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LIMNOLOGICAL AND FISHERIES SURVEY OF THE UPPER SKUNK RIVER, IOWA[1] / *John R. Jones*[2], *David M. Coon*[3], and *Roger W. Bachmann*[4]

ABSTRACT. In 1970, water-quality data and fish samples were collected from stations along a 50-km reach of the Skunk River near Ames, Iowa. High levels of plant nutrients and planktonic chlorophylls were found. Treated sewage effluents introduced at Story City and Ames produced measurable changes in several chemical parameters. Fewer fish species were found than had been reported in 1892. Present distributions were correlated with the geological structure of the stream channel. The greatest diversity of fish species was upstream from Ames, where the bedrock is close to the surface, forming a heterogeneous streambed of pools and riffles. In the southern part of this reach a low-diversity ichthyofauna dominated by carp was found in a more homogeneous substrate of shifting sand. These geological factors seemed more important in determining fish distributions along the river than did the observed water-quality differences.

INTRODUCTION

The United States has a general problem of deteriorating water quality. One effect of poor water quality is its influence on the natural stream life. A study was conducted in 1970 on the Skunk River, Iowa, to determine the ecological characteristics of a central-Iowa stream, with emphasis on the influence of water quality and geological structure on the stream ichthyofauna. This study also served as a pre-impoundment survey for a proposed reservoir 2.4 km north of Ames.

The Skunk River lies entirely within the State of Iowa in a long, narrow basin extending from northcentral to southeastern Iowa, draining an area of 6,968 km^2 as a tributary of the Mississippi River.

From its source to 1 km north of Ames the Skunk River meanders south in a narrow postglacial valley with a rock, sand, and mud channel characterized by riffle and pool areas. North of Ames the river enters a preglacial channel, which widens below Ames into a broad flood plain. The preglacial channel has a shifting sand substrate. Profiles of the underlying rock formations in the Skunk River explain the change of substrate in the river bed (Dougal, 1969; Kent, 1969; Akhavi, 1970). For acceleration of drainage the stream channel 5 km below Ames to Colfax was artificially channelized by dredging during 1893 to 1923. This channelized reach is presently undergoing the processes of re-establishing a meandering course (Wells, 1956).

Stream-stage and discharge measurements were collected at two locations within the study reach by the U.S. Geological Survey, Iowa City, Iowa. The northern gauge is located 4.02 km north of Ames and meters the drainage from 507.15 km^2. The average discharge at this location is 3.79 m^3/sec, with ranges of 244.23 m^3/sec

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to periods of no flow. The southern gauge, below Ames, is located 0.32 km below the confluence of Squaw Creek and the Skunk River, metering drainage from 895.16 km^2. The average discharge at this location is 6.79 m^3/sec, with ranges of 262.06 m^3/sec to no-flow periods.

Three sources of municipal sewage are located along the study reach. Story City, Iowa (population 2,104) and Ames, Iowa (population 39,505) discharge secondarily treated sewage directly into the Skunk River. Cambridge, Iowa (population 661) has a septic-tank system connected to a tributary stream.

MATERIALS AND METHODS

In January 1970, seven sampling sites for chemical analyses were selected at bridge sites indicated in Fig. 1 (Coon, 1971; Jones, 1972). Stations 1, 2, and 3 were located along the meandering postglacial channel with a rock, sand, and mud substrate. Stations 4 and 5 were located along the meandering sand-bottom region. Stations 6 and 7 were located within the channelized region and had a shifting-sand substrate. At the Story City and Ames sewage-treatment plants, water samples were collected 90 m above (Stations 1A and 4A, respectively) and 90 m below (Stations 1B and 4B, respectively) the outfalls as well as from the sewage effluents (Stations 1E and 4E).

Sampling began for chemical analyses February 7, 1970, and continued on a weekly basis until June 2, 1970. During the summer months, sampling was conducted twice a week. From September 3, 1970, to December 21, 1970, sampling was limited to twice a month. Samples were collected at all stations between 0700 and 1200 hours on each sampling date. Collection began at Story City (Station 1) and continued downriver, following the numerical sampling sequence. Samples were returned to the laboratory and refrigerated to retard biological alteration. All chemical tests were completed within 12 hours after sample collection.

