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ASSESSMENT OF WATER QUALITY CONDITIONS

IN

SKAMOKAWA CREEK, WASHINGTON

by

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INTRODUCTION

Skamokawa Creek is a small tributary of the lower Columbia River basin which enters the Columbia at River Mile 27. Periodic dissolved oxygen depletion during warm summer months, other water quality problems, and fish kills historically have occurred in the creek, particularly the lower portion.

At the request of the Department of Ecology (DOE) Southwest Regional Office, the DOE Water and Wastewater Monitoring Section conducted a sanitary survey to determine water quality conditions within the Skamokawa basin. In addition, possible explanations for the periodic occurrence of fish kills in the creek were investigated.

STUDY AREA DESCRIPTION

Skamokawa Creek and its tributaries (Water Segment No. 12-25-06) are located in Wahkiakum County. The unincorporated town of Skamokawa is located near the mouth of the creek and contains the majority of the residences in the area.

Major land uses in the area include scattered dairy farms in the lower watershed and state-owned forest lands in the upper drainage basins of Skamokawa Creek and Wilson Creek.

Skamokawa Creek and its tributaries have a drainage basin of more than 31 square miles. The principal tributary, Wilson Creek, has a drainage basin of about 13.4 square miles (USGS, 1977).

The lower portion of Skamokawa Creek is heavily influenced by tidal action from the Columbia River estuary causing it to act as a settling basin at high tide. This sedimentation process has produced very silty bottom conditions in the affected areas of the creek. The Army Corps of Engineers has completed several projects on the creek including construction of a levee along the lower sections of the creek north of Skamokawa and rip-rapping the banks at various points. In addition to these modifications, a large portion of the vegetative cover has been removed from the creek's banks below Oatfield Road (Station 3 - see Figure 1).

Skamokawa Creek is designated as a Class A water in the Washington State Water Quality Standards (DOE, 1977).

Skamokawa Creek supports modest runs of Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*), and Steelhead trout (*Salmo gairdneri*). Chinook salmon are generally main-stream spawners frequenting larger rivers and are not indigenous to Skamokawa Creek (Hart, 1977). Chinooks probably were introduced into Skamokawa Creek by dumping of hatchery spawner excesses (Tracy, 1975).

