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An ecological investigation of the Portneuf River, Idaho: a semiarid-land stream subjected to pollution

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Summary

The Portneuf River (mean monthly discharge near mouth 1·4–15·4 m^3/s) in south-eastern Idaho, U.S.A., flows through an area of reduced precipitation (approx. 33 cm/year) and is dependent on underground aquifers and snowmelt runoff from the surrounding mountains for its water. The stream was examined at ten locations, distributed over its 156-km course, during the period 1967–1971. The Portneuf River is shown to have undergone a number of changes from its natural state as evidenced by alterations in water quality and the distribution of benthic invertebrates along the stream course. Of particular interest are changes brought about by the use of the stream for irrigation and by runoff from agricultural lands, factors whose effects are magnified by the semiarid conditions of the region and by poor soil-conservation practices. However, the stream also is affected by wastes from a sewage-treatment plant, phosphate-processing operations, and an assortment of scattered urban sources. Benthic invertebrates were collected during all four seasons by means of artificial substratum samplers and during summer and autumn by a qualitative dip-net technique. In general, the samplers were more effective in obtaining a representative picture of the fauna. However, neither procedure alone gave as much information as the combined results. The artificial substratum collections are not believed to be representative of the usual effects of stream dewatering by irrigation withdrawal in as much as the samplers provide refugia for the benthos during the periods of reduced habitat.

Introduction

Ecologically oriented studies of stream pollution began in earnest in the 1920's and have continued sporadically to the present time. Recently increased interest has been shown in the documentation of the behaviour of chemical and physical parameters in polluted streams (MacCrimmon & Kelso, 1970; Soltero, 1969) and their effects on the biota (e.g., Mackenthun, 1969). There has been particular interest in measuring the responses of the benthic invertebrates because these seem to provide one of the best cumulative indicators of the extent and significance of pollution (Hynes, 1965). Many of the past investigations of stream pollution were conducted in western

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Europe, which was the first major area to feel the full impact of the Industrial Revolution. Investigations of North American flowing waters have been less frequent and considerable work remains to be done. There is particular need for year 'round studies to define the annual pattern of chemical–physical variations in both natural and polluted waters and to determine the response of the benthic invertebrates to resultant stresses. The need for year 'round studies is especially great in streams which show a great seasonal variation in discharge (Livingstone, 1963), and even this will not take into account variations due to wetter and dryer years.

The purpose of the present study was to assess selected physical, chemical, and biological conditions of an entire river over an extended peroid in an effort to gain better understanding of the behaviour and possible interaction of these factors. The study is of particular interest because it was conducted in an area of limited precipitation where the use of stream water for agricultural purposes is especially critical and where the impact of such uses on lotic habitats is pronounced. In addition, the data obtained serve to pinpoint sources of contamination, provide evidence of the kinds and amounts of pollutants entering the river, and serve as a baseline from which to measure future changes in its condition.

This investigation was conducted on the Portneuf River in southeastern Idaho, U.S.A. (Fig. 1) during the period 1967–1971. Most of Idaho is semiarid and lies in a rain shadow formed by the Coastal Mountain Range to the west. The precipitation, which is rather evenly distributed throughout the year, varies from an annual average of about 33 cm (13 in.) at Pocatello to about 76 cm (30 in.) in the mountains. Winter snows, which melt rapidly in the spring, and intense summer rainstorms result in flooding and soil erosion. Mean discharge of the Portneuf River measured at Pocatello varies between 1·4 m^3/s (50 cfs) in summer and 15·4 m^3/s (550 cfs) or more during snow-melt runoff in the spring. Maximum recorded discharge values were 81·2 (2900 cfs), 83·7 (2990 cfs), and 69·2 m^3/s (2470 cfs) in 1911, 1962, and 1963, respectively (U.S. Army Corps of Engineers, 1970).

Maximum elevation in the Portneuf drainage is 2830 m (9280 ft), with the river mouth located at an elevation of 1326 m (4350 ft). The mountains in and surrounding the Portneuf River Basin are upthrusts of old sedimentary rocks (mostly Paleozoic shales, limestones, and dolomites); the valleys are filled partly with the weathering products of these rocks and partly with basalt from relatively recent (Pleistocene) lava flows. The topsoil in most of the basin is loess. Land in the Portneuf River Basin is used principally for range [rough pasture] (61%), cropland [arable] (33%), timber (2·5%), and meadow hayland (1%) (Merrell & Onstott, 1965). Most of the foothill slopes of the river basin have been farmed for over 70 years. Approximately 80% of the cropland is dry-farmed, mainly for wheat. Much of this area, especially on benchland along the west of Marsh Creek, currently is exposed to severe erosion. The other 20% of the cropland is irrigated for growing potatoes, sugar beets, and alfalfa.

The Portneuf, like many streams of the semiarid intermountain West, arises as a series of pristine mountain streams, passes through agricultural and pasture lands where the water may be used for irrigation, and receives waste-waters from one or more municipalities. Almost inevitably waters from such streams become impounded in reservoirs, where they produce additional problems of an ecological nature. A further source of contamination in the present study was wastes from the processing of phosphate ore. Among the important pollutants entering the Portneuf River were suspended solids from tilled croplands, organic wastes from cattle and municipal sewage, and

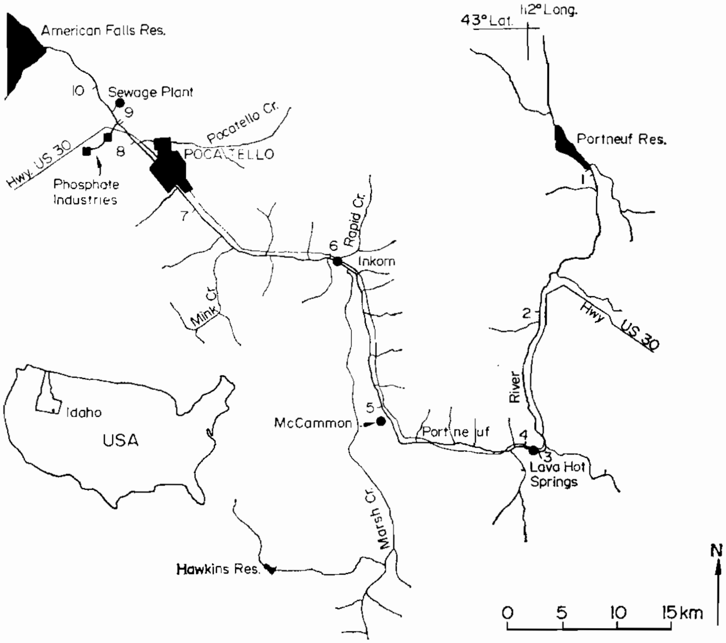

Fig. 1. Map of the Portneuf River, Idaho (U.S.A.).

Location	Description
Station 1 (Distance 1 km; elevation 1667 m)	Upstream of all urban or industrial pollution sources and most significant rural sources; subject to wide fluctuations in discharge and periodic chemical control for removal of aquatic plants due to management for irrigation flow (Plate 1a).
Station 2 (Distance 12 km; elevation 1617 m)	Located upstream from the entrance of Pebble Creek but below the inflow of numerous springs and possibly some irrigation return water from 'Upper Portneuf' basin. A considerable number of cattle are raised in the upper basin.
Station 3 (Distance 27 km; elevation 1555 m)	Located in one of the most turbulent sections of the river; downstream from the confluence with Fish Creek and a large waterfall; immediately upstream from any influence from the resort town of Lava Hot Springs, but in an area of periodic thermal spring activity.
Station 4 (Distance 29·5 km; elevation 1525 m)	About 1 km below Lava Hot Springs, just above the entrance of Dempsey Creek, and 10·5 km upstream from the diversion dam of Portneuf-Marsh Valley Canal Co. (Plate 1b).
Station 5 (Distance 47 km; elevation 1433 m)	Below the town of McCammon, just north of Merrill Road bridge; below all major irrigation diversions, but above the return flows (Plate 1c).
Station 6 (Distance 67 km; elevation 1373 m)	At the northern (downstream) edge of the town of Inkom; 2·7 km below the confluence of Marsh Creek (main source of irrigation return water) and 0·8 km below entrance of Rapid Creek.
Station 7 (Distance 72 km; elevation 1353 m)	Cheyenne Street bridge; above the City of Pocatello at the head of a recently completed flood control project (Plate 1d).

Station 8 (Distance 79 km; elevation 1345 m)	Samples for chemical analysis were collected at the Kraft Road bridge in a pooled section formed by Swanson diversion dam; benthos collections were made in a riffle section just below the dam; location is below City of Pocatello and Pocatello Creek; upstream waste sources include city storm sewers, a petroleum waste-recovery plant, a meatpacking plant, and septic tanks.
Station 9 (Distance 84·5 km; elevation 1342 m)	At Batiste Road bridge; 350 m below 'east' and 100 m below 'west' industrial effluents; wastes and spills (acids, ammonia, phosphates, fluorides, sewage, heated water, etc.) from phosphate ore processing and manufacturing operations enter via the two effluents; for the benthos collections a second 'control' site (9a) was established 200 m above the most upstream ('east') effluent.
Station 10 (Distance 86 km; elevation 1335 m)	Syphon Road bridge; below the entrance of wastes (since halted) from a dairy and from the City of Pocatello's primary sewage treatment plant; a large number of springs also enter in this area.

nitrogen and phosphorus compounds from fields, animal wastes, a sewage-treatment plant, and a phosphate-fertilizer plant.

The Portneuf River drains an area of approximately 3574 km^2 (1380 sq miles) over its 156-km (97-mile) course and enters American Falls Reservoir on the Snake River (U.S. Army Corps of Engineers, 1970) (Fig. 1). The gradient of the river is 4·31 m/km in the upper reaches, decreasing to 1·13 m/km in the Pocatello area (Fig. 2). Four municipalities are situated on the stream (Lava Hot Springs, pop. 593; McCammon, pop. 557; Inkom, pop. 528; and Pocatello, pop. 39,000), but at the time of this study only Pocatello was dumping (treated) wastes. The other towns were all served by sewage lagoons which released no effluent. The main tributary to the Portneuf River is Marsh Creek, which received its present shape when Lake Bonneville (present remnant: Great Salt Lake) overflowed and passed down Marsh Creek to the Snake River.

Description of sampling sites

Ten sampling stations were established along the mainstream of the Portneuf River following a comprehensive ground reconnaissance of the stream and several months of preliminary analyses. The sites were chosen to reflect major environmental changes in the condition of the river and an effort was made to select locations which were as similar as possible in relation to the morphological features of the stream in order to facilitate comparisons. Pertinent features regarding each site are given in the caption to Fig. 1. The distance given is the location downstream from the Portneuf Reservoir dam.

Aquatic macrophyte growth was restricted almost entirely to the upper reaches of the stream and to the region of Station 10 and below, although some *Potamogeton crispus* L. was collected from Station 7. The largest standing crop of aquatic plants occurred in the vicinity of Station 2, where *Rorripa nasturtium-aquaticum* (L.) S. and T., *Ranunculus cymbalaria* Pursh, and *Cladophora glomerata* (L.) Kuetz. were important components. Stations 1 and 4 supported successively lesser amounts. At Station 1 *Potamogeton pectinatus* L. and *C. glomerata* were most abundant, and at Station 4 the common forms were *Potamogeton filiformis* Pers. and *R. nasturtium-aquaticum*. Based solely on observation, Station 10 appeared to support the second largest amount of aquatic plants, predominantly *P. pectinatus*, *P. crispus*, and *R. cymbalaria*.

