Missouri River Dams Larval Walleye Entrainment Investigation

PPL-Montana MOTAC project 781-12

Prepared by

Grant Grisak and Brad Tribby
Montana Fish, Wildlife & Parks

Andrea Spake and McKenzie Leonard
University of Great Falls

Montana Fish, Wildlife & Parks

University of Great Falls

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Introduction

Studies have shown that since the increase in walleye numbers in Canyon Ferry Reservoir in 1996-97 there has been a sustained increase in walleye numbers in the Missouri River below Holter Dam (Grisak et al. 2012). This relationship suggests that walleye produced upstream in Canyon Ferry, Hauser and/or Holter reservoirs may be flushing past the dams and residing in the Missouri River downstream of Holter Dam.

During the annual brown trout population estimate in the Craig section (April/May) of the Missouri River, Montana Fish, Wildlife & Parks (MFWP) fishery workers have observed a small number of post-spawn female walleye, which indicates natural reproduction is occurring in this section of river. Since 2009, seining surveys for young of the year (YOY) walleye in the Missouri River between Cascade and Great Falls have shown some preliminary but predictable trends in YOY walleye distribution and abundance. In general, YOY walleye are distributed throughout this 55-mile reach in low numbers consistent with the relatively low adult walleye numbers measured during trout population estimates. From 1983 to 2011, in the Craig section, during spring electrofishing walleye averaged 0.7% (range 0.1-3.0%) of the total fish handled. From 1982 to 2011, in the Craig section, during fall electrofishing, walleye have averaged 0.4% (range 0.1-2.9%) of the total fish handled.

In order to understand the contribution of larval walleye produced in upstream reservoirs to the Missouri River population we evaluated entrainment of larval walleye through Canyon Ferry, Hauser and Holter dams by sampling for larval fish below each dam. Additionally we sampled two sites near Cascade and Great Falls to determine if walleye reproduction in this section of the Missouri River could be measured using larval fish sampling methods and to determine the relative contribution these fish have to the Missouri River below Holter Dam.

This project was conducted by students from the University of Great Falls (UGF) and personnel from Montana Fish, Wildlife & Parks (MFWP) and was funded by PPL-Montana as part of FERC license 2188.

Study area

The study area spanned 131.5 miles from Canyon Ferry Dam to the mouth of the Sun River near the city of Great Falls. We sampled larval fish below Canyon Ferry Dam near the warning cable located approximately 520 feet below the dam. At the Hauser site, we sampled at the boundary of the “no wake” zone located 2.9 miles downstream of Hauser Dam. The reason for not sampling directly below Hauser Dam was because of the added time it would have taken to travel 5.8 miles roundtrip in the no wake zone. Anglers frequently wade fish this section of river at night and sampling this distance below the dam reduced the risk of endangering wade anglers at night. At the Holter site, sampling occurred in the short reach of river between the Fish & Game warning cable and approximately 100 feet below the dam. This site was selected because public boating is not permitted above the cable which reduced angler conflicts during the sampling period. Also, it was possible to situate the nets in the flow from the spillway gates and the powerhouse tailrace giving us the highest probability of differentiating the source of larvae in the river at this site.

The Cascade site was located 0.52 mile downstream of the city boat ramp. The purpose of selecting this site was because it is located 1.6 miles downstream of a known walleye spawning site identified by Grisak et al. (2012) and is located within the theoretical drift zone of that site.

The Great Falls site was located in the east channel of Park Island 0.55 mile upstream of the mouth of the Sun River. The reason for selecting this site is because the reservoir influence of Black Eagle Dam is diminished at this location and there was sufficient velocity to provide drift for hyponeuston, larval fish and debris.

