lake Coeur d'Alene and Lake Washington (Thut 1969)

Characteristic	Lake Washington	Lake Coeur d'Alene
Depth	60 m	56 m[a]
Length	30.8 km	38.6 km
Average width	2 km	3.1 km
Minimum dissolved O_2	0.2 in Oct.	4.0 mg/l in northern waters 1.0 mg/l in southern waters
Number of species collected below 10 m	24	29
Micropsectra	Not collected	Common in northern waters; uncommon in southern waters
Pontoporeia affinis	Common	Not collected
Helobdella stagnalis	Common between 20-45 m	Common only in southern portion in shallow water

[a]From Kemmerer *et al.* 1923.

SUMMARY

1. Benthic macroinvertebrates were collected and identified from four depths in four areas of Lake Coeur d'Alene in July and September, 1971, and in March, 1972, in an attempt to determine their distribution and relative numbers.

2. Chironomid larvae and oligochaetes made up 90% of the 62 taxa of macroinvertebrates identified. The most commonly collected organisms were chironomids in Lake Coeur d'Alene and oligochaetes in Round and Chatcolet Lakes.

3. Macroinvertebrates were most abundant in shallow water where aquatic macrophytes were common. Diversity was low at stations greater than 20 m in depth; however, more than 2,500 *Chironomus*/m^2 were observed in the Cougar Bay area.

4. High concentrations of zinc and other heavy metals occur in the sediments over the entire length of the lake north of the Coeur d'Alene River but decrease in bays protected from the main flow of the lake. Metal concentrations in the sediments decrease south of the Coeur d'Alene River and are low in Round and Chatcolet Lakes.

5. The distribution of benthic chironomids or oligochaetes did not seem to be substantially affected by 1,000-7,000 ppm zinc and other metals in the sediments.

6. The southern portion of the lake system contained many macroinvertebrates associated with nutrient-rich waters. The northern portion contained many organisms associated with oligotrophic waters.

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