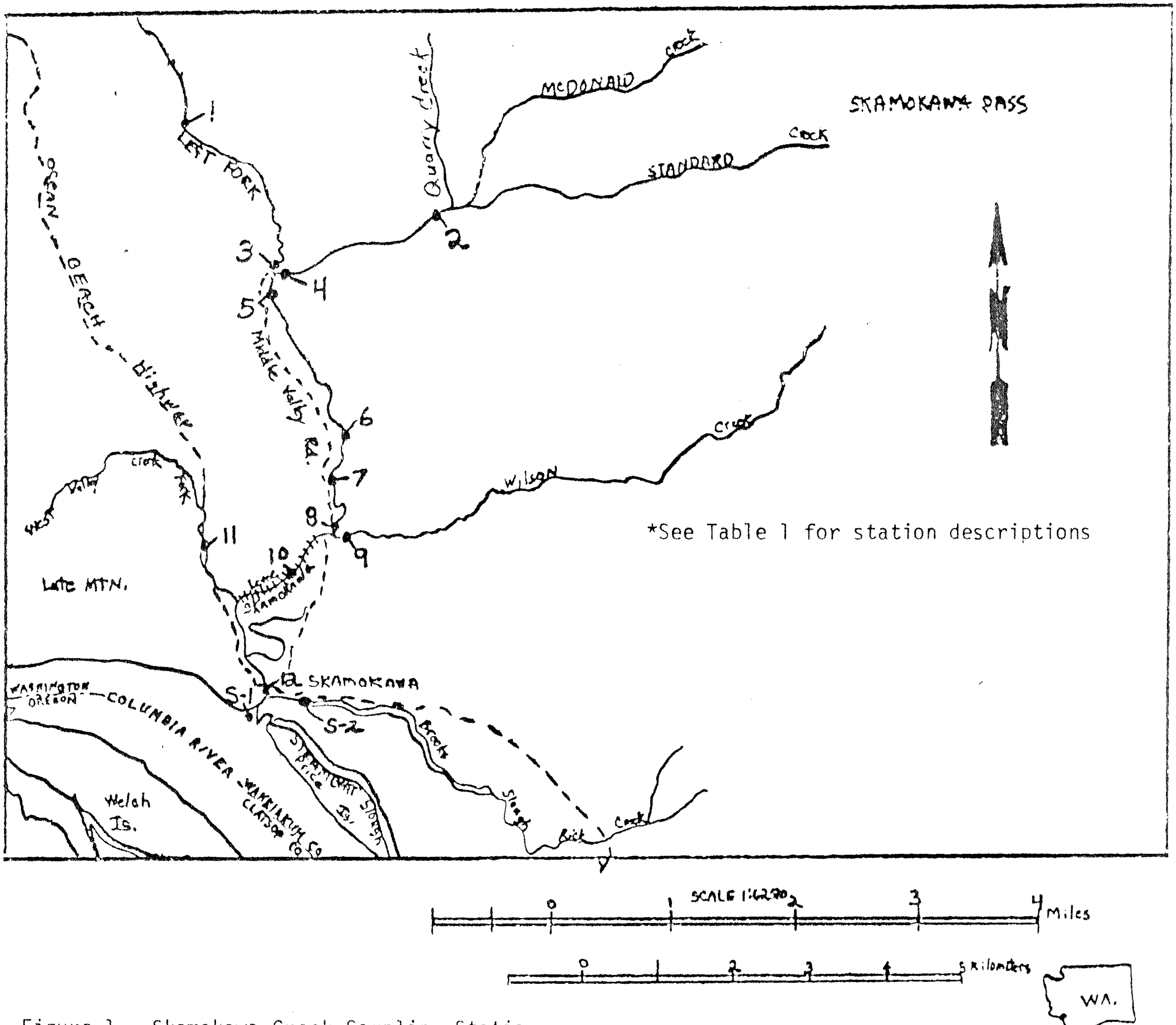

Figure 1. Skamokawa Creek Sampling Stations.

In 1975 a serious fish kill occurred in the creek in which 2,361 three- and four-year-old Chinook salmon and a number of juvenile Coho salmon died (Tracy, 1975). Since 1975, periodic fish kills have continued in the creek.

The upper portions of the creek have good vegetative cover and provide excellent spawning areas for salmonids. However, some of these valuable spawning areas could be threatened by logging road construction in the upper drainage basin which has caused periodic silt inputs to Skamokawa Creek from Quarry Creek (Fiscus, personal communication).

MATERIALS AND METHODS

Fourteen sampling stations were established along Skamokawa Creek and several tributaries in order to characterize water quality conditions during low flow conditions (Figure 1).

On August 11 and 12, 1980 an initial survey of the creek was performed. Measurements were taken in the field for temperature (°C), dissolved oxygen (Winkler-Azide modification), and specific conductivity. In addition, flow measurements were made with a Marsh-McBernie magnetic flow meter and a top-setting rod. A velocity profile and depth measurements were used to calculate the flow.

Water samples were collected simultaneously. Samples were packed in ice and transported to the DOE Tumwater laboratory for the following analyses:

1. pH
2. Specific conductivity (μmhos/cm)
3. Turbidity (NTU)
4. Chemical Oxygen Demand (mg/L)
5. Biochemical Oxygen Demand (mg/L)
6. Total Suspended Solids (mg/L)
7. Ammonia-nitrogen (mg/L)
8. Nitrite-nitrogen (mg/L)
9. Nitrate-nitrogen (mg/L)
10. Orthophosphate-P (mg/L)
11. Total Phosphate-P (mg/L)
12. Fecal Coliform (org/100 ml)
13. Chlorophyll *a* (μg/L)
14. Pheophytin *a* (μg/L)

Biological samples were collected at stations 1-8 (Figure 1). Benthic macroinvertebrates move very little over their life span, thus examining the macroinvertebrate community structure present in an area provides a good indication of the long-term effects of pollution.

For the biological sampling, three stones of approximately equal size and shape (oval and about 5 by 6 inches in diameter) were collected from a representative riffle near each station. Each stone was placed in a small-mesh net, washed, and rinsed until all visible organisms were removed, then the organisms were preserved in 70% alcohol (Bernhardt and Yake, 1979). The organisms were later keyed to the most specific taxonomic level readily attainable and the Shannon Diversity Index (Lloyd, *et al*., 1968) was computed for each station.

Sampling on the creek was repeated on September 16, 1980 and October 1, 1980 with the emphasis placed on characterization of temperature increases, dissolved oxygen depletion, and other water quality conditions during above-normal atmospheric temperature conditions. Atmospheric temperatures were approximately 5 to 6 °F above normal during sampling reaching a maximum in the late afternoon of 81.5°F on September 16, 1980 and 71°F on October 1, 1980 (Weaver, personal communcation).

Initial temperature and dissolved oxygen readings were taken in the morning before substantial heating had occurred. During the late afternoon, flows, specific conductivity, temperature, and dissolved oxygen measurements were made in the field. Water samples were collected for parameters 1, 2, 3, and 7 through 14 previously listed. In addition, samples were collected for fecal streptoccocal and total alkalinity.

RESULTS

Water quality data collected on Skamokawa Creek are summarized in Tables 1 and 2.

Physical and Chemical Factors

pH - All pH measurements (Tables 1 and 2) fell within the 6.5 to 8.5 pH standard for Class A waters (DOE, 1977). The highest value recorded was at station 5 with a value of 8.1, while the lowest value was 6.9 at station 11.