Description of the dams

The outlet structures on Canyon Ferry Dam include the three penstocks that provide water for the power generation turbines, the four spillway overflow gates that control the surface elevation and surplus water, and the Helena valley irrigation intake. The top of three penstock intakes are located 91 feet below the surface of the lake and each intake measures 572 ft^2. The turbine penstock capacity is theoretically 45,000 gallons per second when all three turbines are operating at full capacity, but according to the Bureau of Reclamation (BOR), it is rare for the releases from these to be much more than 6000 cfs (all three combined). The penstocks for each unit are 13.5 feet in diameter. The Helena Valley Pumping Plant penstock is located 107 feet below the lake surface. It is 13 feet in diameter and the maximum capacity of the intake is 1000 cfs. It normally operates at about 750 cfs during irrigation season, with approximately 50% of the water going towards Helena Valley Reservoir, and the other 50% returning to the river. The four river outlet gates ar elocated at 143.5 feet below the lake surface and release water from the lower part of the dam. They are each 84 inches in diameter. They have a combined maximum capacity of 9500 cfs when all four are completely open. The BOR indicates this does not happen due to turbulence in the stilling basin, so the actual maximum operating capacity of the four gates combined is approximately 4000 cfs. The four spillway radial gates are located at the top and center of the dam. Each gate is 51 feet wide by 34.5 feet tall. The theoretical maximum capacity of the spill gates is 150,000 cfs, but the realistic maximum operational capacity of the four gates combined is approximately 25,000 cfs.

The outlet structures on Hauser Dam include six penstock intakes. Penstocks 1-5 are 12 feet in diameter and each have a cross sectional area of 452 ft^2. The top of these five intakes is located

17 feet below the lake surface. Penstock number six is 14 feet in diameter and its crossectional area is 615 ft^2. The top of this intake is located 15 feet below the lake surface. Operation of this dam was adequately described by Spinelli (2010). Hauser Dam is equipped with 24 spillway gates that are approximately 5.5 feet wide and 12.5 feet deep. Five of these spillbays are equipped with hydraulic gates. The turbine capacity of Hauser Dam is 4,740 cfs.

The outlet structures on Holter Dam include four 14 foot diameter penstock intakes that are located approximately 20 feet below the surface of the lake (at full pool). The intakes each have a cross sectional area of 615 ft^2. The operation of spillway gates is poorly understood by these authors, but observations made by MFWP fisheries staff indicate that surplus water is generally spilled from 2-3 gates on the east end of the dam until head depth reaches about 6 feet, then additional gates are opened to pass surplus water. Using gates on the east end of the dam serves to abate gas supersaturation by spilling water directly into a concrete wall downstream of the spill apron. The turbine flow capacity of Holter Dam is 7,100.

Methods

We used a stratified systematic sampling design to measure larval fish abundance in which the strata were day/night(AM/PM), left bank/right bank (looking upstream) and upper water column/lower water column. Systematic sampling occurred twice weekly on Monday and Thursday. The nighttime sampling involved an equal amount of effort between AM and PM periods where sampling occurred before sunrise or after sunset to account for possible vertical diurnal migrations of larval fish in the reservoirs and potential differences in entrainment susceptibility.

To capture larval fish we used ½-meter diameter, 2 meters long, 70-micron mesh conical plankton nets with removable cod ends. A General Oceanics model 2030R mechanical flow meter was fitted to the opening of each net to record the amount of water sampled during each tow. We used a 2 inch square steel pipe fixed to the bow of the boat to suspend one net from each side of the boat using a 3/8 inch diameter braided nylon rope. Depending on the water velocity, we used a 2 or 4 pound sash weight attached near the opening of each net and the length of the rope was adjusted to achieve the desired sampling depth. When nets were deployed, the boat was held in position using the outboard engine. On the right side of the boat, we sampled the lower water column, near the bottom, and on the left side of the boat we sampled the upper water column near the surface of the river. The sampling time was adjusted according to the amount of debris collected in the nets, but did not exceed 22 minutes per site. During each event, we collected samples from the right bank and left bank in order to account for differences in larval drift and to ensure we were sampling both the powerhouse tailrace and the spillway of each dam. The same protocol was used at the Cascade and Great Falls sites to maintain the standardized practice.

