

**Fish Entrainment at the Lower Yellowstone Diversion Dam,
Intake Canal, Montana
1996 - 1998**



Prepared by:

Steve Hiebert, Rick Wydoski and Tom Parks

U.S. Department of Interior
Bureau of Reclamation
Denver Office
Montana Area Office

Prepared in Cooperation:
Montana Fish, Wildlife, and Parks
and
Lower Yellowstone Irrigation Project



April 2000

EXECUTIVE SUMMARY

This study, conducted from 1996 to 1998, estimates fish entrainment into the Intake Irrigation Canal (Intake Canal), Montana, and provides baseline fishery data on the Lower Yellowstone River. This information is critical for any future canal headwork modifications.

Initially nets were designed in 1996 specific for the study site, and sampling of fish entering the canal at the headworks began in June 1996. More intense sampling occurred in 1997 with frequent netting over the irrigation season and for eight 24-hour periods. In 1998, data on all species were collected over the irrigation season, but maintaining live collection of sturgeon chub was emphasized. The sturgeon chub were used for reintroduction in native waters and as brood stock for culture facilities. Debris entrained was frequently quantified during 1996 and 1997, and is available for incorporation into possible future screen designs and debris handling equipment.

The Intake Canal is unscreened, and relatively large flows from the Yellowstone River into the canal exceed 1550 cfs from mid-May to mid-September. The diversion is controlled through 11 sluice conduits, and fish enter these because they are unscreened. Potentially significant fish entrainment from the Yellowstone River had not been estimated. This study provides those important values. Estimates were obtained by collecting all fish from 2 to 4 of the 11 conduits with fyke nets set in the flows. During 1996, netting techniques were tested and refined using two conduits. Over the irrigation season in 1997, a total of 8,374 fish was netted. Included in this 1997 sampling were 8 days of 24 hour sampling, as well as a tagging program where 975 netted fish received Floy tags and were returned to the canal. The fish were tagged to determine recapture factors for more accurate entrainment estimates. Thirty-four species were sampled; 25 were native species. Native species—stonecat, flathead chub, sturgeon chub, goldeye and sauger—comprised the highest numbers collected. Average entrainment in 1996 and 1997 was 1.75 and 0.99 fish per acre-foot, respectively. Entrainment rates of individual species varied with month, time of day, and turbidity, over the irrigation season when with entrainment flows into the canal were relatively constant. Diel differences in entrainment for many of the native fish were most pronounced later in the irrigation season when river clarity increased.

The 1998 entrainment netting collected 4,529 fish which included 744 sturgeon chub. About 400 of these sturgeon chub were transported live to restocking or culture facilities. Sauger were the most frequent species encountered. Surprisingly, shovelnose sturgeon accounted for a noticeable high percentage (8 percent) of fish in 1998.

Estimates of total entrained fish were extrapolated from monthly average entrainment rates summarized over the irrigation season. The total estimated number of entrained fish in

1996 was 537,459 ± 198,908. Estimates of total fish entrained in 1997 and 1998 were 382,609 ± 24,487 and 809,820 ± 154,000, respectively. The Lower Yellowstone River appears to be a highly productive system, in spite of entrainment at Intake Canal and other irrigation facilities. Fish numbers in the river remain large.

Reducing the entrainment of fish into Intake Canal could be accomplished by one or more of the following:

- ◆ Relocating the intake area away from the shore toward the center of the river.
- ◆ Placing louvers and positive barrier screens either in the river at the Intake headworks or within the canal.
- ◆ Installing a device to move upstream migrating fish away from the bankline and the headwork mouth of Intake.

Screening within the river, proximate to the Intake Canal headworks, should be modular and designed for seasonal removal to avoid winter ice damage. Effective within-canal screening must include a by-pass system to return fish to the river and be designed to minimize predation. Other techniques, such as sound, lights, or electricity—singly or in combination with other methods— could guide fish away from the canal and reduce entrainment.

Table of Contents

EXECUTIVE SUMMARY	i
INTRODUCTION	7
METHODS AND MATERIALS	8
1996 RESULTS	13
1997 RESULTS	17
Monthly entrainment	20
1997 Tagging results	23
Turbidity	24
River Flows	25
Individual Fish Species Results - 1997	26
1998 RESULTS	40
DISCUSSION	47
Fish Entrainment and Yellowstone River Flows	49
Fish Entrainment Reduction	53
ACKNOWLEDGMENTS	55
LITERATURE CITED	56
APPENDIX	57

Tables

Table 1	List of fishes Collected at Intake Diversion, Montana (1996, 1997, and 1998)	12
Table 2	Estimated entrainment rates of all species collected in 1996 at Intake Canal. Rates are in fish per acre-foot with the standard error of the daily mean in parenthesis. The last row represents estimates of the monthly total acre feet passed into the Intake Canal using staff gauge readings in the canal	15
Table 3	Summarized length and weight measurements of fish from 1997, Intake Canal. . .	19
Table 4	Estimated entrainment rates (fish per acre-foot \pm one standard error of the mean) from fish collected in 1997 at Intake Canal. The last row provides monthly estimates of total acre feet passed into the Intake Canal	21

Table 5	Percentage of tagged fish re-collected at each net during 1997.	23
Table 6	Estimated entrainment rates (fish per acre-foot \pm one standard error of the mean) from fish collected in 1998 at Intake Canal. The last row provides monthly estimates of total acre feet passed into the Intake Canal.	42

Figures

Figure 1	Schematic of netting apparatus and cable guide placement Intake Canal, Montana used over 1996-1998	9
Figure 2	Percent composition of the fish collected with entrainment nets in the Intake Canal, 1996	13
Figure 3	Percent composition of the 6 dominant fish and other fish collected with entrainment nets at Intake Canal 1996.	16
Figure 4	Species composition of the collected entrained fish during the entire 1997 irrigation season, Intake Canal	17
Figure 5	Species composition of fish collected from Intake Canal, 1997	18
Figure 6	Results of fish collected with entrainment nets, tagged, and released back into Intake Canal during the 1997 irrigation season	24
Figure 7	Flows in the Yellowstone River at Sidney, Montana from May 15 to September 30, 1996,1997 and 1998	26
Figure 8	Length-weight relationship and length frequency of stonecat collected in 1997 in the Intake Canal	27
Figure 9	Length-weight relationship and length frequency of flathead chub collected in 1997 in the Intake Canal	28
Figure 10	Length-weight relationship and length frequency of sturgeon chub collected in 1997 in the Intake Canal.	39
Figure 11	Length-weight relationship and length frequency of goldeye collected in 1997 in the Intake Canal.	30

Figure 12	Length-weight relationship and length frequency of sauger collected in 1997 in the Intake Canal	31
Figure 13	Length-weight relationship and length frequency of longnose dace collected in 1997 in the Intake Canal	32
Figure 14	Western Silvery Minnow and Eastern Plains Silvery Minnow grouped together and their length-weight relationship and length frequency collected in 1997 from the Intake Canal	33
Figure 15	Longnose sucker length-weight relationship and length frequency collected in 1997 in the Intake Canal	34
Figure 16	Carp length-weight relationship and length frequency from fish collected in 1997 at the Intake Canal, Montana	35
Figure 17	Length-weight relationship and length frequency of drum collected in 1997 in the Intake Canal	36
Figure 18	Length-weight relationship and length frequency of channel catfish collected in 1997 in the Intake Canal	37
Figure 19	Length-weight relationship and length frequency of river carpsucker collected in 1997 in the Intake Canal	39
Figure 20	Species composition of the fish collected with entrainment nets at Intake Canal, Montana, 1998.	41
Figure 21	The relative percentage of fish collected by night and day from June 1998 in the Intake Canal, Montana..	44
Figure 22	Estimated total numbers of sturgeon chub entrained by month over the 1998 irrigation year	46
Figure 23	Estimated total numbers of sauger entrained by month over the 1998 irrigation year	46
Figure 24	Total fish entrainment estimates for 1996 and 1997 calculated monthly from averaged daily entrainment rates and Intake canal flows..	48
Figure 25	Total fish entrainment estimates for 1998 calculated monthly from averaged daily entrainment rates and Intake canal flows..	49

Figure 26 Daily Yellowstone River flows at the Sidney, Montana monitoring gauge from May 15 to September 30 in 1996,1997,1998, and 1999. 50

Figure 27 The relationship between the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total fish entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999. 51

Figure 28 The relationship between the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total sturgeon chub entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999. 52

Figure 29 The relationship between the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total sauger entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999. 53

**Fish Entrainment at the Lower Yellowstone Diversion Dam,
Intake Canal, Montana ¹
1996 1997 1998**

S. Hiebert
R. Wydoski
T. Parks

Introduction

Water for irrigation is diverted from the Yellowstone River into the Intake Irrigation Canal (Intake Canal), at the Lower Yellowstone Diversion Dam, located about 18 miles downstream from Glendive, Montana. The diversion dam and Intake Canal headworks have been in place for almost a century (i.e., constructed from 1905 to 1907).

Several years of anecdotal information from fisherman and farmers has indicated highly desirable game fish are routinely found in the canal, and any fish in the canal could be transported to the irrigated fields. Because of these concerns and the lack of verifiable information, we initiated this investigation in 1996 to estimate the number and density of fish entrained into the canal and assess any differences over the 4-month irrigation season. The irrigation season is typically from mid-May through mid-September, and water diverted at Intake and utilized through about 225 miles of canals and laterals. Federal, State, and irrigation managers can use these study data to develop management practices which optimize water delivery and reduce fish entrainment.

This report presents results of data collected June 11 to September 19, 1996; May 21 to

¹This investigation is part of a comprehensive Lower Yellowstone River study designed to collect information on all irrigation demands of the river and fish passage information from other low-head dams downstream of Billings, Montana.

September 11, 1997; and May 20 through September 10, 1998. The 1996 sampling season was originally designated for equipment setup and design of sampling logistics; sampling occurred only 10 to 14 days each month. The equipment initially worked well and nets collected many fish and the 1996 data is included in this report. Data are of good quality and provides accurate trends and estimates. Data were collected in 1997 in 2-week periods with 1 week breaks between periods throughout the irrigation season. Data collection in 1998 occurred 14 to 20 days each month with most sampling covering the crepuscular period. Results relate to fish entrained in the canal and may not reflect similar species densities or similar compositions as those in the river. Recommendations and additional studies are located in the Discussion Section.

METHODS and MATERIALS

A netting system was designed to collect fish immediately after entrainment through the control sluice gates in order to accurately record entrainment data. Figure 1 presents a cross section through the Intake headworks with the net frame lowering system and guides in place. The control gates and sluices are 5 feet in diameter with 11 gates across the headworks. The nets are attached to ½-inch steel guide cables secured to the base of the canal side of the headworks below the sluice opening. The above-water portion of the guide cables is connected to a frame structure with turnbuckles which allow tightening of the cables to make a taut guide. Each sluice sampled had cables mounted as described. The guide frames were bolted to the upper deck of the headworks and had a hand winch lifting cable in the center. The lifting cable was attached to the center of the net frame and the lifting frame allowed the net to nearly clear the base of the deck; so the net could be inspected and repaired easily.

The square (6 feet sides) net frames have hollow grips that clamp to the steel guide cables on each side approximately 3 inches from the net frame. The nets were ½-inch delta heavy duty mesh with an 8-inch rubberized chafe collar that was sandwiched between

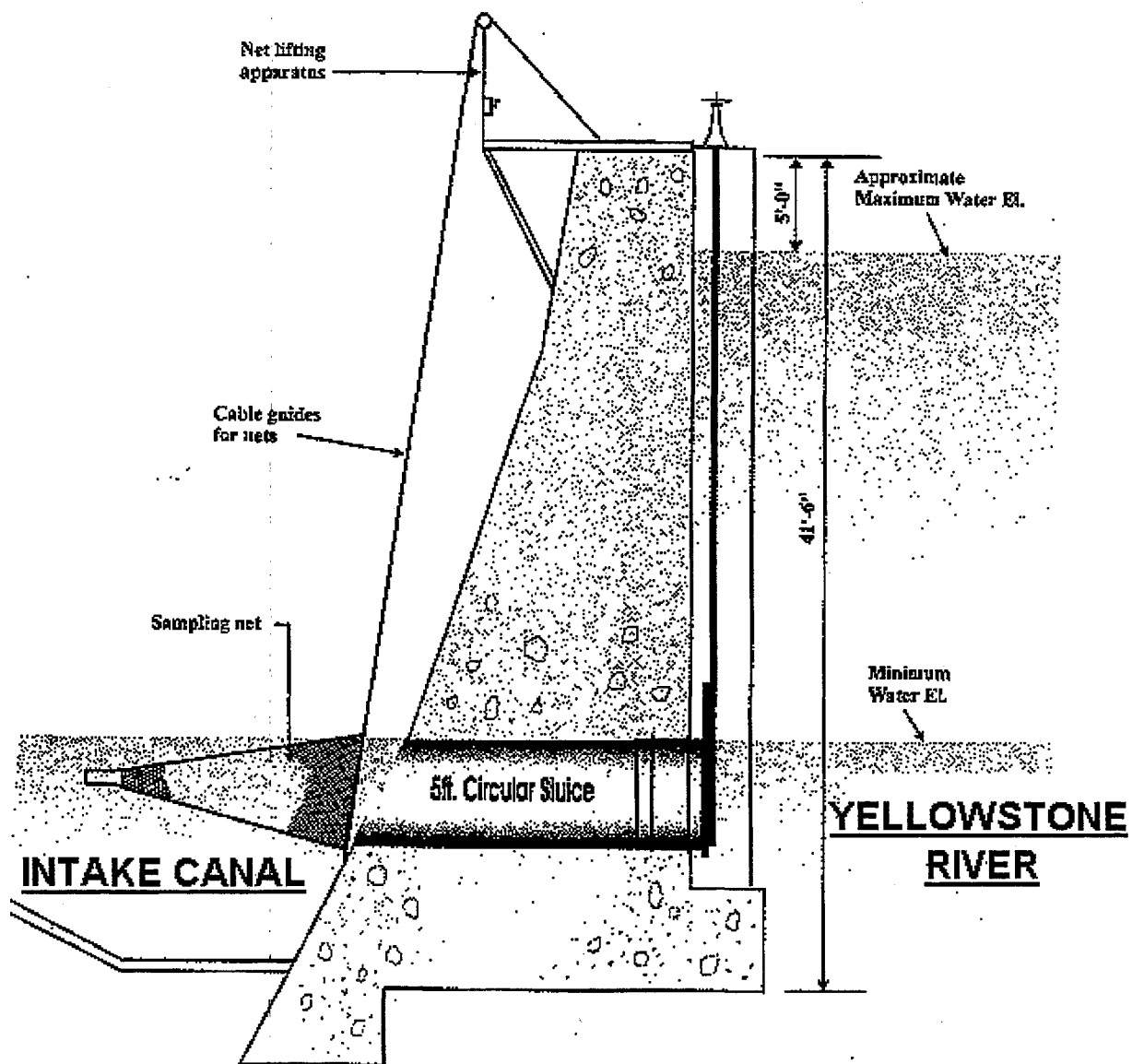


Figure 1 Schematic of netting apparatus and cable guide placement at Intake Canal, Montana, 1996-1998.

a steel band and the net frame and bolted. The mouth was held open at all times by the net frame with the inflow filling the net. The nets has a choker four feet before the cod end to use when lifting the net. The cod end (3/16-inch ace mesh) of the net was 24 inches long fitted with

a 20 inch zipper for removal of contents. The nets were lifted from flowing water to prevent fish swimming out of the nets. Duration of net set was determined by debris loading but generally the nets were set for one hour. Over the irrigation season in 1997, systematic sampling for 2 weeks on (8 to 10 hours a day) and 1 week off was employed. Also in 1997, diel fish entrainment was assessed by sampling hourly for 8 days. Cod end live collection containers were designed and built for use in 1998. These were inserted into the cod end net bag and contained a baffle system that provided a low flow refuge for all but the largest fish.

