To Dr Berner — compliments of the authors

ARTIFICIAL SUBSTRATE SAMPLING, MACROINVERTEBRATES IN A POLLUTED REACH OF THE KLAMATH RIVER, OREGON

William T. Mason, Jr., J. B. Anderson, R. Douglas Kreis, and William C. Johnson

In 1964 the Federal Water Quality Administration (FWQA) initiated the Klamath Basin Study to determine the effects on water quality of agricultural wastes in irrigation return water on the Klamath and Lost rivers. As part of this study, macroinvertebrates were collected at monthly intervals to determine the effects of irrigation return water and pollution from the city of Klamath Falls on the aquatic life.

The advanced eutrophication of Upper Klamath Lake and the enrichment of Klamath River have been noted by several authors. Bonnell and Mote (1) reported the nuisance midge *Chironomus utahensis* attaining summer populations of 133,000/sq yd (111,000/sq m), and the alga *Aphanizomenon* forming mats with 20,000,000 filaments/cu m. Needham and Needham (2) cited the Klamath River at Hornbrook, Calif., as an example of enormous productivity, with 1 sq ft (0.0920 sq m) of stream bottom yielding 4,000 organisms and a standing crop of 5,000 lb/acre (5,600 kg/ha). The abundance of aquatic life was attributed to an immense source of food (microscopic plankton).

Phinney and Peek (3) reported that algal blooms in Upper Klamath Lake have caused concern for at least 60 yr and that the discharge from the lake contained a heavy organic load, high in nitrogen. The great influx of humic water into the lake during late winter and early spring was suspected as a contributing factor to the high algal productivity.

Kreis and Johnson (4) presented an interpretation of Ekman dredge data obtained at three locations in the Klamath River near its junction with the Klamath Strait Drain. The authors concluded that there was a reduction of "pollution-intolerant" organisms immediately below the Klamath Strait Drain caused by agricultural wastes.

During 1965 and 1966, artificial substrates were installed at five locations in a 30-mile (48-km) reach of the Klamath River, Ore. The stream receives enriched water from the Klamath Lake and municipal and industrial wastes from the vicinity of Klamath Falls, Ore. (Figure 1).

Many different artificial substrate samplers have been devised to collect organisms that are not usually found on the natural bottom sediments. One important advantage of an artificial substrate sampler is that a relatively constant and uniform surface area is available to the organisms. Another advantage is that the samplers are

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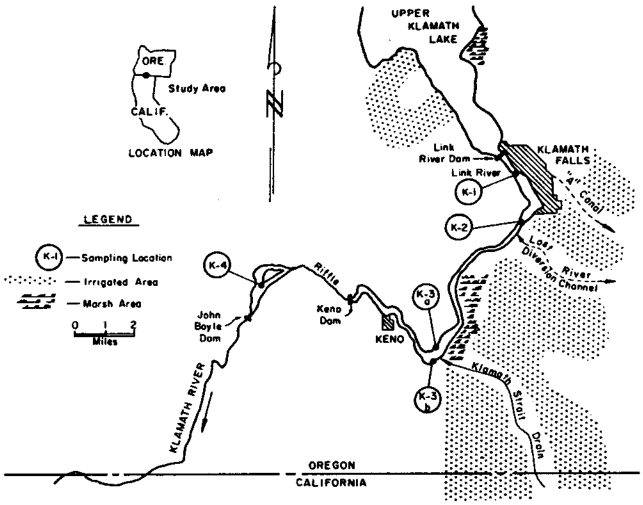

FIGURE 1.—Klamath River station locations.

Station Descriptions

Station K-1 (river mile 252, km 405.7)	At the junction of the Link River and Lake Ewauna, 1.0 mile (1.6 km) downstream from the Link River Dam; upstream from domestic and industrial waste discharge but subjected to enriched water from Upper Klamath Lake (Figure 2A).
Station K-2 (river mile 249.5, km 401.7)	0.5 mile (0.8 km) downstream from Lake Ewauna; subjected to domestic and industrial wastes including lumber processing and log storage, and tallow rendering wastes (Figure 2B).
Station K-3a (river mile 239.6, km 385.8)	At the northwest side of the river, 12 miles (19.3 km) downstream from Klamath Falls; just upstream and on the opposite side from the Klamath Strait Drain.
Station K-3b (river mile 239.5, km 385.6)	At the southeast side of the river 200 yd (183 m) downstream from the Klamath Strait Drain.
Station K-4 (river mile 221.5, km 357)	At the John C. Boyle Reservoir, 30 miles (48 km) downstream from Klamath Falls.

placed at a precise depth below the water's surface for a selected period of time. Scott (5) reported that artificial substrate samplers upstream and downstream from sources of pollution could be compared on a "quasi-quantitative" basis to determine changes in macroinvertebrate communities. The multiplate sampler described by Hester and Dendy (6), or variations thereof, has found wide acceptance, especially for use in shallow streams. This sampler is easily made, lightweight, and has a known surface area. Besch and Hofmann (7) described the use of polyethylene plates (342 sq cm) floating just below the water's surface, for the collection of macroinvertebrates in a pollution study of the Steinach River, near Heidelberg, Germany.

