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# Environmental Impacts in the Vicinity of Spencer Hydropower Dam During Sluicing Activities in the Niobrara River, Nebraska

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# ENVIRONMENTAL IMPACTS IN THE VICINITY OF SPENCER HYDROPOWER DAM DURING SLUICING ACTIVITIES IN THE NIOBRARA RIVER, NEBRASKA

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*ABSTRACT*

Nebraska Public Power District (NPPD) has monitored water quality since 1989 and fish populations since 1993 on the Niobrara River in Nebraska in the vicinity of Spencer Hydro during "flushing" or "sluicing" activities. These sluicing activities alter water quality in the river downstream, which can negatively impact fish populations. Higher numbers of fish were sampled in 1995 when compared to 1993 and 1994. Of the 6,187 fish and 22 total species sampled above and below the hydro, six species comprised approximately 93 percent of the total sample. The most common species sampled were sand shiner, *Notropis ludibundus* (35.4%), red shiner, *Cyprinella lutrensis* (22.9%), flathead chub, *Hybopsis gracilis* (14.4%), carpsucker spp., *Carpoides sp.* (10.9%), bigmouth shiner, *Hybopsis dorsalis* (5.1%), and channel catfish, *Ictalurus punctatus* (4.0%). Operational modifications instituted since 1989, such as opening the flood gates slower and dropping the pond at a slower rate, have reduced sluicing impacts and the hydro structure may not be limiting species diversity to the extent originally thought.

† † †

Nebraska Public Power District owns and operates the Spencer Hydropower Project on the Niobrara River, approximately 8 km south of Spencer, Nebraska, on the Holt and Boyd County line (Fig. 1). The Niobrara River, with headwaters in eastern Wyoming, flows approximately 800 km eastward across Nebraska, joins the Missouri River near Niobrara, Nebraska, and drains a watershed of approximately 28,000 $km^2$.

The hydro project structure (Fig. 2) was installed in 1927 and at that time consisted of: (1) a 1,200-acre reservoir; (2) a short concrete abutment on the north and south bank of the river; (3) a powerhouse containing two generators (2,000 kW and 1,300 kW); (4) a spillway with a combination gate bay; (5) four tainter gate bays; (6) five stop log bays; (7) a sluice gate; and (8) a 3,700-foot long, 18-foot high earth embankment. NPPD conducts sediment-flushing activities (sluicing) to remove accumulated sediment from the reservoir above the hydro in the spring and fall. Sluicing was historically conducted several times a year dating back to 1948 (Mares, 1991). During sluicing, two tainter gates and a sluice gate are typically opened for about a week to essentially drain the reservoir.

Between 1975 and 1989, periodic fish kills were observed below the hydro during sluicing. Fish were particularly vulnerable to sluicing during the summer, at low flows and high water temperatures. Previous investigators such as Hesse and Newcomb (1982) studied fish populations in the vicinity of the hydro and expressed concern about its impacts. In 1980 a variance was drawn up by the Nebraska Department of Environmental Control (NDEC) and the Nebraska Game and Parks Commission (NGPC) stating that NPPD avoid sluicing between April 15 and September 15 of each calendar year, except for emergencies, to minimize impact on the riverine fisheries during that time frame.

We were interested in evaluating water quality conditions and fish populations during sluicing in the vicinity of the hydro, particularly in the fall when conditions can be deleterious to riverine biota, to establish data regarding fishery populations and related impacts of sluicing activities. The objectives of this study were to determine: 1) water-quality conditions during sluicing activities; 2) species composition above and below the hydro to decide if the hydro was acting as a barrier to species diversity and/or migration it in the Niobrara River and; 3) fish diversity and abundance below the hydro before and during sluicing to observe impacts of the activity on Niobrara River fishes.

