RECLAMATION
Managing Water in the West

Technical Memorandum

Lower Yellowstone Project Larval Fish Entrainment 2017

Technical Memorandum – ENV-2019-030

U.S. Department of the Interior

Bureau of Reclamation
Technical Service Center
Denver, Colorado

January 2018

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Technical Memorandum

Lower Yellowstone Project Larval Fish Entrainment 2017

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List of Acronyms/Abbreviation

Acronym/Abbreviation	*Description*
Ac-ft	Acre-foot/acre-feet
Ac-ft/s	Acre-foot/acre-feet/second
Ac-ft/day	Acre-foot/acre-feet/day
ACOE	U.S. Army Corps of Engineers
cfs	Cubic-feet-per-second
cm	Centimeter
larvae/ac-ft	Fish larvae/Acre-foot (feet)
eggs/ac-ft	Fish eggs/Acre-foot (feet)
larvae/ m^3	Fish larvae/Cubic-meter(s)
eggs/ m^3	Fish eggs/Cubic-meter(s)
ft	Foot/feet
ft^3	Cubic-feet
ft^3/s	Cubic-feet-per-second
kg	Kilogram
km	Kilometer(s)
Hr/Hrs	Hour/Hours
LYP	Lower Yellowstone Project
m^3	Cubic meter(s)
m^3/s	Cubic-meter-per-second
m	Meter(s)
min	Minute(s)
mm	Millimeter
rkm	River kilometers
SD	Standard Deviation
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Service

Executive Summary

Researchers examined larval fish entrainment into the Lower Yellowstone Project Main Canal, northeast of Glendive, Montana, during the 2017 irrigation season. As part of an overall retrofit of the Lower Yellowstone Project, the headworks structure for the Main Canal was replaced in 2012 with new headworks and drum screens. The drum screens which have a maximum mesh slot size of 1.75 millimeters are designed to keep fish larger than 40 millimeters out of the canal. In partial fulfillment of the Biological Opinion (FWS 2016) for the continued operation of the Lower Yellowstone Project, Reclamation was tasked with evaluating the entrainment rates of endangered fish into the Main Canal with the new fish screens in place. The objective of the study is to document and determine entrainment rates of the egg and larval life stages of Pallid Sturgeon (*Scaphirhynchus albus*) into the Main Canal.

Larval fish sampling efforts were focused on times when sturgeon were likely to be breeding and began in mid-June and ended in mid-July. Larval fish samples were collected using four 25-centimeter diameter, 500um plankton trawl nets deployed 0.4-kilometers (¼ mile) downstream of the canal headworks to capture fish larvae and fish eggs. In addition, river sampling took place on a limited basis directly upstream of Intake Dam for density comparisons.

In 2017, a total of 388 samples were collected containing 434 larval fish and 425 fish eggs. The average density of larvae in the canal was 0.01 larvae/m^3 (15 larvae/Ac-ft) and 0.02 eggs/m^3 (20 eggs/Ac-ft). The average capture rate in the river was lower with 0.004 larvae/m^3 (4 larvae/Ac-ft) and 0.002 eggs/m^3 (3 eggs/Ac-ft).

Data from previous years suggests that over 90 percent of the larval fish could be protolarvae, which is the earliest developmental life stage. Protolarvae are unable to swim effectively and instead, drift downstream within the water column, pass through the fish screens and are entrained into canal flows. Previous larval fish sampling in 2012-2013 suggests that the majority of larvae in the Main Canal are likely to be Cyprinids (minnows) and Catostomids (suckers). Peak larval entrainment typically occurs in late-June and early-July, while fish egg entrainment is highest in June.

Introduction

The Lower Yellowstone Project (LYP) was authorized by the Secretary of the Interior in 1904 under the Reclamation Act of 1902. Construction of the diversion dam, canal headworks and delivery canals for the LYP began in 1905. The diversion dam is a 12-foot-high and 700-foot-long rocked-filled timber crib weir structure that spans the width of the Yellowstone River and diverts water into the Main Canal. The diversion dam raises the upstream water elevation from two to five feet depending on river flows. The diversion dam is located approximately 70 river miles upstream from the confluence of the Yellowstone and Missouri Rivers (Figure 1) and is about 17 miles northeast of Glendive, Montana. The LYP includes the Lower Yellowstone Diversion Dam, canal headworks, Thomas Point Pumping Plant, 71 miles of Main Canal, 225 miles of lateral canals and 118 miles of drains. The LYP provides a dependable water supply sufficient to irrigate approximately 58,000 acres of bench lands above the west bank of the Yellowstone River in eastern Montana and western North Dakota. Water is carried by gravity to the greater portion of project lands and is also pumped from the Main Canal to irrigate approximately 823 acres in the Intake Irrigation District and 2,300 acres in the Savage Irrigation District. The average annual volume of water diverted for these projects is 327,046 acre-feet (USBR 2014).

The rock-filled timber crib weir structure across the Yellowstone River is a partial barrier to many fish species and is likely a total barrier during most years to species such as Pallid Sturgeon (*Scaphirhynchus albus*), Shovelnose Sturgeon (*S. platorynchus*), and Paddlefish (*Polydon spathula*) (Glickman et al., 2004). Pallid Sturgeon is one of the rarest fish species in the Missouri and Mississippi River basins and was listed as endangered in 1990 (USFWS Federal Register 55 FR 36641-36647) under the 1973 Endangered Species Act (ESA). The original canal headworks, did not include fish screens or a fish bypass structure. Fish entrainment monitoring by Hiebert et al. (2000) indicated that thousands of fish of 36 different species were entrained annually into the Main Canal.

The Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (the Corps) have made modifications to the LYP headworks and Main Canal and are currently proposing modifications to the low-head diversion dam. Modifications to reduce fish entrainment included the construction of a new headworks facility and installation of fish screens on the upstream (Yellowstone River) side of the intake conduits. The second component of the retrofit to the LYP is a proposed modification to the low-head diversion dam to allow fish passage.