Wene and Wickliff (8) described the "basket method" in which wire baskets were filled with graded rock and placed on the stream bottom. They concluded that rubble substrate placed in a riffle was more productive than gravel for aquatic insects.

The rock-filled samplers used in this study provide an attractive habitat for a variety of organisms, as reported by

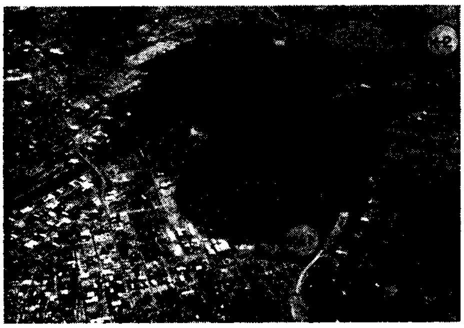

FIGURE 2A.—Aerial view (looking south) of Klamath Falls, Ore., and Lake Ewauna.

Anderson and Mason (9). Rocks provide crevices for larvae such as caddisflies and chironomids (midges). Spaces between the rocks harbor omnivores (gastropods and crayfish), predators (odonates and hemipterans), and scavengers (leeches and isopods). Algal growth on the rocks provides food for clinging mayflies, certain midge larvae, and other herbivores. Worms are usually prevalent in samples when sediment accumulates.

Description of the Study Area

The Klamath River originates from the eutrophic Upper Klamath Lake and flows 253 miles (407 km) through south central Oregon and northwestern California to the Pacific Ocean. The Upper Klamath Lake, impounded by the Link River Dam, is located on a semiarid plateau [elevation 4,100 ft (1,250 m)], and is approximately 35

FIGURE 2B.—Log storage 0.5 mile (0.8 km) downstream from Lake Ewauna, Station K-2.

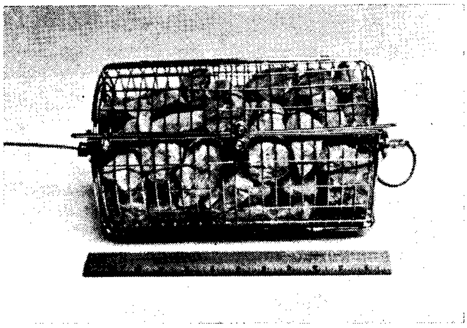

FIGURE 3.—Basket sampler.

miles long (56 km), 5 miles (8 km) wide, and has a mean depth of 9 ft (2.7 m). Water from the lake flows swiftly 1 mile through the Link River channel to Lake Ewauna, which is merely a widened portion of the Klamath River, 2 miles (3.2 km) long and approximately 6 ft (1.8 m) deep. The city of Klamath Falls, Ore., is situated on the east bank of Lake Ewauna at the junction of the Link River. At its southern end, Lake Ewauna gradually narrows to form the Klamath River which is contained within a diked channel approximately 450 (137 m) wide and 8 ft (2.4 m) deep. Keno Dam is located 17 miles (27 m) downstream from Klamath Falls.

Irrigation return water from the Lost River system enters the Klamath River through the Klamath Strait Drain, 14 miles (23 km) downstream from the Link River Dam. From Lake Ewauna to Keno Dam, the river is maintained at a constant level throughout most of the year. Below the dam, the river is aerated by riffles as it descends 240 ft (73.1 m) in 5 miles

TABLE I.—Average Daily Flow (cfs)

Month	1965		1966	
	K-1	K-4	K-1	K-4
July	464	319	575	368
August	611	803	915	798
September	1,555	1,708	814	909
October	2,357	2,399	1,294	—

Note: Cfs × 1.7 = cu m/min.

TABLE II.—Klamath River, Ore., Macroinvertebrates Collected During the Summers of 1965 and 1966 in the Rock-Filled Sampler

Station K-1	1965				1966			
	July	Aug.	Sept.	Oct.	July	Aug.	Sept.	Oct.
Organisms:								
Diptera (True flies)								
Chironomidae (Midges)					980	5,576	2,108	220
Facultative	2,288	430	262	248				
Pollution-associated	1,264	2,528	68	132				
Other Diptera			4	24		4		
Trichoptera (Caddisflies)	16	4	72	280	4	44	272	328
Ephemeroptera (Mayflies)		168	36	64		16	116	36
Odonata (Dragon and Damselflies)		80	4	8			16	4
Hemiptera (True bugs)								
Coleoptera (Beetles)	8					4		
Lepidoptera (Aquatic moths)								
Amphipoda (Scud)	312	1,136	112	84	108	128	156	136
Isopoda (Sowbugs)	112	32	12	32	8	12	92	28
Oligochaeta (Worms)	3,000	640		932	64		180	1,072
Hirudinea (Leeches)	16	72		4	44	8	12	4
Turbellaria (Flatworms)	72			12	20	64	76	28
Pelecypoda (Clams)								
Gastropoda (Snails)	32	8		24	8	72	44	28
Bryozoa (Moss animals)	X							
Coelenterata (Hydras)	X			X				X
Porifera (Sponges)								X
Total Individuals	7,120	5,098	570	1,844	1,236	5,928	3,072	1,864
Station K-2								
Organisms:								
Diptera (True flies)								
Chironomidae (Midges)					272	5,416	1,674	956
Facultative	1,079	36	80	288				
Pollution-associated	574	988	360	1,196				
Other Diptera		4						
Trichoptera (Caddisflies)				20				
Ephemeroptera (Mayflies)			4					
Odonata (Dragon and Damselflies)		4			2			12
Hemiptera (True bugs)						16		
Coleoptera (Beetles)								
Lepidoptera (Aquatic moths)					1			
Amphipoda (Scud)	32	12	32	28	8	8	4	16
Isopoda (Sowbugs)	250	64	16	12	116	32	456	292
Oligochaeta (Worms)		40		944	123			80
Hirudinea (Leeches)	28	4	20		152	24	32	308
Turbellaria (Flatworms)					140	8		
Pelecypoda (Clams)								
Gastropoda (Snails)	68	12			65	48		12
Bryozoa (Moss animals)								
Coelenterata (Hydras)								
Porifera (Sponges)								
Total Individuals	2,031	1,164	512	2,488	879	5,552	2,166	1,676