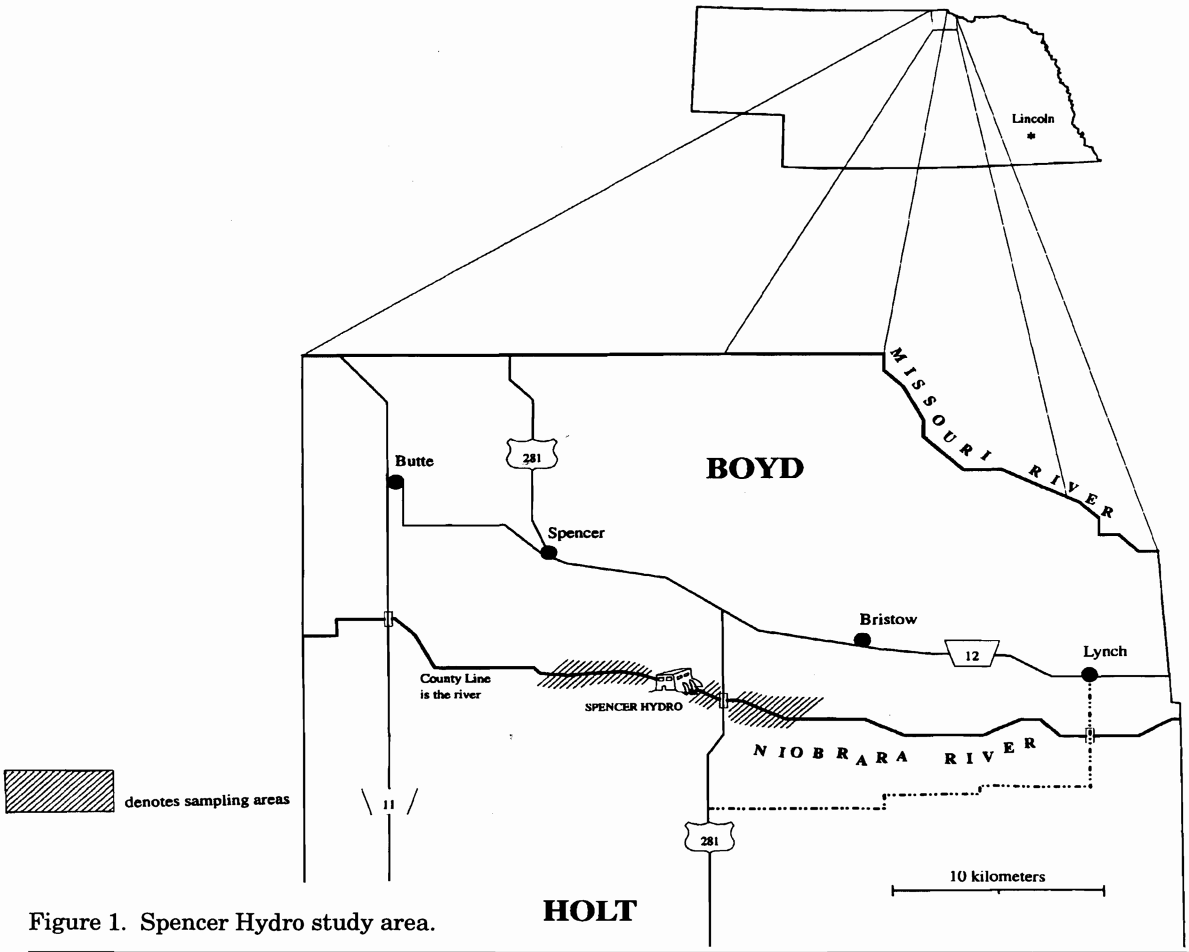


Figure 1. Spencer Hydro study area.

## METHODS

### Water quality

Water-quality parameters below the hydro during sluicing have been monitored since spring 1989. The four parameters monitored or determined to be important were temperature, conductivity, settleable solids, and turbidity (as measured by secchi disc) (Table 1). Temperature and conductivity were evaluated with a Yellow Springs Instruments (YSI) temperature/conductivity meter. In 1990–94 settleable solids were determined with use of a 1,000 ml graduated cylinder and in 1995 an imhoff cone (1000 ml) was used.