Fish specimens were collected at the same stations as well as at some intermediate points (indicated by letters in Fig. 1), from April 11 to Nóvember 23, 1970.

Statistical analyses were performed with assistance from the Statistical Laboratory, Iowa State University, Ames, Iowa.

PHYSICAL MEASUREMENTS

Turbidity, in Jackson Turbidity Units (JTU), was measured by use of a Hach Laboratory Turbidimeter Model 2100. Discharge measurements from the USGS gauge north of Ames were used as flow values for stream-sampling Stations 1, 2, and 3. Discharge measurements at the southern gauge were used as flow values for samples collected above the Ames effluent (Station 4A). Flow values for stations below the Ames effluent (Stations 4B through 7) were calculated by combining flow values from the southern gauge and the mean Ames effluent discharge (m^3/sec) for that date.

CHEMICAL MEASUREMENTS

River-water samples for chemical analyses were collected by immersing BOD Bottles 10 to 20 cm below the water surface. The following colorimetric tests were made by use of a Hach DR Colorimeter (Hach, 1967). Ammonia nitrogen was determined by direct Nesselerization, nitrate nitrogen was determined by cadmium reduction, nitrite nitrogen was determined by diazotization, and orthophosphate was determined by the stannous chloride method.

The pH was determined in the field by use of a Beckman Model N pH meter. An Industrial Instruments Conductivity Bridge Model RC 16B1 was used to measure specific conductance, recorded in micromhos/cm at 25C. The mercuric nitrate method was used to determine the chloride concentration. Chemical oxygen demand (COD) was measured by the dichromate oxidation method (A. P. H. S., 1965) by use of 0.025 N reagents. The Winkler method was employed to measure dissolved oxygen.

