Effects of stream channelization on fishes and bottom fauna in the Little Sioux River, Iowa

by

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ABSTRACT

Differences in certain physical factors, bottom fauna and fish populations were evaluated in channelized and unchannelized portions of the Little Sioux River, Iowa, during 1969-71. Little Sioux River is a turbid, warmwater river located in western Iowa. Characteristic stream channels were a meandering, non-uniform channel with heavy vegetative cover in the unchannelized section; and a straight channel with relatively uniform depth and no heavy vegetative cover in the channelized section.

Recorded water temperatures showed greater daily fluctuations during summer in the channelized section. Maximum and mean daily water temperatures averaged 0.3 C and 1.3 C, greater, respectively, in the channelized section during July. Consistently higher turbidities were measured in the channelized section during a period of low runoff, averaging 31.2% higher than the unchannelized section.

Composition of bottom fauna was similar in the two sections. Colonization of macroinvertebrates on artificial substrates suggested a lack of suitable attachment areas in the channelized section. Higher numbers of drift organisms in the channelized section were further evidence of this. Numbers of fish species were greater in the unchannelized section. Major changes in composition of fishes reported in 1950 studies resulted from a control structure near the mouth, blocking upstream movement of certain species from Missouri River. Unbaited hoopnet catches revealed the presence of more large channel catfish, the most important game species, in the unchannelized section. Hoopnet catches and Primacord explosive samples collected greater numbers of smaller channel catfish (less than 254 mm) in the channelized section during late summer and early fall. Because of possible downstream movement from unchannelized section into channelized section, suggested by movement studies and similar growth rates, drastic differences in standing crops of fish were not measurable in comparisons of the two areas.

INTRODUCTION

Channelization of natural streams has recently become a controversial environmental issue. Stream channelization has been carried out for a variety of reasons. At the turn of the century, drainage enterprises straightened miles of streams by cutoffs through natural meanders, for the primary purposes of increasing agricultural production. More recently under the name of channel improvement, channelization has been used for purposes of navigation, highway construction, and flood control.. It has become a major program under Federal Flood Control Acts of 1948 and 1960 and under the small watershed program of Public Law 566. Stream channelization has usually consisted of straightening the natural meanders of a stream, widening and deepening the channel, and clearing the banks of vegetation.

Several thousand miles of stream have been channelized in the past. Seven midwestern States reported a total of 29,081 miles of their streams had been channelized, and this was considered a minimal estimate (Thrienen, 1971). Future plans call for several more thousands of miles of streams and rivers to be channelized. In North Carolina, 235 watersheds have been deemed feasible for assistance under Public Law 566 (Bayless and Smith, 1967). As of 1967, studies by the U.S. Corps of Engineers were underway on 17 Iowa river drainage systems (U.S. Corps of Engineers, 1967). Applications for 4,523 watershed projects across the United States have been received by the Soil Conservation Service as of January 1, 1971, according to a letter dated May 18, 1971 from the Natural Resources Defense Council, Inc., Washington, D.C.

The physical changing of a stream or river channel can have a serious environmental impact. Ecological problems, resulting in adverse effects upon fish and wildlife resources, often occur. / Bayless and Smith (1967) reported a 90% reduction in the number of fish over 6 inches per acre in 23 channeled streams as compared to 36 proximate natural streams. In a 40-year period following channelization, there was no significant return toward normal stream populations. The Tippah River, Mississippi experienced a 98% reduction in pounds of fish per acre following channelization (Wharton, 1970). Changes have been reported in the bottom fauna of rivers as well. Morris, Langemeier, Russell, and Witt (1968) reported the standing crop of drifting invertebrates to be eight times greater in the unaltered portion of the Missouri River. /Besides effects on the fish and wildlife resources, channelization has caused concern over its effects on ground water levels and the pollution assimilating capacities of a natural system (Wharton, 1970). Physical effects, such as channel instability, headward erosion of tributary streams, and increased downstream flood hazards have been summarized by Johnson, Saxton, and Deboer (1969). Considering the multitude of these changes and the magnitude of future channelization plans, channelization of natural stream environments should be given serious consideration in the future.

The purpose of this study was to evaluate changes in the fish and macroinvertebrate populations of the Little Sioux River, Iowa as a result of channelization. Also, the study was intended to evaluate certain physical factors and their effects upon the biological populations in an attempt to gain further insight into potential mitigative practices that would lessen undesirable environmental effects of stream alterations upon aquatic organisms. Data on the aspects of stream alteration have been requested by Iowa and Federal agencies serving on the Advisory Board of Iowa State Water Resources Research Institute.

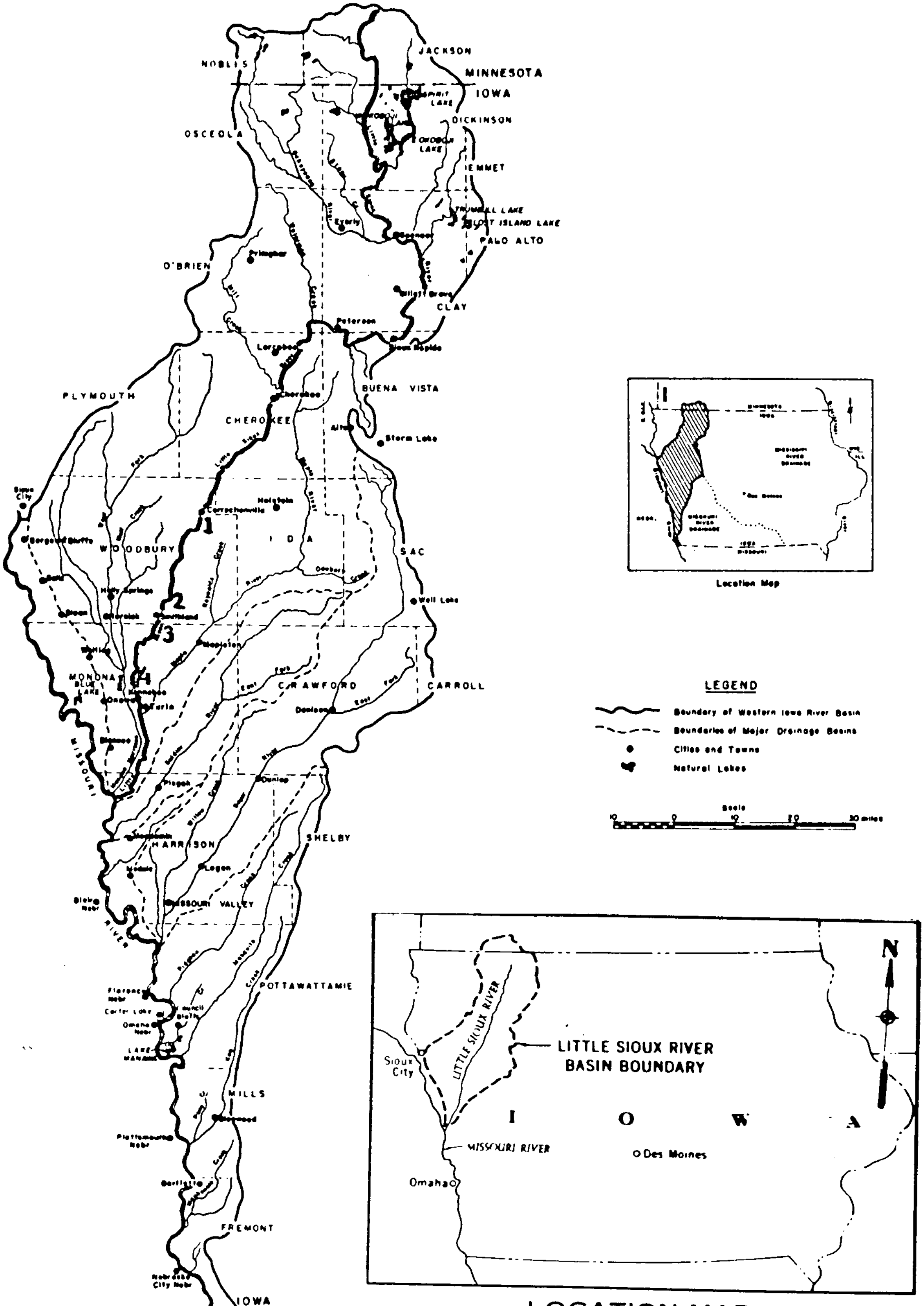
LITTLE SIOUX RIVER

Location and Description

Little Sioux River, the largest stream in western Iowa, originates in Jackson County, Minnesota and flows toward the southwest, entering the Missouri River in Harrison County, Iowa (Fig. 1). The Ocheyedan and Maple Rivers are the major tributaries throughout its length. The last approximately 25 miles of Little Sioux River flow through the broad Missouri River flood plain. The river and its basin have been described in considerable detail in Bulletin No. 8 of the Iowa Natural Resources Council (1959).

The Little Sioux River basin is located in northwestern Iowa and a small portion of southeastern Minnesota, draining an area of 4,204 and 303 square miles, respectively. The basin demonstrates a variable topography throughout the length of the river. From the headwater region in Minnesota to Dickinson County, Iowa, the terrain is typically level to undulating, with areas of hilly moraine. The river channel is relatively shallow and natural drainage is not well developed. Farther south, to about the Woodbury County line, the topography becomes progressively more geologically mature, with an almost level to gently undulating topography and better developed natural drainage. South of there, the river has cut a deeper

Fig. 1. Map of western Iowa river basins showing location of Little Sioux River and the four sampling stations and location map of Iowa showing Little Sioux River watershed



LOCATION MAP

channel through a rolling, upland type of topography, with areas of deep loess deposits and poor natural drainage. Finally, the river flows through the broad Missouri River bottom, where the basin slope is very flat and natural drainage is poorly developed.

The Little Sioux River has been well known for its highly variable streamflow and its frequent, and often severe, floods (Iowa Natural Resources Council, 1959). In the areas of poor natural drainage, agricultural interests have turned to artificial drainage by ditches and channel straightening of natural streams to provide relief from floods and better drainage of the fertile agricultural bottomland.

Early Drainage Attempts

Between 1905 and 1920, drainage districts carried out extensive channel straightening projects on the Little Sioux River and other streams in western Iowa. A study by the Iowa State Planning Board (1936), showed that 1 mile of straightened channel had replaced about 2.5 miles of natural meandered channel in western Iowa streams. The Little Sioux River was shortened considerably from its mouth to the town of Smithland by major cutoffs through natural meanders. Minor cutoffs extended into Woodbury County below the town of Anthon. From its mouth to Smithland, the channel was shortened from 63 miles to 38.5 miles, a 39% reduction. This reflects the extent of meandering of the stream in its natural condition, as well as the extent of channel straightening. According to a drainage engineer at the Iowa State Drainage Convention (1904), a cutoff of 1/4 mile would shorten the Little Sioux River channel by 3 miles in certain areas.

In addition, the Monona-Harrison Drainage Ditch was constructed to intercept the flow of the West Fork, a branch and tributary of the Little Sioux. This ditch paralleled the Little Sioux River throughout its lower reaches. At one point below Turin, an equalizer ditch was constructed to join the two channels and equalize the flows during periods of high flow.

These efforts were partially successful but also created new problems. Sediment deposition in the ditches and straightened channels made them inefficient, requiring frequent removal of sediment deposits and repair of levees. The flow of the Little Sioux River had gradually become almost completely diverted into the Monona-Harrison Drainage Ditch, which had a shorter route to the Missouri River. This caused the Little Sioux River channel to deteriorate rapidly below the equalizer ditch. The increased flow also caused the Monona-Harrison Ditch to degrade rapidly, resulting in flood damage, poor lateral drainage, and large expenditures for repairs. This prompted the drainage districts to request Federal aid, and in 1956 construction was begun on the Little Sioux River Flood

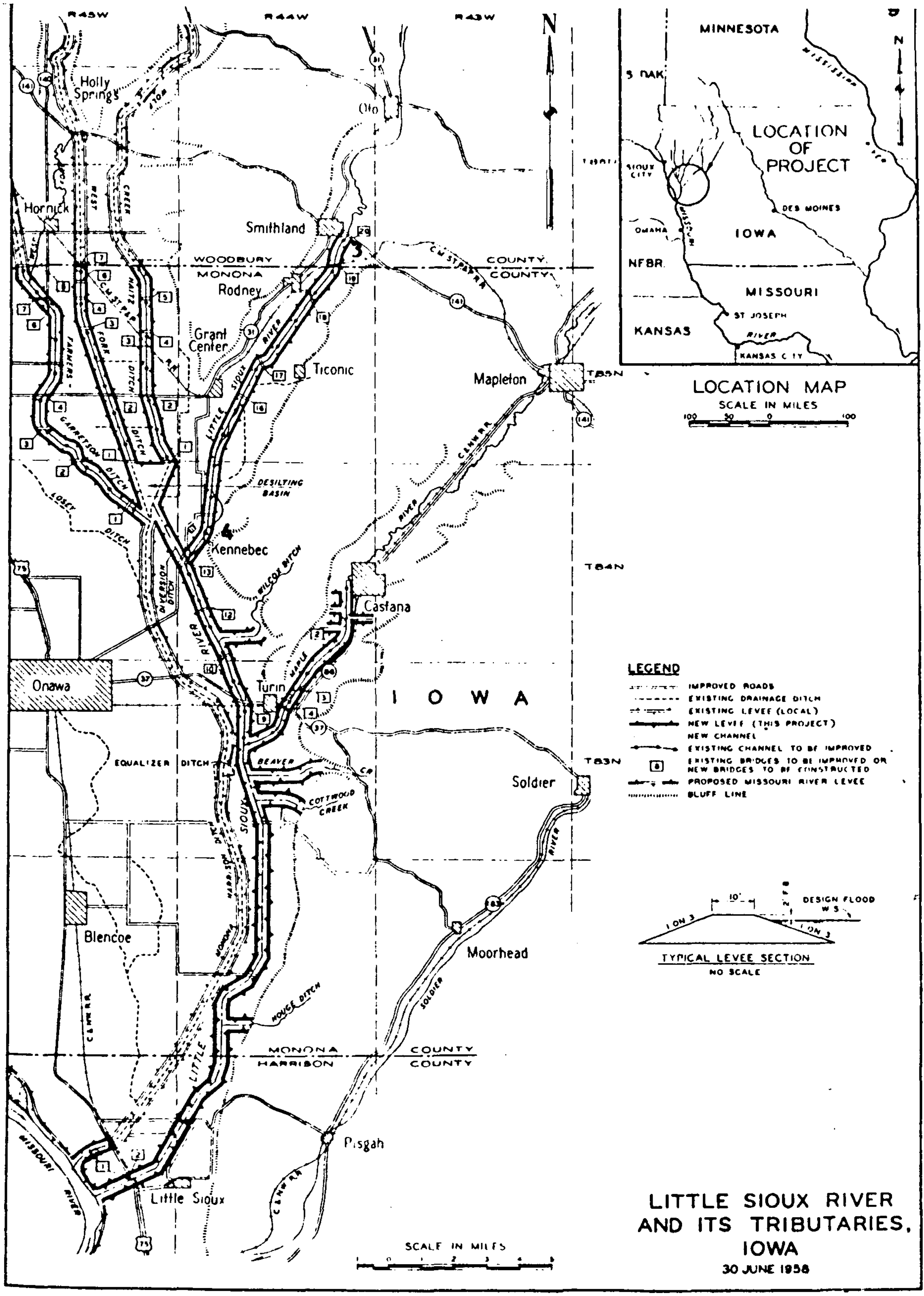
Protection Project by the U.S. Army Corps of Engineers.

Corps of Engineers Project

The Corps of Engineers Project included channel straightening and enlargement, as well as levee construction, beginning at the mouth of the Little Sioux River and proceeding upstream to Smithland (Fig. 2). A diversion ditch below Kennebec was constructed, replacing the old equalizer ditch and separating the flow of the two channels during normal periods of flow. Four control structures were constructed near the downstream end of the Little Sioux River channel to control bed grade degradation. One of these was a low head dam approximately 6 miles upstream from the mouth of the channel (Fig. 3).

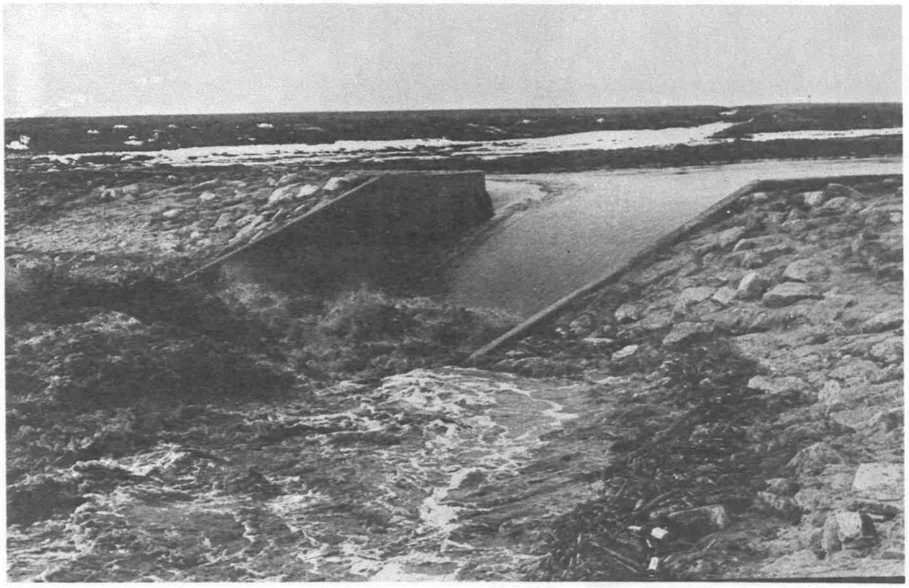
The channel straightening and enlargement operations were confined primarily to the existing channel of the river. Parts of the channel were relocated however, shortening the previous channel by an additional 4.5 miles and leaving a channel of 34 miles from its mouth to Smithland. The old channel was rechanneled to a bottom width of 100 feet and a berm width of 50 feet. The designed average channel depth was 17 feet below the berm and 19 feet below the natural ground. Sioux quartzite riprap was placed for short distances around bridge and drainage structures and on some of the gradual bends in the channel. Design discharge of the project ranged from 23,000 cfs (cubic feet per second) from Smithland to the new diversion

Fig. 2. Map of channelized portion of Little Sioux River showing location of sampling stations 3 and 4



LITTLE SIOUX RIVER AND ITS TRIBUTARIES, IOWA
30 JUNE 1958

Fig. 3. Control structure, shown during high water level, located approximately 6 miles upstream from mouth of Little Sioux River, Iowa



ditch, to 35,000 cfs from the mouth of the Maple River to the Little Sioux River mouth. Gated drainage structures were located along the channel to conduct interior drainage from within the protected area to the channel. The final contract of the project was completed in September of 1965; however, the rechanneling had been completed by 1962 and the low head dam constructed in 1963.

Study Area

The study area consisted of approximately 32 miles of the Little Sioux River from Correctionville, Iowa to the diversion ditch near Kennebec, Iowa. This included 19 miles of unchannelized and 13 miles of channelized channel. Correctionville is located in Woodbury County about where the river enters the thicker loess area, and Kennebec is located in Monona County about where the river leaves the loess area and enters the Missouri River flood plain. The slope of this portion of the river was approximately 1.8 feet per mile in 1955 (Iowa Geological Survey, 1955). After the Corps of Engineers project, the slope, calculated from distances measured on recent maps and from gauge elevations of the U.S. Geological Survey (U.S. Department of Interior, 1969), was approximately 2.2 feet per mile.