During fall sluicing activities, water-quality measurements were made before sluicing commenced and approximately at 2, 4, 6, 8 and 24 hours after the sluice gates were opened. Water-quality samples were taken from the south bank of the river just above the Highway 281 bridge approximately 0.6 km below the hydro facility. River discharge was calculated from staff gauges located in the hydro powerhouse forebays (see Table 2).

### Fish sampling

Fish sampling was conducted in the fall from 1993–95. Fish were sampled by seining and electrofishing before the gates were opened and 2–24 hours after the gates were opened. In 1993 fish were sampled a week after the gates were opened. All sampling was conducted within 5 km of the hydro in habitats conducive to an effective sampling effort.

The seine used was approximately 8 m wide (5 mm mesh size) and 1 m high and haul lengths were 15 m. Sampling occurred before the gates were opened (pre-sluice) and during the time that the gates were open during sluicing (post-sluice). A Smith-Root Model 15-C backpack shocker was used to shock 30.45 m sections of bank habitat. Two dip nets were used to collect fish. Sampling was done at selected locations (Fig. 1) below the dam within 5 km of the hydro dam along bank habitats and in some mid-channel habitats that contained shale outcrops or rocky cobble below the hydro. Initially, in 1993, approximately ten seine hauls and ten electroshock segments were sampled above and below the hydro. In 1994 and even more so in 1995 the effort was reduced to accommodate available staff at the time (sampling effort is shown in Tables 3 and 4). Habitat for seining and electroshocking was fairly accessible the first few km downstream, but the habitat for several km above the hydro in the pond was difficult to sample and most of the available sampling areas were 4–5 km above the dam. Habitat heterogeneity