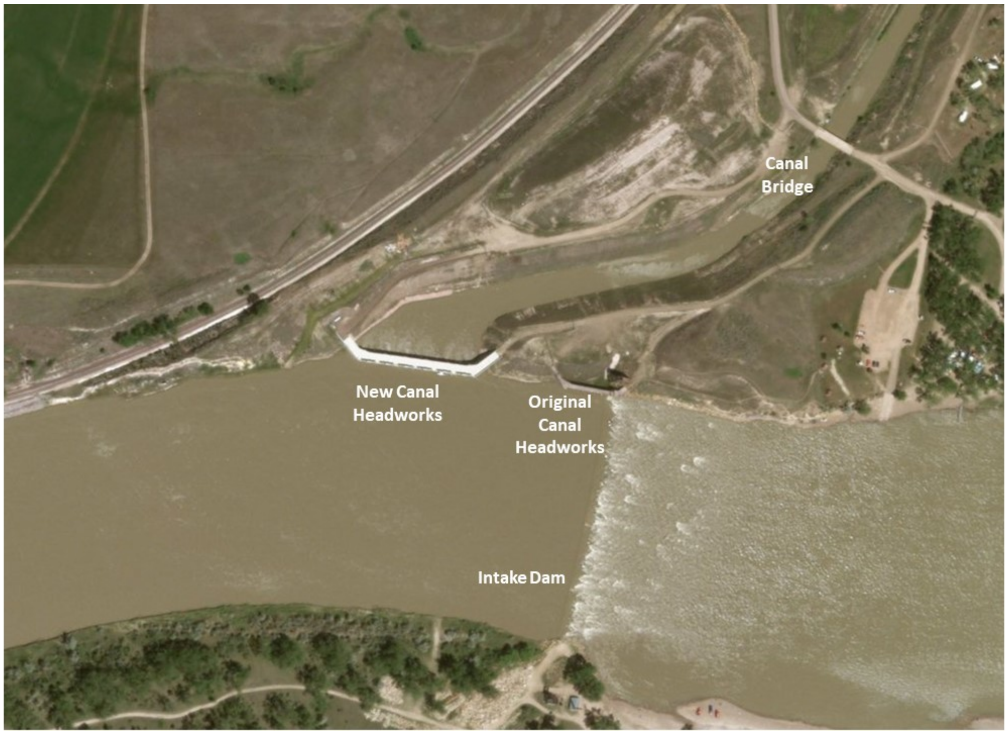

Figure 1. New Intake Canal headworks, original canal headworks, access bridge and low-head diversion dam across the Yellowstone River (ESRI, 2016).

Fish Screens

The purpose of the headworks replacement was foremost to correct the unscreened condition of the previous headworks structure and to protect Pallid Sturgeon as well as other native fish in the lower Yellowstone River by reducing or eliminating incidental fish entrainment. The new headworks consists of 12 rotating drum screens (ISI T78-100 Tee Fish Screens) that are track mounted and located on the river-side of the inlet conduits. Screens are designed to raise 1.5-meters (m) or 5-feet above the 100-year, ice-impacted water surface and are individually controlled with the capacity to be raised or lowered as necessary (USBR 2014) (Figure 2).

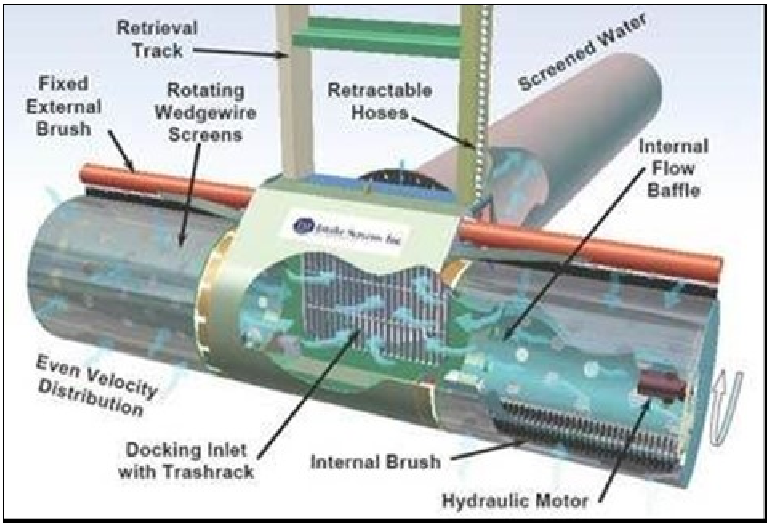

Figure 2. New Intake Canal fish screens from Intake Screens, Inc. showing ISI T78-100 Tee Screen (diagram from Intake Screens, Inc.).

Eleven of the intake conduits will be used to fulfill the LYP full water right of 1,374-ft^3/s and the one additional inlet conduit and drum screen will be used as a back-up. Each drum screen measures approximately 2-m (6.5-ft) in diameter and 7.6-m (25-ft) in total length. The drum screens have a maximum mesh slot size of 1.75-mm and are designed to keep fish larger than 40mm out of the canal (Figure 3). Fixed brushes are mounted on the inside and outside of the drum screen and are automated to intermittently rotate and clean both sides of the screen. The screen cylinders rotate against the brushes to remove debris and fish as well as other aquatic organisms impinged on the surface of the screen (USBR 2014). Because fish screen criteria specific to Pallid Sturgeon are lacking (USFWS 2007), the fish screens were designed to meet salmonid screening criteria established by the USFWS and the National Marine Fisheries Service (USBR 2014).

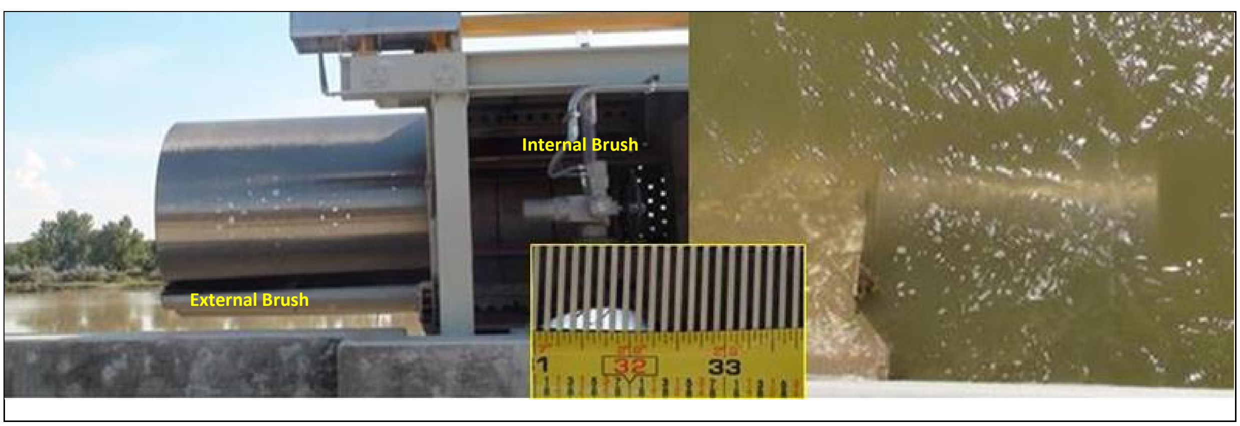

Figure 3. Photo of Raised ISI T78-100 Tee Screen drum (left) and submerged position (right) with inset photo showing 1.75-mm slots of wedge wire screen.