TABLE II.—*Continued*

Station K-3a	1965				1966			
	July	Aug.	Sept.	Oct.	July	Aug.	Sept.	Oct.
Organisms:								
Diptera (True flies)								
Chironomidae (Midges)					1,660	228	73	4
Facultative	505	1	1	30				
Pollution-associated	330	1		50				
Other Diptera								
Trichoptera (Caddisflies)		1		2				
Ephemeroptera (Mayflies)	2	2		10				
Odonata (Dragon and Damselflies)	20	20	17	104	12		4	12
Hemiptera (True bugs)	8					1	2	
Coleoptera (Beetles)	1	1			4			
Lepidoptera (Aquatic moths)								
Amphipoda (Scud)	495	74		40	1,036	2	1	8
Isopoda (Sowbugs)	8	7		8	20	88	12	12
Oligochaeta (Worms)	8			36		28	1,431	4,284
Hirudinea (Leeches)	576	58	1	16	524	320	255	240
Turbellaria (Flatworms)						3		
Pelecypoda (Clams)				44			1	
Gastropoda (Snails)	28	21	25		600	12	45	68
Bryozoa (Moss animals)	X	X				X		
Coelenterata (Hydras)		X		X				
Porifera (Sponges)								
Total Individuals	1,981	186	44	340	3,856	682	1,824	4,628
Station K-3b								
Organisms:								
Diptera (True flies)								
Chironomidae (Midges)					648	1,158	13	
Facultative	577	612	4					
Pollution-associated	173	64	1	44				
Other Diptera	4					1		
Trichoptera (Caddisflies)								
Ephemeroptera (Mayflies)	8	4	2	64	12			
Odonata (Dragon and Damselflies)	68	64	44	96	8			24
Hemiptera (True bugs)		4						
Coleoptera (Beetles)					4	10		
Lepidoptera (Aquatic moths)								
Amphipoda (Scud)	704	60	7	12	56			
Isopoda (Sowbugs)				8	4	13	9	
Oligochaeta (Worms)				240	368	55	168	1,436
Hirudinea (Leeches)	116	36	17	56		172	227	256
Turbellaria (Flatworms)					8			
Pelecypoda (Clams)								
Gastropoda (Snails)	36	16	4	40	184	6		56
Bryozoa (Moss animals)	X	X						
Coelenterata (Hydras)								
Porifera (Sponges)								
Total Individuals	1,686	860	79	560	1,292	1,415	417	1,772

TABLE II.—*Continued*

Station K-4	1965				1966			
	July	Aug.	Sept.	Oct.	July	Aug.	Sept.	Oct.
Organisms:	No Sample						No Sample	No Sample
Diptera (True flies)								
Chironomidae (Midges)					600	2,568		
Facultative		44	519	52				
Pollution-associated		28	149	48				
Other Diptera								
Trichoptera (Caddisflies)								
Ephemeroptera (Mayflies)		7		8		8		
Odonata (Dragon and Damselflies)		64	36	88	28	32		
Hemiptera (True bugs)								
Coleoptera (Beetles)		3						
Lepidoptera (Aquatic moths)								
Amphipoda (Scud)		14	128	388	12	8		
Isopoda (Sowbugs)					4			
Oligochaeta (Worms)		20		340		560		
Hirudinea (Leeches)		2			12	8		
Turbellaria (Flatworms)			4		56	24		
Pelecypoda (Clams)								
Gastropoda (Snails)		73	24	80		64		
Bryozoa (Moss animals)					X	X		
Coelenterata (Hydras)			X	X				
Porifera (Sponges)								
Total Individuals		255	860	1,004	712	3,272		

(8 km) into a 9-mile (14.5-km) long reservoir retained by the John C. Boyle Dam. Below the dam, the river cascades through canyons with a drop of 100 to 200 ft/mile (18.9 to 37.8 m/km) to the Pacific Ocean, which is approximately 235 miles (378 km) away.