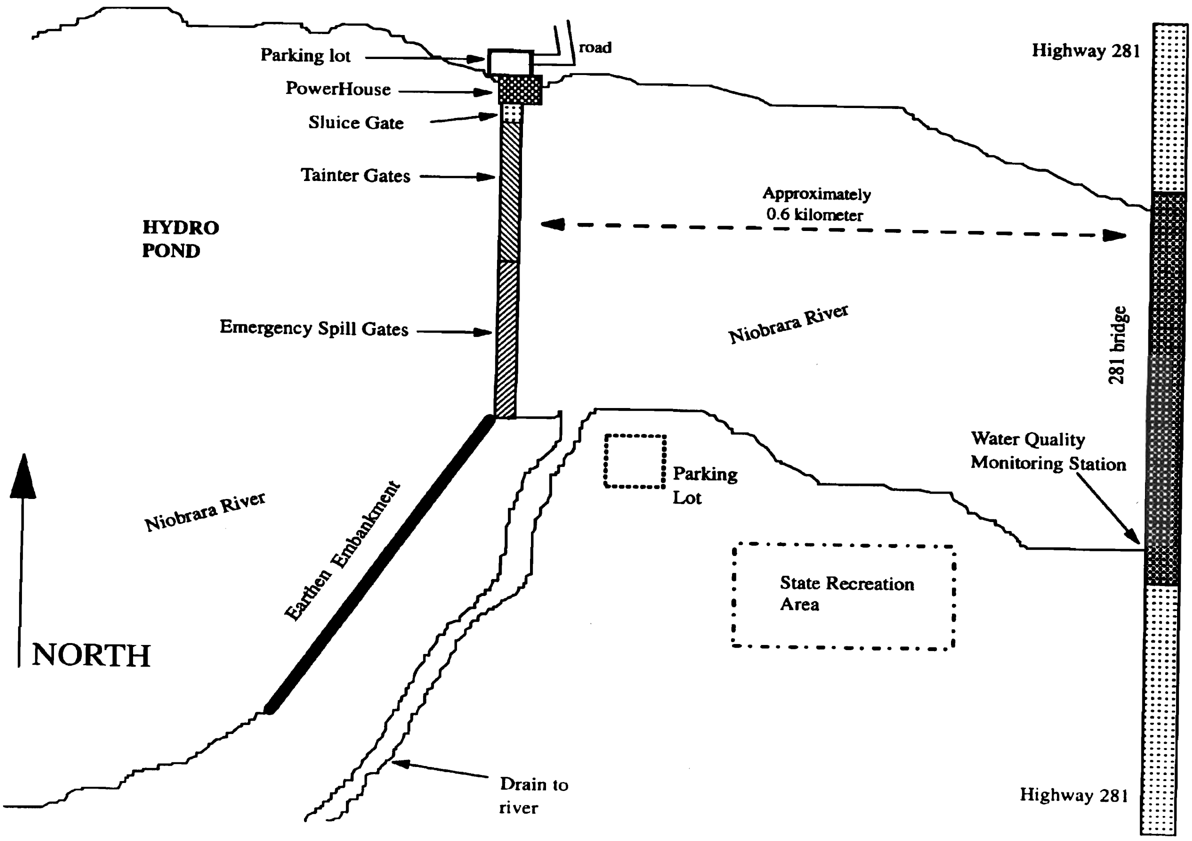


Figure 2. Location of Spencer Hydro structures and dam on Niobrara River, Nebraska.

was different when comparing above and below habitats. The area below the hydro was degraded, with shale outcrops that provided ample, shallow riffle areas, and the area above was deeper, with sand aggregates and other detrital accumulations.

All fish collected from both sampling gears were enumerated and identified to species. Data sets were analyzed statistically using one-way analysis of variance from before and after sluicing for seining and electroshocking for all three years.

## RESULTS

### Water quality

Daily water temperatures increased as much as 7.3°C but generally increased 3 to 4°C during sluicing (Table 1). Conductivity also increased slightly as the sluicing progressed. Settleable solids before sluicing were 10 mg/l or below but exceeded that level considerably after 8–24 hours. Secchi disc readings normally dropped to between 1 and 5 cm after 6 hr and remained that way until the majority of accumulated silt has been removed from the pond above. Generally, turbidity decreased 48–72 hr after the gates were opened, with primarily fine sand and silt being removed from the pond the first 24 hr.

### Fish species composition and abundance

Initially, in our study for analysis purposes, we separated fish sampled upstream and downstream from the hydro. Fall sampling resulted in 1,121 fish upstream and 5,066 fish downstream for a total of 6,187 fish and 22 species. Above the hydro (Table 3) the most common species were bigmouth shiner, *Hybopsis dorsalis* (27%), carpsucker spp., *Carpoides spp.* (20%), fathead minnow, *Pimephales promelas* (16%), red shiner, *Cyprinella lutrensis* (14%), and sand shiner, *Notropis ludibundus* (12%). Downstream of the hydro (Table 4), the species most observed were the sand shiner (42%), red shiner (29%), and flathead chub, *Hybopsis gracilis* (16%). Black bullhead (*Ictalurus melas*), black crappie (*Pomoxis nigromaculatus*), emerald shiner (*Notropis atherinoides*), sauger (*Stizostedion canadense*), and stonecat (*Noturus flavus*) were the only species not sampled above the hydro that were sampled below. From some incidental spring sampling in 1994 we were able to document the presence of river shiners, *Notropis blennius*, below the hydro, but it is not presented in our species list. When we combined upstream and downstream sampling within 5 km of the hydro, six species comprised approximately 92% of our catch. Sand shiner (36%), red shiner (26%), flathead chub (13%), carpsucker spp. (6%), bigmouth shiner (6%), and channel catfish (5%) were the most common species sampled.

