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# THE EFFECT OF POINT-SOURCE DISCHARGES ON THE DIVERSITY OF BENTHIC INVERTEBRATES OF THE YAMPA RIVER, STEAMBOAT SPRINGS TO HAYDEN, COLORADO

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by

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## ABSTRACT

A survey was conducted by the U.S. Environmental Protection Agency during September, 1975 to determine the effect of known point-source discharges on the benthic invertebrates of the Yampa River, Steamboat Springs to Hayden, Colorado, a distance of approximately 61 km (38 mi). Using modified surber samples, three samples were collected at each of 17 sampling locations. Mean diversity ($\bar{d}$) and equitability (e) were computed at each sampling location. Mean diversity and equitability decreased immediately downstream of known point-source discharges. With increasing downstream distance from the discharge, mean diversity and equitability gradually increased.

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# INTRODUCTION

With development of coal mining in northwestern Colorado, many towns located in surrounding areas will be markedly impacted by accelerated growth. The town of Steamboat Springs, Colorado, is projected to increase in resident population from 6,000 to 10,000 in the next ten years with seasonal peaks growing from 13,305 to 19,500 within the same time period (EPA, 1976).

The town of Steamboat Springs, Colorado and associated housing developments and trailer parks on its periphery presently discharge varying quantities and qualities of treated sewage effluent to the Yampa River. A cooperative effort between the Environmental Protection Agency (EPA) Region VIII, and the U.S. Geologic Survey (USGS), Colorado District, was initiated to determine the effect of known point-source discharges on the Yampa River. Personnel from the USGS modeled the waste assimilative capacity of the Yampa River while personnel from the EPA determined the effect of point-source discharges on the benthic communities within the study area. Samples for both benthic and chemical analysis were collected during the latter part of September, 1975.

The following report states the findings of the EPA study. The complete results of the modeling effort by the USGS are described by Bauer, Steele, and Anderson (1976). The data presented from both studies will be useful in formulating growth development plans for Steamboat Springs, Colorado and the surrounding area.

## SUMMARY AND CONCLUSIONS

In September, 1975, as part of a cooperative effort between the U.S. Geologic Survey, Colorado District and the U.S. Environmental Protection Agency, Region VIII, a survey was conducted by EPA to determine the effect of known point-source discharges on the benthic invertebrates in the Yampa River, Steamboat Springs to Hayden, Colorado.

Three Surber samples were collected at each of 17 stations on the mainstem Yampa River from upstream of Steamboat Springs to downstream from Hayden, Colorado. Mean diversity ($\bar{d}$) and equitability (e) were computed for each sample at each station. The respective values for each parameter were then averaged for each station.

Although extremely low mean diversities were not observed (i.e. $<1.00$), the diversity of benthic invertebrates in the study area, on the basis of the data presented here, is markedly affected by known point-source discharges. Mean diversity and equitability at stations immediately downstream of known point-source discharges were usually significantly lower than the diversity of the control station. With increasing downstream distance from the area of major point-source discharges, the diversity gradually increased. The lowest mean diversity (2.097) was observed immediately downstream from the Steamboat Springs Sewage Treatment Plant (STP), the KOA Campgrounds, and the Sleepy Bear Trailer Park.

Seasonal sampling would be required to determine the extent of changes in the benthic diversity during different times of the year.

# RESULTS OF STUDY

## I. Study Area

The Yampa River lies in the northwestern portion of Colorado, with the headwaters located upstream of Stillwater Reservoir. A tributary of the Green River, the Yampa River flows through Routt and Moffat Counties passing the towns of Yampa, Phippsburg, Oak Creek, Steamboat Springs, Milner, Hayden, Craig, Maybell, and Sunbeam. The confluence of the two rivers is located in Echo Park, Dinosaur National Monument, Colorado.

Approximately 61 km (38 mi) of the Yampa River were included in the study area with benthic samples collected at 17 mainstem stations, from approximately 6.4 km (4 mi) upstream from Steamboat Springs to approximately 0.8 km (2 mi) downstream from Hayden, Colorado (Figure 1). Mainstem sampling stations, tributary inflows, and known point-source discharges are listed in their respective downstream order in Table 1.

The river bed within the study area was consistently composed of small to medium sized rubble throughout the study area. The top layer of substrate was composed of rocks averaging 15 to 25 cm (5.9 to 9.6 in) in diameter with the spaces between the larger rubble filled with smaller stones and coarse gravel.

## II. Methods and Materials

Samples of benthic invertebrates were collected at each of the 17 mainstem sampling sites using both artificial substrates and Surber samplers. Artificial substrates were placed on August 19-21, 1975. All samples were collected during the period, September 22-26, 1975.

All Surber samples were taken with modified Surber samplers. The samplers were modified by replacing the standard mesh bag with a 1.2 m (4 ft) long bag constructed of 207 micrometer mesh Nitex net. A large piece of naugahyde was sewn to the bottom of the bag to prevent abrasion by the substrate. The longer length of the bag effectively reduced any backwash incurred due to the smaller mesh size.

At the time of sampling, the substrate enclosed within the square foot bottom of the Surber frame was removed from the stream and placed in a large bucket partially filled with water. Each rock was then cleaned using a soft bristle brush and the bag of the Surber sampler inverted and cleaned in the bucket. The contents of the bucket were then poured into a #60 mesh (250 micrometers) sieve. The collected samples were then placed into pint jars, preserved with 80% ETOH, and returned to the laboratory for sorting and identification.

