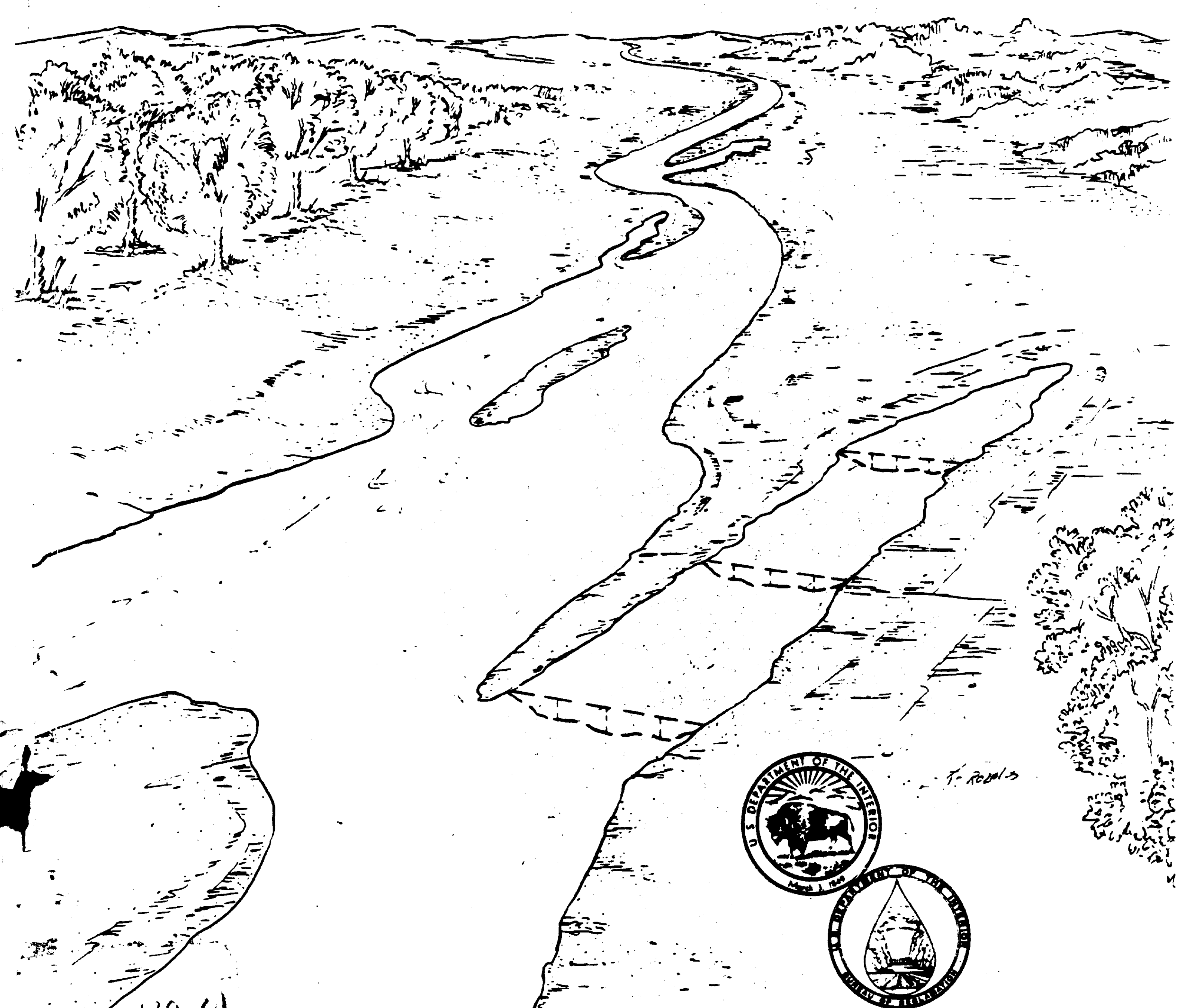
SOME ASPECTS OF TROPHIC INTERACTIONS IN SELECTED BACKWATERS AND THE MAIN CHANNEL OF THE GREEN RIVER, UTAH

1987 - 1988

SPECIAL REPORT



U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

SOME ASPECTS of TROPHIC INTERACTIONS in SELECTED BACKWATERS and the MAIN CHANNEL of the GREEN RIVER, UTAH 1987 - 1988

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July 1989

Performed for
BUREAU OF RECLAMATION
Upper Colorado Regional Office
Salt Lake City, Utah

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ACKNOWLEDGMENTS

We thank Mr. Bob Williams and the USBR Upper Colorado Region for funding this 2-year study designed to characterize selected backwaters of the Green River limnologically and to describe some aspects of trophic interactions in these backwaters. Dr. Harold Tyus, US Fish and Wildlife Service Technical Officer, and others of the USFWS Colorado River Fishery Project Office, Vernal, Utah, provided assistance in study design, selection of study areas, and field collections. Personnel from the USBR Denver Office's Environmental Sciences Section assisted frequently with fieldwork. Other individuals and agencies provided valuable input regarding aspects of sampling, data analysis and report review. Dr. Charles Liston, IPA from Michigan State University in the Environmental Sciences Section, provided suggestions for study design and data analysis.

EXECUTIVE SUMMARY

This 2-year study of an 84 mile reach of the Green River near Vernal, Utah, was conducted to characterize selected backwaters of the Green River at Island Park, Jensen, and Ouray limnologically and to describe some aspects of trophic interactions of these backwaters. This report describes limnological conditions prevailing in selected backwaters that are documented nursery areas for larval endangered Colorado squawfish. Food habits of young fish in these backwaters were investigated to determine the extent of dietary overlap and possible competition for available food resources.

Flows in the Green River differed substantially between 1987 and 1988. Average flows from July 1 to October 31, 1987, were 1,983 ft^3/sec, but only 1,532 ft^3/sec for the same period in 1988. In addition, daily fluctuations after mid-August 1988 were of lower magnitude and frequency than during the similar period in 1987. Limnological data collected from the Green River and backwaters at Island Park, Jensen, and Ouray suggest an upstream to downstream trend in abiotic and biotic characteristics in both the river and backwaters in this reach of river. Average seasonal water temperature was higher downstream than upstream, and warmer in the backwaters than at nearby river sites. Average water temperatures at all sites were higher in 1988 compared to 1987, probably due to the lower average river flow in 1988. Average water temperatures in the main river in 1987 increased from 17.1 °C at Island Park to 19.7 °C at Ouray, and increased from 17.5 °C to 20.4 °C in 1988. In backwaters, average water temperatures in 1987 increased from 19.7 °C at Island Park to 22.0 °C at Ouray, while in 1988, average water temperatures at these same sites were 21.3 °C and 22.9 °C, respectively.

Dissolved oxygen levels were generally inversely related to water temperatures, although dissolved oxygen exhibited a less consistent seasonal trend. Average dissolved oxygen in the river decreased slightly downstream, from 8.1 mg/L at Island Park to 7.4 mg/L at Ouray. In backwaters, average dissolved oxygen was highest at 8.2 mg/L at Jensen, and lowest at 7.5 mg/L at Ouray. pH was usually above 8.0.

Specific conductance increased downstream in the river and was generally higher in backwaters than in the main river. Average specific conductance in the main river in 1987 ranged from 659 μS/cm at Island Park to 717 μS/cm at Ouray, while in 1988, specific conductance ranged from 731 μS/cm at Island Park to 772 μS/cm at Ouray. In backwaters, average specific conductance ranged from 685 μS/cm at Jensen to 720 μS/cm at Ouray, while in 1988, specific conductance was highest at 1,154 μS/cm in Jensen backwaters, and lowest at 772 μS/cm in Ouray backwaters. High average specific conductance in Jensen backwaters was due to the high values recorded in BA 300.5, during both the regular 2 week sampling and with the continuous monitoring instrument.

Turbidity was greater in downstream backwaters but exhibited no consistent seasonal pattern compared to the river. Turbidity averaged 37, 36, and 142 NTU in the main river at Island Park, Jensen, and Ouray, respectively, in 1987, and 93, 61, and 49 NTU at these sites in 1988. In backwaters, average seasonal turbidity was 32, 34, and 49 NTU at Island Park, Jensen, and Ouray, respectively, while in 1988, turbidity averaged 27, 34, and 59 NTU at these respective sites.

Slightly warmer water temperatures and greater nitrogen and phosphorus concentrations in Ouray backwaters may stimulate production of blue-green algae; blue-green algae were a major component of the <25 μm size-fraction of phytoplankton (nannoplankton) collected from backwaters. The average increase in turbidity in Ouray backwaters was due in part to greater nannoplankton abundance and higher concentrations of particulate organic material. Seasonal turbidity in BA 250.8 averaged 77 NTU in 1988, the highest seasonal average for a backwater sampled during this study, due in part to high POM concentrations in the <25 μm size-fraction. Other Ouray backwaters averaged 53 NTU, while the river averaged 49 NTU.

Zooplankton densities were low in both the river and backwaters, although greater in backwaters, and generally greater in Ouray backwaters than in Island Park or Jensen backwaters. Zooplankton densities increased from 0.44 individuals per liter in upstream Island Park backwaters to 1.5 individuals per liter in downstream Ouray backwaters, although the magnitude of the increase was not as great as with the <25 μm size-fraction of the blue-green algae, which constituted the major component of this size-fraction. Among the backwaters sampled, those larger backwaters with narrow connections to the river, with a lower exchange rate and a greater retention time (BA 300.5 and BA 251.0), generally had higher densities of zooplankton.

Continuous monitoring of temperature, DO, pH and specific conductance in one backwater each at Island Park, Jensen, and Ouray revealed diel fluctuation in these limnological parameters, with some of the fluctuations directly influenced by changes in riverflow. Fluctuations in riverflow that increase water level in backwaters result in importation of riverine nutrients and POM into backwaters, as well as resuspension of organic material from the inundated periphery of the backwater with possible leaching of nutrients from the inundated zone. Water level fluctuations in backwaters that resuspend organic material increase turbidity which may provide cover for the native fish that evolved in this ecosystem, and reduce the likelihood of predation on Colorado squawfish by nonnative fish. Decreasing water levels in backwaters resulting from reduced riverflows may result in export of nutrients and biota to the river. The extent of export of nutrients and biota to the river cannot be addressed at this time.

Concentrations of major nutrients (nitrate-N, ammonia-N, and phosphorus) generally increased in backwaters from upstream at Island Park to downstream at Ouray. Seasonal average TIN (NO_3-N + NO_2-N + NH_3) concentrations in the river were greater than in backwaters at Island Park and Jensen, but greater in Ouray backwaters than in the river there. Seasonal average TP concentrations were lower in Island Park backwaters than in the river there, but greater than in the river at Jensen and Ouray backwaters. Ouray backwater nutrient concentrations exceeded river concentrations. Higher nutrient concentrations in Ouray backwaters compared to Island Park and Jensen backwaters and the river at Ouray may indicate internal nutrient recycling within these backwaters or a response to attenuated riverflows compared to upstream wherein nutrients transported into the backwaters from the river during rising water levels are retained as riverflow decreases, or leached from the inundated backwater shoreline. The less severe action of inundation and draining in Ouray backwaters caused by attenuated riverflows may reduce the tendency for violent mixing of water in backwaters, and reduce export of POM and nutrients during draining.

Average macroinvertebrate abundance in backwaters increased progressively downstream within the study reach, although variability was high among the several backwaters sampled at a site. Total riverine benthos averaged 599, 359, and 46/m^2 in 1988 at Island Park, Jensen, and Ouray respectively. Riverine substrate at Ouray was mostly shifting sand. In backwaters, total benthos in the 1988 averaged 2,411, 2,111, and 3,326/m^2 for Island Park, Jensen, and Ouray, respectively. In many samples, chironomid larvae comprised over 90 percent of the benthic fauna.

Benthic algae and detritus, although not sampled in this study, probably contribute to the food base for the collector-gatherer chironomid larvae and the other grazing macroinvertebrates. It comprised a large portion of the stomach contents of the young suckers collected. Predatory chironomid larvae, although few in number in the backwaters sampled, likely prey on the grazing chironomids. Food web interactions at this lower trophic level may result in nutrient recycling within some Green River backwaters.

Food habit studies of 16 species of native and nonnative fish collected from backwaters, indicated some dietary overlap due to heavy utilization of chironomid larvae by some young fish <20 mm TL. The 14 Colorado squawfish <20 mm TL collected in 1987 and 1988 consumed mostly chironomid larvae, while Colorado squawfish >20 mm TL showed evidence of piscivory, but continued to consume chronomid larvae. As the Colorado squawfish grow and include larval fishes, primarily red shiner, in their diet, along with chironomid larvae, dietary overlap with other fish species diminishes because of the expanded food resource. The stomachs of some young fish, such as the native suckers, contained mostly algae. Few fish species other than Colorado squawfish and

Gila spp. consumed larval fish. After Colorado squawfish become piscivorous, red shiners, fathead minnows, occasional catostomids, and other introduced fish species are found in the diet suggesting less dependence on the relatively abundant chironomid larvae.

Observations from qualitative seine hauls used in this study to collect fish for food habit studies, revealed young Colorado squawfish in Jensen and Ouray backwaters, with more fish observed in shallow (about 0.3 m deep), more turbid backwaters having a relatively wide connection to the river. Bottom composition of these shallow backwaters was generally muck or gyttja, often with organic material and some sand.

Shallow backwaters with a large surface area in the Ouray area that were seasonally permanent after runoff subsided were generally warmer compared to upstream backwaters at Island Park and Jensen; they had higher concentrations of nutrients, particulate organic material, and greater densities and weights of benthic macroinvertebrates, and moderate chlorophyll *a* levels. Benthic macroinvertebrates were the principal food source for most young fish, except suckers. The river is one nutrient source for backwaters. Increased concentrations of some nutrients in the river at Ouray compared to Jensen, result from upstream agricultural runoff and return flows.

INTRODUCTION

The Green River in Wyoming, Colorado, and Utah, is a major tributary of the Colorado River, and since the completion of Flaming Gorge Dam near Dutch John, Utah, in 1962, is strongly influenced by controlled releases for power generation from the dam. Sixty-five river miles downstream of Flaming Gorge Dam, the Yampa River enters the Green River, and 97 miles below this confluence the Duschesne and White Rivers enter the Green River near Ouray, Utah (figure 1). These three tributaries have their highest relative flows during the spring runoff period. Since the impoundment of the Green River by Flaming Gorge Dam in the early 1960s, there has been a subsequent reduction in the abundance of several indigenous species of fish including the Colorado squawfish (*Ptychocheilus lucius*) in the Green River below Flaming Gorge Dam.

USFWS, USBR, and others have conducted various studies since 1978 in both the Green River and the upper Colorado River to understand better some of the environmental requirements of various life history stages of the Colorado squawfish (Tyus et al. 1987). This limnological and trophic study of selected Green River backwaters is one of six biological studies and four hydrology studies identified in an interagency agreement between Reclamation and the Fish and Wildlife Service to obtain information needed by the FWS to formulate a Biological Opinion regarding operational strategies for Flaming Gorge Dam that will ensure survival and promote recovery of endangered fish species in the Green River. At present, Flaming Gorge Dam is operated with annual moderate and peaking power flows from July or when small fish are observed in the system until 1 October, with greater fluctuations and flows during the remainder of the year. Several investigations to date indicate that backwaters associated with the Green River are important nursery habitats for larval and young-of-the-year (YOY) Colorado squawfish as well as other native and nonnative fish species.

Radio telemetry studies of adult Colorado squawfish have revealed aggregations of mature fish in the lower 20 miles of the Yampa River during early summer. Evidence suggests both water temperature and hydrograph stage (Nesler et al. 1988; Tyus et al. 1987) and possibly other environmental factors, provide cues for Colorado squawfish spawning. Spawning can occur from late June through August. The squawfish eggs incubate in the substrate for about 6 days. After hatching and emerging from the gravel, the larval Colorado squawfish drift passively down the Yampa River to the Green River, then down the Green River into low water velocity nursery areas such as backwaters. Backwater habitat is important for young Colorado squawfish (Tyus et al 1987; Valdez and Wick 1983), provides some protection from fluctuating flows and high discharges, and is generally more productive than main river habitats (Holland and Huston 1984). Kallemeyn and Novotny (1977), cited in Persons (1979), and Sheaffer (1984) reported that many fish species preferred backwater areas, and that backwater areas were important spawning and nursery areas for some species of fish. The success (survival) of the larval and young Colorado squawfish in Green River nursery areas probably depends on the ecological characteristics of the habitat and their ability to exploit the available resources. Feeding habits of young fish, food availability, some limnological characteristics, and development and relationship of main river and backwater habitat in the Green River occupied by young Colorado squawfish are not well known.
The goal of this study was to augment existing information on the physical,

chemical, and biological characteristics of the diverse array of backwater habitats in the Green River between the confluence with the Yampa River and the White River where larval, YOY, and 1+ Colorado squawfish have been found.

The objectives of this study were:

1. To identify energy sources which fuel secondary productivity in nursery habitat.

2. To identify important trophic interactions leading to production of food organisms available to young Colorado squawfish.

3. To identity food organisms utilized by young Colorado squawfish.

4. To quantify competition between fish species, with emphasis upon interactions between young Colorado squawfish and other species for specific size food items.

5. To estimate predator-to-available-prey ratios for nursery habitats.

6. To quantify the potential for predation on various sizes for young Colorado squawfish.

7. To limnologically and physically characterize nursery areas utilized by larval Colorado squawfish.

Characterization of physical, chemical, and biological attributes of these backwaters, such as morphometry, structure availability, densities of phyto- and zooplankton and benthic macroinvertebrates, and predator-prey relationships are necessary to identify possible limiting factors that may control or affect the survival of Colorado squawfish populations.

The Green River Watershed

The watershed of the Green River, a fifth order stream located in southwest Wyoming, northwest Colorado, and northeastern Utah, encompasses about 44,700 mi^2 (Andrews 1986). The river flows through a semiarid region typically of rolling hills and deeply incised canyons (Annear and Neuhold 1983). Andrews (1986) described some hydrologic features of the Green River, especially streambed degradation and aggradation, that resulted from altered riverflow and sedimentation regimes that occurred after operation of Flaming Gorge Dam in 1962. Riverflow manipulation as required for power generation at Flaming Gorge Dam altered downstream riverine conditions from warm and turbid with native cyprinids to one with tailwaters of the dam more suited for salmonids (Stanford and Ward 1986). Below the Yampa River confluence, conditions more closely resemble historic conditions, and this area does provide habitat for sparse populations of endangered fish species. Annear and Neuhold (1983) described some limnological conditions in the Green River from Flaming Gorge Dam to a site near Jensen. Cooke and Ahern (1985) discussed potential water quality problems, particularly salinity issues, as they relate to expected future development of the Green River water resources.

METHODS AND MATERIAL

Study Area

Three widely separated areas in an 84-mile reach of the Green River, near Vernal, Utah, with a range of backwater types and with previously reported differing populations of larval Colorado squawfish were selected for the study with assistance of USFWS and USBR personnel. The three study areas were located at Island Park in Dinosaur National Monument, at Jensen downstream from the Route US 40 bridge over the Green River, and at Ouray on the Ouray National Wildlife Refuge (fig. 1). Previous studies by the USFWS and the Utah Department of Natural Resources indicated increasing abundance of larval Colorado squawfish in backwaters downstream from Island Park to Ouray. Abundance of larval Colorado squawfish was greatest in Ouray area backwaters.

In 1986, USFWS personnel familiar with the river designated certain backwaters that apparently persisted from year to year as "reference" backwaters, cnadidates for long-term study. They also defined five categories of backwaters, including ephemeral, deep side channel, tributary, wash, and flooded bottom. In 1987, the "reference" backwater at Island Park did not develop, however, so a main river site and two backwaters were selected upstream near the confluence of Garden Creek (BA 332.2) and at Big Island (BA 333.2). Garden Creek backwater was initially large but decreased substantially in size as river flows decreased during the summer and eventually became the "small" backwater at Island Park. Initially the small backwater was a backwater off a side channel of the river; this backwater dried up as riverflows dropped, resulting in a cut-off side channel. This was

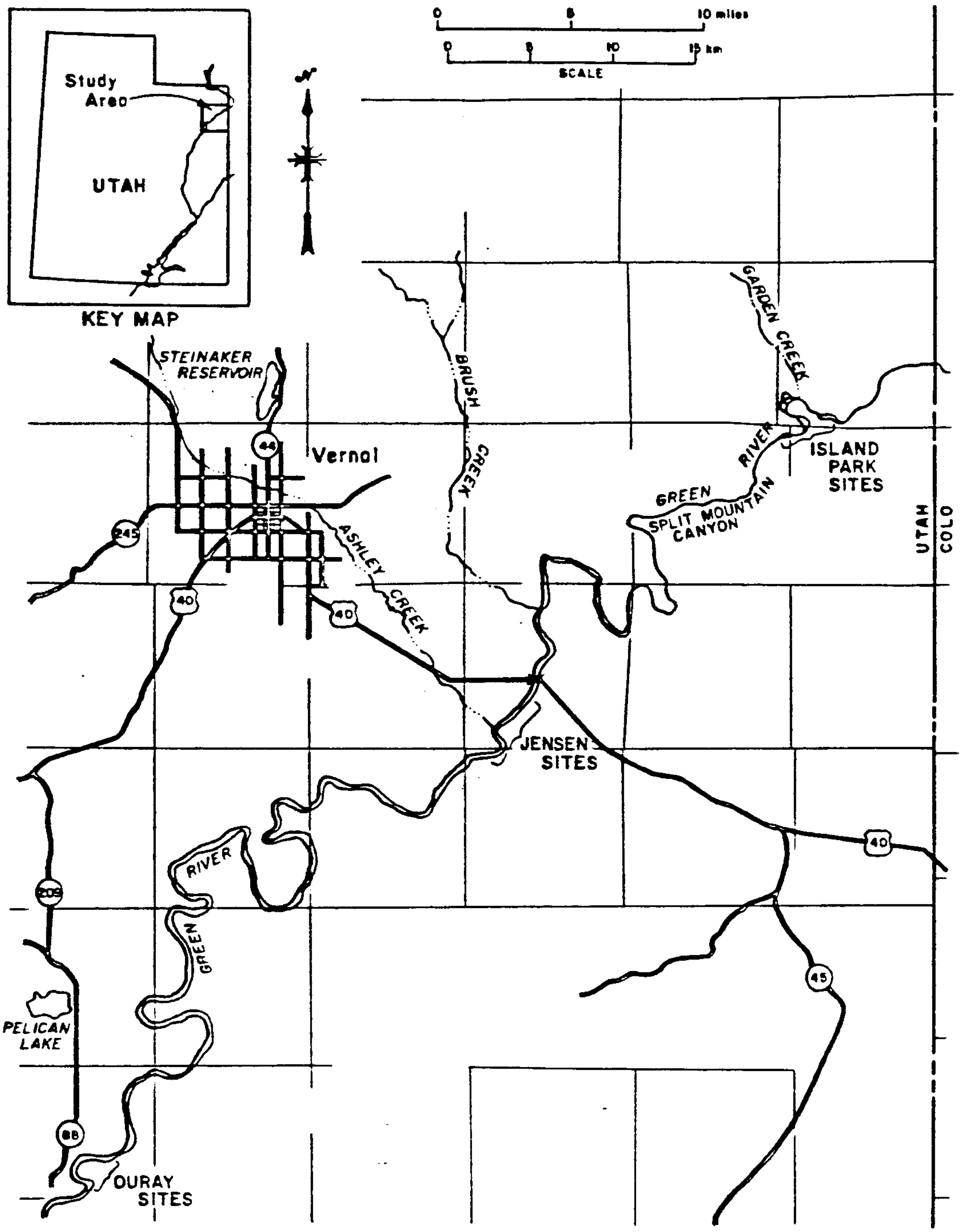

Figure 1. - The Green River near Vernal, Utah.

the "large" of Big Island backwater, designated BA 333.2. These two backwaters and the main river at about RMI 332.2 were sampled in 1987. In 1988, the BA 332.2 did not form, and was replaced with Rainbow Park, BA 327.6.

At Jensen, the designated reference backwater BA 300.26, persisted throughout the 1987 study period. A small, ephemeral backwater, BA 300.27 was located a short distance upstream from the reference backwater. This shallow, broad, backwater became intermittently isolated from the main river flows for short periods of time later in the season at low river flows. The main river was sampled at RMI 300.26. We sampled a backwater downstream at RMI 298.6, about 200 m upstream from the confluence with Squaw Creek, named BA 298.6 or Squaw Creek.

Among Jensen backwaters, only Squaw Creek formed in 1988, but it eventually dried up, so new backwaters were selected. An "ephemeral" backwater (BA 300.6), a long, narrow and deep backwater (BA 300.5, Pumps), a mid-season substitute for dried up Squaw Creek (BA 299.2, Deer Track) and a small backwater below an intermittent tributary (BA 298.4, Below Squaw Creek) were selected in 1988.

At Ouray, the reference backwater also dried up as riverflows decreased, but another smaller backwater formed at that site. This near-reference backwater (BA 251.0) persisted throughout both sampling seasons. The main river was sampled at RMI 251.0. A broad, shallow backwater at RMI 250.8 was designated Moult Bend (BA 250.8). Further downstream about 200 m upstream from the confluence with Old Charley Wash at RMI 249.7 was another backwater we selected for sampling. Old Charley Wash backwater (BA 249.7) in 1987 was similar in size, shape and orientation as Squaw Creek backwater. In 1988, BA 249.7 was dry, so BA 249.3 at the mouth of Old Charley Wash was sampled. A new, persistent, relatively deep, backwater at RMI 250.7 (Sand Beach) was added to the sampling program in 1988.

Mapping of backwaters was undertaken to determine their surface area and volume and to relate, if possible, size of these backwaters to limnological characteristics or other environmental attributes. Length of the backwater was measured. Two to five transects were then established and measured to determine width; depth was determined at three points along the transect. From this information, surface area and volume of backwaters was later estimated.

Figures 2 to 11 illustrate the general size and shape of the 10 backwaters sampled in 1988, at both high and low river flows. Surface area of shallow backwaters changes more noticeably than deeper backwaters. Surface area and volume for these backwaters are listed in Table 1.

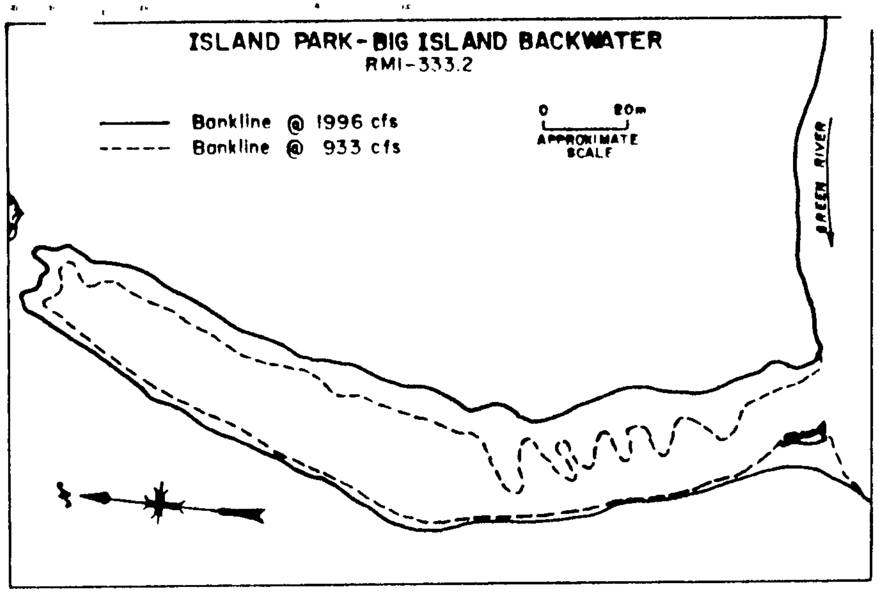

Figure 2. - Island Park Backwater 333.2, Big Island, 1988.

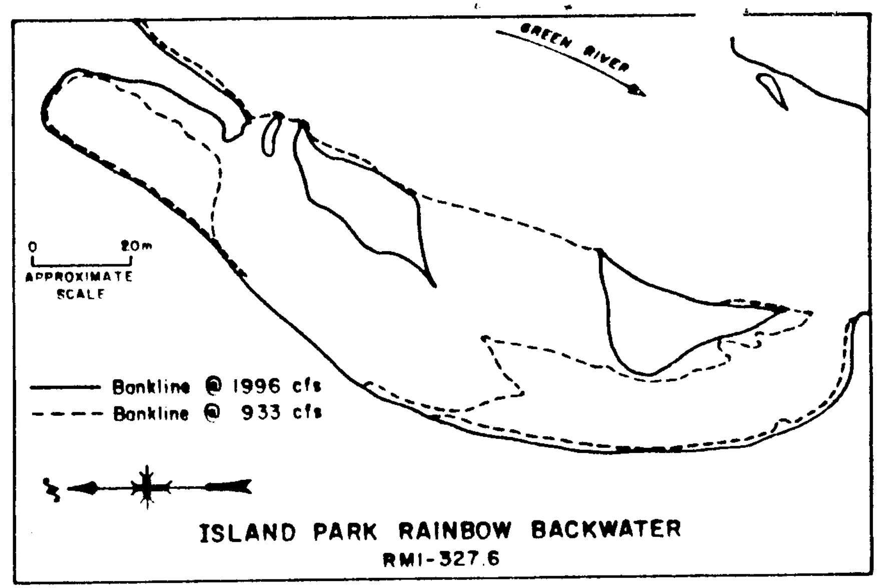

Figure 3. - Island Park Backwater 327.6, Rainbow Park, 1988.