Four sampling stations were selected within the study area. Each station consisted of approximately 1 mile of the river channel and all sampling was confined within this area. Stations 1 and 2 in the unchannelized section were located at the Woodbury County Conservation Park near Correctionville and approximately 1 mile above Smithland, respectively (Fig. 4). The lower portion of the channel at station 2 had been straightened slightly by a minor cutoff in the early 1900's; however, it appeared typical to the natural channel at station 1 in other respects. Generally, stations 1 and 2 were characterized by a meandering channel with steep banks, numerous brushpiles creating deep holes, and trees and shrubs along the banks (Fig. 5). The channel bottom was primarily mud, with occasional areas of sand and gravel, and the channel width varied from 26 to 31 m.

Stations 3 and 4, in the channelized section, were located just below Smithland and near the Diversion Ditch, respectively (Fig. 2). In contrast to stations 1 and 2, stations 3 and 4 consisted of a straight channel with only gradual bends, no brushpiles, primarily a shifting sand bottom, and no woody forms of vegetation along the banks (Fig. 5). The average channel width was approximately 31 m, with relatively uniform water depth between the banks. Meandering of the stream within the banks, during periods of low flow, caused some nonuniformity in depth. Areas of riprap were present at both stations 3 and 4.

Fig. 4. Unchannelized portion of Little Sioux River study area showing sampling stations 1 and 2

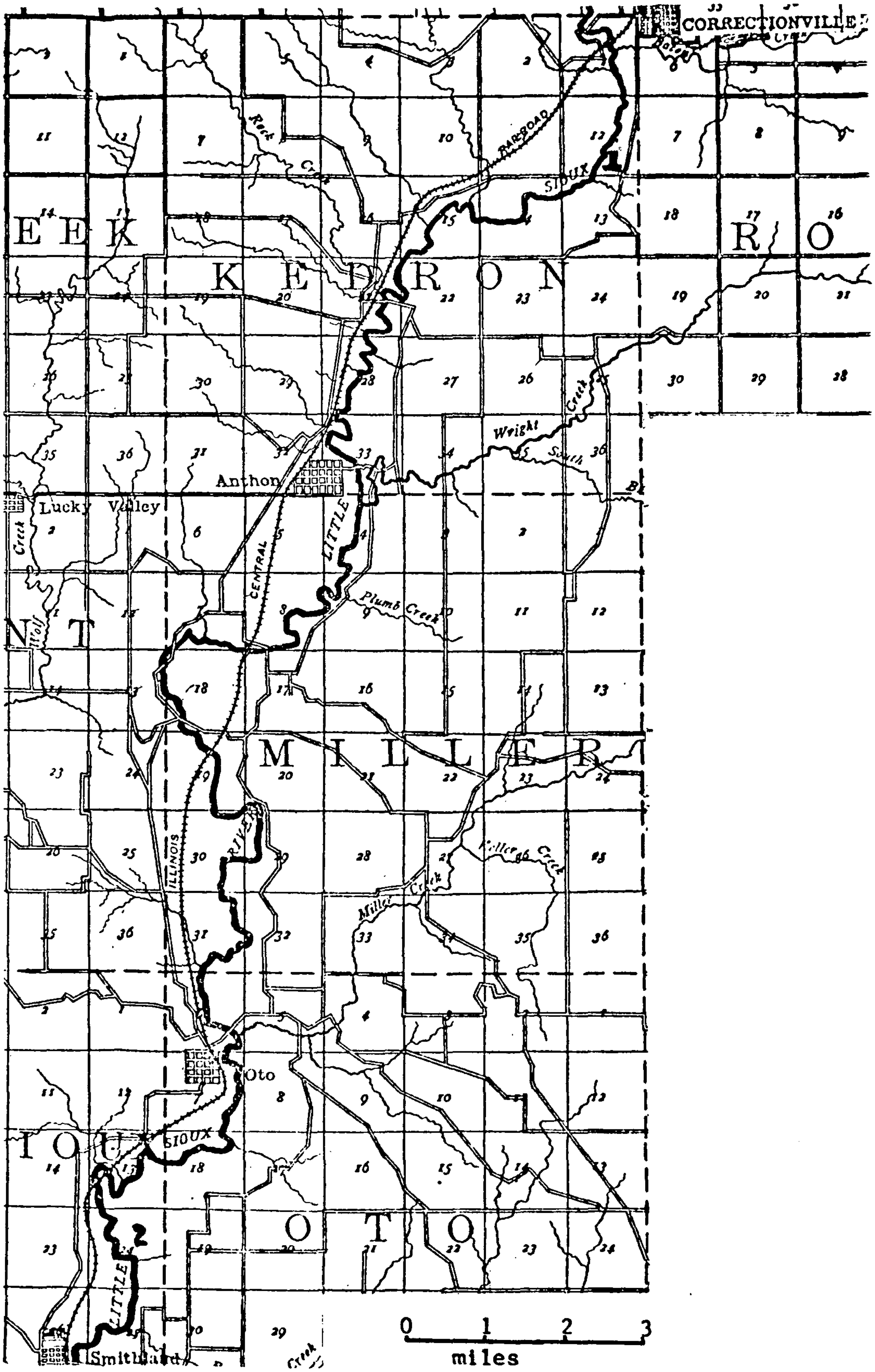
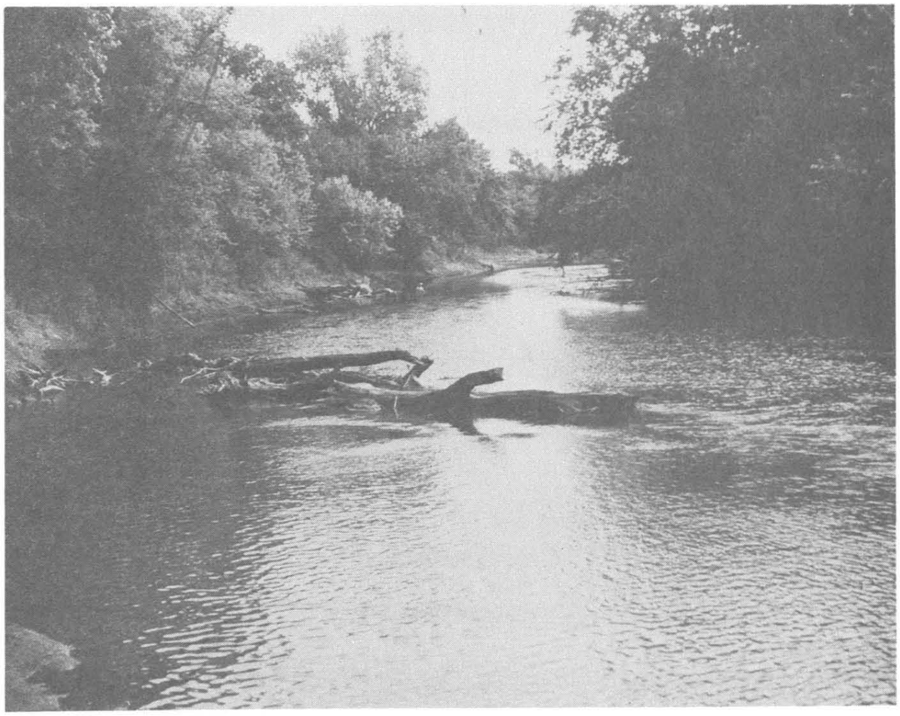

CORRECTIONVILLE
Rock Creek
RAILROAD
SIOUX
EEK
KEDRON
RO
Wright Creek
South
Anthon
Lucky Valley
Creek
LITTLE
CENTRAL
Plumb Creek
Wolf
NT
MILLER
ILLINOIS
RIVER
Keller Creek
Miller Creek
Oto
SIOUX
IOU
OTO
LITTLE
Smithland
Creek
0 1 2 3
miles

Fig. 5. Top: Unchannelized section of Little Sioux River at Woodbury County Conservation Park, near Correctionville, Iowa

Fig. 5. Bottom: Channelized section of Little Sioux River below Smithland, Iowa



METHODS

Physical Characteristics

Cross-sectional stream profiles

On two occasions during the summer of 1970, stream profile measurements were made at various sites within stations 1 and 4. The primary concern was the bottom type, stream width, depth, and velocity at certain depth intervals. The stream velocity was measured at 10-cm depth intervals, beginning at the bottom, at 4.6-meter (15-foot) intervals across the stream. The velocities were measured with a Gurley No. 625 Pygmy Current Meter. Sections of the stream were selected for measurement to represent as many different cross-sections as possible. In addition, discharge data were obtained from the Geological Survey, Water Resources Division, Iowa City, Iowa.

Turbidity

Turbidity of the river was measured on an irregular sampling basis during the summer of 1970, using a Hach Model 2100 Turbidimeter. Seven samples were collected at each station throughout the summer. Samples were obtained by holding a 250-ml plastic bottle approximately 30 cm below the surface of the water in the mainstream of the river. Because the samples had to be sent to Ames, Iowa to be analyzed, 5 ml of formaldehyde solution were added to each sample to preserve the organic material. On one occasion, two samples from the same station, with and without formaldehyde, were analyzed after a waiting period of about one day. The preserved sample measured 46 JTU (Jackson Turbidity Units), while the unpreserved sample measured 56 JTU. The formaldehyde apparently prevented further organic production by the plankton in the sample from adding to the turbidity of the sample. A test also showed that the addition of 10 ml of formaldehyde gave the same results as the addition of 5 ml.

Water temperature

Model 1000B Marshalltown recording thermometers were placed at stations 1 and 4 from July 8 to August 24, 1970. Each instrument was adjusted to the correct degree Fahrenheit temperature while in the laboratory. The instrument boxes were enclosed in plywood boxes attached to a large log along shore at station 1, and to a bridge pier at station 4. The recorder at station 4 was moved to a new location due to vandalism, and was subsequently attached to a large log also. A flexible cable connected the instrument box to the thermocouple, which was suspended on a steel rod in 0.9 to 1.2 m of water, approximately 30 cm from the bottom and 1.5 m from shore. Continuous temperatures were recorded over weekly intervals; however, two periods of no record were caused by the vandalism and difficulties with the ink marking mechanism. Periodic checks were made with a hand thermometer to assure accuracy of the instruments. Mean daily temperatures were calculated by averaging the temperatures at 4-hour intervals. Conversions were made to degrees Centigrade when necessary for presentation in the metric system.

Map measurements

Channel lengths before and after channelization were measured with a map measurer on Iowa Geological Survey maps (Iowa Geological Survey, 1909), and U.S. Army Corps of Engineers maps (Iowa Natural Resources Council, 1959).

Macroinvertebrate Sampling

Drift organisms

Drift organisms were sampled with a drift net, designed with a 30.5- by 30.5-cm (1-square foot) opening supported by a #9 wire frame; attached to a tapering, fiberglass screen net, approximately 61 cm in length. The fiberglass screen had a mesh size of 1 mm, with 16 openings to the inch. A 250-ml widemouth plastic bottle attached to the end of the net with a hose clamp served as a collecting bottle. The net was suspended in the water with two 1.0-cm (0.4-inch) steel rods forced into the stream bottom slightly over 30.5 cm apart. Hose clamps were attached to swivel snaps located in each corner of the frame. The hose clamps were slipped over the steel rods and the top of the net adjusted to approximately 2.5 cm below the water surface.

Weekly samples were collected during the summer of 1970, with occasional samples being taken at other times during the study. When possible, samples were taken from all stations on the same day, as close together in time as possible. When this was not possible, samples from the two sections were taken on successive days, at approximately the same time. All samples were taken from the mainstream, between 4 m from shore and the middle of the river, depending upon the depth of the water. On each sampling date, two samples were taken per station. Each sample was for a measured length of time, from 10 to 30 minutes, depending upon the amount of debris in the water. Samples were preserved in formaldehyde solution and taken to the laboratory in the plastic bottles.

While the drift samples were being taken, the surface velocity of the river was measured by timing a partially floating object over a measured distance to obtain the volume of flow through the drift net. Results from stream profiles showed there was very little variation in velocity in the upper 30 cm of water, suggesting surface velocity was an adequate measure of the average velocity of water flowing through the net. The volume of water sampled was determined from the formula used by Morris, Langemeier, Russell and Witt (1968). The volume of water sampled was equal to the time length of the sample, times the surface velocity, times the area of the net opening.

In the laboratory, the preserved samples were placed in a white enameled pan and macro-organisms picked with forceps. Organisms were placed in 10% formalin and identified to genera, when possible, at a later date. When identification to genera was not possible, the organisms were identified to the lowest possible taxa. Pennak (1953) and Usinger (1956) were used for identification of aquatic organisms and Borror and Delong (1964) for terrestrial insects. The organisms from the two samples at a station were combined, blotted on filter paper, and weighed to the nearest 0.1 mg on an analytical balance. Absolute weights of organisms were affected to some degree by preservation of up to 12 months in formalin. Abundance of drift on each sampling date for a station was calculated as the total weight of drifting macroinvertebrates per unit volume of water passing through the drift net.

Attached macroinvertebrates

During July and August of 1970, the colonization potential of the macroinvertebrate fauna was measured using multiple plate artificial substrate samplers described by Hester and Dendy (1962). Eight 76-by 76-mm (3- by 3-inch) pieces of 3.2-mm (0.12-inch) masonite, separated by 25-mm (1-inch) squares of the same material, were fastened together with a 64-mm (0.25-inch) diameter bolt through the center of the squares. Nuts on either end held the plates in place. This arrangement provided slightly over 930 square cm (1 square foot) of surface for the attachment of organisms. A modification of this sampler was used in an experimental attempt to simulate a natural brushpile habitat. The original design was modified by sawing off the corners of the large plates and adding two more plates to make up for the lost surface area. The sampler was suspended inside a 30.5-cm length of 10.2-cm diameter plastic pipe, in which nine 13-mm diameter holes had been drilled (Fig. 6). Three sets of three holes were distributed equally over the surface of the pipe to reduce the flow of water passing through the plates, as might be the situation in a natural brushpile. The holes permitted some water to flow through as well as on top and bottom of the pipe; however, the flow was greatly reduced.

Both types of samplers were suspended approximately 15 to 30 cm from the bottom, attached by wire to a steel rod forced into the bottom. The original plate samplers were placed in two different habitat types. At each station, three samplers were placed in the mainstream and three in a quiet water area along the bank. Modified samplers, used only at stations 1 and 4 were placed in two different types of habitat within each station. Three were placed in the mainstream and three immediately upstream from a natural brushpile. At the same time, three original samplers were suspended directly in the brushpile (Fig. 6) to serve as a comparison to the simulated brushpiles. All samplers were left in the water for exactly

Fig. 6. Top: Multiple plate artificial substrate sampler being placed within brushpile in unchannelized section of Little Sioux River, Iowa

Fig. 6. Bottom: Plastic perforated pipe inside of which artificial substrate samplers were suspended

1 week. They were enclosed in plastic bags before removing from the water to prevent organisms from being washed off by the current. Formaldehyde solution was added to the bags, which were then taken to the laboratory.

In the laboratory, the samplers were disassembled, and all of the attached material was scraped into an enameled pan. This material was preserved and stored in 500 ml plastic bottles until the organisms could be sorted. The large volume of organisms were concentrated by running the sample through a #30 seive several times. This also removed any silt from the sample, allowing the organisms to be easily picked off the screen. The organisms were then preserved in 10% formalin, identified, and weighed to the nearest 0.1 mg on an analytical balance, after being blotted on filter paper.

Fish Sampling

Hoopnets

Standard two-throated hoopnets of two mesh sizes were used throughout the study. The 13-mm (0.5-inch) bar mesh nets were 0.6 m in diameter and 1.2 m long (2 feet by 4 feet), and the 19-mm (0.75-inch) bar mesh nets were 0.6 m by 22.0 m (2 feet by 6 feet). One net of each size was set at each station for either 1 or 2 days. The captured fish were removed and the net reset in its same location. Location of the nets was changed weekly to sample as many habitats as possible within each station. In the unchannelized section, nets were usually placed in holes just below brushpiles. In the channelized section, containing few brushpiles, nets were placed in deeper water along the bank or in depressions washed out by the current. The nets were tied to logs and brushpiles when available, or to iron stakes when necessary. The nets were not baited in an attempt to reduce selectivity for certain species to a minimum.

Electric shocking

An electric shocking unit consisted of two paddle-type electrodes with a 60-cycle, 7.5-amp, 230-volt, A.C., gasoline driven Homelite generator as the source of power. The electrodes consisted of a 30.5-by 15.2-cm copper wire grid at one end of a 5.1-cm diameter wooden pole, with a push-to-close type safety switch. Rubber gloves and waders were worn as safety measures. The shocking operation usually consisted of two people operating the electrodes, with a third person netting the stunned fish and pulling the boat containing the generator and other equipment. When a third person was not available, the two people operating the electrodes could also pull the boat and net the stunned fish without a significant loss of efficiency. The electrodes were kept approximately 2 to 3 m apart as the operators waded upstream along the bank, alternating from side to side when necessary or desirable.

Shocking in an upstream direction proved more efficient in netting stunned fish than shocking downstream. Stunned fish were placed in tubs of water. When the tubs reached satisfactory capacity, the fish were weighed, measured, marked, and returned to the river. Actual shocking time in minutes was recorded for each sampling station and date.

During periods of high water, a boom-type, three-electrode shocking unit was used with the same 230-volt generator. A dead man's foot-switch was operated by a person in the front of the boat netting the stunned fish, while another person ran the outboard motor. This method was used very little due to its relative inefficiency and the escapement of stunned fish in the turbid water. Of the two shocking methods, the paddle shockers were by far more successful, being more efficient around brushpiles and other obstructions. Fish collected with the boom-type shocker were not included in the quantitative analysis of the data.

Primacord

Primacord detonating cord has been used successfully as a sampling technique by the Idaho Fish and Game Department (Irizarry, 1969). Due to the difficult nature of electrofishing in the Little Sioux River, Primacord was considered potentially useful for this study. Primacord sampling was conducted during August and October of 1970, taking a total of 35 samples at the four stations.

A sample consisted of a 15.2-meter (50-foot) length of Primacord, containing 50 grains of PETN explosive per foot. After a suitable sampling site had been chosen, one end of the Primacord was tied to a float with a string and drifted downstream over the area. The string was then tied to a stake and placed near the bottom of the stream. The upper end was also tied to a stake with string, but was left out of the water until an electrical blasting cap was connected. The blasting cap was enclosed with electrician's tape onto the Primacord and connected to a 30.5-meter, size 14-2 electrical cord. The Primacord was then placed on the bottom of the stream, with the electrical cord suspended by the stake to relieve the strain on the electrical cap wires. The electrical cord was stretched its full length to the adjacent bank, upstream from the Primacord. During this time a 5-meter, 16-mm (0.6-inch) bar-mesh trawl was staked in position approximately 6 to 9 m downstream from the Primacord to collect the affected fish. All operations were conducted with a minimum of disturbance. After waiting 5 to 30 minutes, allowing conditions to return to normal, the Primacord was detonated with a 6-volt lantern battery. Any fish appearing as if they would miss the net were picked up with a dip net. After waiting another 5 to 15 minutes, the net was picked up and the collected fish counted and weighed.