Table 1. Summary of water quality parameters observed near Spencer Hydro from in the Niobrara River, Nebraska 1990–1995.

| | Monitoring Dates | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **10/3–5/90** | **9/30–10/1/91** | **9/15–16/92** | **9/27–29/93** | **9/22–23/94** | **9/20–21/95** |
| **Water Temperature (°C)** | | | | | | |
| Before | 11.2 | 15.8 | 22.0 | 10.9 | 9.6 | 12.2 |
| 2 hours | 13.0 | 15.7 | 22.0 | 11.9 | 9.5 | 11.6 |
| 4 hours | 16.1 | 16.8 | 23.0 | 15.2 | 10.6 | – |
| 6 hours | 18.5 | 19.6 | 24.0 | 16.0 | – | 11.1 |
| 8 hours | 18.5 | 20.1 | 24.0 | 16.0 | – | – |
| 24 hours | 13.7 | 14.2 | 18.0 | 11.2 | – | 8.6 |
| **Conductivity (μ ohms)** | | | | | | |
| Before | 180 | 202 | – | 185 | 249 | 184 |
| 2 hours | 197 | 217 | – | 190 | 254 | 177 |
| 4 hours | 222 | 230 | – | – | 255 | – |
| 6 hours | 261 | 257 | – | – | – | 182 |
| 8 hours | 261 | 274 | – | – | – | – |
| 24 hours | 233 | 210 | – | – | – | 184 |
| **Settleable Solids (mg/L)** | | | | | | |
| Before | 10.0 | 10.0 | 10.0 | <5.0 | <10.0 | <10 |
| 2 hours | 10.0 | 10.0 | 10.0 | <10.0 | <10.0 | <10 |
| 4 hours | 25.0 | 20.0 | 10.0 | 10.0 | 20.0 | – |
| 6 hours | 60.0 | 25.0 | 20.0 | 20.0 | – | <10 |
| 8 hours | 40.0 | 20.0 | 25.0 | 25.0 | – | – |
| 24 hours | 20.0 | 30.0 | 20.0 | 20.0 | – | <10 |
| **Secchi Disc (cm)** | | | | | | |
| Before | 17 | 30 | 23 | 20 | – | – |
| 2 hours | 10 | 28 | 19 | 19 | – | – |
| 4 hours | 5 | 10 | 17 | 7 | – | – |
| 6 hours | 3 | 3 | 5 | 3 | – | – |
| 8 hours | 1 | 3 | 3 | 5 | – | – |
| 24 hours | 3 | 5 | 3 | 5 | – | – |
| **Sluice Date & Time (Start)** | 10/4/90 8:00 | 9/30/91 9:00 | 9/15/92 15:30 | 9/27/93 8:10 | 9/23/94 8:15 | 9/20/95 8:00 |

**Sluicing impact on fish populations**

Fish sampling Catch-Per-Unit-Efforts (CPUE) estimates below the hydro during pre-sluice and post-sluice are shown in Table 4. All three years were then combined and there was no significant difference between pre-sluice and post-sluice sampling for both electroshocking ($P = 0.32$) and seining ($P = 0.10$).

During sluicing, fish sampled by seining and electroshocking combined showed a significant difference, with higher numbers sampled in 1995 when compared with 1994 ($P = 0.02$) and 1993 ($P = 0.05$). There was not a significant difference when 1993 and 1994 were compared ($P = 0.35$).

## DISCUSSION

Suspended sediment is the primary contaminant of concern. Recent interest has been increasing toward sediment effects on fish, especially threatened and endangered species and warmwater fish (Dieter, 1990; Muncy et al., 1979; Newcombe and MacDonald, 1991). The major threat to fish from sediment is to their reproductive success and loss of rearing habitat. Developing eggs and newly hatched fry may be stressed or killed by suspended sediment through suffocation or inhibition of emergence from spawning gravels, and fine sediment concentrations may cause visual impairment in feeding behavior (Waters, 1995). Previous NPPD investigations concluded that the rate at which the hydro pond was dropped was a significant factor in impacting the fish. Operational modifications, such as monitoring and slowing the rate at which the pond is dropped above the hydro, were significant in reducing fish mortality. The flood and sluice gates were normally opened quickly and the pond drained rapidly. The increased sediment load and loss of acclimation time under the low flow-higher water temperature conditions were thought to be the major causes of the fish kills (Gutzmer, 1993). The movement of sediment through the flood and sluice gates can also strand fish above and below the hydro due to shifting stream channels and deposited sediment. Fish in the Niobrara, however, are adapted to highly turbid, increased sediment (sand) conditions, as it is estimated that the river transports more than 300 metric tons of sediment per day in this reach of the river (Hotchkiss et al., 1993).