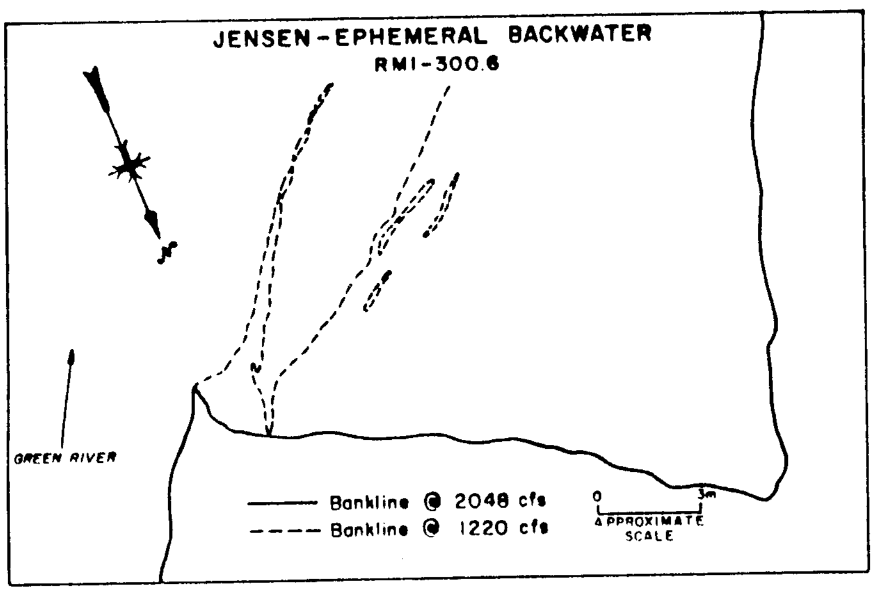

Figure 4. - Jensen Backwater 300.6, Ephemeral, 1988.

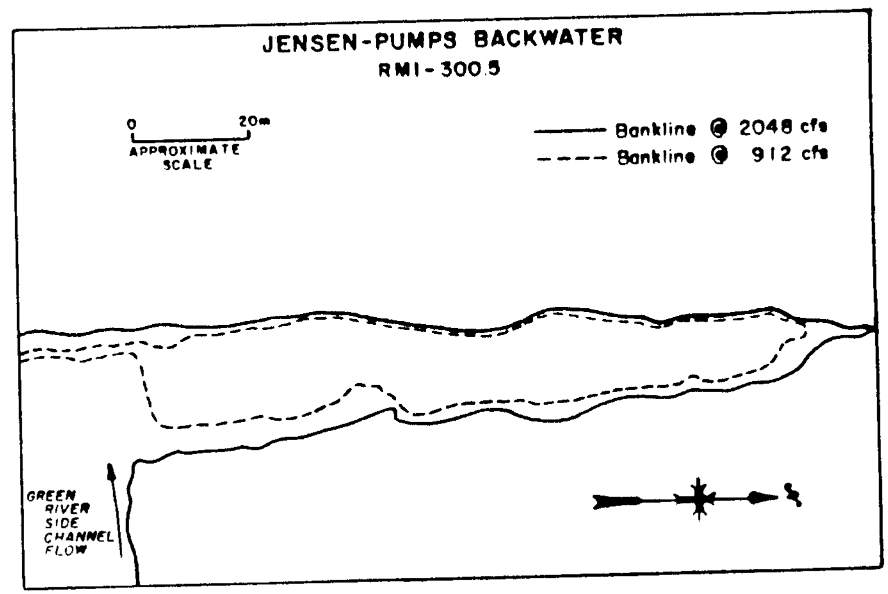

Figure 5. - Jensen Backwater 300.5, Pumps, 1988.

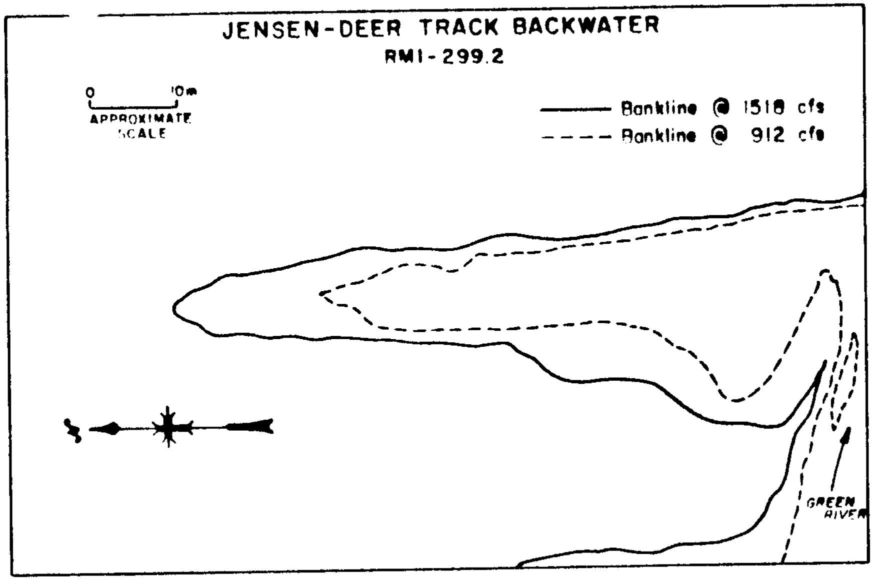

Figure 6. - Jensen Backwater 299.2, Deer Track, 1988.

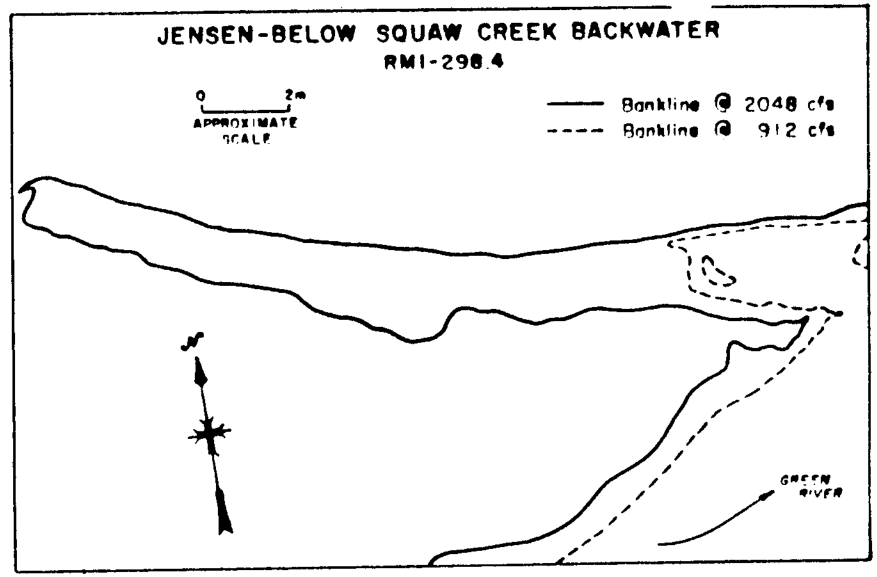

Figure 7. - Jensen Backwater 298.4, Below Squaw Creek, 1988

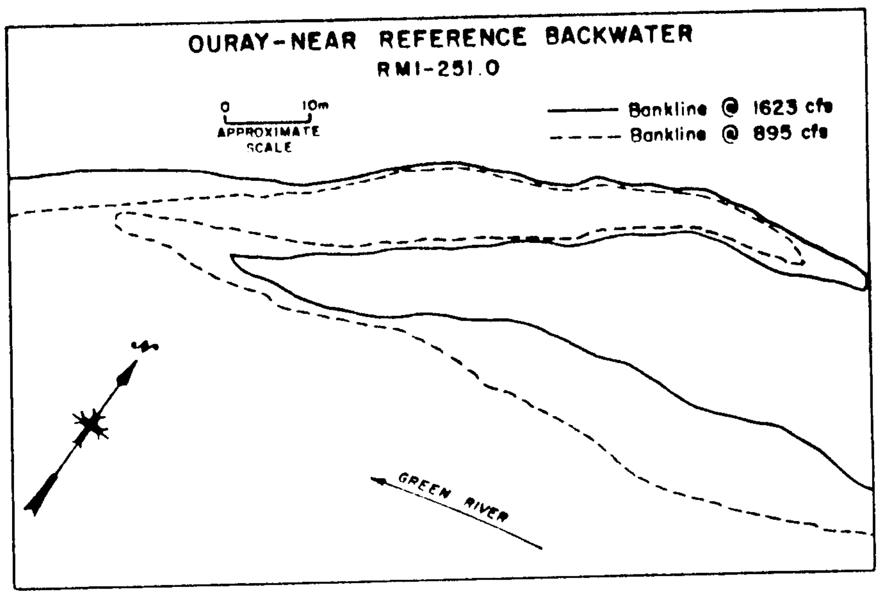

Figure 8. - Ouray Backwater 251.0, Near Reference, 1988.

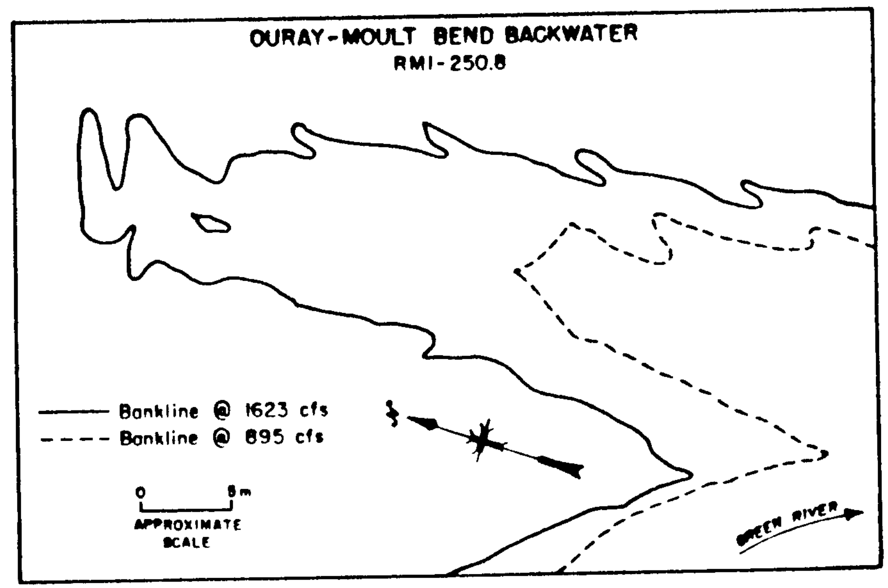

Figure 9. - Ouray Backwater 250.8, Moult Bend, 1988.

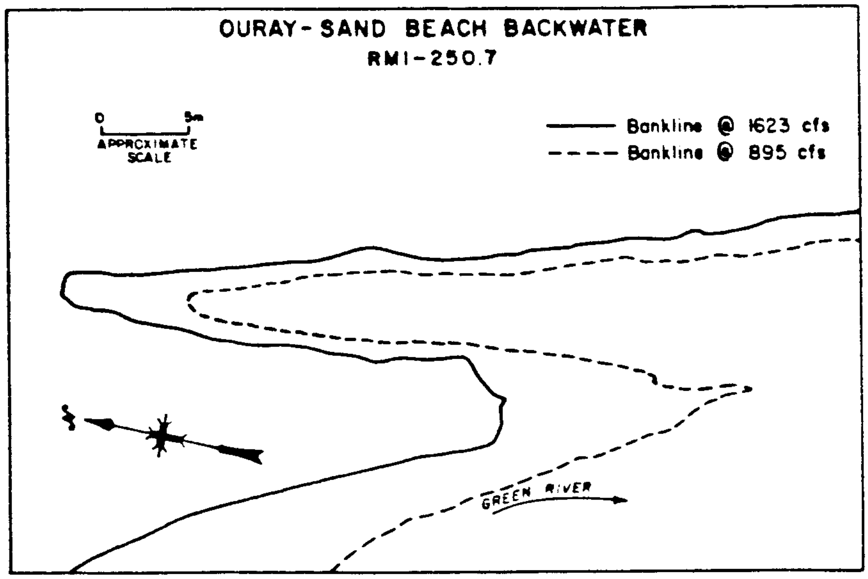

Figure 10. - Ouray Backwater 250.7, Sand Beach, 1988.

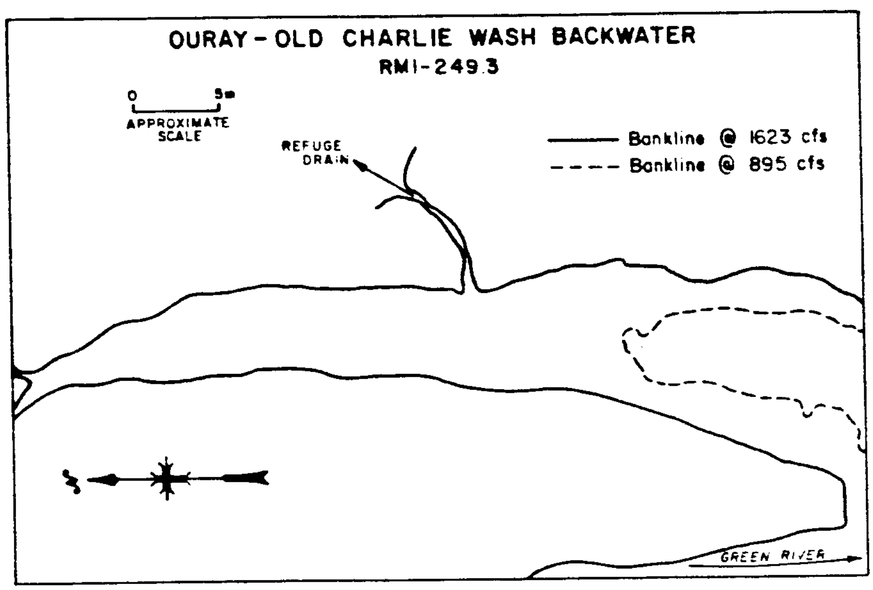

Figure 11. - Ouray Backwater 249.3, Old Charlie Wash, 1988.

Table 1. - Surface area and volumes of backwaters sampled at Island Park, Jensen, and Ouray on the Green River, Utah, in 1988.

GREEN RIVER BACKWATER VOLUMES 1988 — VOLUME IN CUBIC METERS, SURFACE IN SQUARE METERS

SAMPLING LOCATION	RIVERMILE INDEX	JULY 12-14 VOLUME	JULY 12-14 SURFACE	JULY 26-28 VOLUME	JULY 26-28 SURFACE	AUG 9-11 VOLUME	AUG 9-11 SURFACE	AUG 23-25 VOLUME	AUG 23-25 SURFACE	SEPT 6-8 VOLUME	SEPT 6-8 SURFACE	SEPT 20-22 VOLUME	SEPT 20-22 SURFACE	OCT 11-13 VOLUME	OCT 11-13 SURFACE
IP-BA-BIGISL	313.20	720.3	2810.1	657.5	2596.8	204.6	1564.5	222.4	2035.2	533.1	1949.5	322.5	2139.5	319.9	2469.6
IP-BA-RAINBO	327.00	429.4	1009.4	210.8	692.3	506.2	1733.8	347.7	1297.1	316.6	1184.8	404.7	1309.3	296.0	1495.9
JN-BA-EPHEM	300.60	1.6	42.9	24.9	235.3	2.9	22.6	13.2	150.9	19.3	259.1	8.0	137.3	4.0	117.7
JN-BA-PUMPS	300.50	450.8	779.5	365.8	757.9	273.0	576.6	288.1	646.4	131.3	447.2	189.1	557.3	211.4	597.9
JN-BA-ARVSOU	290.60	7.7	66.4	7.1	82.0	151.3	1518.0	128.4	664.3	43.1	377.1	38.0	312.5	84.4	575.9
JN-BA-BLWSOU	298.40	6.4	108.1	1.5	34.5	1.4	36.7	1.0	24.5	0.3	8.5	0.8	19.5	0.8	34.5
OU-BA-NEARPE	251.01	254.7	543.5	154.6	397.1	61.3	291.0	59.1	319.6	20.6	211.3	62.2	322.0	58.1	329.9
OU-BA-MOULT	250.80	67.3	459.0	31.8	325.6	4.7	120.6	7.3	127.2	6.6	108.5	5.4	112.6	2.6	78.2
OU-BA-SANDBE	250.60	27.4	94.5	19.4	79.0	59.5	183.4	53.5	158.2	41.9	150.2	54.4	163.7	46.6	164.4
OU-BA-OLDCHA	249.40	155.0	606.9	20.1	112.1	12.8	86.2	14.9	90.4	5.1	59.2	15.0	97.7	20.4	120.3

Limnological Sampling

At each study location (Island Park, Jensen, and Ouray) one main river and several backwater sites were sampled. The physical-chemical profile was collected using a Hydrolab Corp.[1] Surveyor II multiparameter probe which measured water temperature (°C), dissolved oxygen (mg/L), pH, specific conductance (μS/cm), and oxidation-reduction potential, used to calculate E_7, a measure of the proportion of oxidized to reduced constituents in an aquatic system (Reid and Wood 1976). In the main river, the calibrated multiparameter probe was held about 0.2 m below the water surface, in flowing water, and parameters were recorded after instrument equilibration. In the variously-sized backwaters, the probe was held between 0.1 and 0.3 m below the water surface, and parameters recorded after instrument equilibration.

Major ions, nutrients, and heavy metals. - Water samples for analysis of major ions (Na, K, Ca, Mg, HCO_3, CO_3, Cl, and SO_4), nutrients (total P, ortho-P, NO_3-N, NO_2-N, NH_3-N, and TKN), and heavy metals (Cd, Cu, Fe, Pb, Mn, Zn) were collected biweekly in the main river and backwaters. Initially, a one-liter water sample was collected for major ions and kept cold, a 500-mL water sample was collected for nutrients and placed on dry ice, and a 250-mL water sample was collected for heavy metals and preserved with 2.0 mL of concentrated HNO_3. Midway through the 1987 sampling season, based on initial water sample analyses, we increased the sampling interval of water samples for major ion and heavy metals from biweekly to quarterly. Only samples for nutrient

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[1]Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the Bureau of Reclamation.

analysis were collected in 1988. Water sample analyses were conducted in the Chemistry, Petrography, and Chemical Engineering Laboratory of the Bureau of Reclamation, or by contract, using methods in Standard Methods for the Examination of Water and Wastewater (APHA 1985) for major ions, phosphomolybdate method for total phosphorus and orthophosphate, the automated phenate method for ammonia, colorimetric method with sulfanilamide for nitrate and nitrite with hydrazine reduction used to convert nitrate to nitrite and flame and electrothermal atomic absorption spectroscopy for heavy metals.

Turbidity, light extinction coefficient and Secchi depth. - Turbidity was measured using a Hach Chemical Co. Model 16800 Turbidimeter, with backwater samples collected prior to any other sampling activity. The calibrated turbidimeter provided a direct readout of turbidity in NTUs. Light extinction coefficient is an index or measure of photic depth. Light penetration in both the main river and backwaters was calculated from readings obtained from a Kahl Scientific Instrument Corp. Model 268WA310 underwater irradiameter (limnophotometer). A reading was obtained in air, just beneath the water surface (0.01 m), then at 0.1 m depth increments to the bottom or to 1.0 m. When clouds were present, corresponding air readings (ambient) from a deck cell were recorded to adjust underwater readings for changing solar radiation. Secchi depth was also measured at each main river and backwater site.

Chlorophyll _a_. - Water samples were collected and filtered on-site for subsequent laboratory chlorophyll _a_ determination. Replicate 250 to 500 mL water samples from each site were vacuum-filtered through separate 0.45 μm pore-size fiberglass filters in the field; the folded filters were placed in separate labeled envelopes and placed on dry ice for transport to the laboratory for analysis. Chlorophyll a extraction and analysis was performed according to methods outlined in Parsons and Strickland (1963).

Particulate organic material. - Organic material composed of living or dead suspended particulate material is important to the ecosystem since it represents a potential food source for aquatic fauna such as zooplankton or larval fish. Two size-fractions (>25 μm and <25 μm) of inorganic and organic suspended particulate material in the river and backwaters were determined as follows; fifty liters of water were filtered through a 25 μm pore-size net. About 10 L of the filtrate passing through the 25-μm net was retained in a clean container. The >25 μm fraction retained by the net was collected and preserved with sufficient formalin to yield about a 2 percent solution for subsequent laboratory analysis. From the 10 L of filtrate that passed through the net (the <25 μm fraction), two replicate 500 to 1500 mL volumes were vacuum-filtered through separate, preweighed, preashed Gelman A/E fiberglass filters, and returned to the laboratory. These preweighed and numbered filters were dried in an oven, weighed, ashed to burn off the organic portion of the filtered material, and weighed to determine the percent of organic vs. inorganic material. The same procedure was used to separate organic from inorganic material in the >25 μm size-fraction.

Phytoplankton and zooplankton. - Duplicate 25-L water samples were collected and filtered through an 80 μm plankton net (in 1987) to determine abundance and identity of net phytoplankton and zooplankton in both the main river and backwaters. Samples were preserved in sufficient buffered formalin to yield a 5 percent concentration. In 1988, plankton samples were collected using a 25 μm plankton net. At selected sites, 1 liter of the <25 μm filtrate was carefully filtered through 0.45 µm pore-size polycarbonate filters to determine species composition and abundance of nannoplankton, defined as plankton in the size range 0.45 to 25 µm.

Benthic macroinvertebrates. - Bottom samples for determining species composition and abundance of benthic macroinvertebrates were collected with an 0.0232 m^2 (15 x 15 cm) Ekman sampler and screened in a 600 µm mesh littoral bucket. Replicate samples were collected at each main river and backwater site. Samples were preserved with sufficient buffered formalin to yield a final concentration of 5-10 percent for subsequent laboratory identificaiton and enumeration. Benthic organisms were sorted from the preserved samples, identified to lowest practical taxon, and enumerated. Questionable taxa were examined by personnel from the Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. Undetermined chironomid larvae were placed in the nearest genera or classified as unidentified. Dry weights of identified organisms were determined after overnight drying in an oven at 90 °C, to determine dry weight biomass/m^2. Benthic macroinvertebrates were identified using Pennak (1978), Merritt and Cummins (1978), Simpson and Bode (1980), Stewart and Loch (1973), Mason (1968) and Beck (1979).

Fish sampling and food habit studies. - Fish for food habit studies were provided by the USFWS in 1987; in 1988, we collected fish using a 3/16-inch (4.8 mm) mesh 10-foot-(3 m)-long seine, and a 1/16-inch (1.6 mm) larval seine. qualitative seine hauls were made and a subsample of the fish preserved for later analysis by the Larval Fish Laboratory (LFL), Colorado State University, Fort Collins, Colorado. At the LFL, specimen and sample examinations were performed under binocular dissecting or compound light microscopes fitted with calibrated eyepiece reticles. Data were entered directly into a Lotus 123 or dBase III+ computer file.

Fish samples were processed according to standard LFL procedures, i.e., species identification, measuring and counting of fish, and data reported by sample. Up to five fish specimens per species per sample representing a graded size series (total length; largest-smallest) were then selected for food habit analysis. Mouth gape width (Hubbs and Lagler 1974) and total length (mm) were measured for each fish collected in 1987, to compare with size range of available zooplankton and other prey. Digestive tracts (hereafter referred to as stomachs) were removed from fished using needle probes and fine dissecting scissors. After removal, each stomach was measured and its volume calculated. After measuring, each stomach was opened and its contents (food sample) washed into a watch glass. Percent stomach fullness for each fish was estimated visually. Individual food items were identified to the lowest practical taxon (considering reliability of identification, time, and cost) and enumerated. Data were grouped under two size categories per fish species (≤20 mm and >20 mm TL). These size categories were chosen to separate larval from YOY and 1+ juvenile fish (Snyder 1981). Percent composition by number (where possible) and percent frequency of occurrence of each food item by fish species and size category were determined.

Continuous monitoring. - Continuous recording of temperature, dissolved oxygen, pH, and specific conductance in one backwater per location, and in the river at Ouray in 1988, was done with a calibrated multiparameter data-recording probe set to record every 60 minutes. In addition, a digital recording pressure transducer was installed in Ouray BA 251.0 to monitor depths hourly during the 1988 sample season. The data collected were later dumped to a computer for analysis.

RESULTS AND DISCUSSION

Green River Flows

Water releases out of Flaming Gorge Dam into the Green River were fairly well-regulated in 1987 to provide previously-negotiated flow regimes for other ongoing studies. Flows out of Flaming Gorge Dam were gradually reduced from mid-June to about mid-August, to allow quantification of size and numbers of backwaters at various flows using remote sensing techniques, and to determine which flows maximize backwater development. Daily average flows in the Green River from June to November 1987 and July to October 1988 are shown in figure 12; sampling periods are highlighted to show flow conditions.

Physical and Chemical Parameters

Water temperature

Main River. - In 1987, water temperature initially increased from early June to a high in early August at Island Park, Jensen and Ouray, then decreased steadily to the last sampling period in mid-November. During most sampling periods water temperature increased from Island Park downstream to Ouray. However, in mid-November, main river water temperature was lower downstream. Main river water temperatures ranged from 4.54 to 20.81 °C in 1987 and 10.59 to 23.3 °C in 1988 at Island Park, 3.43 to 22.55 °C in 1987 and 10.63 to 23.95 °C in 1988 at Jensen, and 1.72 to 24.18 °C in 1987 and from 11.74 to 24.31 °C in 1988 at Ouray. Main river water temperatures generally were warmer downstream in 1988, with the maximum water temperature recorded earlier in the season than in 1987. Maximum water temperatures among main river sites

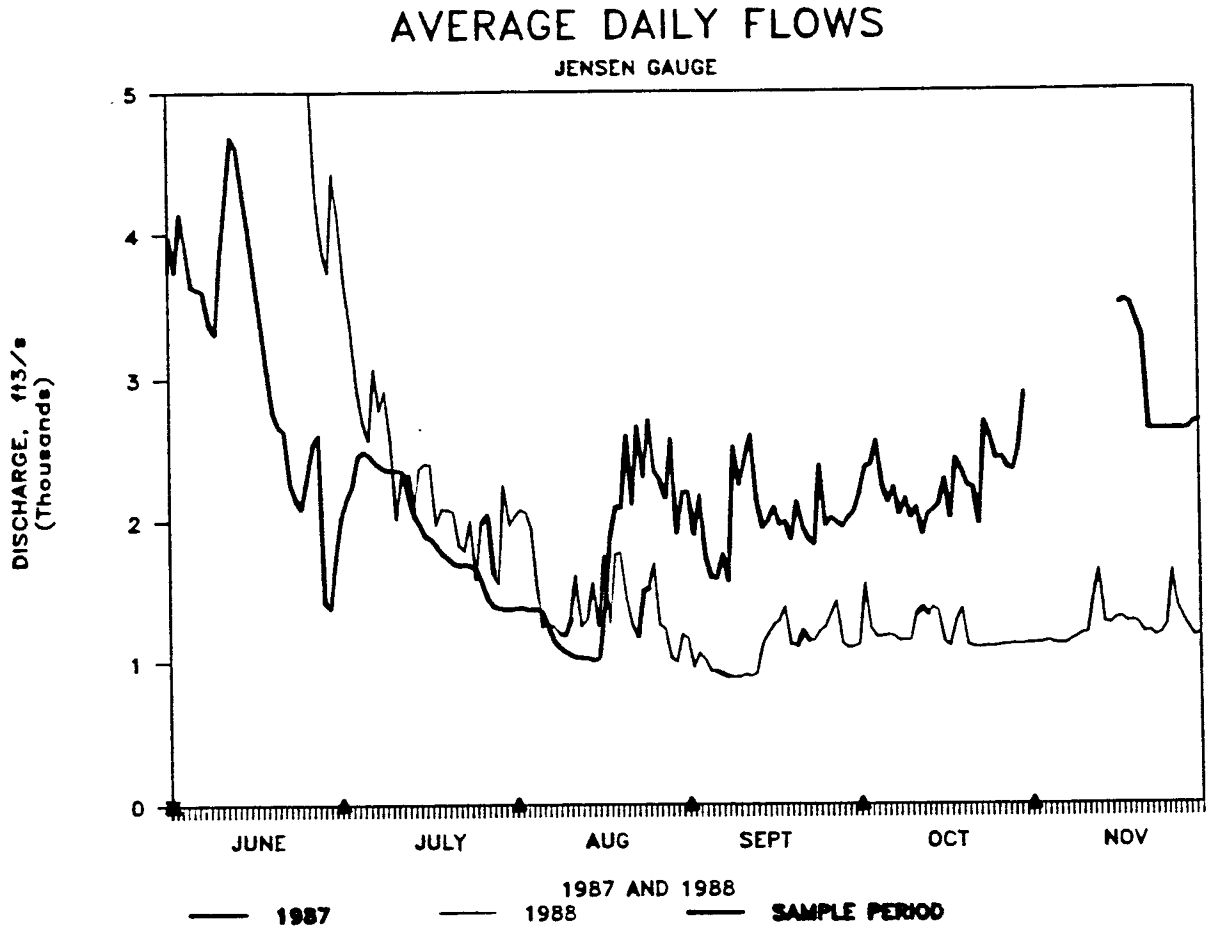

Figure 12. - Averaged daily Green River flows measured at the Jensen, Utah, gauge, June to November, 1987 and 1988.

in 1988 did not coincide as closely as they did in 1987, with highest water temperature at Island Park occurring 2 weeks prior to that at Jensen, and maximum recorded water temperature at Jensen occurring about 1 month prior to that at Ouray. This may be a result of the different flow regime in the river in 1988 compared to 1987. After the latter part of August, water temperatures at all main river sites decreased through the end of the sampling season. Seasonal water temperature fluctuations in the river were greater at Ouray than at upstream sites.