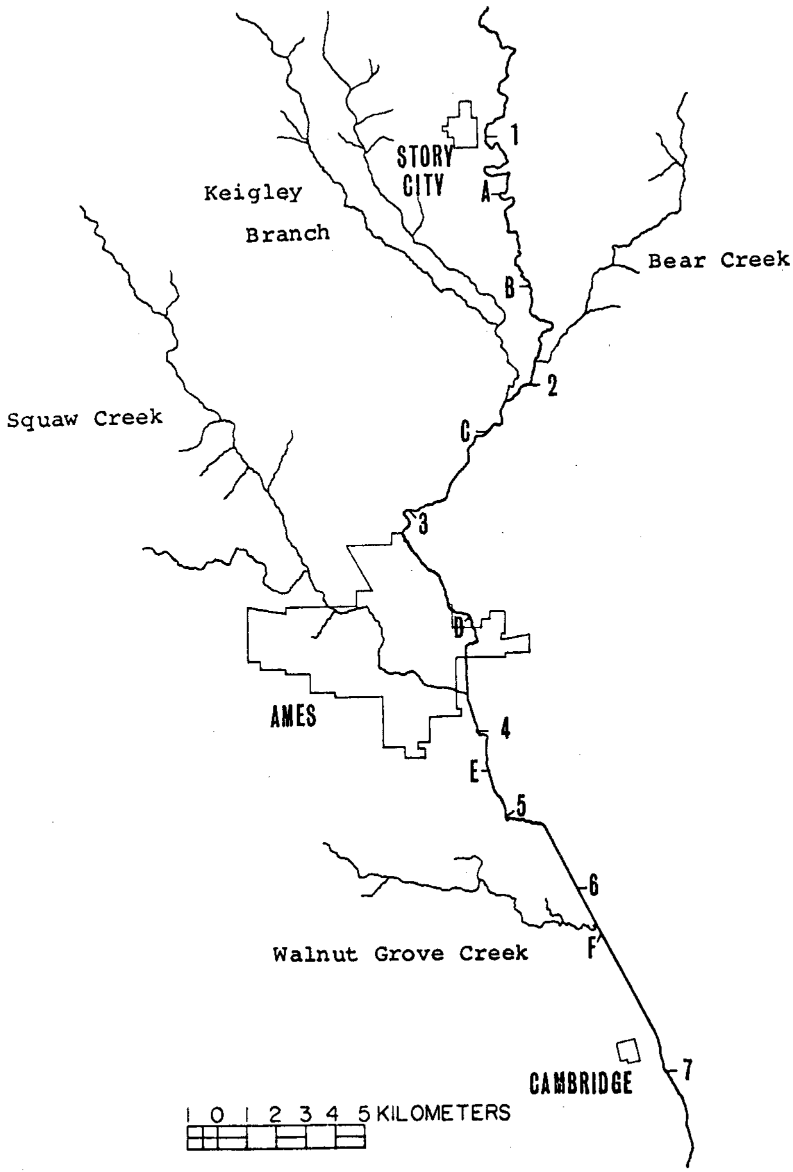

Figure 1. Map of the study area on the Skunk River, Iowa, with the primary stations (Arabic numbers) and secondary stations (capital letters).

BIOLOGICAL MEASUREMENTS AND FISH COLLECTION

Samples for chlorophyll a measurements were taken by immersing a 1-liter polyethylene bottle 10 to 20 cm below the water surface. In the laboratory a measured subsample was filtered through a Type A Gelman glass fiber filter. The filter was stored up to 40 days frozen over desiccant. Chlorophyll concentration was determined by use of the methods of Richards with Thompson (1952) and Yensch and Menzel (1963). Values were calculated from the equations of Parsons and Strickland (1963).

Four types of gear were utilized in collecting fish: (1) a 3-m common-sense minnow seine with 6-mm mesh, (2) a 7.62-m bag seine, (3) 1.8-m to 3-m long hoopnets of 0.06-m diameter, and (4) a 230-volt AC electric shocker. Fish were weighed to the nearest gram on a Hanson scale and measured to the nearest 0.1 cm before being returned to the river.

A least significant difference test (LSD) (Steel and Torrie, 1960) was performed to test all paired means with the level of significance set with $P = 0.05$.

RESULTS

Data collected on limnology of the Skunk River in 1970 indicated that water quality from Story City to Ames was different from quality between Ames and Cambridge, Iowa (Table 1). This difference resulted from the Ames sewage effluent. Hence, data collected from Story City to Ames (Stations 1A to 4A) were grouped together for analysis. A second group of data included stations below Ames.

Table 1. Mean water-quality parameters in the Skunk River in 1970 for stations located between Story City and Ames, Iowa, and stations between Ames Ames and Cambridge, Iowa.

Parameter	Mean value from Story City to Ames	Mean value from Ames to Cambridge
PO_4 (mg/1)	0.52	1.50
NH_3-N (mg/1)	0.75	0.89
NO_2-N (mg/1)	0.052	0.054
NO_3-N (mg/1)	3.0	3.1
Chloride (mg/1)	26.08	21.11
Chlorophyll a (mg/m^3)	39.12	34.23
COD (mg/1)	21.9	25.3
Specific conductance (micromhos/cm at 25 C)	690.6	684.7

Turbidity values ranged from 4 to 405 JTU during the study. Mean turbidity values increased progressively downstream from Stations 1A to 7. Mean turbidity values for Stations 1A to 3 were significantly lower than means for Stations 4A to 7 (Table 2).

Chloride measurements were quite variable and ranged from 8.90 mg/1 to 52.50 mg/1. Values for Stations 1A through 3 were consistently higher than Stations 4A through 7. The mean chloride value for Station 4B was higher than values for other downstream stations because of addition of chloride to the river from the Ames effluent which averaged 42.39 mg/1 chloride. The Story City effluent averaged 39.28 mg/1 chloride, but did not greatly increase the Station 1B mean value, because of high river chlorides in this reach. On six sampling dates the Story City effluent had a lower chloride concentration than did the river at Station 1A.