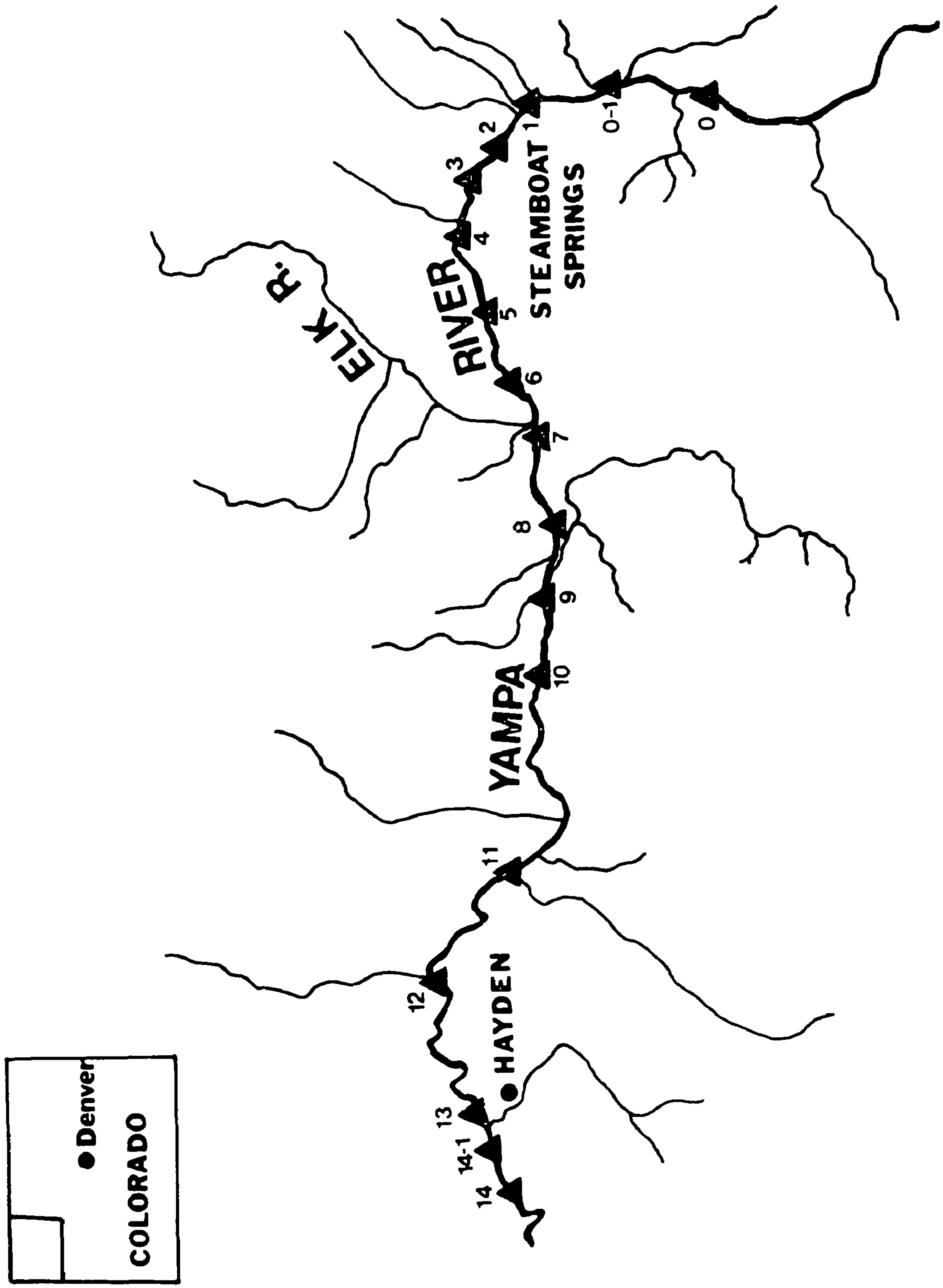


Figure 1. Sampling station locations on the Yampa River, Steamboat Springs to Hayden, Colorado.
(Adapted from Steele, Bauer, Wentz, and Warner, 1976.)

TABLE 1

STATION DESIGNATIONS AND DESCRIPTIONS FOR YAMPA RIVER STUDY
STEAMBOAT SPRINGS TO HAYDEN, COLORADO[1]

| Station Designation[2] | | T/R-S[3] | Station Description (Intervening Tributaries and Point-Discharges) |
|---|---|---|---|
| YM-0 | 402544<br>106493600 | 6/84-32 | Yampa River downstream from Oak Creek near Steamboat Springs- 6.4 km (4 mi) south of the city of Steamboat Springs. |
| YT-1 | 402508<br>106493800 | | Agate Creek |
| YT-2 | 402700<br>106485400 | | Walton Creek |
| YM-0-1 | | | Yampa River upstream from Mt. Werner Sewage Disposal Ponds. |
| YE-1 | | | Mt. Werner Sewage Disposal Ponds |
| YT-3 | 402759<br>106493100 | | Fish Creek |
| YT-4 | 402857<br>106494000 | | Spring Creek |
| YM-1 | 09239500<br>402901<br>106495400 | 6/84-17 | Yampa River at Steamboat Springs- bridge at southeast end of town, at gaging station. |
| YT-5 | 402944<br>106495900 | | Butcherknife Creek (Pole Bear Ranch) |
| YT-6 | 402920<br>106505400 | | Soda Creek (Whitman School) |
| YM-2 | 402934<br>106505400 | 6/84-7 | Yampa River upstream from Steamboat Springs STP, downstream from Steamboat Springs- bridge south of cemetery just downstream from camp. |
| YE-3 | | | Steamboat Springs Sewage Treatment Plant |