Backwaters. - Water temperatures were higher in both the small and large Island Park backwaters compared to the main river in both years, except the large backwater in mid-November 1987. Water temperatures in the small backwater ranged from a high of 22.1 °C in early August to a low of 3.8 °C by mid-November. Water temperature in the larger backwater in 1987 ranged from 26.8 °C in early August to 5.4 °C by mid-November. In 1988, both backwaters were fairly large and warmer than the river by an average of 3.8 °C.

Water temperature in Jensen backwaters in 1987 reached an average high of 25.2 °C in August then decreased steadily to 4.1 °C in mid-November. the Jensen reference backwater (BA 300.26) was cooler than the main river, while other backwaters were always warmer than the main river. Squaw Creek (BA 298.6) was generally the warmest backwater sampled at Jensen in 1987. In 1988, backwaters averaged 3.6 °C warmer than the main river, which averaged 18.9 °C.

Water temperatures for several Ouray backwaters in 1987 increased to 27.1 °C in early August, then decreased through mid-November. Seasonal average water temperatures were generally higher at Ouray than at Island Park and Jensen. The water temperature at Ouray BA 251.0 was close to that of the main river, while Moult Bend and Old Charley Wash backwaters were warmer. Old Charley Wash backwater was warmer than Moult Bend except in early August. Ice formed on many backwaters in November.

In 1988, water temperatures peaked in late August at Ouray BA 250.8 and BA 250.7, but in late July in BA 251.0 and BA 249.3, then decreased to mid-October. Backwaters averaged 2.5 °C warmer than the 20.4 °C average in the river. BA 250.8 (Moult Bend) was shallower in 1988, and with the highest seasonal average temperature of 25.9 °C, was the warmest backwater at Ouray. Neuswanger (1980) reported higher surface water temperatures in a Mississippi River backwater compared to the main channel.

Dissolved oxygen

Main River. - Dissolved oxygen levels at three main river sites generally exhibited a trend opposite to that seen for seasonal water temperature. Dissolved oxygen decreased to a low in early August then increased steadily into the fall. Dissolved oxygen levels downstream at Ouray were usually lower than upstream at Island Park. The minimum dissolved oxygen levels of 6.5 mg/L and 6.24 mg/L for 1987 and 1988, respectively, both occurred at Ouray. A greater seasonal change in both temperature and dissolved oxygen concentrations occurred downstream at Ouray compared to upstream at Island Park.

Backwaters. - Dissolved oxygen concentrations generally increased as water temperature decreased in both the main river and backwaters at Island Park.

Dissolved oxygen in Island Park BA 332.2 was slightly lower at 8.1 mg/L than the 8.5 mg/L measured in the main river, coincident with the slightly higher water temperature in the backwater. Average dissolved oxygen concentration in backwaters at Island Park were lower by about 0.5 mg/L in 1988 compared to 1987.

Dissolved oxygen concentrations in Jensen backwaters varied considerably during the 2 sampling seasons. In 1987, the lowest dissolved oxygen level of 4.15 mg/L was measured in BA 300.26 in early August; it later increased to 9.75 mg/L in mid-November. Dissolved oxygen levels in other backwaters fluctuated seasonally, but were generally greater than 5.0 mg/L. Dissolved oxygen levels in BA 298.6 corresponded closely with those in the river. The highest dissolved oxygen level measured in Squaw Creek was 9.51 mg/L in late October.

In 1988, dissolved oxygen levels averaged higher in backwaters compared to the main river. Seasonal average dissolved oxygen concentrations were 7.2 and 8.2 mg/L for the main river and backwaters, respectively.

Dissolved oxygen concentrations at Ouray also varied seasonally and inversely with water temperature. In 1988, Moult Bend backwater had dramatic fluctuations in dissolved oxygen. Dissolved oxygen levels at Ouray backwaters were usually above 5 mg/L, but reached a minimum of 4.57 mg/L at Moult Bend in mid-August, 1988.

pH

Main River. - Seasonal average pH at all main river sites was around 8.5-8.6.

pH generally increased in September then decreased in the fall. A slight decrease in pH occurred in mid-August 1987 at each of the three main river sites, subsequent to increased riverflows. In 1988, no substantial decrease in pH was observed; riverflows were lower but more stable in 1988 compared to 1987.

Backwaters. - The average seasonal pH of 8.44 and 8.35 in Island Park backwaters in 1987 and 1988, respectively, was lower than the 8.60 average in the river. pH fluctuated more in 1987 than in 1988. Generally, the pH in BA 332.2 was close to that of the river. pH in BA 333.2 and BA 327.6 in 1988 was usually less than that of the main river.

pH averaged 8.45 in the Jensen backwaters during the 1987 sampling season, with greatest pH range of from 7.87 to 8.6 found in the reference backwater BA 300.26. Lower pH in the reference backwater, earlier in the 1987 sampling season, may be related to being more shaded than other backwaters, resulting in reduced primary production.

pH in Jensen backwaters averaged 8.4 in 1988, while main river pH averaged 8.5.

pH averaged 8.48 in Ouray backwaters in 1987, with the greatest range of 8.05 to 8.69 in the near-reference backwater. The lowest pH of 8.11 in Ouray backwaters in 1988 also occurred in the near-reference backwater. pH was highest at all sites in late September of both years.

Specific Conductance

Main river. - Specific conductance at the main river sites was low early in the season, increased steadily to late September, and decreased in the fall. Specific conductance was higher downstream at Ouray than upstream at Island Park, except in late September 1987. Ouray specific conductance peaked at 806 µS/cm in late October 1987. The lowest specific conductance of 451 µS/cm was measured at Island Park in early June. In 1988 maximum river specific conductance of 872 µS/cm again occurred at Ouray in late September, with the minimum of 603 µS/cm at Island Park in mid-July.

Backwaters. - Specific conductance in most backwaters generally peaked about the third week of September, followed by a decline in the fall. Specific conductance in Island Park BA 332.2 in 1987 was almost identical to that of the main river (659 µS/cm), except in mid-November when BA 332.2 increased in size due to increasing riverflows, resulting in decreased specific conductance. In 1988, an average specific conductance of 1277 µS/cm in BA 333.2 was almost twice that measured in the river. Specific conductance in BA 333.2 in 1987 ranged from 564 to 854 µS/cm, while in 1988 it ranged from 874 to 1520 µS/cm.

Specific conductance in Jensen backwaters averaged 685 µS/cm in 1987, ranging from 465 to 781 µS/cm, and 1154 µS/cm in 1988, ranging from 628 to 4530 µS/cm.

Specific conductance was substantially greater in Jensen backwaters in 1988, with the two upstream-most backwaters having relatively high values. In early September, BA 300.5 (Pumps) had a high specific conductance of 4530 µS/cm, followed by a decrease to 1660 µS/cm by mid-October. Specific conductance in other backwaters corresponded more closely to that in the river. BA 300.5 was a source of irrigation water. The dramatic increase in specific conductance in this backwater in September when river specific conductance was 793 µS/cm, is not easily explained, unless some saline irrigation return flows enter this backwater.

Specific conductance increased to a high in late September in Ouray backwaters, and was similar at all sites except Moult Bend in early August, 1987. Specific conductance averaged 800 and 864 µS/cm in 1987 and 1988 respectively.

$\underline{E_7}$

Backwaters. - Oxidation-reduction potential adjusted to pH 7.0 defines E_7 and indicates the possibility of release of heavy metals from the sediments, if E_7 falls much below 300 mV (Sartoris, et al. 1981). E_7 at or near the water-sediment interface would provide an index of the intensity of chemical reactions there. E_7 was calculated for all sites, although it is more important to consider it in backwaters than in the river. Only once at Ouray was E_7 below 300 mV, suggesting that oxidizing rather than reducing conditions prevailed in the backwaters, and that release of heavy metals from the sediments is unlikely. Results of water analyses for heavy metals in 1987 revealed very low or non-detectable levels of heavy metals.

Backwaters at Island Park, Jensen, and Ouray appear to be oxidizing rather than reducing, minimizing the potential for release of heavy metals from sediments.

Turbidity

Main river. - Turbidity generally increased from upstream at Island Park to downstream at Ouray, except for mid-August, 1987, when turbidity at Island Park was greater than at Jensen but less than the 946 NTU measured at Ouray, and again in mid-August, 1988, when turbidity was higher upstream at Island Park than downstream at Ouray. The significant increase in turbidity in mid-August was due to increased river flows. Except for mid-August, turbidity did not vary much among main river sites.

Backwaters. - No clear pattern emerged when comparing main river and backwaters turbidities at Island Park in 1987 and 1988. During early June, mid-August and late fall 1987 the river was more turbid than the backwaters; at other times backwaters were more turbid than the main river. Average seasonal turbidity in the river at Island Park in 1988 was about 2.5 times the 1987 average turbidity of 37 NTU, but average seasonal turbidity in Island Park backwaters was lower in 1988 than in 1987. Turbidity peaked in early to mid-August both years. Turbidity in the small backwater was close to that of the main river, while turbidity in the large backwater was often greater than in the main river.

In 1987, turbidity in Jensen backwaters reached a maximum of 72 NTU in mid-August, then decreased to relatively low levels in both the river and backwaters and remained low at least until mid-November. Early in the season, turbidity was lower in the main river than in most of the Jensen backwaters, while later in the season, and coincidentally corresponding to lower river flows, turbidity was greater in the main river than in the backwaters.

Turbidity in Jensen backwaters averaged 33.8 NTU in 1988, very similar to the 1987 average of 33.5 NTU.

Turbidity in Ouray backwaters averaged 49 NTU, ranging from 12 to 117 NTU in 1987; in 1988, they averaged 59 NTU, ranging from 19 to 239 NTU. The highest turbidity of 239 NTU occurred in Moult Bend in mid-August. Average turbidity in backwaters increased downstream from Island Park to Ouray, as did main river turbidity. Although turbidity levels throughout the study area sometimes exceeded turbidity stnadards established by several states, there is no consensus regarding allowable levels for protection of fish, especially fish species that evolved in ecosystems that experience periodic high turbidity levels (Lloyd 1987).

Light Extinction Coefficient and Secchi Depth

Main river. - Light extinction coefficient is an index of light penetration in a water column. Both the light extinction coefficient and the Secchi depth fluctuated considerably during both sampling seasons, but in general light penetration was greater upstream compared to downstream in both years, consistent with downstream increases in turbidity. Low light extinction coefficients are usually accompanied by greater Secchi depths. High riverflows accompanied by very turbid conditions during early and mid-season decreased light penetration. The greatest light extinction coefficient of 12.96 occurred at Jensen in late July 1987 while the lowest coefficient of 0.73 was calculated for Island Park in early September 1988.

Backwaters. - Generally, light extinction coefficients were higher in backwaters than in the main river at Island Park, but with no consistent seasonal pattern. Secchi depth was reduced when light extinction coefficient was high. Due to occasional shallow water levels in backwaters, the light extinction coefficient could not be calculated.

Light penetration in Jensen backwaters fluctuated greatly for about the first half of the 1987 sampling season, then increased and remained relatively constant for the remainder of the season. Lower stable flows with lower turbidity later in the season resulted in greater light penetration. Light penetration in backwaters was generally greater than in the main river in 1987, while in 1988, light penetration was often greater in the river than in backwaters. Secchi depths were often 10 to 15 cm greater in Missouri River open backwaters than in the nearby main channel (Persons, 1979).

Light penetration in Ouray backwaters increased during the 1987 sampling season, with no clear pattern among the several sites. During the 1988 sampling season, light extinction coefficient did not exhibit any obvious seasonal trend. The river at Ouray in both years was usually clearer than backwaters. Carp were sometimes observed flailing about in backwaters, which contributed to turbidity and hence, reduced light penetration.

The euphotic depth, or depth in the water column with sufficient light energy to drive photosynthesis, is generally considered to be down to the depth of the 1 percent light level. In the shallow rivers and backwaters the 1 percent light level is rarely reached, except during episodes of extremely high turbidity, indicating that light energy for photosynthesis is rarely limiting.

<u>Major ions, nutrients and heavy metals</u>

Major ions. - Total dissolved solids, as determined in the laboratory, increased in the river during the 1987 sampling season, and generally from upstream at Island Park to downstream at Ouray. Island Park backwaters had a greater average TDS than the river throughout the sampling season. Except for late June, average TDS in Jensen and Ouray backwaters was less than the river. The highest TDS measured was 514 mg/L in the river at Ouray in mid-November, 1987. For the early season samples, the increase in TDS may be the result of decreased average riverflows, as found in backwaters in the lower Colorado River (Hiebert and Grabowski 1988).

Calcium was the most abundant cation in the river and backwaters, followed by sodium, magnesium, and potassium. Concentration of cations generally increased from early June to late July, at each of the three main river sites, and to a lesser extent from upstream at Island Park to downstream at Ouray. Among the anions, bicarbonate often predominated, followed by sulfate and chloride. Occassionally, sulfate levels exceeded bicarbonate, especially downstream and later in the season.

Phosphorus. - Relatively low concentrations of nutrients were measured in the Green River and associated backwaters during the 2 years of this study. Total phosphorus (TP) was always detected, but orthophosphate (soluble reactive phosphorus) was detectable in only 25 of 92 samples from 1987 and in 52 of 91 samples from 1988. Five of the 25 1987 samples with detectable orthophosphate occurred in mid-August during the very turbid conditions associated with higher flows. Orthophosphate was detected more often late in the 1987 season. In 1988, orthophosphate was more common in Ouray backwaters than at upstream backwaters. Orthophosphate is typically present in concentrations of 10 percent or less of TP (Hynes 1970). Bacterial and other chemical actions tend to release and recycle phosphate rapidly (Hynes 1970; Reid and Wood 1976), so

TP is a valid measure of phosphorus availability.

On a seasonal basis, average concentration of TP increased from 0.015 mg/L upstream at Island Park to 0.035 mg/L downstream at Ouray in the river in 1987. In 1988, average TP was highest at Island Park, at 0.032 mg/L, decreased to 0.020 mg/L at Jensen then increased to 0.028 mg/L at Ouray. In 1987 TP averaged 0.022 mg/L in both Island Park and Jensen backwaters, and increased to 0.031 mg/L in Ouray backwaters. Similarly, in 1988, average TP was 0.022 mg/L at both Island Park and Jensen backwaters, but increased to 0.038 mg/L in Ouray backwaters. In 1987, average TP in Island Park backwaters exceeded that measured in the river, was almost the same at Jensen, while at Ouray, average TP in backwaters was less than that found in the river. In 1988, average TP in Island Park backwaters was less than in the river, again was about the same at Jensen, and at Ouray, average TP was greater in backwaters than in the river. BA 250.8 (Moult Bend) had the highest seasonal average TP during both years.

At Jensen, during 1987, TP fluctuated throughout the sampling season with the lowest concentration in September and the highest concentrations in mid-August. Concentrations in backwaters usually equalled or exceeded concentrations in the river, and lower concentrations occurred in the small backwater compared to the reference or Squaw Creek backwaters.

Nitrogen. - Nitrogen is an essential nutrient for algae and macrophyte metabolism, and for later incorporation into tissues of grazing and predatory animals. More chemical and biological reactions are involved in the conversion of nitrogen species. The organic forms of nitrogen like proteins, amines and amino acids, are broken down into the simpler inorganic molecules nitrate-N, nitrite-N, and ammonia-N (NO_3-N, NO_2-N, NH_3-N). Total inorganic introgen (TIN) is the sum of nitrate, nitrite, and ammonia, with nitrite a minor component. Nitrite was present in only eight samples in 1987; in 1988, nitrite occurred in 43 of 92 water samples; 9 from the river and 34 from backwaters, and then in low concentrations. Low concentrations or the absence of nitrite indicate that the Green River is a relatively unpolluted system (Reid and Wood 1976). In some cases, none of the three inorganic forms of nitrogen were detected at a particular site. A nondetectable level of a nitrogen form at a site was considered zero for the analysis.

Ammonia and nitrate are easily assimilated by algae (Brezonik 1972). Nitrite is converted to nitrate by bacterial action. TIN is, therefore, a good measure of biologically available nitrogen in rivers and backwaters.

Average TIN increased from upstream to downstream in the river in 1987, increasing from 0.050 mg/L at Island Park to 0.121 mg/L at Ouray. Only a 0.005 mg/L increase occurred between Island Park and Jensen. In 1988, average TIN in the river was highest at Jensen at 0.120 mg/L and lowest at Ouray at 0.103 mg/L. In backwaters, average TIN concentrations were less than concentrations in the river and increased downstream, averaging 0.070 mg/L and 0.116 mg/L in Ouray backwaters in 1987 and 1988, respectively.

Generally, there is seasonal fluctuation in TIN in the main river. Meybeck et al. (1988) reported seasonal variability in nutrient concentrations in the River Loire. With a few exceptions, TIN concentrations peaked in mid-August at both river and backwater sites. This peak coincided with the peak of total phosphorus concentrations and with high riverflows. Sheaffer (1984) reported that backwater habitats receive an influx of nutrients from the main channel during high riverflows.

The nitrogen to phosphorus ratio is sometimes used as an indicator of whether an aquatic system is nitrogen or phosphous limited. Lambou (1976) uses TIN/TP since the breakdown and recycling of organic phosphate is more rapid and less complicated chemically than recycling of nitrogen. Using TIN:OP is valid since it represents nutrients easily assimilated by algae (Grimm, et al. 1981). Using the criterion of an N:P ratio near 15:1 to differentiate nitrogen-limited from phosphorus-limited systems, the river at Ouray and Moult Bend backwater were phosphorus-limited, and the near reference and Old Charley Wash backwaters were nitrogen-limited, in 1987. In 1988, OP was detected more often than in 1987. Average seasonal TIN:OP in the river was 22.8, 41.3, and 25.9 at Island Park, Jensen, and Ouray, respectively. For combined backwaters, TIN:OP was 18.8, 17.7, and 20.4 for Island Park, Jensen and Ouray, respectively. Overall, using the criterion TIN:OP, the Green River and associated backwaters are phosphorus-limited. Seasonal averages for specific backwaters ranged from 7.9 to 28.6. The range for all backwaters for all sampling dates is from 1.61 to 62.0. The trend in nutrient limitation is one of nitrogen limitation early in the season, with a switch to phosphorus limitation in both the river and backwaters after about mid-August. Backwaters act uniquely, with some going from a nitrogen-limited condition to phosphorus-limited earlier or later than mid-August. Two Ouray backwaters only 0.1 mile apart (Moult Bend and Sand Beach) acted entirely different from each other. Moult Bend remained nitrogen-limited until early September, while

Sand Beach became phosphorus-limited in late July. These data are in contrast to those of Grimm, et al. (1981), who used TIN:OP and who found low N:P in free flowing desert streams.

Using TIN:TP as an index of nutrient limitation, the Green River system was always nitrogen-limited in 1987, and frequently so in 1988. The average TIN:TP ratio for the main river and backwaters ranged from 2.62 to 3.46 for the river and from 1.56 to 2.57 in backwaters in 1987, and from 1.16 to 18.86 in the river and, from 1.11 to 16.50 in backwaters in 1988. In the river, TIN:TP decreased from 3.33 at Island Park to 2.62 at Jensen, then increased to 3.35 at Ouray; the opposite pattern prevailed in 1988. In backwaters, TIN:TP increased progressively downstream from 1.76 at Island Park to 2.32 at Ouray in 1987; in 1988, Jensen was higher at 5.30 than Island Park or Ouray. Hill and Rai (1984) reported an NO_3-N:PO_4 ratio of 2:1 in the Kern River, California.

Brush Creek and Ashley Creek, two tributary inflows into the Green River near Jensen, had seasonal average TIN concentrations of 0.74 and 4.79 mg/L, respectively. OP was detected only once in Ashley Creek, and not at all in Brush Creek. Seasonal TP averaged 0.013 and 0.024 mg/L for Brush and Ashley creeks, respectively. TIN:TP ratios indicate phosphorus-limiting conditions in these tributary streams, except for Brush Creek in early September. Ashley Creek drains more of an irrigated agriculture watershed than Brush Creek, and the likely use of chemical fertilizers for crop production coupled with runoff and return flow, results in high levels of TIN, especially NO_3-N, in the creek. TP is not elevated in Ashley Creek compared to other Green River sites, but both TIN and TP increase downriver at Ouray. Increased nitrate entering the river from Ashley Creek may account for the higher TIN:OP ratio in the river at Ouray, although Ouray is about 40 miles downstream from Ashley Creek and the flow of the Green River is large compared to the creek. Kaushik et al. (1981) reported that fertilizer used in agriculture could increase nitrate levels in streams.

Heavy metals. - Water samples were analyzed for cadmium, copper, iron, lead, manganese, and zinc in 1987. The seasonal average heavy metal concentrations and concentrations by sample date for 1987 are shown in the appendix. Copper was constant at 0.002 mg/L at all main river sites. In backwaters, copper was slightly higher compared to the river, but also relatively uniform from upstream to downstream. Except for BA 332.2 at Island Park, the concentration of copper did not exceed the EPA standard of 0.010 mg/L.

Iron concentrations increased in the river from upstream to downstream, by an order of magnitude between Island Park and Jensen. Iron concentrations were higher in backwaters, but at Island Park backwaters the seasonal average concentration was almost an order of magnitude greater, compared to the river, while at Jensen and Ouray backwaters, the iron concentration was only slightly greater. Iron concentrations did not exceed the EPA water quality standard of 1.0 mg/L for freshwater aquatic life, and only twice, at Ouray, did it exceed the EPA standard of 0.3 mg/L for iron in domestic water supplies.

Lead concentrations increased in the river from upstream at Island Park to downstream to Ouray. Average seasonal concentrations in backwaters were greater than in the river at all sites, with the greatest average difference occurring at Island Park. Lead concentrations did not exceed the EPA water quality standard of 50 µg/L (0.050 mg/L) any time during the study.

Manganese concentrations increased downstream in the river, with the greatest increase occurring between Island Park and Jensen. Backwaters again had higher concentrations than the main river, with the highest seasonal average manganese concentration occurring at Jensen in BA 300.26. On several occasions throughout the 1987 sampling season, manganese exceeded the EPA domestic water quality standard of 50 µg/L (0.050 mg/L).

Average concentrations of zinc in the main river increased downstream, by an order of magnitude between Island Park and Jensen, but with slight decrease between Jensen and Ouray. Zinc concentrations were much higher in Island Park backwaters compared to the river than in Jensen or Ouray backwaters, with zinc concentrations in Ouray backwaters higher than in Jensen backwaters. Jensen and Ouray backwaters had higher zinc concentrations compared to the river. Zinc concentrations at all sites were well below the EPA water quality standard of 5 mg/L.

Cadmium concentrations decreased downstream, with the same concentration found in the river at both Island Park and Jensen, and a decrease between Jensen and Ouray. Cadmium concentrations in backwaters decreased downstream, to a low in Ouray backwaters. Cadmium concentrations were slightly lower in Jensen backwaters, and slightly higher in Ouray backwaters compared to the river. At Island Park BA 332.2, cadmium exceeded the EPA water quality standard of 0.010 mg/L.

Iron, lead, manganese and zinc concentrations increased in the river and backwaters from upstream at Island Park to downstream at Ouray. Metal concentrations in backwaters were generally higher, compared to the river. Copper concentrations were the same at the three river sites; concentrations in backwaters were higher compared to the river, but about the same for backwaters at all sites. Cadmium concentrations decreased from upstream to downstream in both the river and backwaters. Most metal concentrations were below published EPA water quality standards, with manganese being the notable exception. Metal concentrations should not pose a threat to aquatic life in this reach of the Green River.

Chlorophyll a

Chlorophyll a concentrations for both total and the <25 μm size-fraction were determined for the Green River and each backwater to serve as an index of algal biomass.

Main river. - Total chlorophyll a levels in the river ranged from 1.54 mg/m^3 at Jensen in late October to 17.64 mg/m^3 at Ouray in early June, with a 1987 average for the river of 5.77 mg/m^3. Chlorophyll a in the <25 μm size-fraction averaged 69 percent (ranging from 60 to 75 percent) of the main river chlorophyll a.

Total chlorophyll a in the main river in 1988 averaged 4.35 mg/m^3, with the highest average of 6.09 mg/m^3 at Ouray. Total chlorophyll a concentrations from the river were lowest in late August and early September, 1988. Chlorophyll a in the <25 μm size-fraction averaged 85 percent of the total river chlorophyll a, ranging from 55 to 100 percent.

Backwaters. - Chlorophyll a in Island Park, Jensen and Ouray backwaters averaged 3.43 mg/m^3, 5.69 mg/m^3, and 6.93 mg/m^3, respectively. In Island Park backwaters, the highest chlorophyll a of 7.51 mg/m^3 was in BA 333.2 on August 4. The lowest chlorophyll a, 0.47 mg/m^3, also occurred in BA 333.2, on October 20. Jensen BA 300.26 had a high chlorophyll a of 20.03 mg/m^3 on August 19 and the lowest concentration of 0.71 mg/m^3 in late October. Ouray BA 251.0 had a high chlorophyll a of 15.24 mg/m^3 in early June and a low of 1.8 mg/m^3 in mid-November. Average chlorophyll a in backwaters increased from upstream at Island Park to downstream at Ouray. Jensen BA 300.26 had the highest seasonal average chlorophyll a concentration of 9.65 mg/m^3. BA 332.2

at Island Park had the lowest seasonal average chlorophyll a of 3.26 mg/m^3.

The <25 μm size-fraction of chlorophyll a averaged 87 percent (ranging from 72 to 100 percent) of total chlorophyll a in backwaters. Figure 13 presents the 1987 average total chlorophyll a concentrations for each site along with the proportion of the total chlorophyll made up by the <25 μm size-fraction. Planktonic algae <25 μm in size comprised much of the total algae in both number and biomass, which accounts for the high proportion of chlorophyll a in this size-fraction.

Chlorophyll a averaged 6.29 mg/m^3 for all backwaters in 1988. Chlorophyll a in Island Park, Jensen and Ouray backwaters averaged 6.06 mg/m^3, 5.40 mg/m^3, and 7.30 mg/m^3, respectively, and ranged from 1.6 to 12.31 mg/m^3 at Island Park, 0.81 to 22.8 mg/m^3 at Jensen, and 2.42 to 27.68 mg/m^3 at Ouray.

Ouray BA 251.0 had the highest average chlorophyll a concentration of 12.54 mg/m^3 and Jensen BA 298.4 had the lowest seasonal average chlorophyll a of 4.05 mg/m^3.

Chlorophyll a in the <25 μm size-fraction averaged 90 percent (ranging from 52 to 100 percent) of the total backwater chlorophyll a. Figure 14 presents the 1988 average chlorophyll a concentrations along with relative proportions of <25 μm chlorophyll a of the total for each site. The average chlorophyll a concentration at all river sites was less than in backwaters at each site. In addition, chlorophyll a concentrations in both the river and combined backwaters at Ouray were higher than at upstream sites.