It was apparent that as sediment concentrations increased there was also an increase in ambient water temperature. Reduction of water transparency caused by suspended silt and reduced light availability for photosynthesis were the main points emphasized by Ellis (1936) in his early warning research. Ellis expressed concern for possible effects of suspended sediment on other water characteristics such as temperature and conductance. Hydrogen sulfide concentrations were initially thought to be a factor by various regulatory agencies, but testing revealed undetectable or non-toxic levels (Gutzmer, 1993).

Our fish-species composition was somewhat comparable to previous studies conducted in the river. Hesse and Newcomb (1982) sampled above and below the hydro and found sand shiners composed 75.9%, river shiners 20.1%, and bigmouth shiners 4.0% of their upstream sample. In the downstream river section below the hydro they found sand shiners composed 88.6%, river shiners 10.3% and bigmouth shiners 1.1%. Our sampling revealed that sand and bigmouth shiners still were well represented, but only a few river shiners were observed in some incidental spring sampling and no apparent adults in the fall were identified. As in the Hesse studies, some species showed up in samples during certain times of the year and not in others. Certain habitats were much more accessible than others. This was especially true above the hydro as high flows, inclement weather and oftentimes very different habitat types (deeper, marshy wooded sandbars with intermittent isolated or partially connected meandering streams to the river itself) were common for several kilometers. Channel catfish young-of-the-year were very prevalent below the hydro in late summer as were carpsucker species. It appears to a certain extent that migration (adults in the spring) and recruitment of individuals through summer reproduction, and time of year we conducted sampling, affected our results both

Table 2. Summary of river flows (cfs) in the Niobrara River at the Spencer Hydro April 1990 through October 1995.

| | Monthly Flow | | |
|---|---|---|---|
| | **Mean** | **Minimum** | **Maximum** |
| **1990** | | | |
| Apr | 1690 | 1300 | 2600 |
| May | 1947 | 1370 | 2950 |
| Jun | 1542 | 929 | 2720 |
| Jul | 996 | 738 | 1990 |
| Aug | 1044 | 817 | 1880 |
| Sep | 899 | 760 | 1070 |
| Oct | 1200 | 675 | 1770 |
| **1991** | | | |
| Apr | 1856 | 1420 | 2400 |
| May | 2166 | 1390 | 2980 |
| Jun | 2175 | 1100 | 4040 |
| Jul | 935 | 781 | 1140 |
| Aug | 932 | 682 | 1320 |
| Sep | 1000 | 718 | 1650 |
| Oct | 1164 | 666 | 1590 |
| **1992** | | | |
| Apr | 1542 | 1310 | 1990 |
| May | 1217 | 1010 | 1870 |
| Jun | 1524 | 1140 | 2150 |
| Jul | 1422 | 1090 | 1860 |
| Aug | 1489 | 944 | 2600 |
| Sep | 1306 | 1110 | 1610 |
| Oct | 1380 | 1140 | 1950 |
| **1993** | | | |
| Apr | 2455 | 2030 | 3620 |
| May | 2280 | 1530 | 4390 |
| Jun | 1803 | 1270 | 2540 |
| Jul | 2245 | 1610 | 3980 |
| Aug | 1249 | 932 | 1950 |
| Sep | 1453 | 967 | 2740 |
| Oct | 1552 | 1350 | 2540 |
| **1994** | | | |
| Apr | 1780 | 1350 | 2280 |
| May | 1793 | 1160 | 3480 |
| Jun | 1588 | 797 | 2970 |
| Jul | 1299 | 948 | 2040 |
| Aug | 1220 | 920 | 2820 |
| Sep | 1321 | 443 | 2560 |
| Oct | 1259 | 1021 | 1405 |
| **1995** | | | |
| Apr | 4402 | 1987 | 10075 |
| May | 4579 | 2694 | 6566 |
| Jun | 3047 | 2129 | 4168 |
| Jul | 1335 | 974 | 2032 |
| Aug | 1200 | 949 | 1827 |
| Sep | 1254 | 949 | 2216 |