The fishes of the Portneuf River were studied by Mohr (1968) but no quantitative data are available. Three species, *Rhinichthys cataractae* (Girard), *R. osculus* (Cope), and *Richardsonius balteatus* (Cope), occur throughout the stream. Eight other species, *Catostomus discobolus* Cope, *Cottus bairdi* (Girard), *C. beldingi* (Eigenmann and Eigenmann), *Gila atraria* (Girard), *Salmo clarki* (Richardson), *S. gairdneri* (Richardson), *S. trutta* (L.), and *Salvelinus fontinallis* (Mitchell), are found mainly in the upper reaches, ending about in the region of Station 5. *Catostomus ardens* (Jordan and Gilbert) is found in the middle reaches (Stations 5–8) and *Prosopium williamsoni* (Girard) is reported only in the lower reaches (Station 10).

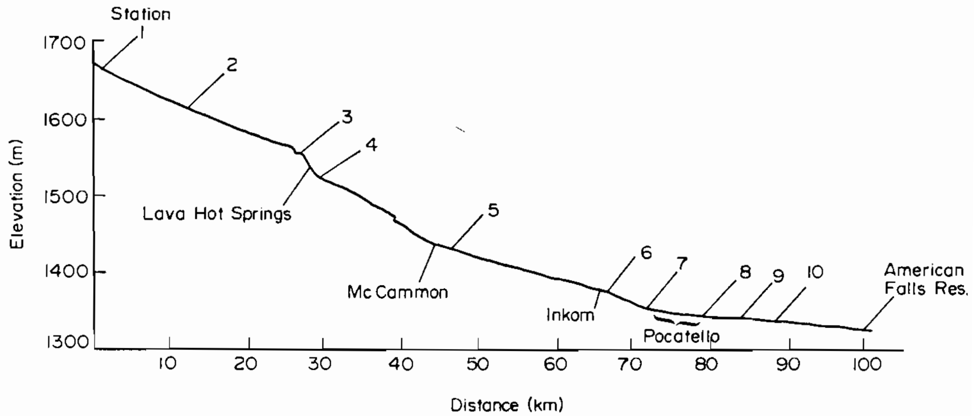

Fig. 2. Vertical profile of the Portneuf River.

Methods

Water chemistry

Collections were made on eleven sampling dates at approximately monthly intervals, beginning September 1968 and ending September 1969. (No collections were made in January or June). Additional collections made in September 1967 and February 1967, 1970, and 1971 give an indication of longer-term trends.

Procedures for chemical analysis of the water are based on those outlined by the American Public Health Association (1965). All tests, except those for dissolved oxygen and pH, were performed in the laboratory within a day of collection (most were analysed immediately after returning from the field). Analyses for nitrate-nitrogen and phosphate-phosphorus were carried out by colorimetric measurements, using reagents prepared by the Hach Chemical Co. and a Bausch and Lomb 'Spectronic 20' colorimeter. Turbidity also was determined with the colorimeter. Fluoride concentrations were measured by means of an Orion specific-ion meter and electrode. Dissolved oxygen concentrations determined by the azide modification of the Winkler method were at or near saturation at all stations whenever measured and so were not determined routinely. An Orion portable potentiometer was used for measurement of pH. The specific conductance of each sample was measured with an Industrial Instruments Co. Wheatstone bridge (Model RC-16B2). All measurements were corrected for temperature and converted to approximate total dissolved solids equivalents by multiplying by the factor 0·65 (±0·1) (Rainwater & Thatcher, 1960).

Temperature

Maximum and minimum temperatures were measured by means of recording thermometers (Taylor no. 5458) encased in sections of protective pipe and hidden on the stream bottom. The accuracy of the thermometers was checked against a tele-thermometer (Yellow Springs Instrument Co.) each time the values were read and the appropriate corrections were made before converting the values to °C.

Discharge

Data on stream discharge were obtained from records of the U.S. Geological Survey (Water Resources Data for Idaho 1967–1971). The gauging sites were located approximately 6·5 km below Station 4 and 2·9 km above Station 8.

Benthos

Benthic invertebrates were collected by means of baskets (Hilsenhoff, 1969) filled with equal amounts and uniform sizes of freshly quarried lava basalt. Collections were made during each of the four seasons, beginning in October–December 1969 (autumn series) and continuing through January–March, April–June, and July–September 1970. One sampler was placed at each station and allowed a colonization period of approximately 2 months. At the end of this period the baskets were retrieved with a 'sampler-catcher', agitated in the stream forty times in a standard manner (Hilsenhoff, 1969) to rinse off any invertebrates and placed in plastic bags for return to the laboratory. The invertebrates were concentrated in the collecting bag (8 mesh per cm) of the 'catcher', placed in labelled containers, preserved with formalin, and returned to the laboratory for processing. Current velocity at the front of each basket and depth to the top of the sampler base were measured just after placement and just before removal of the samplers (Table 1). The vertical distance from the sampler base to the centre of the basket was 12 cm.

To test the degree to which the rinsing procedure removed invertebrates from the samplers, the October–December series of samples was treated further after being returned to the laboratory. Each basket was suspended over the collecting bag and washed with a strong flow from a hose for 1 min. They were then inverted and washed again for 1 min. Any invertebrates that washed out, plus any that were found in the plastic bags used to return the samplers to the laboratory, were retrieved and counted. Of the nine samplers treated in this way only two yielded more than 2–3 additional specimens. The sampler from Station 5 produced fifty more invertebrates (mainly *Simulium*) after this treatment and that from Station 10, about twenty (mostly *Physa*).

All organisms were removed from the associated debris by hand, sorted to the lowest taxonomic group practicable, and counted. In situations where large numbers of *Simulium* were collected, a subsample of the group was removed, counted, blotted dry, and weighed. The total number of *Simulium* was then estimated from the (blotted dry) weight of the whole lot.

In order to supplement the samplers, qualitative collections were taken during the summer (June 1970 and July 1971) and autumn (September 1970) by means of a dip

Table 1. Current velocity, depth, and maximum–minimum temperatures at the locations of the quantitative samplers. Current meter was inoperable in September 1970. Depth was measured from the surface of the water to the top of the sampler base

		Station										
		1	2	3	4	5	6	7	8	9a	9b	10
Current velocity (m/s)												
Oct. 9 1969		0·201	0·596	0·586	0·611	0·845	1·083	1·098	0·729	0·921	0·655	0·235
Dec. 4 1969		—	0·645	1·043	0·739	1·048	1·038	0·901	0·527	1·331	0·800	0·472
Jan. 8 1970		0	0·433	1·625	0·660	0·805	1·078	0·517	0·201	0·665	0·349	0·453
March 6 1970		0	0·403	1·377	0·911	1·124	0·916	0·075	0·635	—	—	0·566
April 8 1970		—	—	0·835	0·805	0·566	1·281	0·835	0·650	0·457	0·556	0·630
June 18 1970		—	—	1·230	0·769	0·810	0·556	0·650	0·845	0·393	0·413	0·299
July 15 1970		—	—	1·017	0·840	0·433	1·063	0·265	0·369	0·216	0·764	0·206
Sept. 16 1970		—	—	—	—	—	—	—	—	—	—	—
Mean		—	0·519	1·102	0·762	0·804	1·002	0·620	0·565	0·664	0·590	0·409
Depth (cm)												
Oct. 9 1969		36	48	50	60	40	50	45	50	45	55	60
Dec. 4 1969		—	45	—	36	65	70	75	70	75	65	40
Jan. 8 1970		34	34	34	54	55	55	35	60	50	34	30
March 6 1970		37	30	30	65	100	90	50	55	—	—	55
April 8 1970		—	—	34	50	70	70	55	60	65	70	60
June 18 1970*		—	—	30	60	60	50	45	35	39	40	20
July 15 1970		—	—	25	65	35	49	23	23	20	20	20
Sept. 16 1970		—	—	28	60	52	44	—	45	40	43	60
Mean		35·7	39·3	33·0	56·3	59·6	59·8	46·9	49·8	47·7	46·7	43·1
Maximum–minimum temperatures (°C)												
Sept. 25 1969 to	Max	17·8	15·6	40·6	—	21·1	16·1	—	—	—	11·1	16·7
Dec. 4 1969	Min	1·1	4·4	2·8	—	3·3	0·6	—	—	—	0·0	5·6
Dec. 4 1969 to	Max	9·4	Broken	7·8	—	11·7	—	7·7	—	—	—	11·1
March 6 1970	Min	−1·1	—	4·4	—	3·9	—	2·8	—	—	—	8·9
April 8 1970 to	Max	—	25·6	42·2	—	25·6	—	18·9	—	—	25·0	18·9
June 18 1970	Min	—	7·7	17·2	—	7·7	—	7·8	—	—	2·2	11·1
July 15 1970 to	Max	—	—	30·6	—	21·1	—	33·3	—	—	27·2	19·4
Sept. 16 1970	Min	—	—	8·3	—	10·0	—	11·1	—	—	11·1	11·7

* Stations 9a, 9b, 10 sampled June 28 1970 due to high water.

net (8 mesh per cm). In these collections an effort was made to sample all of the habitats representative of a given site in order to detect any common taxa missed by the samplers.

Results

Seasonal changes in water chemistry

Seasonal trends in general water quality are shown by the data for total dissolved solids, pH, and alkalinity (Fig. 3). Except for Station 1, all of the collecting sites show the same general pattern in regard to total dissolved solids. All stations showed increases in April corresponding with a seasonal peak in discharge (Fig. 4), and there was an increase in total dissolved solids content of the water at Stations 6 through 10 during the irrigation season. The low values for Station 1 from April through August are due to the large releases of water from the reservoir immediately upstream during this period. Values for total dissolved solids were remarkably similar in the lower reaches of the river, beginning with Station 5 (Fig. 3). The high values at Stations 2 and 4 presumably are due to the entrance of relatively large volumes of mineral-spring water upstream from both sites. Similar explanations hold for the mean alkalinity values for Stations 1, 2, and 4. Unlike total dissolved solids, however, alkalinity continued to decline gradually from Station 5 through 9, probably due to a combination of deposition (as insoluble carbonate) and utilization by aquatic plants. Further decline below Station 9 was halted by the entrance of additional springwater.