Netted fish were identified to species, weighed and measured. Some were tagged in 1997. All fish, except blue suckers and shovelnose sturgeon, were released back into the canal. Length-weight relationships were calculated from the 20 most common species from fish where both total length and weight data were recorded. Length frequency of the same group of fish is also presented. Table 1 presents a list of fish species collected over the three years. Smaller fish could pass through the net mesh of $\frac{1}{2}$ inch and consequently the fish netted were primarily over 30 mm total length. Small fish were collected in the nets, but most likely in numbers under-representing their actual entrainment. Fish not identified in the field were preserved and identified positively in the lab.

Rates of entrainment were calculated using the proportion of canal flow each net sampled and determining fish per acre-foot rate for each net set by species. Individual gate positions and daily canal flows were recorded and used for each net's individual entrainment rate. The three step extrapolation procedure to obtain fish entrainment estimates per month was: **a)** Divide the number of fish collected by the volume of water sampled (acre-feet) for each nets sampling **b)** Average each days netting to fish per acre/foot by day and month **c)** Multiply monthly average rates per species by the canal inflow over each month for an estimate of fish entrained per month. The monthly entrainment rates include a recapture factor. The recapture factor (See following) was usually around 0.95 and was multiplied times the entrainment rate. In addition, the monthly entrainment rates include a standard error of the mean. The raw data from each net is provided in Appendix A, B, and C corresponding to 1996, 1997, and 1998.

A tapered gap between the upper portion of the net mouth and the concrete wall of the headworks allowed fish to enter and be re-captured. This tapered gap varied from no gap at the bottom of the net to about 14 inches at the top of the net. This gap potentially could also have been an escape avenue, if the entrained fish was able to work its way up through high inflow current. In 1997, about 976 fish were tagged (i.e., Floy spaghetti tags inserted between or behind the dorsal rays) to identify fish recaptured in the nets and released in the canal. Fish that were tagged were limited to larger (>125 mm total length) life stages and species. Tagging results provided a recapture factor for certain species and information on residence time of certain species in the proximate area of the canal headworks.

The Yellowstone River stage height was recorded twice each day by the Lower Yellowstone Irrigation Project personnel and turbidity was monitored (i.e., Hach Inc., Model 1800 turbidimeter) when the nets were fished. All gate positions were recorded daily to estimate for distribution of water in the netted sluice ways. Each of the four nets sampled between 3.5 and 9.6% of the total canal diverted water, almost 40% of the flow was sampled at times. Field corrections to the flow data were made through out the study. For example quantitative flow estimates were made when a gate became restricted with logs and other other debris. Turbidity was recorded in NTU's (Nephelometric Turbidity Units) and serial dilutions with turbidity-free water were performed when the river turbidity exceeded the range of the turbidimeter.

Table 1. List of fishes collected at Intake Diversion, Montana (1996, 1997, and 1998)

Common name	Scientific name	Family	Native
Goldeye	<i>Hiodon alosoides</i>	Hiodontidae	x
Shovelnose Sturgeon	<i>Scaphirynchus platyrhynchus</i>	Acipenseridae	x
Common Carp	<i>Cyprinus carpio</i>	Cyprinidae	
Western Silvery/Plains Minnow*/	<i>Hybognathus argyritis/placitus</i>	Cyprinidae	x
Brassy Minnow	<i>Hybognathus hankinsonidae</i>	Cyprinidae	x
Sturgeon Chub	<i>Macrhybopsis gelida</i>	Cyprinidae	x
Sicklefin Chub*	<i>Macrhybopsis meeki</i>	Cyprinidae	x
Emerald Shiner	<i>Notropis atherinoides</i>	Cyprinidae	x
Spottail Shiner	<i>Notropis hudsonius</i>	Cyprinidae	
Fathead Minnow*	<i>Pimephales promelas</i>	Cyprinidae	x
Longnose Dace	<i>Rhinichthys cataractae</i>	Cyprinidae	x
Creek Chub*	<i>Semotilus atromaculatus</i>	Cyprinidae	x
Flathead Chub	<i>Platygobio gracilis</i>	Cyprinidae	x
River Carpsucker	<i>Carpiodes carpio</i>	Catostomidae	x
Longnose Sucker	<i>Catostomus catostomus</i>	Catostomidae	x
White Sucker	<i>Catostomus commersoni</i>	Catostomidae	x
Blue Sucker	<i>Cycleptus elongatus</i>	Catostomidae	x
Smallmouth Buffalo	<i>Ictiobus bubalus</i>	Catostomidae	x
Bigmouth Buffalo	<i>Ictiobus cyprinella</i>	Catostomidae	x
Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>	Catostomidae	x
Black Bullhead	<i>Ameiurus melas</i>	Ictaluridae	
Channel Catfish	<i>Ictalurus punctatus</i>	Ictaluridae	x
Stonecat	<i>Noturus flavus</i>	Ictaluridae	x
Paddlefish @	<i>Polyodon spathula</i>	Polyodontidae	x
Northern Pike	<i>Esox lucius</i>	Esocidae	
Rainbow Trout*	<i>Oncorhynchus mykiss</i>	Salmonidae	
Brown Trout*	<i>Salmo trutta</i>	Salmonidae	
Mountain Whitefish*	<i>Prosopium williamsoni</i>	Salmonidae	x
Cisco @	<i>Coregonus artedii</i>	Salmonidae	
Burbot	<i>Lota lota</i>	Gadidae	x
Brook Stickleback*	<i>Culaea inconstans</i>	Gasterosteidae	x
Green Sunfish	<i>Lepomis cyanellus</i>	Centrarchidae	
White Crappie	<i>Pomoxis annularis</i>	Centrarchidae	
Sauger	<i>Stizostedion canadense</i>	Percidae	x
Walleye	<i>Stizostedion vitreum</i>	Percidae	
Freshwater Drum	<i>Aplodinotus grunniens</i>	Sciaenidae	x

* only collected in 1997

/ may have been identified as flathead chub in 1996

@ only collected in 1998

1996 Results

In 1996, two nets collected 2931 fish representing 27 species. Flathead chub (Figure 2) made up the largest percentage, followed by stonecats and sturgeon chub. Sauger and channel catfish were the only two game fish commonly encountered (14.4 and 10.5 percent respectively, Figure 2). Sauger were collected primarily during July and August—their highest entrainment rate on August 10th. Intake canal flows were relatively constant near 1350 cfs (cubic feet per second) while the river stage fluctuated over the season.

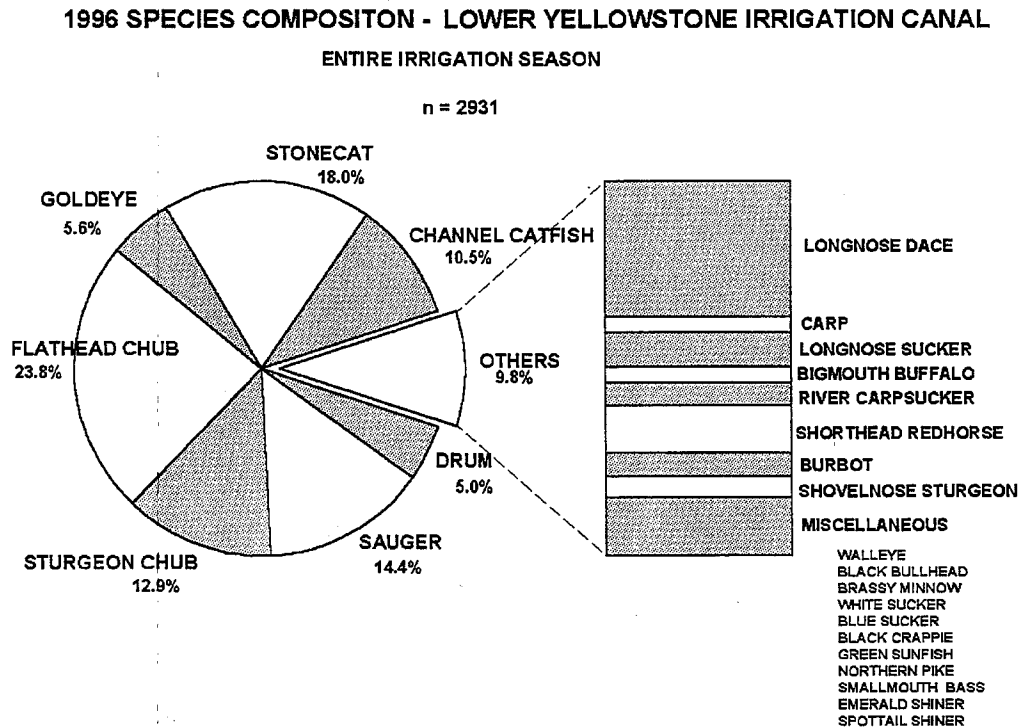


Figure 2 Percent composition of fish collected with entrainment nets in the Intake Canal, 1996.

Differences were noted between catches by the two nets; east net (furthest down stream along the face of the headworks) averaged about two times more fish. Shovelnose sturgeon were the only species collected most in the west net. Total fish entrainment averaged 1.75 fish per acre-foot. This calculation was derived from averaging the rates between both nets over the entire 1996 sampling season. Table 2 presents the monthly average entrainment rate calculated for each species of fish collected and the estimated water passing into the canal.

Over the 1996 irrigation season, the species composition changed. Figure 3 provides composition differences for the six most common species (stonecat, channel catfish, flathead chub, goldeye, sturgeon chub, and sauger) and others. The dominant fish by month were stonecats in June, sauger in July, flathead chub and sturgeon chub in August, and channel catfish and others in September.

Table 2. Estimated entrainment rates of all species collected in 1996 at Intake Canal. Rates are in fish per acre-foot with the standard error of the daily mean in parentheses. The last row represents estimates of the monthly total acre feet passed into Intake Canal from staff gauge readings in the canal.

Species	June	July	August	September
Stonecat	1.468 (± 0.407)	0.0159 (± 0.0122)	0.0418 (± 0.0414)	0.250 (± 0.169)
Flathead chub	0.522 (± 0.117)	0.144 (± 0.009)	0.401 (± 0.104)	0.138 (± 0.042)
Sturgeon chub	0.270 (± 0.089)	0.0215 (± 0.0165)	0.363 (± 0.378)	0.009 (± 0.004)
Goldeye	0.521 (± 0.120)	0.088 (± 0.002)	0.030 (± 0.0177)	0.0217 (± 0.0074)
Sauger	0.036 (± 0.018)	0.589 (± 0.031)	0.362 (± 0.058)	0.0411 (± 0.0294)
Longnose Dace	0.0244 (± 0.0105)	0.0	0.102 (0.059)	0.029 (± 0.0120)
Longnose Sucker	0.032 (± 0.010)	0.0	0.0146 (0.0042)	0.0149 (± 0.009)
Carp	0.0142 (± 0.0097)	0	0.0014 (0.0011)	0.020 (± 0.008)
Drum	0	0.137 (± 0.025)	0.129 (± 0.0189)	0.0187 (± 0.005)
Channel Catfish	0.009 (± 0.014)	0.300 (± 0.104)	0.0268 (± 0.0137)	0.415 (± 0.259)
Bigmouth Buffalo	0.003 (± 0.001)	0.0734 (± 0.003)	0.002 (± 0.0032)	0
Burbot	0.154 (± 0.035)	0	0.0011 (± 0.001)	0.017 (± 0.007)
River Carpsucker	0	0	0.003 (± 0.001)	0.019 (± 0.0102)
Shovelnose sturgeon	0.005 (± 0.004)	0	0.008 (± 0.003)	0.020 (± 0.008)
Walleye	0	0	0.004 (± 0.003)	0.002 (± 0.001)
White Sucker	0.005 (± 0.002)	0	0.0018 (± 0.001)	0
Shorthead Redhorse	0	0.017 (.006)	0.037 (± 0.009)	0.009 (± 0.005)
Emerald Shiner	0	0	0.007 (± 0.003)	0
Brassy Minnow	0.015 (± 0.011)	0	0.005 (± 0.002)	0
Black Crappie	0.005 (± 0.005)	0	0.001 (± 0.0008)	0.007 (± 0.004)
Green Sunfish	0	0	0.001 (± 0.001)	0.004 (± 0.003)
Smallmouth bass	0	0	0	0.001 (± 0.001)
Northern pike	0	0	0.001 (± 0.0007)	0.001 (± 0.0007)

Species	June	July	August	September
Unidentified small	0	0	0.038(±0.040)	0.171(±0.093)
Spottail Shiner	0	0	0.002(±0.001)	0.004(±0.002)
Black Bullhead	0	0	0.0007(±.008)	0
Total Fish	3.095 (±0.262)	1.388 (±0.302)	1.586 (±0.221)	1.218 (±0.255)
Monthly Estimated acre- feet	74,443	81,843	82,409	51,394

1996 SPECIES COMPOSITION LOWER YELLOWSTONE IRRIGATION CANAL

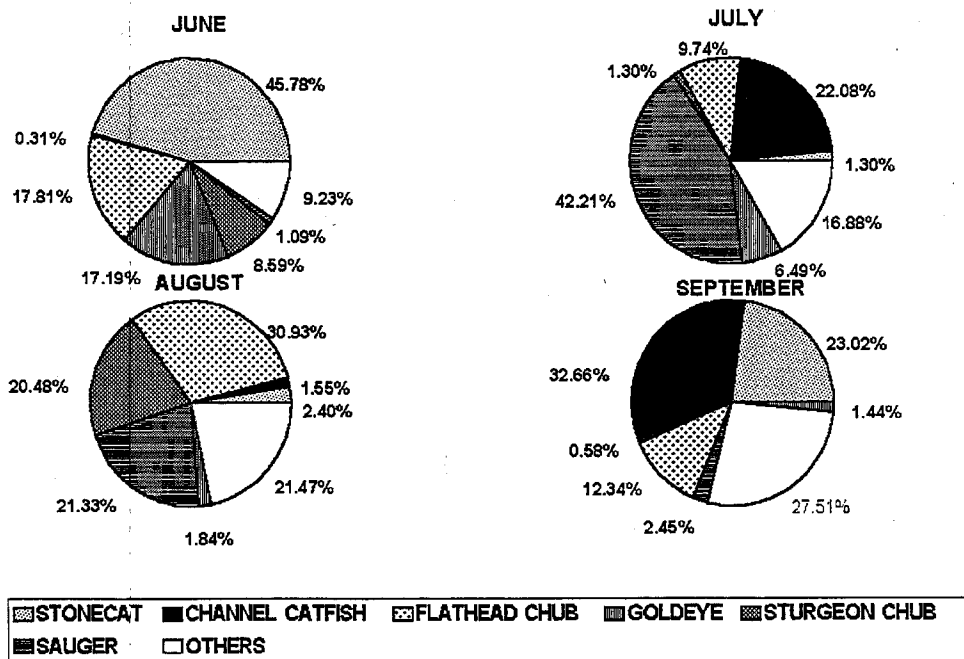


Figure 3. Percent composition of the six dominant fish and other fish collected with entrainment nets at Intake Canal 1996.

1997 Results

There were 34 species collected in 1997 from May 21 through September 11 with four or fewer nets sampling the Intake Canal at a time. Of the total 7,980 fish collected, 39.5 % were stonecat. Other fish collected in relatively high numbers include flathead chub (16.7%), sturgeon chub (12.7%), goldeye (8.5%), and sauger (6.2%). A daily average entrainment rate of 0.99 fish per acre-foot was calculated for the entire irrigation season. Species composition, presented in Figure 4, shows the great diversity of fish entrained.