Table 1 - continued

| Station Designation | | T/R-S | Station Description (Intervening Tributaries and Point-Discharges) |
|---|---|---|---|
| YM-3 | 402958<br>106515200 | 6/85-1 | Yampa River downstream from treatment plant downstream from Steamboat Springs-access downstream from treatment facility. |
| YE-4 | | | KOA Campground package plant |
| YT-7 | 403022<br>106524000 | | Slate Creek |
| YE-5 | | | Sleepy Bear Park package plant |
| YM-4 | 403017<br>106525800 | 6/85-2 | Yampa River downstream from camp-grounds near Steamboat Springs (cross-section, access just downstream from YE-5). |
| YE-6 | | | Steamboat II treatment plant |
| YM-5 | 403002<br>106545500 | 6/85-3 | Yampa River downstream from Steamboat II near Steamboat Springs (cross-section downstream from treatment plant, upstream from gravel pit). |
| YM-6 | 402932<br>106568900 | 6/85-8 | Yampa River upstream from Elk River confluence near Milner (WQ Recon. Y-63) (bridge crossing, approx 1.6 km (1 mi) upstream from Elk River). |
| YT-8 | 402913<br>106580400 | | Elk River |
| YT-9 | 402903<br>106584100 | | W. Fork Elk River |
| YM-7 | 402902<br>106580000 | 6/85-18 | Yampa River downstream from Elk River confluence near Milner (cross-section, access from Elk River just upstream). |

Table 1 - continued

| Station Designation | T/R-S | Station Description (Intervening Tributaries and Point-Discharges) |
|---|---|---|
| YM-8 402840 107004200 | 6/86-15 | Yampa River at Milner (Colo. Health Dept. Station 000038) (Bridge, upstream from Trout Creek). |
| YT-10 402816 107003800 | | Trout Creek |
| YT-11 402908 107014000 | | Cheney Creek |
| YM-9 402854 107020500 | 6/86-16 | Yampa River downstream from Trout Creek confluence near Milner (WQ Recon Y-50) (bridge southwest of Milner). |
| YT-12 402908 107025100 | | Tow Creek |
| YM-10 402902 107043600 | 6/86-18 | Yampa River at Tow Creek Oil Field (foot bridge 2.4 km (1½ mi) downstream from Tow Creek). |
| YT-13 402832 107080200 | | Wolf Creek |
| YT-14 402856 107085800 | | Grassy Creek |
| YM-11 09244410 402918 107093300 | 6/87-9 | Yampa River downstream from Diversion near Hayden (WQ Recon Y-47) (U.S. 40 Hwy bridge, approx. .2 km (0.1 mi) upstream from Sage Creek). |
| YT-15 402918 107094400 | | Sage Creek (Hayden Power Plant) (WQ Recon. Y-46). |
| YT-16 403123 107115500 | | Morgan Creek |

Table 1 - continued

| Station Designation | | T/R-S | Station Description (Intervening Tributaries and Point-Discharges) |
|---|---|---|---|
| YM-12 | 403051 107124500 | 7/88-36 | Yampa River downstream from Morgan Creek confluence near Hayden (cross-section, access by farm road on north side of river). |
| YM-13 | 403006 107154800 | 6/88-4 | Yampa River at Hayden (WQ Recon Y-45) (bridge, north of town, 1.6 km (1 mi) upstream from Dry Creek). |
| YT-17 | 402952 107161600 | | Dry Creek (Hayden treatment plant). |
| YM-14-1 | | | Yampa River downstream from Dry Creek. |
| YM-14 | 402930 107174200 | 6/88-8 | Yampa River downstream from Hayden (WQ Recon Y-44) (U.S. 40 Hwy bridge west of Hayden). |

[1] Adapted from Steele, Bauer, Wentz, and Warner, (1976), Table 3.

[2] YM- Sampling stations on the Yampa River
YT- Tributary of the Yampa River
YE- Point-source discharge to Yampa River

Numbers adjacent to Station Designation indicate USGS station numbers, either 15 digit latitude-longitude number and/or 8 digit downstream order number

[3] T/R-S Township, range, and section

Prior to collection of each sample, the water velocity was determined with a Marsh-McBurnay, electro-magnetic, direct readout current meter. An attempt was made to collect all Surber samples at similar velocities to reduce any variability in benthic community composition due to water velocity. All Surber samples were taken in riffle areas.

Three Surber samples were collected at each sampling station. The contents of each sample were individually processed and the results from each sample reported separately.

Cylindrical barbeque baskets 16.5 cm (6.5 in) in diameter and 25.4 cm (10 in) in length filled with rocks taken from the river were used as artificial substrates. A large piece of plastic sheeting was attached to each basket. The plastic would be used to enclose the baskets during removal to restrict water flow through the baskets and prevent loss of invertebrates. All rocks placed in a basket were first scrubbed with a brush to remove any attached invertebrates. After a basket was filled a hole slightly larger than the artificial substrate was excavated in the stream bottom. Using a facemask and snorkel to allow good visual inspection, the basket was then placed in the excavated hole. When the basket was placed in the excavated hole, the attached plastic was rolled to the sides of the basket and secured with rocks.

Following placement of the artificial substrate in the excavated hole, the rocks were rearranged around the basket so that the top layer of rocks within the basket were at the same level as the river bed.

All substrates were placed in riffle areas with predetermined water velocities. Two artificial substrates were placed at each sampling station.

After approximately 5½ weeks exposure, the artificial substrates were removed. During removal, rocks surrounding the baskets were carefully moved to allow enclosure of the baskets with the attached plastic sheet. The baskets were then lifted into a Surber net and removed from the river. The rocks were removed from the basket and placed in a bucket partially filled with water and cleaned with a small brush. The contents of the bucket were then poured into a #60 mesh sieve and the retained material placed in pint jars, preserved with 80% ETOH, and returned to the laboratory for examination.

All samples were sorted following procedures outlined by EPA Biological Field and Laboratory Methods (1973). All organisms were identified to the lowest taxonomic level possible using available taxonomic texts (Pennak, 1953; Usinger, 1968; Johannsen, 1969; EPA, 1973; Ross, 1944; Hilsenhoff, 1975; Needham, Traver and Hsu, 1935; Gaufin, et. al, 1972). The extremely small size of many of the invertebrates collected, due to the time of year of sampling, precluded identification to the species level.