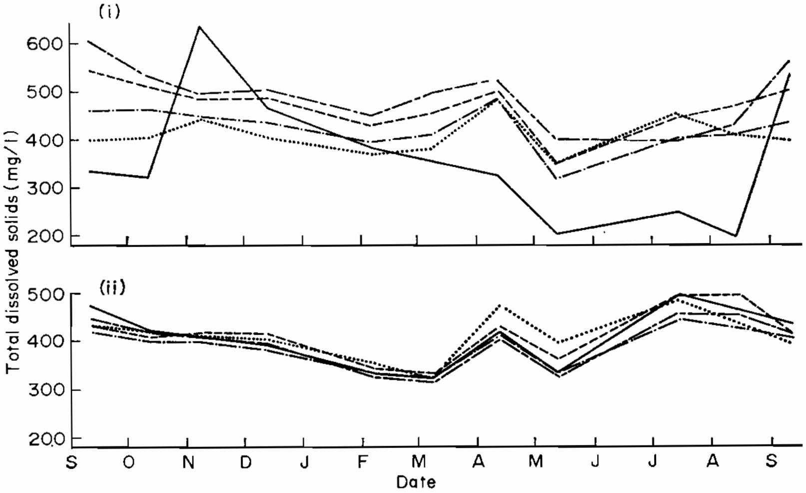

Fig. 3a. Seasonal changes in total dissolved solids in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i) and 6 (ii); —— —— Stations 2 (i) and 7 (ii); – · – · –, Stations 3 (i) and 8 (ii); – – –, Stations 4 (i) and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

No seasonal pattern of pH is evident, not even a marked decrease during the growing season due to photosynthesis. This, of course, is a reflection of the large buffering capacity of the stream. Drastic fluctuations in pH, which are known to occur in the region of Station 9, are not reflected in our data due to the sporadic occurrence of such instances. The consistently low values at all stations in August are believed to be due to a systematic error resulting from an improperly functioning pH meter. Alkalinity on the other hand shows a definite seasonal pattern, with a distinct reduction during the growing season. This is especially pronounced in the section between

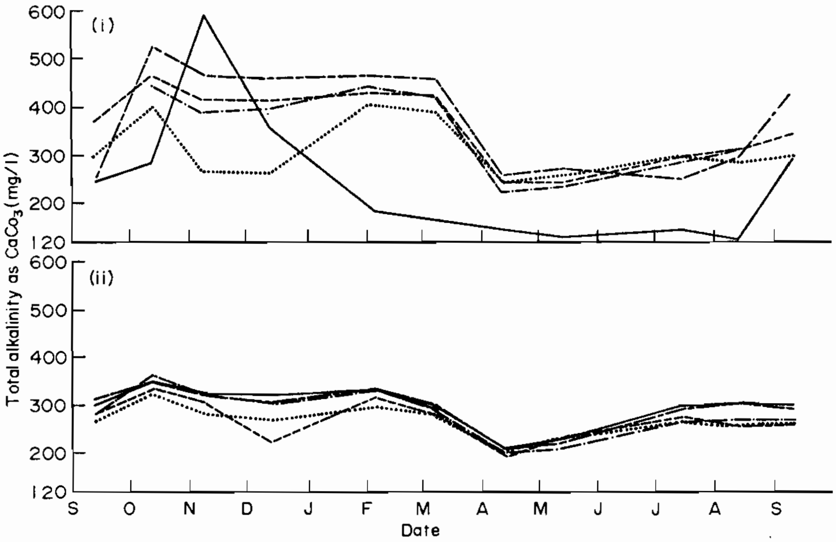

Fig. 3b. Seasonal changes in total alkalinity in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i) and 6 (ii); — — —, Stations 2 (i) and 7 (ii); – · – · –, Stations 3 (i) and 8 (ii); - - -, Stations 4 (i)and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

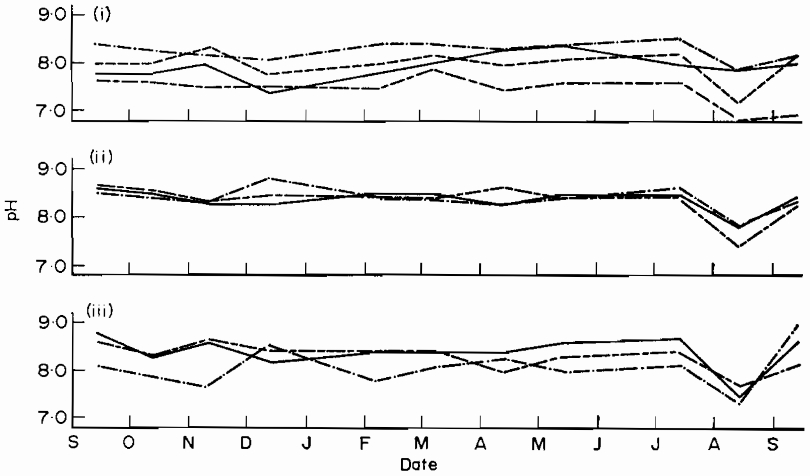

Fig. 3c. Seasonal changes in pH in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i), 5 (ii) and 8 (iii); — — —, Stations 2 (i), 6 (ii) and 9 (iii); – · – · –, Stations 3 (i), 7 (ii) and 10 (iii); - - -, Station 4 (i).

Stations 1 and 5 due to the larger stands of aquatic plants in that area. The values at Station 1 are influenced additionally by the reservoir.

Two other major nutrients for plant growth, in addition to carbon dioxide, are nitrates and phosphates (Fig. 3). Nitrate values were highest during the winter, became reduced during the period of spring runoff, and declined progressively during

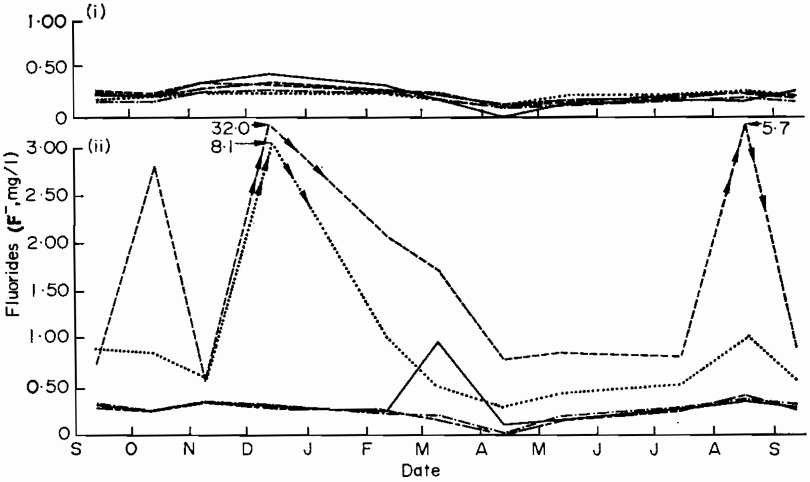

Fig. 3d. Seasonal changes in fluoride in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i) and 6 (ii); — — —, Stations 2 (i) and 7 (ii); – · – · —, Stations 3 (i) and 8 (ii); – – –, Stations 4 (i) and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

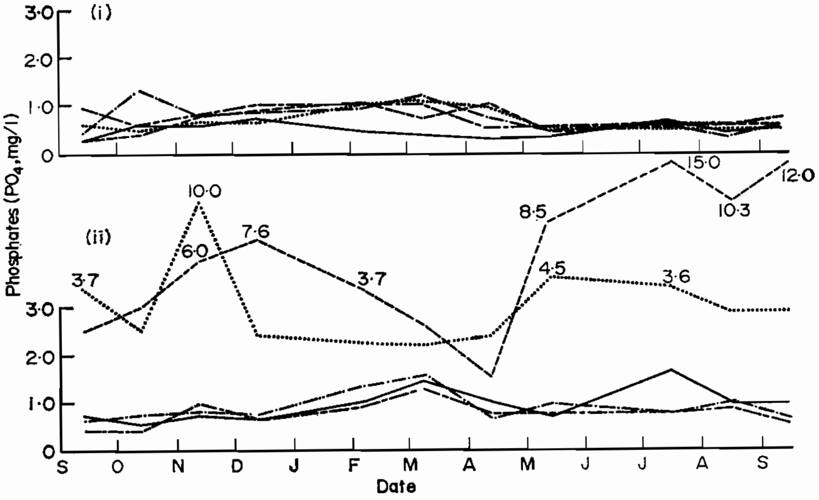

Fig. 3e. Seasonal changes in total phosphate-P in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i) and 6 (ii); — — —, Stations 2 (i) and 7 (ii); – · – · —, Stations 3 (i) and 8 (ii); – – –, Stations 4 (i) and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

the summer. There was a general downstream increase in mean nitrate concentrations. The single exception was Station 2, which had the highest mean value for the upper section of the stream. Several stations showed concentrations approaching 0, especially during the latter half of the growing season (Fig. 3). Station 6 showed the least variation; the remainder all exhibited a range in excess of 1 mg/l. Except for Stations 9 and 10, phosphate concentrations showed less seasonal variation than did nitrate and remained consistently low. However, a seasonal trend still was evident, especially at Station 2 through 5, where it generally increased gradually from September through March and declined during the growing season. At Stations 9 and 10 it appears that during the period of high spring runoff the river water, with its relatively lower concentration of phosphate, was able to dilute the more concentrated incoming wastewaters. However, during the remainder of the year the normal discharge of the river was not so effective and much higher values were attained.

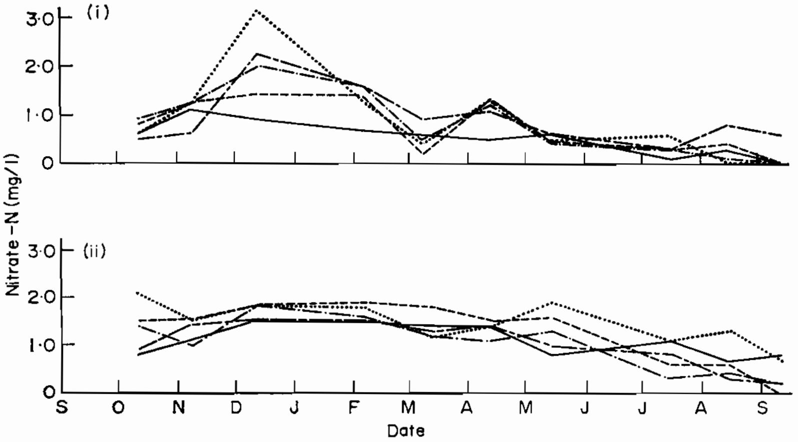

Fig. 3f. Seasonal changes in nitrate-N in the Portneuf River from 28 September 1968 through 25 September 1969. No water samples were analysed in January or June. ———, Stations 1 (i) and 6 (ii); — — —, Stations 2 (i) and 7 (ii); – · – · –, Stations 3 (i) and 8 (ii); – – –, Stations 4 (i) and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

The longitudinal pattern of mean phosphate values was remarkably similar to that of nitrate as far downstream as Station 8, at which point mean values rose abruptly from less than 1 mg/l to over 6 mg/l. The high values at Station 9 were due to wastes from the processing of phosphate ore; those at Station 10 reflect the complicating interaction of an additional phosphate load from a municipal sewage treatment plant plus the influx of a large volume of spring water low in phosphate.

Fluoride showed a similar pattern to that for phosphate. This could be expected since fluoride commonly is associated with phosphate-bearing rocks (as calcium fluorophosphate). The most striking feature of the fluoride values is the lack of any seasonal variation and the similar concentrations at all stations except 9 and 10. A single anomalous value was recorded for Station 6 in March. The concentrations of fluoride at Stations 9 and 10 followed each other more closely than did those of phosphate, possibly because fluoride is less affected by complex biological interactions and also because only a single source is involved, whereas dual sources (phosphate industry and sewage disposal plant) are responsible for the increased phosphate levels.