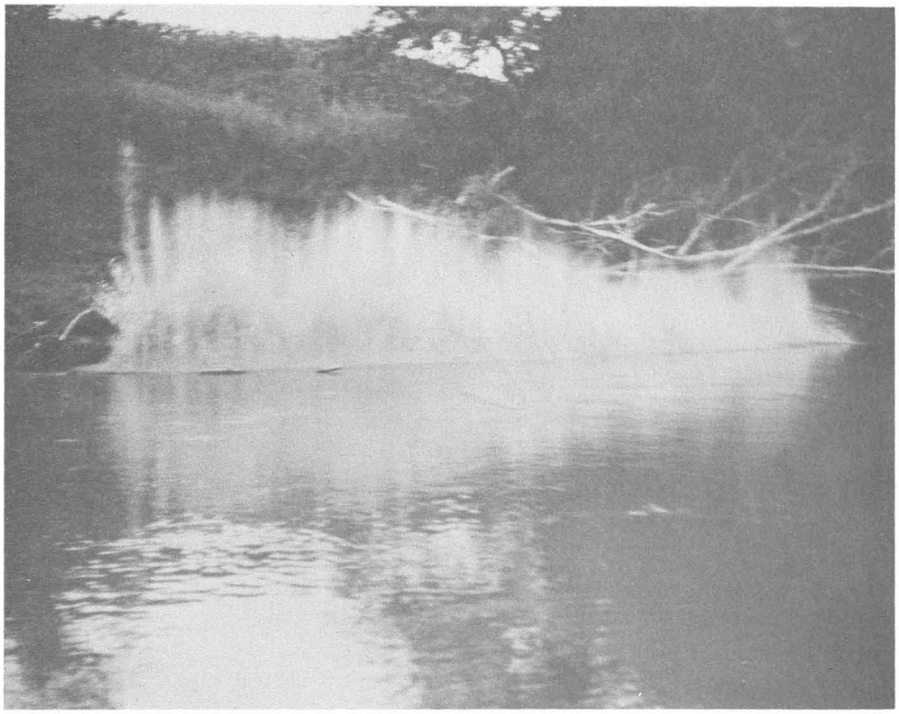
A variety of areas was sampled with the Primacord. In the unchannelized section, samples were taken close to brushpiles or in areas deepened by the current (Fig. 7). In the channelized section, different depths were sampled as well as different habitat types, although few in number (Fig. 7). In both sections, sites were selected where the water current would wash the dead or stunned fish into the collecting net.

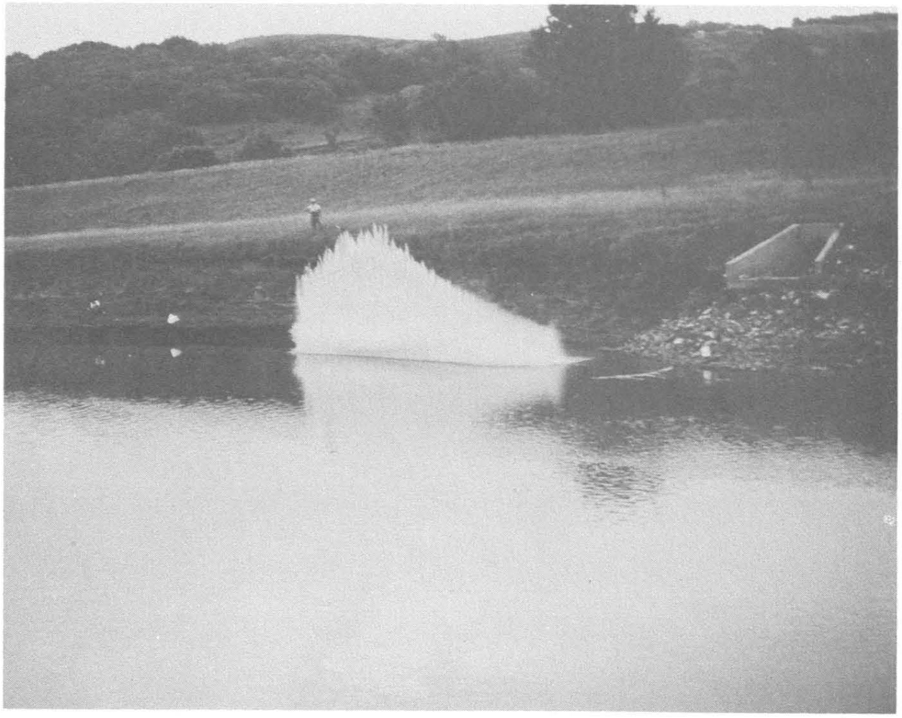
The collecting net appeared to be effective in most cases. Occasionally small fish, which had probably passed through the mesh, were observed downstream from the net. In the first few samples, some stunned fish were observed swimming out of the collecting net after recovering. To prevent this, the net was examined frequently and tied off in front of any fish appearing to be only stunned or recovering.

Experimental tests were conducted previously to determine the effectiveness of the Primacord. Different sizes and species of fish caught in hoopnets were placed in cages at various distances from the Primacord. It was determined that fish within 1.5 m (5 feet) on either side or end of the Primacord were effectively killed or stunned. Therefore, a 15.2-meter length of Primacord gave an instantaneous sample of the fish present in an area 3.0 by 18.3 m (10 x 60 feet), or 0.006 hectares (0.014 acres).

Fig. 7. Top: Explosion of 15.2-m Primacord sample near brushpile in unchannelized section of Little Sioux River, Iowa

Fig. 7. Bottom: Explosion of 15.2-m Prinacord sample near riprapped drainage structure in channelized section of Little Sioux River, Iowa





Handling of fish

All collected fish were weighed to the nearest gram on a platform scale. Standard and total lengths of fish captured by hoopnets and shocking were measured to the 0.1 inch. Lengths were later converted to mm when necessary, for presentation of data in the metric system. Only the larger fish taken with Primacord were measured. During 1969, fish captured at stations 2 and 3 were marked with a right and left pelvic fin clip, respectively, to detect any possible movements between the two areas. Beginning in May, 1970, fish taken at stations 1 and 4 were also marked with a right or left pectoral fin clip, respectively. Recaptured fish were readily identifiable, with very little regeneration of fins observed.

Age and growth of channel catfish

Right pectoral spines were removed from 41 channel catfish collected in hoopnets during the summer of 1970. The fish were not selected by any systematic method; however, an effort was made to select as many different size groups as possible in the limited sample. The fish were not grouped according to sex, but were grouped as to location of capture, in the channelized or unchannelized section. Spines were sectioned at the distal end of the basal groove (Sneed, 1951) using dental saw blades on a small "Handee" electric motor. Sections placed on glass slides and covered with a few drops of alcohol were viewed with an overhead, microscope slide projector at a magnification of 38 times, using transmitted light. Nomograph strips (Carlander and Smith, 1944) placed over the image were marked at the center of the lumen and where each annulus in the expanded posterior portion of the section intercepted the strip. Annuli were marked at the outer edge of the light zones or rings. Only those rings appearing complete were considered to be annuli. The first annulus was incomplete in some of the older fish, but in all cases it was visible in the portion of the section being marked.

Lengths at each annulus were calculated using a nomograph. A direct proportional relationship between body length and spine radius was assumed, and no correction factor was used to represent the body length at time of spine formation. Several variables (Harrison, 1955a; Muncy, 1957) may cause errors in the calculations, questioning the use of a correction factor. Therefore, the center of the lumen as marked on the nomograph strip, was placed at zero on the nomograph when back-calculating the approximated lengths at each annulus.

RESULTS

Physical Characteristics

Streamflow

Discharge data for the Little Sioux River study area were available at two gaging stations operated by the U.S. Department of Interior, Geological Survey. The gaging station located at Correctionville, near sampling station 1, had a drainage area of 4025 square kilometers (2500 square miles). The other gaging station, located near Kennebec at sampling station 4, had a drainage area of 4408 square kilometers (2738 square miles). Records were available for the Correctionville station since 1918 and from the Kennebec station since 1939.

For the 42 years of record at the Correctionville station, the average discharge was 671 cfs. Average discharge at the Kennebec station for the 30 year period ending 1969 was 780 cfs. During the period of record ending September, 1958, prior to completion of the Corps of Engineers Project, the extremes at the Correctionville station were a minimum daily discharge of 4 cfs and a peak discharge of 20,900 cfs. At the Kennebec station from 1939 to 1958, the minimum daily discharge and the peak discharge were 11 cfs and 13,500 cfs, respectively. Discharge data for the calendar years 1960 to 1969 indicated large variations in discharge at each of the two stations (Table 1).

Table 1. Discharge data (cfs) for calendar years 1960-69 for the Little Sioux River at two U.S. Geological Survey gaging stations

Year	Correctionville (2500 sq. miles) Minimum daily	Maximum daily	Mean	cfs per sq. mile	Kennebec (2738 sq. miles) Minimum daily	Maximum daily	Mean	cfs per sq. mile
1960	110	14,200	943	.38	110	14,900	1,014	.37
1961	56	15,600	829	.33	90	13,700	897	.33
1962	80	18,500	1,326	.53	120	18,000	1,460	.53
1963	30	8,670	305	.12	45	11,600	383	.14
1964	36	2,900	318	.13	50	3,190	369	.13
1965	57	27,900	1,267	.51	70	27,900	1,427	.52
1966	34	5,430	384	.15	50	4,900	433	.16
1967	24	6,090	386	.15	45	5,900	437	.16
1968	16	2,150	228	.09	20	2,200	263	.10
1969	135	20,400	1,640	.66	Discontinued			

Discharge data for the entire study period was available only at the Correctionville station. An inspection of the data for the years 1960 to 1969 indicated a close relationship between the discharge at the two stations; therefore, streamflow conditions at Correctionville were considered generally characteristic of the entire study area. Field observations also indicated a direct relationship between discharge at the two stations. Streamflow and subsequent water levels were extremely high during 1969, with a maximum mean daily discharge of 20,400 cfs on April 8 at Correctionville. During the sampling period of July, August, and September of 1969, average discharges ranged from 3,924 cfs to 689 at Correctionville and from 4,118 to 699 cfs at Kennebec.

During the 1970 sampling period, daily streamflow decreased steadily from a mean of 1,426 cfs in April to 90 cfs in September, with only minor fluctuations (Table 2). The minimum daily discharge for 1970 was 56 cfs on September 13.

Table 2. Discharge (cfs) at Correctionville (station 1) during 1970 sampling period

Month	Minimum	Maximum	Mean
May	740	2140	1299
June	293	1470	640
July	143	279	210
August	87	227	150
September	56	181	90

Cross-sectional profiles

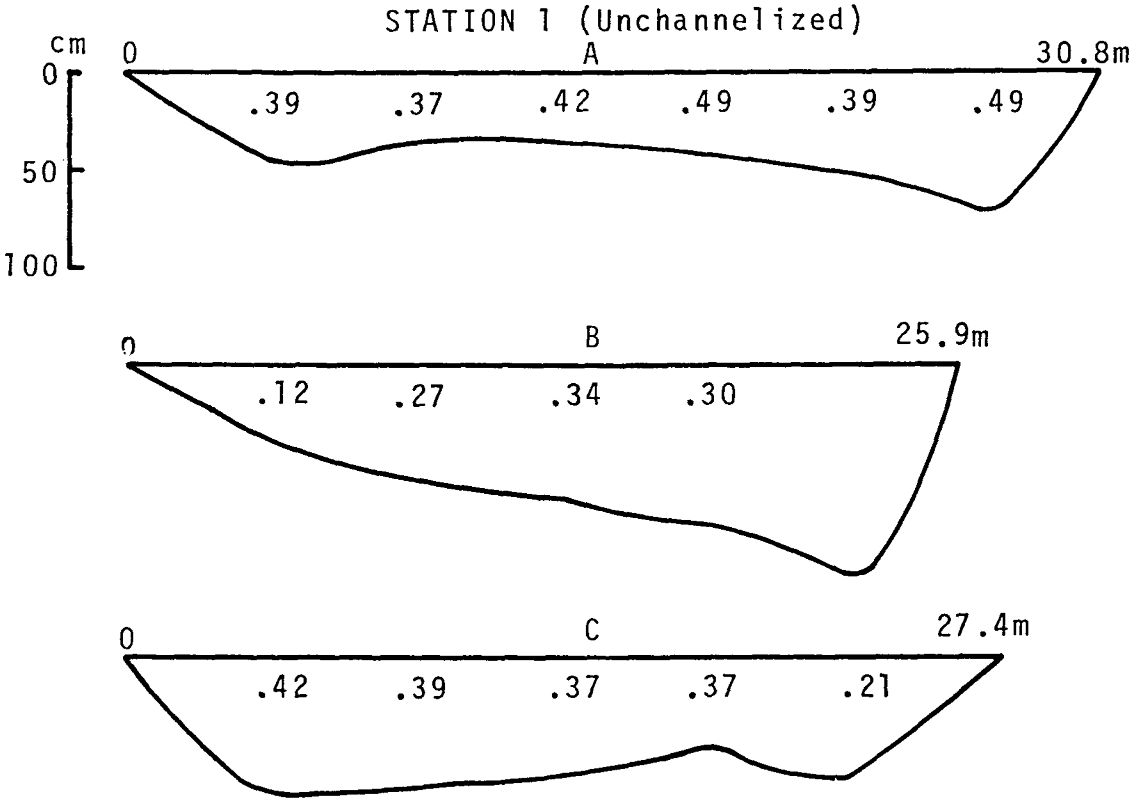
Cross-sectional profiles of the river channel at sites within stations 1 and 4 were constructed from measurements made on July 7 and August 25, 1970. Discharges at station 1 on these days were 207 cfs and 132 cfs, respectively. In addition, measurements at a different location within station 4 were made on July 23, when the discharge measured at station 1 was 233 cfs. Three sites within station 1 were measured on the first date and two sites on the second date. Only one site was measured within station 4 on a single sampling date because of the uniformity of the channel.

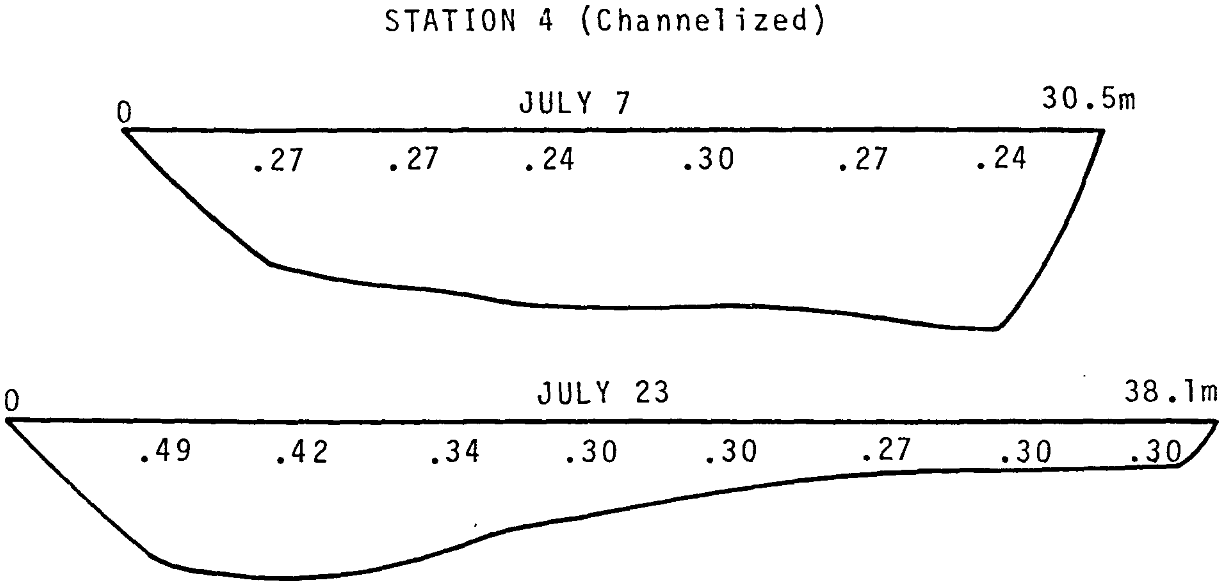
On July 7, the average channel width of the station 1 sites, measured from the edge of the water, was 28.0 m, ranging from 25.9 m to 30.8 m. Maximum depths at the three sites, in downstream order, were 70 cm at site A, 105 cm at site B, and 70 cm at site C. Because measurements were restricted to depths that could be waded, maximum depths indicated were not considered characteristic of the entire unchannelized portion of the river.

The channel width at the station 4 on July 7 was 30.5 m, with a maximum depth of 100 cm. This site was located within a gradual bend in the river channel. The measurements on July 23 at station 4 were made at a site upstream from this bend, where the channel was straighter and wider. Channel width at this site was 38.1 m and maximum depth 80 cm. Cross-sectional representations and average stream velocities of the three sites in station 1 and the two sites in station 4 revealed the contrasting characteristics of the two sections of the river (Fig. 8). The noticeably lower velocities at station 4 as compared to station 1 on July 7, were difficult to attribute to any definite causes other than entrance of the channel on to the floodplain or the effects of the bend in the channel. Velocities at the upstream site in station 4 appeared higher than at the other site, possibly because of the straighter channel and an increase in discharge of 26 cfs on the later date. Part of the channel at site C in station 1 was located about 15 m downstream from a brushpile and its influence upon the velocity of water directly below it was apparent, being much lower than at other areas across the channel. Site A was located about 180 m downstream from a riffle area and site B just below a sharp bend in the channel. The influence of these channel characteristics upon the stream velocity was also apparent, being higher and lower respectively.

Measurements made on August 25, at approximately the same sites, were similar to the earlier measurements with respect to cross-sectional morphology of the channel. As the discharge decreased from 207 cfs to 132 cfs during this time, maximum depths also decreased. Stream velocities decreased proportionately at each station; however, the decrease was slight. One site at sampling station 3 was also measured on

Fig. 8. Cross-sectional representations of Little Sioux River, Iowa channel showing depth, width, and average current velocities (m/sec) at three sites in station 1 (unchannelized), July 7, 1970, and two sites in station 4 (channelized) on indicated dates, 1970


STATION 1 (Unchannelized)
cm
0
50
100
0
A
30.8m
.39
.37
.42
.49
.39
.49
0
B
25.9m
.12
.27
.34
.30
0
C
27.4m
.42
.39
.37
.37
.21


STATION 4 (Channelized)
0
JULY 7
30.5m
.27
.27
.24
.30
.27
.24
0
JULY 23
38.1m
.49
.42
.34
.30
.30
.27
.30
.30

August 25. The cross-sectional morphology of the channel at this site was similar to the site in station 4 on July 23 (Fig. 8); however, the average velocities were much higher. Average velocities across the 25.0-meter channel at the station 3 site were as follows: 0.30, 0.46, 0.52, 0.49, and 0.40 meters per second. The straighter and narrower channel at this station, located directly below the unchannelized section, was responsible for the considerably higher velocities.

Bottom-type was also observed at each of the sampling sites. Sites A and B in station 1 had primarily sand and gravel bottoms with small areas of silt-covered sand. Site C had scattered areas of sand and mud. More extensive mud bottoms were also observed throughout the summer in the deeper holes below brushpiles and the areas directly above brushpiles. Much of the sediment carried by the water is deposited in these areas as a result of the reduced velocities.

Sites at station 4 had a shifting sand bottom with areas of silt along the banks. The velocity of the water was fast enough in the mainstream of the channel to keep the suspended sediment from depositing on the bottom. Only in the shallower areas along the banks, where the velocity was reduced, was there a deposition of sediment. Rock was also found on the bottom along the banks that had been riprapped.

Suspended sediment and turbidity

As the Little Sioux River flows through the thicker loess of the Missouri River bluff area, from Correctionville to Kennebec, it has one of the highest sediment yield rates in the United States. Instantaneous suspended sediment concentrations of 105,000 parts per million have been observed near Kennebec. A comparison of the relationship between streamflow and sediment load with other rivers in Iowa to 1954 also indicated this extreme. With a mean monthly streamflow of 1.0 cfs per square mile, the mean monthly suspended sediment yield for the Little Sioux River was 88 tons per square mile at Correctionville and 230 tons at Kennebec, compared to 45 tons per square mile for the Iowa River at Iowa City, Iowa and 17 tons per square mile for the Cedar River at Cedar Rapids, Iowa (Iowa Geological Survey, 1955).

Large amounts of suspended sediment in this area have undoubtedly always been caused by natural erosion of the loess-type soil. However, agricultural, drainage, and channel straightening practices have accelerated this process to the extremes experienced more recently. Detailed sediment records available (Iowa Geological Survey, 1955) for the Correctionville and Kennebec stations from May, 1950 to September, 1954, showed the relationship between the suspended sediment load and the geology and man-made changes in the watershed.