Fish Assemblage in the Lower Yellowstone River

The Yellowstone River is the longest free-flowing river in the in the contiguous United States. The Yellowstone River flows from its headwaters in the Absaroka Range into Yellowstone Lake where the main stem originates and then flows in a north-east direction through Wyoming, Montana, and North Dakota until it empties into the Missouri River above Lake Sakakawea (Figure 4). Because the main stem is not impounded, the river retains a near natural hydrograph fed by large flows of mountain snow-melt that scour sediment from the upper, middle, and the lower section of river thus, maintaining high turbidity levels in the lower section. From its headwaters the river changes from a cold water alpine system to a warm water prairie river system. Based on the fish distribution, the river can be divided into three zones; the upper portion, 802 – 993 river kilometers (rkm) is the salmonid zone, the middle portion (477 – 801-rkm) is the transition zone and the lower portion (0 – 476-rkm) is the warm water zone. The mean annual discharge near the mouth is 362 cubic meters per second (m^3/s) or 0.3 acre-feet/second (ac-ft/s) and the average annual discharge is about 9.3 million ac-ft (White and Bramblett 1993).

A total of 56 fish species representing 16 families are found in the main stem Yellowstone, with 20 species being non-native to the river. The salmonid zone of the Yellowstone River is dominated by salmonids and is inhabited by 16 fish species representing 6 families. The transition zone has 30 fish species representing 7 families and the warm water zone has 50 fish species and representing 15 families. Additionally, Brook Stickleback (*Culaea inconstans*), Cisco (*Coregonus artedi*), Sicklefin Chub (*Macrhybopsis meeki*) and Spottail Shiner (*Notropis hudsonius*) have been documented in the lower Yellowstone River (White and Bramblett 1993, Hiebert et al. 2000, Montana Fish, Wildlife and Parks 2003) (Table 1).

The young larvae and embryos of most fish species found in the lower Yellowstone River cannot swim effectively under their own power and instead, drift within the current of the water column. They are therefore susceptible to altered river flows and water withdrawals. Drift dispersal and dynamics are not well known or understood, although it has been speculated that dams (including low-head dams) may contribute to increased mortality of eggs and larvae if they pass over and/or through the structure. Settlement and concentration of large numbers of drifting eggs and larvae in dam pools and within river sediment may also lead to poor survival and dispersal of the affected species (Gilligan 2014).

Larval fish in large rivers, such as the lower Yellowstone River, typically become suspended in the water column and are carried downstream for long distances. Larval Pallid and Shovelnose Sturgeon were found to drift from 94-km to 530-km (58.4 to 329.3-miles) in the Missouri River, depending on water velocities (Braaten et al. 2008). However, larval fish in rivers and streams are highly susceptible to entrainment into water diversions such as canals and pumping facilities (Paller et al. 1992). Entrainment potential for larval fish likely escalates when the volume of the river decreases after peak spring runoff and when irrigation needs increase during the summer period. The number of diversions and longer downstream drift distances for larval fish, (e.g. Pallid Sturgeon) also increase the potential for entrainment.

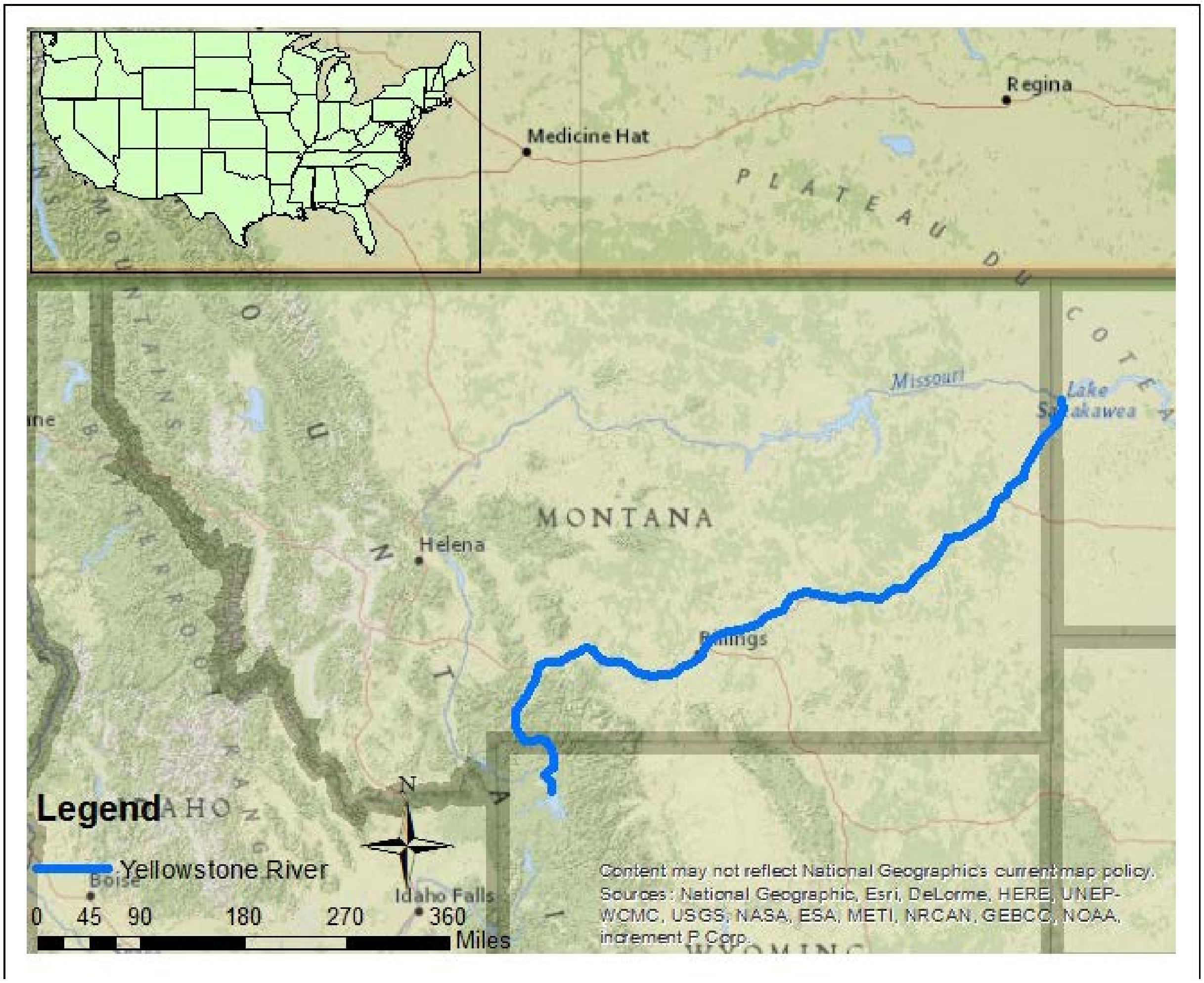

Figure 4. Map of Yellowstone River from Yellowstone Lake in Wyoming to the Missouri River upstream of Lake Sakakawea in North Dakota.