Seasonal changes in turbidity and discharge

Values of turbidity generally were low and showed a narrow range of variation through Station 5; at Station 6 the mean value doubled over that at Station 5. There was an additional slight increase in turbidity between Stations 8 and 9, followed by a significant decrease between Stations 9 and 10 again due to the influx of spring water. The seasonal pattern of turbidity reflects a similar trend in runoff and stream discharge (Fig. 4) except that the highest turbidity values occurred at the start of the period of heaviest runoff and not, as expected, during the time of peak discharge. The apparent lag in when the peak in turbidity was reached at the stations nearer to the headwaters

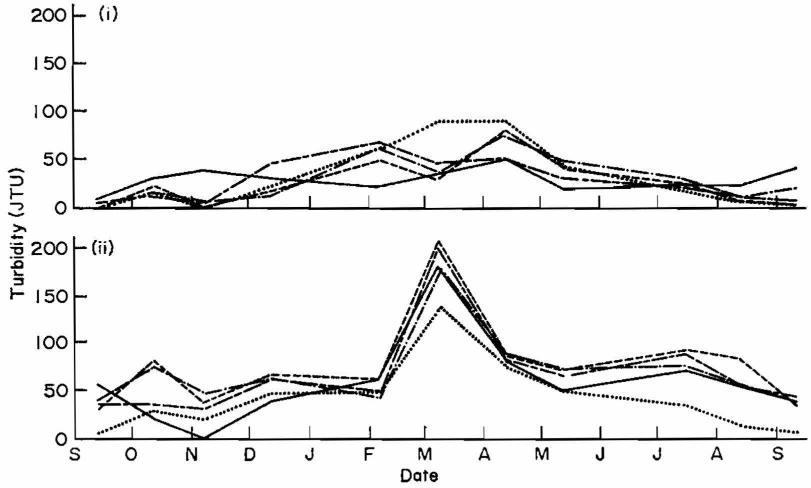

Fig. 4a. Seasonal changes in turbidity in the Portneuf River from 28 September 1968 through 25 September 1969. ———, Stations 1 (i) and 6 (ii); — — —, Stations 2 (i) and 7 (ii); — · — · —, Stations 3 (i) and 8 (ii); - - -, Stations 4 (i) and 9 (ii); . . . ., Stations 5 (i) and 10 (ii).

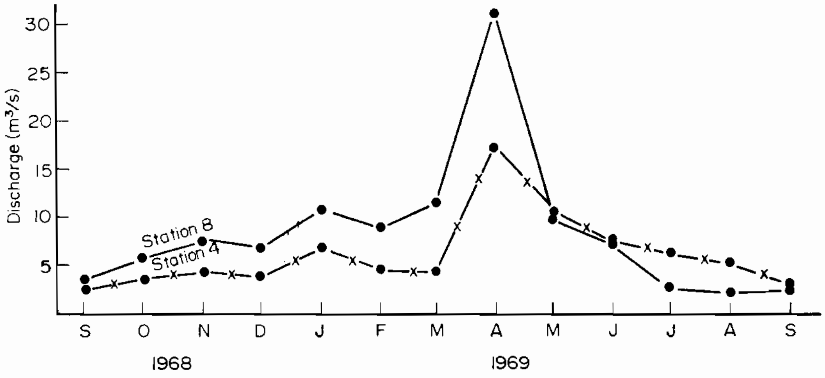

Fig. 4b. Seasonal changes in discharge in the Portneuf River from 28 September 1968 through 25 September 1969.

(1–4) is due to the fact that surface runoff occurred during the day the March samples were collected. The collections at Stations 1 through 4 were made in the morning before runoff from the melting snow started and consequently the increases in turbidity levels were not detected. Relatively high turbidity values occurred during the summer at Stations 6 through 9 as a result of irrigation return flows. The values for Station 10 declined markedly during this same period because the reduction in stream discharge resulted in a progressively greater dilution by non-turbid spring waters which enter between Stations 9 and 10. It also is interesting to note that following the start of irrigation, the volume of flow above the main irrigation diversion (Station 4) exceeded that further downstream at Pocatello (Station 8) (see Plate 1).

Seasonal changes in temperature

The seasonal records of temperature are represented by maximum–minimum recordings for three well separated sections of the stream (roughly upper, middle, and lower reaches) (Fig. 5). It is difficult to relate conditions between stations because of a series of complicating factors which confuse the normal 'expected' pattern. These factors include the inflow from hot springs near Station 3 and warm springs above Station 10, the exposure of sections of the stream to increased solar heating during periods of dewatering due to irrigation withdrawal, and the inflow of heated waters from industrial effluents.

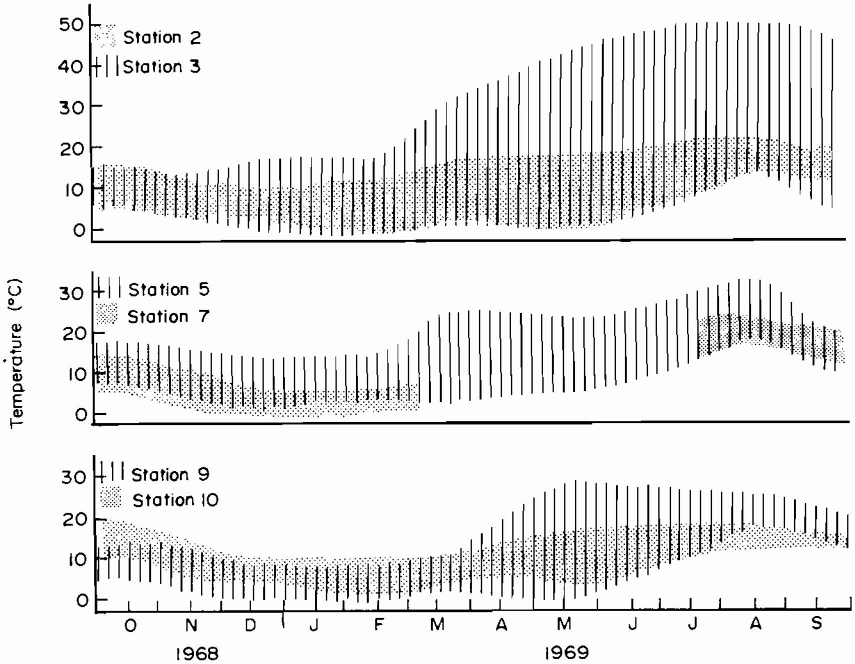

Fig. 5. Seasonal changes in maximum–minimum temperatures in the upper, middle, and lower reaches of the Portneuf River from 28 September 1968 through 25 September 1969.

The most striking feature of the temperature records presented in Fig. 5 is the considerably higher maximum temperatures at Station 3 from December onwards as

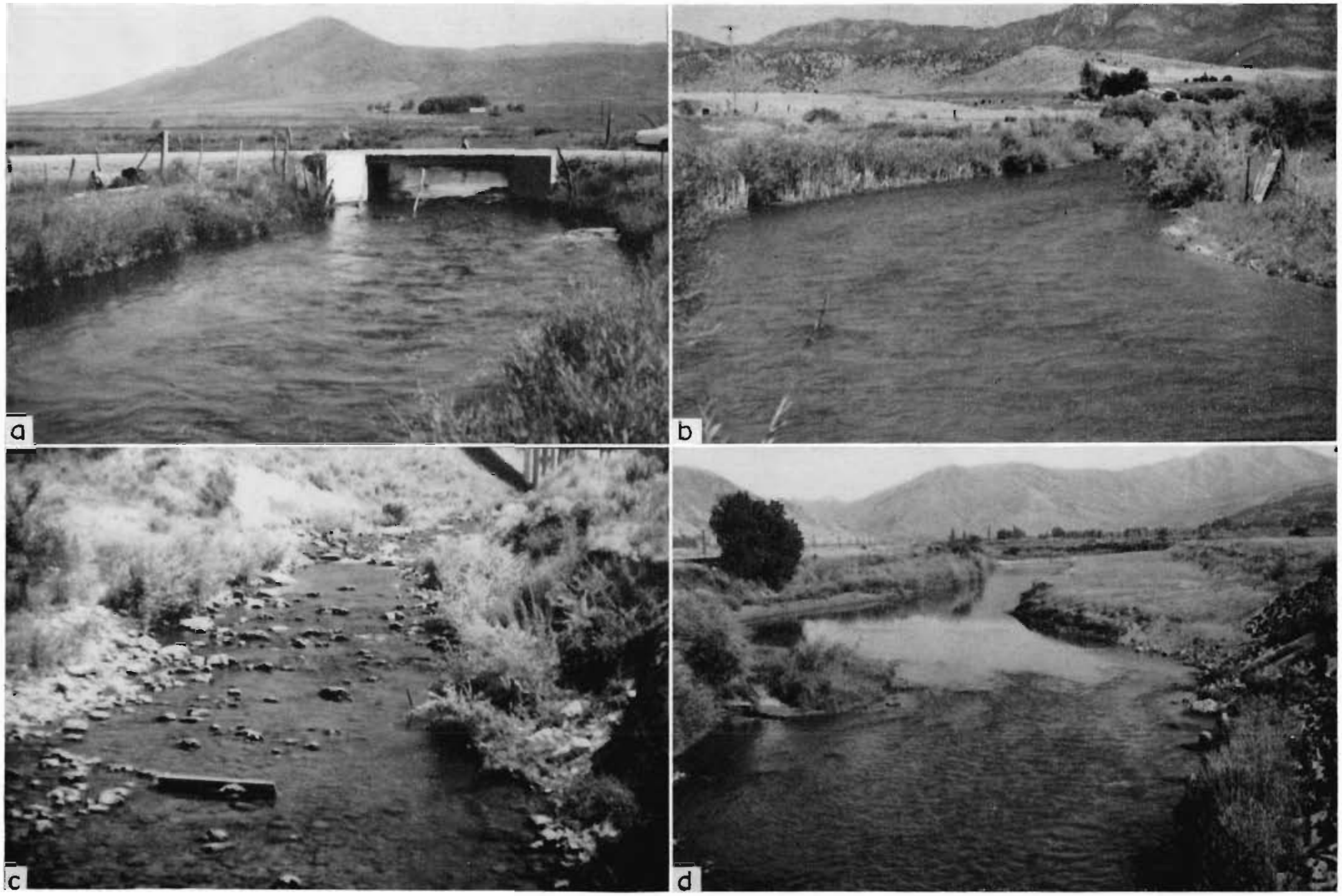

Plate 1. Portneuf River, Idaho during peak of the irrigation season: (a) Station 1 near release point from reservoir; (b) Station 4, typical mid-river section; (c) Station 5 showing water loss due to irrigation withdrawal; (d) Station 7, typical lower river. Station 4 is above the main irrigation diversion; Station 5 is below the diversion but above the main point of return; Station 7 is below the main return point but still is carrying less volume of flow than Station 4. All views taken facing upstream on 28 July 1971.

compared with the other stations. The fact that the minimum values recorded at Station 3 always were as low or lower than those of the other stations further emphasizes the extreme temperature variations experienced by the organisms inhabiting this area. The extremes recorded at Station 3 were all the more evident because abnormal temperatures were never observed during visits to the stream. This indicates that surges of hot water periodically enter the Portneuf much in a manner observed for eruptions of many of the hot springs in Yellowstone National Park (located several hundred kilometers to the north).