The samples were catalogued, stored in quart mason jars and then preserved in the field using 70% ethanol that contained phloxine-B dye. Samples were sorted at the University of Great Falls laboratory and the Montana Fish, Wildlife & Parks laboratory which involved removing dyed fish and eggs and storing them in 50 ml glass vials with 70% ethanol. Larvae were subsequently identified by FWP staff to Family for catostomidae (suckers) and to Genus for carp, shiners, yellow perch and walleye. The metrics we used to identify fish included presence/absence of teeth on jaw, number of post-anal and pre-anal myomeres, number of visible otoliths, dorsal fin fold location, anal fin rays, peritoneum coloration, and location and patterns of melanophores (Holland-Bartels et al. 1990, Wallace et al. 1990, Kay et al. 1994).

Larval fish catch data were analyzed using single factor analysis of variance (ANOVA) to test for differences in mean number of larval fish caught at each site. Data from each stratum were analyzed using Fishers F test to test for equality in variance within each stratum. Depending on whether the data sets had equal or unequal variances, we use the appropriate two sample t-test to test for differences in mean number of larval fish sampled within each stratum. Sampling below Canyon Ferry Dam and Holter Dam offered the highest liklihood of measuring larval fish entrainment because the samples were collected close enough to the dam spill gates and powerhouse tailraces that mixing of these two water sources was greatly minimized.

To estimate the number of larval walleye that moved past a sampling point we used models from Van den Avyle (1993). The formula for estimating larval walleye population size ($\hat{N}$) at each sampling point was ;

$$\hat{N} = \frac{A}{a}\bar{n}$$

where A = the total amount of water that flowed past a sampling point during the study period, a = the amount of water sampled at a sampling point during the study period, and $\bar{n}$ = the average number of fish caught per sample at each site. Larval fish catches were analyzed for correlation with river discharge using simple linear regression. We calculated the population variance, coefficient of variance and standard deviation with 95% confidence intervals using the two tailed t-statistic. The level of significance for all tests was $\alpha = 0.05$.

Results

We conducted 360 samples (tows) for larval fish between May 10 and July 9. Mean duration of each sampling event was 16.4 minutes (range 3.0-22.5). The mean amount of water sampled per tow was 3,682 ft^3 (range 185-13,792). Mean water temperature during the sampling period was 55.7 ^oF (range 46.6-69.1).

Overall we sampled 576 larvae. The Cascade site had the highest number of larvae (ANOVA $F(4,15)=3.38$, $P=0.03$), followed by Great Falls, Hauser, Canyon Ferry then Holter (Table 1). Sampling was conducted 72% during daytime hours and 28% during nighttime hours. For nighttime samples, 52% occurred during twilight hours in the AM and 48% occurred in the PM. Nighttime catch rates (1.86 fish per sample) for all sites were slightly higher than daytime catch rates (1.51 fish per sample), but the differences were not significant ($t(8)=-0.57$, $P=0.58$). The Cascade site had the highest number of larval fish for both day and night sampling periods, followed by night time sampling at Great Falls (Table 2). Overall, 59% of the fish sampled during the study came from the left bank and 41% came from the right bank, but the difference in catch was not significant ($t(13)= -0.457$, $P=0.65$). The right bank at the Cascade site had the highest catch of any site and represented 41% of all fish sampled. Catch by location in the water column was 78% from the upper water column and 22% from the lower water column, but the difference was not significant ($t(10)=1.59$, $P=0.14$).

Peak flows at Hauser and Holter were 8,910 cfs and 8,950 cfs, respectively, and occurred at both sites on June 8, and peak flow at the Ulm gage was 11,000 cfs which occurred on June 9 (Figure 1).