Total Alkalinity - The Environmental Protection Agency (EPA) has recommended a quality criterion of 20 mg/L or more as $CaCO_3$ in order to maintain adequate buffering capacity for the protection of freshwater aquatic life (EPA, 1976). The alkalinity values shown in Table 2 are all above the suggested criterion of 20 mg/L. A maximum value of 67 mg/L was found at station 12. Tidal influence from the Columbia River estuary which frequently has alkalinity values in the 60 to 80 mg/L range (USGS, 1977), probably is the cause of the increased value found at station 12.

Specific Conductivity - Conductivity values (Tables 1 and 2) remained fairly constant between stations 1 through 11 with a maximum value of 89.8 µmhos/cm at station 9 and a minimum value of 65.0 µmhos/cm at station 1. Conductivity values increased sharply at station 12 which most likely indicated an influx of water from the Columbia River at high tide.

Turbidity and Total Suspended Solids - The Class A standard for turbidity states that "turbidity shall not exceed 5 NTU (nephelemetric turbidity units) over background turbidity when the background turbidity is 50 NTU or less." (DOE, 1977). Stations 1 through 9 (Tables 1 and 2) all had turbidity values of 1 NTU which are well within the state's Class A standard. Total suspended solids also were recorded at low levels between stations 1 through 9 (Table 1), with a maximum value of 3 mg/L at stations 7 and 9.

Turbidity values in the lower creek between stations 11 and S-1 ranged from 5 mg/L at station 12 to 8 mg/L at station 11. Total suspended solids also were recorded at increased levels in the lower creek with a value of 34 mg/L at station 12.

Table 1: Results of Physical and Chemical analyses collected 8/11-12/80 on Skamokawa Creek, WA.

Station Number and Description	Flow (cfs)	Temperature (°C)	Diss. Oxygen (mg/L)	O_2 Saturation (%)	pH (Standard Units)	Total Alkalinity as $CaCO_3$ (mg/L)	Spec. Conductivity (µmhos/cm)	Turbidity (NTU)	COD (mg/L)	BOD_5 (mg/L)	Nitrate-N (mg/L)	Nitrate-N Load (lbs/day)	Nitrite-N (mg/L)	Ammonia-N (mg/L)	Orthophosphate-P (mg/L)	Total Phosphate-P (mg/L)	Total Phosphate-P Load (lbs/day)	Fecal Coliform (No./100 ml)	Fecal Strep. (No./100 ml)	Chlorophyll-a (µg/L)	Pheophytin (µg/L)	Total Suspended Solids (mg/L)
1: Left fork 1.5 mi. abv. confl. w/main fork. R.M. 5.7	2.08	13.8	10.4	98	7.05	--	67.5	1	18	<4	.23	2.58	<.01	<.01	<.01	.02	.22	28*	--	.6	.7	<1
2: Richardson Ranch R.M. 5.5	7.19	13.4	10.6	101	7.10	--	78.0	1	8	<4	.32	12.40	<.01	<.01	<.01	.02	.78	130	--	.5	1.1	<1
3: Left fork 25' abv. Oatfield Rd. Br. R.M. 4.2	2.45	16.5	10.4	106	7.20	--	74.0	1	12	<4	.14	1.85	<.01	<.01	<.01	.04	.53	260	--	.7	1.2	1
4: Main fork 50' abv. confl. w/left fork. R.M. 4.2	4.17	14.1	10.5	101	7.45	--	71.0	1	8	<4	.29	6.52	<.01	.01	<.01	.04	.90	360*	--	.9	1.1	<1
5: 100' below confl. of left & main forks R.M. 4.0	6.62	15.5	10.6	105	7.50	--	73.0	1	12	<4	.25	8.92	<.01	.01	<.01	.04	1.43	330*	--	1.4	2.3	2
6: Maki Rd. Br. R.M. 2.5	7.07	16.4	10.7	109	7.18	--	73.5	1	8	<4	.24	9.15	<.01	.02	.02	.04	1.52	1100*	--	1.5	3.7	<1
7: 1/4 mile abv. confl. w/Wilson Cr. R.M. 2.25	5.89	16.4	10.7	109	7.15	--	74.5	1	12	<4	.25	7.94	<.01	.03	.01	.04	1.27	1600*	--	1.5	3.2	3
8: Main fork 50' abv. confl w/Wilson Cr. R.M. 2.0	8.14	15.7	9.9	99	7.05	--	76.8	1	12	<4	.29	12.72	<.01	.03	.03	.05	2.19	1200*	--	1.2	3.0	2
9: Wilson Cr. 200' abv. confl. w/Skamokawa Creek	6.70	16.4	9.9	100	7.18	-	89.8	1	16	<4	.15	5.42	<.01	.03	.03	.04	1.44	650*	--	1.8	2.5	3
10: Main fork, middle of levee near hay bin R.M. 1.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11: West fork at Look Residence. R.M. 1.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12: Boat launch at Hwy. Br. R.M. .25	--	18.4	8.1	85	6.98	--	103.5	5	16	<4	.15	--	<.01	.03	.04	.05	--	1600*	--	6.7	5.8	34
S-1: Mouth at Mid-channel	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S-2: East inlet at mouth 200' upstream from Duck Inn	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

*Values are based on estimated (non-ideal) counts. R.M. = River Mile

Table 2: Results of Physical and Chemical analyses collected 9/16/80 on Skamokawa Creek, WA.