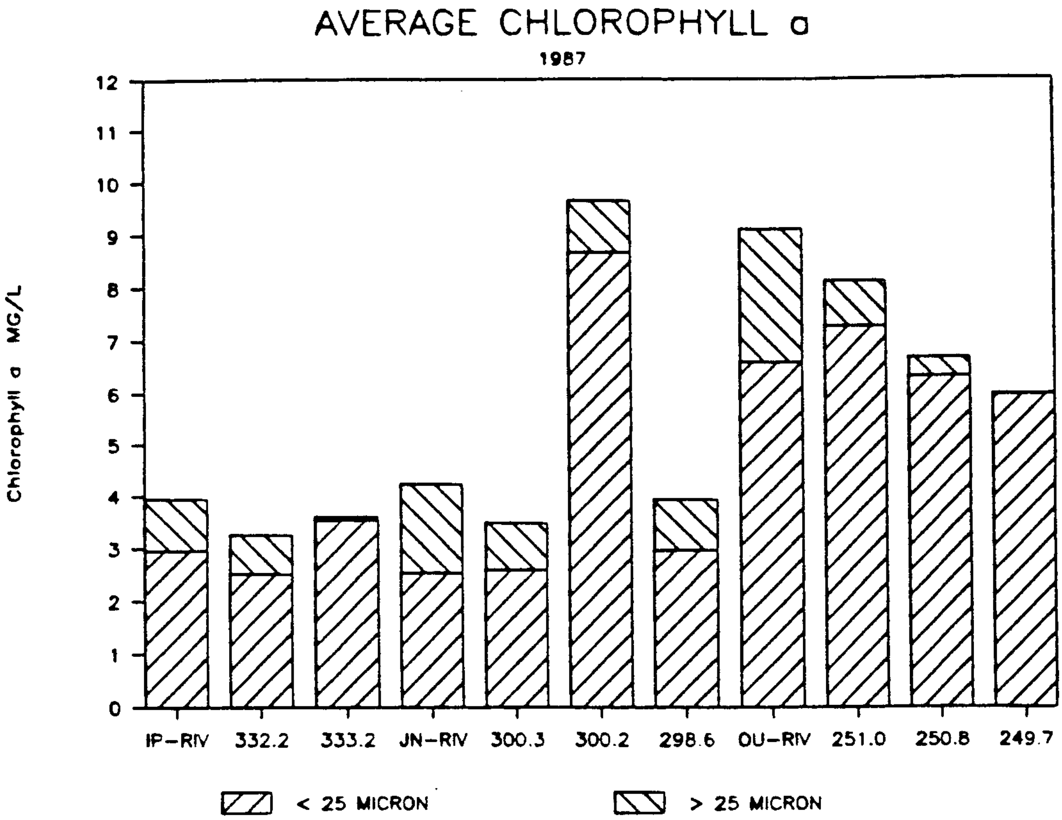

Figure 13 . - 1987 average chlorophyll a, mg/m^3, in two size fractions for the main river and backwaters at Island Park, Jensen, and Ouray.

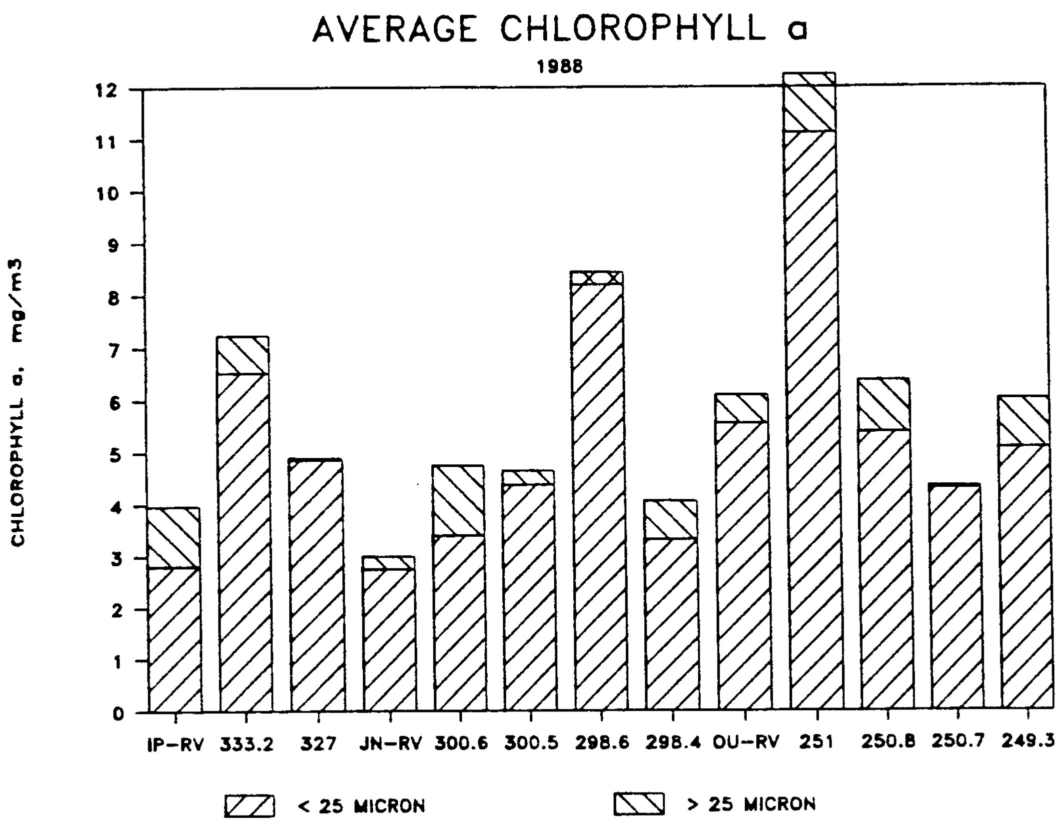

Figure 14 . - 1988 average chlorophyll a. In the two size fraction for the main river and backwaters at Island Park, Jensen, and Ouray.

Twenty chlorophyll extractions from the mid-August sampling period were acidified with HCl to determine phaeophytin a, the degradation product of chlorophyll a (APHA, 1975), to determine if degradation of the samples had occurred. The ratio of the average absorbance at 663 nm of the unacidified/acidified sample was 1.5, near the optimum 1.7, indicating the samples were in generally good condition and chlorophyll a had not degraded appreciably.

Particulate organic material

Particulate organic material (POM) composed of dead or living suspended particulate matter, is an important component of stream drift and represents potential food for organisms ranging from detritivores to young fish. POM was separated into 2 size-fractions; >25 μm particles and <25 μm particles down to 0.45 μm (Bilby and Likens 1980; Webster et al. 1979).

Main river. - Average POM concentration in the river increased downstream from Island Park to Ouray in 1987, with a total river average of 7.5 g/m^3. The <25 μm size-fraction made up 6.5 g/m^3 (87 percent) of the total. Highest levels of POM at the river sites in 1987 occurred during mid-August when riverflow almost doubled to 2,000 ft^3/s over a two day period. During this time period, the <25 μm POM concentration in the river increased about 10 times, to 54 g/m^3, compared to the previous three-trip average of 5.2 g/m^3. Lowest river POM concentrations occurred in late October.

The concentration of the <25 μm size-fraction of POM ranged from 13.5 to 89 times higher than the >25 μm size-fraction, for both river and backwater sites. Figure 15 shows this along with the average total POM concentrations at each site for the 1987 sample season.

Average POM concentration in the river increased downstream from Island Park to Ouray in 1988, with a total river average of 6.59 g/m^3. The <25 μm size-fraction of POM made up 92 percent (6.05 g/m^3) of the total.

Backwaters. - The concentration of the <25 μm size-fraction of POM varied between backwaters, with the highest 1987 average concentration of 6.2 g/m^3 occurring in Ouray backwaters during August and September. The <25 μm size-fraction of POM in Island Park backwaters was highest in mid-August 1987; in Jensen backwaters, the high POM concentration occurred on or before mid-August.

The organic portion of the total suspended matter (seston) made up an average of 24.2 percent (from 11.5 to 61.0 percent) of the total suspended solids in both river and backwater in 1987. The organic portion of the <25 μm size-fraction suspended solids averaged 14.9 percent (ranging from 8.7 to 33.7 percent) of the total <25 μm size-fraction suspended material.

In 1988, the <25 μm size-fraction of POM averaged 5.91 g/m^3 for all backwaters, while total POM averaged 6.49 g/m^3. The highest average concentration of 7.4 g/m^3 occurred in Ouray backwaters, with lower concentrations upstream; 4.98 and 4.79 g/m^3 in Jensen and Island Park backwaters, respectively. Highest concentration of <25 μm POM in Ouray backwaters occurred in mid-August. The <25 μm size-fraction of POM ranged from 3.3 to 31.6 times higher than the >25 μm size-fraction. Figure 16 shows the 1988 average POM concentrations at each site along with the proportion of the <25 μm size-fraction. The river POM concentration of 7.5 g/m^3 in 1987 was

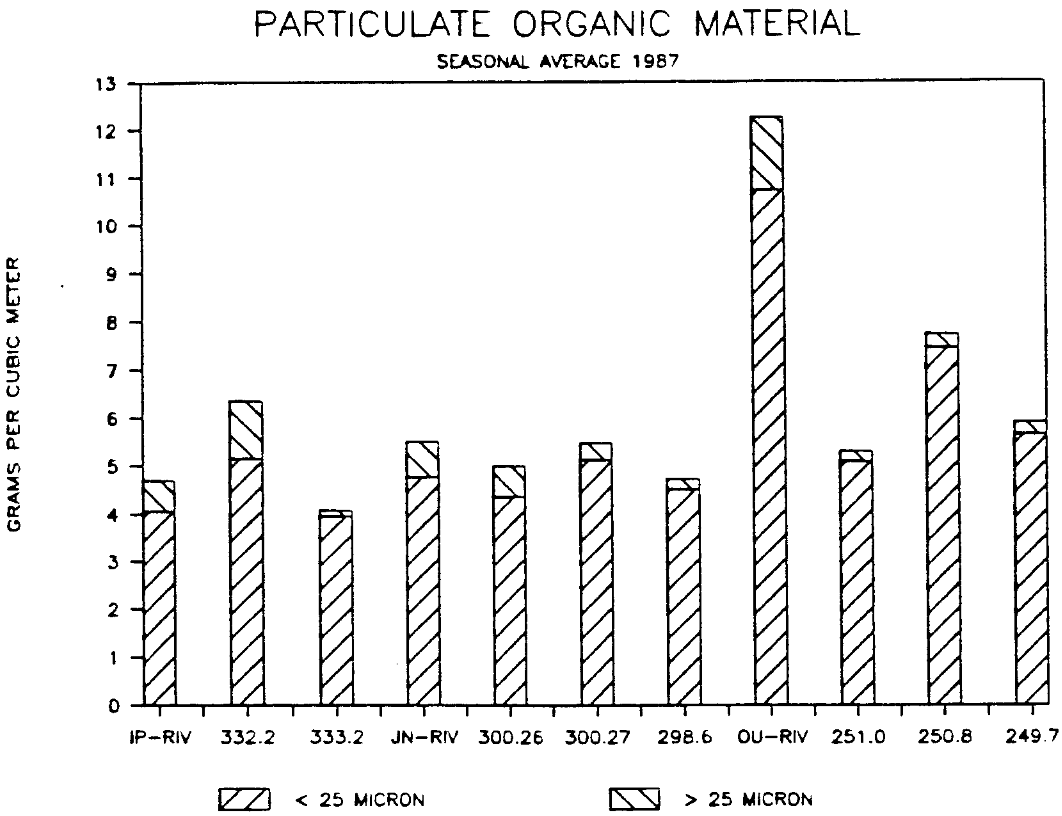

Figure 15. - 1987 average total particulate organic material, g/m^3, in two size fractions for the main river and backwaters at Island Park, Jensen, and Ouray.

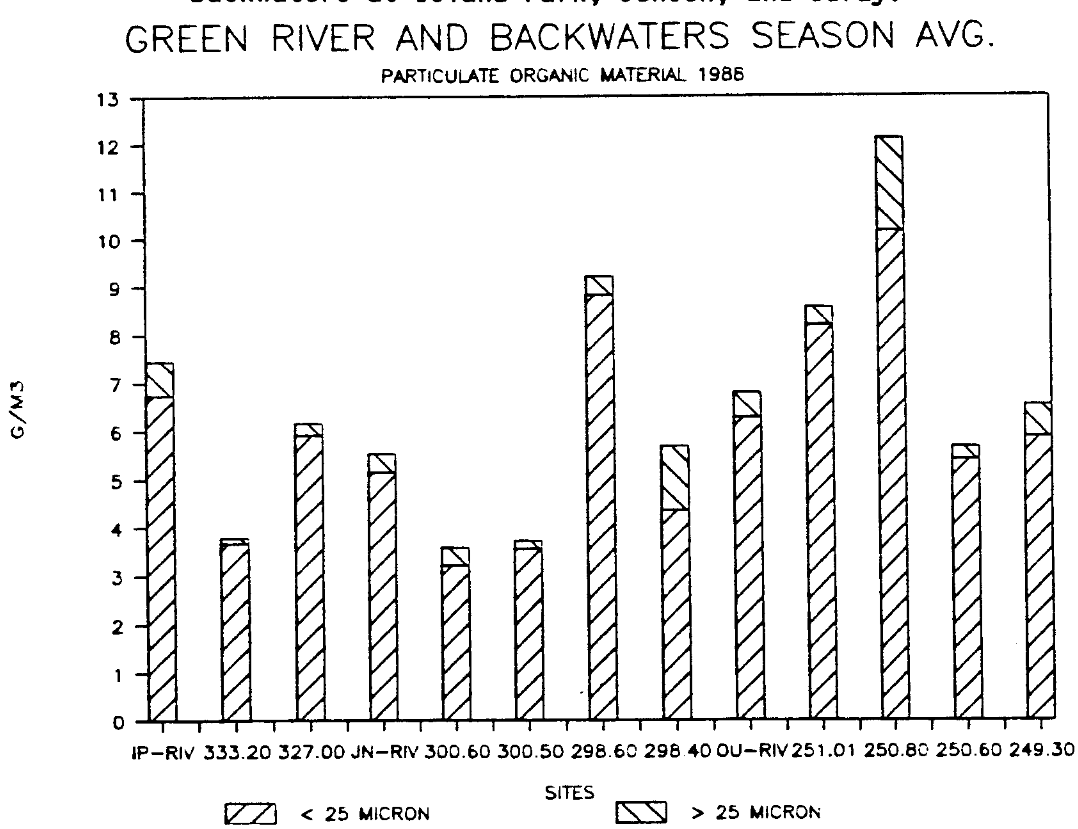

Figure 16. - 1988 average total particulate organic material, g/m^3, in the two size fraction for the main river and backwaters at Island Park, Jensen and Ouray.

greater than the average river POM of 6.59 g/m^3 in 1988, while the average backwater POM concentration of 5.57 g/m^3 in 1987 was less than the backwater average of 6.49 g/m^3 in 1988.

Organic matter made up an average of 26.23 percent (ranging from 13.9 to 43.5 percent) of the total suspended solids in 1988. The organic portion of the <25 μm size-fraction of suspended solids averaged 15.1 percent (ranging from 10.7 to 27.3 percent) of the total.

Plankton

Nannoplankton. - Nannoplankton, the less than 25 μm size-fraction of the plankton, was collected at one backwater each at Island Park, Jensen, and Ouray on each of the sampling trips in 1988. It comprised a major portion of the algae, based on chlorophyll a analyses. Green algae, diatoms, and blue-green algae were the major nannoplankton groups. Blue-green algae was the most abundant group in all samples, making up 92 percent of the nannoplankton in Island Park BA 333.2; 97 percent in Jensen BA 300.5; and 97 percent in Ouray BA 251.0. Gloeotheca sp. and Synechococcus sp. were the major blue-green taxa. Green algae was the next most abundant group with Ankistrodesmus sp. and Closterium sp. the major taxa. Navicula sp. and Centrales sp. were the major diatoms.

The only obvious seasonal trend occurred in Island Park BA 333.2 where nannoplankton concentration increased gradually throughout the season. There was a downstream trend of increasing densities of green and blue-green algae with blue-green algae predominant (figure 17). The seasonal average of blue-green algae at Ouray BA 251.0 was nearly 31 million cells and colonies per liter.

Phytoplankton. - Phytoplankton was present but not abundant in 1987 river and backwater samples. Phytoplankton was collected with an 80-μm mesh net in 1987, which resulted in underestimating phytoplankton abundance. Recent work suggests that smaller taxa may not be retained by the 80-μm net, and investigators recommend a 20-25-μm-mesh net, which was used in 1988 sampling.

Fifty-nine phytoplankton taxa were collected in 1987 from main river and backwater sites. Number of taxa in both the river and backwaters fluctuated during the sampling season, such that no trend was apparent. Seasonal highs and lows did not always occur simultaneously in the river and backwaters. Over the sampling season, there was a slight increase in phytoplankton taxa in the river downstream compared to upstream. Number of phytoplankton taxa in backwaters was similar to that in the river, although on some sampling dates more phytoplankton taxa were found in the river than in backwaters.

In 1988 phytoplankton was collected with a 25-μm-mesh net to quantify taxa composition and abundance, determine their contribution to trophic interactions in the backwaters, and determine their importance as food for larval fish. Fifty taxa were identified and enumerated. Three major groups of phytoplankton were identified from the Green River in 1988: green algae (Chlorophyta), blue-green algae (Cyanophyta) and diatoms (Chrysophyta, subphylum Bacillariophyceae). Green algae and diatoms dominated at most sites. Of the 19 green algae genera identified, Closterium sp. was the predominant taxon, with high concentrations of Actinastrum sp., Scenedesmus sp., and Ulothrix sp. in most samples, particularly later in the season. Principal species of diatoms were Navicula sp., Gyrosigma sp. (highest at Ouray), Cocconeis sp. (highest at Island Park and Jensen) and Centrales sp. The blue-green algae was generally low at all sites, with Anabaena sp. the dominant of the 12 genera identified, followed by Oscillatoria sp., and Gloeocapsa sp. (principally at Ouray). Average phytoplankton concentrations in the river were lower than the average concentrations in the combined backwaters. In Cottonwood Slough, a Mississippi River backwater, Neuswanger (1980) found high standing crops of phytoplankton compared to free-flowing side channels, with a resulting higher turbidity in the backwater. At Island Park there was a general trend over the sampling season of increasing concentrations of phytoplankton, with a sample season average of 1043 individuals per liter in the river and 2401 in backwaters. BA 333.2 (Big Island) had the highest seasonal average concentration of 3583 phytoplankters per liter with 8 percent greens, 89 percent diatoms and 3 percent blue-greens. The river at Jensen had an average phytoplankton concentration of 1039 individuals per liter, similar to the river at Island Park. The backwaters at Jensen had a seasonal average of 1805 individuals per liter, with 45 percent green algae, 34 percent diatoms and 21 percent blue-green algae. There was a general seasonal increase of phytoplankton at Jensen, with the lowest phytoplankton concentration occurring on July 27. Jensen BA 298.4 had the highest seasonal average phytoplankton concentration of 2932 individuals per liter, with the green algae _Closterium_ sp. and blue-green algae _Anabaena_ sp. low in comparison with the upstream backwaters. Average numbers of _Asterionella_ sp. and green algae _Pediastrum_ sp. and _Actinastrum_ sp. increased compared to upstream backwaters. Ouray BA 251.0 had the highest average phytoplankton concentrations with a sample season average of 3947 individuals per liter, composed of 47 percent green algae, 43 percent diatoms and 9 percent blue-green algae. Figure 18 presents the 1988 seasonal average phytoplankton concentration of major groups for each site.

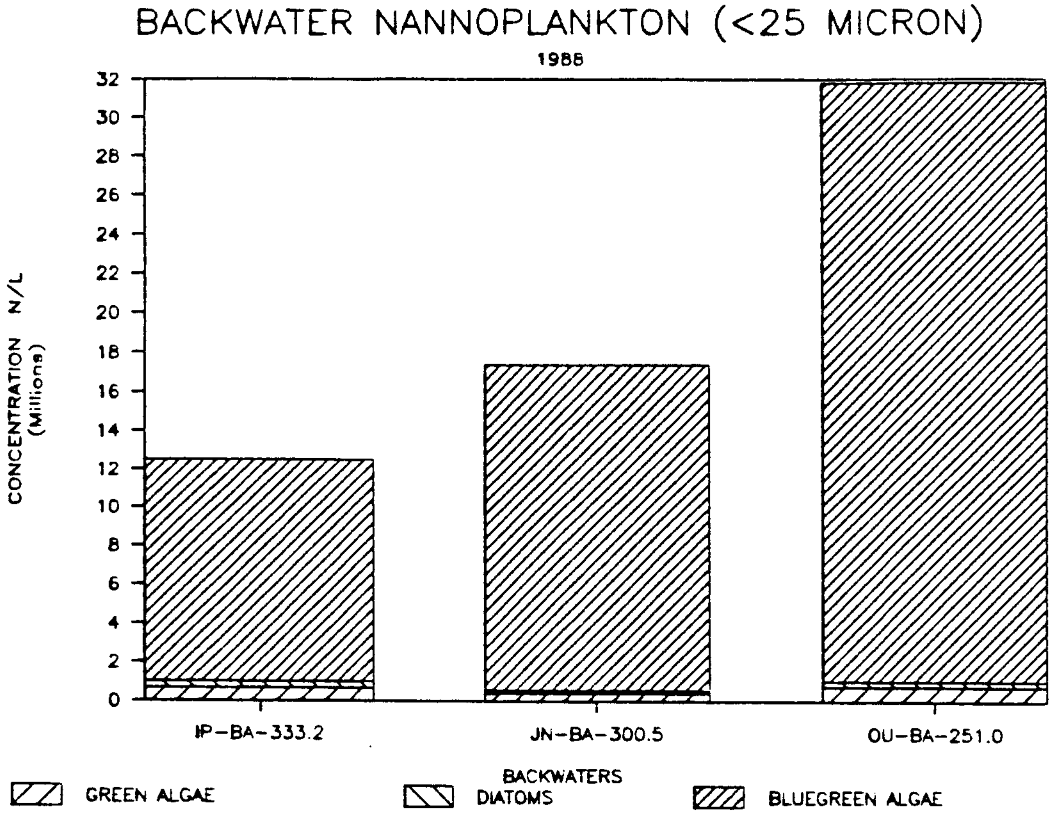

Figure 17. - Average 1988 seasonal nannoplankton concentrations from three backwaters.

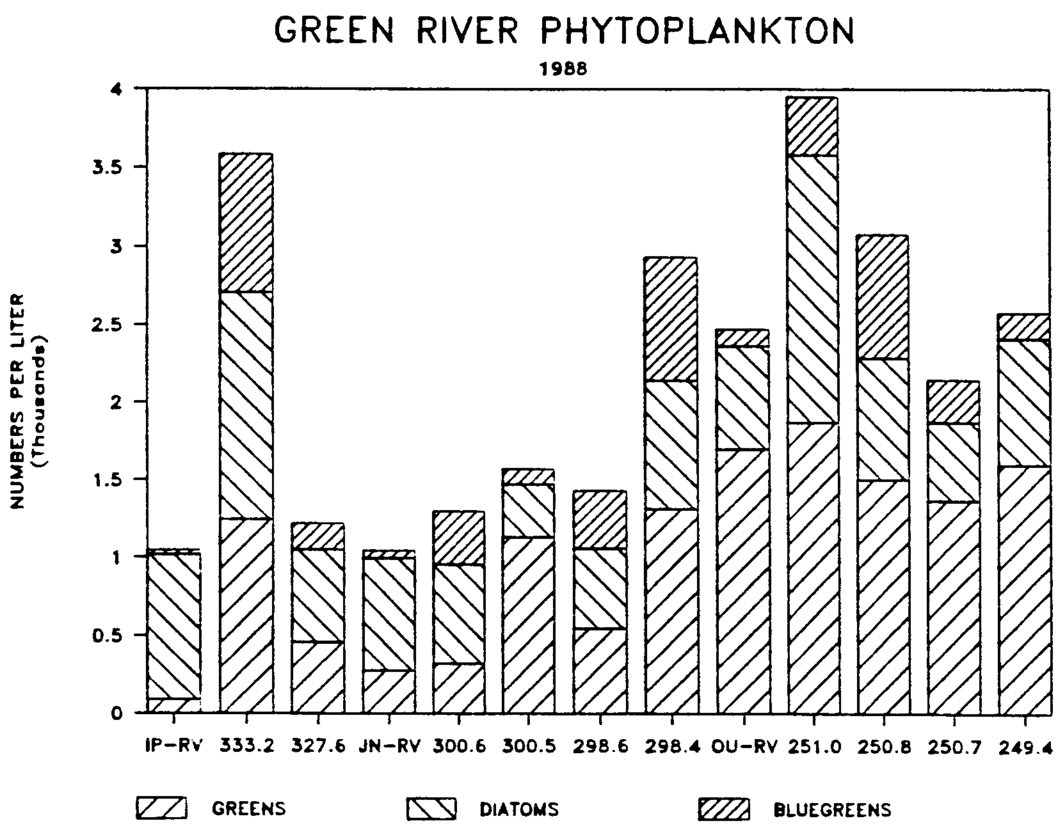

Figure 18. - 1988 Phytoplankton average concentration from the main river and backwaters at Island Park, Jensen, and Ouray. Numbers under bars indicate river index of backwater.

Zooplankton. - Zooplankton were collected to assess species composition and spatial and temporal relative abundance, and to determine flow related changes in populations and their availability as food for young fish in the Green River backwaters. Table 2 presents a list of zooplankton taxa collected in the main river and backwaters during two sampling seasons.

Table 2. - Zooplankton taxa collected from the Green River, Utah, from June 2 to November 19, 1987, and from July 12 to October 13, 1988.

1987

- Copepoda
  - Nauplii
    - Eucopepoda
      - Calanoida
        - Diaptomus sp.
      - Cyclopoda
        - Copepodites
- Cladocera
  - Chydoridae
    - Eurycercus sp.
  - Daphnidae
    - Daphnia sp.
  - Macrothricidae
    - Acantholeberis sp.
- Rotatoria
  - Asplanchnidae
    - Asplanchna sp.
  - Branchionidae
    - Monostyla sp.
    - Brachionus sp.
    - Kellicotia sp.
    - Keratella sp.
    - Lecane sp.
  - Synchaeta
    - Synchaeta sp.

1988

- Copepoda
  - Nauplii
    - Eucopepoda
      - Calanoida
        - Diaptomus
      - Cyclopoda
        - Bosminidae
- Cladocera
  - Chydoridae
    - Eurycercus sp.
  - Daphnidae
    - Daphnia sp.
    - Bosmina sp.
  - Macrothricidae
    - Acantholeberis sp.
- Rotatoria
  - Asplanchnidae
    - Asplanchna sp.
    - Asplanchnopus sp.
  - Branchionidae
    - Monostyla sp.
    - Philodina sp.
    - Brachionus sp.
    - Lepadella sp.
    - Keratella sp.
    - Filinia sp.
    - Lecane sp.
    - Cephalodella sp.
    - Pedipartia sp.
    - Testudinella sp.
    - Trichocerca sp.
    - Trichotria sp.
    - Polyarthra sp.
    - Monommata sp.
  - Synchaeta
    - Synchaeta sp.

At Island Park, average zooplankton concentrations were lower in the river than in the backwaters in 1987. The highest concentration of zooplankton from the river, 0.16 individuals per liter, occurred in late June. The highest concentration of zooplankton collected at BA 333.2 was 0.34 per liter in late July, with copepods, mostly nauplii, averaging 62 percent of all zooplankton. Zooplankton at Island Park BA 332.2 was nearly as sparse as that in the river with a sample season average of 0.02 individuals per liter.

At Jensen, the highest river zooplankton concentration of 0.1 individuals per liter occurred in early June, after which time numbers declined to zero. The river had lower concentrations of zooplankton than did backwaters at Jensen. In BA 300.27, copepods constituted the major group from June to August, after which cladocerans (mostly Acantholeberis sp.) dominated in September and October. BA 300.26 had relatively high concentrations of zooplankton, with 8.06 zooplankton per liter present in late June, with 99 percent copepods. Jensen BA 298.6 had a high zooplankton concentration of 0.22 individuals per liter on June 24, of which 54 percent were rotifers (Brachionus sp. and Monostyla sp.) and 45 percent were copepods (all nauplii).

Zooplankton concentrations in BA 300.26 were highest in the fall with cladocerans predominant; zooplankton in BA 300.27 peaked in the early summer with copepods most numerous.

Zooplankton was present throughout the season in the river at Ouray, with a high of 0.22 zooplankton per liter on June 25. In BA 251.0 in early June, 92 percent of the 0.98 individuals per liter were copepods. Rotifers, principally Brachionus sp. were always present in samples from BA 251.0, but often in very low concentrations. Copepods constituted 100 percent of the zooplankton collected from BA 250.8 from August 20 until November. BA 249.7 had the highest concentration of zooplankton of 0.2 copepods per liter in late June, comprised of 50 percent nauplii and 50 percent cyclopoids. Zooplankton concentrations at Ouray were highest in the early summer, with copepods predominant.

Average zooplankton concentrations for 1987 are presented in figure 19. The average river zooplankton concentrations were highest at Ouray and lowest at Jensen. Island Park BA 332.2 had the lowest average backwater zooplankton concentration. Cladocerans were sparse except in Jensen BA 300.27.