Chemical data were collected by the USGS for use in the waste assimilative capacity model. The chemical data collected for sampling stations on the mainstem of the Yampa River are shown in Appendix 1. A complete listing of all chemical parameters collected by the USGS is given by Bauer, Steele, and Anderson (1976).

Periphyton biomass determinations, both dry weight and ash weight, were determined by the USGS.

Mean diversity of collected benthic invertebrates was computed using the machine formula of the Shannon-Weaver function (Lloyd, Zar, and Karr, 1968) as outlined in the Biological and Laboratory Methods Manual (1973). The formula used for computation of mean diversity is as follows:

$$\bar{d} = \frac{C}{N} \left(N \log_{10} N - \sum_{i}^{s} n_i \log_{10} n_i\right)$$

where; $\bar{d}$ = mean diversity
$C$ = 3.321928 (converts base 10 log to base 2)
$N$ = total number of individuals
$n_i$ = total number of individuals in the $i^{th}$ species
$s$ = total number of taxa

Equitability of collected benthic invertebrates was computed following the methods proposed by Lloyd and Ghelardi (1964) as outlined in the Environmental Protection Agency, Biological and Laboratory Methods Manual (1973). The formula used for computation of equitability is as follows:

$$e = \frac{s'}{s}$$

where; $s$ = the number of taxa in the sample
$s'$ = the number of expected taxa, a tabulated value from Lloyd and Gherlardi (1964)

## RESULTS AND DISCUSSION

Water velocities measured at the point where each Surber sample was collected averaged 45.1 cm/sec (1.48 ft/sec) and ranged from 24.4 to 73.2 cm/sec (0.8 to 2.3 ft/sec). The reported values are within the range reported by Stanford and Reed (1974) for effective use of a Surber sampler.

The total number of organisms, kinds of organisms, and the number of genera found in each sample at every station in both Surber samples and artificial substrates are shown in Appendix A and B, respectively. Only data obtained from the Surber samples will be discussed as a large number (approx. 30%) of the artificial substrates were not recovered. The data obtained from the remaining substrates, however, are included for use in comparison with the Surber sample data.

Figure 2 shows the average total number of organisms and the average number of genera collected at each of the sampling stations. *Hydrophysche* sp. and *Chuematophysche* sp. were the predominate caddisflies (Tricoptera) collected at all stations while the major stonefly (Plecoptera) was *Alloperlla* sp.. *Ephemerella* sp. and *Orthocladius* sp. were consistently the most abundant mayfly (Ephemoptera) and midge (Chironominea), respectively, collected in the study area. The total number of organisms and the number of genera collected in each sample and the standard deviation of samples collected at each station are listed in Appendix C. No relationship between either number of genera and point-source discharge or total number of organisms and point-source discharges was observed.

The diversity of the benthic communities sampled, on the basis of the Surber samples collected, were found to be closely related to the known point-source discharges. Mean diversity decreased immediately downstream from point-source discharges throughout the entire study area. With increasing downstream distance from a point-source discharge, the mean diversity gradually increased until introduction of another effluent. Figure 3 shows the change in mean diversity and equitability in relation to known point-source discharges and tributary inflows to the Yampa River. The values plotted are the average values of the three Surber samples collected at each station (Table 2, Appendix 4).

As can be seen from Figure 3 and Table 2, the mean diversity at the control station YM-0 was 3.42. After introduction of effluent from the Mt. Werner Sewage Disposal Ponds (YE-1) diversity declined to 2.68 at Station YM-1. The mean diversity at Station YM-2 rose slightly to 2.99. However, following introduction of effluent from the Steamboat Springs STP, the mean diversity again declined. With additional effluents from the KOA Campground package plant (YE-4), Sleepy Bear Park package plant (YE-5),

Figure 2. Mean total number of organisms per square meter and mean number of genera collected at each sampling location on the Yampa River, Steamboat Springs to Hayden, Colorado.