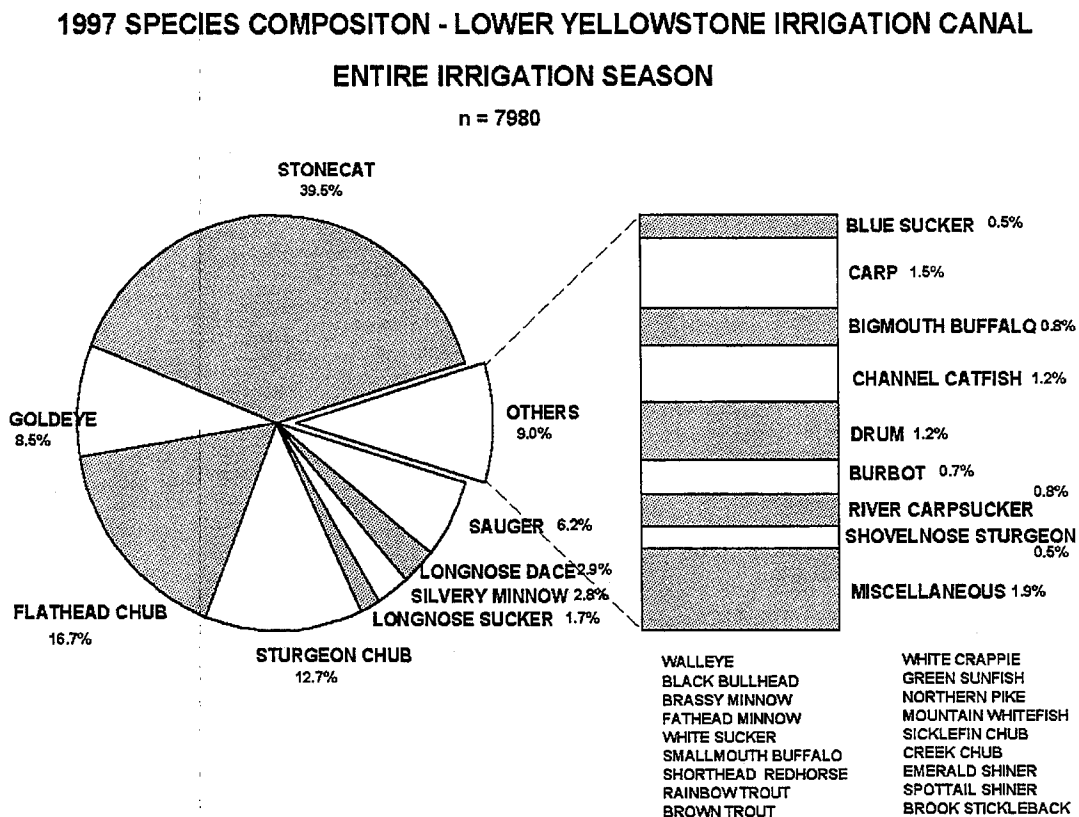


Figure 4. Species composition of the entrained fish collected during the entire 1997 irrigation season, Intake Canal

Over the 1997 irrigation season, the species composition changed and these changes are shown in Figure 5 for the five most common species (stonecat, flathead chub, goldeye, sturgeon chub, and

sauger) and all others grouped into one. Stonecat were the dominant fish in June, sauger in July, flathead chub and sturgeon chub in August, and flathead chub the dominant species in September.

1997 SPECIES COMPOSITION LOWER YELLOWSTONE IRRIGATION CANAL

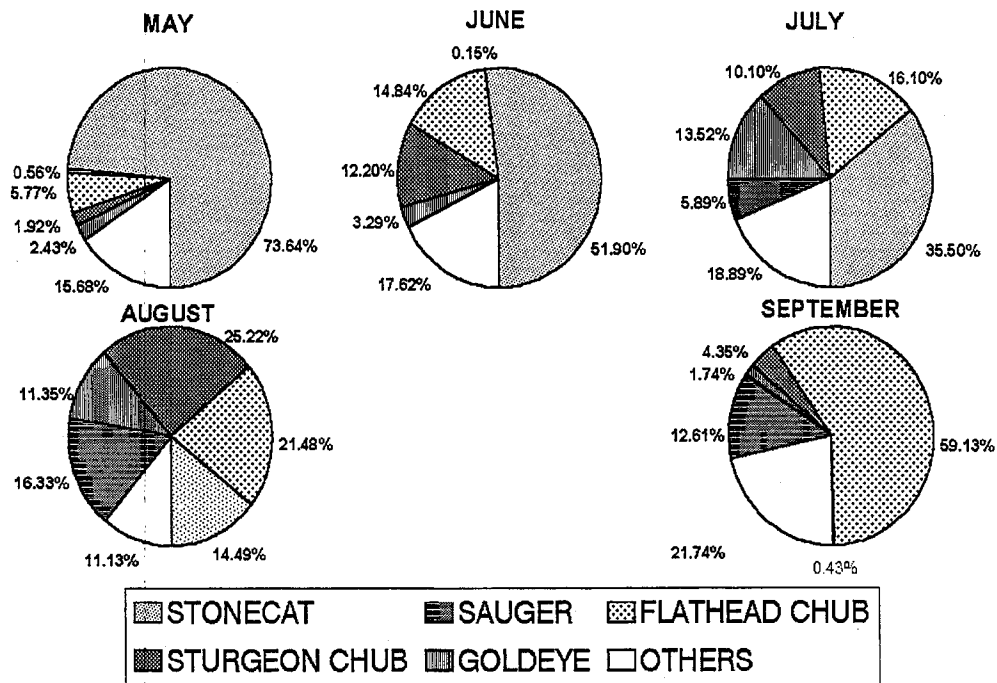


Figure 5. Species composition of fish collected from Intake Canal, 1997

Table 3 summarizes the lengths and weights of most of the species of entrained fish from 1997. Not all fish were weighed and therefore the number of fish weighed (Table 3) is usually less than the number measured.

Table 3. Summarized length and weight measurements of fish from 1997, Intake Canal.

FISH COLLECTED FROM SIEVE NETS AT INTAKE DIVERSION, 1997

SPECIES	TOTAL LENGTH (mm)			WEIGHT (g)		
	N	RANGE	MEAN	N	RANGE	MEAN
STONECAT	3134	36-224	129	412	1-138	25
FLATHEAD CHUB	1327	32-282	147	1111	1-202	35
STURGEON CHUB	984	32-93	69	819	0.3-7.3	2.4
GOLDEYE	673	36-405	309	615	0.1-450	238
SAUGER	493	42-544	309	473	1-983	222
LONGNOSE DACE	241	34-95	63	125	0.2-8.3	2.5
WESTERN SILVERY MINNOW	227	30-120	72	139	0.1-13.7	3.4
LONGNOSE SUCKER	145	45-405	304	116	0.4-698	359
CARP	121	21-672	313	96	0.5-4070	999
DRUM	98	65-446	271	98	1-1094	254
CHANNEL CATFISH	94	50-621	256	86	1-2350	216
BIGMOUTH BUFFALO	65	66-691	99	18	0.1-4265	463
BURBOT	61	80-446	219	27	3-370	71
RIVER CARPSUCKER	59	41-527	239	34	3-2060	821
SHOVELNOSE STURGEON	44	390-923	634	44	86-2740	850
BLUE SUCKER	41	305-851	632	36	248-4080	2011
WHITE SUCKER	25	30-433	235	13	4-530	286
SHORTHEAD REDHORSE	22	51-370	187	19	1-560	152
CREEK CHUB	21	23-124	79	14	1-18	7
EMERALD SHINER	17	42-95	57	14	0.5-2.9	1.4
BRASSY MINNOW	10	46-120	71	0		
RAINBOW TROUT	9	201-518	353	4	1110-1120	1118
WALLEYE	9	266-370	327	8	154-900	345
SMALLMOUTH BUFFALO	6	275-640	493	5	290-2940	1841
BROOK STICKLEBACK	4	32-39	37	2	0.2-0.4	0.3
WHITE CRAPPIE	4	34-123	87	1		22
BLACK BULLEAD	3	125-191	163	1		102
NORTHERN PIKE	3	383-580	504	3	308-1005	796
BROWN TROUT	2	169-494	332	1		1070
SICKLEFIN CHUB	2	95-102	100	2	6-10	8.2
FATHEAD MINNOW	2	28-45	37	0		
SPOTTAIL SHINER	1		84	1		3.9
GREEN SUNFISH	1		39	1		1.1
MOUNTAIN WHITEFISH	1		100	1		7.4

Monthly Entrainment

The daily average entrainment was calculated for each collection period and averaged by month for each species, similar to 1996. Table 4 lists monthly rates of entrainment for each species. This rate multiplied by the monthly acre feet in the canal estimates entrained fish numbers. These numbers should not be used for extrapolation to riverine population estimations. Fish densities in the diversion dam area and near the shore line are unnaturally high and most likely not representative of those in the river. May and September canal flows (acre-feet) take into account less than a full month of irrigation water in the canal.

Table 4. Estimated entrainment rates (fish per acre-foot \pm one standard error of the mean) from fish collected in 1997 at Intake Canal. The last row provides monthly estimates of total acre feet passed into the Intake Canal.

Species	May	June	July	August	September
Stonecat	0.497 (± 0.098)	0.411 (± 0.063)	0.246 (± 0.0559)	0.174 (± 0.0403)	0.002(± 0.002)
Flathead chub	0.040 (± 0.008)	0.117 (± 0.0151)	0.160 (± 0.025)	0.267(± 0.032)	0.904(± 0.509)
Sturgeon chub	0.0136 (± 0.004)	0.106 (0.0204)	0.125(± 0.036)	0.463(± 0.123)	0.043(± 0.013)
Goldeye	0.015 (± 0.005)	0.0318 (± 0.0061)	0.120 (± 0.024)	0.166 (± 0.0221)	0.010(± 0.006)
Sauger	.004(± 0.009)	.0026 (± 0.0016)	0.045(± 0.010)	0.112(± 0.040)	.067(± 0.034)
Longnose Dace	.020(± 0.004)	0.047 (± 0.007)	0.0365(± 0.012)	0.0103(± 0.004)	0
Longnose Sucker	0.018 (± 0.005)	0.019 (± 0.0052)	0.016(± 0.005)	0.009(± 0.004)	0
Carp	0.004 (± 0.001)	0.017 (± 0.003)	0.014(± 0.004)	0.030(± 0.008)	0.016 (± 0.005)
Drum	0	0.002(± 0.002)	0.013(± 0.005)	0.018(± 0.005)	0.011(± 0.007)
Channel Catfish	0	.002(± 0.002)	0	0	0
Bigmouth Buffalo	0.001 (± 0.0009)	0.006 (± 0.002)	0.018(± 0.008)	0.001(± 0.001)	0
Burbot	0.017 (± 0.003)	0.008 (± 0.002)	0.004(± 0.001)	0.001(± 0.001)	0
River Carpsucker	0.010 (± 0.0019)	0.003 (± 0.002)	0.010(± 0.003)	0.002 (± 0.0015)	0.002(± 0.002)
Shovelnose sturgeon	0	0.002(± 0.002)	.0007(± 0.0005)	0.005(± 0.002)	0.057(± 0.040)
Walleye	0.0008 (± 0.0008)	0.0025 (0.002)	0.0009 (0.0007)	0.003(± 0.0023)	0
White Sucker	.008(± 0.008)	.006(± 0.004)	.0003(± 0.0002)	.004(± 0.002)	0

Species	May	June	July	August	September
Shorthead Redhorse	0.002 (±0.001)	0.005 (±0.003)	0.002(±0.0008)	0.004(±0.002)	0.004(.004)
Emerald Shiner	0	0.002(.002)	0.0072(0.004)	.0004(0.0004)	0
Brown Trout	0.0007 (±0.0007)	0.002 (±0.0016)	0	0.0008 (±0.0008)	0
Rainbow Trout	0.004 (±0.0019)	0.002 (±0.002)	0	0	0
White Crappie	0	.002(±0.0019)	0	0.0003(.0003)	0
Green Sunfish	0	.002(±0.002)	.0004(±0.0004)	0	0
Smallmouth Buffalo	0	.002 ±(.002)	.0046(±0.004)	0	0
Northern Pike	0	0.0016 (0.0016)	.0006(±0.0004)	0	0.003 (±0.0029)
Mountain Whitefish	0	.0016(±0.0016)	0	.0012(±0.0012)	0
Spottail Shiner	0	.0016(±0.0016)	0.0004(.0004)	0	0
Sicklefin Chub	0	0.0016 (±0.0016)	0.001(±0.0008)	0	0
Creek Chub	0.0019 (±0.0013)	0.0032 (±0.0019)	0.005 (±0.0026)	0	0
Silvery Minnow	.010(±0.0014)	0.030 (±0.007)	0.053 (± 0.017)	0.012(±0.004)	0
Blue Sucker	0.005 (±0.0018)	0.007 (±0.0023)	0.008 (±0.0037)	0.006 (±0.004)	0
Fathead Minnow	0	.002(.002)	.0004(±0.0004)	0	0
Black Bullhead	0.0003 (±0.0003)	0.002 (±0.0017)	0	.0006(±0.0006)	0
Total Fish	0.678 (±0.099)	0.766 (±0.093)	0.910(±0.096)	1.58(±0.150)	1.16(±0.430)
Monthly Estimated acre-feet	50536	101085	80160	108848	65595

1997 Tagging Results

In 1997, there were 975 tagged fish netted and returned into the canal; 51 were recovered. Stonecat represented the fish most tagged and recovered (i.e., 19 recovered out of 367 tagged). For all fish, time until recapture ranged from less than 1 hour to 336 days (two sauger were recaptured in spring 1998). This indicates some degree of survival in the canal over winter and/or recapture of a tagged fish by-passed to the river at a turnout, and then recaptured from the river in 1998. During periods of lower irrigation needs, the Intake Canal does return some water to the river at Burns Creek about 8 miles down canal and at locations further down.

Tagging results from each net over the season are presented in the Table 5. The nets represent an upstream to downstream gradient of sluice sampling. This table presents each net and the corresponding percentage tag returns.

Table 5 Percentage of tagged fish re-collected at each net during 1997.

Blue West Net	Yellow West Net	Blue East Net	Yellow East Net
31%	6%	18%	45%

The most eastwardly located net (yellow east) collected the most recaptures. This net had a large gyre of water behind it in the canal for most of the irrigation season. Its circular flow could have repositioned entrained fish into the narrow (tapered) space between the net mouth and the concrete headworks face. Fish were shown to be subject to recapture as an artifact of the tapered gap between the headworks dam and the net mouth. Therefore, fish were tagged to determine whether they were recaptured in nets after release in the canal and, if so, to account for recapture when estimating entrainment rates. Figure 6 shows the percent of tagged fish recaptured from the canal by species. Incorporating recaptures provides a more accurate estimate of entrainment when used with tagged species. As an example, 11% of the tagged burbot were recovered, therefore a factor of 0.89 results, which is multiplied by the estimated burbot entrainment. A value of 0.95 was used for total fish entrainment estimations. This was obtained by calculating the mean of all tag return factors.