Zooplankton concentrations were low in the river again in 1988, with an average 0.5, 0.04 and 1.0 zooplankton per liter at Island Park, Jensen and Ouray, respectively. No zooplankton were collected from the river at Jensen in September and October. Island Park backwaters were dominated by 89 percent rotifers, with 8 percent copepods. Major rotifers included _Syncheata_ sp., _Lecane_ sp., and _Keratella_ sp. The seasonal average zooplankton concentration in Island Park backwaters was 0.43 zooplankters per liter, with the highest concentration in BA 333.2.

Jensen backwaters averaged 1.31 zooplankters per liter with BA 300.6 having the highest seasonal average of 4.06 zooplankton per liter, and the highest concentration of 16.6 individuals per liter in mid-June, consisting of 71 percent rotifers, primarily _Filinia_ sp., _Keratella_ sp., and _Polyarthra_ sp., and 27 percent copepods, with less than 1 percent cladocerans.

The river at Ouray averaged 1.0 individuals per liter, of which 95 percent were copepods. Ouray backwaters averaged 1.51 zooplankter per liter, which was greater than the seasonal average of upstream backwaters. BA 251.0 had the highest average zooplankton concentration of 5.16 individuals per liter with a high of 15.14 zooplankters per liter occurring in mid-August. Rotifers made up 88 percent of the zooplankton in the Ouray backwaters with Polyarthra sp. and Filinia sp. the major genera; the remaining twelve percent were cyclopoid copepods. Ouray BA 250.8 (Moult Bend) had the lowest zooplankton concentration of 0.14 individuals per liter over the sample season.

Figure 20 presents the average zooplankton concentrations for each sample site on the Green River in 1988, with the contribution each of the major groups made to the total.

Zooplankton concentrations from the Green River and the associated backwaters are low compared to lakes but somewhat similar to concentrations in other riverine systems. The lower Colorado River 41 miles (61 km) below Parker Dam had an average annual zooplankton concentration of 1.02 zooplankters per liter in 1984 (Hiebert and Grabowski 1987), and the Yellowstone River near Sidney, Montana, in 1960-1961 had a zooplankton average of 0.1 individual per liter (Public Health Service 1962). Zooplankton concentrations in the river were generally lower than in backwaters, and Hynes (1970) reported that plankton in rivers are reduced by turbidity because of reduced algal production and interference with the feeding mechanism of zooplankton. Persons (1979) reported zooplankton densities in backwater ponds along the Missouri River 25 times greater than in the main channel, and Schramm and Lewis (1974) stressed the importance of slack water areas to abundance of plankton and benthos.

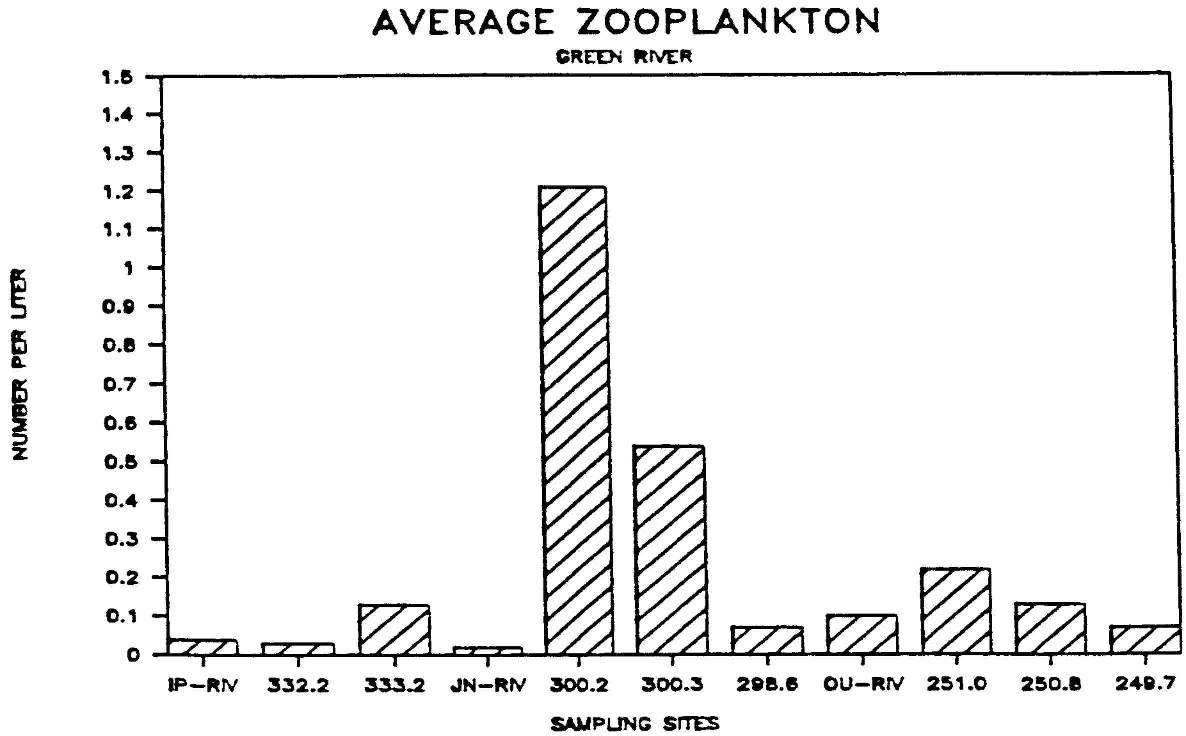

Figure 19 . - Average total zooplankton per liter for the main river and backwaters at Island Park, Jensen, and Ouray, during the 1987 sampling season.

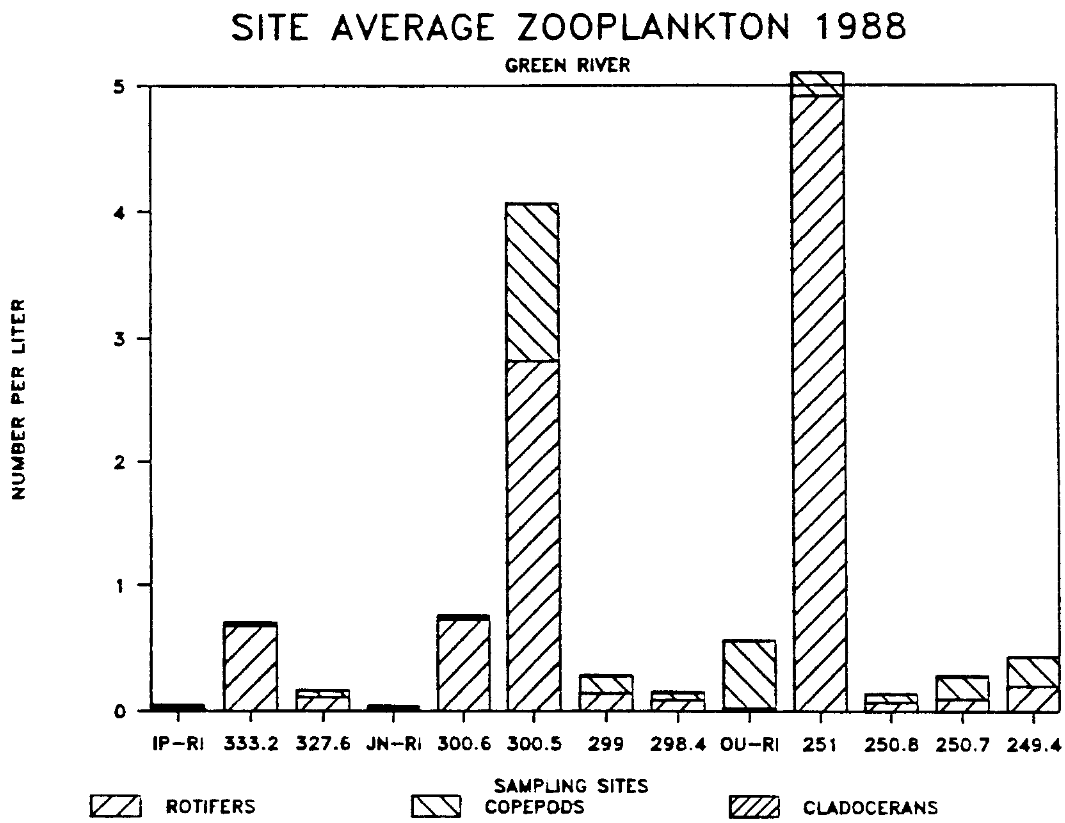

Figure 20 . - Average total zooplankton by groups from sampling sites in the main river and backwaters.

In 1988, the average zooplankton concentration in backwaters was about 14.5 times greater than zooplankton concentration in the river.

Lentic plankton, originating in quiet backwaters, can be reduced in numbers rapidly upon entering the turbulent water of the mainstream. Hynes (1970) reported that rotifers, as opposed to crustaceans, comprise the largest proportion of riverine plankton biomass. Rotifers were dominant riverine zooplankter collected from the Green River in 1988, similar to that reported by Lieberman (1985) for the Bill Williams River, Arizona, where rotifers made up 41.9 percent of the zooplankton population.

Backwater zooplankton concentrations generally averaged higher than river zooplankton concentrations and are probably greatly influenced by retention time and exchange of water with the river. Water movement through a reservoir that exceeds a few millimeters per second will often develop low plankton densities (Hynes 1970). Cowell (1967) found that high flushing rates of 8 to 10 days resulted in little in situ zooplankton production.

Benthic macroinvertebrates

The benthic macroinvertebrate community in both the main river and backwaters at Island Park, Jensen, and Ouray, consisted of the taxa shown in table 3. Chironomid larvae were dominant in benthic collections at most sites in both years, and when possible, were identified to genus. Oligochaetes appeared often in benthic samples and occasionally reached high numbers. Nematodes and certopogonid larvae appeared occasionally. Other taxa were collected infrequently. Numbers and dry weights of chironomid larvae and other benthic macroinvertebrates will be discussed below. Because of the high percentage of chironomid larvae in most samples, and the predominance of chironomid larvae in the diet of Colorado squawfish and other fish species, discussions of the benthos will emphasize chironomid larvae.

At Island Park, chironomid larvae were usually but not always less abundant in benthic samples collected from the river than in samples from backwaters.

Table 3. - Benthic invertebrates collected in the Green River and selected backwaters from Island Park, Jensen, and Ouray.

TAXA
- Nematoda
- Annelida
  - Oligochaeta
- Arthropoda
  - Insecta
    - Ephemeroptera
      - Paracloeodes
    - Odonata
      - Anisoptera
    - Hemiptera
      - Corixidae
    - Trichoptera
      - Hydropsychidae
        - Hydropsyche
        - Unidentified
    - Coleoptera
      - Hydrophilidae

Diptera (larvae)
- Tipulidae
- Simuliidae
- Chironomidae
  - Tanypodinae
    - Tanypus
    - Procladius
- Chironominae
  - Chironomini
    - Chironomus
    - Dicrotendipes
    - Cryptochironomus
    - Paracladopelma
    - Polypedilum
    - Phaenopsectra
    - Paralauterborniella
    - Strictochironomus
    - Endochironomus
    - Pseudochironomus
  - Tanytarsini
    - Tanytarsus
    - Rheotanytarsus
  - Diamesinae
    - Diamesini
  - Prodiamesini
    - Monodiamesa
    - Orthocladiinae
    - Metriocnemus
    - Cricotopus
    - Pseudosmittia

Unidentified chironomid larvae
Chironomid pupae
Unidentified Dipteran larvae
Dipteran pupae
Adult dipteran
Ceratopogonidae
Gastropoda
- Snail shells

Averaged over the sampling period, early June to mid-November, 1987, chironomid larvae comprised 37.7 percent of the river benthos, 61.3 percent of benthos in BA 332.2, and 76.1 percent of benthos in BA 333.2. In 1988, the seasonal percent chironomid larvae was 84.1, 67.4 and 74.0 percent in the river, BA 333.2 and BA 327.6, respectively.

At Island Park, the percentage of chironomid larvae in both river and backwater samples gradually decreased during each years' sampling period, June to November 1987, and July to October 1988, probably due to emergence of the several species of midges, or predation by larval and juvenile fishes. In 1988, BA 327.6 backwater had a greater percentage of chironomid larvae than BA 333.2 backwater.

The substrate in the river was sand or silty sand, while the substrate in BA 332.2 was mostly silt. Substrate in BA 333.2 generally consisted of cobble, gravel, sand, and some silt, while substrate in BA 327.6 was silty sand and some gravel.

At Jensen, chironomid larvae generally contributed less to the benthic community in the river than in backwaters with a sampling season average of 63.3 percent in the river and 74.2, 82.2, and 79.6 percent in BA 300.26, BA 300.27, and BA 298.6, respectively. The percentage of chironomid larvae in benthic samples was high, as high as 100 percent through mid-summer, then decreased in late summer and fall. In 1988, seasonal average percent of chironomid larvae was 60.7, 79.7, 90.8, 76.9 and 37.7 percent in the river, BA 300.6, BA 300.5, BA 298.6, and 298.4, respectively.

At Ouray, chironomid larvae were present infrequently in the river benthos, but always present in the backwaters throughout the sampling period. In the river, chironomid larvae comprised only 44.8 percent of the riverine benthic community during the 1987 sampling season, while comprising 96.4, 96.1, and 88.3 percent of the benthic community in Ba 251.0, BA 250.8, and BA 249.7, respectively. In 1988, river samples had a seasonal average of 33.3 percent chironomids, with 53.4, 93.0, 96.7, and 44.9 percent found in BA 251.0, BA 250.8, BA 250.7, and BA 249.3, respectively. At Ouray, the percentage of chironomid larvae in both the river and backwaters often reached 100 percent up to early September then decreased in the fall, again probably due to emergence of midges and predation. The contribution of chironomid larvae to the riverine and backwater benthic community increased downstream in 1987. In 1988, percent chironomid larvae in the river decreased from Island Park to Ouray, while percent chironomid larvae in backwaters increased downstream. Chironomid larvae were sometimes absent from river benthic samples at Jensen and Ouray from late June to late September 1987, and periodically in 1988. In the river at Ouray, chironomid larvae reappeared in late October, and increased to 100 percent of the riverine benthos by mid-November 1987.

Over 80 percent of the benthic organisms collected at all sites during both sampling seasons consisted of chironomid larvae (midges), oligochaetes, and ceratopogonid larvae (biting midges, sandflies, no-see-ums) (table 4). Often they amounted to over 90 percent of the benthic organisms. In Cottonwood Slough along the Mississippi River, Neuswanger (1980) found that chironomid larvae, oligochaetes and Ephemeroidea (burrowing mayflies) comprise 96 percent of numbers of macrobenthos.

Percentage of chironomid larvae in Green River backwaters increased progressively downstream from Island Park to Ouray, more noticeably in 1987 than in 1988. Percentage of oligochaetes in backwaters decreased from upstream to downstream in 1987, but increased downstream in 1988. Ceratopogonid larvae were more abundant in samples collected from the river than from backwaters; in backwaters, ceratopogonid larvae comprised a very

Table 4. - Percent abundance of chironomid larvae, oligochaetes, and ceratopogonid larvae at main river and backwater sites in the Green River, Utah, for the 1987 and 1988 sampling season.

Site		Chironomid larvae 1987	Chironomid larvae 1988	Oligochaetes 1987	Oligochaetes 1988	Ceratopogonids 1987	Ceratopogonids 1988
Island Park	River	37.7	84.1	52.8	3.6	3.8	3.6
	BA 333.2	76.1	67.4	0.8	18.0	0.5	8.1
	BA 332.2	55.7		31.2		0.4	
	BA 327.6		74.0		23.0		0.4
Jensen	River	63.3	60.7	6.0	0	23.2	37.6
	BA 300.6		79.7		7.1		6.2
	BA 300.5		90.8		7.9		0.2
	BA 300.27	82.2		14.1		1.5	
	BA 300.26	74.2		22.2		0.6	
	BA 298.6	79.6	76.9	18.4	19.6	0.6	0.6
	BA 298.4		37.7		50.8		2.9
Ouray	River	44.8	33.3	0	6.7	44.8	40.0
	BA 251.0	96.4	53.4	2.1	46.0	1.5	0
	BA 250.8	96.1	93.0	3.7	0.1	0	0.6
	BA 250.7		96.7		1.8		0.5
	BA 249.7	88.4		10.9		1.4	
	BA 249.3		44.9		54.6		0

small percentage of the benthic organisms. Neuswanger (1980), however, found more ceratopogonids in Cottonwood Slough than in a free-flowing side channel. Other benthic invertebrate taxa contributed little to the benthic community at the study sites.

In summary, by percent abundance in the benthos, chironomid larvae in the river generally decreased downstream from Island Park to Ouray, while chironomid larvae in backwaters increased progressively downstream. Percentages of oligochaetes in the river decreased rapidly downstream, but in backwaters decreased downstream in 1987 and increased downstream in 1988.

Percentages of ceratopogonids in the river increased downstream; in backwaters, they increased downstream in 1987, but decreased downstream in 1988.

Numbers of total benthic invertebrates and chironomid larvae fluctuated considerably by site and sample date during the two year study. Benthic organisms were often absent from river samples, especially in mid-season. Averaged seasonally, benthos in the river decreased from upstream at Island Park to downstream at Ouray, except for the river at Jensen in 1987, which had the highest average abundance of benthos of all river sites. Very high numbers of chironomid larvae occurred in some backwaters, more often in the more isolated backwaters, such as BA 251.0 and BA 249.3 at Ouray (figures 21 and 22). Sheaffer (1984) found greater benthic densities in backwaters along the Mississippi River than in the main channel.

In 1987, Jensen backwater benthos abundance peaked in late July - early August, with chironomid larvae comprising most of the benthos.

In the river at Ouray, total benthos was sparse in both years, having the lowest average number per square meter of any site sampled. Very few chironomid larvae were collected there. In backwaters at Ouray, peaks in abundance occurred throughout the season for different backwaters. For the same backwaters sampled both years (BA 251.0 and BA 250.8), peak abundance and seasonal patterns of benthos were not similar. Chironomus sp. comprised up to 100 percent of the chironomid larvae. Abrupt decreases in chironomid larvae from one sampling period to the next are probably the result of emergence (Neuswanger 1980), predation, or other life history phenomena, such as

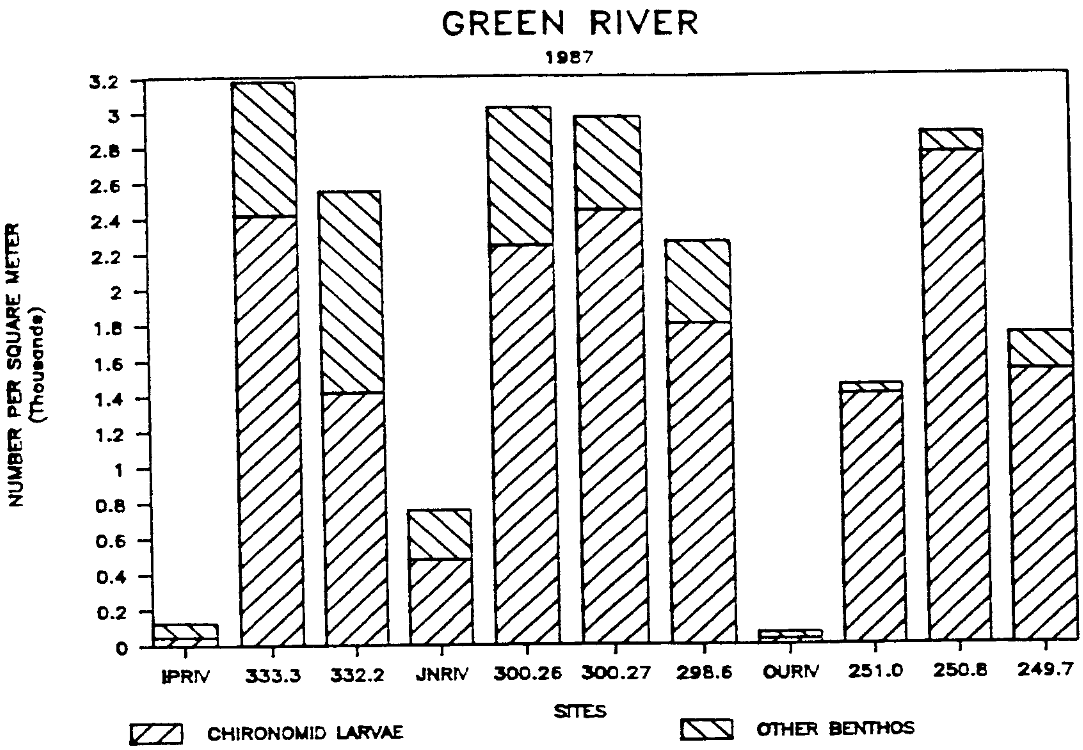

Figure 21. - Average number per m^2 of benthic macroinvertebrates for the main river and backwaters at Island Park, Jensen, and Ouray for 1987.

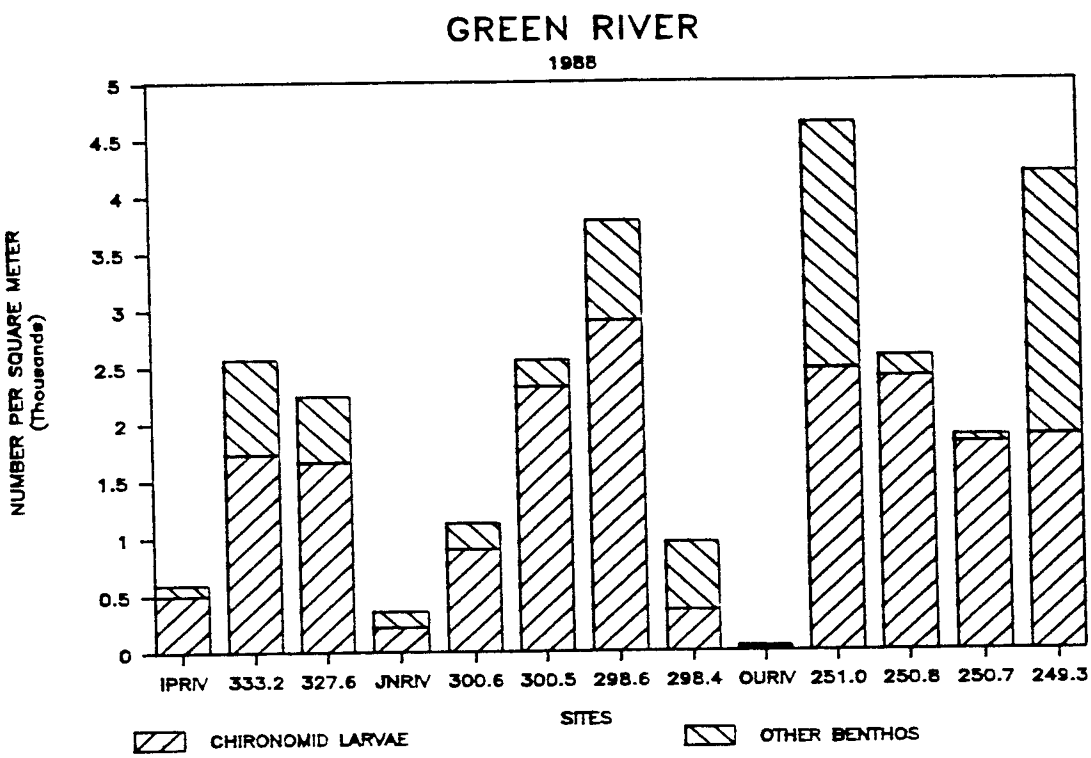

Figure 22. - Average number per m^2 of benthic macroinvertebrates for the main river and backwaters at Island Park, Jensen, and Ouray for 1988.

contagious distribution or use of distinct microhabitats (Cochran and McConville 1983) and migration (Hilsenhoff 1967, cited in Barton 1988).

Ouray BA 251.0 in 1988 had the greatest seasonal average for total benthic organisms per square meter of any backwater sampled during the two years of the study, and about half of these organisms were chironomid larvae. BA 250.8 (Moult Bend) had the greatest seasonal average total benthos in 1987, with a similar abundance in 1988.

Average dry weights in grams per square meter for chironomid larvae, oligochaetes, ceratopogonid larvae and total benthos at Island Park, Jensen, and Ouray river and backwater sites for the 1987 and 1988 sampling seasons are shown in figures 23 and 24. Dry weights are low in the river, but substantially higher in the backwaters.

For 1987, total benthos dry weight was greatest at Jensen and lowest at Ouray for main river sites. In combined backwaters, total benthos dry weight increased progressively downstream, with the greatest dry weight at Ouray backwaters. BA 250.8 had the greatest total benthos dry weight of all backwaters.

In 1988, total benthos dry weight in the river decreased from upstream at Island Park to downstream at Ouray, while dry weight of benthos in backwaters increased downstream. BA 251.0 had the greatest dry weight of both total benthos and chironomid larvae among Ouray backwaters. BA 250.8 had lower benthos dry weights in 1988 than in 1987, although total numbers of benthos increased slightly compared to 1987. Dry weights of benthic organisms varied throughout the sampling seasons, often in concert with fluctuations in number

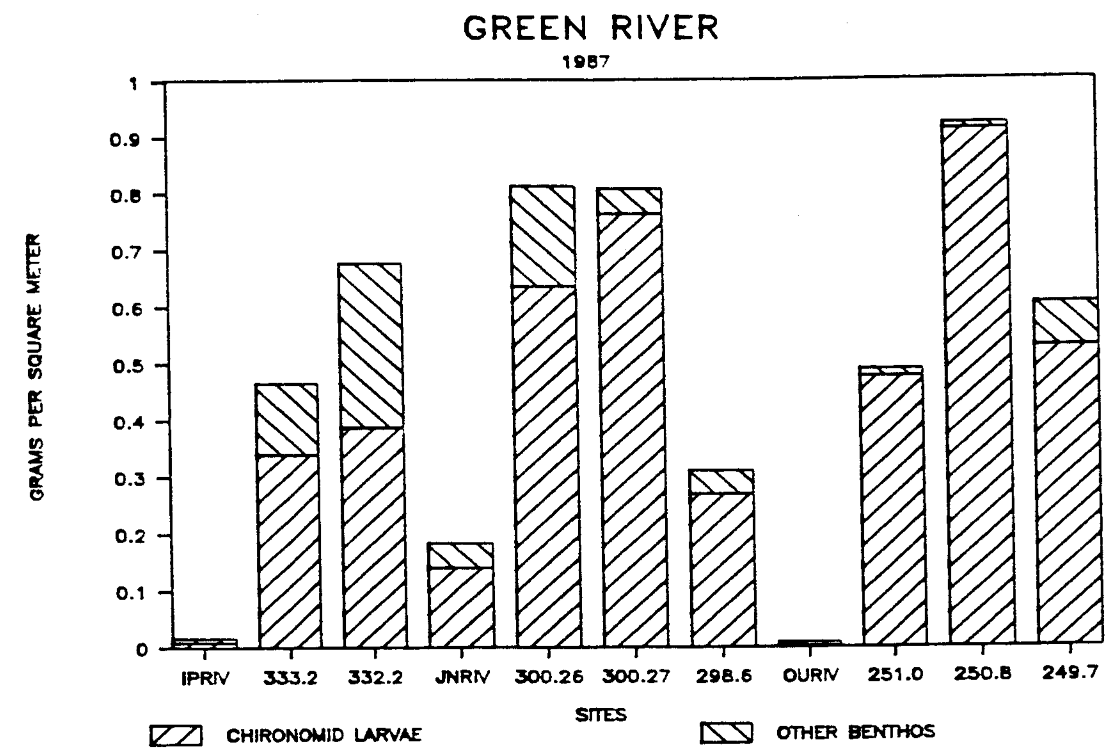

Figure 23. - Average dry weights, g/m^2, for chironomid larvae, oligochaetes, ceratopogonid larvae, and total benthos for the main river and backwaters at Island Park, Jensen, and Ouray for 1987.