Method and Materials

The prototype rock-filled sampler used for collecting macroinvertebrates during 1965 was cubical in shape, 8 in. (20.3 cm) on a side (10). The basket sampler (11) used in 1966 (Figure 3) was a chromium-plated, welded-wire, cylindrical barbeque * basket, 7 in. (17.8 cm) in diameter and 11 in. (27.9 cm) in length. The artificial substrates were filled with approximately thirty, 2- to 3-in. (5.1- to 7.6-cm) diam native rocks (andesite).

At each station samplers were suspended from a stationary structure on 0.125-in. (0.32-cm) wire cable, 18 to 48 in. (45.7 to 121.9 cm) below the water's surface for 1 month. All the samplers were at least 8 in. (20.3 cm) above the bottom.

The collection procedure consisted of emptying the rocks into a tub partially filled with water. Each rock was cleaned with a stiff-bristled brush to remove the organisms. The samples were concentrated in a U. S. Standard Number 30 sieve and preserved in 70 percent ethanol or 7 percent formalin. The samples were processed at the FWQA's Analytical Quality Control Laboratory in Cincinnati. In order to reduce processing time, aliquots of samples containing a large number of organisms were counted. The 1966 samples were not identified beyond family.

* Manufactured by Hewitt Home Products, National City, Calif. (Model RB-100 Tumble Basket). Mention of commercial sources or trade names does not constitute endorsement by the U. S. Department of the Interior.

Note: Hewitt Co. is out of business.
Substitute source: Androck Inc.
28 Union St., Worcester, Mass. 01608
Model 2911 Chicken Basket

Discussion

Physical factors that were relatively constant during the study included the sampler substrate type (andesite), period of exposure (1 month), and collection depth (not more than 48 in. (121.9 cm) or less than 18 in. (45.7 cm) below the water's surface.

Variables influencing the stream environment included stream velocity, irrigation return water, and municipal and industrial wastes. Water temperatures varied slightly (15° to 20°C) in this reach of river from June to October. Average daily flows are shown in Table I. Water diverted from the Klamath River for irrigation purposes sometimes caused fluctuations in the flow at the downstream station (K-4).

The organisms collected were divided into two categories, pollution-associated and facultative. No strictly "clean water" organisms were collected during August, September, and October, 1965. Some of the taxa included in the pollution-associated category i.e. capable of withstanding extended periods of low DO and usually found in large numbers were: chironomids, *Procladius* sp. (12), *Chironomus attenuatus* (13), *C.* sp. 1 (1), *C.* sp. 2 and *Glyptotendipes lobiferus* (14); oligochaetes; pulmonate snails, *Physa*; and leeches, *Helobdella stagnalis* and *Dina parva.* These and other organisms considered pollution-associated are marked with an asterisk in Table III. The facultative category consists of less tolerant organisms not as abundant in water with low DO. Their presence and abundance increases in better oxygenated and enriched water. Some representatives were: chironomids, Orthocladinae and Tanytarsini; caddisflies, *Hydropsyche;* mayflies, *Caenis, Baetis;* crustaceans, *Asellus, Gammarus,* and *Hyalella azteca;* odonates, *Argia* and *Aeshna;* and gilled snails.

The two categories distinguished should not be considered rigid, because species within each major group may be found in waters with varying degrees of pollution. For example, not all species of oligochaetes and pulmonate snails are strictly limited to pollution environments. However, these broad categories serve to characterize degrees of pollution in a general way by the prevalence and distribution of certain taxa in a particular aquatic environment.

The number of macroinvertebrates collected in the Klamath River, Ore., during the summer of 1965 and 1966 ranged from a minimum of 44 collected in September 1965 at K-3a to a maximum of 7,120 collected in July 1965 at K-1 (Table II). Eighty-four taxa representing 15 orders were identified from samples collected each month at every station during 1965 (Table III). The most prevalent organisms in the samples during 1965 and 1966 were those which are found in marginal zones of pollution (15): chironomid larvae, oligochaetes, amphipods, isopods, odonates, leeches, and gastropods. The most common chironomids were *Glytotendipes* spp., *Chironomus* spp. (*plumosus* group), *Parachironomous abortivus,* and *Cricotopus* spp. The amphipods *Hyalella azteca* and *Gammarus,* and the isopod *Asellus* were quite numerous. *Helobdella stagnalis* and *Dina parva* were the most abundant leeches. The mayfly *Caenis,* the snails *Parapholyx* spp., and the worms *Nais* and *Stylaria* were sporadic in abundance.

Caddisflies were restricted almost entirely to K-1. The number of midges collected during August and September 1966 was considerably greater than the number collected in 1965 during the same months. The occurrence of worms in the samples was irregular, and no stoneflies were present in any of the samples during the course of the study.