PERCENT RECAPTURED FROM INTAKE CANAL

SPECIES (# FISH TAGGED)

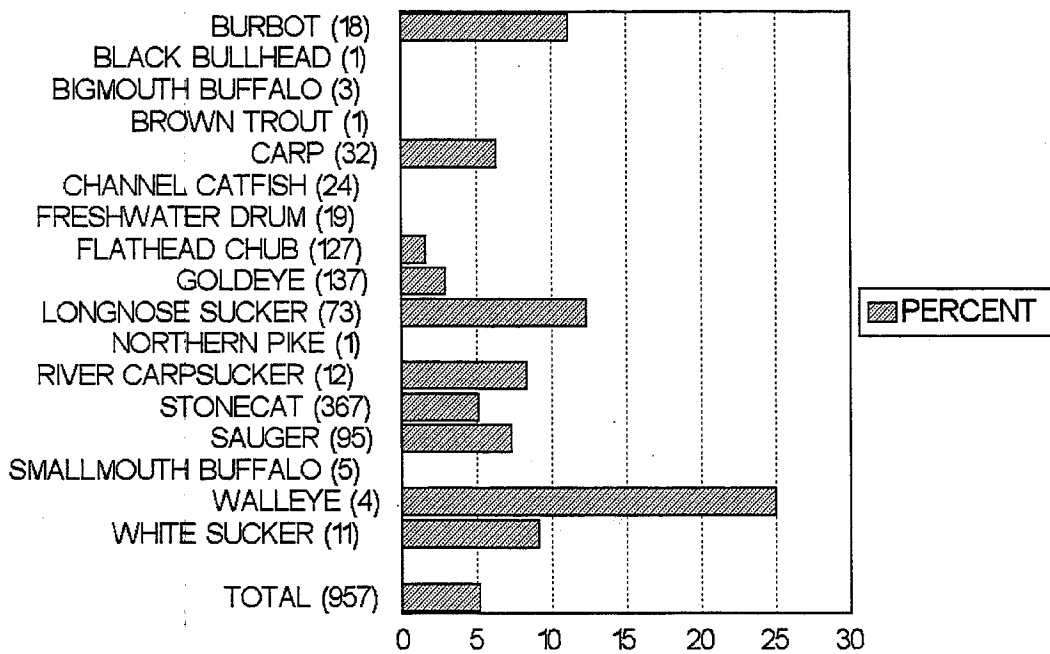


Figure 6. Results of fish collected with entrainment nets, tagged, and released back into Intake Canal during the 1997 irrigation season.

Turbidity

Turbidities varied over the irrigation season, and exceeded highest values on the turbidity

meter. Highest average turbidities were in June, and all exceeded the 1000 NTU (Nephelometric Turbidity Unit) maximum value of the meter. Appropriate dilutions were made to allow meter readings, and turbidities of 1230 to 2600 NTU were estimated. Average turbidity during the sampling in May was 756 NTU, in July was 338 NTU, in August was 596 NTU, and in September was 25 NTU.

River Flows

The Yellowstone River generally peaked in June at Intake Dam in 1996, 1997, and 1998 had a protracted runoff and peak flows in July. In 1997, peak flows reached nearly 90,000 cfs. A gap in the 1997 flow data occurred during the rising spring flows because high water and debris disabled the gauge station. Low spring flows in 1998 resulted in a low water year. Figure 7 presents the flows over the irrigation season for the three years. In all years sampled, flows in the river decreased to base flow— 6500 to 8000 cfs— by the end of September.

**FLOWS IN THE YELLOWSTONE RIVER
USGS GAGING STATION, SIDNEY, MT
1996 - 1998**

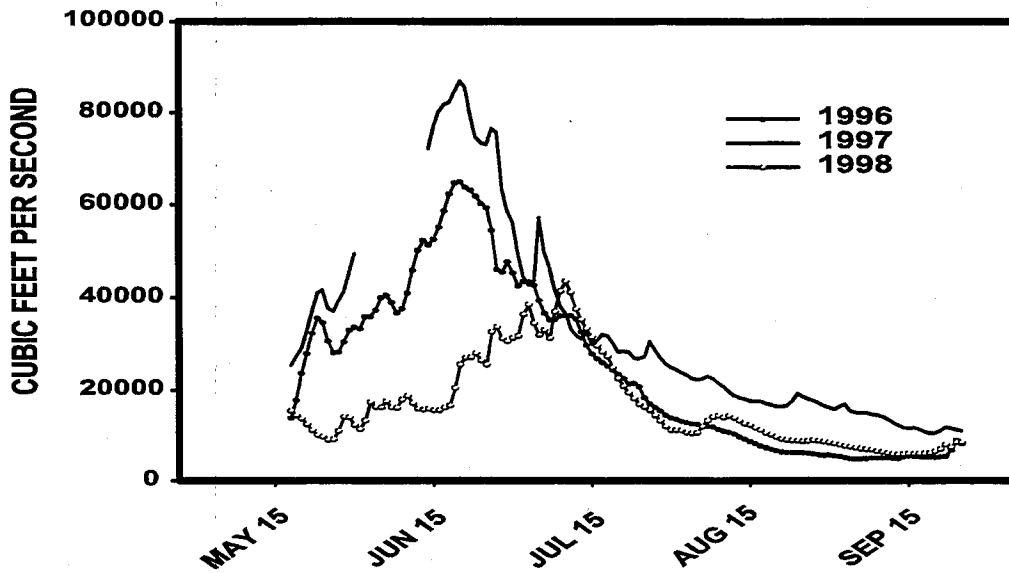


Figure 7 Flows in the Yellowstone River at Sidney, Montana, from May 15 to September 30, 1996, 1997, and 1998.

Individual Species Results - 1997

Stonecat were the most numerous fish netted in 1997. A total of 3,134 were sampled, primarily in May, June, and July. Mean stonecat total length (TL) was 129 mm

(range 36 and 224 mm TL). A length-weight relationship of $\log(y) = 3.129(\log(x)) - 5.137$ was derived from 412 fish with a $r^2 = 0.953$ (Figure 8). Highest concentrations of stonecat occurred between 2000 and 0400 hours during the diel collections, and the greatest day/night difference was observed later in the season.

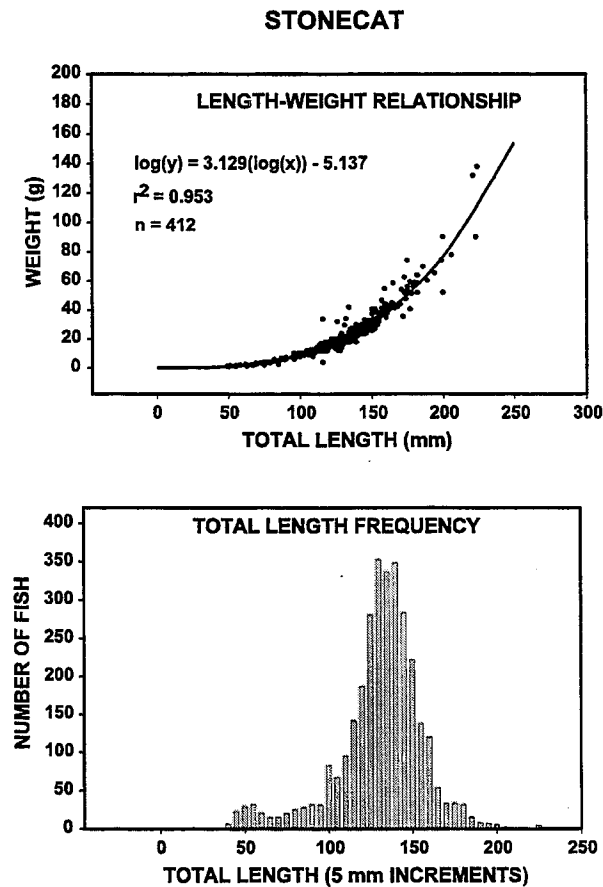


Figure 8 Length-weight relationship and length frequency of stonecat collected in 1997 in the Intake Canal.

Flathead chub were frequently collected (1,327 total, total length 32 to 282 mm TL) in 1997. Figure 9 provides length-frequency relationship and length frequency.

Flathead chub entrainment rates increased over the season with a peak daily average occurring on September 11 of 1.918 fish/acre foot.

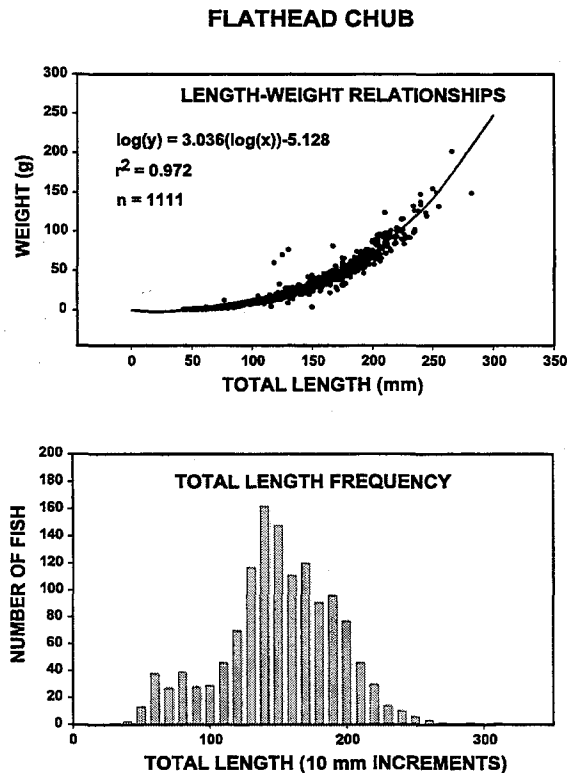


Figure 9 Length-weight relationship and length frequency of flathead chub collected in 1997 in the Intake Canal

Sturgeon chub were frequently collected, with 1008 collected in 1997. Sturgeon chub TL ranged from 32 to 93 mm with most of the individuals in the 68 to 73 mm range. A length-weight regression ($n=819$) of $\log(y) = 2.90(\log(x)) - 4.98$ with a r^2 of 0.861 was calculated (Figure 10). Average entrainment over the season was 0.191 fish per acre-foot and highest daily average entrainment rate was August 7 at 1.29 fish per acre foot. In diel entrainment tests most noticeable day versus night differences occurred with clearer water. In the August diel samples with the clearer water, few sturgeon chub were collected during

the daylight and highest collections were between 2100 and 0400 hours. At other times of the year when the turbidity was > 200 NTU, day and night entrainment was similar with slightly higher entrainment rates sometimes at night.

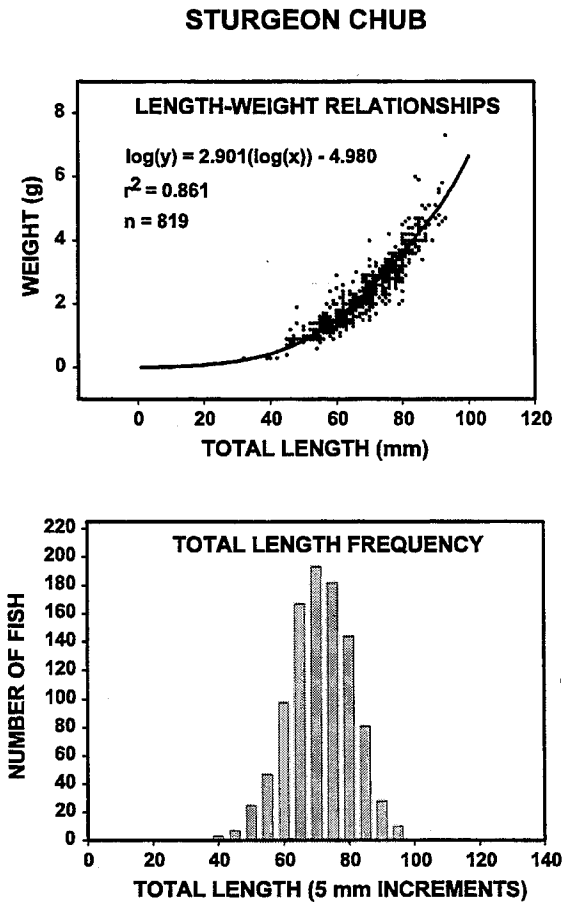


Figure 10 Length-weight relationship and length frequency of sturgeon chub collected in 1997 in the Intake Canal.

Goldeye diel collections had no clear pattern except that lowest rates of collection occurred at night. The greatest number of goldeye were collected in July with the highest daily average entrainment rate of 0.375 fish per acre foot on July 12. Goldeye collected were in a size range between 36-405 mm TL with an average of 309mm TL and

an average weight of 238 grams.

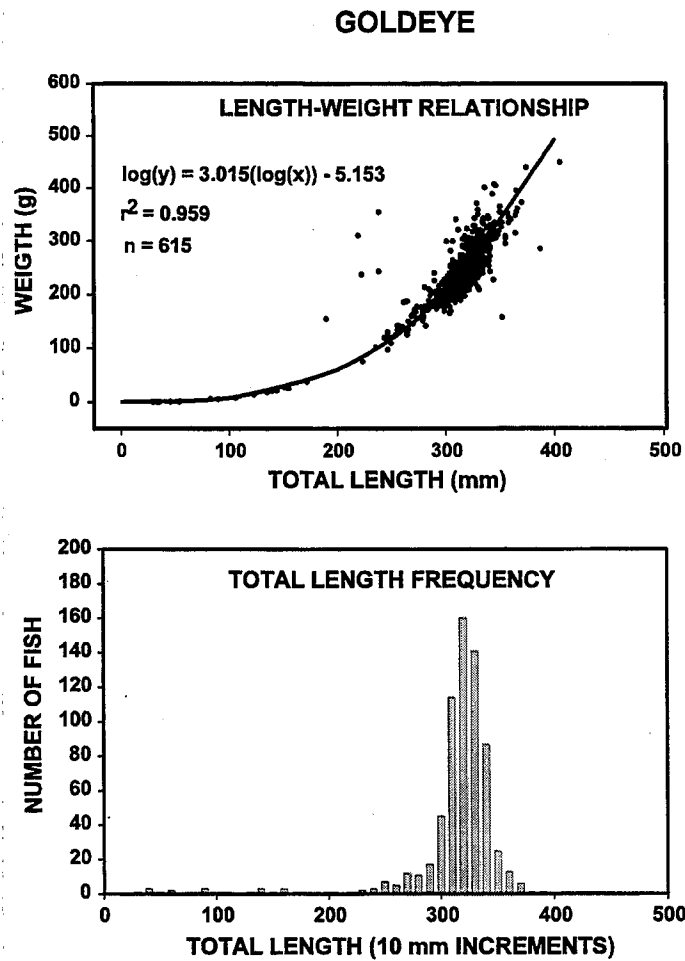


Figure 11 Length-weight relationship and length frequency of goldeye collected in 1997 in the Intake Canal.

Four hundred ninety three sauger were sampled ranging from 42 to 544 mm TL (mean total length = 309 mm). The length-weight relationship ($n=615, r^2 = 0.947$) is shown in Figure 12. Highest rates of collection were in August when water was clearing.

The highest daily average entrainment rate of 0.398 sauger per acre foot occurred on August 19. No definite pattern was noted in diel sampling except highest entrainment occurred at night during August.