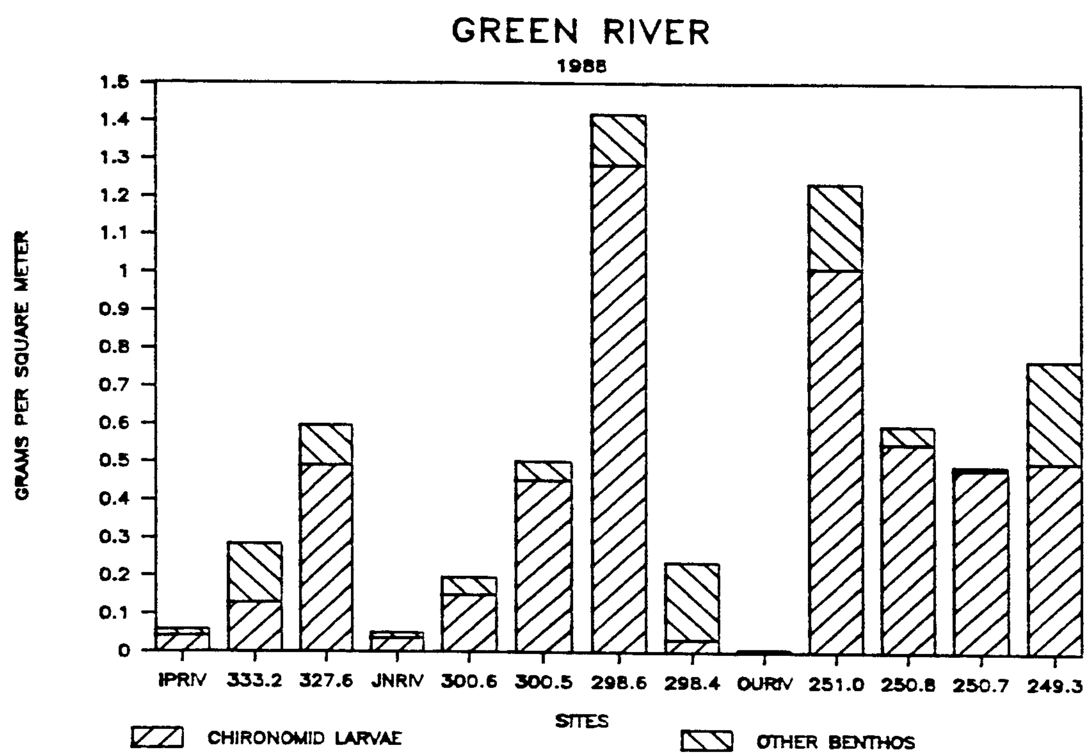

Figure 24. - Average dry weights, g/m^2, for chironomid larvae, oligochaetes, ceratopogonid larvae, and total benthos for the main river and backwaters at Island Park, Jensen, and Ouray for 1988.

of organisms, but sometimes inversely with numbers because of the larger size of some species of invertebrates later in the season.

In summary, the greatest dry weights for total benthos in the river occurred at Jensen in 1987 and at Island Park in 1988. Dry weights of riverine benthos were always less than in backwaters. Average dry weights for total benthos in backwaters increased downstream from Island Park to Ouray during both years, with a greater magnitude of change in 1988. In contrast, average numbers of benthic organisms in backwaters decreased progressively downstream in 1987, indicating that benthic organisms tended to be larger downstream at Ouray than upstream at Island Park. If size-selective predation by larval or juvenile fish occurs, larger benthic organisms would provide more energy per individual for the effort involved in capture than smaller organisms. Chironomid larvae were dominant in the diet of young Colorado squawfish and the young of other fish species; food habits of young fish are discussed elsewhere in this report. In 1987, the highest dry weight of benthos occurred in BA 250.8, although this backwater ranked fourth in average seasonal numbers of benthic organisms. In 1988, both the greatest dry weight and highest seasonal average number of total benthos occurred in BA 251.0.

There appeared to be both a spatial and temporal zonation of total benthic invertebrates in both the main river and backwaters. In the main river, highest abundance occurred at Jensen in 1987 and at Island Park in 1988. Average backwater abundance decreased from upstream to downstream, except at Ouray in 1988. BA 250.8 (Moult Bend) averaged more chironomid larvae in 1987 than any other site, river or backwater, sampled. In 1988, BA 251.0 had this distinction. Chironomid larvae made up the bulk of the larval Colorado squawfish diet in BA 250.8, and the high number of chironomid larvae here may provide a good food base for these fish. Statzner and Higler (1986) suggest that stream hydraulics determine the zonation of benthic invertebrates in river systems, but did not address other likely conditions that could influence benthic community structure. Neuswanger (1980) investigated backwater seral stage as a determinant of benthos community structure in the Mississippi River. As discussed above, other biological, chemical, and physical parameters exhibit upstream to downstram trends, and several of these, including nutrient concentrations, probably play a major role in determining benthic invertebrate numbers and size. Vannote et al. (1980), suggest that a continuous gradient of physical and chemical conditions exist from upstream to downstream in a riverine ecosystem and that these varying conditions influence the development and stability (or dynamics) of the river community. Schaeffer et al. (1986) reported that abiotic gradients determine distribution of riverine benthos. The River Continuum Concept of Vannote et al. (1980) considered unperturbed rivers from headwaters to mouth, but they suggest that system perturbations "reset" or reorient the dynamics of the system. Relative to the study section of the Green River, upstream to downstream trends were observed in physical, chemical, and biological parameters, even though a comparatively short reach of the river was investigated. Changes in riverflow, both natural from rainfall events and man-caused by releases from Flaming Gorge Dam, certainly perturb the riverine ecosystem and reduce stability even if temporarily. The effects of fluctuating flows from Flaming Gorge Dam are ameliorated further downstream, although these flows may still have a destabilizing effect on some physical, chemical and biological parameters, as reported by Andrews (1986), especially as seen with conditions during and shortly after the high riverflows in mid-August, 1987. Ecosystem dynamics will vary with location in the river, and will be influenced by these river perturbations.

We did not investigate food habits of benthic macroinvertebrates, although algae and detritus are reportedly consumed by several chironomid taxa. Kajak and Wood (1968) reported that chironomid larvae digest and assimilate diatoms better than green or blue-green algae, while some taxa, such as the obligate predator Cryptochironomus, utilize a faunal food base (Armitage 1968).

Fish

The USFWS provided larval and juvenile fish for food habit studies in 1987 and determined fish density in backwaters. In 1988, we seined backwaters qualitatively to obtain fish for food habit studies. Subsamples from the 1987 fish collections were provided to the USBR for subsequent stomach analyses at the Larval Fish Laboratory at Colorado State University. In 1987, six Colorado squawfish were collected in Island Park backwaters, 12 in Jensen backwaters, and 27 in Ouray backwaters. These numbers represent only the number of Colorado squawfish collected in random qualitative seine hauls in the backwaters and not fish density. Although these numbers are small, they tend to support previous observations by USFWS and Utah Division of Wildlife Resources personnel that larval and juvenile Colorado squawfish are more abundant at downstream Ouray backwaters than at upstream Island Park backwaters.

Forty-five Colorado squawfish were collected by the USFWS in 1987 during quantitative sampling in backwaters selected for the trophic dynamics study.

Other fish collected included 7951 red shiners, 1810 fathead minnows, 197 suckers, 132 sand shiners, 39 green sunfish, 36 speckled dace, 8 each chubs and carp, 6 channel catfish, 4 roundtail chubs, and 10 unidentified fish. These numbers do not represent densities.

Fish Food Habits

Analysis of stomach contents of 845 small fish in 1987, 73 of them larval and juvenile Colorado squawfish, and 933 small fish in 1988, 47 of them Colorado squawfish, was conducted to elucidate trophic interactions and predator-prey relationships in Green River backwaters. Fish stomach data were grouped into two size categories, <20 mm TL for larval fish and >20 mm TL for juvenile fish (Snyder 1981).

Colorado squawfish - Larvae. - Eleven larval Colorado squawfish were collected from Jensen and Ouray backwaters in 1987, and three were collected at Jensen in 1988. Larval Colorado squawfish were collected in late July and mid-August. None were collected after August. Percent fullness of larval Colorado squawfish stomachs ranged from 30 to 100 percent. The larval Colorado squawfish ranged in size from 14 to 19 mm TL in 1987, with gape widths from 1.1 to 1.8 mm (average 1.3 mm), and from 11.7 to 19.3 mm TL in 1988.

All three of the larval Colorado squawfish stomachs from BA 300.27 collected in late July, 1987, were 100 percent full, predominantly with monocotyledon plant seeds. Four larval Colorado squawfish stomachs from BA 198.6 contained chironomid larvae, with Chironomus and Polypedilum in three of the four guts. One fish stomach from this backwater contained one ceratopogonid larva. All four larval fish stomachs from BA 250.8 (Moult Bend) collected in late July and mid-August contained chironomid larvae exclusively, with 92 percent of these *Chironomus* sp.

Chironomids were present in stomachs of the three Colorado squawfish collected in 1988, and made up 88 percent of stomach content by volume. *Chironomus* sp. predominated in number and volume. Unidentified organic material made up 10 percent of stomach contents by volume and minerals about 2 percent of the 11.7 mm TL Colorado squawfish. Table 5 shows food items encountered and frequency of occurrence in larval Colorado squawfish in 1988.

Table 5. - Food items encountered and percent frequency of occurrence of these food items in stomachs of 3 larval Colorado squawfish collected from backwaters at Island Park, Jensen, and Ouray on the Green River during the 1988 sampling season.

Food items in the stomach	Total number counted	Percent of total	Percent frequency occurrence	Average Percent by Volume
Diptera				
Chironomidae				
Larvae				
Chironomus sp	23	85	100	71
Polypedilum sp	2	7.4	66	11
Rheotanytarsus sp	1	3.7	33	1.6
Unidentified	1	3.7	33	3.3
Only volumetrically counted				
Unidentified digested material				
Mineral sediment			33	2.3
Organic matter			33	10
TOTAL NUMBER	27	100 percent		100

Colorado squawfish stomachs contained no identifable phytoplankton or zooplankton, and no larval Colorado squawfish had empty stomachs.

Colorado squawfish - Juveniles. - Sixty-two juvenile Colorado squawfish stomachs were examined in 1987, with at least one juvenile collected from each backwater. Squawfish ranged in size from 22 to 80 mm TL and had an average gape of 3.2 mm. Table 6 lists percentages of identifiable food items and percent frequency of occurrence for juvenile Colorado squawfish. Table 7 lists average numbers or percents of stomach contents by general categories and average percent fullness for all juvenile Colorado squawfish stomachs in each backwater by sampling date. Most Colorado squawfish were collected from Ouray backwaters, principally from BA 250.8 (Moult Bend).

YOY and yearling Colorado squawfish utilized various invertebrates, larval fish, woody plant material and other unidentifiable food items. Chironomid larvae appeared in most stomachs that contained invertebrates, with a lower frequency of occurrence of ceratopogonid larvae, tipulids, dipteran pupae, coleopterans, corixids, and infrequently, sparse zooplankton and unidentified invertebrate eggs. Colorado squawfish stomachs all contained some food, except in June and November. Stomach contents varied, but chironomid larvae constituted 39 percent of stomach contents, with larval fish of other species increasing in importance and constituting about 32 percent of stomach contents. Chironomus spp. appeared frequently, with lesser numbers of Tanytarsus, Paracladopelma, and Parachironomus. Chironomus spp. were also the most abundant chironomid larvae in most backwaters. Red shiners (Notropis lutrensis) were most frequent in stomachs containing identifiable fish remains, followed by fathead minnow (Pimephales promelas) and catostomids.

Table 6 , - Food items encountered and percent frequency of occurrence of these тood items in stomachs of juvenile Colorado squawfish collected from backwaters at Island Park, Jensen, and Ouray during the 1987 sampling season

Foot items in the stomach	Total number counted	Percent of total	Percent frequency occurrence
Eucopepoda			
Cyclopoida	7	3	2
Diptera	212	82	47
Pupae	3	1	5
Chironomidae	190	73	42
Larvae	182	70	39
Chironomus sp	62	24	21
Parachironomus sp	2	1	2
Paracladopelma sp	46	18	6
Polypedilum sp	12	5	5
Tanytarsus sp	18	7	13
Diamesinae	1	0	2
Orthocladinae	38	15	8
Unidentified	3	1	3
Pupae	2	1	3
Adults	6	2	5
Ceratopogonidae	14	5	5
Larvae	13	5	5
Pupae	1	0	2
Tipulidae (larvae)			0
Limoniinae	5	2	3
Coleoptera (larvae)	1	0	2
Corixidae	4	2	2
Insect (unidentified)	4	2	5
Larvae	2	1	2
Adults	2	1	3
Osteichthyes	32	12	29
Unidentified	7	3	10
Cyprinidae	24	9	19
Unidentified	2	1	2
Notropis Lutrensis	19	7	13
Pimephales promelas	3	1	3
Catostomidae	1	0	2
Unidentified invert. eggs			2
Plant tissue			2
Unidentified digested material			18
Mineral sediment			5
Organic matter			18
TOTAL NUMBER	260		

Table 7. - Stomach content information of juvenile Colorado squawfish from Green River backwaters in 1987

Backwater	Date	Number stomachs	Average percent full	Chiro	Ceratop	Tipulid	Other diptera	Fish	Zoopl	Other	Coleop	Average percent unident matter
Island Park												
BA-333.2	Aug 17	1	65					1				
BA-332.2	Nov 17	1	0									
Jensen												
Sheep Camp	June 3	3	80	56								25
BA-300.27	Sept 2	1	40				2					
	Nov 18	3	30		4			1				25
BA-330.26	Sept 2	1	80					1				
BA-298.7	Sept 23	3	33					1				
	Oct 21	3	24					2				
Ouray												
Old reference	June 4	2	25	2	10							17
BA-251.1	June 4	1	0									
	June 25	1	70	26								
	Sept 3	10	58	57			2	7				19
	Nov 19	1	0									

Table 7 . - Stomach content information of juvenile Colorado squawfish from Green River backwaters in 1987 - Continued

Backwater	Date	Number stomachs	Average percent full	Chiro	Ceratop	Tipulid	Other diptera	Fish	Zoopl	Other	Coleop	Average percent unident matter
BA-250.8	July 24	1	2									
	Aug 6	1	75	5				3				
	Aug 1	1	70	3				4				
	Sept 3	3	53	13 + many parts					7			
	Sept 24	2	55	9								
	Oct 22	4	37	16		5						
	Nov 19	3	0									
BA-249.7	Sept 3	8	47	4				13			1	9
	Oct 22	4	45					3		Wood		
	Nov 19	4	3							Corixid		

* Chiro = Chironomid larvae
Ceratop = Ceratopogonidae larvae
Tipulid = Tipulidae larvae
Zoopl = Zooplankton
Coleop = Coleptera

The absence of food in YOY or yearling Colorado squawfish in November indicate reduced feeding activity as water temperatures decreased. Empty stomachs may have implications on overwinter survival of Colorado squawfish.

In 1988, fish were a major component of the diet of juvenile Colorado squawfish. Fish were found in 37 percent of the stomachs examined and constituted 38.3 percent of stomach contents by volume, with Notropis lutrensis the fish present most often. Chironomids were found in 43 percent of the juvenile stomachs and constituted 36 percent of contents by volume. Chironomus spp. was the usual chironomid present and made up 65 percent by number and 72 percent by volume of all chironomid larvae found in stomachs. Rheotanytarsus spp. was also present in relatively large numbers making up 31 percent by number and 23 percent by volume of all chironomid larvae. Identifiable phytoplankton were absent in the juvenile stomachs and zooplankton (only cyclopoid copepods) were found in just 6 percent of the stomachs. Unidentifiable organic material and mineral material made up 18 and 4.5 percent of stomach contents by volume, respectively. Table 8 shows percentage of food items and percent frequency of occurrence for juvenile Colorado squawfish for 1988. Table 9 lists average numbers and percents of stomach contents by general categories for juvenile Colorado squawfish collected in 1988.

Gila sp. - Larvae. - Five larval Gila sp. were collected from the Island Park backwaters in 1988. Unidentified insect parts made up 36 percent of stomach contents by volume. Unidentified invertebrate eggs and protozoans made up 28 percent of contents by volume. Chironomids were found in 80 percent of the stomachs and made up 9.8 percent of contents by volume with Polypedilum sp.

Table 8. - Food items encountered and percent frequency of occurrence of these food items in stomachs of 44 juvenile Colorado squawfish collected from backwaters at Island Park, Jensen, and Ouray on the Green River during the 1988 sampling season.

Food items in the stomach	Total number counted	Percent of total	Percent frequency occurrence	Average Percent by Volume
Eucopepoda				
Cyclopoida	13	7	7	1.4
Diptera				
Chironomidae				
Larvae				
Chironomus sp	72	38	34	24
Polypedilum sp	0	0	0	0
Rheotanytarsus sp	34	18	22	8
Procladius	1	.5	2	.2
*Harnischia	3	2	4.5	.5
Unidentified	2	1	4	1
Pupae	2	1	2	3
Ceratopogonidae				
Larvae	8	4	9	1
Pupae	1	.5	2	.2
Coleoptera (larvae)	3	2	4	2.5
Corixidae	4	2	2	2
Oligochaeta	5	2	2	2
Osteichthys				
Unidentified	20	11	27	19
Cyprinidae				
Notropis lutrensis	19	10	20	17
Catostomidae	1	.5	2	2
Only volumetrically counted				
Insect (unidentifiable parts)			13	7
Ephemeroptera nymphs			2	2
Unidentified invert. eggs			2	.3
Plant tissue			2	.3
Unidentified digested material				
Mineral sediment			4	.4
Organic matter			18	6.2
TOTAL NUMBER	188	100 percent		

*Includes Paracladopelma sp.

Table 9 . - Stomach content information of juvenile Colorado squawfish from the Green River in 1988

Backwater	Date	Number stomachs	Average percent full	Chiro	Ceratop	Corixid	Average percent unident insect	Fish	Zoopl	Coleop	Other	Average percent unident matter
Jensen												
BA-300.6	July 13	1	70				15	1				
BA-300.5	Aug 10	2	82	23								3(mineral)
	Oct 12	1	10				100					
BA-299.4	Aug 24	8	71	33	6		1	12	8	2		5(organic)
	Sept 7	1	0									
	Oct 12	10	28	11				9				10(organic)
BA-298.1	July 13	1	90	4								30(organic)
	Aug 10	3	80	11	2						3%seeds	17(mintorg)
Ouray												
BA-251.1	July 28	1	60				15			1		60(mintorg)
	Sept 22	1	65					2				
BA-250.8	Aug 11	2	72	4					2			
	Aug 25	3	68	18		4			3			
	Sept 8	2	75	28								
	Sept 22	1	70					3				
	Oct 13	1	80					1			5 Oligo.	
BA-250.7	Aug 25	1	50	6			50					
	Sept 8	1	30				100					
	Sept 22	5	64	3	1			11				
	Oct 13	2	0									

* Chiro = Chironomid larvae
Ceratop = Ceratopogonidae larvae
Zoopl = Zooplankton
Coleop = Coleptera
Oligo = Oligochaetes

the major taxon. Unidentifiable organic material made up 8.8 percent of contents by volume. No identifiable zooplankton, phytoplankton, or mineral material was found.

Gila sp. - Juvenile. - Twenty-four juvenile *Gila* sp. stomachs were examined from fish ranging in size from 21 to 80 mm TL. Fourteen of the fish were collected from Island Park backwaters, eight from Jensen backwaters and two from Ouray backwaters. *Gila* sp. stomachs contained predominantly Diptera, with some identifiable chironomid larvae. Plant seeds were found in few *Gila* sp. stomachs with digested fish present in one *Gila* sp. collected from Island Park. Five *Gila* sp. collected in June and November had empty stomachs.

The *Gila* sp. stomachs from Island Park contained parts of adult Diptera in June, August and September. Two of these stomachs also contained chironomid larvae and adults.

Gila sp. stomachs from Jensen backwaters contained Coleoptera adults, chironomid larvae, plant seeds, Diptera adults, diatoms and unidentified insect parts and digested material present. Two of the stomachs were 100 percent full, one containing 40 chironomid larvae, predominantly *Polypedilum* sp. and *Paracladopelma* sp., the other containing unidentified digested material and some diatoms. Stomachs from both *Gila* sp. collected from the Ouray backwaters were empty.

In 1988, juvenile *Gila* sp., with one exception, were collected only from the Island Park and Jensen backwaters. Unidentified insect parts were present in 35 percent of the stomachs and made up 26 percent of contents by volume. Chironomids made up 27 percent of contents by volume with *Chironomus* sp. the primary taxon, especially in Jensen backwaters. Fish (unidentifiable and *Notropis lutrensis*) were found in 7 percent of the *Gila* sp. stomachs and averaged 4.7 percent of contents by volume. Monocotyledon seeds were present in 14 percent of the stomachs and made up a 7.1 percent by volume. Ephemeropteran adults were only present in *Gila* sp. juveniles from Island Park but made up 100 percent of stomach contents. Unidentified material made up a relatively small percent of contents by volume with only 5.2 percent organic material and 1.2 percent mineral matter.

Red shiner - Larvae. - Stomachs from sixty-two red shiner larvae ranging from 7 to 20 mm TL were examined. Most larval red shiners were collected in July and August, with some larval fish collected in June from Ouray backwaters and a few from most backwaters into September. Larvae were collected as late as October in Jensen BA 300.26.

Larval red shiners predominantly utilized zooplankton, phytoplankton, and chironomid larvae as food in 1987. Unidentified digested material was found in 63 percent of the larval stomachs. Of the chironomids, *Tanytarsus* sp. was found in 10 percent of the stomachs. Phytoplankton and zooplankton were abundant in stomachs up to late August. Chlorophyta and Rotatoria were found in 18 and 23 percent of the stomachs, respectively.

Ceratopogonidae (larval and adult combined) were found in 19 percent of the stomachs and monocotyledon plant seeds were found in 18 percent of the stomachs. Hydracarina, Nematoda, Orthoptera nymphs, coleopteran larvae and terrestrial Hemipterans were infrequent food items.

In 1988 unidentified organic material was present in 52 percent of the stomachs and averaged 29 percent of contents by volume. Phytoplankton was present in 31 percent of red shiner larvae stomachs with unidentifiable single cell algae contributing 5.6 percent of contents by volume and colonial algae comprising 3.9 percent by volume. Total phytoplankton made up 15.4 percent of contents by volume in 1988. Zooplankton made up 9 percent of stomach contents by volume and occurred in 25 percent of the stomachs; cyclopoid copepods and cladocerans were the major groups present. Ceratopogonids (pupa and larvae) made up 8.8 percent of stomach contents by volume. Chironomid larvae were present in 22 percent of the stomachs and constituted 11.3 percent of stomach contents by volume. Chironomus sp. was the most numerous.

Red shiner - Juvenile. - Red shiner juveniles were widely distributed among all backwaters in 1987. One hundred fifty-three stomachs from 21 to 74 mm TL juvenile red shiners were examined. No obvious differences in stomach contents were noted. Zooplankton and phytoplankton were less frequent in stomachs of larger fish than in stomachs of larval fish. Chironomids were present in 38 percent of the stomachs with Chironomus sp. found in 14 percent of the stomachs. Ceratopogonids were present in 12 percent of the stomachs. Coleoptera, Hymenoptera, Ephemeroptera, and Trichoptera had a 4, 4, 2, and 5 percent frequency of occurrence, respectively. Unidentified digested material percent frequency of occurrence was 48 percent, lower than that observed in larval stomachs.

In 1988, unidentified organic material had a 45 percent frequency of occurrence and was 20 percent of stomach contents by volume. Chironomids made up 16 percent of contents by volume with Chironomus sp. the major taxon present. Red shiners had the most diverse assemblage of chronomid larvae found in fish stomachs, represented by 10 taxa, although chironomid larvae contributed less to percent of contents by volume than that found in other species, including Colorado squawfish. Fish were present in 1 percent of the stomachs with identifiable fish being Notropis lutrensis. Plant seeds were present in 10 percent of the stomachs and constituted 6 prcent of contents by volume. Unidentified insect parts, unidentified dipterans, corixids, and coleopterans each made up about 5 percent of stomach contents by volume.

Fathead minnow - Larvae. - Sixty-four larval fathead minnow stomachs were examined from fish collected in 1987 and ranging in size from 9 to 20 mm TL. Chrysophyta were the most frequent phytoplankton present. Diatomaceae were present in 19 percent of the stomachs with Navicula sp. the major taxon. Larval fathead minnow stomachs contained a slightly different assemblage of zooplankton than larval red shiner stomachs. Eucopepods were present in 17 percent of the stomachs, cladocerans in 6 percent and Rotatoria in 13 percent of the stomachs. The predominant identifiable food item was chironomid larvae, found in 44 percent of the stomachs. Tanytarsus sp. and Polypedilum sp. were present at 16 and 11 percent frequency of occurrence, respectively. Unidentified digested material, predominantly organic, was present in 94 percent of the stomachs. Plant seeds were present in 9 percent of the larval fathead minnow stomachs and made up 95 percent of stomach contents in two fish. Ephemeroptera and coleoptera larvae were found infrequently.

In 1988, fathead minnow larvae stomachs contained Chironomus sp. and Rheotanytarsus sp. at 17 and 14 percent frequency of occurrence, respectively, with Chironomus sp. constituting 4.8 percent by volume. Total zooplankton averaged 16.5 percent of the stomach contents by volume with cladocerans and cyclopoid copepods the major taxa present. Unidentified organic matter made up 33 percent and mineral matter 29 percent of stomach contents by volume.

Fathead minnow - Juvenile. - Unidentified digested material occurred in 94 percent of the juvenile fathead minnow stomachs collected in 1987, similar to larval fathead minnow stomachs. Chironomid larvae occurred in 30 percent of the stomachs and were the most frequently identifiable items in the stomachs. Tanytarsus sp. was the predominant chironomid found in 10 percent of the stomachs. Ceratopogonid larvae, pupae, or adults were found in 7 percent of the juvenile fathead minnow stomachs. Chrysophyta occurred in 26 percent of the stomachs with the diatom Navicula sp. present in most stomachs. Chlorophyta, specifically Closterium sp., was present in 10 percent of the stomachs. A small number of zooplankton were found in stomachs from fish collected in Ouray backwaters.

In 1988, unidentified organic and mineral material constituted 51 and 30 percent, respectively, of major stomach contents by volume for fathead minnows. Chironomus sp. averaged 5.5 percent of contents by volume and made up 68 percent of the chironomids found in stomachs. Unidentified insect parts were present in 7.4 percent of the stomachs and made up 1.7 percent of the stomach contents by volume. Ostracods were present in 1.8 percent of the stomachs and made up 5.8 percent by volume.

Speckled dace - Larvae. - The stomachs from 25 larval speckled dace collected in 1987 contained predominantly chironomid larvae, present in 64 percent of the stomachs. Zooplankton were more abundant in the stomachs of the smaller (9 to 12 mm TL) fish. Ceratopogonids were rare, found in only 4 percent of the stomachs; plant seeds were present in 12 percent of the stomachs and unidentified digested material in 28 percent.

In 1988, speckled dace larvae were collected from the Island Park and Jensen backwaters. The major stomach contents were chironomids, found in 77 percent of the stomachs and constituting 58 percent of contents by volume. *Chironomus* sp. was the major taxon, with *Nanocladius* sp. the next most common taxon. Ceratopogonid larvae made up 8 percent of stomach contents by volume. Unidentifiable organic material was found in about one-half of the stomachs at 12 percent of contents by volume.

Speckled dace - Juvenile. - Juvenile speckled dace were all collected from Island Park and Jensen backwaters. Chironomid larvae and pupae were found in 90 percent of the stomachs. One fish stomach contained 43 percent filamentous Chlorophyta. Monocotyledon plant seeds were found in 5 percent of the stomachs while unidentified digested plant material was found in 52 percent of the stomachs.

In 1988, eighteen speckled dace were collected, primarily from Jensen backwaters. Chironomids averaged 54 percent of stomach contents by volume, with *Chironomus* sp. and *Rheotanytarsus* sp. the major taxa. Unidentifiable organic material made up 22 percent of contents by volume.

White sucker - Juvenile. - No larval white suckers were collected either year. Seventeen juvenile white suckers were collected from Island Park and Jensen backwaters. Stomachs ranged from 30 to 100 percent full. Chironomid larvae were found in 14 stomachs making up from 15 to 100 percent of the contents. Ceratopogonidae were found in only a few stomachs; ostracods were found in about one-third of the stomachs. Zooplankton (cyclopoid copepods and cladocerans) were found in stomachs of four white suckers collected from Island Park and Jensen, and phytoplankton (Crysophyta and Chlorophyta) was found only in white suckers collected in the early June samples.

In 1988, unidentifiable organic material made up 32 percent of contents by volume with mineral material making up 21 percent. Zooplankton occurred in 83 percent of the stomachs at 22.5 percent of contents by volume. Chironomids were found in one-half of the white sucker stomachs, all collected in September.

Bluehead sucker - Larvae. - Thirty-seven larval bluehead suckers, ranging in size from 10 to 20 mm TL, were collected in 1987. Unidentified digested material occurred in 86 percent of the larval stomachs and made up 100 percent of the contents of 11 of the stomachs. Rotifers were the most frequent zooplankton with Keratella sp. most abundant in some stomachs. Diatoms were frequent with Navicula sp. present in 38 percent of the stomachs. Chlorophyta was present in 30 percent of the stomachs. Chironomid larvae were present in 27 percent of the stomachs, with rotifers present in 14 percent.

In 1988, unidentified organic matter and mineral material made up 62 and 21 percent, respectively, of the stomach contents. Chironomids were present in 28 percent of the stomachs with Beckidia sp. the predominate identifiable taxon. Diatoms predominated among the phytoplankton with all phytoplankton accounting for less than 1 percent of stomach contents by volume. Unidentified coleoptera remains made up 7 percent of the stomach contents by volume.

Bluehead sucker - Juvenile. - Ninety-six percent of the 45 juvenile bluehead sucker stomachs examined contained unidentifiable digested material, ranging from 50 to 100 percent of stomach content by volume. Diatoms, predominantly Navicula sp. and Natzschia sp., were found in 64 percent of the juvenile stomachs. Eucopepoda, cladocerans and rotifers were found in high numbers in a few fish stomachs earlier (June) in the year at all sample areas. Chironomid larvae were found in 33 percent of the bluehead suckers with no obvious preference among the six genera found. No juveniles had empty stomachs, and the lowest percent fullness was 20 percent.