Table 3. Fish abundance, catch-per-unit-effort (before and after sluice events), and percent composition above Spencer Hydro during the fall, 1993–95.*

| | 1993 before sluice | | 1994 before sluice | | 1995 after sluice | | 1993–95 Percent |
|---|---|---|---|---|---|---|---|
| | seine | shock | seine | shock | seine | shock | composition |
| Bigmouth Shiner | 301 | | 23 | | | | 26.75 |
| Bluegill | | 8 | | 17 | | | 2.06 |
| Brassy minnow | 1 | 1 | 4 | | | | 0.50 |
| Carpsuckers (spp.) | 123 | | 112 | | 4 | 1 | 19.82 |
| Channel catfish | | | 1 | | | | 0.08 |
| Common carp | | 4 | 2 | 1 | | | 0.58 |
| Fathead minnow | 170 | 21 | 4 | | | | 16.10 |
| Flathead chub | 10 | 2 | 3 | | 9 | 1 | 2.06 |
| Grass pickerel | | 1 | | 3 | | 1 | 0.41 |
| Green sunfish | | 5 | | 9 | | 2 | 1.32 |
| Largemouth bass | | 6 | 5 | 13 | 1 | | 2.06 |
| Northern pike | | 1 | | | | | 0.08 |
| Red shiner | 76 | 59 | 17 | 12 | 6 | 1 | 14.12 |
| Sand shiner | 63 | 39 | 40 | | | | 11.73 |
| Shorthead redhorse | | 7 | | 3 | | | 0.83 |
| White crappie | | 1 | | | | | 0.08 |
| White sucker | | 7 | | 8 | | | 1.24 |
| Yellow bullhead | | | | 1 | | | 0.08 |
| Unknown juvenile (YOY) | 1 | | | | | | 0.08 |
| # of fish sampled | 745 | 162 | 211 | 67 | 20 | 6 | 1121 |
| Distance sampled (feet) | 400 | 700 | 400 | 600 | 150 | 200 | 2450 |
| Catch-per-unit-effort | 1.86 | 0.23 | 0.53 | 0.11 | 0.13 | 0.03 | 0.46 |

* Note that above sluicing sampling was not always conducted in a consistent manner because of access, staff availability and weather conditions.

temporarily and spatially in regard to species diversity and abundance. To some extent this may have also accounted for some distribution differences.

The CPUE estimate was higher for downstream (1.27) sampling than for upstream (0.46) and this can partially be explained through habitat heterogeneity, level of sampling effort and the fact that hydros can act as a barrier and concentrate fish. The sluicing process had no significant impact on fish numbers sampled for all three years between pre-sluice and during or post-sluice periods. What was observed was a significant increase in the numbers of fish sampled in 1995. The reasons for the higher fish numbers sampled in 1995 are unknown. Less sampling effort due to minimal staff and uncontrollable time constraints limited our effort, but the mean CPUE values for after or during sluicing were considerably higher (21.9 and 5.99 respectively). Table 2 shows that average flows in the Niobrara River during mid and late spring 1995 (May and June) were higher than the previous two years, which may have accounted for increased recruitment to the population by inundation of spawning areas not normally used. Other factors could have contributed but were not assessed in this evaluation.

## CONCLUSIONS

The operational modifications of raising the gates slowly and dropping the hydro pond at a reduced rate has been successful in avoiding fish kills since 1989. Simultaneously monitoring water quality and observing fish stress in the vicinity of the hydro during sluicing aids the operators in minimizing deleterious impacts to riverine biota. The similar number of species sampled above the hydro, when compared to downstream presence, indicates the hydro may not be limiting diversity and distribution as once originally thought. This appears evident when comparing our species composition to previous studies.