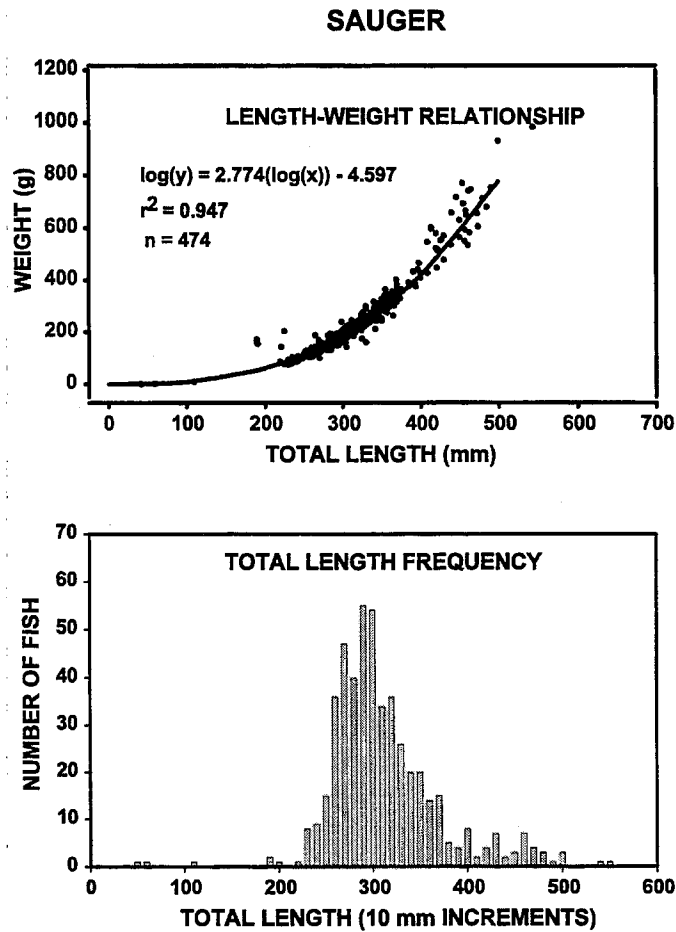


Figure 12 Length-weight relationship and length frequency of sauger collected in 1997 in the Intake Canal.

Longnose dace were collected all season (total= 241) with a peak of 0.116 longnose dace per acre foot on July 11. Longnose dace averaged 67 mm, ranging from 38 to 110 mm TL. A length weight relationship ($r^2 = 0.836$) is calculated and presented in

Figure 13.

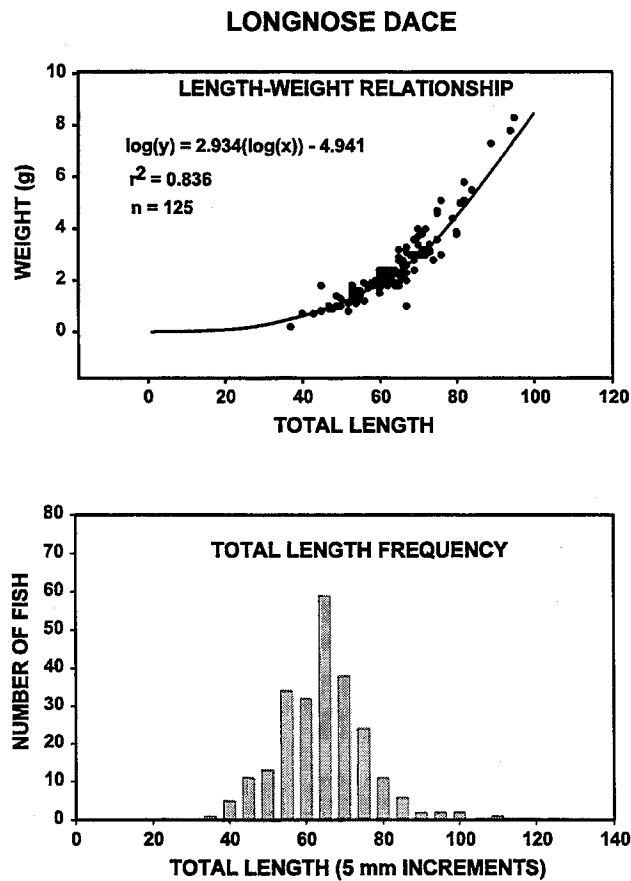


Figure 13 Length-weight relationship and length frequency of longnose dace collected in 1997 in the Intake Canal

Western silvery minnow and eastern plains silvery minnow were lumped into one category (silvery minnows) because they were not identified past Genus, *Hybognathus*. The length-frequency relationship had an $r^2=0.907$ and the length frequency is shown in Figure 14.

SILVERY MINNOWS

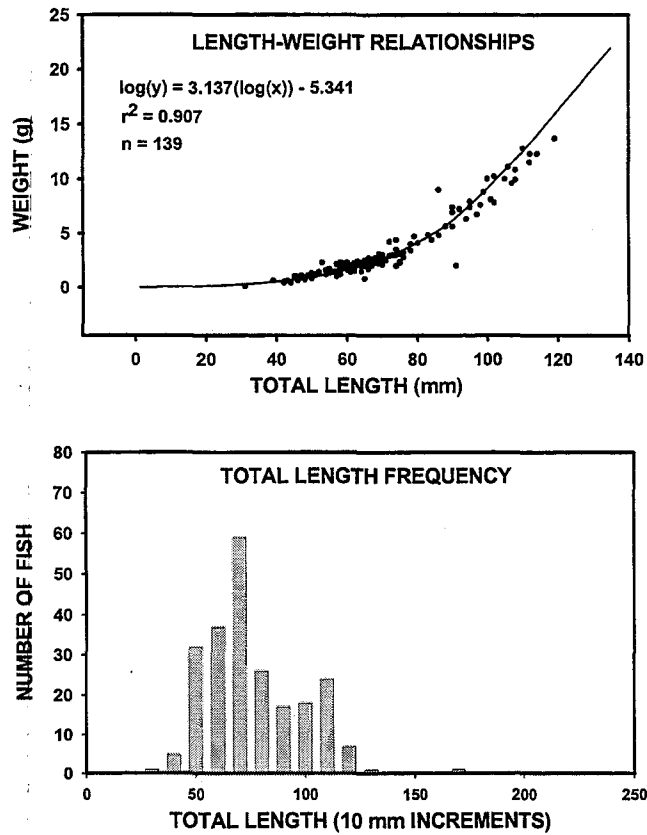


Figure 14 Western Silver Minnow and Eastern Plains Silvery minnow grouped together and their length-weight relationship and length frequency collected in 1997 in the Intake Canal.

Longnose sucker ranged from 45 to 405 mm TL and were more frequently collected earlier in the season from May through July. Figure 15 presents the length-frequency relationship along with the length frequency of longnose sucker.

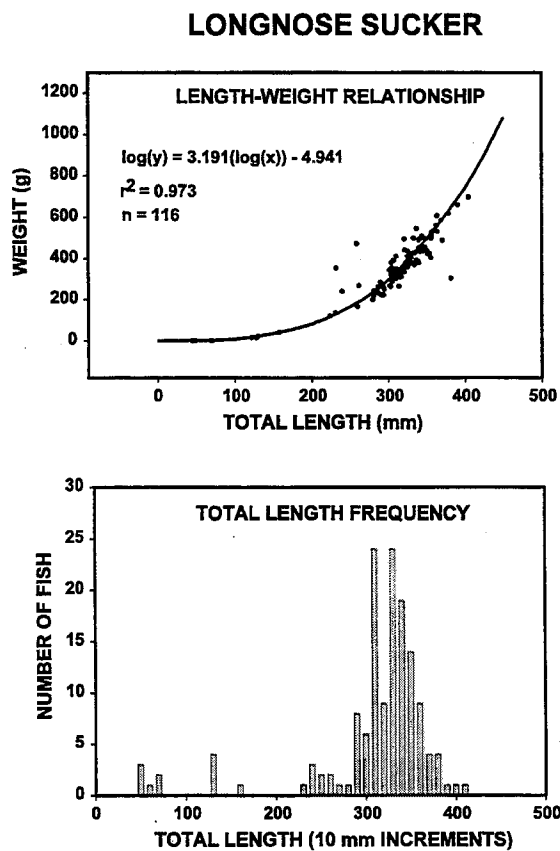


Figure 15 Longnose sucker length-weight relationship and length frequency collected in 1997 in the Intake Canal

Carp were collected in the entrainment nets throughout the season, with largest carp netted 676 mm TL in August. A total of 121 carp were collected with an average weight of .99 Kg. Figure 16 presents carp length-weight relationships.

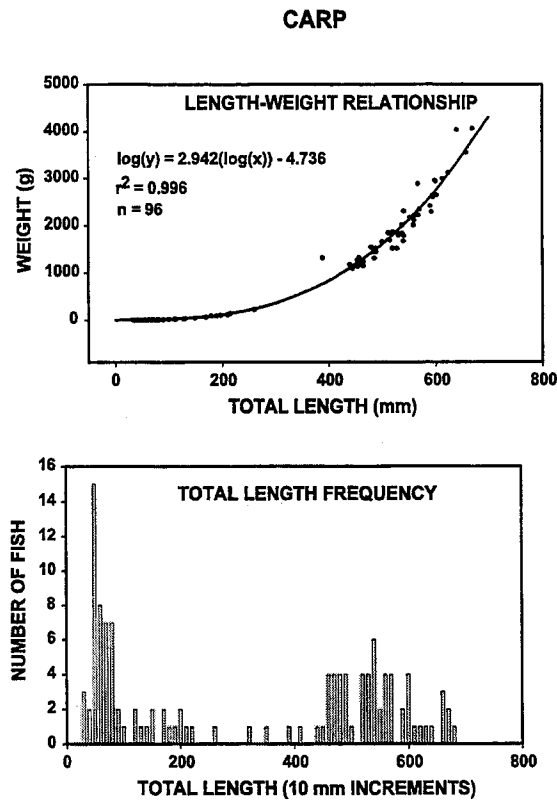


Figure 16 Carp length-weight relationship and length frequency from fish collected in 1997 at the Intake Canal, Montana

Drum were primarily entrained later in the season from mid July through September. Average drum size was 271 mm TL (range = 21 to 446 mm TL). Figure 17 presents drum length-weight relationships.

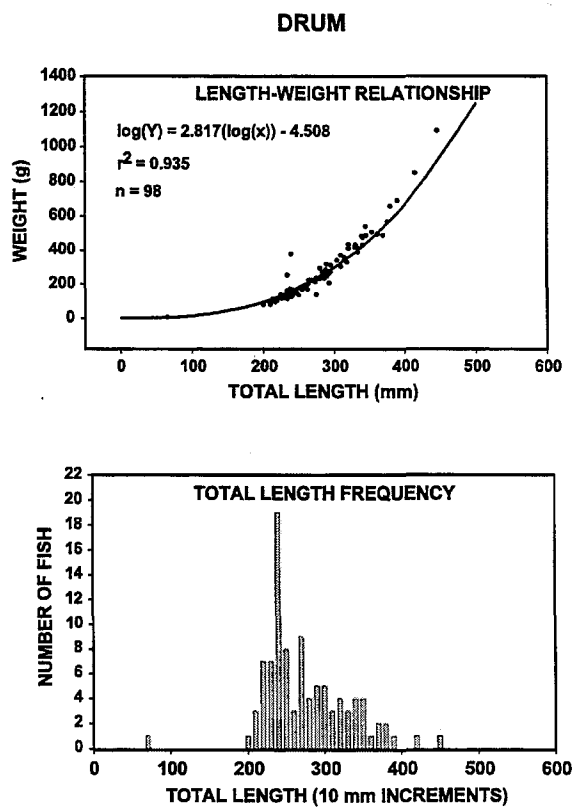


Figure 17 Length-weight relationship and length frequency of drum collected in 1997 in the Intake Canal

Channel catfish were rarely encountered, especially compared to 1996 data, with highest number collected in August. The average channel catfish size entrained was 256 mm TL and 216 grams. Figure 18 presents length-frequency data and the length weight relationships.

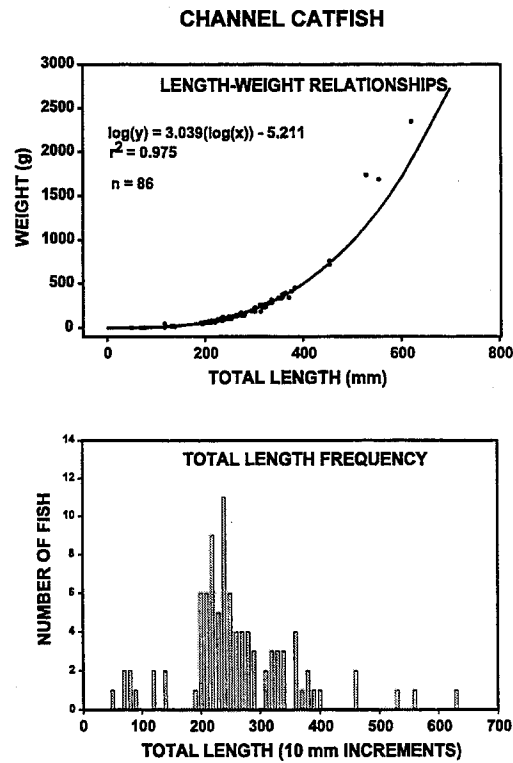


Figure 18 Length weight relationship and length frequency of channel catfish collected in 1997 in the Intake Canal

Bigmouth buffalo were the largest fish entrained, and the largest of these weighed 4.2 Kg. Most of the bigmouth buffalo were collected in July with the highest entrainment rate of 0.041 bigmouth buffalo per acre-foot on July 10.

Few burbot (total = 61) were collected, most were sampled by the furthest downstream net along the face of the headworks. The majority of these fish had tissue samples removed non-lethally for genetic studies by the State of Montana. Fish ranged in size from 80 to 440 mm TL.

River carpsuckers were also relatively rare with 59 collected in 1997. These fish ranged in size from 41 to 527 mm total length. Figure 19 presents the length-weight relationships and length frequency for fish collected in 1997.

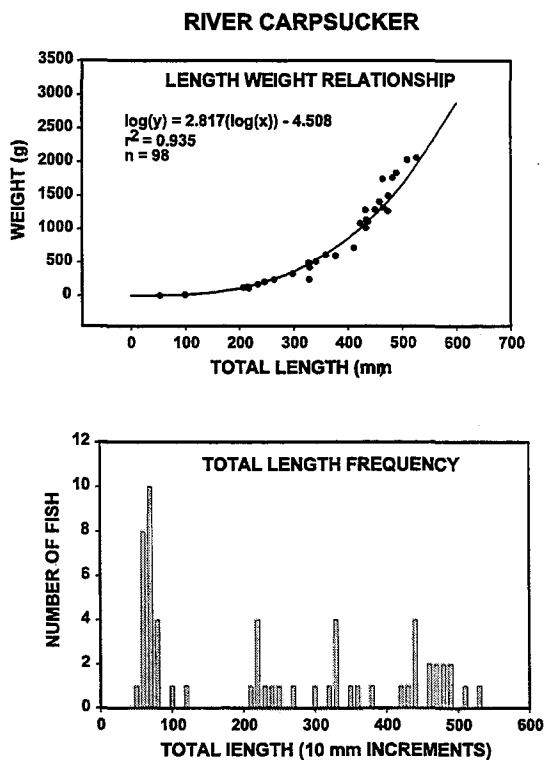


Figure 19 Length-weight relationship and length frequency of river carpsucker collected in 1997 in the Intake Canal

Shovelnose sturgeon were primarily collected later in the irrigation season with the peak collection of sturgeon September 10. All sturgeon collected were released back into the river. The 44 sturgeon collected ranged from 390 to 923 Fork Length (FL) and averaged 850 grams.

All of the blue suckers (total =41) were large (305 to 851 mm TL). This seems to go along with the local trend of only finding larger size fish in sampling from the lower Yellowstone River (pers com, Phil Stewart).

Other species of fish were relatively rare in the entrainment nets. Two sickle fin chub (95 and 100 mm TL), a species of special concern by the State of Montana, were collected on July 13 and July 16, 1997. These fish were released back into the river.

1998 RESULTS

In 1998 entrainment netting, additional emphasis was placed on collection of live sturgeon chub and providing live chub for a reintroduction program. Additionally the sturgeon chub were collected later in the season for use as brood stock in a fish culture program. Data was collected on all species, similar to previous irrigation seasons. A total of 4,391 fish were netted; the species composition was similar to previous years. The noticeable addition to major fish collected was the shovelnose sturgeon, which made up about 8 percent of the entrained fish in 1998.