The mean specific conductance values for Stations 2 through 7 were not significantly different (Table 2), although mean values decreased slightly at the downstream stations. Specific conductance measurements of effluent samples were consistently

Table 2. Mean water-quality parameters in the Skunk River in 1970 for stations 1A to 7.[a]

Parameter (mean)	Stations 1A	1B	2	3	4A	4B	5	6	7
JTU	37	33	34	38	44	42	45	46	51
Chloride	28.35	28.82	28.40	27.00	20.57	23.68	22.47	21.08	19.79
Specific conductance	721	736	694	679	667	688	687	687	674
COD	24.3	26.7	26.2	26.1	21.2	27.1	24.8	25.2	24.0
Dissolved oxygen	8.85	8.75	8.32	8.64	9.61	9.32	9.15	9.11	9.06
Orthophosphate	0.60	1.06	0.61	0.48	0.39	2.26	1.42	1.50	1.56
NH_3-N	0.81	0.98	0.76	0.76	0.69	1.22	0.90	0.90	0.84
NO_2-N	0.064	0.070	0.059	0.048	0.035	0.070	0.052	0.052	0.052
NO_3-N	2.94	3.10	3.23	3.04	3.05	3.12	3.02	2.94	3.17
Chlorophyll *a*	26.69	26.83	48.36	49.98	31.45	31.65	35.86	32.64	34.17

[a]Any two means joined by the same straight line are not significantly different by the Least Significant Difference test (P = 0.05).

higher than were river values, causing increased values at Stations 1B and 4B. The mean specific conductance value during the period of study was 976.0 micromhos/cm at 25 C for the Story City effluent and 831.1 micromhos/cm for the Ames effluent.

COD values, expressed as mg/l oxygen, ranged from 3.8 mg/l to 132.0 mg/l in river samples. The results of a LSD test indicated that none of the mean COD values of the various stations differed significantly (Table 2). COD values of the Ames and Story City sewage effluents averaged 47.8 mg/l and 65.9 mg/l, respectively, causing slightly higher values below the outfalls.

Diurnal fluctuations of dissolved oxygen (DO) (mg/l) made it difficult to draw comparisons between DO samples taken in successive order at various locations along the sampling reach. Stations sampled later in the day yielded values closer to the daily maximum. Analysis of the mean DO values by the LSD test indicated that four groups of mean values described the DO averages from Stations 1A through 7 (Table 2). Stations located downstream from the Ames (Stations 5, 6, and 7) and Story City outfalls (Stations 2 and 3) had mean DO values significantly below mean values for samples collected above and immediately below the effluents. This decrease resulted even though the downstream samples were collected later in the day.

During the study orthophosphate varied from 0.03 mg/l to 4.60 mg/l in river samples. Mean orthophosphate concentrations were significantly higher for sampling stations below Ames than for stations upstream. Mean PO_4 values for the study period at Stations 1B and 4B (below the effluents) differed significantly from those of all other stations and from one another because of the addition of orthophosphate from the sewage effluents. The Story City effluent had a mean value of 21.76 mg/l PO_4, whereas Ames effluent had a mean of 22.56 mg/l PO_4.

In river samples, ammonia nitrogen ranged between 0.21 and 3.60 mg/l NH_3-N. Samples taken from the Ames effluent averaged 8.72 mg/l NH_3-N, and the Story City effluent averaged 10.34 mg/l. Mean NH_3-N values from both effluents were lower than actual values because ammonia concentration in effluent peaks in the afternoon. In composite effluent samples, the Ames water-pollution-control-plant personnel found a mean of 17.5 mg/l NH_3-N during 1970, which was twice the morning grab sample. Mean NH_3-N concentration at Stations 5, 6, and 7 were significantly greater than mean values for upstream stations. Concentrations at Stations 1B and 4B were significantly higher than those of all other stations (Table 2).

Nitrite-nitrogen values ranged from 0 to 0.187 mg/l NO_2-N during the study period. Mean nitrite-nitrogen values decreased from Story City to Ames. Stations below Ames had a significantly higher mean NO_2-N concentration than Station 4A (Table 2). The Ames sewage effluent averaged 0.423 mg/l NO_2-N; the Story City wastewater mean was 0.420 mg/l NO_2-N during the study.