Miller and Tash (16) conducted a study of the nutrients and dry weights of phytoplankton in Klamath Lake in

TABLE III.—Klamath River Macroinvertebrates from Artificial Substrate Samplers, 1965

Organisms	Stations and River Miles				
	K-1, Klamath Falls, (RM 252)	K-2, Big K Mill (RM 249.5)	K-3a, Teeters Landing-NW (RM 239.5)	K-3b, Teeters Landing-SE (RM 239.6)	K-4, Boyle Dam (RM 221.5)
Diptera (True Flies)					
Chironomidae (Midges)					
Tanypodinae					
Ablabesmyia sp. Joh.	X				X
**Procladius* sp. Skuse		X			
Orthocladiinae					
Orthocladius sp. Wulp					X
Cricotopus sp. Wulp	X				
C. trifasciatus Gr. (Panzer)		X		X	
C. exilis Gr. Joh.	X				
C. bicinctus Gr. (Meigen)					X
Psectrocladius spp. Kieffer	X	X			X
Tricholcladius sp. Kieffer		X	X	X	X
Cardiocladius obscurus (Joh.)	X				
Corynoneura scutellata Winnertz					X
Chironominae					
**Chironomus attenuatus* Walker	X	X	X	X	X
**C.* sp. 1 (see note)		X	X		
**C.* sp. 2		X			
Dicrotendipes modestus Gr. Say	X	X	X	X	X
D. nr. *fumidus* Joh.			X	X	
D. incurvus Gr. Sublette					X
Parachironamus abortivus (Mall)	X	X	X	X	X
**Glyptotendipes lobiferus* (Say)	X	X	X	X	X
**G.* sp. 1	X	X	X	X	X
**G.* sp. 2 (prob. *barbipes*)	X	X	X		X
Tanytarsus sp. Wulp					X
Cladotanytarsus sp. Kieffer					X
Calopsectra sp. Kieffer	X				X
Stempellina (sp. A. Joh.)	X				
Micropsectra sp. Kieffer	X	X		X	
Ceratopogonidae (Biting Midges)					
Palpomyia sp. Meigen			X		
Bezzia sp. Kieffer				X	
Simuliidae (Blackflies)					
Simulium sp. Latreille	X	X			X
Trichoptera (Caddisflies)					
Hydropsychidae					
Hydropsyche sp. Pictet	X	X	X		
Psychomyiidae					
Polycentropus cinereus Hagen			X		
Leptoceridae					
Mystacides sp. Berthold	X				
Limnephilidae					
Limnephilus sp. Leach	X				
Phryganeidae					
Agrypnia sp. Hagen			X	X	
Hydroptilidae					
Agraylea sp. Curtis	X				
Ephemeroptera (Mayflies)					
Caenidae					
Caenis sp. Stephens	X	X	X	X	X
Tricorythodes fallax Traver	X		X		X

TABLE III.—*Continued*

Organisms	Stations and River Miles				
	K-1, Klamath Falls, (RM 252)	K-2, Big K Mill (RM 249.5)	K-3a, Teeters Landing-NW (RM 239.6)	K-3b, Teeters Landing-SE (RM 239.5)	K-4, Boyle Dam (RM 221.5)
Baetidae					
Baetis sp. Leach	X	X	X		
Callibaetis sp. Eaton	X	X	X	X	X
Ephemerella mollita? Seemann		X			
Odonata					
Anisoptera (Dragonflies)					
Aeshna sp. Fabricius		X	X	X	X
Anax sp. Leach			X	X	X
Zygoptera (Damselflies)					
Ischnura sp. Charpentier	X	X	X	X	X
Enallagma sp. Charpentier	X		X	X	X
Argia sp. Rambur	X	X			X
Hempitera (True bugs)					
Corixidae					
Corisella inscripta (Uhler)			X	X	
Coleoptera (Beetles)					
Elmidae					
Optioservus sp. Sanderson	X				
Dytiscidae					
Laccophilus sp. Leach					X
Haliplidae					
Haliplus sp. Latreille			X		X
Brychius sp. Thomson			X		
Gyrinidae					
Gyrinus sp. Müller	X				
Lepidoptera (Aquatic moths)					
Parargyractis sp. Lange	X	X			
Crustacea					
Amphipoda (Scud)					
Hyalella azteca (Saussure)	X	X	X	X	X
Gammarus sp. Fabricius	X	X	X	X	X
Isopoda (Sowbugs)					
Asellus sp. Geoffrey	X	X	X	X	
*Oligochaeta (Worms)					
Naididae					
Nais sp. Müller		X			
Stylaria lacustris (L).	X	X	X		X
S. fossularis Leidy	X	X			
Ophidonais serpentina (Müller)		X	X	X	X
Lumbriculidae	X				
Tubificidae		X	X	X	
*Hirudinea (Leeches)					
Glossophonidae					
Glossophiona complanata (L.)	X	X	X	X	
Helobdella stagnalis (L.)	X	X	X	X	X
Theromyzon sp. Philippi				X	
Erpobdellidae					
Erpobdella annulata (Moore)	X	X	X	X	
Dina parva Moore	X	X			
Mooreobdella sp. Pawlowski			X		
Piscicolidae					
Pisciola gometra (L.)	X	X			