Table 1. Larval fish (all species) catch by sampling site and location in the water column and time of day, Missouri River, Montana. 2012.

	total fish	Right bank upper	Right bank lower	Left bank upper	Left bank lower	Day larvae	Night larvae
Canyon Ferry	17	4	0	10	3	14	5
Hauser	38	21	3	9	5	28	10
Holter	12	3	4	4	1	10	2
Cascade	348	63	47	207	32	267	79
Great Falls	161	83	10	49	19	72	89
total	576	174	64	278	60	391	185

Table 2. Larval fish catch rates by time of day. Missouri River, Montana, 2012.

site	fish/day	fish/night
Canyon Ferry	0.35	0.14
Hauser	0.64	0.63
Holter	0.16	0.13
Cascade	4.79	5.00
Great Falls	1.29	5.56

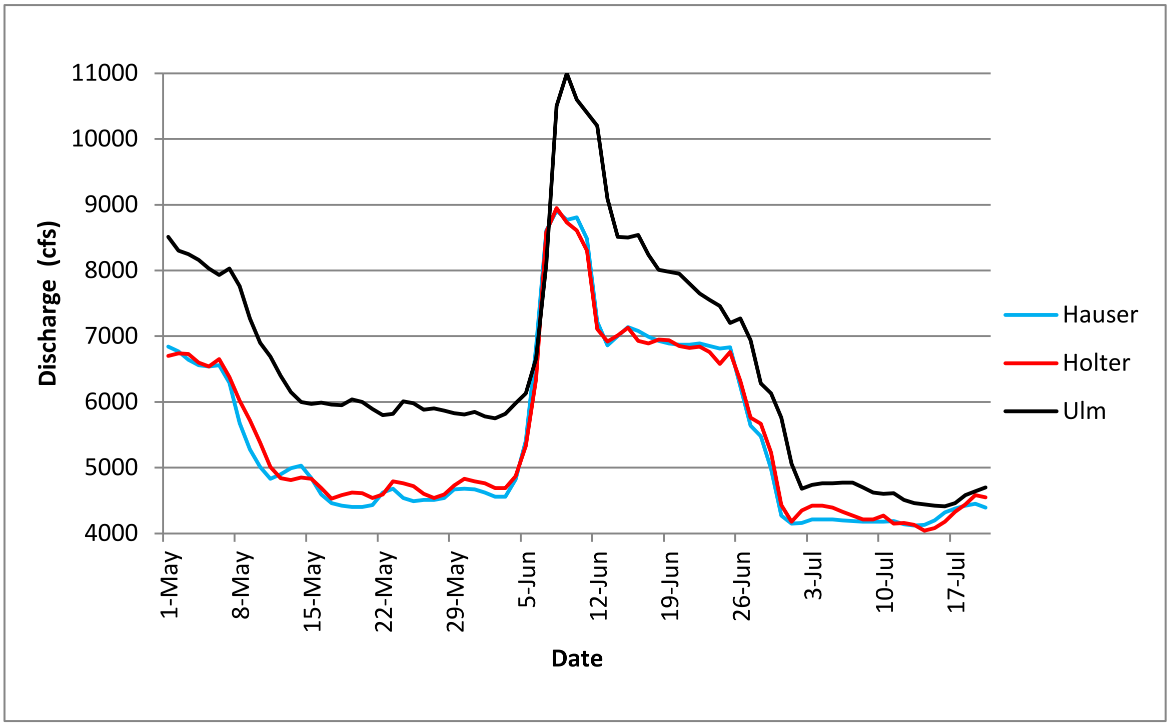

Figure 1. Peak flow of the Missouri River measured at the Hauser, Holter and Ulm gage sites, 2012.

At the Canyon Ferry site, sampling crews from UGF and MFWP noted discharge from the spill gates for 15 days between June 7 and June 21. Mean discharge during this period was 7,562 cfs (range = 6,860-8,910).

In 2012, turbine capacity of Hauser Dam was reached and spill occurred for a 33 day period from May 10 through May 15 and from June 4 to June 29. Mean discharge during these dates was 6,557 cfs (range 4,820-8,910). No larval walleye were sampled at the Hauser site. Given the distance of this sampling site downstream of the dam we would not be able to confidently discern if fish passed through the power house, over the spillway or were spawned in the reach of river between the dam and Beaver Creek.