Average streamflows for these years were above the average by 62% for the entire period of record at Correctionville and by 40% at Kennebec. Suspended sediment values were assumed by the Geological Survey to be above average for that reason.

From 1950 to 1954, the sediment loads at Correctionville and Kennebec were 4,806,180 tons and 15,044,548 tons, respectively, an increase of 213% between the two stations. There was also an increase in the average discharge of 10% during this time. The increase in sediment load between the two stations took place over an increased drainage area of only 451 square kilometers or 11.4%. A small portion of the Correctionville drainage area was not of the loess-type soil; however, from the large increases in suspended sediment load over such a small increase in drainage area, and from particle size analyses indicating that suspended sediments at Kennebec had a coarser size distribution, the Geological Survey concluded that gully and channel erosion were the principal causes of the high suspended sediment concentrations at the Kennebec station.

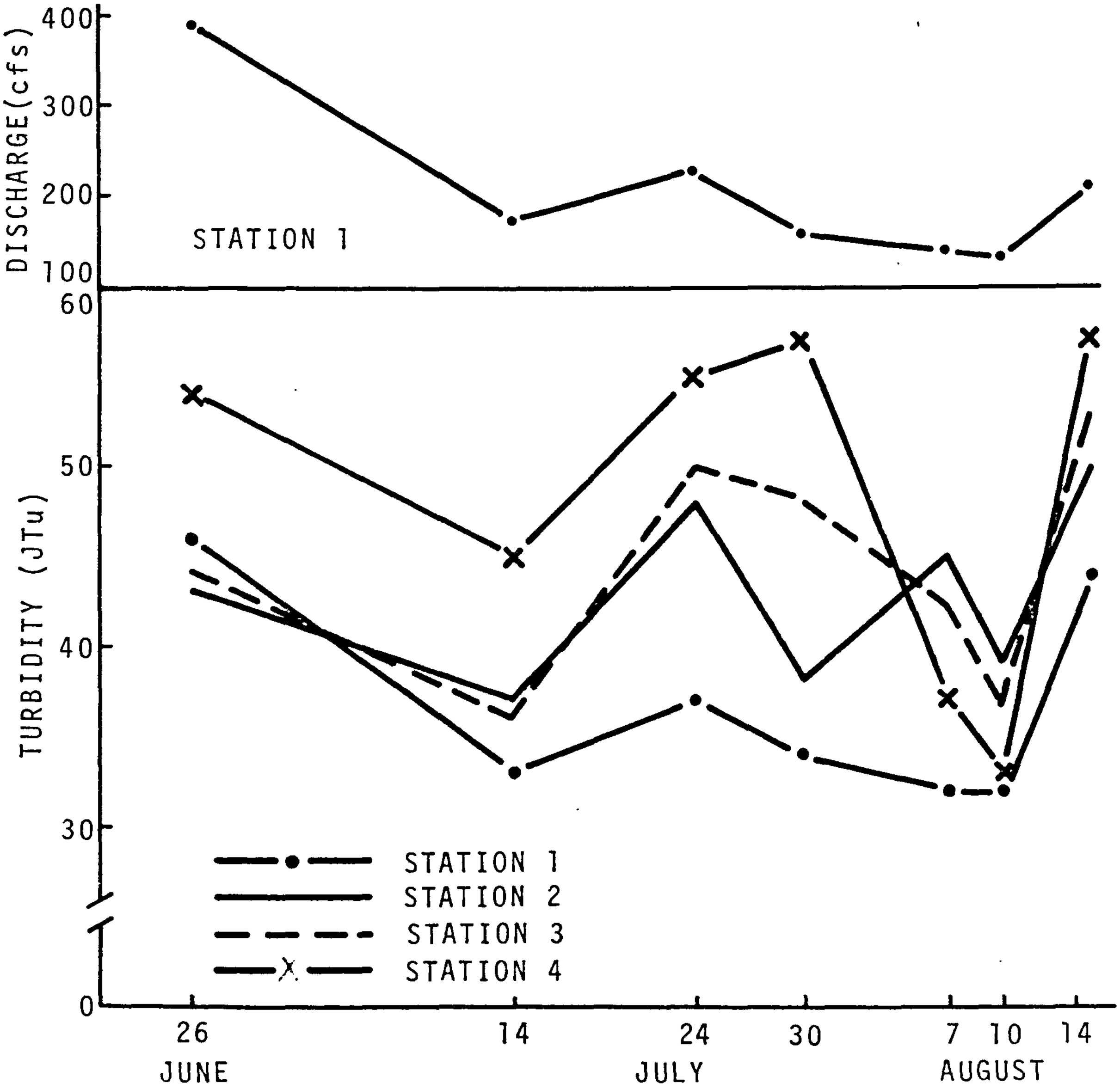
Turbidity samples taken during 1970 showed an increase in turbidity from station 1 to station 4 (Table 3). Values at stations 2 and 3 were within 3 JTU of each other on all but one sampling date, but were variable with respect to stations 1 and 4 (Fig. 9). Turbidity at station 4 varied over a wider range than did turbidity at station 1 but was consistently higher.

Table 3. Turbidity (JTU) and percentage increase in turbidity from unchannelized section (station 1) to channelized section (station 4) and the discharge (cfs) at station 1 for 1970 sampling dates, Little Sioux River, Iowa

Date	Station 1	Station 4	% increase	Discharge
June 26	46	54	17.4	392
July 14	33	45	36.4	174
July 24	37	55	48.6	226
July 30	34	57	67.6	154
August 7	32	37	15.6	138
August 10	32	33	3.1	133
August 14	44	57	29.5	206
Average	36.9	48.3	31.2	203

To provide a general idea of the relative magnitude of turbidity values in the Little Sioux River, a comparison was made to turbidity values from the Skunk River near Ames, Iowa. During periods of no precipitation and runoff, the Skunk River is considered a relatively clear stream. John R. Jones (I.S.U., M.S. Thesis, in preparation), using the same turbidimeter used in this study, measured turbidity values ranging from 9 JTU to 25 JTU during the same time period for the values in the Little Sioux River.

Fig. 9. Turbidity (JTU) at stations 1, 2, 3, and 4 and discharge (cfs) at station 1 on sampled dates, 1970



DISCHARGE(cfs)
400
300
200
100
STATION 1
TURBIDITY (JTu)
60
50
40
30
0
STATION 1
STATION 2
STATION 3
STATION 4
26
JUNE
14
24
30
JULY
7
10
14
AUGUST

Discharge at station 1 on each sampling date ranged from 133 cfs to 392 cfs (Table 3) and was directly related to turbidity at station 1 (Fig. 9). If the assumption was correct that discharges at the two stations were directly related (Table 1), turbidity was not as directly related to the discharge at station 4 as at station 1. The turbidity at station 4 may have been affected by other factors, such as organic production or channel erosion.

Measurements or observations were not made of organic production; however, channel erosion was reported as a serious problem in the earlier channel straightening projects on the Little Sioux River (Iowa Natural Resources Council, 1959). Rock riprap has prevented this in certain areas of the channelized section, but in several other observed areas the banks appeared irregularly shaped and the channel widened as a result of channel erosion. The lack of heavily rooted vegetation along the banks in the channelized section was probably responsible for this and a large amount of the suspended sediment in the water. Without vegetation, the soil particles along the bank are not held as closely together and will erode more easily (Sigafoos, 1964).

Other sources of suspended sediment considered were tributary streams and surface runoff. No major tributary streams were located within the study area and minor tributaries were dry during this period. The effects of rain and subsequent runoff were believed to be very minimal during this time, with no heavy or prolonged rains and very few brief thunder showers. Precipitation for the Kennebec area, measured at the nearest weather station in Onawa, Iowa, was 5.1 cm and 2.0 cm (below normal) for July and August, 1970, respectively (U.S. Department of Commerce, 1970).

Water temperature

Continuous water temperatures were recorded from July 8, 1970 to August 24, 1970 at stations 1 and 4. Maximum daily water temperatures of 31.1 C at station 1 and 33.9 C at station 4 occurred on July 30. The mean daily temperatures were highest at station 1 on July 31 and at station 4 on July 30, and were 30.0 C and 30.6 C, respectively.

From July 8 to July 18 and July 23 to August 3, mean daily temperatures averaged 0.3 C higher at station 4 than at station 1. During this same time however, the maximum daily temperatures averaged 1.3 C higher at station 4 while the minimum daily temperatures averaged 0.2 C lower at station 4.

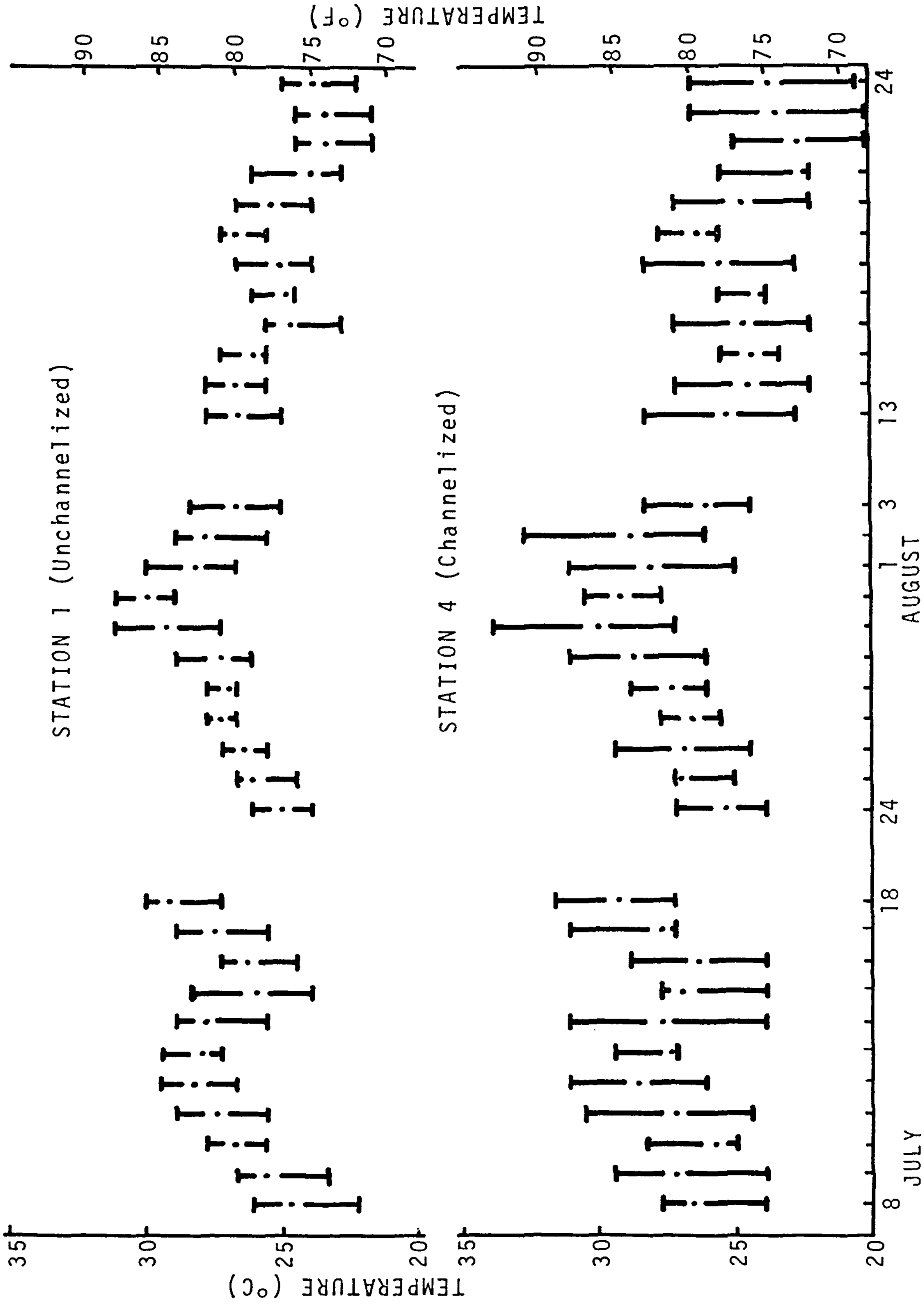
After a period of no record from August 4 to August 13, temperatures were recorded until August 24. Water temperatures were cooler during this period than the previous period, the average mean daily temperatures dropping from 27.2 C to 25.1 C at station 1 and from 27.5 C to 24.3 C at station 4. Maximum temperatures at station 4 still averaged higher than at station 1, but by 0.6 C as compared to 1.3 C earlier. The average minimum temperatures were 1.4 C lower at station 4 during this period as compared to 0.2 C lower during the first period. The higher maximum and lower minimum temperatures at station 4 during both periods of record reflected the larger variation in daily water temperature at station 4 (Fig. 10).

Water temperature data were available from the Iowa Geological Survey (1955) for 1951-54, prior to the Corps of Engineers Project. Temperatures were taken on a random once-daily basis at Correctionville and Kennebec, and were assumed to be within 10% of the daily mean. This assumption was based on data from other Iowa rivers showing small fluctuations in daily water temperature.

The maximum temperatures during these years averaged 1.0 C higher at Kennebec than at Correctionville. Average temperatures of July ranged from 20.2 to 24.4 C, averaging 23.3 C at Correctionville, and from 23.3 to 25.0 C, averaging 23.8 C at Kennebec. Average August temperatures ranged from 21.1 to 22.8 C, averaging 21.9 C at Correctionville, and from 21.7 to 22.2 C, averaging 21.8 C at Kennebec.

The trend of higher maximum temperatures at the Kennebec station, apparent in 1970, was also apparent from 1951 to 1954, but to a lesser degree. The mean monthly temperatures for July and August were slightly higher and lower, respectively, at Kennebec, as was the case in 1970. Lower water temperatures and smaller daily fluctuations in the unchannelized section may

Fig. 10. Mean daily water temperature (dots) and ranges (brackets) at station 1 (unchannelized) and station 4 (channelized), Little Sioux River, Iowa, on sampled dates, 1970


STATION 1 (Unchannelized)
STATION 4 (Channelized)
TEMPERATURE (°C)
TEMPERATURE (°F)
35
30
25
20
90
85
80
75
70
8
JULY
18
24
1
AUGUST
3
13
24

have been partly due to the shading effect produced by the canopy of trees in most of this area. This has also been reported by Gray and Edington (1969), working on a smaller stream. The effects of the shading on a larger river would not be as great because of the larger volume of water and areas without a continuous tree canopy. The increased width and lack of trees in the channelized section were probably contributors to the higher water temperatures, along with the higher turbidities.

There was also a noticeable increase in average and maximum temperatures from 1951-54 to 1970. The maximum water temperature at Correctionville was 3.9 C higher in 1970 than during 1951-54, and at Kennebec it was 5.6 C higher. The average water temperatures for the two distinct time periods in 1970 were 3.9 C and 3.2 higher at Correctionville, and 4.2 C and 2.5 C higher at Kennebec than during similar time periods from 1951 to 1954. Some differences could be attributed to the once-daily sampling in 1951-54 and to higher average atmospheric temperatures during July and August of 1970. Average atmospheric temperatures measured at Onawa, Iowa were 0.4 C higher in July and 2.4 C higher in August of 1970 than in the same months from 1951 to 1954 (U.S. Department of Commerce, 1951-54; 1970).

Macroinvertebrates

Attached

Artificial substrate samplers were placed in the river during summer 1970 for three 1-week periods consisting of different experimental conditions. Unmodified (original) samplers were placed in two habitat areas, mainstream and bank, from June 11 to 18. Modified or simulated brushpile samplers were placed in mainstream from June 18 to 25. The third series, July 28 to August 4, consisted of unmodified samplers in mainstream and within natural brushpiles and modified samplers above the natural brushpiles. Discharge was approximately equal to the 42-year mean at station 1 during the first two sampling periods. Discharge was below normal during the third series of artificial substrate samplers, from July 28 to August 4.

Ephemeroptera, Trichoptera and Diptera were the most common orders of insects collected, averaging at least 99.0% of the total number and weight per sampler in each situation (Tables 4, 5, 6). Heptageniidae and Baetidae were the most common families of Ephemeroptera, and Trichoptera consisted primarily of Hydropsychidae. Chironomidae and Simuliidae were the only families of Diptera collected. Large differences, with respect to number and kinds of species collected, were not apparent between stations; however, relative abundance of the main orders varied between stations and habitats.

Table 4. Average number[a] and weight (mg)[a] of macroinvertebrates collected on unmodified artificial substrate samplers in two habitat areas within stations 1 (unchannelized) and 4 (channelized), June 11-18, 1970 (Percentage of total in parentheses)

Taxonomic group	Mainstream				Bank			
	Station 1		Station 4		Station 1		Station 4	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Ephemeroptera	43.5	81.4	88.0	326.2	72.6	185.9	201.6	482.2
	(7.3)	(5.7)	(15.0)	(18.2)	(30.2)	(42.6)	(36.8)	(45.9)
Heptageniidae	16.5	59.2	24.7	53.6	46.7	157.2	87.6	227.6
Stenonema	13.5		19.7		39.0		67.3	
Heptagenia	3.0		5.0		6.0		20.3	
Baetidae	27.0	22.2	63.0	272.6	25.9	29.0	114.0	254.6
Isonychia	10.5		43.0		3.3		43.0	
Baetis	10.5		8.3		18.3		32.3	
Caenis	6.0		12.0		4.3		27.0	
Tricorythodes							1.7	
Trichoptera	530.5	1346.0	467.9	1437.9	149.3	236.4	297.6	540.5
	(88.5)	(93.6)	(79.5)	(80.3)	(62.0)	(54.2)	(54.3)	(51.4)
Hydropsychidae	530.5	1346.0	467.3		149.3	236.4	297.6	540.5
Hydropsyche	106.5		20.3		36.0		29.3	
Cheumatopsyche	424.0		447.0		113.3		268.3	
Leptoceridae			0.3	T[b]				
Psychomyiidae			0.3					
Diptera	20.0	13.3	29.7	25.7	18.1	13.8	43.9	28.6
	(3.3)	(-)[c]	(5.0)	(1.5)	(7.5)	(3.2)	(8.0)	(2.7)
Chironomidae	11.5	3.3	13.0	5.7	8.3	1.8	17.6	2.7
Simuliidae	8.0	9.6	16.7	20.0	9.1	12.0	25.6	25.9

Oligochaeta	5.5 (-)	T	2.7 (-)	T	0.7 (-)	T	5.3 (-)	T
Ave. total	599.5	1440.7	588.6	1789.8	240.7	436.1	548.5	1051.3
Minimum	367	1336.6	488	1536.1	27	25.5	185	543.4
Maximum	832	1558.0	730	2224.5	408	735.3	790	1320.1
No. samplers	2		3		3		3	

---

[a] Orders and families composite of lower taxa.

[b] Negligible.

[c] Less than 1.0%.