TABLE III.—*Continued*

Organisms	Stations and River Miles				
	K-1, Klamath Falls, (RM 252)	K-2, Big K Mill (RM 249.5)	K-3a, Teeters Land-ing-NW (RM 239.6)	K-3b, Teeters Landing-SE (RM 239.5)	K-4, Boyle Dam (RM 221.5)
Turbellaria					
Planariidae (Flatworms)	X	X	X		X
Nematoda (Roundworms)	X	X			
Mollusca					
Gastropoda (Snails)					
*Physidae					
Physa sp. Draparnaud			X	X	
*Planorbidae					
Helisoma sp. Swainson			X	X	
Gyraulus sp. Charpentier	X	X	X	X	X
Parapholyx sp. Hanna		X	X		
P. klamathensis	X	X	X	X	X
Amnicolidae					
Fluminicola sp. Stimpson	X				X
*Lymnaeidae					
Lymnaea (*Stagnicola*) sp. Jeffreys			X	X	X
Valvatidae					
Valvata sp. Müller	X	X	X	X	X
Bulimidae					
Pyrgulopis sp. ? Call and Pilsbry	X				
*Lancidae					
Lanx sp. Clessin	X	X			
*Ancylidae					
Ferrissia sp. Walker					X
Pelecypoda (Clams)					
Sphaeriidae					
Sphaerium sp. Scopoli			X	X	
Bryozoa (Moss animals)					
Plumatellidae					
Plumatella sp. Lamarck	X		X	X	
Coelenterata (Hydras)					
Hydra sp.	X	X	X	X	X
Total Taxa	50	44	45	36	40
Percent Pollution—Associated Taxa	30	48	40	39	28

* Pollution-associated
X = Present
Note: *Chironomus* sp. 1 is probably the species reported by Bonnell and Motte (1942) as *utahensis* (Personal communication with James E. Sublette, Eastern New Mexico University, Portales).

1965 and found lower dry weights at the end of August than in late July and September. All basket samples taken during September 1965 and 1966, except at Station K-4, showed a sharp decline in number of organisms as compared to those taken in August or October. This may have been due to less food, emergence of adult insects, and unfavorable current, in addition to pollutional effects.

Figure 4 shows that there was little variation in the number of taxa in the August 1965 collections. The number of organisms, however, varied considerably. Station K-3a consistently had fewer organisms than the other stations.

Figure 5 illustrates the total number of organisms and the percentages of pollution-associated and facultative organisms collected during August, September, and October 1965. Station

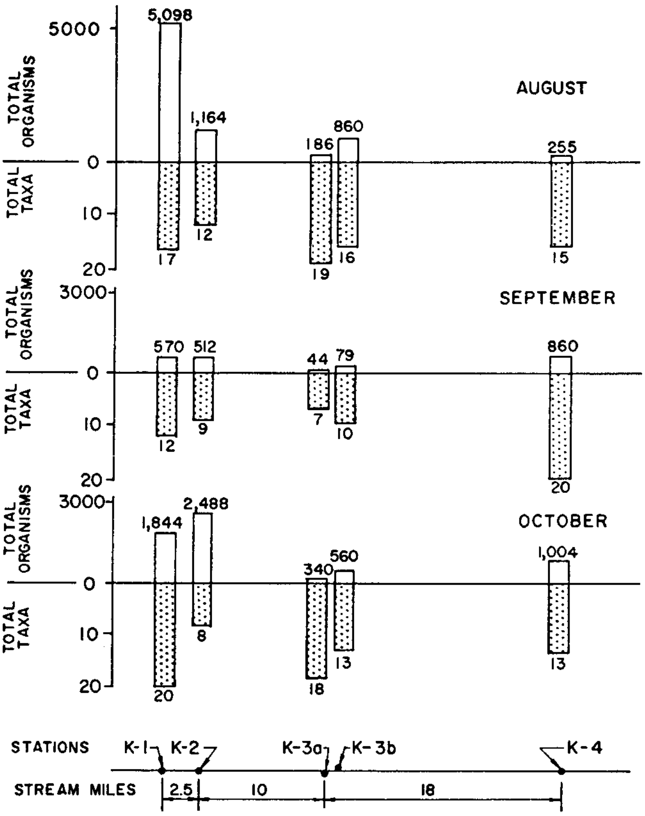

FIGURE 4.—Total organisms and total taxa in each basket sampler during August, September, and October 1965.

K-2 had the largest percentage of pollution-associated organisms during the combined 3-month period.

Figure 6 illustrates the percent composition of pollution-associated and facultative organisms to the total sample during each month of the period illustrated in Figure 5. The percent of pollution-associated organisms at Station K-2 was consistently high, ranging from 75 to 90 percent. At the other stations, the composition of pol-

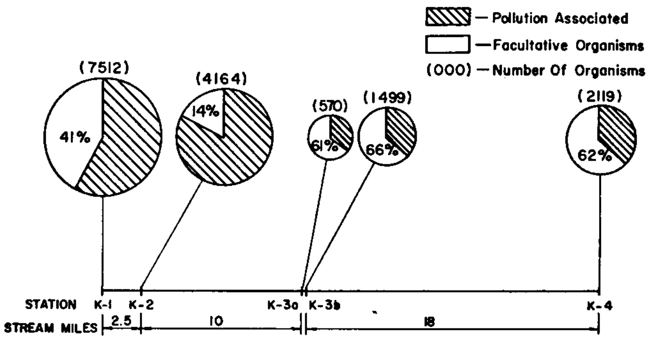

FIGURE 5.—The percent composition of facultative and pollution-associated organisms in composite samples from August, September, and October 1965 collections.