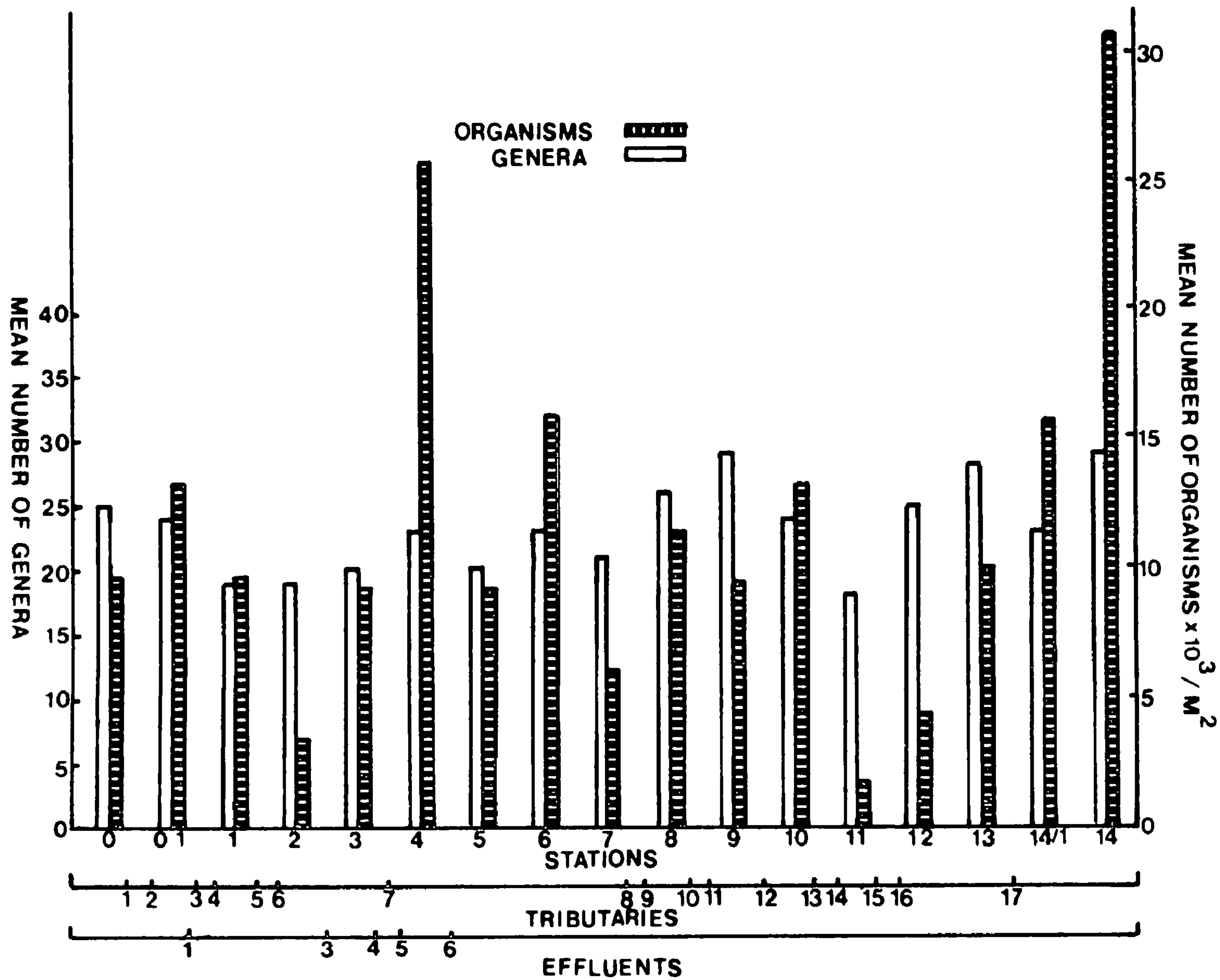

TABLE 2

MEAN DIVERSITY ($\overline{d}$) AND EQUITABILITY (e) OF
BENTHIC INVERTEBRATES COLLECTED AT EACH SAMPLING STATION

| Station | Mean Diversity[1] ($\overline{d}$) | Equitability[1] (e) |
|---|---|---|
| 0 | 3.38 | 0.62 |
| 0-1 | 3.16 | 0.54 |
| 1 | 2.66 | 0.46 |
| 2 | 2.92 | 0.58 |
| 3 | 2.60 | 0.43 |
| 4 | 2.49 | 0.34 |
| 5 | 2.09 | 0.30 |
| 6 | 2.50 | 0.35 |
| 7 | 2.88 | 0.49 |
| 8 | 2.67 | 0.36 |
| 9 | 2.96 | 0.38 |
| 10 | 3.01 | 0.48 |
| 11 | 3.19 | 0.74 |
| 12 | 3.13 | 0.49 |
| 13 | .62 | 0.65 |
| 14-1 | 2.27 | 0.29 |
| 14 | 2.69 | 0.33 |

[1]Values shown are averages of three samples collected at each station.