Station Number and Description	Flow (cfs)	Temperature (°C)	Diss. Oxygen (mg/L)	O_2 Saturation (%)	pH (Standard Units)	Total Alkalinity as $CaCO_3$ (mg/L)	Spec. Conductivity (umhos/cm)	Turbidity (NTU)	COD (mg/L)	BOD_5 (mg/L)	Nitrate-N (mg/L)	Nitrate-N Load (lbs/day)	Nitrite-N (mg/L)	Ammonia-N (mg/L)	Orthophosphate-P (mg/L)	Total Phosphate-P (mg/L)	Total Phosphate-P Load (lbs/day)	Fecal Coliform (No./100 ml)	Fecal Strep. (No./100 ml)	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)
1: Left fork 1.5 mi. abv. confl. w/main fork. R.M. 5.7	2.70	[12.5] (13.8)	[10.4] (9.9)	[97] (94)	7.3	24	65	1	--	--	.35	5.09	<.01	<.01	.01	.03	.44	170	100	.4	.9	--
2: Richardson Ranch R.M. 5.5	7.12	[11.9] (14.2)	[10.6] (10.1)	[98] (97)	7.3	24	74	1	--	--	.43	16.50	<.01	<.01	.01	.03	1.15	23*	150	.5	.3	--
3: Left fork 25' abv. Oatfield Rd. Br. R.M. 4.2	--	(17.0)	(9.5)	(98)	7.3	24	77	1	--	--	.20	--	<.01	.01	.01	.03	--	140*	54	.7	1.6	--
4: Main fork 50' abv. confl. w/left fork. R.M. 4.2	--	(15.6)	(9.9)	(98)	7.4	25	73	1	--	--	.42	--	<.01	<.01	.01	.03	--	200	150	.8	1.6	--
5: 100' below confl. of left & main forks R.M. 4.0	10.30	[12.8] (15.8)	[10.5] (9.8)	[100] (98)	8.1	39	73	1	--	--	.36	19.99	<.01	<.01	.01	.03	1.67	230	110	.7	1.3	--
6: Maki Rd. Br. R.M. 2.5	--	[14.5] (19.6)	[10.2] (9.0)	[99] (97)	7.3	27	77	1	--	--	.32	--	<.01	.01	.02	.05	--	960	290	.8	2.2	--
7: 1/4 mile abv. confl. w/Wilson Cr. R.M. 2.25	--	[14.3] (19.8)	[10.4] (9.0)	[101] (101)	7.6	31	74	1	--	--	.32	--	<.01	.01	.02	.05	--	5000	370	1.1	6.0	--
8: Main fork 50' abv. confl w/Wilson Cr. R.M. 2.0	14.74	[13.7] (18.6)	[10.2] (9.3)	[98] (99)	7.3	35	78	1	--	--	.38	30.19	<.01	.04	.03	.06	4.77	240	920	.7	1.9	--
9: Wilson Cr. 200' abv. confl. w/Skamokawa Creek	11.23	[14.3]	[9.3]	[89]	7.4	29	87	1	--	--	.18	10.90	<.01	.02	.02	.05	3.03	110	86*	.7	1.9	--
10: Main fork, middle of levee near hay bin. R.M. 1.5**	--	[12.2] (14.8)	[10.0] (10.3)	[93] (101)	7.2	25	82	2	--	--	.40	--	<.01	<.01	.03	.06	--	110	--	1.2	1.8	--
11: West fork at Look Residence. R.M. 1.5**	5.60	[14.0] (15.2)	[8.8] (8.0)	[85] (78)	6.9	23	87	8	--	--	.33	9.96	<.01	<.01	.04	.05	1.51	180	--	2.4	3.0	--
12: Boat launch at Hwy. Br. R.M. .25	--	(19.6)	(8.6)	(92)	7.5	67	159	7	--	--	.08	--	<.01	.02	.03	.06	--	23*	22*	5.2	7.2	--
S-1: Mouth at Mid-channel	--	(19.4)	(8.7)	(94)	7.9	--	163	7	--	--	.07	--	<.01	.02	.03	.05	--	40	16*	4.6	2.2	--
S-2: East inlet at mouth 200' upstream from Duck Inn	--	(19.8)	(8.7)	(94)	7.6	--	151	6	--	--	.08	--	<.01	<.01	.03	.05	--	70	35*	--	--	--

*Values are based on estimated (non-ideal) counts. R.M. = River Mile

**Data collected on 10/1/80.

[ ] - Bracketed figures are a.m. collection.

( ) - Parenthesized figures are p.m. collection.