Common Name	***Scientific Name***	**Native**
Sturgeons	**Acipenseridae**	
Pallid Sturgeon	*Scaphirhynchus albus*	Y
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	Y
Paddlefishes	**Polyodontidae**	
Paddlefish	*Polydon spathula*	Y
Mooneyes	**Hiodontidae**	
Goldeye	*Hiodon alosoides*	Y
Carps and Minnows	**Cyprinidae**	
Lake chub	*Couesius plumbeus*	Y
Common Carp	*Cyprinus carpio*	N
W. Silvery minnow	*Hybognathus argyritis*	Y
Brassy Minnow	*Hybognathus hankinsoni*	Y
Plains Minnow	*Hybognathus placitus*	Y
Sturgeon Chub	*Machrybopsis gelida*	Y
Sicklefin Chub	*Macrhybopsis meeki*	Y
Golden Shiner	*Notemigonus crysoleucas*	N
Emerald Shiner	*Notropis atherinoides*	Y
Spottail Shiner	*Notropis hudsonius*	N
Sand Shiner	*Notropis stramineus*	Y
Fathead Minnow	*Pimephales promela*	Y
Flathead Chub	*Platygobio gracilis*	Y
Longnose Dace	*Rhinichthys cataractae*	Y
Creek Chub	*Semotilus atromaculatus*	Y
Suckers	**Catostomidae**	
River Caprsucker	*Carpiodes carpio*	Y
White Sucker	*Catostomus commersonii*	Y
Longnose Sucker	*Catastomus catastomus*	Y
Mountain Sucker	*Catastomus platyrhynchus*	Y
Smallmouth Buffalo	*Ictiobus bubalus*	Y
Bigmouth Buffalo	*Ictiobus cyprinellus*	Y
Shorthead Redhorse	*Moxostoma macrolepidotum*	Y
Bullheads and Catfishes	**Ictaluridae**	
Black Bullhead	*Ameiurus melas*	N
Yellow Bullhead	*Ameiurus natalis*	N
Channel Catfish	*Ictalurus punctatus*	Y
Stonecat	*Noturus flavus*	Y

Common Name	***Scientific Name***	**Native**
Continued		
Pikes	**Esocidae**	
Northern Pike	*Esox lucius*	N
Trouts and Salmons	**Salmonidae**	
Cisco	*Coregonus artedi*	N
Rainbow Trout	*Oncorhynchus mykiss*	N
Mountain Whitefish	*Prosopium williamsoni*	Y
Brown Trout	*Salmo trutta*	N
Cods	**Gadidae**	
Burbot	*Lota lota*	Y
Killifishes	**Cyprinodontidae**	
Plains Killifish	*Fundulus zebrinus*	N
Sticklebacks	**Casterosteidae**	
Brook Stickleback	*Culaea inconstans*	Y
Sunfishes	**Centrarchidae**	
Rock Bass	*Ambloplites rupestris*	N
Green Sunfish	*Lepomis cyanellus*	N
Pumpkinseed	*Lepomis gibbosus*	N
Bluegill	*Lepomis macrochirus*	N
Smallmouth Bass	*Micropterus dolomieu*	N
Largemouth Bass	*Micropterus salmoides*	N
White Crappie	*Pomoxis annularis*	N
Black Crappie	*Pomoxis nigromaculatus*	N
Perciforms	**Cercidae**	
Yellow Perch	*Perca flavescens*	Y
Sauger	*Sander canadensis*	Y
Walleye	*Sander vitreus*	N
Drums and Croakers	**Sciaenidae**	
Freshwater Drum	*Aplodintus grunniens*	Y

Table 1. Fish species found in the lower Yellowstone River near Intake Diversion (White and Bramblett 1993, Hiebert et al 2000, and Montana Fish, Wildlife and Parks 2003).

Methods

Larval Fish Sampling

To evaluate larval fish entrainment into the Main Canal, we sampled in the canal downstream from the fish screens using plankton trawl nets. Sampling started in mid-June and ended in mid-July, in order to focus efforts on the time when sturgeon were likely to be breeding (pers. comm., M. Backes) (Figure 5).

In 2017, four 30 cm diameter by 2.5 m long plankton trawl nets were deployed simultaneously from the Intake Dam fishing and camping access bridge about 0.4-km (¼-mile) downstream from the headworks (Figure 6a and 6b). The distance from the headworks to the bridge was thought to be enough to allow for sufficient mixing of all the 12 inlet conduits (see Figure 1). Nets were spaced evenly along the access bridge and lowered to the bottom of the water column. Nets were deployed for approximately 30 minutes every two hours depending on debris loads. Select dates for larval sampling were also conducted directly upstream of Intake Dam by boat. River sampling entailed using paired 50 cm by 75 cm trawl nets. The sampling boat was anchored in the river current near the thalweg of the river and nets were deployed simultaneously for 10 – 30 minutes depending on debris load. To estimate the volume of water filtered by the net, a General Oceanics mechanical flowmeter was attached to the net’s collar using stranded steel cable wire (Figure 6a). The flowmeter was checked daily for water leakage, air bubble formation, and proper propeller rotation and was flushed and refilled as necessary. Both the start and stop counts registered by the flowmeter were recorded along with the duration of deployment.

All samples retrieved from the nets were placed into 0.95 L plastic jars. The samples were preserved in 95 percent ethanol so that if sturgeon larvae were captured and further laboratory DNA analysis were necessary samples would be easier to identify. The samples were then labeled numerically and logged into a notebook along with the date, time, location, depth, and flow meter count. Samples were then transported to a lab for processing.

In the lab, the samples were poured into a number 40 sieve (0.42-mm or 0.0165-inch), thoroughly rinsed with tap water and then placed onto one side of a deep-dish plastic container (Figure 7a). The sample was then carefully spread out into smaller portions and the larval fish separated from the detritus, similar to Wanner et al. 2011 (figures 7b). Larval fish and eggs were placed into a scintillation vial filled with ethanol and labeled with the appropriate sample number.

The number of larval fish and eggs was tallied for each sample and density was calculated based on the volume of water filtered (using the formula in the General Oceanics Flowmeter Manual,

2008) then extrapolated further using daily canal flows to estimate daily entrainment rates (e.g. density larvae/m^3 and density eggs/m^3). The daily canal gage measurements were used to estimate daily canal flow and was assumed not to change within a day when sampling occurred. By using our rate of entrainment or density per cubic-meter of water from the plankton nets, we estimated the total number of fish larvae and the total number of eggs entrained per acre-foot of canal water for the days sampled.

In 2013, all larval fish collected were sent to the University of New Mexico, Museum of Southwestern Biology for identification. The Museum of Southwestern Biology found that the vast majority of larval fish from 2012 and 2013 were Cyprinids or Catastomids. However, the purpose of this study is to determine the entrainment rates for sturgeon only. Therefore, beginning in 2015, any larvae with Acipenseridae-like qualities were removed from the rest of the sample and sent to Southern Illinois University for DNA analysis. All other larvae were simply counted and used in calculations of total entrainment.