Nitrate-nitrogen concentrations differed greatly between sampling dates at all stations. On June 30, 1970, no NO_3-N was detected at any river station. The highest NO_3-N value measured was 9.9 mg/l at Station 2 on May 16, 1970. No significant differences existed between the mean NO_3-N concentration for Station 1A through 7 (Table 2). During the study the Story City effluent averaged 2.1 mg/l NO_2-N, and the Ames effluent averaged 2.8 mg/l NO_3-N. Composite samples taken by the Ames water-pollution-control plant averaged 4.6 mg/l during 1970.

There was little variation in pH between stations on seven dates sampled during the study period, although pH tended to be lower at stations below tha effluents. The pH values ranged from 7.60 to 8.63.

Chlorophyll a concentrations ranged from 177.53 to 0.98 mg/m^3. Chlorophyll concentrations at each sampling station during the spring and fall periods were lower than summer values. Concentrations of chlorophyll a varied between stations on any given sampling date; stations located above Ames, however, normally contained higher concentrations. Mean chlorophyll a values at Stations 2 and 3 were significantly greater than those of all other stations (Table 2).

Total chlorophyll a (mg/sec) is computed by multiplying the chlorophyll a concentration (mg/m^3) by stream flow (m^3/sec). Total chlorophyll a (mg/sec) is the amount of chlorophyll a (mg) carried by the river per unit of time (sec). The mean, total, chlorophyll a (mg/sec) value between May 16 and September 12, 1970, at Station 3 was 77.37 mg/sec; Station 5 had a mean of 146.67 chlorophyll a mg/sec. The chlorophyll a concentration (mg/m^3) at Stations 3, 4A, and 5 during this period averaged 62.41, 38.70, and 45.41 mg/m^3, respectively. The results of a LSD analysis indicate that the mean total chlorophyll a values (mg/sec) at Stations 4A and 5 were significantly greater than the Station 3 mean. This same test, applied to the chlorophyll a concentration (mg/m^3) at these stations during this period, indicated that the mean value at Station 3 was significantly greater than the mean values at Stations 4A and 5. These results suggest that, even though the mean chlorophyll a concentration (mg/m^3) decreased from Station 3 to Ames, the total chlorophyll a (mg/sec) load carried by the river was greater downstream, indicating dilution by the Ames effluent.

For each measured parameter and chlorophyll a concentration, a linear regression analysis was performed, and a correlation coefficient was calculated to determine relationships with stream discharge. There seemed to be no uniform variation among the measured variables and stream flow. Variables could be separated, however, into those whose concentrations either showed a significant increase with increasing flow, a significant decrease with increasing flow, or no change with stream discharge (Table 3). Orthophosphate and specific-conductance measurements were the only variables not altered uniformly by stream discharge within the study reach. The regression of orthophosphate data on stream discharge at stations above Ames was not significant. A negative relationship was found between PO_4 and stream discharge for stations below Ames. This relationship is to be expected since the Ames effluent, the major source of orthophosphate for stations below Ames, is diluted with an increase in stream flow.

Table 3. Interrelationships of the measured parameters with stream-discharge data collected between February and December, 1970, Skunk River, Iowa,

Variables having a significant increase with increased flow	Variables having a significant decrease with increased flow	Variables having no significant correlation with flow
NO_3-N	Chloride	NH_3-N
NO_2-H	PO_4 (below Ames)	PO_4 (above Ames)
COD	Chlorophyll a (mg/m^3)	
Turbidity	Specific conductance (below Ames)	
Chlorophyll a (mg/sec)		

Specific-conductance values from Stations 4A to 7 had a significant inverse relationship with stream discharge. The coefficient of regression of flow and specific-conductance values from stations above Ames were negative, but not significant.

FISH SPECIES COLLECTED

A total of 8,292 fish were collected in the study area (Table 4), representing 35 species, 6 families, and 3 orders. The family Cyprinidae comprised 72% of all fish collected, and carp along represented 52% of the total.