In 1988, chironomids were the primary food item in stomachs of juvenile bluehead suckers. Chironomus sp. predominated with a 53 percent frequency of occurrence and 3.5 percent of stomach contents by volume. Zooplankton (primarily Eucopepoda) made up 17 percent of all food items but only 1.6 percent of contents by volume. Unidentifiable organic material made up 54 percent of stomach contents by volume and mineral material was 23 percent.

Flannelmouth sucker - Larvae. - Chironomid larvae, pupae, or adults were present in 62 percent of larvae flannelmouth sucker stomachs; chironomid larvae were present in 46 percent of the stomachs. Copepods were the predominant zooplankton, found in 19 percent of the stomachs, primarily those collected from Ouray backwaters. Chlorophyta phytoplankton, primarily Closterium sp., was present in 27 percent of the stomachs and Cyanophyta in 12 percent. Diatoms were present in 12 percent of the stomachs and unidentified digested material was present in 58 percent of the stomachs. No larval flannelmouth suckers were collected after late June, and none were collected in 1988.

Flannelmouth sucker - Juvenile. - Stomachs from thirty-two juvenile flannelmouth suckers collected in 1987 from Island Park and Jensen backwaters were examined, with chironomid larvae the dominate identifiable food item found in 75 percent of the stomachs. Eleven chironomid taxa were identified. Ceratopogonid larvae were present in 22 percent of the stomachs and Trichoptera were present in 13 percent of the stomachs. Eucopepods were the primary zooplankton found in 1 percent of the juvenile stomachs. Chrysophyta and Chlorophyta were present in 19 percent of the stomachs with Navicula sp. the predominant diatom. Ninety-four percent of the stomachs contained some unidentified digested material and no stomachs were empty.

In 1988, juvenile flannelmouth suckers were again collected from Island Park and Jensen backwaters. Unidentified organic material occurred in 98 percent of the stomachs, and made up 34 percent of stomach contents by volume. Zooplankton, primarily cyclopoid copepods, made up 13.2 percent of stomach contents by volume. Phytoplankton accounted for 1.2 percent of contents by volume, with diatoms most abundant. Chironomids made up 17.6 percent of stomach contents by volume, with Chironomus sp. and Rheotanytarsus sp. the most common of the 8 chironomid taxa present.

Sand Shiner - Larvae. - Stomachs from larval sand shiners collected in 1987 contained predominantly chironomid larvae with 53 percent of the stomachs containing unidentified digested material. Copepods, cladocerans and rotifers were found in only a few fish. Monocotyledon plant seeds were found in one third of the larval sand shiner stomachs, primarily from Jensen and Ouray backwaters. No larval sand shiner stomachs were empty, with the lowest percent fullness of about 20 percent.

In 1988, larval sand shiners were collected only from Island Park and Jensen backwaters. Chironomids made up 41 percent of stomach content by volume. Chironomus sp. and Rheotanytarsus sp. accounted for 60 and 23 percent, respectively, of all chironomid larvae by number. Zooplankton made up 11.8 percent of contents by volume with cladocerans the most abundant. Unidentified organic material made up 33 percent of the stomach contents by volume and mineral material made up 6 percent.

Sand shiner - Juvenile. - Chironomid larvae occurred in 53 percent of the 49 juvenile sand shiners stomachs examined. Ceratopogonid larvae, Tipulidae, and Callophoridae had 10, 2, and 4 percent frequencies of occurrence, respectively. Unidentified insect parts were present in 33 percent of the stomachs. Unidentifiable digested material was found in 88 percent of the stomachs, with monocotyledon plant seeds present in 18 percent of the stomachs.

In 1988, juvenile sand shiners from Island Park and Jensen backwaters contained unidentifiable organic material at 31 percent of contents by volume. Cladocerans and rotifers were the principal zooplankters found in 25 percent of the stomachs. Insect parts made up 11 percent of stomach contents by volume. Chironomid larvae made up 15.9 percent of stomach contents by volume; unidentifiable chironomid larvae predominated in the stomachs, followed by Chironomus sp.

Redside shiners - Juvenile. - Twenty-one juvenile redside shiners were collected in 1987; no larval fish were collected. Insect larvae and adults were found in 57 percent of the stomachs. Chironomid larvae were found in 14 percent of the stomachs. Trichoptera and Hemiptera both had a 14 percent frequency of occurrence, and Ephemeroptera occurred 10 percent of the time. Plant seeds were present in 14 percent of the stomachs and unidentified digested material occurred in 57 percent of the stomachs.

In 1988, all but one of the juvenile red shiners were collected from Island Park and Jensen backwaters. Unidentified insect parts constituted 28 percent of stomach contents by volume. Stomach contents included a diversity of insects with sparse chironomids and a notable absence of zooplankton and phytoplankton. Unidentified invertebrate eggs and/or protozoans made up 22 percent of stomach contents by volume.

Carp - Larvae. - Stomachs from two larval carp collected at Jensen in early June, 1987, were examined. The stomachs averaged 46 percent full. Chironomid larvae, including some Chironomus sp. were present in both stomachs; one stomach also contained 19 ceratopogonid larvae, while the other contained one diptera pupa.

Carp - Juvenile. - Ninety-five percent of the stomachs from juvenile carp collected in Jensen and Ouray backwaters in 1987 contained chironomid larvae, with Paracladopelma sp. the most frequent genus observed. Copepods, plant seeds, and ceratopogonids were present infrequently. The stomach of the largest (84 mm TL) juvenile carp collected, in BA 249.6, contained one red shiner larva. Unidentified organic material was present in 77 percent of the carp stomachs.

In 1988, juvenile carp were collected primarily from Ouray backwaters. Chironomids were the dominant food item in 83 percent of the stomachs, with

Chironomus sp. accounting for 73 percent of all food items and constituting 36 percent of stomach contents by volume. Gut parasites made up 2.7 percent of the stomach contents by volume with unidentified organic material making up 28 percent of stomach contents by volume. Plant seeds were present in 5 percent of the stomachs. Carp from Missouri River backwaters, ranging in size from 5 to 33 mm TL, consumed cladocerans and cyclopoid copepods, which constituted 88 percent of the food items in the stomachs (Persons 1979).

Channel catfish - Juvenile. - Stomachs from eight channel catfish (24 to 108 mm TL) collected from Ouray backwaters, primarily BA 250.8, were examined. Channel catfish stomachs averaged 75 percent full. All stomachs contained chironomid larvae with Chironomus sp. present in 88 percent of the stomachs. Ceratopogonids were present only in the stomachs from BA 249.7. Unidentified digested material was present in 63 percent of the stomachs. Trichoptera cases and Ephemeroptera nymphs were also present in one stomach from BA 250.8. No stomachs were empty.

In 1988, ninety-two percent of the channel catfish were collected from Ouray backwaters and ranged in size from 27 to 113 mm TL. Food items were diverse with chironomids dominating stomach contents by volume. Chironomus sp. made up 77 percent of the chironomid larvae by number. Unidentified organic material making up 15 percent of stomach contents by volume. Plant seeds were found in 11 percent of the stomachs. Unidentified insect parts made up 11 percent of contents by volume in 32 percent of the stomachs. Zooplankton and phytoplankton were absent.

Black bullhead - Juveniles. - Black bullheads collected in 1988 ranged in size from 33 to 135 mm TL. Chironomid pupae and larvae principally Chironomus spp. were found in 100 percent of the stomachs and constituted 67 percent of stomach contents by volume. Corixidae were more common in bullheads than in stomachs of other fish species and made up 12 percent of contents by volume. Zooplankton and phytoplankton were absent and unidentified organic material made up only 4.2 percent of contents by volume.

Green sunfish - Larvae. - Six larval green sunfish were collected in June 1987, primarily from Jensen BA 300.26. None were collected in 1988. The stomachs had an 83 percent frequency of occurrence of cyclopoid copepods and a 67 percent frequency of occurrence of Cladocera (Eurycercus lamellatus). Chironomid larvae were present in four of the six stomachs. Unidentified digested material was present in one-half of the larval green sunfish stomachs.

Green sunfish - Juvenile. - Chironomid larvae occurred in 89 percent of stomachs of the 9 juvenile green sunfish collected in 1987, primarily from Jensen backwaters, with Chironomus sp. the predominant genus. Two of the smaller juvenile green sunfish contained more zooplankton than larger juveniles. Stomachs averaged 69 percent full, with none empty.

In 1988, chironomids were found in 91 percent of the stomachs, while making up 50 percent of contents by volume. Chironomus sp. was the dominant chironomid taxon found in 83 percent of the green sunfish stomachs. Corixids occurred in 41 percent of the stomachs, and constituted 15 percent of contents by volume. Unidentified organic material was found in one-half the stomachs, and constituted 12 percent of contents by volume.

Largemouth bass - Juvenile. - One 86 mm TL largemouth bass was collected from BA 249.7 in early September, 1987. The stomach contained one partially digested fish constituting 45 percent of the gut contents. The remaining contents were Corixidae and unidentified digested material.

Northern pike - Adult. - One 400 mm TL northern pike was collected from BA 300.26 in early June, 1987. The stomach contained remains of three fish, two unidentifiable about 30-40 mm and 50-60 mm TL. The other was a catostomid (possibly a bluehead sucker) 60-70 mm TL.

Mottled Sculpin - Larvae. - Two mottled sculpin larvae were collected in early June, 1987, one each from BA 333.2 and BA 300.26. Chironomid larvae were present in both stomachs, with *Tanytarsus* sp. common to both. Both stomachs were about 95 percent full. Unidentified digested material made up 65 percent of the stomach contents from the fish collected in BA 333.2.

Tables 10 and 11 show the percent frequency of occurrence of major food items in 1987 and 1988. Table 12 shows the percent of major stomach contents by volume for fish from all backwaters.

Summary of Fish Food Habits

Fish stomachs contained a variety of aquatic and terrestrial food items. Chironomids were present in the stomachs of most of the fish species collected, and were the dominant food item in stomachs of a few species. Interestingly, plant seeds (monocotyledon) were present in many of the fish stomachs and were the exclusive contents in three Colorado squawfish stomachs.

Table 10. - Average percent frequency of occurrence of major food items in stomachs of several fish species collected in Green River backwaters, 1987.

Species		Number of stomachs	Percent frequency of occurrence							
			Chironomids	Ceratopogonids	Other Dipterans	Fish	Phytoplankton	Zooplankton	Plant seeds	Unidentified digested material
Colorado squawfish	Larvae	11	82	9	0	0	0	0	27	27
	Juveniles	62	42	5	3	29	0	2	0	18
Gila Sp.	Juveniles	24	33	0	0	4	4	0	17	21
Red shiner	Larvae	62	47	19	0	0	10	12	18	63
	Juveniles	153	38	12	1	0	5	2	20	48
Fathead minnow	Larvae	64	45	5	0	0	10	12	9	94
	Juveniles	136	30	7	1	0	16	3	3	94
Speckled dace	Larvae	25	64	4	4	0	4	16	12	28
	Juveniles	21	90	14	0	0	5	0	5	52
White sucker	Juveniles	11	82	18	0	0	22	18	0	100
Bluehead sucker	Larvae	37	27	3	3	0	24	7	5	86
	Juveniles	45	31	9	0	0	45	8	2	96
Flannelmouth sucker	Larvae	26	62	4	0	0	16	14	4	58
	Juveniles	32	75	22	0	0	19	8	6	94
Sand shiner	Larvae	15	73	7	7	0	10	13	33	53
	Juveniles	49	53	10	3	0	13	2	18	88
Redside shiner	Juveniles	21	33	5	14	0	0	7	14	57
Carp	Larvae	2	100	50	0	0	0	0	0	50
	Juveniles	22	95	14	5	0	0	18	5	77
Channel catfish	Juveniles	8	100	25	0	0	0	0	13	63
Green sunfish	Larvae	6	67	0	0	0	0	75	0	50
	Juveniles	9	89	11	0	11	11	22	0	33
Largemouth bass	Juveniles	1	0	0	0	100	0			100
Norther pike	Adult	1	0	0	0	100	0	0	0	100
Mottled scullpin	Larvae	2	100	0	0	0	0	0	0	50

Table 11. - Percent frequency of occurrence of major food items in stomachs of fish species collected in Green River backwaters at Island Park, Jensen, and Ouray, 1988.

Species		Number of stomachs	Percent frequency of occurrence							Unidentified	
			Chironomids	Ceratopogonids	Other Dipterans	Fish	Phytoplankton	Zooplankton	Plant seeds	organic material	mineral material
Colorado squawfish	Larvae	3	100	0	0	0	0	0	0	10	2
	Juveniles	44	43	11	0	37	0	6	2	18	4
Gila Sp.	Larvae	5	80	1	10	0	0	0	0	60	0
	Juveniles	42	38	10	12	7	2	0	14	21	7
Red shiner	Larvae	144	22	15	7	0	31	25	10	52	15
	Juveniles	199	31	13	16	1	37	1	10	45	14
Fathead minnow	Larvae	41	43	0	24	0	14	43	2	97	73
	Juveniles	161	23	3	0	0	30	4	5	95	81
Speckled dace	Larvae	31	77	19	12	0	12	12	3	25	3
	Juveniles	18	77	16	0	0	0	5	11	50	27
White sucker	Juveniles	6	50	0	33	0	0	83	0	83	66
Bluehead sucker	Larvae	7	28	14	0	0	42	14	0	100	57
	Juveniles	39	12	0	0	0	59	20	2	94	87
Flannelmouth sucker	Juveniles	58	63	24	5	0	18	56	5	98	82
Sand shiner	Larvae	32	71	15	0	0	9	25	6	81	37
	Juveniles	22	59	13	18	0	9	9	32	77	18
Redside shiner	Juveniles	8	12	25	12	0	0	0	25	12	12
Carp	Juveniles	18	83	11	16	0	0	22	5	72	22
Channel catfish	Juveniles	37	67	35	21	0	0	0	11	51	5
Green sunfish	Juveniles	12	91	0	16	0	0	25	0	50	0
Black bullheads	Juveniles	7	100	14	16	0	0	0	14	14	14

Table 12. - Average percent of major stomach contents by volume collected in Green River backwaters at Island Park, Jensen, and Ouray, 1988.

Species		Average fullness	*Percent of major stomach by volume								Unidentified	
			Chironomids	Ceratopogonids	Other Dipterans	Other insects	Fish	Phytoplankton	Zooplankton	Plant seeds	organic material	mineral material
Colorado squawfish	Larvae	85	86	0	0	0	0	0	0	0	10	2
	Juveniles	53	36	1	0	14	38	0	1	3	6	4
Gila Sp.	Larvae	68	10	1	15	42	0	0	0	0	9	0
	Juveniles	71	27	3	5	43	5	4	7	7	5	1
Red shiner	Larvae	62	11	9	3	9	0	15	9	4	29	3
	Juveniles	57	16	4	9	34	1	3	5	6	20	3
Fathead minnow	Larvae	72	15	0	2	3	0	7	18	3	33	29
	Juveniles	74	8	1	0	2	0	2	1	1	51	30
Speckled dace	Larvae	73	58	10	6	4	0	1	4	3	12	1
	Juveniles	72	54	3	0	6	0	0	1	4	22	4
White sucker	Juveniles	90	10	0	3	1	0	0	22	0	32	21
Bluehead sucker	Larvae	83	5	1	0	7	0	1	1	0	62	21
	Juveniles	77	4	0	0	0	0	15	2	5	54	23
Flannelmouth sucker	Juveniles	81	18	3	1	1	0	8	13	9	34	22
Sand shiner	Larvae	69	41	5	0	1	0	1	12	8	33	6
	Juveniles	80	16	2	7	21	0	2	7	12	31	3
Redside shiner	Juveniles	46	6	1	6	59	0	0	0	10	1	1
Carp	Juveniles	71	42	6	2	7	0	0	2	5	28	2
Channel catfish	Juveniles	67	40	6	8	29	0	0	0	1	15	6
Green sunfish	Juveniles	71	50	0	5	27	0	0	5	0	12	0
Black bullheads	Juveniles	82	67	6	0	19	0	0	0	0	4	1

* Calculated with stomachs containing food.

The relationship between larval Colorado squawfish gape and zooplankton prey size was not clear, since no identifiable zooplankton were found in larval Colorado squawfish stomachs. Mikheev (1984) concluded that maximum prey size, in the case of young fishes feeding upon zooplankton was related to the dimension of the mouth. The larger zooplankton available as food, primarily cladocerans, ranged in length from 0.7 to 3 mm (measurements from Pennak 1978). Other zooplankton available ranged in size from 0.15 to 1.2 mm. The average larval Colorado squawfish gape of 1.3 mm limited consumption of large zooplankton but does not explain the complete lack of zooplankton in the gut of the larval fish collected. The average gape of juvenile Colorado squawfish was 3.2 mm, which would not appear to limit utilization of the zooplankton; however, zooplankton were encountered infrequently in juvenile Colorado squawfish stomachs. Frank and Leggett (1986) reported that the size structure of the available plankton community can affect both growth and survival of larval capelin, but with so few zooplankton present, no attempt was made to determine size structure of the planktonic community.

Chironomid larvae appear to be an important food item for larval and juvenile Colorado squawfish, with a 2-year frequency of occurrence of 91 percent in larval squawfish and 43 percent in juveniles. Vanicek (1967) reported that Colorado squawfish up to 50 mm utilized both chironomid larvae and zooplankton as important food items. Other species of fish collected from backwaters that utilized chironomids heavily in the diet included: speckled dace, sand shiner larvae, carp, channel catfish, green sunfish, and black bullheads. The wide range of fish species that utilize chironomid larva suggests some dietary overlap with possible competition if chironomids were limited by factors such as unfavorable environmental conditions. Very few fish species besides Colorado squawfish had fish remains in their stomachs. Fish were a major food item in 33 percent of Colorado squawfish stomachs, making up 39 percent of the stomach contents by volume in 1988. Predation on larval or juvenile Colorado squawfish by larvae or juveniles of other fish species was not suggested by data from this study. The introduced red shiner was the major forage fish species for the juvenile Colorado squawfish and appeared in squawfish stomachs over the summer and fall, possibly because of protracted spawning in the red shiner and their great abundance and availability. Percent fullness of juvenile Colorado squawfish stomachs declined through the fall, with most fish having empty stomachs in November 1987. Reduced feeding by Colorado squawfish in the fall may have implications to overwinter survival.

Stomachs from larval Gila sp. collected in 1988 contained primarily unidentifiable insect parts, while stomachs from juvenile Gila sp. contained primarily dipterans and unidentifiable insect parts. Fish remains were also found in 5 percent of the stomachs of juvenile Gila sp.

Red shiner larvae primarily utilized zooplankton, phytoplankton, and chironomids as food, while juveniles utilized less plankton and more chironomids and other insects.

Fathead minnow larvae stomachs contained diverse food items including zooplankton and unidentifiable organic material as major components. Stomachs of juvenile fathead minnows contained abundant unidentifiable organic material and high numbers of chironomids.

Larval and juvenile speckled dace contained predominantly chironomids.

Sucker stomachs contained primarily unidentifiable organic material, and generally a more diverse assemblage of food items than other fish species. Food items included phytoplankton (primarily diatoms), zooplankton, chironomids, ceratopogonids, unidentifiable insect parts, and plant seeds, suggesting omnivorous feeding behavior.

Stomachs of larval and juvenile sand shiners contained predominantly chironomids, with a high amount of unidentifiable organic material.

Stomachs of juvenile redside shiners contained abundant unidentifiable insect parts and various other food items.

Carp larvae and juvenile stomachs contained primarily chironomids. Chironomids were also dominant in the stomachs of the limited sample of juvenile channel catfish, black bullhead, and green sunfish.

Continuous Monitoring Instrumentation

Continuous recording water quality measuring instruments provided hourly information from one backwater each at Island Park, Jensen and Ouray. These instruments were located in the deepest portion of the backwater, at least 5 meters from the backwater mouth and were positioned such that the measuring probes were about 0.3 meter above the substrate. Analysis of the water quality data from these instruments included a comparison between 1987 and 1988 data from the Island Park and Ouray backwater, where monitors were in the same backwaters both years.

A water quality monitor was in place in BA 333.2 at Island Park from June 23 to November 18, 1987; it measured and stored temperature, pH, specific conductance, and dissolved oxygen data every hour. Similar water quality monitors were placed in BA 300.26 at Jensen and BA 251.0 at Ouray for nearly the same period of time. The average seasonal high and low values of water temperature, pH, dissolved oxygen and specific conductance are presented on table 13. At BA 333.2, maximum daily summer water temperatures generally occurred at 7:00 p.m. and the minimum temperatures usually occurred around 11:00 a.m. The maximum summer dissolved oxygen levels in this backwater usually occurred about 6:00 p.m. Summer pH values change slightly (plus or minus 0.2 unit) with lows in the early morning and highs in the late afternoon.

Maximum fall water temperatures at BA 333.2 occurred around 4:00 p.m. with minimum temperatures between 6:00 and 7:00 a.m. Dissolved oxygen values were not collected during the fall. The daily pH and specific conductance trends in the fall were similar to those in the summer.

Table 13. - Averaged seasonal maximum and minimum values for some water quality parameters measured from June 23 to November 18, 1987, in three backwaters on the Green River.

Date in parenthesis.

Average		Site	Temp °C	D.O. mg/L	pH units	Specific conductance µS/cm
Maximum	IP	BA 333.2	24.5 (8/04)	8.69 (10/10)	8.55 (7/05)	990 (10/22)
	JN	BA 300.26	24.4 (7/28)	8.97 (10/01)	8.56 (10/30)	800 (10/8)
	OU	BA 251.0	25.5 (7/28)	9.3 (10/12)	8.87 (9/25)	990 (11/17)
Minimum	IP	BA 333.2	4.9 (11/17)	3.71 (6/28)	7.76 (10/13)	510 (6/27)
	JN	BA 300.26	7.9 (10/22)	2.81 (6/26)	7.5 (8/04)	670 (multiple)
	OU	BA 251.0	3.7 (11/18)	4.65 (6/30)	7.93 (9/09)	710 (Sept)

Data recorded in Jensen BA 300.26 showed a similar trend. The maximum summer daily water temperatures in this backwater occurred around 6:00 p.m. and the minimum temperatures were recorded around 9:00 a.m. The maximum dissolved oxygen concetrations in the summer occurred between 3:00 and 5:00 p.m., with the pH values also being slightly higher during this time period. Later during the fall, the highest water temperatures and dissolved oxygen levels occurred at about the same time, between 5:00 and 6:00 p.m. As the season progressed, the dissolved oxygen levels remained high around 5:00 p.m. while the highest water temperatures occurred later each day until the highest water temperatures occurred between 7:00 and 8:00 p.m. pH levels varied little but did fluctuate similar to the oxygen concentrations.

In BA 251.0 at Ouray, maximum daily summer water temperatures occurred from

4:00 to 7:00 p.m. These highest summer water temperatures occurred over a wider time period than the summer high temperatures recorded in upstream backwaters. The lowest daily water temperatures were recorded around 8:00 to 9:00 a.m. Dissolved oxygen concentrations during the summer were highest around 3:00 p.m. and lowest around 5:00 a.m. In the fall, the highest water temperature still occurred during the relatively wide period of time from 4:00 to 6:00 p.m. Dissolved oxygen also continued to peak around 3:00 p.m. each day through the fall. pH remained stable through the fall with only slight fluctuations similar to the oxygen.

Figure 25 shows the diel cycle of water temperature, D.O., pH, and specific conductance at BA 251.0 for July 28 and 29, 1988. Other backwaters were similar with the highs in the afternoon and the lows in the early morning.

To compare backwater sites monitored in 1987, a standard time period of July 23 to November 6 was used to obtain average seasonal values. Table 14 presents the seasonal average water temperatures, dissolved oxygen concentrations, pH, and specific conductance along with the average daily standard deviation over the season for the three sites. All three backwaters were relativelly large and connected to the river all season.

Average seasonal water temperature and D.O. at BA 300.26 was the lowest probably because of its location immediately to the west of a large grove of cottonwood trees atop a 2-meter-high bank. In the summer, full sun did not reach this backwater until after 10:00 a.m. BA 251.0 had the highest average temperature over the time period and remained warmer longer, even when ice covered this backwater. The standard deviation of temperature was almost identical for the three backwaters.

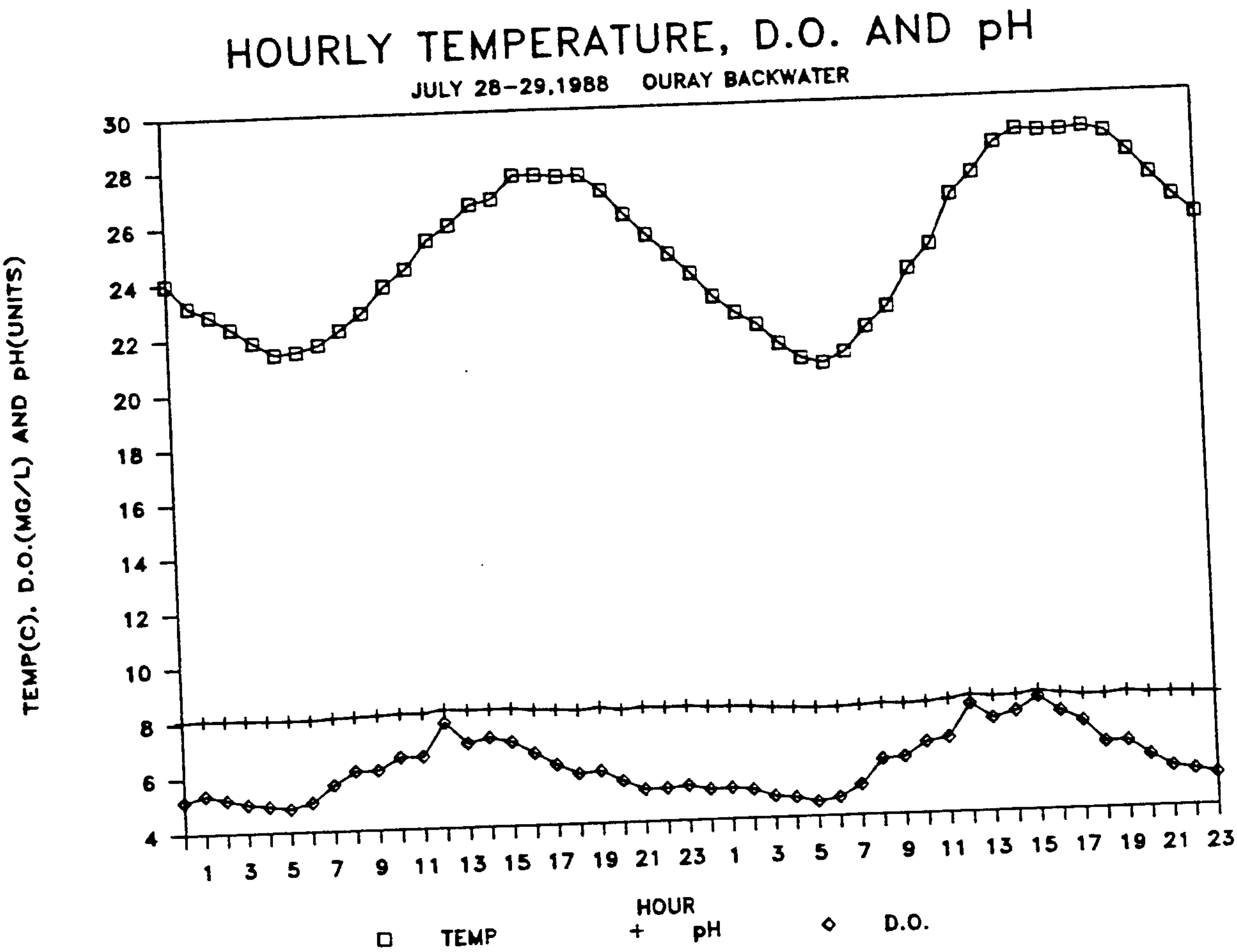

Figure 25. - Diel cycle of water temperature (C), dissolved oxygen (mg/L), and pH in BA 251.0 at Ouray for July 28-29, 1988.

Table 14. - Averaged daily water temperature, D.O., pH, and specific conductance from July 23, 1987 to November 6, 1987 in three backwaters on the Green River. Standard deviation in parenthesis.

Site	Temp °C	D.O. mg/L	pH	Specific conductance µS/cm
BA 333.2	17	7.37	8.02	813
	(4.88)	(1.21)	(0.17)	(83)
BA 300.26	16.38	7.11	8.17	711
	(4.65)	(2.2)	(0.33)	(14)
BA 251.0	18.59	7.26	8.27	740
	(4.8)	(2.2)	(0.26)	(43)

Average dissolved oxygen concentration over this time period was highest at Island Park BA 333.2. The lower average D.O. at Jensen BA 300.26 was probably due to reduced insolation by shading from the cottonwood trees.

pH increased in the backwaters downstream. The average seasonal backwater specific conductance was highest in Island Park BA 333.2.