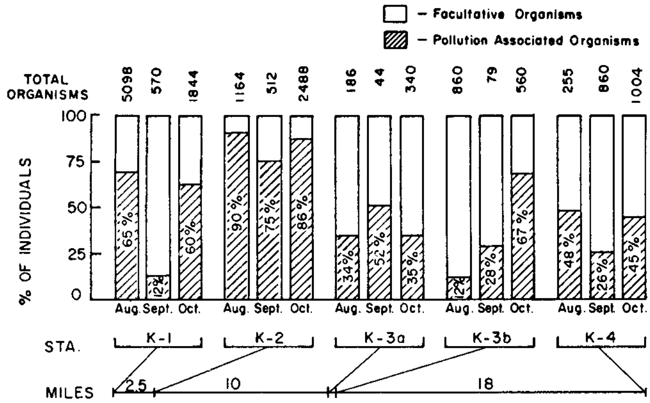

FIGURE 6.—The percent composition of facultative and pollution-associated organisms in each sample during August, September, and October 1965.

lution-associated organisms was more variable, ranging from a low of 12 percent to a high of 67 percent.

Station Summary

An exceptionally large number of organisms per sample (sometimes over 5,000) was collected at Station K-1. This abundance reflects the highly enriched, oxygenated water flowing from Upper Klamath Lake (Figure 5). This was the only station at which caddisflies appeared consistently during 1965 and 1966. Mayflies (mostly *Caenis* and *Tricorythodes*) were more numerous at this station, and the fauna was characterized by a large percentage of midges, oligochaetes, and amphipods (Table II). The caddisfly and mayfly populations occurring at Station K-1 are believed to be the result of ample current and DO.

The macroinvertebrate population in 1965 at Station K-2 was composed of 48% of pollution-associated taxa (Table III). Low stream velocity and log pond wastes undoubtedly accounted for the abundant midges. Few caddisflies or mayflies were collected at Station K-2 in 1965 and were entirely absent in 1966. *Callibaetis* was the only mayfly other than *Caenis* to be present at all stations. *Callibaetis* was reported by Gaufin and Tarzwell (17) to be occurring in a zone of moderate organic pollution during a study of Lytle Creek, Ohio. During August, September, and October 1965, over 4,000 organisms, were represented primarily by eight taxa, four of which were pollution-associated chironomids (*Chironomus* sp. 1, *C. attenuatus*, *Glyptotendipes* sp. 2, probably *barbipes*, and *G. lobiferus*). During this period, oligochaetes and bloodworms comprised 86 percent of the number collected.

Station K-3b was 200 yd (183 m) downstream and on the same side of the Klamath River as the Klamath Strait Drain discharge, whereas K-3a was on the opposite side of the river. The agricultural wastewater of the Klamath Strait Drain transports considerable amounts of organic material and silt from the Lost River system. However, the silt settles rapidly on entering the Klamath River.

The 1965 macroinvertebrate data for Stations K-3a and K-3b (Figures 5 and 6) show a large reduction in number of individuals and a decrease in the percentage of pollution-associated organisms as compared with Station K-2. The baskets contained fewer midges, pulmonate snails, and worms. Thirty-six taxa were collected at K-3b compared with 45 at K-3a, but the percentage of pollution-associated taxa was nearly the same at both stations

TABLE IV.—Temperature, Dissolved Oxygen, and pH Recorded 9:30 AM, August 17, 1966

Location	Water Temperature (°C)	Dissolved Oxygen (mg/l)		pH
		Surface	Bottom	
Above K-1 (Fremont Bridge)	18.9	8.1	7.6	9.3
K-1	22.2	8.2	8.2	9.7
Below K-1 (downstream end of Lake Ewauna)	22.2	3.9	1.0	9.5
Above K-2	21.1	0.7	0.5	9.0
K-2	22.2	0.5	0.0	9.0
Below K-2	23.3	0.9	0.0	8.6
Above K-3a and K-3b	22.2	1.2	1.2	8.3
K-3a	22.8	1.2	0.7	8.3
K-3b	22.2	1.8	1.1	8.4
Keno, Ore. (between K-3a and K-4)	—	3.2	2.6	7.5

(Table III). The smaller diversity of mayflies and beetles at K-3b may have been result in part of turbid water coming from the Klamath Strait Drain. The percent composition of facultative and pollution-associated macroinvertebrates at Station K-4 remained about the same as at Stations K-3a and K-3b during August, September, and October 1965, and the number of individuals at K-4 was slightly greater.