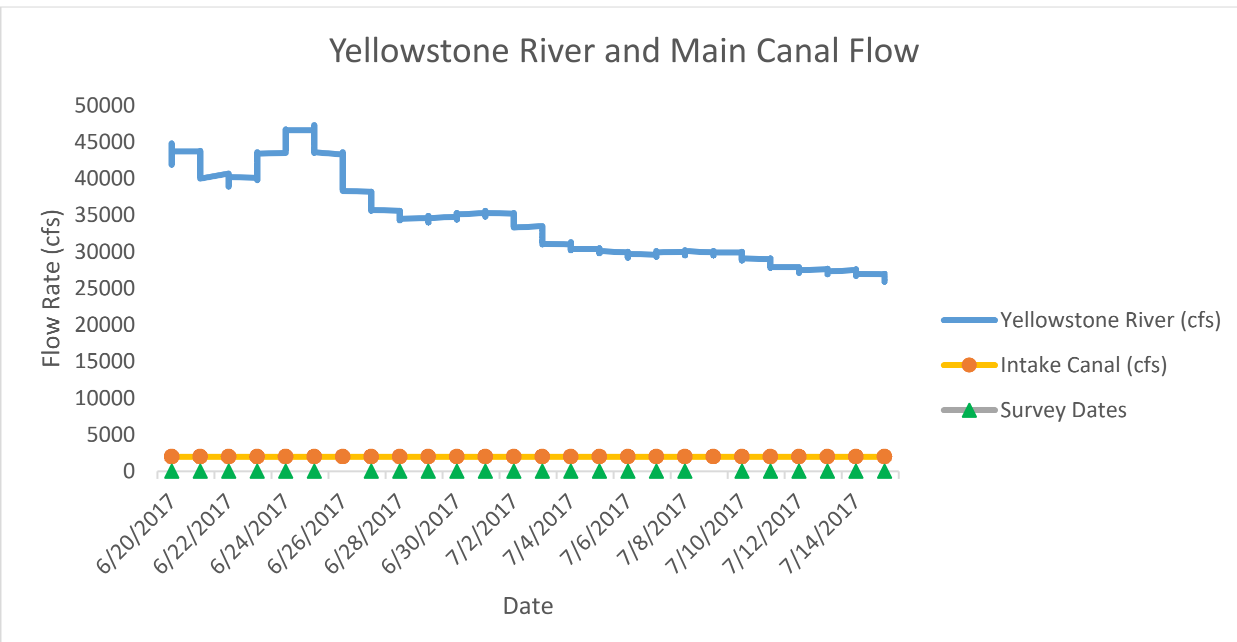

Figure 5. Flow rates in the main channel Yellowstone River and LYP channel 2017 (USGS gage 06327500 near Glendive, MT). Larval fish sampling periods are designated by green triangles.

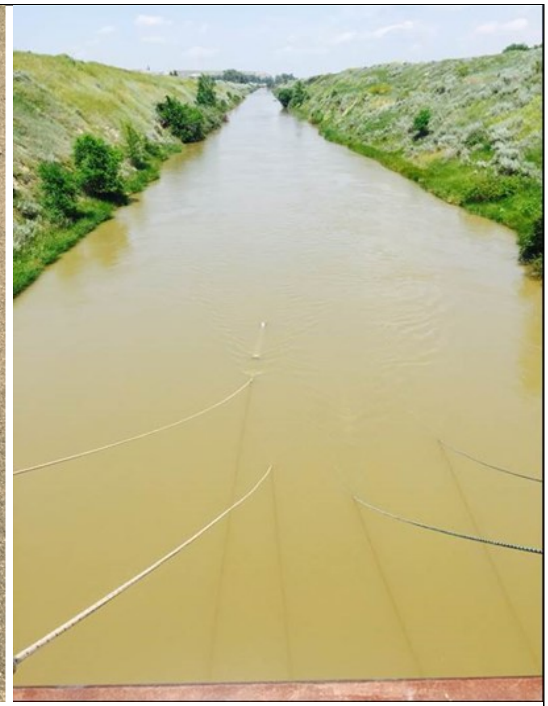

Figure 6a. (Left). Photo of larval fish sampling gear showing plankton trawl net, depressor weight, flow meter, and PVC collecting bucket at the back end of the net.

Figure 6b. (Right). Photo of Intake Canal looking downstream from the access bridge showing the surface sampling nets and the ropes leading to the bottom sampling nets.

Figure 7. Separating larval fish in the laboratory using a plastic dropper.

Results

Larval fish Results

In the Lower Yellowstone Main Canal, a total of 388 samples were collected in 24 days of sampling between June 20th and July 15th. The average sample collection time was 30 minutes. In June and July 2017, the Yellowstone River was flowing between 25,900 – 47,300 ft^3/second (cfs) near Glendive, MT which is a relatively normal discharge for this stretch of river at this time of year (see Figure 5). The sampling period encompassed the time when sturgeon larvae in the Yellowstone River are thought to be drifting downstream. On average, samples contained 1.03 larvae and 1.2 eggs. Over the entire sampling effort, 434 larvae and 425 eggs were caught. The average capture rate was 0.01 larvae/m^3 (15 larvae/Ac-ft) and 0.02 eggs/m^3 (20 eggs/Ac-ft) (Figures 8 and 9).

In addition to sampling at the Main Canal, samples were also collected from the main-stem Yellowstone River from a boat using somewhat different protocols. In the main stem Yellowstone River, a total of 54 samples were collected in 4 days of sampling between June 2nd and July 11th. The average sample collection time was 21 minutes. Flows were much lower in the Main Canal, 1,989 cfs/day, than in the Yellowstone, 25,900 – 47,300 (average 34,111 cfs). On average, samples from the main stem contained 0.9 larvae and 0.6 eggs. Over the entire sampling effort, 50 larvae and 34 eggs were caught. The average capture rate in the river was much lower than in the canal with 0.004 larvae/m^3 (4.4 larvae/Ac-ft) and 0.002 eggs/m^3 (2.6 eggs/Ac-ft). Comparisons between densities in the main-stem Yellowstone River and the Main Canal suggest higher numbers of larval fish and eggs being entrained into the canal relative to what was captured in the river for 2017.

Estimated Larval Entrainment

Because the LYP provides water to so many users, a significant amount of water is dispersed through the LYP Main Canal. The average daily water volume through the Main Canal was 3,945 Ac-ft per day during our survey dates. Though the fish screens prevent larger fish from being entrained into the canal, they do not prevent fish larvae or eggs from being entrained. The average rate of entrainment for fish larvae was 4.4 larvae/Ac-ft of water. The average rate of entrainment for eggs was 2.6 eggs/Ac-ft of water. When we extrapolate the canal larvae and egg density over the volume of water entering the Main Canal, we find that on average, 59,762 larvae were entrained each day of the 2017 sampling season. For eggs, an average of 69,969 were entrained each day (Figures 12 and 13). However, due to high variability in fish and egg densities between samples, the accuracy and significance of extrapolated data should be read with caution. Estimates assume that dispersal of eggs and larvae are equal throughout the water column.