The increases in turbidity and total suspended solids in the lower areas of Skamokawa Creek are most likely being produced by tidal inflow from the Columbia River estuary. The Columbia River is carrying a heavy sediment load especially since the May 18, 1980 eruption of Mount St. Helens and consequent dredging projects which could produce the higher turbidity and total suspended solids values found.

Nutrients - Nutrient results are presented in Tables 1 and 2. Nitrite-nitrogen (NO_2-N) levels at all sampling stations were below detectable limits (less than 0.01 mg/L). Ammonia-nitrogen (NH_3-N) levels also were uniformly low throughout the creek with levels ranging from less than 0.01 mg/L in the upper reaches (above station 5) to a maximum of 0.04 mg/L at station 8.

Nitrogen uptake by algae generally is in the nitrate form if nitrate is available (EPA, 1977). Nitrate-nitrogen (NO_3-N) values in Skamokawa Creek on August 11 and 12, 1980 (Table 1) generally were below the threshold value of 0.3 mg/L required to produce an algae bloom suggested by Klein (1959), but the values had slightly increased to levels above the bloom threshold on September 16, 1980 (Table 2). A sharp drop in NO_3-N levels were recorded between the upper creek stations and stations 12, S-1, and S-2. The primary reason for the drop in NO_3-N levels probably is due to a separate water mass from the Columbia River estuary moving into the creek at high tide which could have different NO_3-N concentrations than are present in the creek.

Generally speaking, most waters are phosphorus limited requiring only a small amount of phosphorus to support algal growth in relation to the amounts of carbon and nitrogen required (EPA, 1977). Consequently, algal bloom potential values of 0.01 mg/L for orthophosphate-phosphorus (O-PO_4-P) and 0.05 mg/L for total phosphate-phosphorus (T-PO_4-P) have been suggested by Klein (1959) to give an indication of possible algal growth problems in streams.

Orthophosphate-phosphorus probably is more important to evaluate than total phosphate-phosphorus in assessing algal bloom potentials since it is only the soluble orthophosphate form that is immediately available for uptake by aquatic plants (EPA, 1977). Orthophosphate-phosphorus levels in Skamokawa Creek on September 16, 1980 ranged from 0.01 mg/L in the upper stations (Table 2) to a maximum of 0.03 mg/L in several of the lower creek stations. Table 1 shows orthophosphate-phosphorus levels on August 11 and 12, 1980 to be below the level of detection at stations 1 through 5 while they are only slightly above the bloom potential value (0.01 mg/L) in the lower reaches ranging from 0.01 mg/L to 0.04 mg/L).

Total phosphorus levels also remained at low levels in the creek with values ranging from 0.02 mg/L to 0.06 mg/L.

Examination of the data suggests that, while NO_3-N generally is available in sufficient quantities for algal blooms to occur, phosphorus may be the limiting nutrient. It is available in quantities sufficient to produce an algae bloom only at some of the lower creek stations, provided adequate sunlight is available. Generally, nutrients would be expected to be at low levels during the late summer when surface runoff from adjacent pasture lands is at a minimum.

Bacteriological Factors

Fecal Coliforms - Fecal coliforms are bacteria found in the intestinal tracts of humans and other warm blooded animals. Since they are restricted to the intestinal tracts of warm blooded animals, their presence in a water sample gives a good indication of whether the water has recently come in contact with fecal material originating in warm blooded animals.

The fecal coliform standard for Class A waters states that "fecal coliform organisms shall not exceed a median value of 100 organisms per 100 ml, with not more than 10% of the samples exceeding 200 organisms per 100 ml" (DOE, 1977). A median value of approximately 200 organisms per 100 ml was found to be present in Skamokawa Creek with 50 percent of the samples exceeding 200 organisms per 100 ml (Figure 2). Thus, Skamokawa Creek violated the state's Class A standard. Fecal coliform concentrations proved to be quite variable throughout the survey with the highest concentrations occurring between stations 6 and 9 (Figure 2). In addition, an estimated count of 1600 organisms per 100 ml was found to be present at station 12. The variability present in the coliform data probably is best explained by the fact that bacteria are irregularly distributed in natural waters.

Biological Factors

Information on the diversity (numbers and types of organisms) of benthic macroinvertebrate populations can be very useful when assessing the impacts of pollution on a stream. While water sampling may fail to identify or may miss pollutants discharged intermittently, examination of the composition of the benthic community present in an area can provide indications about the long-term effects of pollution on a stream (Yake and Cloud, 1979).

Normally, high diversity (low numbers with many species) values represent stable, healthy communities in a favorable habitat while low diversity (high numbers with only a few species) implies unstable communities exposed to stress conditions (Bernhardt and Yake, 1979).