At the Holter site, turbine capacity was reached on June 7 when flows increased from 6350 to 8590 cfs in a 24 hr period. Spill over Holter Dam occurred during a 22 day period from June 7 through June 28. During this time mean discharge at the Holter gage was 7,155 cfs (range 5,670-8,950). Observers witnessed spilling from 1 to 3 gates at Holter during a 15 day period when flows were below the 7,100 cfs turbine capacity. Mean discharge during this time period was 6,667 cfs (range 5,670-7,010).

Fish abundance

Catostomidae (sucker) were the most abundant larval fish sampled representing 94% of the total catch, followed by carp (2%), undetermined larvae (2%), sculpin (1%), walleye (1%), fathead minnow (<1%) and emerald/golden shiner (<1%). Mean length of larval suckers was 12.2 mm (range 9-16). There was no correlation between larval sucker catch and flow as measured from the Ulm gage for both the Cascade (R^2=0.45, *P*=0.26) and Great Falls sites (R^2=0.35, *P*=0.35) (Figure 2). Peak sucker catch occurred on June 7 at the Great Falls site and on June 11 at the Cascade site. Peak flow at the Ulm gage occurred on June 22.

Carp larvae were sampled at the Holter (*n*=8) site between June 28 through July 7 and at the Great Falls (*n*=3) site on June 21. Mean length of carp was 5.5 mm (4-7). Carp were sampled from both the right and left banks at both sites.

Sculpin larvae were sampled at the Great Falls site (*n*=4) in all four nets during day time hours on May 17 and from the Canyon Ferry site (*n*=2) in one sample during day time hours on June 27. Mean length of sculpin was 9 mm (range 8-10).

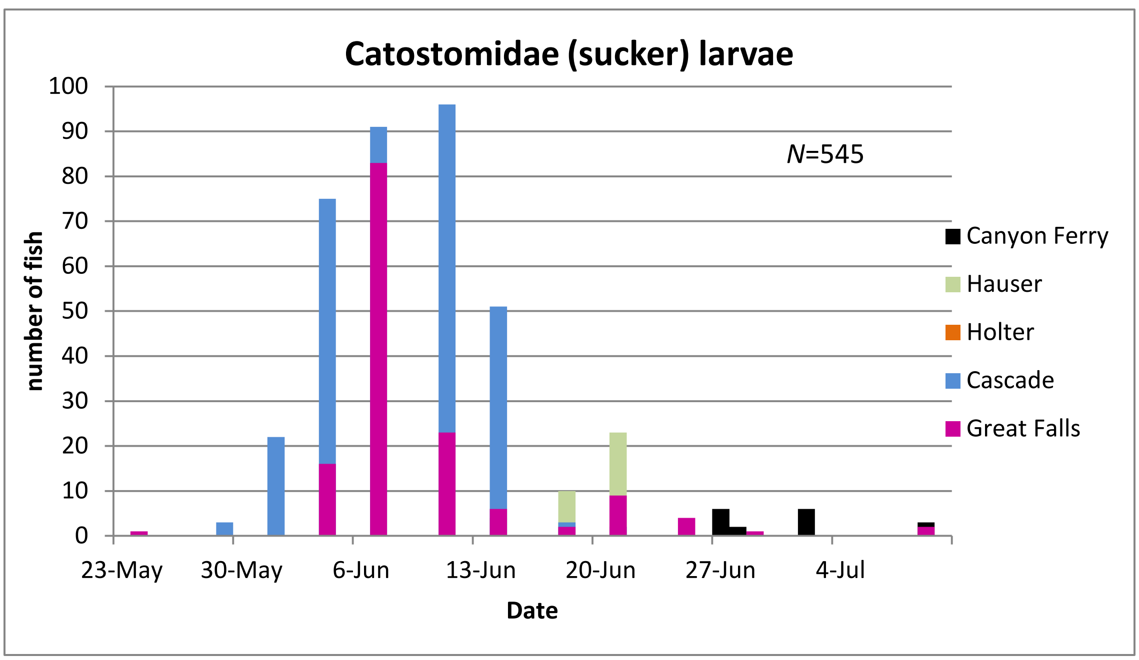

Figure 2. Catostomidae catch at five sampling sites in the Missouri River, Montana, 2012.