Temperatures at all stations were lowest in December, January, and February but continued to reach low values through May. Maximum values began to rise in March and reached their peak in July and August (except at Station 9). Maxima at Station 5 generally were higher than those at Station 2 (and likely also at Station 7), especially during the period April through August. Possibly this is due to the severe exposure of the area due to irrigation withdrawal (Plate 1c). However, this explanation does not account for the unusual high value at Station 5 in March. Stations 7 and 10 exhibited similar narrow temperature ranges, although a more pronounced seasonal pattern was evident at Station 7. The reduced seasonal variation at Station 10 is but another effect of the springs in the area. Temperatures at Station 9 generally were more extreme than those at Station 10. The temperature range at Station 9 was wider than that of either Stations 7 or 10 and was more like that at Station 5. But Station 9 lacked the March high of Station 5 and reached a maximum in May instead of later in the summer. In general the mean maximum temperatures increased from Station 1 to 3 and then gradually declined downstream. Minimum temperatures were similar at all stations, but mean minimum values generally increased downstream.

Comparison of annual water quality conditions

Sufficient data are available to permit comparisons over several years for the months of February (1967, 1969–1971) and September (1967–1969). The February values are representative of a period of cold temperatures, variable discharge (the three largest floods on record all occurred in February), and minimal aquatic plant growths. The September values represent a period of warm temperatures, low discharge, and high aquatic plant standing crops.

The levels of total dissolved solids (Fig. 6) showed relatively large differences between each of the years, but for the most part the general relationships between stations remained the same and were similar to the mean conditions described earlier. February values were lowest in 1971 and highest in 1970, whereas the September values generally were the lowest in 1967 and highest in 1968. However, there were several exceptions to these generalizations; the September levels for Station 1 were highest in 1969 and at Station 9 the situation was the reverse of the general one. At Station 2 in September 1967 the normal high was considerably suppressed.

Somewhat surprisingly the years of highs and lows for alkalinity (Fig. 6) did not correspond with those for total dissolved solids. With the exception of Stations 1 and 2, the lowest values in both February and September were recorded in 1967. For February the high occurred in 1969, whereas the September values for 1968 and 1969 were quite similar. The carbonate concentrations in September generally were lower than in February of the same year and below Station 5 showed less variation between years. As with total dissolved solids, the overall relationships between the stations were quite similar even though the magnitudes involved in each of the years differed.

Between-year comparisons of phosphate concentrations (Fig. 6) are somewhat complicated by the fact that in 1967 and 1971 only ortho-phosphate was determined, while in 1968, 1969, and 1970 total-phosphate was measured. February total-phosphorus values for 1969 and 1970 considerably exceeded the ortho-phosphate values measured in 1967 and 1971 in most cases except at Stations 9 and 10. This indicates that the

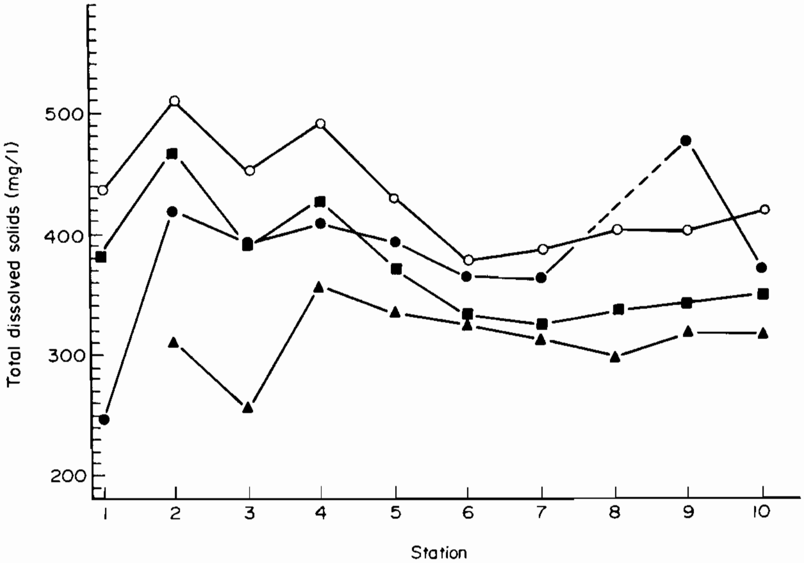

Fig. 6a. Total dissolved solids in the Portneuf River in February over several years. ●——●, 1967; ■——■, 1969; ○——○, 1970; ▲——▲, 1971.

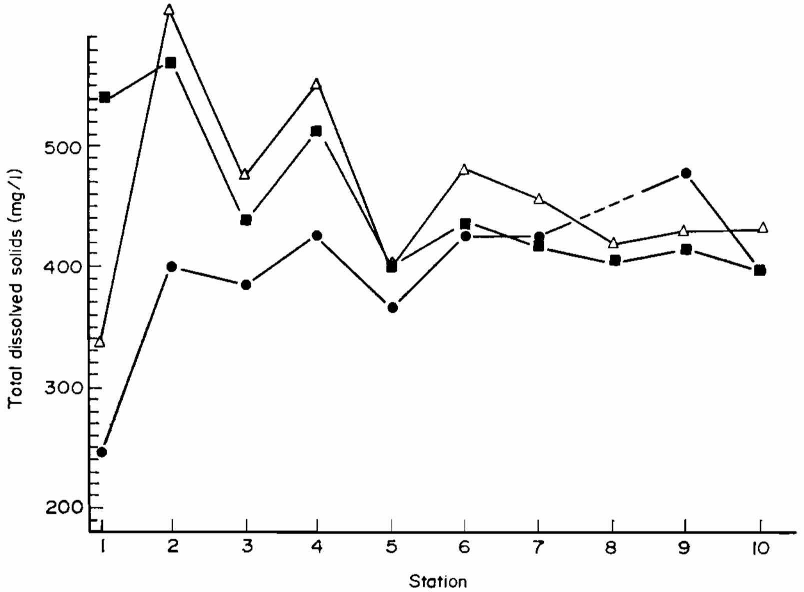

Fig. 6b. Total dissolved solids in the Portneuf River in September over several years. ●——●, 1967; △——△, 1968; ■——■, 1969.

biologically available ortho form makes up a relatively small proportion of the total phosphate load until Stations 9 and 10 are reached and the situation becomes reversed.

Total-phosphate values for February were highest in 1970 at all stations except Station 2. Ortho-phosphate values were reasonably similar, during the two years in which they were measured, only in the middle reaches of the stream (Stations 3–6).

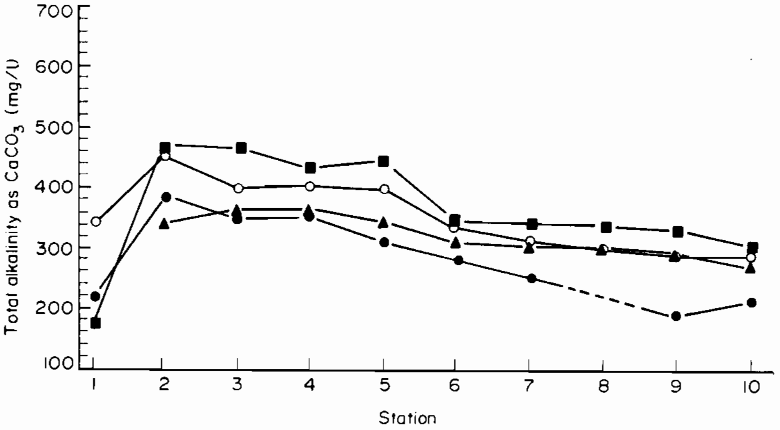

Fig. 6c. Total alkalinity in the Portneuf River in February over several years. ●——●, 1967; ■——■, 1969; ○——○, 1970; ▲——▲, 1971.

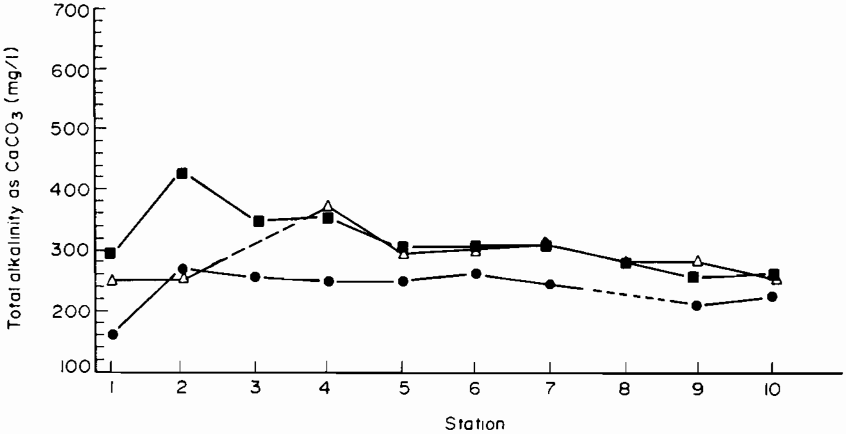

Fig. 6d. Total alkalinity in the Portneuf River in September over several years ●——●, 1967; △——△, 1968; ■——■, 1969.

The high ortho-phosphate concentration at Station 2 in February 1971, which exceeds even the total-phosphate values of previous years, is the only important exception to the general longitudinal pattern described under the comparison of each station. The September values for Stations 1 through 8 showed much closer relationships between years (even when total and ortho levels are compared) than did the February levels. This may reflect the lack of transport by surface runoff, greater reduction to ortho-phosphate, and greater utilization by plants at this time.

In February 1969 the levels of turbidity (Table 2) were similar at all stations (except

Station 1) but in 1971 and especially in 1970 there was a noticeable increase in the lower reaches, possibly due to increased surface runoff (Table 3). The September values were markedly lower than the February levels in the upper reaches, but again there was a sharp increase in concentrations beginning at Station 6. The increase in levels during a period of little precipitation and runoff is due to a combination of sediment-bearing irrigation return flows and year 'round leaching from the streambed of Marsh Creek. Station 1 was a notable exception to the general trends and is but

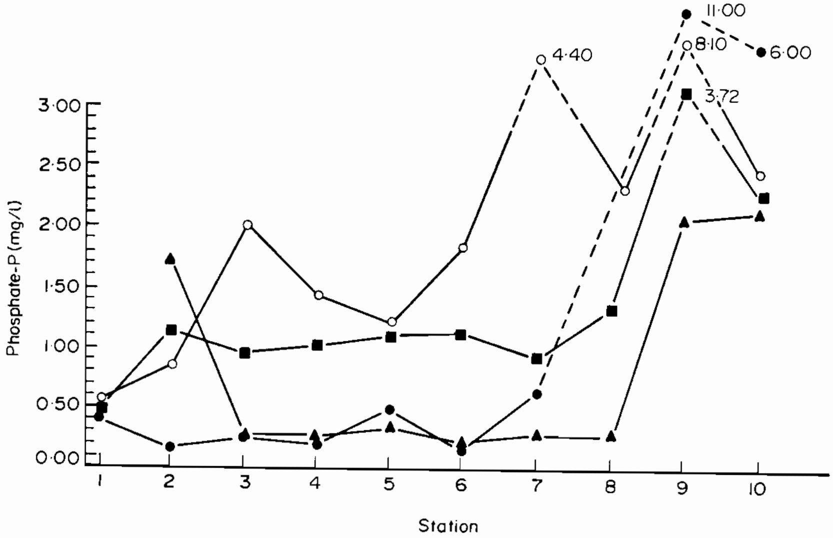

Fig. 6e. Phosphate-P concentrations in the Portneuf River in February over several years. ●——●, 1967 ortho; ■——■, 1969, total; ○——○, 1970, total; ▲——▲, 1971, ortho.