Very low numbers of paddlefish and cisco were collected for the first time with the entrainment nets in 1998. Figure 20 presents the species composition for 1998. Sauger comprised the larger portion of 1998 total entrainment at 20.3%, followed by stonecat and sturgeon chub. Lower flows in 1998 could have contributed change in species composition. Entrainment rates were determined for each species by month and reported in Table 6.

1998 SPECIES COMPOSITION - LOWER YELLOWSTONE IRRIGATION CANAL

n = 4391 FISH

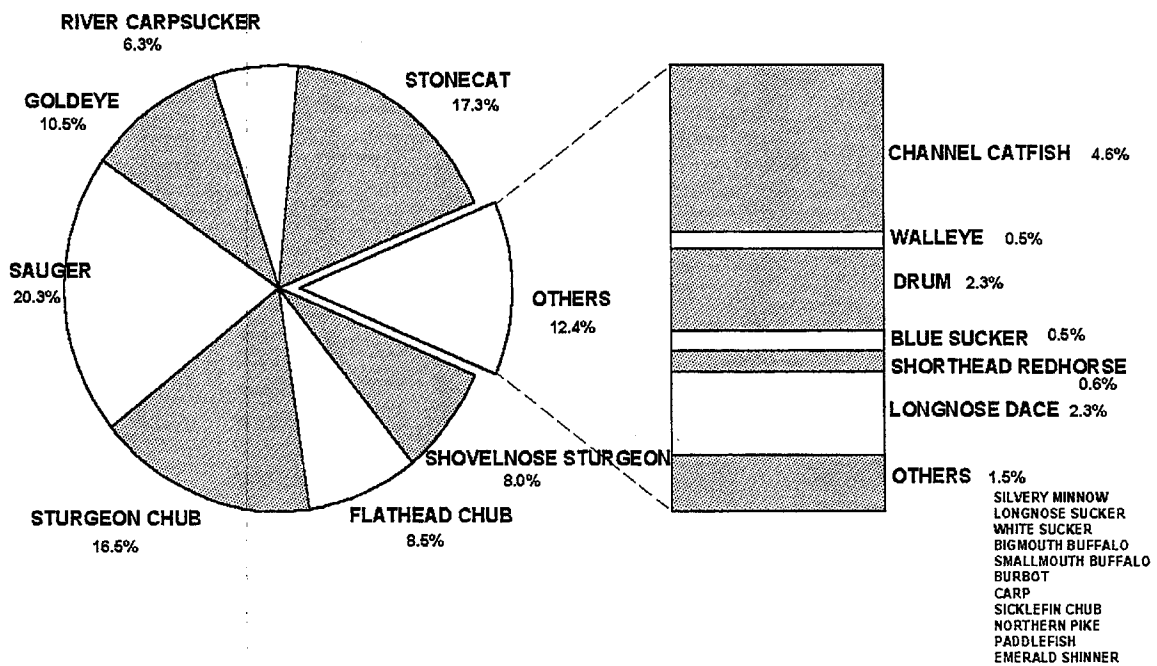


Figure 20 Species composition of the fish collected with entrainment nets at Intake Canal, Montana, 1998.

Table 6 Estimated entrainment rates (fish per acre-foot \pm one standard error of the mean) of all species collected in 1998 at Intake Canal. The last row in this table represents an estimate of the monthly total acre feet passed into the Intake Canal.

Species	June	July	August	September
Stonecat	1.132 (± 0.406)	0.114 (± 0.015)	1.109 (± 0.494)	0.013 (± 0.126)
Flathead chub	0.216 (± 0.069)	0.145 (± 0.045)	0.821 (± 0.332)	0.108 (± 0.108)
Sturgeon chub	0.802 (± 0.336)	0.691 (± 0.268)	0.670 (± 0.168)	0.133 (± 0.101)
Goldeye	0.252 (± 0.103)	0.031 (± 0.007)	0.111 (± 0.047)	0.025 (± 0.025)
Sauger	0.552 (± 0.185)	0.674 (± 0.129)	0.165 (± 0.056)	0.057 (± 0.057)
Longnose Dace	0.045 (± 0.015)	0.270 (± 0.110)	0.048 (± 0.028)	0.005 (± 0.005)
Blue Sucker	0.008 (± 0.004)	0.010 (± 0.006)	0	0
Longnose Sucker	0.008 (± 0.004)	0.007 (± 0.004)	0.008 (± 0.005)	0.002 (± 0.002)
Carp	0.004 (± 0.003)	0.007 (± 0.004)	0.041 (± 0.030)	0
Drum	0.026 (± 0.014)	0.096 (± 0.033)	0.029 (± 0.015)	0.005 (± 0.005)
Channel Catfish	0.137 (± 0.037)	0.166 (± 0.030)	0.444 (± 0.282)	0.121 (± 0.006)
Bigmouth Buffalo	0.008 (± 0.004)	0.002 (± 0.002)	0	0
Burbot	0.011 (± 0.004)	0.001 (± 0.001)	0	0
River Carpsucker	0.143 (± 0.057)	0.072 (± 0.024)	0.043 (± 0.015)	0.016 (± 0.016)
Shovelnose sturgeon	0.009 (± 0.004)	0.028 (± 0.010)	1.223 (± 0.121)	0.317 (± 0.248)
Walleye	0.014 (± 0.006)	0.006 (± 0.004)	0	0
White Sucker	0.001 (± 0.001)	0.001 (± 0.001)	0	0
Shorthead Redhorse	0.012 (± 0.005)	0.008 (± 0.005)	0.010 (± 0.005)	0.002 (± 0.002)
Emerald Shiner	0	0.002 (± 0.002)	0.007 (± 0.004)	0.004 (± 0.004)
Brassy Minnow	0.007 (± 0.007)	0	0	0
Paddlefish	0	0.014 (± 0.006)	0	0

Species	June	July	August	September
Western Silvery Minnow	0.003(\pm 0.003)	0.004(\pm 0.002)	0	0.002(\pm 0.002)
Flathead Minnow	0.003(\pm 0.003)	0	0	0
Smallmouth Buffalo	0.0004 (\pm 0.0004)	0 0.007(\pm 0.004)	0	0
Northern pike	0.003(\pm 0.002)	0	0.002(\pm 0.002)	0.004(\pm .004)
Cisco	0.0009 (\pm 0.0009)	0	0	0
Sicklefin Chub	0.0007(\pm 0.0007)	0	0	0
Black Bullhead	0.0004 (\pm 0.0004)	0	0	0
Total Fish	3.394(\pm 0.949)	2.354(\pm 0.248)	4.735(\pm 1.319)	0.927(\pm 0.699)
Monthly Estimated acre-feet	64538	75755	77105	51090

In 1998 the nets were operated day and night and live collection of sturgeon chub was performed with more frequent retrieval of nets and the special cod end live cars. When operating the nets day and night, strong diel differences were observed for certain species. Figure 21 presents the day and night species composition during June, 1998. In June many more stonecat and sturgeon chub were collected at night, where as sauger and goldeye were more common during the day.

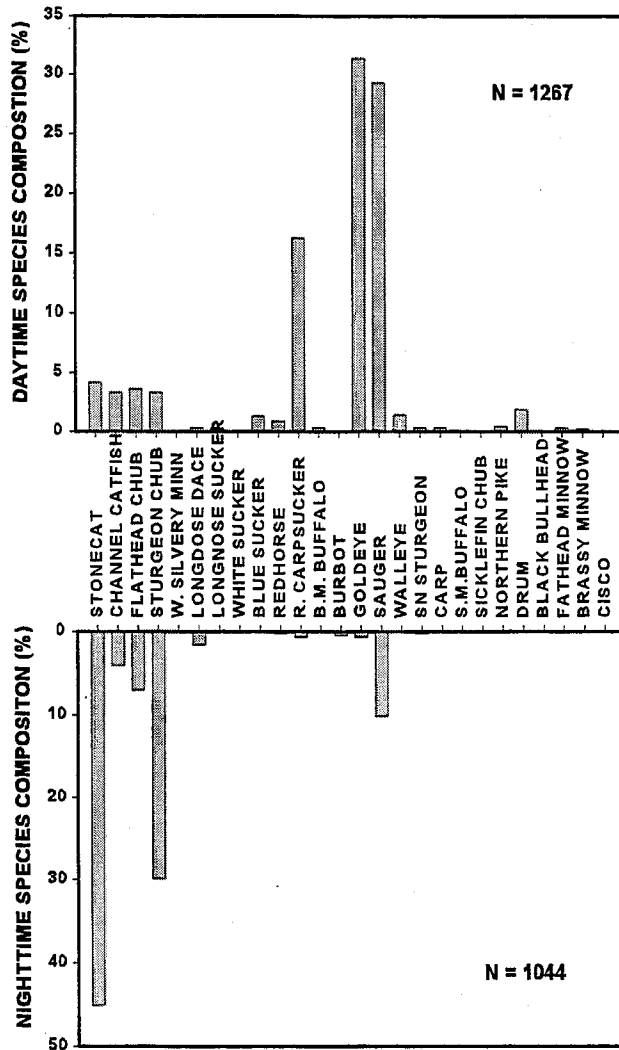
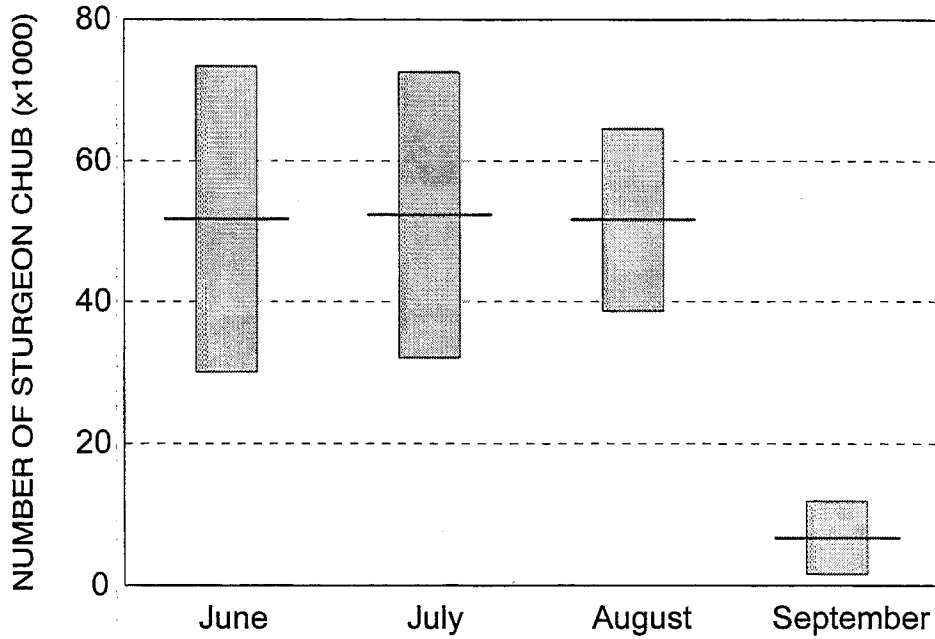


Figure 21 The relative percentage of fish collected by night and day from June 1998 in the Intake Canal, Montana.

Detailed analysis of sturgeon chub entrainment in 1998 shows highest entrainment

rates in June and similar but lower rates in July and August. Figure 22 presents extrapolated estimates of entrained sturgeon chub per month.

Sauger are the most popular sport fish in the Intake Canal and appeared to be entrained in high numbers in 1998. The entrainment rates for sauger were highest in July (.674 fish per acre foot). Figure 23 presents an estimate of sauger entrained per month. These values are extrapolated estimates from averaged monthly rates and the water volumes in the canal.



1998 MONTHLY TOTAL STURGEON CHUB ENTRAINMENT

Figure 22 Estimated total numbers of sturgeon chub entrained by month over the 1998 irrigation year. Error bars are one standard error of the mean.

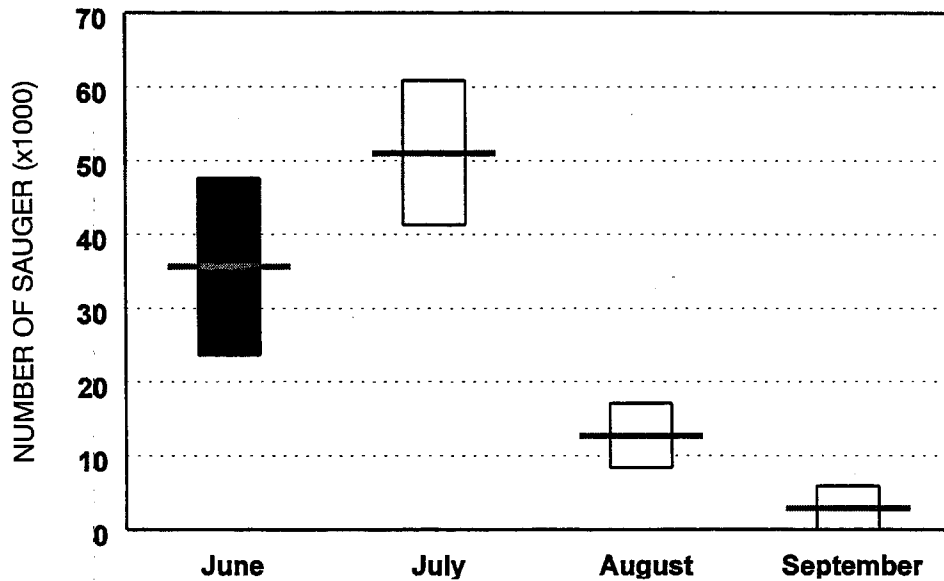


Figure 23 Estimated total numbers of sauger entrained by month over the 1998 irrigation year. Error bars are one standard error of the mean.

Discussion

Fish are entrained into the Intake Canal over the irrigation season. The significance of fish loss from natural streams to irrigation diversions has been recognized since the early 1920s (Prince 1922). Seasonal variations in species entrainment rates possibly can be explained by movements of fish up and down stream through the Intake Diversion dam area. Three species, stonecat, flathead chub and sturgeon chub were the most frequently entrained fish. These and other species entrained in higher numbers, show diel trends during seasons and over the crepuscular periods.

Fish moving up and down the Yellowstone River along the shore are most susceptible to entrainment. In general, larger numbers of fish were collected from the net most downstream (furthest east Intake sluice), suggesting fish moving upstream along the river edge are entrained once they pass over the top of the rock dam (Intake Diversion Dam). Intake headworks is positioned on the outside of a river bend nearest to the thalweg, possibly affecting fish response to Intake entrainment flows. Fish may react differently if the Intake was positioned on an inside bend or straight river run. The condition of fish netted was generally good. Fish condition decreased with greater length of time in the entrainment nets and increased debris loads. As the study progressed, better cod ends were designed to improve the survival and condition of fish entrained and collected.

Figure 24 presents monthly total fish entrainment estimates based on the daily average rates multiplied by the monthly total acre feet passing into the canal for 1996 and 1997. Differences between total entrainment in these two years is significant only in the June estimates. This is probably due to several factors. In 1996, two nets were fished and used for entrainment information, whereas four were used in 1997. Fish entering the canal were not evenly distributed across the sluice openings and possibly extrapolating data from only two nets inflated estimates because more numbers of fish passed through those nets in the spring. This was demonstrated in 1997 when collections from four nets were compared. The most eastern net (most downstream with relation to the river) generally collected the most fish.

The more likely reason for the difference between years was 1997 was a relatively high

water year than 1996. Several factors could be affecting entrainment with high water and will be elaborated later in this section. In examining the Yellowstone River discharge, the greatest difference between the two years was in the peak period, primarily during June.