Temperature, dissolved oxygen, pH, and specific conductance were monitored in Island Park BA 333.2 from July 22 to October 12, 1988. Water quality monitors were also in Jensen BA 300.5 and Ouray BA 251.0 for nearly the same period of time. In addition, a water quality monitor that recorded temperature and specific conductance was placed in the main river at Ouray at about RMI 249.5. The seasonal maximum and minimum values of water temperature, D.O., pH, and specific conductance are presented on table 15.

Daily water temperatures at Island Park BA 333.2 generally peaked around 6:00 p.m. and were lowest between 7:00 and 8:00 a.m. Dissolved oxygen levels were highest in the afternoon between 1:00 and 4:00 p.m. with lowest D.O. in the early morning (5:00 a.m.). pH was relatively constant and specific

Table 15. - Daily average water quality extremes measured from July 22 to October 12, 1988, on three backwaters and the Green River. Date in parenthesis.

	Site		Temp °C	D.O. mg/L	pH units	Conductance µS/cm
Maximum	IP	BA 333.2	25.5 (7/28)	9.84 (9/24)	8.33 (7/16)	1630 (10/10)
	JN	BA 300.5	25.6 (7/29)	15.2 (10/02)	8.5 (8/03)	9650 (9/15)
	OU	BA 251.0	25.3 (7/23)	10.6 (9/24)	8.44 (9/28)	810 (8/13)
	OU	River	26.5 (7/30)			890 (9/24)
Minimum	IP	BA 333.2	13.0 (10/10)	5.5 (8/18)	7.85 (10/01)	640 (7/30)
	JN	BA 300.5	19.34 (10/10)	3.96 (8/12)	6.81 (9/10)	750 (7/16)
	OU	BA 251.0	10.6 (10/13)	2.20 (8/18)	7.15 (8/24)	610 (8/7)
	OU	River	12.5 (10/13)			500 (8/4)

conductance varied slightly with daily fluctuations of 20 to 60 µS/cm and a slow seasonal increase from 1300 to 1600 µS/cm.

At Jensen BA 300.5, daily water temperatures were highest from 4:00 to 6:00 p.m. with some high temperatures extending to 11:00 p.m. during late August and September. Lowest temperatures occurred from 7:00 to 9:00 a.m. with some low temperatures persisting until 11:00 a.m. during September. D.O. was high in the late afternoon (4:00 to 6:00 p.m.) and low from 6:00 to 8:00 a.m. D.O. was very high toward the end of the sampling season. pH was relatively stable with highs occurring from 5:00 to 7:00 p.m. and lows from 5:00 to 6:00 a.m. Specific conductance varied considerably over the season in BA 300.5 with very high daily average values (>2000 µS/cm) increasing almost continuously from August 8 to the end of the sampling season. Diel fluctuations exhibited sharp decreases of up to 100 µS/cm per hour for nearly a day followed by an equally sharp rise to the previous high at certain times in August. The unusually high D.O. concentrations occurred during the period of highest specific conductance in September and October.

Daily temperatures in Ouray BA 251.0 were highest from 5:00 to 7:00 p.m. with daily highs occurring earlier in the day later in the season. Low temperatures were recorded from 5:00 to 6:00 a.m. D.O. was highest from 2:00 to 3:00 p.m. and lowest from 5:00 to 6:00 a.m. pH fluctuated 0.1 to 0.7 unit daily with highest pH in the late afternoon. Specific conductance was relatively steady with average daily fluctuations of 60 µS/cm.

A water quality monitor was placed in the Green River downstream of Ouray BA 250.7 from July 28 to October 13, 1988. It recorded water temperature, specific conductance, and sometimes pH. Highest daily temperatures occurred from 6:00 to 7:00 p.m. with high temperatures occurring around 5:00 p.m. later in the season. The highest water temperature was 29.0 °C at 7:00 p.m. on July 30, 1988. Lowest daily temperatures usually were around 9:00 a.m. Specific conductance did not vary much during the day with daily fluctuations of from 5 to 30 µS/cm. pH was only measured during the month of August and averaged 8.3. Figure 26 presents water temperatures from the river and backwater along with depths at Ouray from September 22 to October 3, 1988.

Table 16 presents the averages of Island Park and Ouray backwater water quality measurements from 1987 and 1988. A standard time period of July 23 to October 10 was selected for the comparison between 1987 and 1988. Water

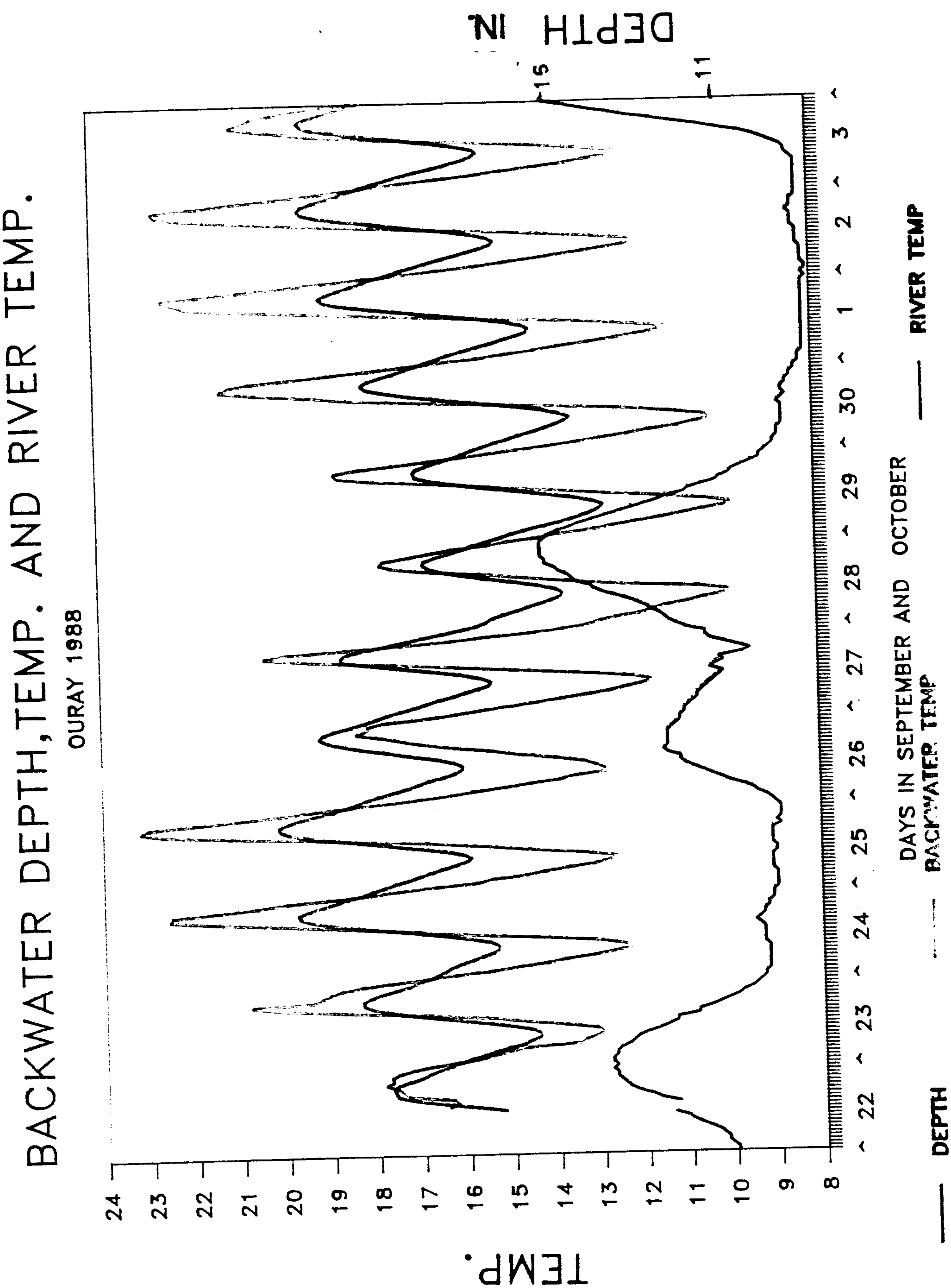

Figure 26. - Hourly river and backwater water temperatures and backwater depths in Ouray BA 251.0 from September 22 to October 3,1988.

temperature was somewhat warmer in 1988 compared to 1987, coincident with lower riverflows in 1988. Backwaters had a greater diel temperature change than the river. Figure 26 shows water temperatures for the river and BA 251.0, along with depth recorded hourly over a 15 day period. Depth in the backwater is related to riverflow. River water temperature appears to decrease with increased flow, and the inflow of this cooler water into the backwater cools it as well, and reduces the amplitude of the diel temperature fluctuation.

Table 16. - Averages of temperature, D.O., pH, and specific conductance monitored in Island Park and Ouray backwaters from July 23 to October 10 in 1987 and 1988. Standard deviation in parenthesis.

Site	Year	Temp (°C)	D.O. (mg/L)	pH	Specific conductance (µS/cm)
Island Park BA 333.2	1987	18.9 (4.9)	7.24 (1.2)	8.04 (0.16)	807 (80)
	1988	20.4 (4.7)	7.0 (1.9)	8.01 (0.24)	1200 (41)
Ouray BA 251.0	1987	20.3 (4.0)	7.09 (2.14)	8.29 (0.26)	733 (43)
	1988	20.8 (4.6)	6.42 (2.96)	8.05 (0.35)	716 (64)

Warmer water temperatures, such as those observed in 1988, are an important factor in development of young squawfish. Total length of squawfish correlated highly with warmer water temperatures (Kaeding and Osmundson 1988). If lower riverflows generally result in warmer water temperature in backwaters (disregarding meteorological conditions) and the development of a more abundant food base, lower riverflows with less fluctuation in backwaters may lead to the development of better backwater habitat for larval and young fish. Better summertime growth resulting in larger YOY fish going into the winter may enhance overwinter survival and result in fish in better condition the following spring.

SUMMARY

Flows in the Green River differed substantially between 1987 and 1988. Average flows from July 1 to October 31, 1987, were 1,983 ft^3/sec, but only 1,532 ft^3/sec for the same period in 1988. In addition, daily fluctuations after mid-August 1988 were of lower magnitude and frequency than during the similar period in 1987. Limnological data collected from the Green River and backwaters at Island Park, Jensen, and Ouray suggest an upstream to downstream trend in abiotic and biotic characteristics in both the river and backwaters in this reach of river. Average seasonal water temperature was higher downstream than upstream, and warmer in the backwaters than at nearby river sites. Average water temperatures at all sites were higher in 1988 compared to 1987, probably due to the lower average river flow in 1988. Average water temperatures in the main river in 1987 increased from 17.1 °C at Island Park to 19.7 °C at Ouray, and increased from 17.5 °C to 20.4 °C in 1988. In backwaters, average water temperatures in 1987 increased from 19.7 °C at Island Park to 22.0 °C at Ouray, while in 1988, average water temperatures at these same sites were 21.3 °C and 22.9 °C, respectively.

Dissolved oxygen levels were generally inversely related to water temperatures, although dissolved oxygen exhibited a less consistent seasonal trend. Average dissolved oxygen in the river decreased slightly downstream, from 8.1 mg/L at Island Park to 7.4 mg/L at Ouray. In backwaters, average dissolved oxygen was highest at 8.2 mg/L at Jensen, and lowest at 7.5 mg/L at Ouray. pH was usually above 8.0.

Specific conductance increased downstream in the river and was generally

higher in backwaters than in the main river. Average specific conductance in the main river in 1987 ranged from 659 μS/cm at Island Park to 717 μS/cm at Ouray, while in 1988, specific conductance ranged from 731 μS/cm at Island Park to 772 μS/cm at Ouray. In backwaters, average specific conductance ranged from 685 μS/cm at Jensen to 720 μS/cm at Ouray, while in 1988, specific conductance was highest at 1,154 μS/cm in Jensen backwaters, and lowest at 772 μS/cm in Ouray backwaters. High average specific conductance in Jensen backwaters was due to the high values recorded in BA 300.5, during both the regular 2 weeks sampling and with the continuous monitoring instrument.

Turbidity was greater in downstream backwaters but exhibited no consistent seasonal pattern compared to the river. Turbidity averaged 37, 36, and 142 NTU in the main river at Island Park, Jensen, and Ouray, respectively, in 1987, and 93, 61, and 49 NTU at these sites in 1988. In backwaters, average seasonal turbidity was 32, 34, and 49 NTU at Island Park, Jensen, and Ouray, respectively, while in 1988, turbidity averaged 27, 34, and 59 NTU at these respective sites.

Slightly warmer water temperatures and greater nitrogen and phosphorus concentrations in Ouray backwaters may stimulate production of blue-green algae; blue-green algae were a major component of the <25 μm size-fraction of phytoplankton (nannoplankton) collected from backwaters. The average increase in turbidity in Ouray backwaters was due in part to greater nannoplankton abundance and higher concentrations of particulate organic material. Seasonal turbidity in BA 250.8 averaged 77 NTU in 1988, the highest seasonal average for a backwater sampled during this study, due in part to high POM concentrations in the <25 μm size-fraction. Other Ouray backwaters averaged

53 NTU, while the river averaged 49 NTU.

Zooplankton densities were low in both the river and backwaters, although greater in backwaters, and generally greater in Ouray backwaters than in Island Park or Jensen backwaters. Zooplankton densities increased from 0.44 individuals per liter in upstream Island Park backwaters to 1.5 individuals per liter in downstream Ouray backwaters, although the magnitude of the increase was not as great as with the <25 μm size-fraction of the blue-green algae, which constituted the major component of this size-fraction. Among the backwaters sampled, those larger backwaters with narrow connections to the river, with a lower exchange rate and a greater retention time (BA 300.5 and BA 251.0), generally had higher densities of zooplankton.

Continuous monitoring of temperature, DO, pH and specific conductance in one backwater each at Island Park, Jensen, and Ouray revealed diel fluctuation in these limnological parameters, with some of the fluctuations directly influenced by changes in riverflow. Fluctuations in riverflow that increase water level in backwaters result in importation of riverine nutrients and POM into backwaters, as well as resuspension of organic material from the inundated periphery of the backwater with possible leaching of nutrients from the inundated zone. Water level fluctuations in backwaters that resuspend organic material increase turbidity which may provide cover for the native fish that evolved in this ecosystem, and reduce the likelihood of predation on Colorado squawfish by nonnative fish. Decreasing water levels in backwaters resulting from reduced riverflows may result in export of nutrients and biota to the river. The extent of export of nutrients and biota to the river cannot be addressed at this time.

Concentrations of major nutrients (nitrate-N, ammonia-N, and phosphorus) generally increased in backwaters from upstream at Island Park to downstream at Ouray. Seasonal average TIN (NO_3-N + NO_2-N + NH_3) concentrations in the river were greater than in backwaters at Island Park and Jensen, but greater in Ouray backwaters than in the river there. Seasonal average TP concentrations were lower in Island Park backwaters than in the river there, but greater than in the river at Jensen and Ouray backwaters. Ouray backwater nutrient concentrations exceeded river concentrations. Higher nutrient concentrations in Ouray backwaters compared to Island Park and Jensen backwaters and the river at Ouray may indicate internal nutrient recycling within these backwaters or a response to attenuated riverflows compared to upstream wherein nutrients transported into the backwaters from the river during rising water levels are retained as riverflow decreases, or leached from the inundated backwater shoreline. The less severe action of inundation and draining in Ouray backwaters caused by attenuated riverflows may reduce the tendency for violent mixing of water in backwaters, and reduce export of POM and nutrients during draining.

Average macroinvertebrate abundance in backwaters increased progressively downstream within the study reach, although variability was high among the several backwaters sampled at a site. Total riverine benthos averaged 599, 359, and 46/m^2 in 1988 at Island Park, Jensen, and Ouray respectively. Riverine substrate at Ouray was mostly shifting sand. In backwaters, total benthos in the 1988 averaged 2,411, 2,111, and 3,326/m^2 for Island Park, Jensen, and Ouray, respectively. In many samples, chironomid larvae comprised over 90 percent of the benthic fauna.

Benthic algae and detritus, although not sampled in this study, probably contribute to the food base for the collector-gatherer chironomid larvae and the other grazing macroinvertebrates. It comprised a large portion of the stomach contents of the young suckers collected. Predatory chironomid larvae, although few in number in the backwaters sampled, likely prey on the grazing chironomids. Food web interactions at this lower trophic level may result in nutrient recycling within some Green River backwaters.

Food habit studies of 16 species of native and nonnative fish collected from backwaters indicated some dietary overlap due to heavy utilization of chironomid larvae by some young fish <20 mm TL. The 14 Colorado squawfish <20 mm TL collected in 1987 and 1988 consumed mostly chironomid larvae, while Colorado squawfish >20 mm TL showed evidence of piscivory, but continued to consume chronomid larvae. As the Colorado squawfish grow and include larval fishes, primarily red shiner, in their diet, along with chironomid larvae, dietary overlap with other fish species diminishes because of the expanded food resource. The stomachs of some young fish, such as the native suckers, contained mostly algae. Few fish species other than Colorado squawfish and *Gila* spp. consumed larval fish. After Colorado squawfish become piscivorous, red shiners, fathead minnows, occasional catostomids, and other introduced fish species are found in the diet suggesting less dependence on the relatively abundant chironomid larvae.

Observations from qualitative seine hauls used in this study to collect fish for food habit studies, revealed young Colorado squawfish in Jensen and Ouray backwaters, with more fish observed in shallow (about 0.3 m deep), more turbid backwaters having a relatively wide connection to the river. Bottom composition of these shallow backwaters was generally muck or gyttja, often with organic material and some sand.

Shallow backwaters with a large surface area in the Ouray area that were seasonally permanent after runoff subsided were generally warmer compared to upstream backwaters at Island Park and Jensen; they had higher concentrations of nutrients, particulate organic material, and greater densities and weights of benthic macroinvertebrates, and moderate chlorophyll a levels. Benthic macroinvertebrates were the principal food source for most young fish, except suckers. The river is one nutrient source for backwaters. Increased concentrations of some nutrients in the river at Ouray compared to Jensen, result from upstream agricultural runoff and return flows.

SUMMARY BY STATED OBJECTIVES

1. To identify energy sources which fuel secondary productivity in nursery habitats.

Data were collected on nutrient concentrations, particulate organic material, and chlorophyll a concentrations to identify and quantify likely energy sources contributing to secondary production in documented nursery areas. Nutrient levels fluctuated, with higher nutrient concentrations present in backwaters after high riverflows, suggesting importation of nutrients from the river or resuspension of nutrient-containing material from the inundated backwater shoreline. Nutrient concentrations were generally greater in Ouray backwaters than in Island Park backwaters. Both nitrogen and phosphorus were limiting for primary production but at different times of the year.

Organic material made up 24 percent of total suspended material, with 91 percent of the organic material present in the <25 μm size-fraction. The highest levels of particulate organic material occurred in August in both 1987 and 1988 following high flows, suggesting inundation and resuspension of organic material from shorelines during increased flows. As water level rises, this resuspended material is carried into backwaters. The shoreline of the backwater is also inundated and nutrients and organic material from this zone are released to the backwater circulation. Higher average POM concentrations were measured in the river and backwaters at Ouray than upstream at Island Park; concentrations were slightly higher in 1988 than in 1987. The magnitude of import and export of POM into and out of backwaters from the river was not measured directly, although correlations between river and backwater POM were higher in upstream backwaters than in downstream backwaters at Ouray, due likely to the greater magnitude of fluctuation in the Island Park backwaters. POM in the small size-fraction was dominant, but all POM imported into a backwater serves as a potential food source for detritivorous macroinvertebrates and possibly larval fish.

Chlorophyll a concentrations, used as an index of algal biomass, were generally greater in downstream backwaters than in upstream backwaters, except for BA 300.26, which received additional nutrient input from the nearby heron rookery. Algal concentrations were higher in backwaters compared to the main river, and were dominated by attached forms of blue-green algae.

Energy sources which fuel secondary production in backwaters include POM and plant nutrients from the river, nutrients and POM released from inundation of the backwater shoreline by rising water levels, and the abundant small algae produced within or imported into the backwater.

2. To identify important interactions leading to production of food organisms available to young Colorado squawfish.

Trophic interactions resulting in production of food organisms for young fish were determined in broad terms, since some measures of production, such as carbon fixation rates, community respiration, nutrient recycling within backwaters and invertebrate food habits were not investigated. Nutrient concentrations generally increased in downstream backwaters, paralleled by downstream increases in algal and macroinvertebrate densities. Increasing concentrations of nutrients downstream resulted in higher concentrations of phytoplankton and greater chlorophyll a concentrations. The greater abundance of benthic invertebrates downstream suggests a greater food supply available to them, or more favorable environmental conditions, such as warmer water temperatures or less water level fluctuations from attenuated flows resulting in a more stable community structure. It is not possible to quantify the link between abundance of phytoplankton, attached algae, and benthic invertebrate densities, since benthic invertebrate food habits were not studied. However, many taxa of chironomid larvae present were grazers, with low numbers of predatory chironomid larvae. Both groups of chironomid larvae were identified from stomachs of larval and young Colorado squawfish. In addition, POM and the sparse zooplankton were available to larval and young fish.

3. To identify food organisms utilized by young Colorado squawfish.

Colorado squawfish were divided into two size classes, based on criteria established at the Larval Fish Laboratory, Colorado State University. Colorado squawfish <20 mm TL were classified as larvae, and fish >20 mm TL as juveniles. In this study, juveniles could therefore be YOY or 1+, depending on the time of year the fish were collected. Stomachs from the 14 larval Colorado squawfish ranging in size from 11.7 to 19.3 mm TL contained mostly chironomid larvae, along with some unidentified undigested material and monocotyledon seeds. The single 11.7 mm TL Colorado squawfish collected in 1988 had chironomid larvae and some organic material in its stomach. The next smallest Colorado squawfish measured 14 mm TL. Data on the type and size of food items consumed by first feeding larval Colorado squawfish is not definitive from this study, since no Colorado squawfish <11.7 mm TL were collected, and the size at hatching is 8-10 mm. Stomachs of YOY and yearling Colorado squawfish (ranging in size from 22 to 80 mm TL) contained predominantly chironomid larvae, with larval fish of other species, principally red shiners, accounting for 34 percent of stomach contents by volume.

4. To quantify competition between fish species, with emphasis upon interactions between young Colorado squawfish and other species for specific size food items.

Dietary overlap was apparent, with the abundant chironomid larvae common in the diet of many young fish. Young fish consuming chironomid larvae included Colorado squawfish, speckled dace, sand shiner, carp, channel catfish, green sunfish and black bullheads. The 14 larval Colorado squawfish <20 mm TL had an average measured gape of 1.3 mm, thus limiting their consumption to smaller food items. Some taxa of chironomid larvae were small and were found in stomachs of these small fish. Colorado squawfish YOY and yearlings >20 mm TL had an average gape of 3.2 mm, enabling them to consume the larger abundant chironomid larvae and other food items, including larvae of other fish species.

5. To estimate predator-to-available-prey ratios for nursery habitats.

Young Colorado squawfish consumed both chironomid larvae and red shiners, both of which were abundant. Red shiners have a protracted spawning period and were available as prey for a long period in the summer and fall. More data on density of young fish in nursery areas is necessary to estimate predator-to available-prey ratios in nursery habitats.

6. To quantify the potential for predation on various sizes for young Colorado squawfish.

Based on the stomach content analyses from this study, limited to several backwaters each at Island Park, Jensen and Ouray, and additionally limited mostly to young fish, Colorado squawfish were not utilized as prey by other fish species. The potential for predation on Colorado squawfish by introduced piscivores certainly exists, in the context of predator-prey relationships, but was not documented in this study. Unknown aspects of the fish's behavioral repertoire or microhabitat requirements may reduce the potential for predation on young Colorado squawfish. Other studies by FWS will aid in understanding this relationship.

7. To limnologically and physically characterize nursery areas utilized by larval Colorado squawfish.

Previous studies by USFWS and Utah DWR indicated that young Colorado squawfish were more abundant in Ouray backwaters than at upstream Jensen and Island Park backwaters. Backwaters in general were warmer than the main river, were warmer downstream than upstream, and had a greater magnitude of diel temperature fluctuations that were exacerbated by higher riverflows. DO levels were not limiting. pH was around 8.0. Specific conductance was greater in the backwaters.

Backwaters at Ouray had higher chlorophyll a concentrations and densities and biomass of benthic macroinvertebrates. Nutrient levels (N and P) varied but were greater in downstream backwaters than in upstream backwaters. Riverflow fluctuations likely influence the limnological characteristics of backwaters by the cycle of inundation and draining. High riverflows result in importation of nutrients and POM into the backwaters and in addition result in release of organic material and nutrients from the inundated backwater shoreline. Higher exchange rates in upstream backwaters compared to downstream backwaters due to greater severity of riverflow fluctuations further upstream may reduce productivity by increasing export of nutrients and phytoplankton during draining. Attenuated riverflow fluctuations result in more moderate exchange rates, more thermal buffering, and possibly reduced export of nutrients and phytoplankton.

Zooplankton were sparse in most backwaters, but slightly greater in larger, deeper backwaters with a narrow connection to the river and consequently less exchange with the river.

A large percentage of the phytoplankton and POM occurred in the <25 μm size-fraction, as did chlorophyll a concentrations.

Smaller, shallower backwaters are more greatly affected by riverflow fluctuations. Reductions in riverflow may result in desiccation of ephemeral backwaters and loss of habitat. Backwaters in Ouray were generally larger and less likely to disappear with a moderate seasonal or daily reduction in riverflows. Attenuated riverflow fluctuations downstream at Ouray probably result in less severe impacts on backwaters due to reduction of exchange rates, allowing a greater degree of stability to develop in Ouray backwaters.

RECOMMENDATIONS

Backwaters on the Green River provide valuable nursery habitat for both native and nonnative fish species, including several federally listed endangered fish species. Backwaters are unique and complex ecosystems influenced in large part by flows and conditions in the associated river. The present study documented physical and limnological characteristics and some trophic interactions of selected Green River backwaters at Island Park, Jensen, and Ouray. Questions remain regarding interactions within backwaters and the "quality" of backwaters, as well as limnological conditions in backwaters further downstream. Because of the short time-frame of the present study, some of these questions remain unanswered. We recommend several additional studies to elucidate more fully the complex biological, chemical, and physical interactions occurring in Green River backwaters.

1. As revised operating criteria are implemented for Flaming Gorge Dam, in response to the Biological Opinion to be issued by the FWS, monitoring of selected backwaters downstream at Ouray should continue, to determine what, if any, changes occur in the backwaters under long-term adherence to the recommended flow conditions. Continued long-term monitoring of backwaters downstream from Flaming Gorge Dam is essential to determine if the limnological conditions observed in this study prevail under the new operating criteria or if new equilibrium conditions develop. Continued monitoring will also help determine the extent of the recovery of Colorado squawfish populations.

2. Backwaters below Desolation Canyon that are known nursery areas for

endangered fish species should be studied intensely to determine their baseline limnological characteristics and trophic interactions and to compare them to upstream backwaters at Island Park, Jensen, and Ouray.

3. The contribution of the White and Duchesne rivers to the nutrient budget, overall water quality, biota, etc., of the Green River and downstream backwaters should be determined. In the present study, Ashley Creek near Jensen was shown to have high nutrient concentrations, although this contribution to the Green River was diluted by the much larger flows in the Green. The White and Duchesne rivers have greater flows and drain much larger watersheds with a great diversity of agricultural activity. They may have a substantial effect on water quality below their confluences with the Green. The contributions from these rivers to the Green may extend downstream to backwaters used as nursery habitat by Colorado squawfish. These rivers may also provide habitat for endangered species of fish.

4. We recommend that one or two important backwaters in the Ouray area be studied intensely to determine the effects of inundation and partial draining on both the backwater and the river downstream. Inundation of a backwater resulting from high riverflows results in importation of nutrients, riverine plankton and other drifting organisms, particulate organic material, etc. Partial draining of a backwater during low riverflows likely results in export of some material to the river but the extent of export from backwaters in the Green River is not known nor are the effects of depletion of resources on the backwater. The cycle of periodic inundation and draining may be both advantageous and disadvantageous to the backwater and to the larval and young fish residing there. Increased water levels may provide habitat for larger

predator fish, which may threaten young fish. On the other hand, higher water levels may provide increased shallow shoreline habitat for young fish, and resuspend organic material. Decreased water levels may result in mortality of some benthic macroinvertebrates, thus reducing food supply of young fish. Nutrients and plankton may also leave the backwater as riverflows decrease. Reduction in habitat may crowd fish and increase competition for available food.

Additional longer term and basinwide limnological and trophic studies on selected backwaters and the nearby river should further elucidate the link between river and backwater and the effect the river has on backwater productivity and suitability as habitat for endangered fish species, on a systemwide basis, and provide information necessary to further refine operating criteria for the dam to enhance survival of endangered fish species.

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