Common shiner was the predominant species collected by seining both above and below Ames, representing 37.1% and 34.1%, respectively. Bigmouth shiner was second in abundance above and below Ames, comprising 21.2% and 33.6%. Black bullhead was the dominant species collected in hoopnets above Ames, representing 25.2%, followed by carp and yellow bullhead with 14.3% and 14.2%, respectively. Below Ames, 82.3% of the fish taken in hoopnets were carp and 6.1% were black bullhead. Carp was the dominant species taken by electro-shocking above and below Ames, representing 32.4% and 88.5%. Both above and below Ames the white sucker was the second most abundant species collected by electro-shocking, comprising 24.5% and 6.8%.

Specimens of only seven sport-fish species were collected in the study area. One northern pike was taken above Station 1A. Forty-one channel catfish were collected, 28 of these from stations above Ames. Nineteen bluegills were collected in the area, 14 from above Ames. All 51 smallmouth bass, of which 37 were young-of-the-year, were taken at stations above Ames. One largemouth bass was collected at Station 3. Twenty-seven of 29 white crappie were taken above Ames, as were the 22 black crappie.

Five major surveys have dealt with the composition, distribution, and abundance of ichthyofauna in the upper Skunk River. Meek (1892) described the Skunk River as being abundant with pickerel, bass, suckers, buffalo-fishes, northern pike, and muskellunge. The river was then bordered by a marsh with many small bayous. Harlan and Speaker (1951) listed the species collected after 1945. No new species were collected in the present study. Golden shiner was not collected in the study reach, but was reported by Harlan and Speaker (1951) and Zach (1968). The slender madtom was collected north of Ames in 1970 and by Harlan and Speaker (1951), but not by Paloumpis (1956) and Zach (1968). Laser, et al. (1969) seined south from Ames to Colfax, Iowa, and found the red shiner, bigmouth shiner, and sand shiner most abundant.

Table 4. Species of fish collected by seining, hoopnetting, and electric shocking in the Skunk River from Story City to Cambridge, Iowa.

Esocidae	
Esox lucius	(Northern pike)
Cyprinidae	
Campostoma anomalum	(Stoneroller)
Cyprinus carpio	(Carp)
Carassius auratus	(Goldfish)
Hybognathus hankinsoni	(Brassy minnow)
Notropis atherinoides	(Emerald shiner)
Notropis cornutus	(Common shiner)
Notropis dorsalis	(Bigmouth shiner)
Notropis lutrensis	(Red shiner)
Notropis stramineus	(Sand shiner)
Phenacobius mirabilis	(Suckermouth minnow)
Pimephales notatus	(Bluntnose minnow)
Pimephales promelas	(Fathead minnow)
Semotilus atromaculatus	(Creek chub)
Catostomidae	
Carpiodes carpio	(River carpsucker)
Carpiodes cyprinus	(Quillback)
Carpiodes velifer	(Highfin carpsucker)
Catostomus commersoni	(White sucker)
Hypentelium nigricans	(Northern hog sucker)
Ictiobus cyprinellus	(Bigmouth buffalo)
Moxostoma macrolepidotum	(Shorthead redhorse)
Ictaluridae	
Ictalurus melas	(Black bullhead)
Ictalurus natalis	(Yellow bullhead)
Ictalurus punctatus	(Channel catfish)
Noturus exilis	(Slender madtom)
Noturus flavus	(Stonecat)
Centrarchidae	
Lepomis cyanellus	(Green sunfish)
Lepomis humilis	(Orangespotted sunfish)
Lepomis macrochirus	(Bluegill)
Micropterus dolomieui	(Smallmouth bass)
Micropterus salmoides	(Largemouth bass)
Pomoxis annularis	(White crappie)
Pomoxis nigromaculatus	(Black crappie)
Percidae	
Etheostoma flabellare	(Fantail darter)
Etheostoma nigrum	(Johnny darter)

The diversity index recommended by Wilhm and Dorris (1969) was applied to the sum of the species of fish collected by seining, hoopnetting, and electro-shocking at each station (Table 5). Diversity index values were lower below Ames than above, because the number of taxa decreased and the number of carp increased. The diversity index values at Stations 4A and 7 might have been higher if more than one seine haul had been conducted because seining would probably have yielded more species of minnows.