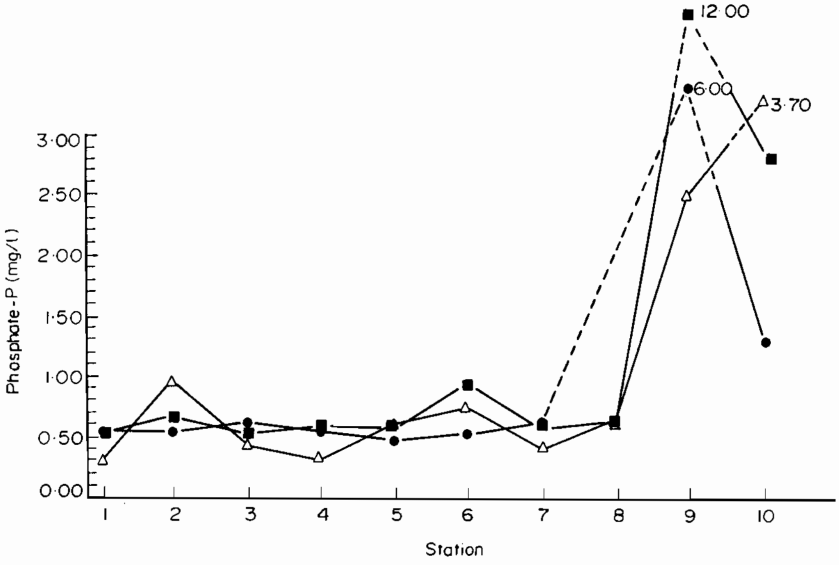

Fig. 6f. Phosphate-P concentrations in the Portneuf River in September over several years. ●——●, 1967 ortho; △——△, 1968 total; ■——■, 1969 total. Station 8—no data in 1967.

Table 2. Some water quality conditions in the Portneuf River over several years for the months of February and September

		Station									
		1	2	3	4	5	6	7	8	9	10
February											
Turbidity (J.T.U.)	1969	22	68	61	49	61	64	49	44	61	49
	1970	20	26	61	49	109	120	137	168	172	153
	1971	—	61	47	56	44	77	86	81	80	61
pH	1967	7·9	7·7	8·3	8·2	8·4	8·3	8·9	—	7·1	7·7
	1969	7·8	7·5	8·4	8·0	8·5	8·4	8·4	8·4	8·4	7·8
	1970	7·4	7·2	8·1	8·2	8·4	8·0	8·3	8·2	8·6	8·0
	1971	—	7·7	8·8	8·5	9·0	8·7	8·8	8·9	8·7	8·4
Nitrate (as N)	1969	0·7	1·6	1·6	1·4	1·3	1·5	1·5	1·6	1·9	1·8
	1970	1·1	1·5	1·3	1·1	1·3	1·8	1·1	3·1	3·6	2·6
	1971	—	1·4	1·6	1·3	1·5	1·4	1·5	1·5	2·1	2·0
Fluoride	1969	0·33	0·27	0·26	0·27	0·27	0·26	0·25	0·23	2·05	1·00
	1970	0·29	0·21	0·19	0·21	0·19	0·19	0·19	0·18	2·64	0·75
September											
Turbidity (J.T.U.)	1968	8	4	—	0	0	56	36	39	30	8
	1969	42	8	20	4	8	39	42	39	36	8
pH	1967[a]	7·3	7·3	8·3	7·9	8·2	8·2	8·4	—	8·4	7·6
	1968	7·8	7·7	8·4	8·0	8·6	8·6	8·5	8·8	8·5	8·1
	1969	8·0	6·9	8·1	8·1	8·4	8·2	8·3	8·6	8·1	8·9
Nitrate (as N)	1967	0·5	0·3	0·7	0·5	0·2	1·2	0·4	0	3·8	2·0
	1969	0	0·6	0	0	0	0·8	0·2	0·2	0	0·7
Fluoride	1968	0·40	0·37	0·30	0·35	0·34	0·44	0·42	0·44	0·87	1·02
	1969	0·29	0·21	0·18	0·22	0·21	0·27	0·27	0·30	0·91	0·57

[a] Hellige Comparator.

Table 3. Discharge (m^3/s) in February and September of selected years at two locations on the Portneuf River measured on the day of water sample collections. Values in parentheses are monthly means

	February		September	
	Station 4	Station 8	Station 4	Station 8
1967	3·34 (3·45)	6·85 (7·19)	4·67 (3·79)	2·24 (2·26)
1968	—	—	3·57 (3·42)	2·57 (3·31)
1969	4·36 (4·58)	8·80 (9·20)	3·08 (4·39)	2·86 (2·46)
1970	4·95 (4·64)	10·25 (9·34)	—	—
1971	5·24 (5·24)	9·40 (10·13)	—	—

another reflection of the influence of present reservoir management practices. Station 1 registered low values in February, when most of the upstream flow was being held back by the reservoir, and a high value in September 1969 (when levels at nearby stations were low) possibly due to the release of plankton-rich water from the reservoir.

In the upper reaches of the stream the discharge was remarkably similar both when comparing February and September of the same year and between one year and the next (Table 3). In sharp contrast, the values in the lower reaches were much more variable. Discharge at Station 8 was consistently several times higher in February than in September; September values were quite similar between years and always less than those at Station 4. Discharge in February at Station 8 was lowest in 1967 and highest in 1970.

In view of the wide variation in chemical concentrations between years (Fig. 6, Table 2), it would appear worthwhile to continue studies of this sort over a number of years in order to define more clearly the range of variations to be expected in any given locality and to attempt to discover the reasons for such variations. Discharge alone does not appear to offer a suitable explanation, even in relatively undisturbed sections of the stream. Large annual variations in chemical concentrations were recorded in the upper reaches in both February and September in spite of the fact that discharge levels remained fairly constant (Table 3). In the present study, the only discharge values showing substantial variation between years were the February values at Station 8, where the low occurred in 1967 and the high in 1970. The high discharge value in February 1970 corresponded to highs (at most stations) in total dissolved solids, total phosphate, and turbidity. However, except for alkalinity, none of the chemical parameters measured registered lows in 1967. Some of the differences between seasons, and also between years, are a reflection of differences in biological activity; but this also needs to be examined more critically. For example, the much lower nitrate concentrations in September than in February most likely are due to uptake by the aquatic vegetation. In fact, of the three major nutrients, nitrate appears to be the limiting factor for growth in most of the Portneuf River at that time of the year (especially in 1969).

Monitoring of chemical parameters

In view of the expense and difficulty of conducting chemical analyses throughout the year, it seems worthwhile to examine the data from an entire year (Fig. 3) in an effort to determine when samples could best be collected to yield the most information for the time expended. It appears that in order to define the range of variation of chemical parameters under normal conditions, at least two collections a year would be necessary, except for pH and fluoride, in which case one sample a year would suffice. February and August appear to be particularly suitable months for the measurement of chemical (and temperature) conditions; in some cases it may be desirable to obtain an additional collection during spring runoff. In the latter case, exact timing is critical as there is a good chance of obtaining an 'atypical' sample. Of the factors considered in this study only alkalinity did not register extreme values in August. The other factors exhibited low values during that month; the exception, of course, was temperature, which reached maximum levels in August. A February sample would be somewhat less satisfactory as an indicator of extreme conditions, but it would provide estimates of the upper end of the seasonal range for alkalinity and nitrate and of the lower end of the range for total dissolved solids and temperature. Measurements early in the period of substantial spring runoff and ground thaw would be necessary to obtain estimates of maximum values for phosphates and turbidity; samples near the peak of stream discharge would be needed to show maximum values for total dissolved solids and minimum values for alkalinity.

The wide and generally unpredictable variations brought about by the addition of urban and industrial wastes would obviously require a more rigorous sampling schedule. But, as in the case of the Portneuf River, the number of stations and parameters studied generally can be reduced substantially with the savings in effort applied to more intensive study of seasonal and diel variations. For example, in future studies of the Portneuf it would be necessary to follow only phosphorus intensively and at only two stations. Under such circumstances it would be feasible to more thoroughly examine other interesting and inadequately documented parameters (e.g., ammonia and pH) and to conduct the analyses much more frequently.

Distribution of benthic invertebrates

The numbers of invertebrates taken in the quantitative collections are given in Table 4 and Figs. 7 and 8. Mean numbers (obtained by dividing the total numbers taken at each station by the number of collections) were used because samples were missing for some stations on some dates. The data in Table 4 have been organized into three groups to emphasize the extent of the distribution of each taxon. Nineteen species (out of fifty taxa) were restricted to the upper reaches of the stream (Table 4a). Of these, the first five listed were numerically important only at Station 1, and the next four generally were absent from Station 1 and predominant at Station 2. The remainder displayed a more scattered distribution and reduced abundance.

Organisms showing a widespread distribution and found at seven stations or more are listed in descending order in Table 4b according to the number of stations at which they occurred. Only Stations 1 and 9b had fewer than ten representatives of this group of fourteen taxa. Chironomidae was the only taxon to be found at all stations; but *Hydropsyche* sp. occurred at all except one and *Ephemerella inermis*, *Simulium* sp., Tubificidae, and *Baetis tricaudatus* occurred at all but two stations. In spite of their widespread occurrence, many of the species in this group showed distinct patterns of distribution which fell into one of three broad categories. These are illustrated for selected species in Fig. 7. The most common pattern was that in which the greatest abundance of a species occurred in the middle section of the river, notably at Station 5

Table 4. Mean number of individuals collected by artificial substratum samplers from the Portneuf River, Idaho

	Station										
	1	2	3	4	5	6	7	8	9a	9b	10
(a) Distribution restricted to upper reaches											
Callibaetis nigritus (Ephemeroptera)	69	.	.	.	.	.	.	.	.	.	.
Oreodytes sp. (Coleoptera)	40	.	.	.	.	.	.	.	.	.	.
Hesperocorixa sp. (Hemiptera)	36	+	.	.	.	.	.	.	.	.	.
Alloperla sp. (Plecoptera)	1	.	.	.	.	.	.	.	.	.	.
Arcynopteryx signata (Plecoptera)	1	.	.	.	.	.	.	.	.	.	.
Paraleptophlebia heteronea (Ephemeroptera)	.	5	.	.	.	< 1	.	.	.	.	.
Lepidostoma sp. (Trichoptera)	+	149	.	< 1	.	+	.	.	.	.	.
Helicopsyche borealis (Trichoptera)	.	104	.	9	.	.	.	.	.	.	.
Isoperla fulva (Plecoptera)	.	11	2	2	< 1	2	.	.	.	.	.
Isoperla mormona (Plecoptera)	.	.	.	2	.	.	.	.	.	.	.
Leptocella sp. (Trichoptera)	.	+	.	3	.	.	.	.	.	.	.
Athripsodes sp. (Trichoptera)	.	+	+	1	.	.	.	.	.	.	.
Helobdella sp. (Annelida)	.	.	+	< 1	.	.	.	.	.	.	.
Acroneuria pacifica (Plecoptera)	.	+	< 1	.	< 1	.	.	.	.	.	.
Epeorus longimanus (Ephemeroptera)	.	.	.	.	< 1	+	.	.	.	.	.
Haliplus sp. (Coleoptera)	.	.	.	.	< 1	.	.	.	.	.	.
Pteronarcys californica (Plecoptera)	.	.	.	.	< 1	< 1	.	.	.	.	.
Ephemerella grandis (Ephemeroptera)	.	< 1	.	.	.	7	.	.	.	.	.
Arctopsyche grandis (Trichoptera)	.	.	.	.	.	< 1	.	.	.	.	.
(b) Present at most stations											
Chironomidae (Diptera)	301	8	5	11	20	5	9	2	1	6	7
Hydropsyche sp. (Trichoptera)	.	8	44	26	380	135	38	39	4	2	< 1
Ephemerella inermis (Ephemeroptera)	10	35	< 1	11	12	11	6	1	.	.	6
Simulium sp. (Diptera)	5	10	3299	169	2056	180	995	9	< 1	.	.
Tubificidae (Annelida)	+	.	5	31	4	1	3	6	49	21	111