Monthly Total Estimated Fish Entrainment Intake Canal, Montana

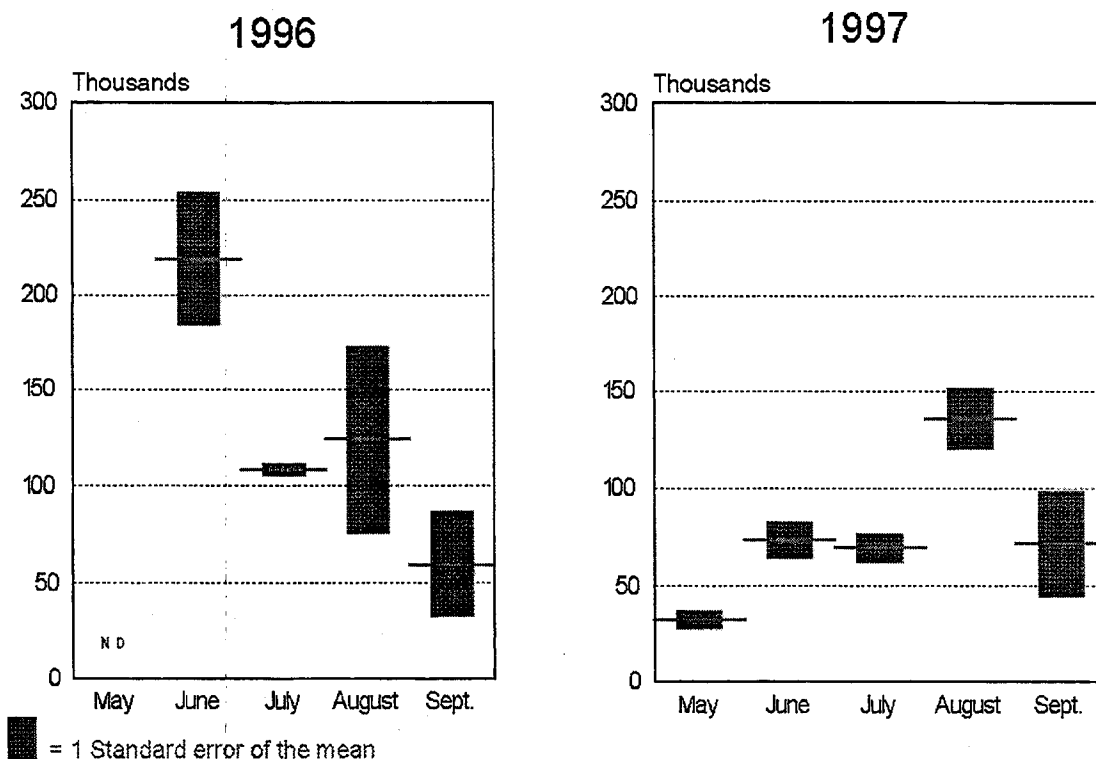


Figure 24 Total fish entrainment estimates for 1996 and 1997 calculated monthly from averaged daily entrainment rates and canal flows. ND = No data

Total fish entrainment for 1998 was higher than 1996 or 1997, and the flows in the Yellowstone River were lower. Highest total fish entrainment was in August, similar to the previous year. The August high monthly average rate of total fish entrained was 4.735 (± 1.319)

fish per acre foot of inflow water. In September the lowest number were entrained. Figure 25 presents the relative levels and estimates of total fish entrained per month from June to September 1998. Total fish entrained was twice that of 1997.

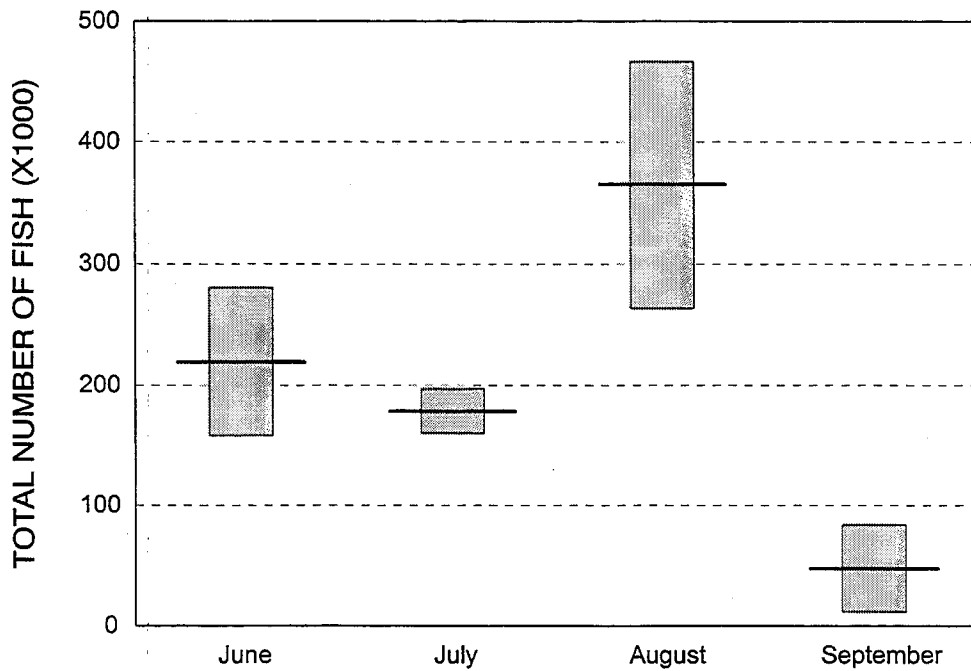


Figure 25 Total fish entrainment estimates for 1998 calculated monthly from averaged daily entrainment rates and Intake canal flows. Error bars are \pm one standard error of the mean.

Fish Entrainment and Yellowstone River Flows

The river flows over four irrigation seasons (includes 1999) and the four years average entrainment were examined for a relationship that could be used to reliably predict entrainment

rates. From May 15 to September 30, the daily average flow in the Yellowstone River and the average fish entrained per acre foot each year were compared in regression analysis. Figure 26 presents the daily average flows during this period in 1996 -1999, and shows the wide range of flows occurring over the four years during the irrigation season.

FLOWS IN THE YELLOWSTONE RIVER USGS GAGING STATION, SIDNEY, MT 1996 - 1999

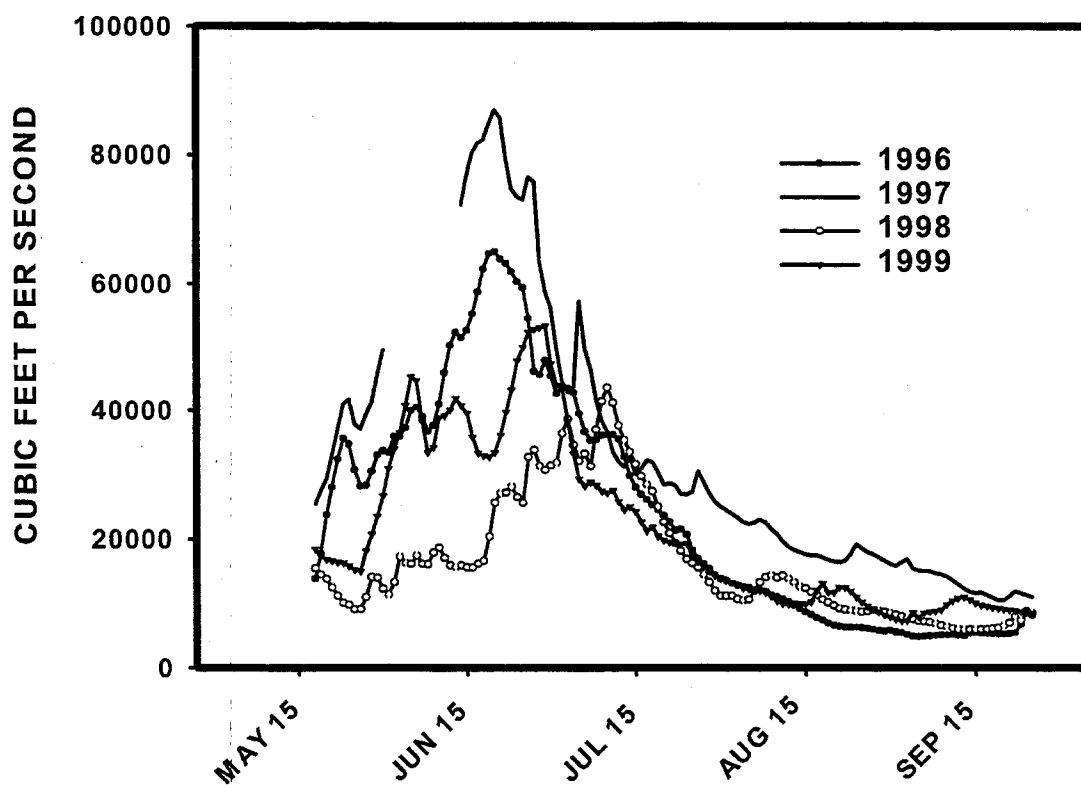


Figure 26 Daily Yellowstone River flows at the Sidney, Montana monitoring gauge from May 15 to September 30 in 1996, 1997, 1998, and 1999.

The data associated with the average Yellowstone River flow per irrigation season in the relation to the average total fish entrainment rates (fish per acre foot) are shown in Figure 27. A surprisingly strong negative relationship ($r^2=0.987$) was found. In general, during years of lower

Yellowstone River flows more fish are entrained at Intake Canal. Several factors could help to explain the relationship including: 1) lower densities of fish exposed to the Intake with higher flows (similar to a dilution), 2) the greater velocity sluice flows swept fish past the Intake at higher flows, 3) the increased river depth at high flow, and 4) the concentration of woody debris at the Intake canal entrance during high flows that could function as a screen of sorts. With the high predictability of this relationship (Figure 27), we could reliably estimate entrained fish using the river flows averaged over the irrigation season. If flows were greater or less than those observed in this four year period, estimates of entrained fish would less reliable.

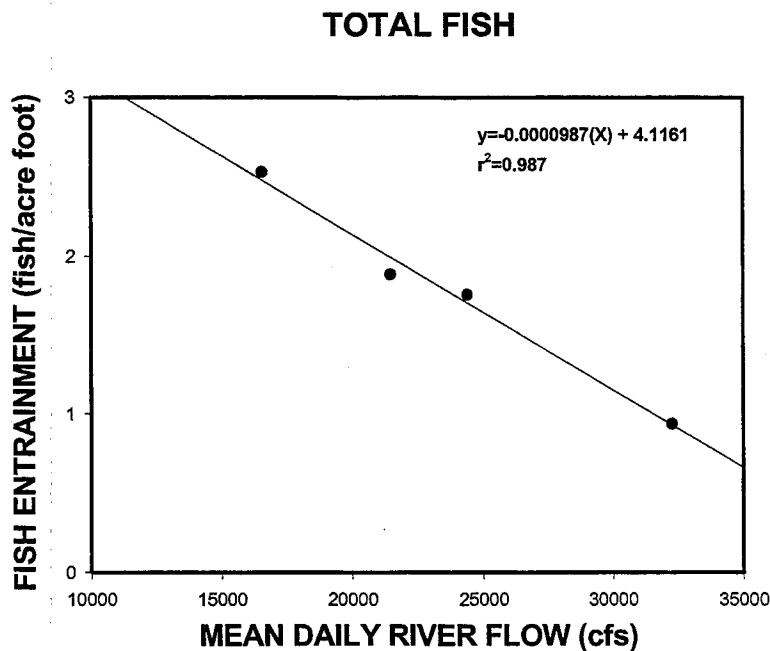


Figure 27 The relationship between the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total fish entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999.

The relationship between flow and sturgeon chub entrainment was analyzed (Figure 28), and again a relatively strong negative relationship ($r^2=.907$) occurred over the irrigation season. The r^2 indicates that 90 percent of the variation in the entrainment rates could be explained by

and related to the flows in the Yellowstone River .

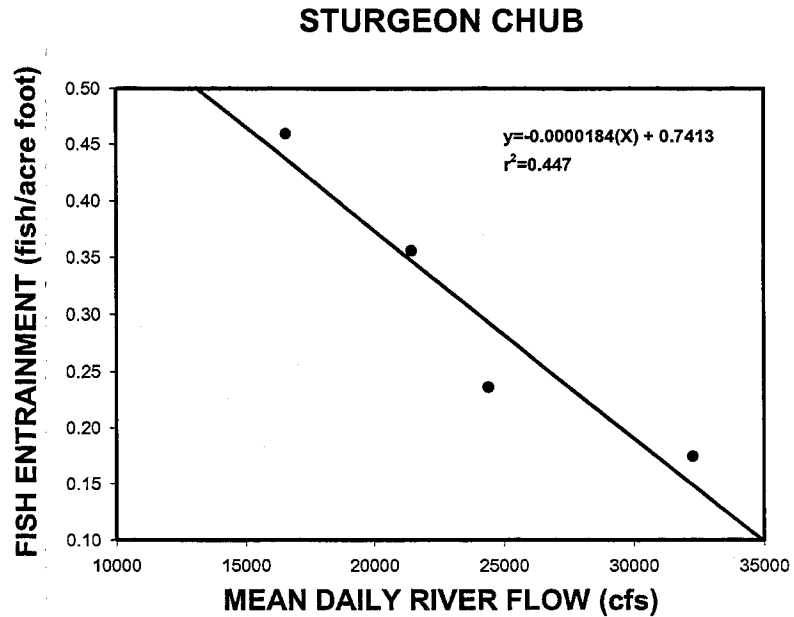


Figure 28 The relationship between the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total sturgeon chub entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999.

The sauger entrainment and river flow relationship was similarly analyzed and is presented in Figure 29. Sauger entrainment and river flow are less closely related than as the sturgeon chub . The lower entrainment of sauger in 1999 may be partially explained by an overall trend in the population noted in the Yellowstone River (Phil Stewart, pers com). The r^2 of 0.447 indicates a portion of the sauger entrainment could be explained by the Yellowstone flow.

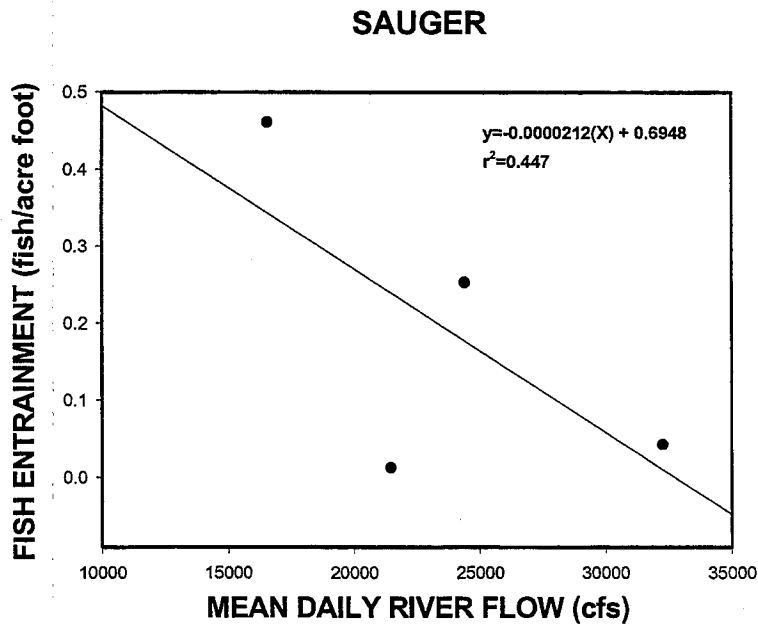


Figure 29 The relationship of the average daily Yellowstone River flows (Sidney gauge) each year and the corresponding average total sauger entrainment rate at the Intake Canal from May 15 to September 15 for 1996, 1997, 1998, and 1999.