Usually, wide variations are present in composition and distribution of benthic communities from one area to the next. This makes it very difficult to establish a diversity index that will allow a comparison of different waters using the same scale. Considering collected data, an appropriate scale for the Skamokawa basin study after Wilhm, 1972 might be as follows:

0-1	Heavy pollution
1-2	Moderate pollution
2-3.0	Slight pollution
>3.0	Unpolluted

Shannon Diversity Index numbers calculated from Table 3 are presented in Figure 3. The values ranged from a high of 3.13 at station 3 to a low

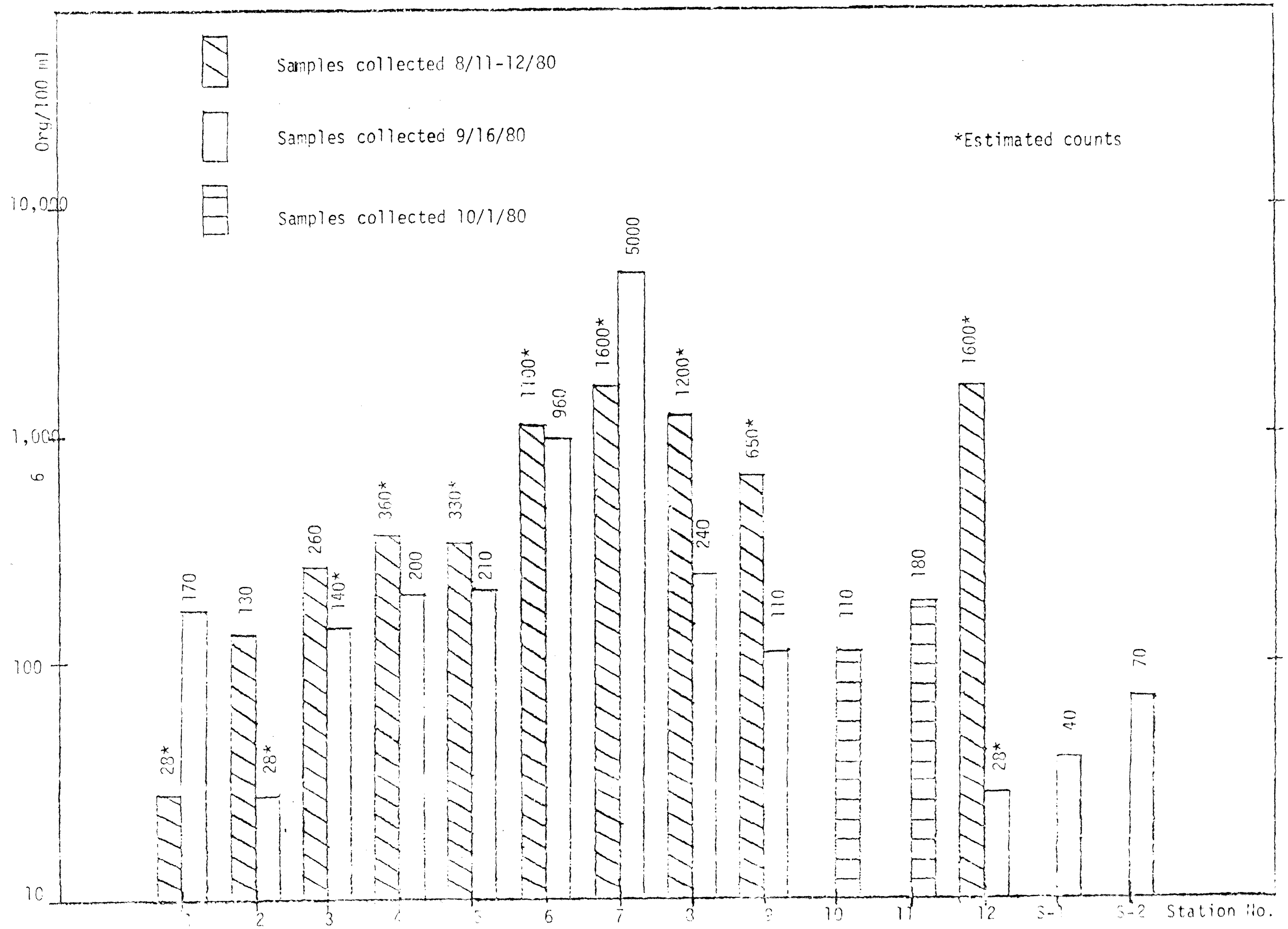

Figure 2: Summary of fecal coliform data collected on Skamokawa Creek, Wa.

of 1.71 at station 7. There was no apparent pattern in index values from the upper end of the basin to the lower end. Most of the index values fell in the slight pollution range. However, stations 2 and 7 had index values in the moderate pollution range.

Examination of the data in Table 3 shows that at least one or more of the species which are considered quite sensitive to environmental changes such as immature or larval stages of *Ephemeroptera* (May flies), *Plecoptera* (Stone flies), *Trichoptera* (Caddis flies), and *Elimidae* (Riffle beetles) (Hughes, 1977) were present at all sampling stations (Table 3).

Diptera of the family Tendipedidae were present at all sampling stations except station 1. Tendipedidae thrive in areas with a rich food supply of organics and bacteria.