DNA Results

In 2017 no larvae were collected that were classified by Reclamation staff as *Acipenseridae*, therefore, no larvae were sent out for DNA analysis.

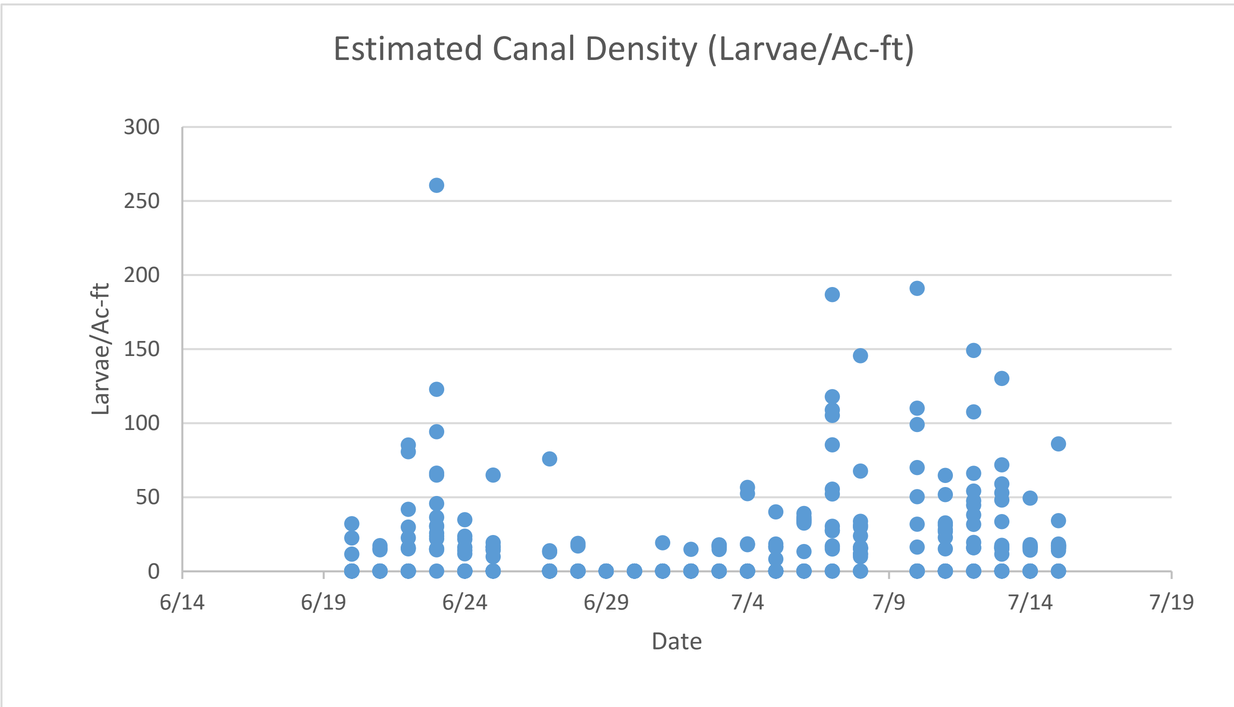

Figure 8. Estimated canal density of larval fish per acre-foot of water during the 2017 sampling period.

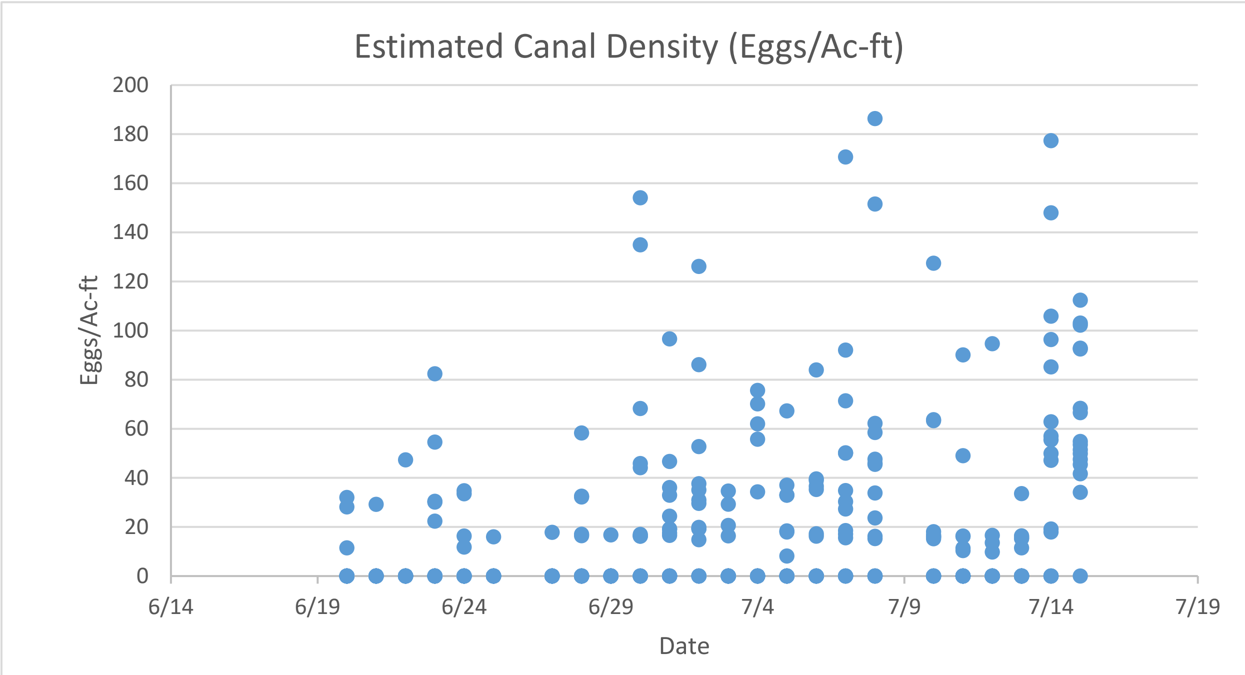

Figure 9. Estimated canal density of fish eggs per acre-foot of water during the 2017 sampling period.