Table 5. Average number[a] and weight (mg)[a] of macroinvertebrates collected on modified artificial substrate samplers in mainstream of stations 1 (unchannelized) and 4 (channelized), June 18-25, 1970 (Percentage of total in parentheses)

Taxonomic group	Station 1		Station 4	
	No.	Wt.	No.	Wt.
Ephemeroptera	81.0	103.1	107.5	373.7
	(50.0)	(35.8)	(42.8)	(50.6)
Heptagenia	22.0	45.1	17.5	59.5
Stenonema	20.0		16.5	
Heptagenia	0.5		1.0	
Cinygmula	0.5			
Baetidae	59.0	58.0	89.5	314.2
Baetis	50.5		22.5	
Caenis	4.5		39.5	
Isonychia	3.0		26.5	
Tricorythodes	1.0		1.0	
Ephemeridae			0.5	T[b]
Ephoron			0.5	
Trichoptera	62.5	162.6	132.0	344.8
	(38.6)	(56.5)	(52.6)	(46.7)
Hydropsychidae	62.5	162.6	131.5	344.8
Hydropsyche	27.5		10.5	
Cheumatopsyche	35.0		121.0	
Leptoceridae			0.5	T
Diptera	18.5	22.3	10.5	6.0
	(11.4)	(7.7)	(4.2)	(-)[c]
Chironomidae	8.5	3.6	7.0	2.8
Simuliidae	10.0	18.7	3.5	3.2
Coleoptera			0.5	0.4
			(-)	(-)
Chrysomelidae			0.5	0.4
Odonata			0.5	13.2
			(-)	(1.8)
Gomphidae			0.5	13.2
Ave. total	162	288.0	251	738.1
Minimum	138	231.5	222	614.0
Maximum	186	344.5	280	862.5
No. samplers	2		2	

[a] Orders and families composite of lower taxa.

[b] Negligible.

[c] Less than 1.0%.

Table 6. Average number^a and weight (mg)^a of macroinvertebrates collected on unmodified and modified artificial substrate samplers in different habitat areas of station 1 (unchannelized) and station 4 (channelized), July 28 - Aug. 4, 1970 (percentage of total in parentheses)

Taxonomic group	Unmodified-mainstream				Unmodified-in brushpile				Modified-above brushpile			
	Station 1		Station 4		Station 1		Station 4		Station 1		Station 4	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Ephemeroptera	27.0	90.4	63.5	147.3	22.3	166.8	11.0	85.4	62.6	176.7	16.0	85.9
	(17.9)	(7.2)	(20.2)	(6.5)	(48.5)	(71.5)	(38.5)	(86.6)	(42.4)	(27.1)	(54.1)	(66.8)
Heptageniidae	9.5	53.0	12.0	76.3	19.0	165.8	10.0	84.8	17.3	131.4	10.0	70.8
Stenonema	9.0		10.5		19.0		10.0		17.3		9.3	
Heptagenia	0.5		1.5								0.7	
Baetidae	17.5	37.4	51.5	71.0	3.3	1.0	1.0	0.6	45.3	45.3	6.0	15.1
Isonychia	0.5								0.3		1.0	
Caenis	2.0		4.5		1.3		0.3		3.7		1.0	
Baetis	15.0		47.0		2.0		0.3		41.3		4.0	
Trichoptera	102.5	1142.6	196.0	2070.4	5.0	28.7	0.7	1.7	50.3	439.3	5.0	31.6
	(67.9)	(91.5)	(62.4)	(91.7)	(10.9)	(12.3)	(2.4)	(1.7)	(34.1)	(67.4)	(16.9)	(24.6)
Hydropsychidae	102.0	1138.4	196.0	2070.4	5.0	28.7	0.3	1.7	49.0	439.3	3.7	24.2
Hydropsyche	48.5		120.0		1.7		0.3		24.7		1.7	
Cheumatopsyche	53.5		76.0		3.3				24.3		2.0	
Leptoceridae	0.5	4.2							0.3	0.1	0.7	5.5
Athripsodes	0.5								0.3		0.7	
Psychomyiidae									1.0	5.8	0.6	1.9
Neureclipsis									1.0		0.3	
Psychomyia											0.3	
Diptera	19.5	7.0	54.5	39.0	18.0	37.2	16.6	7.0	34.4	33.8	8.3	10.2
	(12.9)	(-)^b	(17.4)	(1.7)	(39.1)	(15.9)	(58.0)	(7.1)	(23.3)	(5.2)	(28.0)	(7.9)
Chironomidae	17.5	5.0	35.0	13.0	18.0	37.2	16.6	7.0	31.4	31.3	8.3	10.2
Simuliidae	2.0	2.0	19.5	26.0					3.0	2.5		

Coleoptera	2.0	9.4										
	(1.3)	(-)										
Chrysomelidae	2.0	9.4										
Plecoptera							0.3	4.5				
							(1.0)	(4.6)				
Perlidae							0.3	4.5				
Odonata									0.3	2.2		
									(-)	(-)		
Gomphidae									0.3	2.2		
Isopoda											0.3	0.9
											(-)	(-)
Oligochaeta					0.7	T[c]						
					(1.5)							
Ave. total	151.0	1249.4	314.0	2256.7	46.0	233.3	28.6	98.6	147.6	652.0	29.6	128.6
Minimum	141	1060.1	302	1686.1	30	156.9	7	31.7	92	400.1	17	107.3
Maximum	161	1438.4	326	2827.3	57	350.3	57	172.0	190	888.2	39	155.3
No. of samplers	2		2		3		3		3		3	

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[a] Orders and families composite of lower taxa.

[b] Less than 1.0%.

[c] Negligible.

Average total numbers and weights of organisms collected on the unmodified samplers in the mainstream habitat, June 11-18, were very similar at stations 1 and 4 (Table 4). Relatively large numbers in both areas were probably a function of the greater discharge during this time. The shifting sand substrate in the mainstream of both stations was not suitable for bottom fauna and would suggest the organisms on the samplers were the result of drifting. The composition of organisms was generally similar at each station with Trichoptera dominating in number and weight (Table 4).

Samplers along the bank showed differences in average numbers and weights of organisms between the two habitats. Station 4 averages were similar to those in the mainstream habitat, but station 1 averages were much lower (Table 4). Differences between stations were not statistically significant at 90% level of confidence (T = 1.43, 4 d.f.). The composition of organisms was also different from the mainstream samplers, but generally similar between stations. Dominance of Trichoptera was less evident along the banks, where Ephemeroptera became more abundant in the slower water and areas of silt and mud (Table 4). Diptera was not present in relatively large numbers in either habitat.

The modified samplers placed in the mainstream of stations 1 and 4, June 18-25, revealed a reduction in the total number and weight per sampler from the previous week (Tables 4, 5).

This reduction was most likely the result of reduced flow coming in contact with the samplers because of the perforated pipes surrounding them. Average total numbers and weights of organisms were greater at station 4 than at station 1 (Table 5); however, only weight was statistically significant at 90% confidence levels (T = 3.30, 2 d.f.). Although the samplers were located in the mainstream, composition of organisms collected on them resembled the composition of the bank samplers. Ephemeroptera were relatively more abundant and Trichoptera less abundant at both stations, indicating that current velocity was an important factor in the distribution of Trichoptera, as reported by Allen (1959).

Unmodified samplers placed in the mainstream from July 28 to August 4, showed a different relationship between stations than during the first sampling period. Average total numbers and weights were greater at station 4 during the later period (Table 6) with numbers significant at the 95% level of confidence (T = 10.45, 2 d.f.). At the same time, modified samplers placed immediately upstream from brushpiles at stations 1 and 4 revealed just the opposite results (Table 6), with both numbers and weight significantly greater at station 1 (T = 3.96 and 3.68 respectively, 4 d.f.). Unmodified samplers placed directly within the brushpiles collected relatively few organisms (Table 6) and there were no significant differences in numbers or weights between stations.

Differences between the two stations in the first two situations during this later period may have been caused by several factors. According to Cummins (1962), current velocity, food materials, and substrate are the most important factors in the distribution of bottom fauna living on or beneath the substrate. Substrate was defined as the sediments, mineral or organic, and vegetation growing in or on the bottom. The lack of suitable natural substrate for attachment was a possible cause for the higher numbers in the mainstream of the channelized section. Although the mainstream in most of the unchannelized areas was shifting sand unsuitable for bottom fauna, there were several areas of rock and gravel and an abundance of brushpiles, providing large amounts of natural substrate. Therefore, there may have been fewer organisms available to colonize on the artificial substrates. A greater abundance of organisms in the drift at station 4 during this time also was observed but will be discussed later. Current velocity was not as great as during early June and probably was not as critical a factor.

Modified samplers above brushpiles were not directly comparable because of differences in the substrate surrounding them. Station 1 samplers were located next to a fine silt bottom; however, the sampling location at station 4 was over sand bottom. The organisms found on the samplers in these areas were probably a better indication of the bottom fauna in the immediate habitat area, rather than a result of the drift.

The scarcity of organisms on samplers placed within the brushpiles (Table 6) was likely caused by preference of the organisms for the natural brushpile substrate at station 1 and by the fewer organisms available at station 4.

Although average total numbers on the unmodified mainstream samplers during July 28 - August 4 were considerably lower than during June 11-18, the total weights were slightly greater at station 4 and nearly as great at station 1 (Tables 4, 6). The large increases in size of the Trichoptera, evident from their lower numbers but greater weights, were responsible. Food material for the growth and development of the Trichoptera larvae was apparently adequate for growth in both areas. Ephemeroptera and Diptera increased in relative numerical abundance at both stations as a result of the smaller numbers of Trichoptera; however, neither were gravimetrically important in the mainstream habitat. Conditions on the modified samplers above the brushpiles numerically favored the Ephemeroptera at both stations; however, Trichoptera was gravimetrically more important at station 1. The small numbers of organisms on the samplers within the natural brushpiles consisted primarily of Ephemeroptera and Diptera, with very few Trichoptera.

Drift

Berner (1951) defined drift as the heterogenous, macroscopic group of living and dead organisms including all of the aquatic and terrestrial insects, other invertebrates, and the small fishes being carried by the current on or below the surface of the water. Only the macroinvertebrates were included in this study; however, occasional small fishes were collected.

Organisms of the class Insecta dominated the composition of the drift samples with only minor representations of other groups (Table 7). Smaller crustaceans, if present, were able to pass through the mesh of the net and were not collected in the large numbers reported by Morris _et_ _al_. (1968) in the Missouri River. The orders Ephemeroptera, Trichoptera and Diptera were collected frequently and contributed the majority of the Insecta, comprising approximately 90%, 80%, 80%, and 85% of the total numbers at stations 1, 2, 3, and 4, respectively. Hemiptera also appeared relatively abundant, but the majority of their numbers were collected on one sampling date and otherwise occurred less frequently than the others. A variety of families of Coleoptera, including several terrestrial families, were collected in the drift; however, they occurred infrequently in the sampling. The other groups of insects, excluding Hemiptera, were mainly terrestrial organisms which were collected only in a few samples.

Diptera and Trichoptera, primarily the families Chironomidae and Hydropsychidae, respectively, appeared in different proportions in the unchannelized and channelized sections of the river. Larger numbers of Hydropsychidae,

Table 7. Total numbers[a] and frequency of occurrence for major taxonomic groups and their lowest identified taxa collected in 14 drift net samples, April 4 to Oct. 3, 1970 (Percentage of total in parentheses)

Taxonomic group	Frequency of occurrence				Total number			
	Station				Station			
	1	2	3	4	1	2	3	4
Araneae	7.1	7.1		7.1	1 (-)[b]	1 (-)		1 (-)
Crustacea	7.1	7.1		7.1	1 (-)	1 (-)		1 (-)
Argulus				7.1				1
Hyalella	7.1	7.1			1	1		
Oligochaeta			7.1				1 (-)	
Ephemeroptera	50.0	35.7	42.9	50.0	8 (3.7)	12 (5.5)	20 (7.4)	45 (13.4)
Heptageniidae					2	4	2	3
Stenonema	14.3	14.3	7.1	14.3	2	4	1	3
Baetidae					4	7	17	39
Baetis	7.1	7.1	14.3	35.7	1	1	2	11
Caenis	14.3	21.4	21.4	42.9	3	5	5	18
Isonychia			7.1	14.3			3	3
Tricorythodes				7.1				1
Ephemeridae					2	1	1	3
Ephoron		7.1	7.1	7.1		1	1	2
Pentagenia	7.1				1			
Hexagenia				7.1				1

Trichoptera	64.3	92.9	85.7	85.7	52	73	118	136
					(24.0)	(33.3)	(43.7)	(40.6)
Hydropsychidae					48	70	113	106
Hydropsyche	35.7	42.9	35.7	50.0	9	10	8	24
Cheumatopsyche	50.0	92.9	78.6	71.4	38	59	101	79
Leptoceridae					4	3	4	30
Athripsodes	21.4	21.4	7.1	42.9	4	3	4	30
Psychomyiidae			7.1				1	
Diptera	78.6	78.6	85.7	100	134	88	75	110
					(61.8)	(40.2)	(27.8)	(32.8)
Chironomidae	57.2	71.4	85.7	85.7	120	70	43	74
Simuliidae	50.0	71.4	57.2	71.4	11	17	22	25
Rhagionidae			7.1				1	
Tipulidae		7.1	7.1			1	1	
Culicidae								1
Chaoborus				7.1				1
Dolichopodidae	14.3		7.1		2		7	
Muscidae			7.1				1	
Sciaridae				7.1				4
Coleoptera	28.6	21.4	21.4	35.7	4	5	8	8
					(1.8)	(2.3)	(3.0)	(2.4)
Hydrophilidae			7.1				2	
Haliplidae			7.1	7.1			1	1
Curculionidae	7.1				1			
Chrysomelidae			14.3	7.1			2	1
Dryopidae	7.1	7.1	7.1	14.3	1	1	2	3
Dytiscidae		7.1		7.1		2		1
Pselaphidae			7.1				1	
Tenebrionidae	7.1				1			

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[a] Orders, families, and Crustacea are composites of lower taxa.

[b] Less than 1.0%.

Table 7 (Continued)

Taxonomic group	Frequency of occurrence				Total number			
	Station				Station			
	1	2	3	4	1	2	3	4
Scarabeidae	7.1	7.1			1	1		
Staphylinidae				7.1				1
Carabidae				7.1				1
Cantharidae		7.1				1		
Hemiptera	28.6	28.6	21.4	14.3	7	35	33	25
					(3.2)	(16.0)	(12.0)	(7.5)
Corixidae	28.6	28.6	21.4	14.3	7	35	33	25
Homoptera		14.3	21.4	7.1		2	7	2
						(-)	(2.6)	(-)
Aphididae		7.1	7.1			1	1	
Cicadellidae		7.1	7.1			1	1	
Cercopidae			14.3				5	
Delphacidae				7.1				2
Hymenoptera	14.3	14.3	28.6	28.6	9	2	5	5
					(4.1)	(-)	(1.9)	(1.5)
Formicidae	14.3	14.3	21.4	28.6	9	2	3	5
Eucaritidae			7.1				1	
Pteromalidae			7.1				1	
Lepidoptera	7.1		7.1		1		1	
					(-)		(-)	
Pyralidae	7.1		7.1		1		1	
Orthoptera			14.3	7.1			2	2
							(-)	(-)
Tettigoniidae			7.1				1	
Acrididae			7.1				1	
Total					217	219	270	335

comprising larger percentages of the total, were collected at both of the channelized stations (Table 7). In the unchannelized section, however, Chironomidae was relatively more abundant. The differences become more meaningful when compared on a seasonal basis. Nearly 80% of the total number of Hydropsychidae at station 4 were collected during the four sampling periods in June, when discharge and current velocity were relatively high. At station 1 only 35% of the total number of Hydropsychidae were collected during this time. On the April 4 sampling date 85% of the Chironomidae were collected at station 1, when discharge and velocity were highest, compared to 30% of the total at station 4. Higher current velocities apparently affected each family differently at each station, and may have been caused by differences in the life stages of the organisms. Of the larger number of Chironomidae collected at station 1, approximately 95% were in the adult and pupal stages, which would be more susceptible to the higher current velocities. This would also suggest that areas for production of Chironomidae were more suitable at station 1. Smaller hydropsychid larvae during this time would also be more susceptible to the current and would not have as much natural substrate for protection in the channelized section.

Ephemeroptera were not relatively abundant in the drift at any station, but were generally more abundant in the samples from the channelized stations. Although a wide variety of terrestrial insects were collected, they contributed only 6.5, 2.7, 8.9, and 4.5% of the total number of organisms at stations 1-4, respectively. Surrounding vegetation has been known to contribute a substantial quantity of terrestrial insects to the fauna of some streams (Chapman, 1964).

Average standing crops of drift for the 13 sampling dates in 1970 were similar in number and weight at each of the 4 stations (Table 8). Average standing crops of drift were 827 mg/1000 cu.m in the unchannelized section and 866 mg/1000 cu.m in the channelized section and numerically 199 and 207 organisms per 1000 cu.m, respectively. Although similar on an average basis, the standing crops at each station did not follow a consistent pattern. Standing crops (weight) on a single date were never distributed evenly between stations when tested against a Chi square distribution. A Chi square test for interaction (Snedecor, 1946, p. 191) also showed there was no consistency in the relationship of standing crop (weight) between stations.

Looking only at stations 1 and 4, standing crops (numbers) were greater at station 4 on 10 of the 13 dates sampled. Samples taken June 30 also contained larger numbers (99) at station 4 in a sample of less time than at station 1 (5), but drift rate could not be determined since velocity measurement was not recorded. The average numerical standing crop was

Table 8. Abundance of drift, expressed as wet weight and number per 1,000 m^3, and surface velocity at each station on 1970 sampling dates

Date	Weight(mg)/1,000 m^3				Number/1,000 m^3				Surface velocity (m/sec)			
	Station				Station				Station			
	1	2	3	4	1	2	3	4	1	2	3	4
April 4	6622	8106	7433	5422	1894	1052	726	683	0.7	0.5	0.5	0.5
May 2	222	88	26	222	44	27	21	76	0.8	0.7	0.9	0.6
June 9	1603	198	608	446	36	84	355	104	0.8	0.6	0.5	0.7
June 16	1454	202	1887	1002	86	225	730	383	0.7	0.6	0.8	0.8
June 22	63	180	335	454	127	86	222	207	0.6	0.8	0.7	0.7
July 7	607	280	97	298	259	148	58	113	0.5	0.5	0.8	0.4
July 14	0	115	13	80	0	37	10	113	0.5	0.5	0.6	0.4
July 30	13	127	114	152	27	134	63	131	0.3	0.5	0.6	0.5
August 6	2	80	241	622	15	74	77	303	0.4	0.5	0.7	0.4
August 11	106	182	1411	276	43	257	90	140	0.5	0.5	0.4	0.3
August 20	779	77	24	116	154	31	29	211	0.5	0.6	0.5	0.2
August 25	127	141	144	12	124	121	74	18	0.6	0.4	0.5	0.3
October 3	83	37	109	973	28	70	99	348	0.4	0.4	0.4	0.3
Average	898.5	754.8	957.1	775.0	218.2	180.5	196.5	217.7	0.56	0.55	0.61	0.47

affected by the large number collected on April 4 at station 1; however, these consisted of primarily Chironomidae which did not affect the standing crop in weight as much. The standing crop (weight) was greater at station 4 on only 6 of the 13 samples, suggesting that numerically, drift at station 4 may have been more abundant, but differences in the composition and size of the organisms resulted in inconsistent differences in the standing crop by weight.

The relationship between current velocity at the four stations on a given date was not consistent throughout the year (Table 8) indicating that sampling location within a station may have affected the drift rates. Localized variations in current velocity could not be measured; however, because of the crude method used to measure velocity.

General similarities existed between the composition of the drift organisms and organisms attached to the artificial substrate samplers, with some exceptions. The presence of species of the Ephemeridae, or burrowing family (Pennak, 1953), in the drift indicated production of these organisms in the river. Several of these mayflies were observed burrowing in the bank in both areas during late summer, but were not common in the mainstream where the drift samples were collected. Oligochaeta may have been more abundant than indicated, but were not readily observed due to their small size.

Species composition of the bottom fauna did not exhibit sharp contrasts between the unchannelized and channelized sections of the river. Species differences were attributable to only those collected in very few numbers and were probably unimportant. Efficiency of sampling in representing the composition of the bottom fauna appeared fairly accurate when compared to the fauna collected in the upper Little Sioux River near Milford, Iowa (Bovbjerg, Pearsall, and Brackin, 1970). Although different in some respects, the river in the area sampled by Bovbjerg *et al*. was generally quite turbid with fairly fast current. Similarities were noted in Ephemeroptera, Diptera, and Trichoptera.