Water quality data in Table 1 do not appear to suggest any apparent reason for the lower diversity recorded at station 7. Some degradation may have occurred at station 7 in the past which probably would not be detected by the water quality data collected. However, the presence of sensitive species at site 7 probably is the best indication that conditions were favorable for the benthic community in Skamokawa Creek at this site at the time of the survey.

Overall, it appears that the benthic community in Skamokawa Creek has been only slightly to moderately impacted. It is possible that habitat alteration such as vegetation removal and logging in the upper drainage basin could be as much of a contributing factor in lowering the benthic community's diversity as any possible intermittent pollutants.

SUMMARY AND CONCLUSIONS

During the investigation, Skamokawa Creek met all criteria for Class A waters in the State of Washington with the exception of fecal coliforms. Skamokawa Creek was in violation of the Class A standard with a median value of 200 organisms per 100 ml with 50 percent of the samples exceeding 200 organisms per 100 ml. The high fecal coliform levels most likely result from a combination of sources. Most of the residences in the Skamokawa basin are older homes, built directly adjacent to the creek banks. In addition, many of the homes in town discharge directly into the creek. The proximity of the homes to the creek especially in the town of Skamokawa prevents adequate buffering between the residences' drain fields and the creek to prevent fecal coliform contamination caused by runoff into the creek. In addition, cattle access to the creek is virtually unrestricted throughout most of the area. Contamination from dairy cattle could be expected to increase during the rainy season when runoff from adjacent pastures increases.

During our investigation, Skamokawa Creek appeared to be quite suitable for fish passage and spawning success. Dissolved oxygen concentrations were well within the acceptable limits for fish survival.

Table 3. Summary of Macroinvertebrate Counts from Skookumchuck Creek, Washington, collected August 11 and 12, 1980.

Taxonomy	Station No. 1*	Station No. 2*	Station No. 3*	Station No. 4*	Station No. 5*	Station No. 6*	Station No. 7*	Station No. 8*
Diptera (flies, midges)								
A. Tipulidae								
Antocha sp (P)	1	2	1	1	2	1	1	
Species A (L)	2	5	-	1	3			
Species B (L)	1	5		5	7	-		
Unknown pupae	1	-		2		-		
B. Tendipedidae								
Pentaneura sp. (L)	-	277	20	38	89	8	26	1[illegible]
Species A (L)	-	120	9	23	34	2[illegible]	1	[illegible]
C. Empididae								
Unknown species A	2	3	1	-	-	2		
D. Dolichopodidae								
Unknown species A	-	-	-	-	-	2		
Trichoptera (Caddis flies)								
A. Lepidostomatidae								
Unknown species A	1	-						
B. Limnephilidae								
Species A	14	6	6	-	11	-	-	1
Species B	2	-	-	-	-	2	4	
Species C	-	-	-	-	-	4	-	
C. Psychomyiidae								
Unknown species A	3	-	-	-	-	-	-	
D. Rhyacophilidae								
Unknown species A	-	1	-	-	-	-	1	
Plecoptera (Stoneflies)								
A. Chloroperlidae								
Paraperla sp.	-	1	-	2	1	-	1	
B. Perlodidae								
Isoperla sp.	-	1						
Unknown species A	7	-	1	2	2			
Unknown species B	-	-	-	-	1	1		
Ephemeroptera (Mayflies)								
A. Baetidae								
Baetis sp.	15	18	14	16	18	26	14	2
Species B	59	21	15	153	202	145	158	9
Paraleptophlebia sp.	-	-	-	-	-	1	-	15
B. Heptageniidae								
Ephemerella [illegible]	1	1	1	1	1			
Species A	2	1	2	2	1	-	-	1
Odonata (Dragon flies)								
Unknown species A	1	-				27		
Coleoptera (True beetles)								
A. Elmidae								
Narpus sp.	4	-	-	-	5	2	3	12
Rhizelmis sp.	-	-	2					
Unknown species A	-	-	-	1	-	1		
B. Amphizoidae								
Amphizoa sp.	-	1	-	1	-	1	2	
Gastropoda (Snails)								
A. Pleuroceridae (river snails)	-							
Goniobasis sp.	1	-	18	3	-	16	15	18
B. Lymnaeidae (pond snails)								
Lymnaea sp.	-	-	4	2	2	2	4	7
Collembola (Springtails)								
A. Sminthuridae								
Sminthurides sp.	-	-	-	-	-	1		
Hydracarina (Water mites)								
Unknown species A	1	-	-	-	-	2	-	2
Unknown species B	2	7	2	3	7	1	-	6
Unknown species C	-	-	-	2	1	3	-	-
Unknown species D	-			1	-	-		-
Unknown species E	-				8	1		-
Unknown species F	-					2		2
Total Number Organisms	120	470	96	259	395	3[illegible]	230	246
Shannon Diversity Index	2.73	1.89	3.13	2.18	2.31	2.[illegible]	1.71	2.94
Number per m^2	0.20	0.49	0.10	0.28	0.52	0.44	0.25	0.27

(L) - Larval
(P) - Pupae

*See Figure 1 for station locations (see also site descriptions in Table 1.