Larval walleye were sampled at only the Holter and Cascade sites. At the Holter site larval walleye (*n*=4) were sampled between June 18 and July 2. All samples were collected from the right bank; three during day time hours and one during night time hours. Mean length of walleye was 18.2 mm (range 9-23). We calculated an estimate of larval walleye using the catch by volume of water we sampled as a subset of all the water that flowed past Holter Dam during the study period. The estimate of larval walleye that moved past Holter Dam from May 10 through July 9 was 5,704. We were unable to calculate a population variance and standard deviation because the 4 samples contained only one larval walleye each so there was no sample variance. As such we could not calculate the sum of the squares for samples with only one fish.

At the Cascade site larval walleye (*n*=1) were sampled on June 25 during daylight hours along the right bank. Little can be gleaned from this finding other than supporting evidence provided in other studies that walleye spawning occurs within a 3.5 mile-long reach of the Missouri River immediately upstream of the Cascade sampling site (Grisak et al. 2012).

Fathead minnow (*n*=1) was sampled only at the Cascade site on June 14 from the left bank during night time hours. Total length was 42 mm.

Larval emerald shiner (*n*=1) was sampled only at the Great Falls site on July 7 from the right bank during daytime hours and the total length was 6 mm.

Larval golden shiners (*n*=2) were sampled only at the Great Falls site on June 25 from the right bank during day time hours. Mean length of these fish was 13.5 mm (range 13-14).

Discussion

This study did not measure entrainment of larval walleye through Canyon Ferry Dam in 2012. We could not confidently measure entrainment at Hauser Dam because the sampling occurred nearly 2.9 miles downstream of the dam due to unforeseen sampling limitations. Our results provided evidence of very limited larval walleye entrainment through Holter Dam in 2012.

Given the small sample size of larval walleye at the Holter site, we view this as a very preliminary result and perhaps justification for further investigation under a range of flow conditions. In order to relate the significance of the findings from Holter Dam in 2012 we considered a variety factors that contribute to larval walleye entrainment.

Annual walleye productivity undoubtedly plays a role in the abundance of larval walleye available to be entrained. Fecundity of female walleye is highly variable and can range from 13,000 to 99,000 eggs per kg total weight (Shueller 2005, Morton 2006). Average eggs per kg body weight of female walleye from Ontario was 46,369 (Morton 2006). From 2006-2011, the average length of sexually mature female walleye from Holter Lake was 19.2 inches (range

=12.0-31.0 inches long, *n*=188) (E. Roberts MFWP, personal communication, 2012). Baccante and Reid (1988) reported a typical female walleye measuring 19.5 inches long had 59,900 to 71,300 (mean 65,500) eggs. Although female walleye are capable of producing high numbers of eggs, relative survival is low even in highly productive waters. Low survival is generally attributed to the fact that during spawning the eggs are broadcast over rocks and silt covered substrate and left unprotected by a 'nest' during incubation (Regier et al. 1969). Estimates of egg hatching success range from 12-25% (Raabe 2006) and fry success is estimated at usually less than 1% (Johnson et al. 1996). In order to relate our estimate of larval walleye that entered the Holter Dam tailwater area in 2012 to walleye productivity of the Holter Lake population, we used the mean number of eggs reported for a typical 19.5 inch walleye (65,500) and assumed that 25% of the eggs (16,375) survived to hatch and 1% (164) of the hatchlings survived to fry stage. Therefore, the number of larval walleye estimated to have entrained through Holter Dam in 2012 represents a liberal estimate of the fry produced from 35 adult female walleye from Holter Lake.