	Station										
	1	2	3	4	5	6	7	8	9a	9b	10
Baetis tricaudatus (Ephemeroptera)	.	6	49	8	50	13	<1	1	.	1	1
Physa ampullacea (Gastropoda)	23	5	<1	+	2	.	1	3	<1	.	387
Tricorythodes minutus (Ephemeroptera)	4	14	.	22	7	7	<1	<1	+	.	3
Cheumatopsyche sp. (Trichoptera)	.	2	9	1	76	5	2	1	<1	.	.
Enallagma sp. (Odonata)	10	1	.	<1	+	.	.	.	<1	<1	<1
Acari (Aracnida)	2	5	+	+	.	+	.	.	<1	+	.
Tipula sp. (Diptera)	+	<1	.	.	1	+	+	.	.	<1	<1
Amnicola sp. (Gastropoda)	.	1	.	79	63	3	+	+	.	.	1
Optioservus quadrimaculatus (Coleoptera)	.	1	2	5	2	2	<1	.	+	.	.
(c) Widely distributed but present at five or fewer stations											
Hyalella azteca (Amphipoda)	71	2	.	.	.	<1	.	.	1	.	65
Lymnaea palustris (Gastropoda)	1	.	.	.	+	.	.	<1	<1	.	12
Gyraulus vermicularis (Gastropoda)	5	<1	.	.	<1	<1	.	.	.	.	<1
Gammarus lacustris (Amphipoda)	+	.	.	<1	.	.	.	.	4	<1	19
Erpobdella sp. (Annelida)	2	.	.	.	.	.	.	.	.	+	7
Atherix variegata (Diptera)	5	.	6	.	.	21	<1	.	.	.	.
Nematoda	.	<1	<1	+	14	.	.	.	.	.	<1
Limnephilus sp. (Trichoptera)	.	+	.	.	<1	7	.	.	.	.	<1
Brachycentrus sp. (Trichoptera)	.	4	.	3	<1	1	+	.	.	.	.
Pisidium sp. (Pelecypoda)	.	+	+	<1	2	.	.	.	<1	.	.
Dugesia dorotocephala (Turbellaria)	.	.	8	88	1	.	5	.	.	.	.
Cataclysta sp. (Lepidoptera)	.	.	.	<1	1	.	<1	.	.	.	.
Cinygmula sp. (Ephemeroptera)	.	.	.	+	.	.	<1	.	.	.	.
Dubiraphia sp. (Coleoptera)	.	.	.	.	<1	.	<1	.	.	.	.
Ophiogomphus sp. (Odonata)	.	.	.	.	.	<1	+	+	<1	.	.
Arcynopteryx parallela (Plecoptera)	.	.	.	.	.	<1	.	.	+	.	.
Argia sp. (Odonata)	.	.	.	1	.	.	.	1	7	<1	.

+ Indicates occurrence only in a qualitative collection.

but ranging from Station 3 through 5. In a few instances greatest abundance occurred near the headwaters (e.g., *Ephemerella inermis*) and in others there was a preponderance of individuals in the lowest reaches (e.g., Tubificidae and *Physa ampullacea*).

Members of the third group also were widespread in distribution but were more sporadic in occurrence (Table 4c). Several members of this group (*Hyalella azteca, Lymnaea palustris, Gyraulus vermicularis, Gammarus lacustris*, and *Erpobdella* sp.) are noteworthy because of their occurrence at both Stations 1 and 10. The remainder are arranged in order of a progressive downstream shift in their distribution. Most of the latter were restricted in their distribution to that portion of the stream lying above Station 7; a notable exception was *Ophiogomphus* sp., which was the only species to have greatest abundance at Station 9.

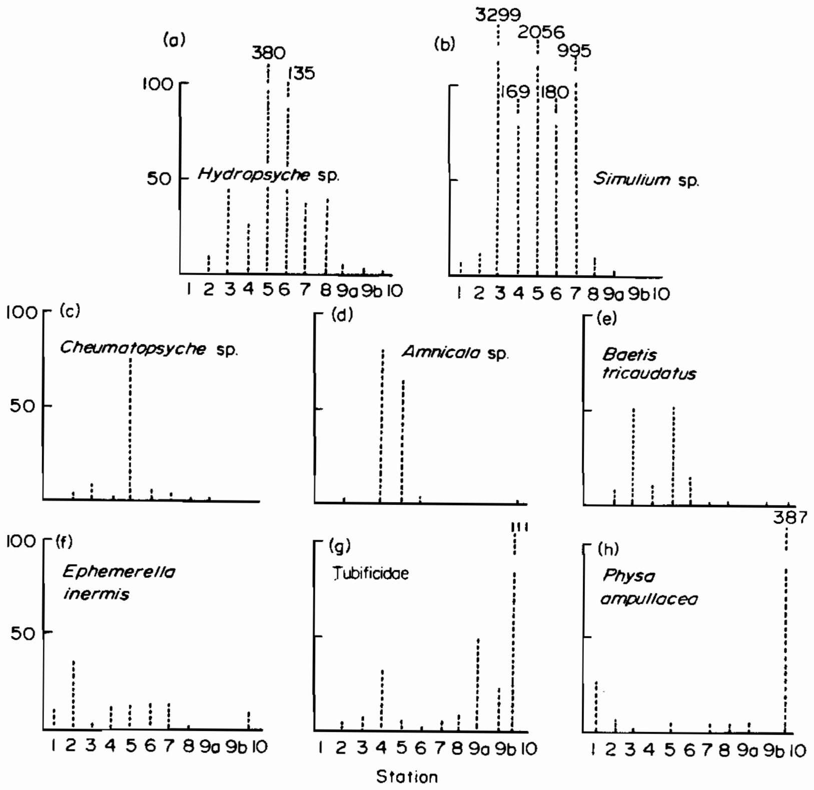

Fig. 7. Mean numbers of invertebrates at each station in the Portneuf River, selected to illustrate three distinct patterns of distribution: (a–e) most abundant in the middle reaches, (f) most abundant in the upper reaches, (g–h) most abundant in the lower reaches.

Simulium sp. was the single most abundant group of organisms collected and made up the bulk of the numbers at Stations 3, 5, and 7 (Fig. 8). The large numbers of *Simulium* at these stations is in keeping with the known environmental requirements of *Simulium*, which need solid substrata for attachment and relatively rapid current velocities to fulfill certain feeding and metabolic requirements. *Hydropsyche* sp. was relatively abundant at Stations 3 through 8 for similar reasons. Apart from *Simulium*

Table 5. Benthic invertebrate fauna of the Portneuf River, Idaho from both net collections (N) and samplers (S)

	Station										
Taxon	1	2	3	4	5	6	7	8	9a	9b	10
Turbellaria											
Dugesia dorotocephala			S	S	S		S				
Nematoda		S	S	S	S						S
Mollusca											
Amnicola sp.		SN		SN	SN	SN	N	N			SN
Gyraulus vermicularis	S	S			S	SN					S
Lymnaea palustris	S				N			S	S		SN
Physa ampullacea	SN	SN	S	N	SN		SN	SN	SN		SN
Sphaerium sulcatum	N			N							
Pisidium sp.		N	N	S	S				S		
Oligochaeta											
Tubificidae	N		S	SN	SN	SN	SN	SN	SN	SN	SN
Hirudinea											
Erpobdella sp.	S									N	S
Helobdella sp.			N	SN							
Acari	S	SN	N	N		N			SN	N	
Amphipoda											
Gammarus lacustris	N			S					SN	SN	SN
Hyalella azteca	SN	SN				SN			S		SN
Ephemeroptera											
Baetis tricaudatus		S	SN	S	SN	SN	SN	SN		S	SN
Caenis simulans	N										
Callibaetis nigritus	S										
Cinygmula sp.				N			S				
Epeorus longimanus					SN	N					
Ephemerella doddsi						N					
E. grandis		S				S					
E. inermis	S	SN	SN	SN	SN	SN	S	SN			S
Ephoron album						N	N	N	N		
Heptagenia sp.						N	N		N	N	
Paraleptophlebia heteronea		S				S					
Tricorythodes minutus	SN	SN		S	S	SN	SN	SN	N		SN
Odonata											
Argia sp.				SN				S	S	S	
Enallagma sp.	S	SN		S	N				S	S	S
Ophiogomphus sp.						SN	N	N	S		
Plecoptera											
Acroneuria pacifica		N	S		S						
Alloperla sp.	SN										
Arcynopteryx parallela						S			N		
A. signata	S										
Isoperla fulva		S	S	S	S	S					
I. mormona				SN		N					
Pteronarcys californica					S	S					
Hemiptera											
Hesperocorixa sp.	S	N									

Taxon	Station 1	2	3	4	5	6	7	8	9a	9b	10
Coleoptera											
Dubiraphia sp.					S		S				
Haliplus sp. (adult & larva)		N			SN	N					
Laccophilus sp.	N										
Optioservus quadrimaculatus (adult & larva)		SN	SN	SN	SN	SN	SN		N		
Oreodytes sp.	SN										
Trichoptera											
Arctopsyche grandis						S					
Athripsodes sp.		N	N	SN							
Brachycentrus sp.		SN		SN		SN	N				
Cheumatopsyche sp.		SN	S	SN	S	SN	SN	SN	S		
Helicopsyche borealis		SN		SN							
Hydropsyche sp.		SN	SN	SN	SN	SN	SN	SN	SN	SN	S
Lepidostoma sp.	N	S		S		N					
Leptocella sp.		N		S							
Limnephilus sp.		N			S	SN					
Lepidoptera											
Cataclysta sp.				S	SN		S				
Diptera											
Atherix variegata	S		SN			SN	SN				
Chironomidae	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
Heleidae	N										
Simulium sp.	SN	SN	SN	SN	SN	SN	SN	S	S		
Tipula sp.	N	SN			S	N	N			S	S
Insect total (43)	16	22	11	19	18	26	17	10	12	7	7
Grand total (57)	25	29	18	29	26	32	21	14	19	11	16
Total in samplers	17	22	14	25	24	22	15	11	14	8	16
Total in net	15	22	11	18	14	26	16	11	11	7	9

sp. and *Hydropsyche* sp., the most abundant organisms and their respective areas of predominance were *Physa ampullacea* (Station 10), Chironomidae (Station 1), Tubificidae (Stations 9a, 9b, 10), *Lepidostoma* sp. (Station 2), *Amnicola* sp. (Stations 4, 5), *Hyalella azteca* (Stations 1, 10), *Baetis tricaudatus* (Stations 3, 5), and *Helicopsyche borealis* (Station 2). The mean number of individuals in each of these groups totalled over 100. Other important taxa included *Callibaetis nigritus* at Station 1, *Dugesia dorotocephala* at Station 4, and *Atherix variegata* at Station 6.