Current velocity appeared to be an important factor in the distribution and abundance of bottom fauna in the river. The shifting sand substrate in the channelized area and parts of the unchannelized area were unsuitable for the attachment of bottom fauna, a commonly accepted fact (Moon, 1939; Eggleton, 1939). The importance of drift, especially in the channelized area, was evident from the relatively large numbers of organisms collected on artificial substrate samplers in the mainstream habitat. A study conducted on Bear River, Utah reported a maximum of 250 organisms per sampler, using Hester and Dendy-type samplers for 19 days. Insect taxa similar to those in the Little Sioux colonized the samplers, placed over what was considered to be a relatively sterile bottom area (Mackenthun and Ingram, 1967). Nilsen and Larimore (1971) collected an average total of 826 organisms per square foot of introduced log substrates placed for 4 weeks in a riffle area of Kaskaskia River, Illinois. Organisms collected were predominantly plecopteran, hydropsychid, and simuliid larvae. Although only a general comparison between rivers is possible, abundance of attached bottom fauna on approximately 1-square foot of artificial substrate in the mainstream of Little Sioux River for 1 week appeared at least equal to abundance in a similar habitat of a turbid stretch of Bear River after 19 days. Numbers of organisms per square foot in Kaskaskia River were somewhat larger; however, the introduced logs were located in a more productive habitat and provided a more natural substrate.

Drift is generally considered to occur passively, resulting from mechanical action of the current (Elliot, 1967). In smaller streams, most drifting invertebrates travel for a short distance downstream and then return to the bottom, where they attach to the available substrate. In a larger river such as the Little Sioux, relatively high velocities and unsuitable substrate would maintain invertebrates in the drift for a longer period of time, and probably for considerable distances. This would especially be true in the channelized section, where bottom substrate and current velocity were relatively uniform across the channel, with few natural substrates for attachment.

This may have been the reason for the usually higher numbers of organisms in the drift and on artificial substrates in the mainstream of the channelized section. Morris *et al*. (1968) reported higher standing crops of drift in the unaltered portion of the Missouri River.

Standing crop of drift was probably not a true indication of relative amounts of bottom fauna production in each area. Production areas in the channelized section were limited to isolated riprap areas, the bank, and possibly some silt covered areas associated with an occasional brushpile. Production in the unchannelized area was benefited by the numerous brushpiles and associated pools, occasional riffles, and some quiet backwater areas. In addition, allochthonous organic matter from the surrounding vegetation, absent in the channelized section, would be an important source of food material (Forbes and Richardson, 1919; Chapman, 1964). Drift rates in the channelized section were undoubtedly affected by the production of an immediate riprap area. Samples were often collected in areas near bridges, where riprap was available. It may have been possible for some organisms to have been produced in the unchannelized area and collected in the drift in the channelized area, especially at station 3.

Sampling techniques may have affected results to a certain degree. The use of artificial substrates has been questioned in both qualitative (Prouse and Crowe, 1971) and quantitative studies (Coffman, 1971). For the purposes of a comparative study, the multiple plate samplers were considered useful by Hester and Dendy (1962). Several complexities arise in the use of artificial substrates. Such things as sampling time, location, number of samples, and selectivity for certain species are important. In a comparative sense, the artificial substrate samplers used in this study were considered generally effective for the purposes intended.

Drift samples were probably a minimal indication of the actual drift. Samples were taken during the day when drifting is considered to be the least (Tanaka, 1960; Waters, 1962). The mesh size of the net obviously allowed the earlier instars of insects to pass through. Sampling only near the surface of the water may have excluded an important part of the drift, depending upon its vertical distribution.

The relative distribution and abundance of bottom fauna in the two sections of the river were a result of several environmental factors. Besides the ones already mentioned, an important consideration may have been the turbidity and its related effects (Berner, 1951). Sand abrasion (Chutter, 1969) did not seem to affect the organisms colonized on the artificial substrates during the sampling period of higher discharge. Water temperature (Macan, 1963), primary productivity, abundance of phytoplankton, and dissolved oxygen are all related to turbidity and may have had some effects, though not obvious. As a result of the lack of dominant areas of suitable bottom substrate, the attached organisms and subsequent drift were an important segment of the biological production in each section of the river.

Fishes

Twenty-eight species were collected at the four sampling stations during 1969 and 1970 (Table 9). Species collected may not include all minnows present in the sampling area because of sampling techniques, but most larger size species in the area were probably collected. Twenty-five species were collected at station 1, 21 at station 2, 22 at station 3, and 17 at station 4. Three species, stoneroller, common shiner, and smallmouth bass, were found exclusively at station 1, in the unchannelized section. The shorthead redhorse and freshwater drum were found only in the channelized area. Brassy minnow, flathead chub, silver chub, bigmouth shiner, bluntnose minnow, bluegill, largemouth bass, and walleye were found at stations 1, 2, and 3 but not at station 4.

Channel catfish was the predominant species collected, comprising a large percentage of the total number taken at each station with hoopnets and Primacord (Table 10). Electric shocking was not effective on channel catfish, but collected larger numbers of carp and carpsucker (river carpsucker and quillback) than the other techniques. Black bullhead and

Table 9. Species composition and occurrence (+) by station of fish collected by hoopnet, electric shocking, and Primacord during 1969 and 1970

Common and scientific names taken from American Fisheries Society (1970).

	Station			
Species	1	2	3	4
Northern pike (*Esox lucius*)	+	+	+	+
Stoneroller (*Campostoma anomalum*)	+			
Carp (*Cyprinus carpio*)	+	+	+	+
Brassy minnow (*Hybognathus hankinsoni*)	+	+	+	
Flathead chub (*Hybopsis gracilis*)	+	+	+	
Silver chub (*Hybopsis storeriana*)	+		+	
Common shiner (*Notropis cornutus*)	+			
Bigmouth shiner (*Notropis dorsalis*)	+	+	+	
Red shiner (*Notropis lutrensis*)	+	+	+	+
Sand shiner (*Notropis stramineus*)	+	+	+	+
Bluntnose minnow (*Pimephales notatus*)	+	+	+	
Fathead minnow (*Pimephales promelas*)	+	+	+	+
Creek chub (*Semotilus atromaculatus*)	+	+		+
River carpsucker (*Carpiodes carpio*)	+	+	+	+
Quillback (*Carpiodes cyprinus*)	+	+	+	+
White sucker (*Catostomus commersoni*)	+	+	+	+
Shorthead redhorse (*Moxostoma macrolepidotum*)				+
Black bullhead (*Ictaluras melas*)	+	+	+	+
Channel catfish (*Ictaluras punctatus*)	+	+	+	+
Stonecat (*Noturus flavus*)	+	+	+	+
Green sunfish (*Lepomis cyanellus*)	+	+	+	+
Orangespotted sunfish (*Lepomis humilis*)	+	+	+	+
Bluegill (*Lepomis macrochirus*)	+	+	+	
Smallmouth bass (*Micropterus dolomieui*)	+			
Largemouth bass (*Micropterus salmoides*)	+		+	
White crappie (*Pomoxis annularis*)		+		+
Walleye (*Stizostedion v. vitreum*)	+	+	+	
Freshwater drum (*Aplodinotus grunniens*)			+	+

Table 10. Species composition of fishes, expressed as percentage of number collected, at each station during 1970, using hoopnets, electric shocking and Primacord (- denotes less than 1.0%)

Common name	Hoopnets				Electric shocking				Primacord			
	Station				Station				Station			
	1	2	3	4	1	2	3	4	1	2	3	4
Channel catfish	44.2	62.4	83.6	59.3	6.1	17.1	8.9	5.8	74.9	77.3	84.7	96.6
Black bullhead	21.8	12.3	1.8	9.3	-	-	-	2.5	0	-	0	0
Stonecat	24.6	16.4	9.8	20.0	1.7	1.8	3.8	3.3	1.0	-	-	-
Carp	5.2	6.5	3.0	5.8	13.9	49.5	40.5	45.8	1.7	-	-	-
Carpsucker	2.8	-	-	-	58.7	15.3	11.4	33.4	5.0	-	-	-
Sand shiner	0	0	0	0	0	0	0	0	6.4	12.1	7.0	1.2
Red shiner	0	0	0	0	2.2	1.8	7.6	3.3	5.8	3.1	2.0	-
Creek chub	-	0	0	0	1.3	-	-	-	0	3.1	0	0
White sucker	-	-	-	2.9	1.7	-	3.8	-	0	0	0	0
Northern pike	-	-	0	0	7.0	2.7	1.3	2.5	0	0	0	0
Green sunfish	0	-	-	-	1.3	4.5	12.6	1.6	0	0	0	0
Walleye	-	-	0	0	1.3	1.8	1.3	0	0	0	0	0
L.M. Bass	0	0	0	0	1.3	-	2.5	0	0	0	0	0
Others[a]	1.4	2.4	1.7	2.8	3.6	3.6	1.3	1.7	4.9	4.4	6.4	2.1
Total number	496	489	968	518	230	111	79	120	295	512	386	415
Effort[b]	68	66	67	68	420	230	130	425	8	10	7	10

[a] Includes species never exceeding 1.0 percent of the total number collected at a station.

[b] Hoopnets-net days; electric shocking-minutes shocked; primacord-number of 50-foot samples.

stonecat were the only other species collected in considerable quantities, primarily in hoopnets.

A limited diversity of fish species in streams within the loess covered watershed was reported by Harrison (1951) and has probably always been the case. Changes in the number and kinds of species within the study section of the Little Sioux River could not be accurately assessed because comparable lists of collections prior to early drainage practices were not available. Fourteen of the 40 species collected by Meek in 1890 (Meek, 1894) from various western Iowa streams, including the Little Sioux, were not found in the same range in 1950 (Harrison, 1951), and 12 of the 38 species found by Harrison were not found by Meek. Harrison attributed most of the species differences between the two collections to inadequacies of sampling gear and differences in sampling locations and felt that species composition had not changed to a great extent between collections. Some of the species not collected by Harrison were reported as rare by Meek and may have disappeared after intensive drainage began in the early 1900's, increasing suspended sediments in streams. Others not found by Harrison were found in subsequent collections. More recent collections have been made on the Little Sioux since Harrison's (1951) collections in 1950. Field data of collections from 1959 to 1966 in the lower Little Sioux River from Cherokee, Iowa to the mouth, including the present study area, were made available by the Iowa State Conservation Commission (ISCC). Bovbjerg *et al.* (1970) also made collections on the upper Little Sioux River during 1969 near Milford, Iowa and points upstream.

Harrison (1951) collected a total of 26 species in 1950 at various locations on the Little Sioux including some locations in the present study area. Distribution of species in the river was not indicated; however, the most noticeable differences from 1969-70 collections were the presence of gizzard shad (*Dorosoma cepedianum*) and bigmouth buffalo (*Ictiobus cyprinellus*) and the absence of stonecat and northern pike in 1950.

Iowa State Conservation Commission personnel collected 26 species in 1964 using hoopnets, seines, and electric shocking, but minnow species were not reported. Collections made by the ISCC from 1959 to 1963, after channelization by the Corps of Engineers but prior to construction of the lowhead dam, were not noticeably different from those by Harrison (1951) in 1950. However, the collections included a number of species not collected in 1969 and 1970. Most notable among these absent were flathead catfish (*Pylodictis olivaris*), sauger (*Stizostedion canadense*), goldeye (*Hiodon alosoides*), shortnose gar (*Lepisosteus platostomus*), smallmouth buffalo (*Ictiobus bubalus*), white bass (*Morone chrysops*), bigmouth buffalo, and gizzard shad, all found throughout the channelized area. All of these species were present in 1964 collections, a year after construction of the lowhead dam, but their absence from 1969 and 1970 collections suggested that their presence in the Little Sioux before 1963 depended primarily upon upstream migration from the Missouri River. The lowhead dam was apparently an effective barrier to this upstream movement and conditions were evidently not favorable for reproduction of those remaining above the dam. Bovbjerg *et al.* (1970) did not collect any of these species in their survey of the upper Little Sioux River. Regardless of the barrier to upstream movement from below the lowhead dam, channel catfish, black bullhead, stonecat, carp, and carpsucker were commonly collected in both sections of the river.

Hoopnet catches of channel catfish at each station were extremely variable during 1970, ranging from zero fish per net day to 333.5 fish per net day at station 3 (Table 11). Seasonal variations in catch per net day at a particular station were to be expected because of changes in netting conditions during the year (Harrison, 1952). Therefore, catch per net day during a particular bi-weekly or weekly time period was most likely not a true indication of the abundance of channel catfish at a station. However, when catch per net day was examined on a seasonal basis and averaged over the entire netting season, comparisons between stations revealed

Table 11. Average number and weight (g) of channel catfish, carp, black bullhead, and stonecat collected per hoopnet day at stations 1-4, Little Sioux River, Iowa during weekly and bi-weekly period of 1969 and 1970

	1969			1970						
	Aug. 14-29	Oct. 1-6	Nov. 17-23	May 1-7	June 1-14	June 15-30	July 1-15	July 16-31	Aug. 1-15	Oct. 1-6
Channel catfish										
Station 1										
No. net days[a]	8	4	2	4	12	12	14	16	8	2
No./net day	5.5	1.8	0	0	1.3	12.2	1.1	1.4	2.2	0
Wt./net day	418.4	211.0	0	0	587.2	6459.2	349.9	71.1	109.2	0
Station 2										
No. net days	7	4	4	4	12	12	14	14	8	2
No./net day	2.4	25.5	0	0.5	0.4	3.4	1.5	1.3	6.0	90.0
Wt./net day	206.0	1456.0	0	13.0	247.8	1549.3	42.6	131.9	2561.1	918.0
Station 3										
No. net days	7	4	4	4	9	14	14	16	8	2
No./net day	1.9	1.0	0	0	0.3	1.2	1.9	3.2	7.9	333.5
Wt./net day	178.6	30.8	0	0	129.6	321.0	342.6	433.9	1415.9	3512.0
Station 4										
No. net days	6	4	2	4	10	14	14	16	8	2
No./net day	1.0	10.0	0	0.2	1.7	0.6	0.1	9.8	14.9	2.5
Wt./net day	50.8	197.2	0	1.5	400.1	156.4	2.9	980.1	1609.8	29.0
Carp										
Station 1										
No./net day	1.0	0.8	0.5	0	0.4	0.4	0.5	0.6	0	0
Wt./net day	57.6	70.8	30.0	0	258.2	705.4	434.0	475.5	0	0
Station 2										
No./net day	0.1	0.2	0	0	0.5	0.3	1.3	0.1	0.2	0
Wt./net day	7.3	22.5	0	0	180.0	213.2	993.6	162.1	92.0	0
Station 3										
No./net day	0.6	0	0	0.5	0.4	0.3	0.8	0.4	0.2	0
Wt./net day	30.4	0	0	86.8	285.3	323.8	342.1	550.2	309.8	0
Station 4										
No./net day	0.5	0.8	0	0.2	0.1	0.6	0.5	0.8	0	0
Wt./net day	26.0	67.8	0	19.2	16.8	474.9	243.2	613.0	0	0

Black bullhead										
Station 1										
No./net day	2.2	2.0	0	1.0	9.0	0.1	0.1	0.1	0.2	0
Wt./net day	240.8	179.0	0	69.0	710.9	2.1	25.1	5.2	40.4	0
Station 2										
No./net day	1.9	0.8	0	0.2	2.3	0.7	0.9	0.1	0.6	0.5
Wt./net day	49.0	26.8	0	6.8	172.3	45.6	83.8	17.3	76.3	32.5
Station 3										
No./net day	1.6	0	0	0.5	0.4	0.1	0.6	0.1	0.4	0
Wt./net day	109.0	0	0	30.0	45.0	2.8	33.5	2.6	50.9	0
Station 4										
No./net day	7.0	2.2	0	1.5	2.5	0.1	0.1	0.4	0.6	1.5
Wt./net day	298.2	46.5	0	132.5	152.9	9.4	11.8	32.0	67.0	206.0
Stonecat										
Station 1										
No./net day	0.1	1.0	0	1.2	5.7	0.6	0.4	1.7	1.1	0
Wt./net day	5.2	61.5	0	84.5	415.8	29.7	27.5	91.3	56.5	0
Station 2										
No./net day	0.4	0.2	0	0	2.8	0.8	1.3	0.5	1.1	2.0
Wt./net day	56.6	35.2	0	0	253.8	51.6	95.1	15.4	71.9	199.5
Station 3										
No./net day	0.7	0.5	0	2.2	3.9	0.4	1.1	0.9	0.6	5.5
Wt./net day	55.3	23.0	0	198.8	357.3	25.2	78.7	67.7	44.2	388.5
Station 4										
No./net day	0.5	0.2	0	1.0	4.2	0.4	0.5	1.4	0.6	9.0
Wt./net day	17.8	32.0	0	73.8	396.8	23.2	18.2	41.2	55.4	443.0

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[a] Number of net days on a given date and station the same for each species.

differences in seasonal and size distribution of channel catfish.

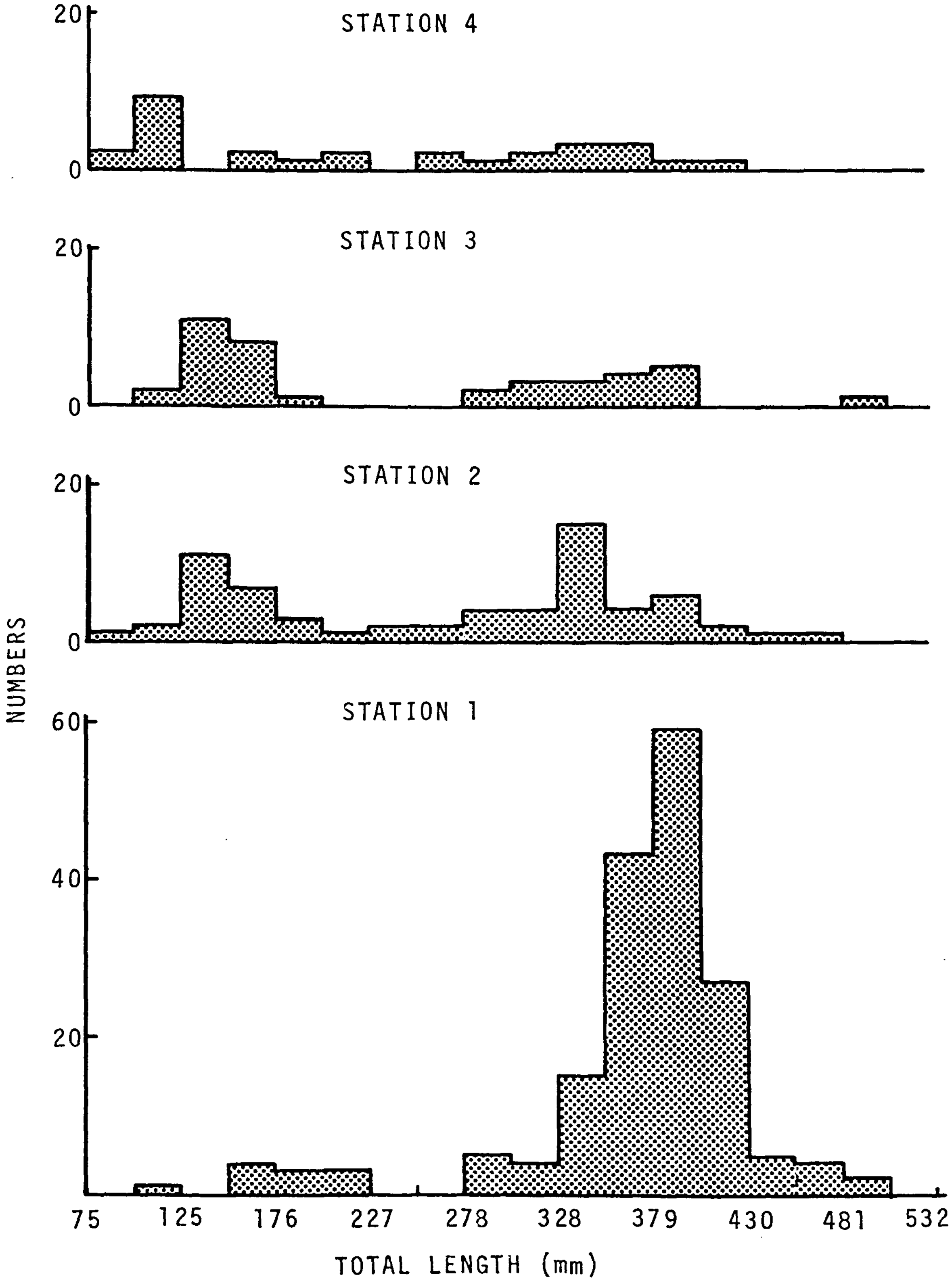
Average number of channel catfish per net day at stations 1 and 2 during 1970 were 3.2 and 4.8, respectively, averaging 4.0 for the unchannelized section. Averages at stations 3 and 4 were 12.4 and 4.5, respectively for a combined average of 8.4. Averages for channelized stations were affected by a very large catch at station 3 in October and relatively large catches at station 4 during late July and at both stations during early August (Table 11). Number per net day at station 1 was relatively high June 15 - 30 but low the rest of the time, while catches at station 2 were largest in October. Average weight per net day for the entire season revealed just the opposite relationship with averages of 1345, 703, 534, and 513 g per net day at stations 1, 2, 3, and 4, respectively. This obvious difference between stations in size composition of the catch was seasonal in nature and was most noticeable in catches at stations 1 and 2 during June 15 - 30 and at stations 2, 3, and 4 during August and October (Table 11).