The best available measure of young walleye abundance in these reservoirs is the annual young of the year beach seining surveys. In 2012, beach seining at Canyon Ferry Reservoir yielded an average 1.3 young of the year walleye per seine haul, which was the second highest on record and ranks in the 94th percentile over the period of record (*n*=18 years, mean= 0.59 per seine, range=0.03-3.2) (A. Strainer, MFWP, personal communication, 2012). At Hauser Lake in 2012, the average number of young of the year walleye seined was 2.3 per haul which ranked in the 53rd percentile (*n*=16 years, mean=2.0 per seine, range= 0.1-5.9) (T. Humphrey, MFWP, personal communication, 2012). At Holter Lake, beach seining in 2012 yielded an average 2.9 young of the year per seine haul and ranks in the 78th percentile over the period of record (*n*=19 years, mean =1.6 per seine, range=0.1-4.8) (T. Humphrey, MFWP, personal communication, 2012). Despite the relatively high abundance of young walleye in Canyon Ferry in 2012, and above average abundance in Hauser and Holter lakes, environmental conditions were apparently not conducive to entrain large numbers of young walleye through these dams. An alternative way of viewing this information is that one would expect young of the year walleye abundance in these lakes to be high(er) if flows were low, entrainment was low, and larval were not flushed downstream into another lake or section of river.

Understanding the behavior and swimming ability of larval walleye could be an important artifact in estimating their vulnerability to entrainment through these dams. Larval walleye are reportedly most commonly found between 1 and 3.7 meters (3-12 feet) below the surface of a lake (Houde 1969a, Noble 1972). Studies have shown lake surface water currents at depths of 0-1 m are generally greater than walleye larvae can swim against and is a major factor in determining their distribution throughout lakes (Houde 1969b). There are varying reports of walleye distribution and abundance in pelagic zones versus littoral zones of lakes (Noble 1972). In 2012, all of the larval walleye we sampled at the Holter site came from the left bank, which suggests these fish were entrained through the powerhouse turbines. Turbine penstocks at Holter

Dam are approximately 20 feet below the water surface, which would suggest larval walleye in Holter Lake could occupy deeper water zones than has been reported for other waters, or the undertow currents created by the turbine penstock intakes are great enough to affect larval walleye at depths much less than the penstock intakes.

In 2012, peak discharge at the Holter gage was 8,950 cfs which ranks in the 30th percentile over the 66 year period of record. Peak discharge at the Hauser gage was 8,910 cfs which ranks in the 27th percentile over the 38 year period of record. During an average flow year as measured by the Holter gage (15,000 cfs) and the Hauser gage (11,700 cfs) the risk of larval walleye entrainment would most likely be greater.

Walleye larvae certainly entrain through Holter Dam. It appears as if the influence of these fish on the population below Holter Dam is yet to be determined. The increase in walleye numbers in the Missouri River after 1996 could be attributed more to the influx of adult walleye that entrained through the dam powerhouse. In 2011, exceptionally high flows (89th percentile) on the Missouri River resulted in anglers catching/returning 6.4% of the adult walleye tagged in Holter Lake from the Missouri River below the dam, and fishery workers sampled the highest number (*n*=167) of adult walleye on record while electrofishing in the Craig section (Grisak et al. 2012). Evaluations of young of the year walleye at 60 seine sites in the Missouri River below Holter Dam did not show an inordinately high number of walleye despite the high flows.

Although the stated turbine capacity of Holter Dam is 7,100 cfs, we observed water moving over the spill gates when flows were as low as 5,600 cfs. This indicates water does spill from Holter Dam when flows are below 7,100 cfs. Spill also occurred at Canyon Ferry Dam when flows reached the operational capacity of 6,000 cfs. During years of minimal spill, such as in 2012, surplus water that is spilled from Canyon Ferry may come from as deep as 30 feet below the surface. Although larval walleye reportedly are found within the top 12 feet of a lake, it is possible that undertow currents generated by the bottom withdrawal from the radial gates could entrain larval walleye and transport them downstream of the dam. Undertow currents would be expected to increase as more water is discharged through the radial gates on the spillway on Canyon Ferry Dam.

More studies of larval walleye entrainment over a broader range of flow regimes would likely answer questions about the relationship between water flow, young of the year walleye abundance in the reservoirs, and the level of entrainment through these dams.

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