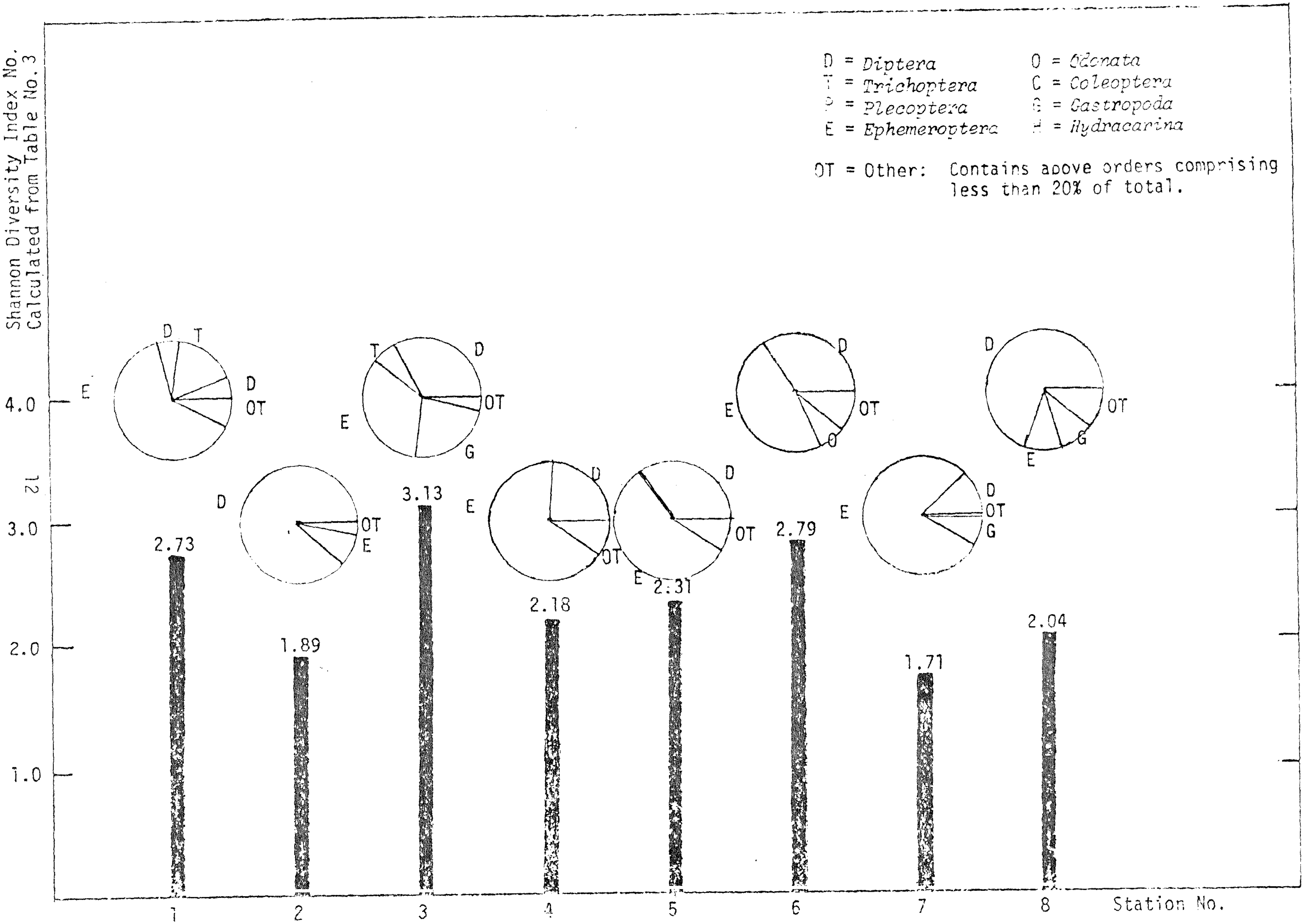

Figure 3. Shannon Diversity Index No. and Community Composition for sampling stations 1-8 collected August 11-12, 1980 at Skamokawa Creek, Wa.

It appears from a review of the available information, that the periodic fish kills have occurred in the early morning hours during periods of very low stream flow when large numbers of fish are spawning.

Aerating falls and riffles as well as attached aquatic plants are almost nonexistent in the lower reaches of the creek due to the silty bottom conditions which prevail. During the early morning hours when dissolved oxygen concentration reach a minimum, the added burden of several hundred fish moving upstream to spawn probably caused critical dissolved oxygen concentrations to be reached (Tracy, 1975).

Recently the Washington State Department of Fisheries has modified its management plans concerning Skamokawa Creek by allowing additional fishing pressure which has reduced the number of fish arriving upstream for spawning. The reduction in the number of spawning fish should eliminate fish kills due to reduced oxygen levels produced from over-spawning the available habitat which historically has occurred (Fiscus, personal communication).

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