Large hoopnet catches of channel catfish in Iowa rivers during spawning season have been reported as a consistent phenomenon (Harrison, 1952). During 1970 most channel catfish in spawning condition were collected from June 15 to 30; however, relatively large hoopnet catches of channel catfish greater than 254 mm during late spring, including spawning season, were made only at station 1 (Fig. 11). During late summer, catches of channel catfish of all sizes, especially from 75 to 227 mm, were much greater at stations 2, 3, and 4 (Fig. 12). Also noticeable during this period was the absence of channel catfish over 278 mm from the catch at station 1, while at the other stations they were collected in numbers similar to the earlier period. This same relationship was also evident in Iowa State Conservation Commission unpublished data from intensive hoopnetting during 1964 with baited hoopnets in the same locations of Little Sioux River.

Total hoopnet catches of channel catfish were undoubtedly minimal indications of abundance because hoopnets were unbaited. However, because they were unbaited catches may have been a better indicator of conditions in each section of the river. When unbaited, success of hoopnets would depend more upon natural movement of fish instead attraction to the net by bait. Movement of fish depends upon several factors including the search for food and shelter, spawning activity, changes in weather and water levels, and water conditions such as temperature (Lagler, 1968).

Increased catches of spawning size channel catfish during the spawning period were observed only at station 1 (Fig. 11) while catches of this size channel catfish at other stations remained rather small and uniform throughout the year (Fig. 11,

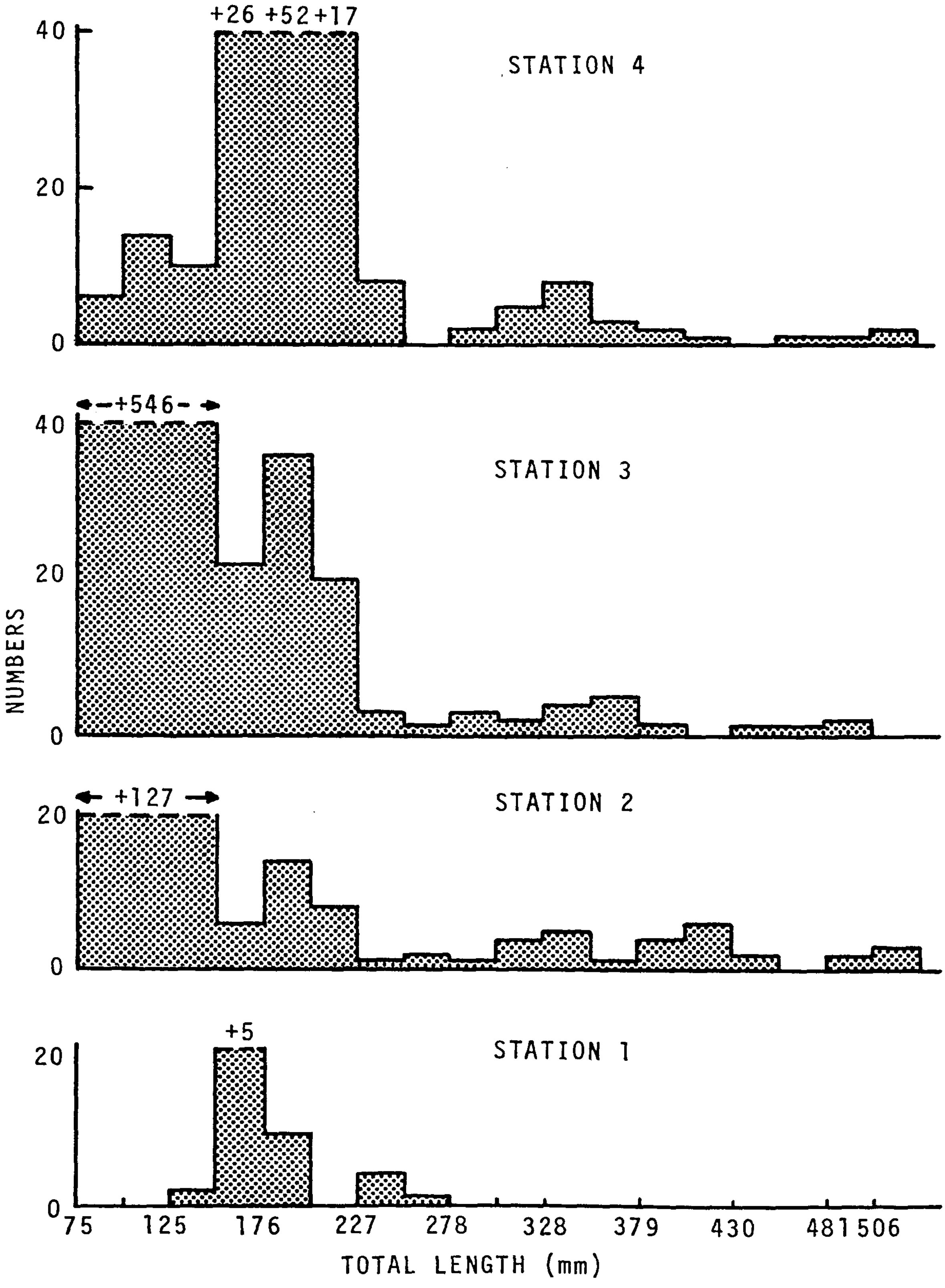
Fig. 11. Length-frequency (25.4-mm size groups) of channel catfish from Little Sioux River, Iowa collected in hoopnets at the four stations from May 2 to July 10, 1970


STATION 4
20
0
STATION 3
20
0
STATION 2
20
0
NUMBERS
STATION 1
60
40
20
75
125
176
227
278
328
379
430
481
532
TOTAL LENGTH (mm)

12). Differences in maximum catch and seasonal variation may have been an indication of spawning activity and suitability of spawning habitat in each station and was possibly an indication of the relative abundance of spawning size channel catfish at each station. If spawning activity and abundance of spawning size channel catfish were similar in each station during this late spring period, one would expect similar catches if they were equally vulnerable to hoopnets in each station. Differences in vulnerability would not be expected during a period of peak activity. The absence of larger channel catfish from station 1 catches during late summer but their presence at other stations during this time (Fig. 12), when catfish movement was at a minimum, may also have reflected the more suitable habitat areas provided by brushpiles and their pools, requiring less movements and more shelter. Several of these larger fish were collected and observed while electro-fishing near brushpiles in the unchannelized section.

Extremely large catches of channel catfish under 227 mm (9 inches) in the lower stations during late summer periods and October (Table 11) when water levels had declined, added further evidence of greater movement required in the channelized area. Also, magnitude of the catches suggested a possible downstream movement of channel catfish 75 to 227 mm long, possibly from the unchannelized area (discussed later).

Fig. 12. Length-frequency (25.4-mm size groups) of channel catfish from Little Sioux River, Iowa collected in hoopnets at the four stations from July 21 to Oct. 6, 1970


+26 +52 +17
40
20
0
STATION 4
+546
40
20
0
STATION 3
NUMBERS
+127
20
0
STATION 2
+5
20
0
STATION 1
75
125
176
227
278
328
379
430
481
506
TOTAL LENGTH (mm)

Not as much can be said about relative abundance of stonecat, black bullhead and carp from hoopnet catches because they were taken in smaller numbers. Stonecat catches at each station during 1970 also showed seasonal variations, catches in unchannelized stations being greater in late spring and catches in channelized stations greater October 1-6 (Table 11). However, catches at all four stations during the late spring period, June 1-14, were generally similar. Although greater in the channelized stations, catches during October 1-6 may not be comparable because of the small numbers of hoopnet days when location of hoopnets within a station could greatly affect the relative catch. Averaged over the entire 1970 sampling period, number per net day was 1.8, 1.2, 1.4 and 1.5 at stations 1, 2, 3 and 4, respectively, averaging 1.5 per net day in both unchannelized and channelized areas. Average weight per net day followed the same relationship between stations and was 106 and 107 g per net day at unchannelized and channelized stations, respectively. From hoopnet catches it appeared that stonecat were approximately equally distributed in number and weight in both sections of the sampling area.

Average hoopnet catches of black bullhead for 1970 were 1.7, 0.9, 0.3 and 0.7 fish per net day at stations 1, 2, 3 and 4, respectively with weight per net day following the same relationship. Catches were largest during June 1-14 at stations 1, 2 and 4, a considerably larger catch occurring at station 1. Catches at station 3 were consistently small. Hoopnet catches indicated the preference of black bullhead for slower moving water around brushpiles at unchannelized stations and station 4 where the channel had widened and current velocity was affected by the lowhead dam downstream. At station 3 the channel was narrow with a relatively high, uniform current velocity. However, the much larger catch at station 1 during June 1-14 also suggested a greater abundance of black bullhead in this area. Noticeably larger numbers at station 4 during August 14-29, 1969 may have been caused by black bullheads entering the river from the diversion channel, which was functional at the time of sampling. During 1970 sampling, water from the diversion channel was not connected to the river channel.

Carp were not collected in hoopnets in large numbers during any time period, the highest catch being 1.3 fish and 994 g per net day at station 2 during July 1-15, 1970 (Table 11). No seasonal patterns were evident from the catches and 1970 average catches were approximately the same at each station. The larger catch at station 2 may have been an indication of relative abundance of carp at that station, also indicated by electric shocking results. Hoopnets were not effective in collecting carp, and sizes of catches were not considered truly indicative of the numerical abundance of carp at any station. However, average weight per net day of carp compared to other species better indicated their relative importance, being second to channel catfish during 1970 hoopnet catches.

Although carp and carpsucker comprised a small percentage of the catch by other methods, electric shocking catches consisted primarily of these species (Table 10). Average catch rate (numbers per hour shocking) of carp during 1969 and 1970 varied from a low of 3 fish per hour at station 1 to a high of 14 fish per hour at station 2 (Table 12). Average catch rate at station 1 included two shocking periods in 1969 when water levels were unsuitable for shocking and only one carp was collected; however, catch rates on 1970 sampling dates were also consistently lower than at the other stations. Average catch rates at stations 2 and 3 were relatively high and similar when considering only 1970 collections, while station 4 averages were lower. Besides the low catch rate at station 1, also noticeable was the larger size of carp collected at station 2. Average weight of carp at station 2 was approximately twice that of carp at any other station. Most noticeable about the average catch rates of carpsucker during 1970 were the much higher rate at station 1 (Table 12). Although catch rates were high at station 1, carpsucker collected at station 1 were smaller in size than those collected at other stations, averaging over one-half the weight of those collected

Table 12. Number, weight, and average number per shocking hour of carp and carpsucker (river carpsucker and quillback) collected with electric shocking on 1969 and 1970 sampling dates

		Carp			Carpsucker		
	Hours shocked	No.	Total wt. (g)	Average no. per hour	No.	Total wt. (g)	Average no. per hour
Station 1							
Oct. 4, 1969	0.5	-	-	-	5	416	10
Nov. 23, 1969	1.5	1	102	1	-	-	-
July 17, 1970	2.5	14	7,851	6	66	9,691	26
July 22, 1970	2.1	5	3,633	2	17	2,137	8
Aug. 18, 1970	1.0	3	3,349	3	21	1,122	21
Aug. 20, 1970	1.5	8	4,086	5	27	4,405	18
Total	9.1	31	19,021	3	136	17,771	15
Station 2							
July 16, 1970	1.5	22	20,853	15	4	495	3
July 28, 1970	2.3	33	54,969	14	13	2,528	6
Total	3.8	55	75,822	14	17	3,023	4
Station 3							
Nov. 22, 1969	1.0	1	124	1	-	-	-
July 16, 1970	0.8	7	3,218	9	2	1,232	2
July 29, 1970	1.2	25	14,823	21	7	1,728	6
Total	3.0	33	18,165	11	9	2,960	3
Station 4							
July 17, 1970	2.0	13	5,968	6	2	589	1
July 21, 1970	2.3	21	16,571	9	7	1,797	3
Aug. 19, 1970	2.8	21	17,293	8	31	10,342	11
Total	7.1	55	39,832	8	40	12,728	6

at channelized stations. The smaller sizes indicated that habitat was more suitable in the unchannelized section for the complete life history of carpsucker, as few of these smaller fish were observed in the channelized section.

Because of several factors affecting the catch rate of fish by electric shocking in turbid, warmwater streams (Harrison, 1955b), the catch rates of carp and carpsucker probably did not give a true picture of their importance to the fish population at a station. Also, because of different conditions at each station, effectiveness of shocking these species would have been different, possibly resulting in rates of catch at each station not related to abundance of carp and carpsucker, but to the stream conditions. For example, carp may have been more abundant at station 1 than indicated because of difficulties in shocking deeper pools where carp were likely to be found. However, the greater numbers of large carp and small carpsucker at stations 1 and 2, respectively, were most likely a result of their relative abundance in these areas. Abundance of carp and carpsucker at station 3 was questionable because of the small amount of effort applied and difficulties in maneuvering in certain areas. Carp and carpsucker were limited to shallower areas at station 4. As a result shocking efficiency was probably much higher and the relatively low rates of catch indicative of their abundance at station 4.

Primacord samples consisted mainly of smaller catfish (under 254 mm) including many young-of-year and minnows, although carp and carpsucker contributed greatly to the weight of some samples (Table 13). Total standing crop estimates (Table 13) for each sample in 1970 ranged from 0 kg/ha at station 4 on October 4 to 1155.5 kg/ha at station 2 on August 4. Highest average total standing crop estimates for the dates sampled were at stations 1 and 2, with 265 and 440 kg/ha, respectively. However, estimates within a station and between stations varied considerably depending upon location of sampling and date. Comparing only those dates August 12-13 and October 3-4, 1970 on which several samples were taken at all four stations, average total standing crop estimates in August were similar at stations 1, 3, and 4 but lower at station 2. In October average total standing crop estimates were highest at station 1 and were progressively lower by a considerable amount at the downstream stations, with no fish being collected at station 4.

Because channel catfish were so numerous in samples, their standing crops were also estimated and revealed a different relationship between stations than when all fishes were considered. In August 12-13 samples, average standing crop estimates of channel catfish were similar at stations 2, 3, and 4, but much lower at station 1. On October 3-4, average estimates were highest at stations 2 and 3 with station 1 some-

Table 13. Number and weight (g) of fishes collected at stations 1-4, Little Sioux River, Iowa in each 15.2-m (50-foot) Primacord sample during 1970 and standing crop estimates (kg/ha) of channel catfish and all species combined

	Channel catfish-under 254 mm	Channel catfish-over 254 mm	Carp	Carpsucker	Stonecat	Black bullhead	White sucker	Bluegill	Green sunfish
<u>Station 1</u>									
Aug. 4, 1970									
Sample 1 (No.)	6								
2 (No.)	17			3	2				
Sample 1 (Wt.)	11								
2 (Wt.)	29			464	1				
Aug. 13, 1970									
Sample 1 (No.)	12		1						
2 (No.)	31				1				
3 (No.)	28		2						
4 (No.)	29			5				1	
Sample 1 (Wt.)	22		329						
2 (Wt.)	120				13				
3 (Wt.)	71		1787						
4 (Wt.)	117			815				1	
Oct. 3, 1970									
Sample 1 (No.)	27		2	5			2	1	
2 (No.)	71			2					
Sample 1 (Wt.)	91		949	1001			104	1	
2 (Wt.)	348			416					
<u>Station 2</u>									
Aug. 4, 1970									
Sample 1 (No.)	13		1						
2 (No.)	15		3						
3 (No.)	22								
Sample 1 (Wt.)	203		653						
2 (Wt.)	177		6271						
3 (Wt.)	65								
Aug. 13, 1970									
Sample 1 (No.)	17			1					
2 (No.)	18				3		1		
3 (No.)	4	1							
4 (No.)	27								
Sample 1 (Wt.)	58			9					
2 (Wt.)	258				78		331		
3 (Wt.)	341	510							
4 (Wt.)	115								
Oct. 4, 1970									
Sample 1 (No.)	123			1	1	1			
2 (No.)	85								
3 (No.)	71					1			

Red shiner	Bigmouth shiner	Sand shiner	Brassy minnow	Bluntnose minnow	Fathead minnow	Creek chub	Flathead chub	Standing crop estimate-all fish kg/ha	Standing crop estimate-ch. catfish kg/ha
	5								
								2.0	2.0
	1							115.9	5.2
1									
1									
	1								
1	2		1						
1								63.1	3.9
1								24.0	21.5
	3							333.5	12.7
1	1		1					225.8	20.9
4					1				
10	1	19					1		
3					1			385.3	16.2
8	1	30					4	144.6	62.4
1									
4								154.1	36.4
								1155.5	31.7
								11.6	11.6
2									
3		5							
	1		1	1					
7								13.3	10.4
4		2						120.6	46.2
								152.5	152.5
	2		1	2				21.5	20.6
7		35	1						
2		14	1						
1		8							

Table 13 (Continued)

	Channel catfish-under 254 mm	Channel catfish-over 254 mm	Carp	Carpsucker	Stonecat	Black bullhead	White sucker	Bluegill	Green sunfish
Sample 1 (Wt.)	847			9	5	2			
2 (Wt.)	611								
3 (Wt.)	522					8			
Station 3									
Aug. 12-13, 1970									
Sample 1 (No.)	30				1				1
2 (No.)	35	1	1		5				
3 (No.)	73		2						
4 (No.)	36								
Sample 1 (Wt.)	128				19				9
2 (Wt.)	65	455	624		146				
3 (Wt.)	383		1248						
4 (Wt.)	243								
Oct. 4, 1970									
Sample 1 (No.)	67							1	2
2 (No.)	35				1				
3 (No.)	50								
Sample 1 (Wt.)	481							33	2
2 (Wt.)	338				42				
3 (Wt.)	330								
Station 4									
Aug. 8, 1970									
Sample 1 (No.)	46								
2 (No.)	28								
3 (No.)	16								
4 (No.)	8								
Sample 1 (Wt.)	172								
2 (Wt.)	77								
3 (Wt.)	41								
4 (Wt.)	20								
Aug. 12, 1970									
Sample 1 (No.)	3								
2 (No.)	42				1				
3 (No.)	130		2	1	1				
4 (No.)	128								
Sample 1 (Wt.)	17								
2 (Wt.)	229				17				
3 (Wt.)	533		1372	596	1				
4 (Wt.)	743								
Oct. 4, 1970									
Sample 1-nothing									
Sample 2-nothing									

Red shiner	Bigmouth shiner	Sand shiner	Brassy minnow	Bluntnose minnow	Fathead minnow	Creek chub	Flathead chub	Standing crop estimate-all fish kg/ha	Standing crop estimate-ch. catfish kg/ha
7		31	2					167.8	151.8
2		5	1					112.3	109.5
1		9						98.0	93.5
					1				
1		3							
	2			1					
	2		1						
					1			28.2	23.0
2		1						229.9	91.4
	2			2				293.0	68.7
	2		1					44.1	43.6
1		14			3				
1		2							
5		7			1				
1		13			7			96.2	86.2
1		2						68.7	60.6
6		6			2			61.6	59.1
		1			1				
3		1							
		2			1			33.4	30.8
9		4						16.1	13.8
								7.4	7.4
								3.6	3.6
		1							
		2							
								3.0	3.0
		1						44.2	41.1
								448.3	95.5
		2						133.5	133.1
								0	0
								0	0

what lower but consisting of only two relatively variable samples.