Future recommendations include the development of a standardized fish survey designed to evaluate fish populations above and below the hydro equidistant

Table 4. Fish abundance, catch-per-unit-effort (before and after sluice events), and percent composition below Spencer Hydro during the fall, 1993–95.

| | 1993 | | 1994 | | | | 1995 | | | | 1993–95 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | before sluice | | before sluice | | after sluice | | before sluice | | after sluice | | Percent |
| | seine | shock | seine | shock | seine | shock | seine | shock | seine | shock | composition |
| Bigmouth Shiner | 19 | 15 | | 1 | | | 1 | 1 | | 4 | 0.81 |
| Black bullhead | | 1 | | | | 5 | | | | 1 | 0.14 |
| Black crappie | | 1 | | | | | | | | | 0.02 |
| Bluegill | 1 | 6 | | 1 | 1 | | | 8 | | | 0.34 |
| Brassy minnow | 3 | 1 | 1 | 1 | | | | | | | 0.12 |
| Carpsuckers (spp.) | 15 | 1 | 7 | | 6 | | 30 | 2 | 74 | 2 | 2.70 |
| Channel catfish | 3 | 5 | | 6 | 47 | 8 | 41 | 7 | 108 | 85 | 6.12 |
| Common carp | | 2 | | 1 | 7 | 6 | | | 8 | 1 | 0.49 |
| Emerald shiner | | 1 | | | | | | | | | 0.02 |
| Fathead minnow | 77 | 9 | 2 | | | | | | | 1 | 1.76 |
| Flathead chub | 3 | 4 | 14 | 8 | 12 | 27 | 34 | 245 | 140 | 324 | 16.01 |
| Grass pickerel | | 1 | | | | | | | | | 0.00 |
| Green sunfish | | 14 | | 13 | 1 | 1 | | | 5 | 2 | 0.71 |
| Largemouth bass | | 6 | | 1 | | | 1 | 4 | 1 | | 0.26 |
| Red shiner | 308 | 382 | 71 | 118 | 22 | 25 | 259 | 56 | 180 | 24 | 28.52 |
| Sand shiner | 326 | 165 | 186 | 20 | 12 | 16 | 256 | 94 | 575 | 453 | 41.51 |
| Sauger | | | | | | | | | 1 | | 0.02 |
| Shorthead redhorse | | 4 | | 1 | | 3 | 2 | | 2 | 1 | 0.26 |
| Stone Cat | | | | | | | | | 1 | | 0.02 |
| White crappie | | 1 | | 1 | | | 1 | | | | 0.06 |
| White sucker | | 2 | | | | 1 | | | | | 0.06 |
| Yellow bullhead | | | | | 1 | | | | | 1 | 0.04 |
| # of fish sampled | 755 | 621 | 281 | 172 | 109 | 92 | 625 | 417 | 1095 | 899 | 5066 |
| Distance sampled (ft) | 500 | 1100 | 400 | 300 | 300 | 400 | 350 | 450 | 50 | 150 | 4000 |
| Catch-per-unit-effort | 1.51 | 0.56 | 0.70 | 0.57 | 0.36 | 0.23 | 1.79 | 0.93 | 21.90 | 5.99 | 1.27 |

from the hydro (i.e., Butte bridge and Lynch bridge), which will allow more representative habitat to be sampled. Instead of sampling within 5 km of the hydro extend the sampling locations 15–20 km upstream and downstream of the hydro project. This would resolve some of the problems and bias of heterogenous habitats that are sampled so close to the hydro. This study design may more fully illustrate fish diversity and abundance as a consequence of Spencer Hydro operation. Close observation of fish during sluicing periods may help explain unaccounted-for acute toxicity as well as any chronic effects or unknown physiological impairments not yet documented or realized to fish during sluicing events.

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