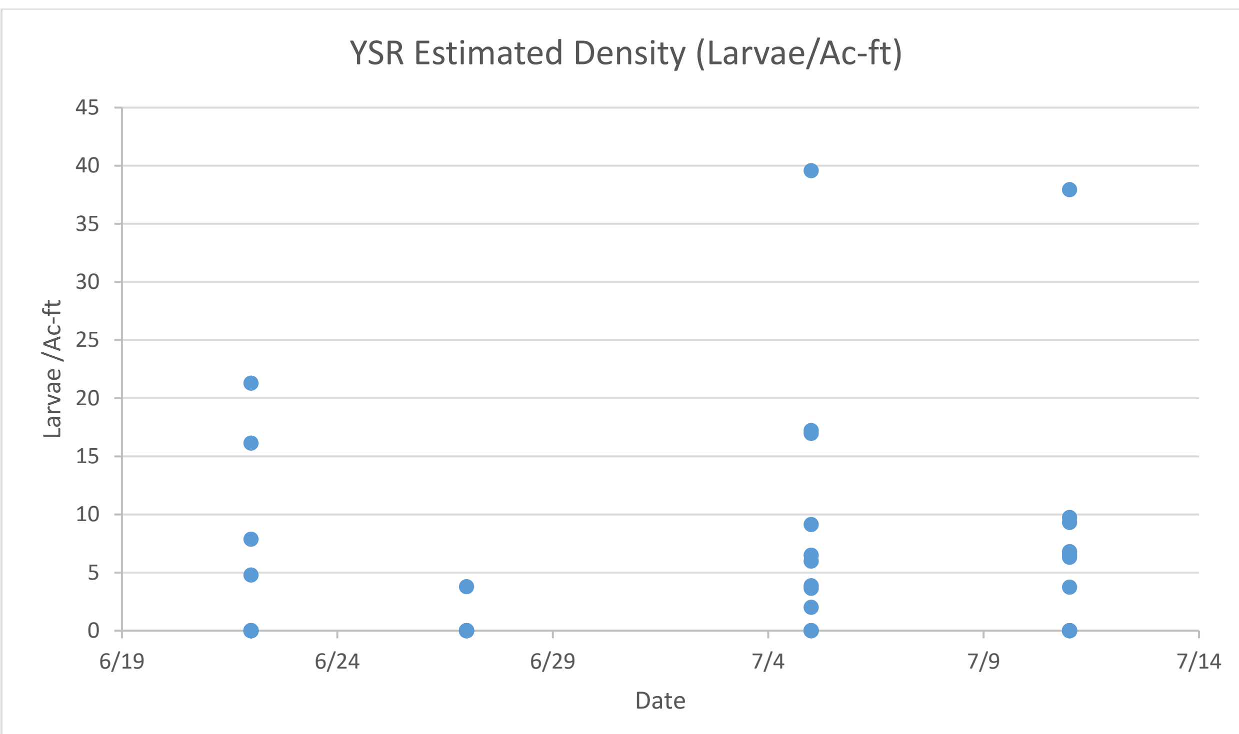

Figure 10. Estimated YSR density of fish larvae per acre-foot of water during the 2017 sampling period.

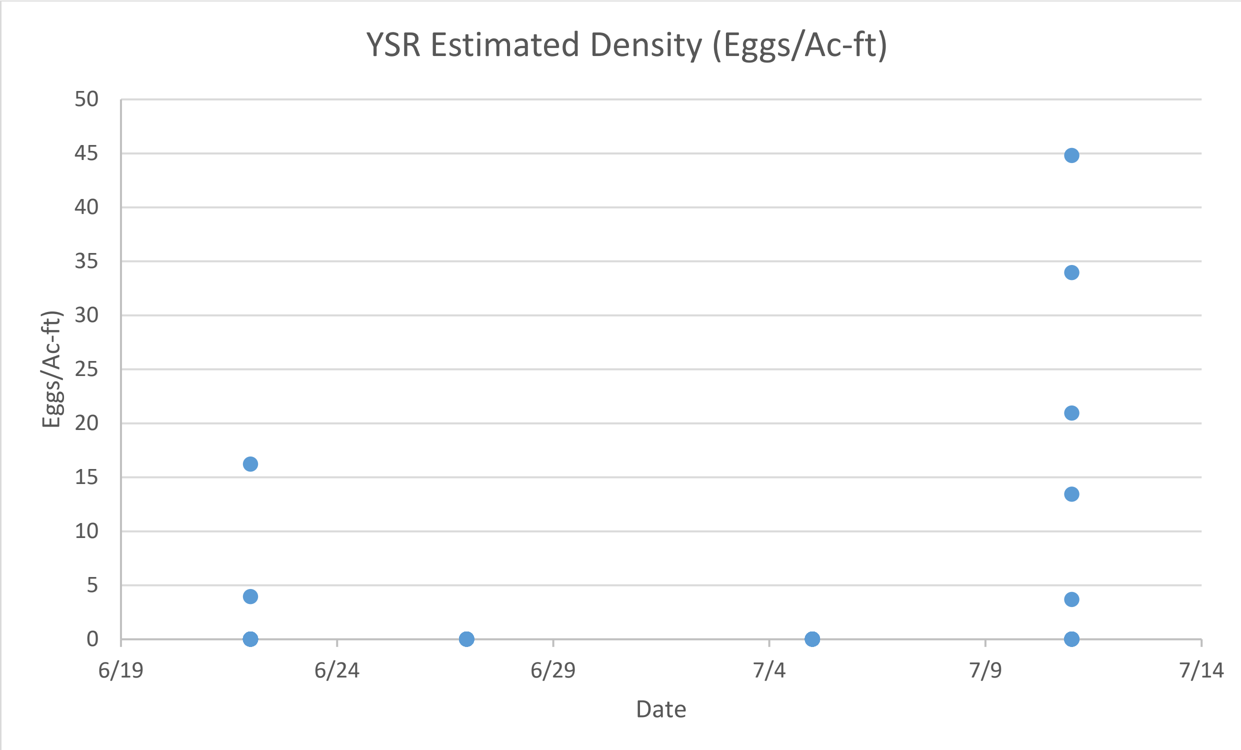

Figure 11. Estimated YSR density of fish eggs per acre-foot of water during the 2017 sampling period.