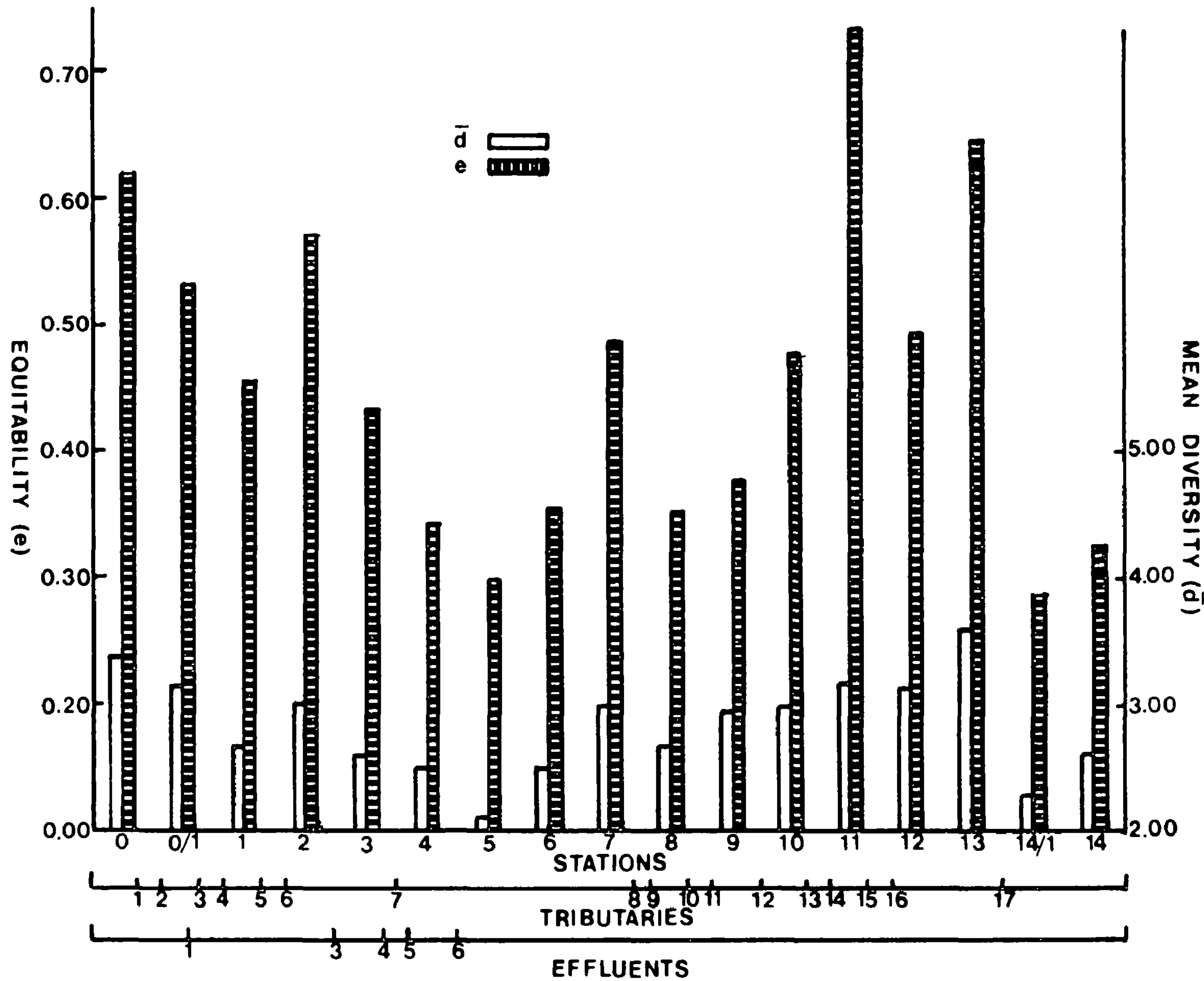


Figure 3. Equitability (e) and mean diversity ($\bar{d}$) of benthic invertebrates collected at each sampling station on the Yampa River, Steamboat Springs to Hayden, Colorado (Values shown are averages of three samples collected at each station).

and Steamboat II treatment plant (YE-6), the mean diversity continued to decrease with Station YM-5 having the lowest mean diversity recorded during the study (2.09). From Station YM-5 to Station YM-13, the mean diversity gradually increased to a high of 3.61 at Station YM-13. Dry Creek, which contains the effluent from the town of Hayden STP, entered the Yampa River between Stations YM-13 and YM-14-1. A subsequent decrease in mean diversity from 3.61 at YM-13 to 2.28 at YM-14-1 was observed. Mean diversity then increased from 2.28 at YM-14-1 to 2.61 at Station YM-14. The mean diversity at YM-13 is higher than the control Station YM-0. The exact reason for this phenomenon is not known.

As shown in Figure 3, the computed equitabilities followed a trend similar to the mean diversity. Equitabilities were found to decrease immediately downstream from known point-source discharges. With increasing downstream distance from the effluent, equitability would gradually rise until introduction of another point-source discharge.

The extremely high equitability reported at Station YM-11 is felt due to a non-representative sample. Station YM-11 was dissimilar from the other stations sampled in that no shallow riffle area could be located for sampling. Collection of the Surber samples in deeper water than was desired resulted in the lowest total number of organisms and the least number of taxa collected at any station.

Various researchers have attempted to correlate mean diversity and equitability with the state of degradation of the receiving body of water. Wilhm (1970) reported that mean diversity generally ranged between 3 and 4 in unpolluted water, whereas mean diversity in polluted waters was generally less than 1. EPA Biological Field and Laboratory Methods (1973) reported that equitability in streams unaffected by oxygen demanding wastes generally ranged between 0.6 and 0.8. Even slight levels of pollution were reported to reduce equitability below 0.5 and often to levels from 0.0 to 0.3. Values for mean diversity ($\bar{d}$) and equitability (e) reported here for stations upstream and downstream from known point-source discharges (Table 2) agree, in general, with the range of respective values reported by both EPA Biological Field and Methods Manual (1973) and Wilhm (1970) for waters affected and unaffected by organic pollutions. Although large decreases in diversity were not noted during the study, the correlation established between known point-source discharges and changes in benthic diversity at sampling sites along the mainstem of the Yampa River is felt to be significant.

Using a two sample t-test, the average mean diversity of the control Station (YM-0) was compared with the average mean diversity of each of the downstream sampling stations. Table 3 shows the results of each of the t-test comparisons. Stations YM-1, 3, 4, 5, 6, 8, 14-1, and 14 were found to be statistically lower than the control Station (YM-0) at the 0.05 level, while Stations YM-5, 6, and 14-1 were found to be statistically lower than the control Station at the 0.025 level. Station 5 was the only station whose average mean diversity was statistically lower than the control Station at the 0.005 level of significance.

TABLE 3

TWO SAMPLE ONE-TAILED T-TEST COMPARISON OF THE MEAN DIVERSITY OF CONTROL STATION WITH THE MEAN DIVERSITY OF EACH DOWNSTREAM STATION

| Hypothesis Tested | Degrees of Freedom df | Calculated t-value | Conclusion |
|---|---|---|---|
| $H_o$: $\mu_o = \mu_{c-1}$<br>$H_a$: $\mu_o > \mu_{o-1}$ | 4 | 0.805 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_1$<br>$H_a$: $\mu_o > \mu_1$ | 4 | 2.640 | Reject at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_2$<br>$H_a$: $\mu_o > \mu_2$ | 4 | 1.677 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_3$<br>$H_a$: $\mu_o > \mu_3$ | 4 | 2.753 | Reject at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_4$<br>$H_a$: $\mu_o > \mu_4$ | 4 | 2.584 | Reject at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_5$<br>$H_a$: $\mu_o > \mu_5$ | 4 | 5.155 | Reject at<br>$\alpha = 0.05$<br>$\alpha = 0.025$<br>$\alpha = 0.005$ |
| $H_o$: $\mu_o =$ 6<br>$H_a$: $\mu_o >$ 6 | 4 | 3.412 | Reject at<br>$\alpha = 0.05$<br>$\alpha = 0.025$ |
| $H_o$: $\mu_o =$ 7<br>$H_a$: $\mu_o >$ 7 | 4 | 1.858 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o =$ 8<br>$H_a$: $\mu_o >$ 8 | 4 | 2.884 | Reject at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o =$ 9<br>$H_a$: $\mu_o >$ 9 | 4 | 1.344 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o =$ 10<br>$H_a$: $\mu_o >$ 10 | 4 | 1.149 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o =$ 11<br>$H_a$: $\mu_o >$ 11 | 2 | 0.779 | Accept at<br>$\alpha = 0.05$ |