Fish Entrainment Reduction

Fish entrainment could be reduced by constructing a barrier device on the face of the diversion which keep fish out of the canal, or a diverter which allows entrainment into the canal and then returns a portion of the water and fish to the river through a side channel. The most practical solution is screening fish at the face of the diversion because fish are not exposed to within canal predators or impingement at debris screens down canal. Fish kept in the river can pass upstream past the diversion to spawning or feeding areas.

A conventional in-canal screen, such as a rotating drum screen, and by-pass system would return entrained fish downstream of the headworks. Fish moving upstream would have to renegotiate the canal headworks again and if entrained again the fish may be trapped in a cycle with little potential to get upstream past the Intake Canal. Bakes et al.(1998) has noted fish need use of the entire river, up and downstream of a diversion on a tributary of the Yellowstone River.

A removable screen system installed in the river at the headworks would allow operation during the irrigation season and its removal during the winter would eliminate ice damage and facilitate its maintenance. National Marine Fisheries Service (NMFS, 1995) has required approach velocity criteria at screens for salmon in California from 0.5 to 0.2 feet per second. Target species, size and other data should be included in the designs of any entrainment reduction devices at Intake Canal. Additional screening criteria and design concepts can be found in Bell, 1991.

A large angler presence is seen in the canal near the headworks and fishing appears good. The in-canal screening technique would allow anglers to catch fish near the diversion but entrained fish would not be stranded in fields or in the canal when drained. Screening placed in the canal would not need to be removed and reinstalled every season to prevent ice damage, but would present a challenge to return screened fish to the river with a bypass system.

Relocating the canal intake area away from the shore toward the center of the river could reduce entrainment. Fish generally moving up or down along the river margin would be less likely to encounter these entrainment canal flows. Louvers and positive barrier screens placed either at the Intake mouth or within the canal would also reduce entrainment.

Operation modifications to reduce entrainment might work for species with large differences in day and night entrainment. Unfortunately, reducing nighttime irrigation flows might cause higher daytime flows encouraging greater numbers of daytime entrained fish. Other operational fish entrainment reduction techniques could include reducing the flows into the Intake Canal and maintaining the first six miles of canal at a shallower depth or shutting the canal off

during periods of no irrigation demand. As well, there are possibly opportunities to use behavioral techniques such as sound, lights, or electricity to guide fish away from the present situation. With any fish technique to reduce entrainment, rigorous evaluation should be incorporated to ensure the barrier works.

Because sturgeon chub are proposed for listing, designing a system to prevent this species' entrainment could be emphasized. A screen system designed for this relatively small species will probably be very effective in reducing entrainment of most all the other species found in the Lower Yellowstone River.

Liston et al. (1991) presents several options and associated costs for a variety of barrier designs on the Tongue River near Miles City, Montana. The sizing techniques and operations could be used to design a screen or louver at Intake Canal. Specific fish species may need to be "targeted" for screening, and these could be used when developing criteria and beginning planning for future modifications at Intake Canal.

ACKNOWLEDGMENTS

We would like to express sincere appreciation to Jerry Nypen and his crew from the Lower Yellowstone Irrigation Project who greatly assisted in setting up the collection system and operated the gates in a very timely manner. Dr. Dennis Scarnecchia, University of Idaho, and his capable assistants were valuable in operating the nets when we were engaged elsewhere. We greatly appreciated Wade King, USFWS, and his tremendous efforts and help in collecting and coordination of the sturgeon chub recovery program. The Bureau's Montana Area Office provided major funding for this program.

Sadly, Tom Parks, a co-author, naturalist, and great friend passed away while working on this study. This report is dedicated to his memory and his continued presence, in spirit, for the fishery resources.

LITERATURE CITED

- Bakes, K.M., V. Riggs, and D. Peters. 1998. Tongue River Entrainment Study on the T&Y Canal, May 29 to October 10, 1997. Montana Fish Wildlife and Parks, Region 7, Miles City, Montana. 16 pages
- Bell, M.C. 1990. Fisheries Handbook of Engineering and Biological Criteria, Fish Passage Development and Evaluation program, Corps of Engineers, North Pacific Division, Portland, Oregon.
- Helfrich, L.A., C.Liston, S.Hiebert, M.Albers, and K. Frazier. 1999. Influence of Low-head Diversion Dams on Fish Passage, Community Composition, and Abundance in the Yellowstone River, Montana. *Rivers* 7 (1): 21-32.
- Liston, C.L., P. Johnson, B.Mefford, and D. Robinson. 1994. Fish Passage and Protection Considerations for the Tongue River , Montana, In association with the Tongue River Dam Rehabilitation Project. Dept. of Interior Memorandum, US Bureau of Reclamation, Technical Services Center, Denver, Colorado. 81 pages.
- National Marine Fisheries Service. Revised Juvenile Fish Screening Criteria. March 2, 1995.
- Prince, E.E. 1922. Irrigation canals as an aid to fisheries development in the West. Transactions of the American Fisheries Society 52:157-165.

APPENDIX

A

**APPENDIX
B**

**APPENDIX
C**

1998

START	STOP	DURATION NET	GATE OPENING	TOTAL GATES	CANAL FLOW CFS	CFS/NET	CF SAMPLE	ACREFT SAMPLE	SCT ACFT	CCT ACFT	FHC ACFT	SCH ACFT	WSM ACFT	LND ACFT	LNS ACFT	WSU ACFT	BSU ACFT	RED ACFT	RCS ACFT	BMB ACFT	BBT ACFT	GE ACFT	SGR ACFT	WE ACFT	SNS ACFT	CAR ACFT	SMB ACFT	SICKLEFIN NP ACFT	DRUM ACFT	PAD ACFT	EMS ACFT	FHM ACFT	BBH ACFT	CISCO ACFT	BRASSY ACFT	TOTAL ACFT			
06/09/98	805	905	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.283594	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.283594		
06/09/98	810	910	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.141797	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	840	940	60 YE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.141797	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	910	1010	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.141797	0	0	0	0.141797	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797	
06/09/98	915	1015	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.283594		
06/09/98	945	1045	60 YE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.141797	0	0	0	0.425391	0.141797	0	0	0	0	0	0	0	0	0	0	0	0	0	0.708984
06/09/98	1015	1115	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	1020	1120	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
06/09/98	1050	1205	75 YE	0.3125	4.6875	1280	85.33333	384000	8.815427	0	0	0	0	0	0	0	0	0	0	0.113438	0	0	0	0.113438	0	0	0	0	0	0	0	0	0	0	0	0	0	0.340313	
06/09/98	1120	1225	65 BE	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0.130889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.261779		
06/09/98	1125	1230	65 YW	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0.130889	0	0	0	0.261779	0	0	0	0	0	0	0	0	0	0	0	0	0	0.523558	
06/09/98	1210	1310	90 YE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0.141797	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	1230	1330	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
06/09/98	1235	1335	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
06/09/98	1345	1445	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
06/09/98	1340	1440	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
06/09/98	1315	1425	65 YE	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	1405	1505	60 BW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.261779		
06/09/98	1445	1545	60 BE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.425391		
06/09/98	1450	1550	60 YW	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.141797		
06/09/98	1425	1525	60 YE	0.3125	4.6875	1280	85.33333	307200	7.052342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.425391		
06/09/98	1510	1615	65 BW	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.352658		
06/09/98	1600	1705	65 BW	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.352658		
06/09/98	1555	1700	65 YW	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.352658		
06/09/98	1550	1700	70 BE	0.3125	4.6875	1280	85.33333	358400	8.227732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.130889		
06/09/98	1530	1640	70 YE	0.3125	4.6875	1280	85.33333	358400	8.227732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.130889		
06/09/98	1835	1945	70 YW	0.3125	4.6875	1280	85.33333	358400	8.227732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.130889		
06/09/98	1830	1935	65 BE	0.3125	4.6875	1280	85.33333	332800	7.640037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.130889		
06/10/98	740	840	60 BW	0.3125	4.6875	1250	83.33333	300000	6.887052	0.1452	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4356	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	740	840	60 YW	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1452	0.2904	0	0	0	0	0	0	0	0	0	0	0	0	0.5808
06/10/98	735	835	60 BE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	730	830	60 YE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	850	950	60 BW	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	845	945	60 YW	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	835	935	60 BE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	830	930	60 YE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5808	
06/10/98	955	1050	55 BW	0.3125	4.6875	1250	83.33333	275000	6.313131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.726	
06/10/98	950	1045	55 YW	0.3125	4.6875	1250	83.33333	275000	6.313131	0.1584	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9504	
06/10/98	940	1040	60 BE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1584	
06/10/98	935	1035	60 YE	0.3125	4.6875	1250	83.33333	300000	6.887052	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1584	
06/10/98	1055	1150	55 BW	0.3125	4.6875	1250	83.33333	275000	6.313131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1452	
06/10/98	1050	1150																																					

1490

2

START	STOP	DURATION NET	GATE OPENING	TOTAL GATES	CANAL FLOW CFS	CFS/NET	CF SAMPLE	ACREFT SAMPLE	SCT ACFT	CCT ACFT	FHC ACFT	SCH ACFT	WSM ACFT	LND ACFT	LNS ACFT	WSU ACFT	BSU ACFT	RED ACFT	RCS ACFT	BMB ACFT	BBT ACFT	GE ACFT	SGR ACFT	WE ACFT	SNS ACFT	CAR ACFT	SMB ACFT	SICKLEFIN NP ACFT	DRUM ACFT	PAD ACFT	EMS ACFT	FHM ACFT	BBH ACFT	CISCO ACFT	BRASSY ACFT	TOTAL ACFT				
06/12/98	2210	2245	35 BE	0.3125	4.4375	1186	83.52113	175394.4	4.026501	9.66583	0	0.496709	3.22861	0	0.248355	0	0	0	0	0	0	0	0	0	0.745064	0	0	0	0	0	0	0	0	0	0	14.40457				
06/12/98	2145	2330	45 YE	0.3125	4.4375	1186	83.52113	225507	5.176929	5.408612	0.772659	0.965823	5.022282	0	0.386329	0	0	0	0	0	0	0	0	0	0.193165	0	0	0	0	0	0	0	0	0	0	0	14.87368			
06/12/98	2240	2310	30 YE	0.3125	4.4375	1186	83.52113	150338	3.451286	9.8514	0.869241	0.579494	3.187218	0	0.289747	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.80533			
06/13/98	2020	2100	40 BE	0.3125	4.4375	1133	79.78873	191493	4.396073	0	0.227476	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.047282			
06/13/98	2000	2045	45 YE	0.3125	4.4375	1133	79.78873	215429.6	4.945583	0.202201	0	0.202201	0.808803	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.26822			
06/13/98	2110	2155	35 BE	0.3125	4.4375	1133	79.78873	167556.3	3.846564	1.039889	0	0.519945	5.189445	0	0.519945	0	0	0	0	0	0	0	0	0	0	0.259972	0	0	0	0	0	0	0	0	0	0	0	8.878945		
06/13/98	2050	2130	40 YE	0.3125	4.4375	1133	79.78873	191493	4.396073	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.412136			
06/13/98	2140	2240	60 YE	0.3125	4.4375	1133	79.78873	287239.4	6.59411	6.824272	0	0.454951	5.459417	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.25515			
06/13/98	2210	2310	60 BE	0.3125	4.4375	1133	79.78873	287239.4	6.59411	7.885825	0	0.15165	0.303301	0	0	0	0	0	0	0	0	0	0	0	0.15165	0	0	0	0	0	0	0	0	0	0	0	0	11.67709		
06/13/98	2245	2345	60 YE	0.3125	4.4375	1133	79.78873	287239.4	6.59411	5.459417	0.15165	0.758252	3.791262	0	0.303301	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.22214		
06/14/98	2120	2200	50 BE	0.3125	3.75	1085	90.41667	271250	6.227043	3.854157	0.16059	0.642359	1.605899	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.065954		
06/14/98	2110	2155	45 YE	0.3125	3.75	1085	90.41667	244125	5.604339	5.174562	0.178433	0.5353	6.066728	0	0.178433	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.20406		
06/14/98	2210	2300	50 BE	0.3125	3.75	1085	90.41667	271250	6.227043	1.605899	0.16059	0.642359	0.963539	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.854157		
06/14/98	2200	2245	45 YE	0.3125	3.75	1085	90.41667	244125	5.604339	2.490065	0.178433	1.070599	4.639263	0	0.356866	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.100092		
06/14/98	2315	2415	60 BE	0.3125	3.75	1085	90.41667	325500	7.472452	2.007373	0.25765	0	0.133825	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.510323		
06/14/98	2300	2400	60 YE	0.3125	3.75	1085	90.41667	325500	7.472452	2.275023	0.25765	0.669124	0.802949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.219171		
06/15/98	2035	2145	50 YW	0.3125	3.75	1085	90.41667	271250	6.227043	1.124129	0.32118	0.16059	0.16059	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.766488		
06/15/98	2030	2130	60 BE	0.3125	3.75	1085	90.41667	325500	7.472452	0	0.5353	1.739724	0	0	0	0	0	0	0	0	0	0	0	0	0	0.133825	0	0	0	0	0	0	0	0	0	0	0	0	0	2.810323
06/15/98	2030	2125	55 YE	0.3125	3.75	1085	90.41667	298375	6.849747	0.437972	0	0.729954	0	0	0.145991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.481843		
06/15/98	2150	2255	65 YW	0.3125	3.75	1085	90.41667	352625	8.095156	0.247061	0.247061	0.123531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.817653		
06/15/98	2140	2240	60 BE	0.3125	3.75	1085	90.41667	325500	7.472452	3.345622	0.133825	0.802949	1.070599	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.74447		
06/15/98	2130	2230	60 YE	0.3125	3.75	1085	90.41667	325500	7.472452	1.873548	0.26765	0.401475	2.141198	0	0.26765	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.352995		
06/15/98	2255	2350	55 BE	0.3125	3.75	1085	90.41667	298375	6.849747	3.357788	0.291982	0.145991	1.459908	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.256688		
06/15/98	2245	2340	55 YE	0.3125	3.75	1085	90.41667	298375	6.849747	3.941751	0.167926	1.313917	0	0	0.145991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.44553		
06/16/98	1430	1535	65 BE	0.3125	3.5	1133	101.1607	394526.8	9.057089	0.62465	0.220822	0.220822	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.110411	0	0	0	0	0	0	0	0	0	0	0	1.656161	
06/16/98	1420	1520	60 YE	0.3125	3.5	1133	101.1607	364178.6	8.36039	0.119512	0.119512	0	0.478447	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.794175		
06/16/98	1540	1640	60 BE	0.3125	3.5	1133	101.1607	364178.6	8.36039	0.232323	0.119512	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.239223		
06/16/98	1550	1650	60 YW	0.3125	3.5	1133	101.1607	364178.6	8.36039	0.232323	0.119512	0.358835	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.956883		
06/17/98	925	1025	60 BE	0.3125	3.25	1108	106.5385	383538.5	8.804832	0.340722	0	0.113574	0	0	0.113574	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.795018		
06/17/98	930	1030	60 YW	0.3125	3.25	1108	106.5385	383538.5	8.804832	0.681444	0	0.227148	0.227148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.590036		
06/17/98	1035	1135	60 BE	0.3125	3.25	1108	106.5385	383538.5	8.804832	0	0	0	0	0	0.113574	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.340722		
06/17/98	1040	1140	60 YW	0.3125	3.25	1108	106.5385	383538.5	8.804832	0.454296	0	0.113574	0	0	0	0.113574	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.908592		
07/21/98	2130	2230	60 YW	0.3125	5.375	1280	74.4186	267907	6.150298	0.162594	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.650375		
07/21/98	2130	2230	60 BE	0.3125	5.375	1280	74.4186	267907	6.150298	0	0.650375	0	0	0	0	0																								