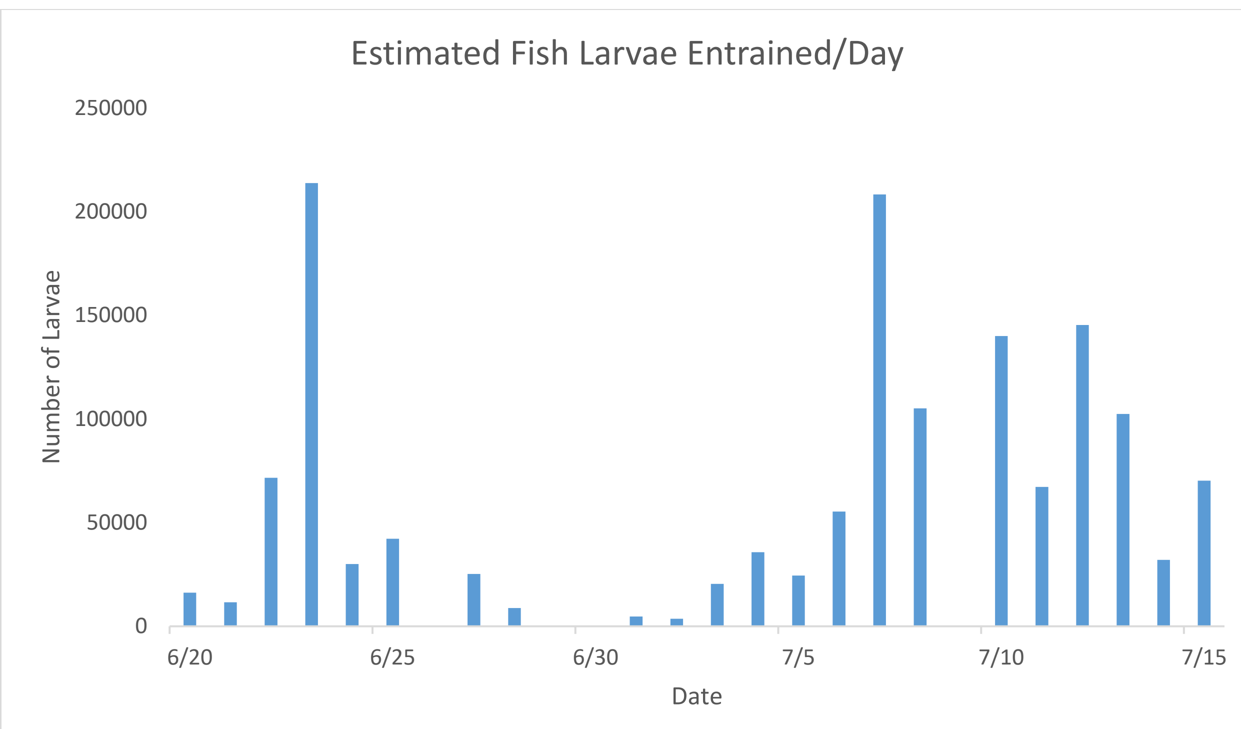

Figure 12. Total estimated entrainment of larval fish per day during the 2017 sampling periods.

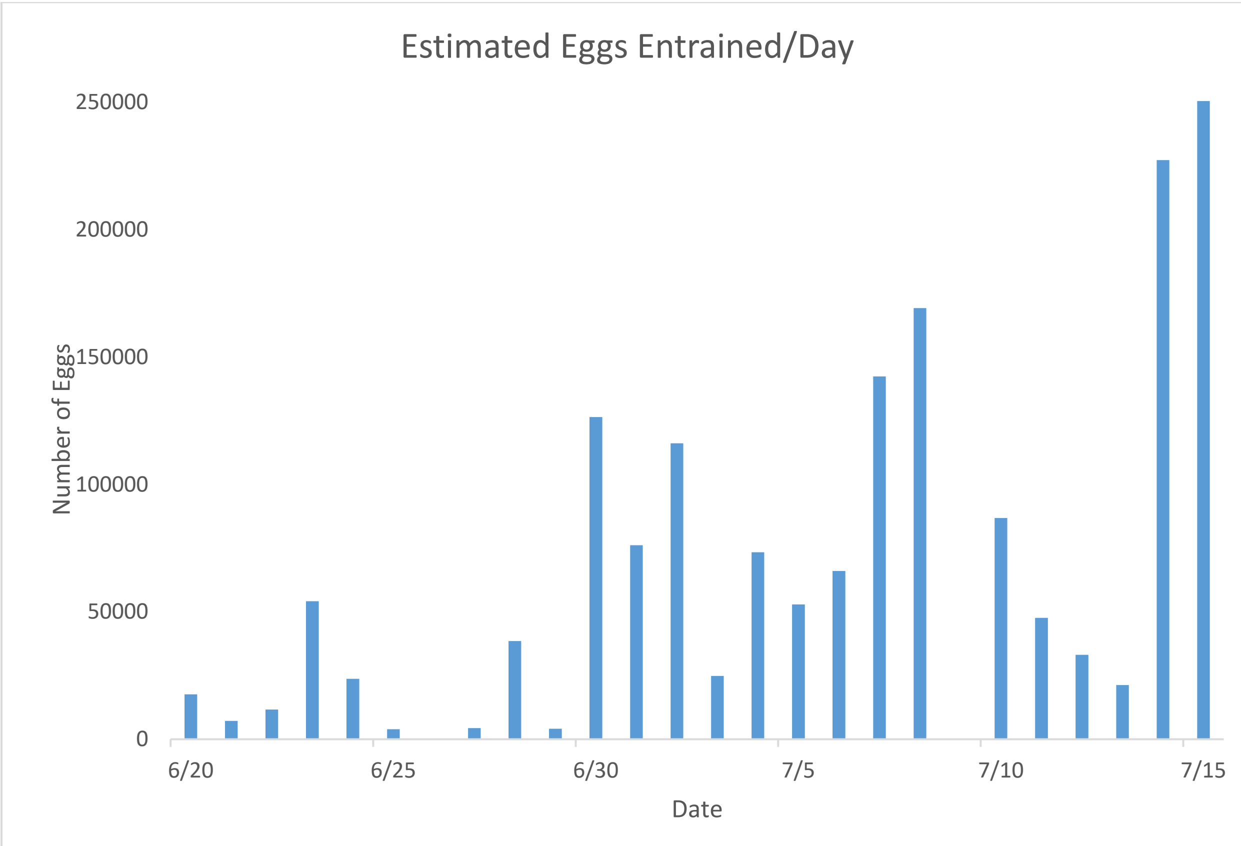

Figure 13. Total estimated entrainment of fish eggs per day during the 2017 sampling periods.

Discussion

Despite the continuous operation of fish screens at the LYP Main Canal since 2013, large numbers of fish larvae and eggs are still being entrained into the canal. This is not unexpected as the screens were not designed to specifically exclude larval fish. Whether the intakes have a measurable impact on sturgeon or other native fish populations is still unknown. However, the screens should prevent adult sturgeon and larger juveniles from becoming entrained during spawning season and becoming lost to the system.

2017 was the second year that samples were collected from the main-stem Yellowstone River in addition to the canal. Converse from 2017 results, 2016 resulted in higher densities of larvae and eggs in the river channel (411 larvae/Ac-ft; 169 eggs/Ac-ft) than in the canal (108 larvae/Ac-ft; 5 eggs/Ac-ft). We can only speculate why larvae and egg densities shift but it is likely related to flows. In June and July 2017, the Yellowstone River was flowing between 25,900 – 47,300 ft^3/second (cfs) near Glendive, MT which is a relatively normal discharge for this stretch of river at this time of year. Conversely, the Yellowstone River was flowing between 5,960 – 17,700 ft^3/second in 2016. The relationship between densities experienced in the river vs. the canal are poorly understood at this time. In addition, with limited data to compare larval densities in the river with densities in the canal, we cannot say if entrainment is reduced due to the screens.

Acipenseridae were absent from all river and canal samples in 2017. While it is known that paddlefish and sturgeon spawning migrations are impeded by Intake Dam, there is a resident population of shovelnose sturgeon that remains upstream of Intake Dam. The collection of only a single larval shovelnose sturgeon in 2013 raises questions as to the effectiveness of our sampling techniques for sturgeon species.

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