Table 3 - continued

| Hypothesis Tested | Degrees of Freedom df | Calculated t-value | Conclusion |
|---|---|---|---|
| $H_o$: $\mu_o = \mu_{12}$<br>$H_a$: $\mu_o > \mu_{12}$ | 4 | 0.913 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_{13}$<br>$H_a$: $\mu_o > \mu_{13}$ | 4 | 0.965 | Accept at<br>$\alpha = 0.05$ |
| $H_o$: $\mu_o = \mu_{14-1}$<br>$H_a$: $\mu_o > \mu_{14-1}$ | 4 | 3.789 | Reject at<br>$\alpha = 0.05$<br>$\alpha = 0.025$ |
| $H_o$: $\mu_o = \mu_{14}$<br>$H_a$: $\mu_o > \mu_{14}$ | 4 | 2.554 | Reject at<br>$\alpha = 0.05$ |

It is recognized that the benthic samples were not collected during an optimal time of the year. Many of the invertebrates collected were early instars, making identification difficult and tedious. The selection of the sampling dates, however, was a result of coordination efforts with the USGS waste assimilative capacity study of the Yampa River during low flow conditions (Bauer, Steele, and Anderson, 1976).

The diversities reported here may fluctuate, both in absolute and relative terms, during the year. High flows and subsequent greater dilution of domestic waste effluents in the Yampa River may result in higher diversities than reported here. Also, different species of benthic invertebrates may be collected during sampling periods conducted during different times of the year. Many of the genera of Plecoptera reported by Oblad (1969) were not observed during this study. Conversely, diversity values reported here may be higher than expected during periods of extreme low flow and associated increases in concentration of domestic waste effluent immediately downstream from point-source discharges. Further sampling is necessary to establish seasonal trends and reach profile trends in diversity.

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# APPENDIX A

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# APPENDIX B

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APPENDIX C

TABLE C-1

Mean Total Number of Organisms and Standard Deviation Computed From Three Surber Samples Collected at Every Station on the Yampa River, Steamboat Springs to Hayden, Colorado

| Station | Number of Organisms/$m^2$ Sample 1 | 2 | 3 | Mean[1] $\bar{X}$ | Standard Deviation[1] s |
|---|---|---|---|---|---|
| 0 | 10652 | 8866 | 9393 | 9637 | 918 |
| 0-1 | 17819 | 7467 | 14418 | 13235 | 5276 |
| 1 | 15086 | 4562 | 9706 | 9784 | 5262 |
| 2 | 3250 | 3389 | 4013 | 3551 | 407 |
| 3 | 17844 | 3874 | 5886 | 9218 | 7581 |
| 4 | 34636 | 22843 | 19981 | 25820 | 7768 |
| 5 | 9329 | 8586 | 9824 | 9246 | 623 |
| 6 | 19196 | 20089 | 8231 | 15839 | 6603 |
| 7 | 5391 | 8156 | 4896 | 6148 | 1757 |
| 8 | 16344 | 7102 | 10878 | 11441 | 343 |
| 9 | 10394 | 8877 | 9415 | 9562 | 769 |
| 10 | 12944 | 22445 | 4638 | 13342 | 8911 |
| 11 | 2443 | 1119 | 1571 | 1711 | 673 |
| 12 | 2787 | 4842 | 5681 | 4437 | 1489 |
| 13 | 12127 | 4412 | 13988 | 10175 | 5078 |
| 14-1 | 26082 | 11384 | 9770 | 15745 | 8988 |
| 14 | 25049 | 33367 | 33743 | 30727 | 4914 |

[1]Mean of standard deviation rounded to nearest whole number.

TABLE C-2

Mean Number of Genera and Standard Deviation Computed From Three Surber Samples Collected at Every Station on the Yampa River, Steamboat Springs to Hayden, Colorado

| Station | Number of Genera/ Sample | | | Mean | Standard Deviation |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | $\bar{x}$ | s |
| 0 | 25 | 25 | 25 | 25.00 | 0 |
| 0-1 | 26 | 20 | 25 | 23.67 | 3.215 |
| 1 | 23 | 16 | 19 | 19.33 | 3.512 |
| 2 | 20 | 16 | 20 | 18.67 | 2.309 |
| 3 | 28 | 15 | 18 | 20.33 | 6.807 |
| 4 | 26 | 23 | 21 | 23.33 | 2.517 |
| 5 | 20 | 23 | 16 | 19.67 | 3.512 |
| 6 | 21 | 29 | 19 | 23.00 | 5.292 |
| 7 | 21 | 25 | 18 | 21.33 | 3.512 |
| 8 | 30 | 28 | 19 | 25.67 | 5.859 |
| 9 | 29 | 32 | 27 | 29.33 | 2.517 |
| 10 | 28 | 26 | 18 | 24.00 | 5.292 |
| 11 | 20 | 17 | 16 | 17.67 | 2.082 |
| 12 | 21 | 28 | 27 | 25.33 | 3.786 |
| 13 | 32 | 24 | 29 | 28.33 | 4.041 |
| 14-1 | 27 | 21 | 21 | 23.00 | 3.464 |
| 14 | 30 | 28 | 28 | 28.67 | 1.155 |