Different relationships between average total standing crops and channel catfish only were reflective of the relative abundance of smaller channel catfish at each station. On all sampling dates, smaller channel catfish comprised a very small percentage of sample weights at station 1. This was also true in August samples at station 2; however, sample weights at station 2 in October and at stations 3 and 4 on all dates consisted of a much greater percentage of smaller channel catfish. A large percentage of sample weights at station 1 consisted of carp and carpsucker.

A change in the relationship of average standing crop estimates of channel catfish at the four stations from August 12-13 to October 3-4, suggested movement of the smaller channel catfish between stations. August 12-13 samples at stations 3 and 4 collected considerably larger average numbers of smaller channel catfish, predominantly young-of-year, than samples at stations 1 and 2, especially two samples at station 4. On October 3-4, however, smaller catfish were not collected in station 4 samples although they appeared in relatively large numbers in samples at upstream stations.

Greater apparent abundance of smaller channel catfish in the channelized section observed in hoopnet catches, was also observed in Primacord samples. As with hoopnet catches, standing crop estimates of channel catfish also indicated that movement of smaller channel catfish in the channelized section was seasonal, apparently caused by decreasing water levels. On August 12-13, when water levels were relatively low but higher than October 3-4, larger numbers were collected at both stations in the channelized section. On October 3-4, however, when water levels were lowest, smaller catfish were distributed differently in that none were collected at station 4 but numbers increased at upstream stations. Low water levels in the lower channelized area apparently forced the smaller catfish upstream or possibly downstream to deeper water. According to Welker (1967a), mean water depth in the pool area above the lowhead dam was generally 0.6 to 0.9 m deeper throughout the summer than other parts of the channelized section and extended upstream approximately 1.6 km (1 mile). Welker reported dramatic increases in hoopnet catches of smaller catfish in the pool area during September, 1964 and catches remained higher than in either unchannelized or channeled sections through October. Greater catches obviously resulted from downstream movement as fish could not move upstream over the dam.

Of 1,930 fish fin-clipped during 1969-70, 55 were subsequently recaptured of which 5 fish had moved upstream from the station at which they were marked. Furthest distances moved were by two channel catfish from station 2 to station 1 and one channel catfish from station 4 to station 3. All three catfish were recaptured during spawning season in spawning condition. One carp and one stonecat had moved from station 3 to station 2. Little can be said of movement patterns from such a small number of recaptures, but it does indicate that some channel catfish move upstream rather long distances to spawn and some fish move from one section to the other. Welker (1967b) reported a general downstream movement of tagged channel catfish recaptured in both sections of the Little Sioux River. Mean distance traveled in a downstream direction was 41.0 km (25.6 miles). In view of this and trends in hoopnet and Primacord catches, it appeared that channel catfish, especially smaller ones and young-of-year, moved into the channelized section from upstream. As physical conditions in this section changed, the fish redistributed accordingly.

Age and growth of channel catfish

Average calculated growth rates were generally similar for channel catfish from each station (Table 14). Any differences could be attributed to small sample size. Average annual growth increment was largest during the third year of life in both sections.

Welker (1967a) reported similar growth rates of channel catfish collected from each section of the Little Sioux River in 1964; however, largest annual increment occurred during the second year in both sections. Harrison (1957) also observed

Table 14. Average calculated lengths (mm) at each annulus from pectoral spine measurements of channel catfish taken from Little Sioux River, 1970

Age group	No.	T. l. (mm) at capture	Ave. t.l. (mm) at annulus 1	2	3	4	5	6
Unchannelized - 1970								
I	0							
II	2	203	53	180				
III	1	320	64	157	297			
IV	0							
V	24	391	66	135	251	325	381	
VI	5	437	64	127	274	358	396	429
Ave. calculated length			66	137	257	330	384	429
Ave. annual increment			66	71	122	76	53	33
Channelized - 1970								
I	1	130	84					
II	0							
III	2	328	66	142	310			
IV	1	358	61	160	323	348		
V	3	394	69	147	249	295	381	
VI	1	521	64	119	272	366	483	511
IX	1	531	84	188	272	361	394	439
Ave. calculated length			71	150	279	328	404	475
Ave. annual increment			71	81	130	58	81	36

larger growth during the second year of life in channel catfish collected 1954 to 1956 from the Little Sioux near Linn Grove, Iowa. Growth rates of channel catfish in the Little Sioux River were relatively faster than channel catfish from the Chariton River, Iowa (Mayhew, 1969) and the Des Moines River, Iowa (Muncy, 1957).

Length-weight relationships were calculated for channel catfish from each section by the least squares method. Samples of 95 and 103 fish were selected from the unchannelized and channelized sections, respectively, by randomly selecting five fish from each 13-mm (0.5-inch) size group collected in hoop-nets. If a size group did not contain five fish, all fish in the size group were included in the sample. Equations best expressing the length-weight relationships in logarithmic form were:

$$\text{Unchannelized:} \quad \text{Log } W = -5.3786 + 3.1394 \text{ Log } L \quad (r = 0.998)$$

$$\text{Channelized:} \quad \text{Log } W = -5.1846 + 3.0631 \text{ Log } L \quad (r = 0.998)$$

where W = weight (g) and L = total length (mm). Regression coefficients (3.1394 and 3.0631) were significantly greater than 3.0 at 0.01 level of probability in both sections (T = 6.45, 93 d.f. and 3.05, 101 d.f., respectively), indicating weight increased at rates greater than a cube function of the length. Regression coefficients were significantly different from each other at 0.01 level of probability; however, tests were affected by uncommon variances of the two groups and a greater percentage of fish from the unchannelized section in larger size groups. Although the regression coefficient was greater in the unchannelized section, biological significance of this difference may be questionable.

DISCUSSION

Results of investigation revealed certain differences in bottom fauna and fish fauna between the two sections of the river. Such differences were not apparent at all times; however, under certain conditions they became more evident. The most obvious factor explaining differences observed from sampling was the lack of suitable habitat areas, associated with brushpiles and pools, within the channelized section.

The channel catfish population was an excellent indicator of conditions in the channelized section. Lack of suitable habitat and cover did not appear to limit numbers of smaller channel catfish in the channelized section under normal conditions. However, under changing conditions such as low water levels and temperature, their movements into more favorable conditions were observed. The channelized section did not support large numbers of larger channel catfish and their numbers remained fairly low throughout the year. Apparently conditions in the channelized section become limiting to the channel catfish as they reach a certain size. The abundance of smaller channel catfish in the channelized section was attributed to possible downstream movement.

Uniformity of the channelized channel was also revealed by the drift and attached organisms. Greater numbers of drifting and attached organisms observed in the channelized section probably resulted from lack of attachment areas. The production of these organisms was limited mainly to areas of riprap however. The usefulness of the macroinvertebrates to fish as a source of food would probably be limited in the channelized section as fish generally do not feed in the faster moving water of the mainstream. Without pool areas in which food organisms are produced and made more available, fish in the channelized section probably depended heavily on riprap areas. Greater numbers of larger channel catfish and carp collected in the unchannelized sections reflected the more suitable habitat and availability of food in those areas.

High turbidities have always been a feature of the Little Sioux River affecting biological production in both areas. Higher turbidities were recorded in the channelized section but its effects on the bottom fauna or fishes were not directly measured. Conditions directly and indirectly related to higher turbidity, however, were evident in the channelized section. Removal of stream bank cover was an important factor contributing to such conditions as higher water temperatures and higher suspended sediment loads from channel erosion. Higher maximum and mean daily water temperatures could approach upper lethal levels of such species as walleye. Stream bank cover may also have been important biologically as well. Surrounding vegetation would contribute large amounts of organic matter to the unchannelized section. In turbid waters, primary production by phytoplankton would be adversely affected by poor light penetration. Bottom fauna and certain fishes would depend a great deal upon this organic matter for production. Channel catfish have been reported to feed heavily in the spring on elm seeds falling into Des Moines River (Bailey and Harrison, 1948).

Sampling results and observations indicated that distribution and presence of fishes in the channelized section depended largely upon movement into or through the section from other areas. Importance of the Missouri River as a major source of fish found in the lower portion of the Little Sioux River prior to construction of the lowhead dam for channel stabilization purposes, was evident from the disappearance of several species of fish (flathead catfish, sauger, etc.) previously found above the dam. Local residents also reported a decline in angling success for larger channel catfish which were previously caught frequently in the channelized section. A recent sport fishing article described excellent fishing for channel catfish in upstream unchannelized areas (Bradshaw, 1971). The major concentration of sport fishing in the channelized area without definable pool areas is limited to below the lowhead dam near Little Sioux, Iowa where fish moving upstream are blocked.

Studies by Bayless and Smith (1967) and reports by Wharton (1970) have shown drastic reductions in standing crops of fishes following stream channelization. In the present study, impact of the loss of species moving upstream from the larger Missouri River prior to this study could not be estimated numerically. Because of favorable habitat immediately upstream and the possible movements downstream into the channelized area, dramatic losses reported by studies of other rivers were not evident in the Little Sioux River. Results seemed to clearly indicate, however, that conditions in the channelized section were not as favorable for stable populations of larger game fishes.

LITERATURE CITED

Allen, K. R.
1959 The distribution of stream bottom faunas. Proc. New Zealand Ecol. Soc. 6:5-8.

American Fisheries Society
1970 A list of common and scientific names of fishes from the United States and Canada. 3rd ed. American Fisheries Society Spec. Publ. No. 6. 150 p.

Bailey, R. M. and H. M. Harrison
1948 Food habits of the southern channel catfish (Ictalurus lacustris punctatus) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 75:110-138.

Bayless, Jack and W. B. Smith
1967 The effects of channelization upon the fish populations of lotic waters in eastern North Carolina. Proc. Ann. Conf. Southeastern Assoc. Game and Fish Comm. 18:230-238.

Berner, L. M.
1951 Limnology of the lower Missouri River. Ecology 32:1-12.

Borror, D. J. and D. M. Delong
1964 An introduction to the study of insects. Rev. ed. Holt, Rinehart, and Winston, New York, N.Y. 819 p.

Bovbjerg, R. V., N. L. Pearsall and M. L. Brackin
1970 A preliminary faunal study of the Upper Little Sioux River. Proc. Iowa Acad. Sci. 77:177-184.

Bradshaw, H.
1971 Little Sioux is big on cats. Outdoor Life 148(1): 64-66, 102-106.

Carlander, K. D. and L. L. Smith, Jr.
1944 Some uses of nomographs in fish growth studies. Copeia 1944:157-162.

Chapman, Donald W.
1964 The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pymatuning Symposia in Ecology: Organism-Substrate Relationships in Streams. Pymatuning Lab. of Ecology, Univ. of Pittsburgh Spec. Publ. No. 4:116-130.

Chutter, F. M.
1969 The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologia 34:57-76.

Coffman, W. P.
1971 Artificial substrates and the problem of lotic sampling. Unpublished mimeographed paper presented at the 19th Ann. Meeting Midwest Bentho. Soc., Univ. Notre Dame, South Bend, Ind. Pymatuning Lab. of Ecology, Univ. of Pittsburgh, Pittsburgh, Penn.

Cummins, K. W.
1962 An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Amer. Midl. Nat. 67:477-504.

Eggleton, Frank E.
1939 Fresh-water communities. Amer. Midl. Nat. 21:56-74.

Elliot, J. M.
1967 Invertebrate drift in a Dartmoor stream. Arch. Hydrobiol. 63:202-237.

Forbes, Stephen A. and R. E. Richardson
1919 Some recent changes in Illinois River biology. State Ill. Nat. Hist. Surv. 13:139-156.

Gray, J. R. A. and J. M. Edington
1969 Effect of woodland clearance on stream temperature. J. Fish. Res. Bd. Canada 26:399-403.

Harrison, H. M.
1951 Preliminary survey of several western Iowa streams. Iowa Conserv. Comm. Biol. Rept. 3(1):13.

Harrison, H. M.
1952 Channel catfish studies in the upper Des Moines River. Iowa Conserv. Comm. Biol. Rept. 4(2):45-49.

Harrison, H. M.
1955a Further studies on the catfish in the Humboldt area of the Des Moines River. Iowa Conserv. Comm. Biol. Rept. 6(4):24-32.

Harrison, H. M.
1955b Results and discussion of the electrical shocking method of conducting stream surveys in Iowa streams. Iowa Conserv. Comm. Biol. Rept. 7(4):16-20.

Harrison, H. M.
1957 Growth of the channel catfish, Ictalurus punctatus (Rafinesque), in some Iowa waters. Proc. Iowa Acad. Sci. 64:657-666.

Hester, F. E. and J. S. Dendy
1962 A multiple-plate sampler for aquatic macroinvertebrates. Trans. Amer. Fish. Soc. 91:420-421.

Iowa Geological Survey
1909 Annual report with accompanying papers. Geology of Harrison and Monona Counties. Iowa Geological Survey 20:271-486.

Iowa Geological Survey
1955 Quality of surface waters of Iowa 1886-1954. Iowa Geological Survey Water Supply Bull. No. 5. 351 p.

Iowa Natural Resources Council
1959 An inventory of water resources and water problems, western Iowa river basins. Iowa Nat. Resources Council Bull. No. 8. 86 p.

Iowa State Drainage Convention
1904 Iowa State Drainage Convention Proceedings, Ames, Iowa 1904:40-42.

Iowa State Planning Board
1936 Water use and conservation in Iowa, Northwestern Iowa River Basins. Iowa State Planning Board VI. 95 p.

Irizarry, R.
1969 The effects of stream alteration in Idaho. Job Completion Report. Porj. No. F-55-R-2. Idaho Fish. and Game Dept. 26 p.

Johnson, H. P., K. E. Saxton, and D. W. Deboer
1969 The effect of man on water yield, peak runoff and sedimentation. Proc. Iowa Acad. Sci. 76:153-166.

Lagler, K. F.
1968 Capture, sampling, and examination of fishes, p. 7-45. In W. E. Ricker (ed.) Methods for assessment of fish production in fresh waters. Blackwell Scientific Publ., Oxford, England, IBP Handbook No. 3.

Macan, T. T.
1963 Freshwater ecology. John Wiley and Sons, New York, N.Y. 338 p.

Mackenthun, K. M. and W. M. Ingram
1967 Biological associate problems in freshwater environments. Their identification, investigation and control. U.S. Dept. Interior, Fed. Water Poll. Control. Admin., U.S. Govt. Printing Office, Washington, D.C. 287 p.

Mayhew, J. K.
1969 Some physical, chemical and biological characteristics of the Chariton River prior to impoundment of Rathbun Reservoir. Biol. Sec., Iowa State Conserv. Comm. 129 p.

Meek, S. E.
1894 Notes on the fishes of western Iowa and eastern Nebraska. Bull. U.S. Fish. Comm. 14:133-138.

Moon, H. P.
1939 Aspects of the ecology of aquatic insects. Trans. Brit. Ent. Soc. 6:39-49.

Morris, Larry A., R. N. Langemeier, T. R. Russell and A. Witt, Jr.
1968 Effects of main stem impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Amer. Fish. Soc. 97:380-388.

Muncy, R. J.
1957 Distribution and movements of channel and flathead catfish in Des Moines River, Boone County, Iowa. Unpublished Ph.D. thesis. Library Iowa State University, Ames, Iowa. 118 p.

Nilsen, H. C. and R. W. Larimore
1971 Establishment of invertebrate communities on log substrates in the Kaskaskia River. Mimeographed. Abst. Rept. Ill. Nat. Hist. Surv. 2 p.

Pennak, R. W.
1953 Fresh-water invertebrates of the United States. Ronald Press, New York, N.Y. 769 p.

Prouse, C. G. and J. M. E. Crowe
1971 Artificial substrate samplers -- can they be used for quantitative assessment and diversity of benthos. Unpublished mimeographed paper presented at 34th Annual Meeting Amer. Soc. Limnol. and Oceanog., Univ. Manitoba, Winnipeg, Manitoba, Canada. Manitoba Dept. Mines and Nat. Res., Winnipeg, Manitoba, Canada.

Sigafoos, R.
1964 Botanical evidence of floods and flood-plain depositions. U.S. Geol. Surv. Prof. Paper 485-A. Original unseen; cited in Wharton, 1970. The Southern River Swamp - A multiple-use environment. Bureau of Business and Economic Research, School of Business Admin., Ga. State Univ., Atlanta, Ga. 48 p.

Snedecor, G. W.
1946 Statistical methods applied to experiments in agriculture and biology 4th ed. Iowa State University Press, Ames, Iowa 485 p.

Sneed, K. E.
1951 A method for calculating the growth of channel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80:174-183.

Tanaka, H.
1960 On the daily change of drifting of benthic animals in stream, especially on the types of daily change observed in taxonomic groups of insects. Fisheries Agency, Tokyo, Bull. Freshwater Fish. Res. Lab. 9:13-24.

Thrienen, C. W.
1971 Stream channelization. Mimeographed report of the Ad Hoc Committee on Stream Channelization, North Central Division, Amer. Fish. Soc. 9 p.

U.S. Army Corps of Engineers
1967 Water resources development in Iowa. U.S. Army Engineer Division, North Central, Chicago, Ill. 59 p.

U.S. Dept. of Commerce, Weather Bureau
1951-54 Climatological data for Iowa. U.S. Dept. of Commerce, Weather Bureau [Publication] 62(13):268-280; 63(13):188-200; 64(13):202-215; 65(13):202-213.

U.S. Dept. of Commerce, Weather Bureau
1970 Climatological data for Iowa. U.S. Dept. of Commerce, Weather Bureau [Publication] 81(13):213-226.

U.S. Dept. of Interior, Geological Survey
1969 Water resources data for Iowa. Part I. Surface water records. Part II. Water quality records. U.S. Dept. of Interior, Geological Survey. 289 p.

Usinger, R. L.
1956 Aquatic insects of California. University of California Press, Berkeley, Calif. 508 p.

Waters, T. F.
1962 Diurnal periodocity in the drift of stream invertebrates. Ecology 43:316-320.

Welker, B. D.
1967a Comparison of channel catfish populations in channeled and unchanneled sections of the Little Sioux River, Iowa. Proc. Iowa Acad. Sci. 74:99-104.

Welker, B. D.
1967b Movements of marked channel catfish in the Little Sioux River, Iowa. Trans. Amer. Fish. Soc. 96: 351-353.

Wharton, Charles H.
1970 The Southern River Swamp - A multiple-use environment. Bureau of Business and Economic Research, School of Business Admin., Ga. State Univ., Atlanta, Georgia. 48 p.

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