DO measurements the first week in August 1966 near Stations K-2, K-3a, and K-3b showed concentrations less than 2.0 mg/l. During mid-August, a large fish kill occurred in the vicinity of Stations K-3a and K-3b. A more detailed survey of the water chemistry was conducted the week following the fish kill in the reach of river between the Link River Dam (above Station K-1) and Keno, Ore. (between Stations K-3a and K-4). Temperature, DO near the surface and bottom, and pH for August 17 are presented in Table IV. The DO concentrations near the bottom decreased from 8.2 mg/l at Station K-1 to nondetectable amounts in the vicinity of Station K-2. There was slight improvement in DO at Stations K-3a, K-3b, and at Keno which permitted the survival of only pollution-tolerant species. Station K-4, located in the reservoir formed by the John C. Boyle Dam, received aerated water from an upstream riffle that generally resulted in higher DO concentrations. The survey also revealed that the water was very basic (pH 9.7) at Station K-1 and became progressively less basic downstream. The chemical measurements before and after the fish kill indicated that conditions associated with organic pollution existed approximately 3 wk.

The combined factors of organic wastes, low DO, and stream flow in 1966 reduced or eliminated many macroinvertebrate taxa at Stations K-3a and K-3b including caddisflies, mayflies, and coelenterates. At K-3b, 1,158 midge larvae were collected in August, 13 in September, and none were present in October. The presence of only four taxa and the complete absence of midges in the October sample were in contrast to the greater diversity in 1965 (Table II). During 1966, the number of worms in the samples increased dramatically.

Macroinvertebrates adapted to quiescent water inhabited the baskets at station K-4. Inspection of Table III reveals that some midge larvae were: *Corynoneura, Dictrotendipes incurvus* gr., *Tanytarsus,* and *Cladotanytarsus.* Caddisfly larvae were not collected at Station K-4 throughout the study probably as a result of little current in the reservior. The only leech collected was *Helobdella stagnalis* whereas four to five species were collected at the other stations.

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References

1. Bonnell, D. D., and Mote, D. C., "Biology of the Klamath Midge, *Chironomus utahensis* (Diptera, Chironomidae)." *Proc. Ent. Soc. of British Columbia,* **39**, 3 (1942).
2. Needham, J. G., and Needham, P. R., "A Guide to the Study of Freshwater Biology." Holden Day, Inc., San Francisco, Calif. (1967).
3. Phinney, H. K., and Peek, C. A., "Klamath Lake, an Instance of Natural Enrichment." *Algae & Metropolitan Wastes,* U. S. Dept. of HEW, SEC TRW 61-3 (1961).
4. Kreis, R. D., and Johnson, W. C., "The Response of Macrobenthos to Irrigation Return Water." *Jour. Water Poll. Control Fed.,* **40**, 1614 (1968).
5. Scott, D. C., "Biological Balance in Streams." *Sew. and Ind. Wastes,* **30**, 1169 (1958).
6. Hester, F. E., and Dendy, J. S., "A Multiple-Plate Sampler for Aquatic Macroinvertebrates." *Trans. Amer. Fish. Soc.,* **91**, 4 (1962).
7. Besch, W., et Hofmann, W., "Le Macrobenthos sur Des Substrats de Polyethylene Les Eaux Courantes." *Annals de Limnologie,* t. 4, fasc. 2, 235 (1968).
8. Wene, G., and Wickliff, E. L., "Modification of a Stream Bottom and Its Effect on the Insect Fauna." *The Can. Ent.,* **72**, 131 (1940).
9. Anderson, J. B., and Mason, W. T., Jr., "A Comparison of Benthic Macroinvertebrates Collected by Dredge and Basket Sampler." *Jour. Water Poll. Control Fed.,* **40**, 252 (1968).
10. Henson, E. B., "A Cage Sampler for Collecting Aquatic Fauna." *Turtox News,* **43**, 12, 209 (1965).
11. Mason, W. T., Jr., Anderson, J. B., and Morrison, G. E., "A Limestone-Filled Artificial Substrate Sampler-Float Unit for Collecting Macroinvertebrates from Large Streams." *Prog. Fish-Cult.,* **29**, 74 (1967).
12. Carr, J. F., and Hiltunen, J. K., "Changes in the Bottom Fauna of Western Lake Erie from 1930 to 1961." *Limnol. & Oceanog.,* **10**, 551 (1965).
13. Curry, L. L., "A Survey of Environmental Requirements for the Midges (Diptera: Tendipedidae)." *Biological Problems in Water Pollution* 1962 Seminar, U. S. Dept. HEW, Cincinnati, Ohio, Publ. No. 999-WP-25, (1965).
14. Paine, G. H., Jr., and Gaufin, A. R., "Aquatic Diptera as Indicators of Pollution in a Midwestern Stream." *Ohio Jour. Sci.,* **56**, 291 (1956).
15. Hynes, H. B. N., "The Biology of Polluted Waters." Liverpool Univ. Press, Liverpool, Eng. (1963).
16. Miller, W. E., and Tash, J. C., "Interim Reports, Upper Klamath Lake Studies, Oregon." FWPCA Publication WP-20-8 (1967).
17. Gaufin, A. R., and Tarzwell, C. M., "Aquatic Invertebrates as Indicators of Stream Pollution." *Pub. Health Rept.,* **67**, 57 (1952).