Representativeness of the artificial substratum samples

Qualitative surveys conducted during the summer and autumn were used to check the effectiveness of the four quantitative collections and to provide a more complete measure of species richness at each of the stations (Table 5). In general, the artificial substratum samplers were more effective than the qualitative net collections in obtaining a representative picture of the composition of the fauna at each station. Only two of the eleven collecting sites had a greater number of taxa in the net collections than in the samplers. However, neither procedure alone gave as much information as the combined results. Generally, between 68 and 92% of all the taxa found at any one station were collected by the samplers alone, whereas between 56 and 81% were taken by the net alone. Only at Station 10 did the samplers yield all of the taxa found.

Considering all stations combined, sixteen taxa commonly were taken by both techniques, sixteen were taken mainly by the sampler (ten were taken only by that means), and ten were taken mainly by the net. Fifteen other taxa which occurred less frequently were collected by both procedures but the results were not considered sufficient to be meaningful. Commonly occurring taxa regularly missed by the net included *Dugesia dorotocephala*, Nematoda, *Gyraulus vermicularis*, *Argia* sp., *Enallagma* sp., and *Isoperla fulva*; those missed entirely or poorly censused by the samplers were *Sphaerium sulcatum*, *Ephoron album*, *Heptagenia* sp., and *Tricorythodes minutus*.

Discussion

As the Portneuf River flows from source to mouth the quality of the water and the nature of the stream bed become altered by both natural factors and, increasingly, by man-induced changes. On the basis of the mean numbers of taxa and individuals of invertebrates collected in artificial substratum samplers (Fig. 8), a substantial difference is evident between conditions in the upper Portneuf River (Station 5 and above) and the lower reaches (Station 6 and below). Between Stations 2 and 4 most of the changes are of natural origin and, except immediately adjacent to thermal springs, a diverse flora and fauna and a viable trout fishery persist. Management of the river between Stations 1 and 2 for irrigation has altered many of the normal chemical and physical features, enhancing the growth of aquatic plants and changing the composition of the invertebrate fauna. The changes in this area, while severe, do not appear to be irreparable; and most of the adverse effects do not extend downstream as far as Station 2.

The distribution of the benthic invertebrate fauna at Station 1 was noteworthy in the fact that the faunal assemblage was marked by a group of species not taken at any other station, plus another group taken mainly at Stations 1 *and* 10. Many of the species involved in both of these groups commonly are associated with slow-moving currents or pond-like habitats. These are conditions one might reasonably expect to find in streams of relatively low gradient, such as near the mouth of a mature river. The unusual feature in the case of the Portneuf is that such faunas were found near the source as well as near the mouth of the river, separated by a stream distance of about 85 km and completely different faunal assemblages. The occurrence of such a fauna at Station 1 appears to be due to the fact that the outflow from the Portneuf Reservoir, plus the gradient, produce conditions comparable to those near the mouth. In addition, the greater species richness found at Station 1 would indicate that conditions below the reservoir presently are more suitable than those found at Station 10.

The significant reduction in both kinds and numbers of animals at Station 3 is another striking feature of the benthic invertebrate distribution in the Portneuf River. Especially noteworthy is the absence of any Amphipoda and Odonata and the reduction in kinds of Mollusca, Ephemeroptera, and Trichoptera (Table 5). To some extent this can be attributed to the surges of hot water in the area (Table 1, Fig. 5). However, this is not the complete answer because several species entirely absent at Station 3 (e.g., *Enallagma* sp. and *Tricorythodes minutus*) show wide distribution in the Portneuf (Table 4b) and elsewhere (Minshall, unpublished data) and could be expected to show a wide range of tolerance to temperature. Certain other widely distributed forms were present at Station 3 and apparently were not adversely affected.

Part of the reduction in fauna at Station 3 apparently is due to elimination of suitable substratum and loss of available food because of the deposition of large amounts of marl. Loss of free carbon dioxide from the water as the result of its dropping over a large waterfall just above the collecting site results in the conversion of the abundant calcium bicarbonate in the water to the insoluble carbonate form and its subsequent loss from solution. In addition this action may have been supplemented by the input of carbonate-charged water from the thermal springs. The result has been the build-up of a large travertine deposit (blocks up to 2 m across are evident along the banks) which is still occurring at a fairly rapid rate; deposits several millimeters thick developed on the recording thermometer during each 1-month interval throughout the study. The marl deposits have eliminated the interstices normally found in the rocky substrata, thus adversely affecting the burrowing (hyporheal) forms and severely reducing the accumulation of detritus particles normally associated with rocky substrata (Rabeni, 1971). In addition, the continuously deposited coating of marl has restricted the development and availability of the algae as well (Stockner, 1968). The

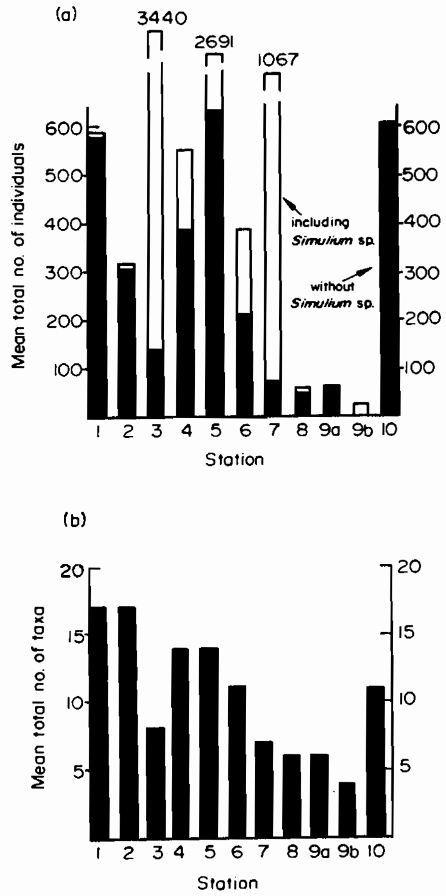

Fig. 8. Comparison of mean total numbers of (a) individuals and (b) taxa collected by quantitative samplers from each sampling station in the Portneuf River during all four seasons (from December 1969 through September 1970).

reduction of detritus and algae serves to decrease the amount of available food and could be expected to bring about a reduction in abundance of many of the species not otherwise adversely affected by the increased temperatures or altered substratum.

Stations 4 and 5 supported similar numbers of taxa and the main difference between the two was in the greater abundance of *Simulium* and *Hydropsyche* at Station 5. This difference can be attributed to the more turbulent flow (current velocities were similar—Table 1) and, presumably, more suspended food at Station 5 than at 4.

The input of sediments from Marsh Creek and the immediately adjacent area of the Portneuf, coupled with a sharp reduction in the gradient of the Portneuf, have produced the most significant alteration in the general condition of the stream from Station 6 through 7. In accordance with the chemical and physical features considered during this study, it would appear that the decline in the benthic fauna at Stations 6 and 7 is due primarily to increased turbidity, sediment, and stream channel alteration, which occurred in the area as direct or indirect results of soil erosion and flooding. The effects of these changes become progressively worse downstream from Station 6. Almost all of the sediment in the Portneuf Basin comes from the dry-farm areas as a result of poor soil conservation practices, and most of it that enters the Portneuf River does so by means of Marsh Creek (Merrell & Onstott, 1965).

Somewhat surprising was the fact that the greatest total number of species of invertebrates (Table 5) was found at Station 6 despite the profound environmental changes that have occurred. Presumably Station 6 was being colonized by animals from Rapid Creek and from the Portneuf above the entrance of Marsh Creek. The greater variety of animals also was enhanced by the somewhat atypical nature of the specific collecting area at Station 6, a relatively shallow gravel bed with fast current (second only to that of Station 3—Table 1). Otherwise, the stream at Station 6 had a more sluggish flow and a mud bottom.

It also is noteworthy that several of the species which showed greatest abundance in the central reaches of the stream (Fig. 7, Table 4) are filter-feeding animals whose food is carried suspended in the water. Thus, the gradual downstream increase in abundance of these species is to be expected, since more organic matter is likely to become available the further the water travels. The fact that these groups do not continue to increase in abundance below Stations 5 (in some cases) and 7 (in others) indicates the imposition of limiting factors whose effects over-ride the increased availability of food.

Immediately below Station 7, the river passes through a biologically and aesthetically sterile 8·5-km rock and concrete faced sluiceway; but it is doubtful that the quality of the water deteriorates any further in this stretch. However, the river below this stretch receives washings from a cement-mixing plant, the effluent and occasional waste spillage from a railroad petroleum-waste treatment plant, and, via Pocatello Creek, mixed urban wastes and the overflow from the settling pond of a meat-packing plant. Our data do not indicate any effect of these wastes on water quality, probably due to the sporadic occurrence of the wastes; but their effects are indicated by a further reduction of faunal abundance and richness. This effect is less pronounced than it might be, however, since most of the less tolerant forms have already been eliminated.

Some of the most evident changes in water quality occurred at Station 9 due to the entrance of wastewaters from phosphate-processing operations. The most dramatic changes shown by our data were in phosphate and fluoride levels, but these alone cannot explain the drastic reduction in invertebrate numbers and kinds within the short (550 m) section separating Stations 9a and 9b. Thus, the influence of other, more toxic waste, is indicated, which on occasion has been known to also kill large numbers of fish (Idaho Fish-Game Dept. records, Osborne Casey, personal communication).

In spite of the fact that an additional large waste load, from the Pocatello sewage treatment plant, enters the river above Station 10, the chemical condition of the water and the quantity and composition of the invertebrate fauna show significant improvement by the time Station 10 is reached. This can be attributed to the entrance of an undetermined but obviously large volume of spring water, which acts to dilute the wastes and speed biological recovery. The few taxa which showed an increase in abundance in the lower reaches of the stream (Fig. 7, Table 5) are known to tolerate low dissolved oxygen concentrations, mud or silt substrata, and other conditions commonly associated with organic pollution. It is significant that even these groups showed a marked reduction in numbers at Station 9b, further indicating the imposition of toxic conditions.

An interesting feature which warrants brief mention is that during the irrigation season there is a decrease in volume of flow in the Portneuf with progression downstream (Plate 1). The full impact of this phenomenon, which is common to many streams in western United States, is presently unknown; but one would expect it to have a fairly important influence on the stream biota, including a reduction of habitat during an important fish production period and an increase in water temperature and decrease in dissolved oxygen content during an already critical time of the year. Because of complications arising from other forms of pollution in the lower Portneuf, it was not possible to examine the effect of decrease in volume downstream in that area. Stream dewatering apparently had no undue effect on the benthic fauna at Station 5, but the artificial substratum samplers do not provide a good measure of the effect of habitat reduction (unless it be an inverse one!) and fish production was not examined.

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