Table 5. Diversity index of fish collected in 1970 at the Skunk River primary stations, with the total number of fish at each station and the percentage of carp.

Station	Diversity index	Number of taxa	Total number of fish	Percent carp
1A	3.35	21	435	4
1B	3.22	18	385	7
2	4.08	30	841	10
3	3.06	27	614	48
4A	1.34	18	487	82
4B	1.36	16	759	80
5	1.19	21	957	84
6	1.82	17	787	69
7	1.88	17	671	69

DISCUSSION

Water quality and geological structure affect the composition and distribution of biota in the Skunk River, which is a nutrient-rich medium with nitrogen and phosphorus concentrations above the levels that Sawyer (1947) reported will promote algal growth. Algal growth in the Skunk River is most likely not nutrient limited but probably is controlled by several physical factors. In this study, chlorophyll a concentration was used as an index of algal concentration. Kilkus (1972), in a survey of central Iowa streams, found a significant positive linear relationship between chlorophyll a concentration and algal-cell counts. The chlorophyll a concentration of the Skunk River had a significant inverse relationship with stream flow. As flow increased, the chlorophyll concentration decreased at all sampling stations. This regulation of plankton populations by factors associated with stream flow has been noted by several authors. Williams (1964) found lower phytoplankton populations in rivers during high-water periods and highest phytoplankton counts when streams approach pool stage. He concluded that flows may have more influence than other factors upon plankton. Tiffany (1958) and Round (1965) also found algal concentrations greater during reduced flows.

Water quality in the upper Skunk River was markedly influenced by the Ames and Story City municipal effluents. With the exception of DO and turbidity, all measured parameters showed a higher mean value below the effluents than above. This alteration of water quality is indicative of a recovery zone below a pollution source, as described by Bartsch (1948). The mean COD was greater below the Story City outfall and remained so until the river reached Ames. Concurrent with an increase in COD values was a decrease in DO below Story City. At Ames (Station 4) the DO level had again recovered. The progressive decrease below Story City in the mean concentration of NO_2-N, NH_3-N, and PO_4 also was characteristic of a recovery zone.

Water quality of the Skunk River underwent a change resulting from the influence of the Ames water-pollution-control plant. This change was expected because the nutrient-rich sewage effluent was added to the river water. At stations below Ames the mean orthophosphate, ammonia nitrogen, and nitrite nitrogen increased significantly over the levels found above Ames.

The mean COD values at stations below Ames were greater than values above Ames. As COD levels increased below the Ames effluent, DO dropped. The DO levels decreased at downstream stations despite the potential increase from photosynthetic action, because downstream samples were collected later in the day. Recovery did take place within the reach, because at Station 7 (15.8 km below Ames) the mean orthophosphate concentration was the only measured parameter that remained significantly higher than the mean concentration measured at Story City (Station 1).

There seemed to be no uniformity in distribution or relative abundance of the ichthyofauna within the study area. The greatest number of sport fishes were collected north of Ames. Below Ames carp was the dominant fish collected at all stations. A larger diversity of fish was found above Ames than below, as reflected in greater diversity index values at stations above Ames.

Three major parameters were considered in determining why the marked difference occurred in the diversity-index values. These parameters were (a) the geology and related substrate, (b) channelization, and (c) the possible influence of the outfall from the Ames water-pollution-control plant. The drop in diversity-index values occurred between Stations 3 and 4 where the substrate in the river changes from boulders and gravel to shifting sand. These changes in diversity and substrate occurred because of the drop in elevation of bedrock under the river channel where bedrock is greatly overlain with sand and gravel. The stream substrate is essentially homogeneous from directly below Station 3 to Station 7. Fish-diversity indices were larger in the heterogeneous substrate reach (Stations 1 to 3) than in the homogeneous substrate reach (below Station 3 to Station 7). The diversity index values in the entire homogeneous shifting-sand substrate reach were low but essentially uniform. Since there were essentially no differences in the diversity-index values between Stations 4A, 4B, and 5 (unchannelized reach), and Stations 6 and 7 (channelized reach), we concluded that the effect of channelization did not seem to limit the fish diversity. The limiting factor seemed to be the shifting sand substrate, which accounted for the low uniform diversity values from Stations 4A to 7. Shelford and Eddy (1929), Stehr and Branson (1938), Trautman (1942), and Tarzwell and Gaufin (1953) also found bottom type a major factor in the distribution of fish species.