# APPENDIX D

## TABLE D-1

Mean Equitability and Standard Deviation Computed From Three Surber Samples Collected at Every Station on the Yampa River, Steamboat Springs to Hayden, Colorado

| Station | Equitability /Sample | | | Mean | Standard Deviation |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | $\bar{e}$ | s |
| 0 | 0.737 | 0.689 | 0.418 | 0.614 | 0.173 |
| 0-1 | 0.444 | 0.566 | 0.620 | 0.542 | 0.091 |
| 1 | 0.360 | 0.481 | 0.552 | 0.464 | 0.097 |
| 2 | 0.569 | 0.750 | 0.432 | 0.584 | 0.159 |
| 3 | 0.362 | 0.554 | 0.383 | 0.433 | 0.105 |
| 4 | 0.425 | 0.290 | 0.291 | 0.335 | 0.078 |
| 5 | 0.271 | 0.234 | 0.386 | 0.297 | 0.079 |
| 6 | 0.420 | 0.241 | 0.391 | 0.351 | 0.096 |
| 7 | 0.535 | 0.450 | 0.482 | 0.489 | 0.043 |
| 8 | 0.307 | 0.289 | 0.475 | 0.357 | 0.103 |
| 9 | 0.309 | 0.450 | 0.380 | 0.380 | 0.071 |
| 10 | 0. 80 | 0.505 | 0.458 | 0.481 | 0.024 |
| 11 | 0.653 | 0.754 | 0.818 | 0.742 | 0.082 |
| 12 | 0.490 | 0.500 | 0.491 | 0.494 | 0.006 |
| 13 | 0.547 | 0.710 | 0.683 | 0.647 | 0.087 |
| 14-1 | 0.206 | 0.279 | 0.391 | 0.292 | 0.093 |
| 14 | 0.310 | 0.274 | 0.407 | 0.330 | 0.069 |

TABLE D-2

Average Mean Diversity and Standard Deviation Computed From Three Surber Samples Collected at Every Station on the Yampa River, Steamboat Springs to Hayden, Colorado

| Station | Mean Diversity ($\bar{d}$) /Sample | | | Ave. Mean Diversity | Standard Deviation |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | d | s |
| 0 | 3.672 | 3.578 | 2.900 | 3.383 | 0.421 |
| 0-1 | 3.035 | 3.006 | 3.434 | 3.158 | 0.239 |
| 1 | 2.592 | 2.493 | 2.904 | 2.663 | 0.215 |
| 2 | 3.014 | 3.087 | 2.645 | 2.915 | 0.237 |
| 3 | 2.859 | 2.594 | 2.349 | 2.598 | 0.251 |
| 4 | 2.977 | 2.306 | 2.191 | 2.491 | 0.425 |
| 5 | 2.036 | 2.028 | 2.212 | 2.092 | 0.104 |
| 6 | 2.674 | 2.371 | 2.447 | 2.497 | 0.158 |
| 7 | 2.997 | 3.000 | 2.653 | 2.883 | 0.199 |
| 8 | 2.731 | 2.561 | 2.705 | 2.666 | 0.092 |
| 9 | 2.697 | 3.334 | 2.875 | 2.969 | 0.329 |
| 10 | 3.241 | 3.209 | 2.584 | 3.011 | 0.370 |
| 11 | 3.201 | 3.176 | 3.204 | 3.194 | 0.015 |
| 12 | 2.879 | 3.296 | 3.222 | 3.132 | 0.222 |
| 13 | 3.600 | 3.564 | 3.700 | 3.621 | 0.071 |
| 14-1 | 2.065 | 2.135 | 2.597 | 2.265 | 0.288 |
| 14 | 2.701 | 2.489 | 2.893 | 2.694 | 0.207 |

# TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1 REPORT NO<br>EPA-908/2-76-001 | 2 | 3 RECIPIENT'S ACCESSION NO |
| 4 TITLE AND SUBTITLE<br>The Effect Of Point-Source Discharges on the Diversity of Benthic Invertebrates of the Yampa River, Steamboat Springs to Hayden, Colorado, September-1975. | | 5 REPORT DATE<br>October, 1975<br>6 PERFORMING ORGANIZATION CODE |
| 7 AUTHOR(S) | | 8 PERFORMING ORGANIZATION REPORT NO<br>S&A/TIB-30 |
| 9 PERFORMING ORGANIZATION NAME AND ADDRESS<br>Technical Investigations Branch<br>Surveillance & Analysis Division<br>U.S. Environmental Protection Agency, Region VIII<br>Denver, Colorado 80203 | | 10 PROGRAM ELEMENT NO<br>11 CONTRACT/GRANT NO |
| 12 SPONSORING AGENCY NAME AND ADDRESS | | 13 TYPE OF REPORT AND PERIOD COVERED<br>September, 1975<br>14 SPONSORING AGENCY CODE |

15 SUPPLEMENTARY NOTES

16 ABSTRACT


A survey was conducted by the U.S. Environmental Protection Agency during September, 1975 to determine the effect of known point-source discharges on the benthic invertebrates of the Yampa River, Steamboat Springs to Hayden, Colorado, a distance of approximately 61 km (38 mi). Using modified surber samples, three samples were collected at each of 17 sampling locations. Mean diversity ($\bar{d}$) and equitability (e) were computed at each sampling location. Mean diversity and equitability decreased immediately downstream of known point-source discharges. With increasing downstream distance from the discharge, mean diversity and equitability gradually increased.


17 KEY WORDS AND DOCUMENT ANALYSIS

| a DESCRIPTORS | b IDENTIFIERS/OPEN ENDED TERMS | c COSATI Field/Group |
|---|---|---|
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|---|---|---|
| 18 DISTRIBUTION STATEMENT<br>Release to the Public | 19 SECURITY CLASS *(This Report)*<br>unclassified | 21 NO OF PAGES<br>43 |
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