During this study sufficient data were not obtained to determine what effect, if any, the effluent from the Ames water-pollution-control plant might have on fish distribution, composition, and relative abundance. The Ames water-pollution-control plant is located downstream, yet, in close proximity to the change in the geology and related substrate. Therefore, it was difficult to determine if the distribution and composition of the ichthyofauna above and below the outfall of the Ames water-pollution-control plant was related directly to the influence of the outfall. Laser et al. (1969)found lower diversity indices below the Ames outfall than above. The absence of sport-fish species below the Ames outfall seems attributable to the character of the substrate, although it is doubtful that the effluent would attract sport-fish species (Godfrey, 1970). Possibly the effluent could attract carp (Laflin, 1970).

The periodic low flow conditions characteristic of the Skunk River influence water quality and the biota. As the Skunk River reaches low-flow conditions, nutrient concentrations decrease corresponding to the period of highest chlorophyll a concentration. With decreased flow and high chlorophyll a values, concentrations of nitrate nitrogen were lower. Orthophosphate levels varied along the study reach. Stations above Ames had lower PO_4 values during low flow; whereas, stations below Ames had higher concentrations due to the effluent influences. The reduction of nutrient concentrations during periods of phytoplankton growth has also been observed on the Des Moines River (Drum, 1964; Gudmundson, 1969).

The reach of the Skunk River in this study seems to support permanent fish populations, which experience slight changes despite the low flow conditions, as shown by the consistent occurrence of the same species of fish present over the past 25 years. Paloumpis (1956) concluded that fish populations in this area were able to survive drought or flood periods in certain areas or sanctuaries.

The upper Skunk River, once described by Meek (1892) as being bordered by bayou and marsh, has since undergone many changes. As agricultural settlement was being established within the watershed the wetland areas were drained by tile systems connected to the river. Concurrent with accelerated drainage the channel was straightened below Ames. These changes are most likely the reason for the elimination of eight species of fish in the reach since Meek's original survey in 1892. The municipal effluents are a more recent change and have a locally profound effect on water quality.

A reservoir has been proposed for the Skunk River 2.4 km north of Ames, Iowa, primarily for flood control of downstream reaches. If the reservoir were constructed, it is doubtful that the smallmouth bass population present in the Skunk River north of Ames would continue to be present in the reservoir, because of the loss of suitable habitat for reproductive purposes. There would be approximately 1 km of tailwater area potentially capable of supporting a sport fishery in terms of an area suitable for smallmouth bass reproduction. Regulations possibly would have to be applied to maintain this reach for a restricted sport fishery.

With the Skunk River as the surface source of water for the reservoir, projections can be made as to its future quality by examining the past water quality of the stream. Plant nutrients will be collected in the reservoir from the influent stream as a potential for excessive algal growths. In the reach of the Skunk River above the proposed reservoir, PO_4, NH_3-N, and NO_3-N concentrations generally have been in excess of 0.3 mg/l, 0.5 mg/l, and 1.0 mg/l, respectively. These levels will be the approximate concentration found in the reservoir, based on the similar concentration of these nutrients found by Kilkus (1972) in the Des Moines River and Red Rock Reservoir. From this evidence we can anticipate that the reservoir will be eutrophic with high populations of plankton algae, as are other bodies of water with nutrient concentrations of this magnitude. Predictions of the thermal structure and fish populations in the proposed reservoir are given in Bachmann and Olson (1973).

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