Evaluation of nonnative fish escapement from Starvation Reservoir

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Nonnative fish escapement, walleye, smallmouth bass, yellow perch, reservoir operations, Strawberry River drainage, stilling basin, spillway, outlet works

EXECUTIVE SUMMARY

Starvation Reservoir, located in northeastern Utah in the Strawberry River drainage, is a 3,310 surface acre reservoir managed for both recreational and agricultural water uses (Figure 1). It is a popular fishing location and contains walleye (*Sander vitreus*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), yellow perch (*Perca flavescens*), and smallmouth bass (*Micropterus dolomieu*). Of these popular sportfish species, smallmouth bass and walleye have been targeted by the Upper Colorado River Endangered Fish Recovery Program (Program) as being problematic for the recovery of the four big-river endangered fishes, Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), bonytail (*Gila elegans*), and humpback chub (*Gila cypha*). Because Starvation Reservoir is operated to maximize annual downstream water availability throughout the summer and fall (by filling to the active storage level during spring flows), the Program targeted Starvation Reservoir for evaluation of nonnative escapement potential beginning in 2002. The information gathered from this study is intended to aid in the discussion of whether or not management recommendations are necessary (i.e., screening the spillway, altering timing of spills, reducing magnitude of spills, etc.) to prevent or to limit escapement of target species from the reservoir.

The Division of Wildlife Resources (Division) had initially planned to sample spills directly by suspending a net over a section of the spillway during the annual spill; however, this was not feasible in accordance with operation protocols for the reservoir. Instead, crews began intensive drainings of both the outlet stilling basin (outlet basin) and the spillway stilling basin (spillway basin) in an effort to evaluate escapement (Figure 2). Evaluation occurred through multiple drainings each year: one draining towards the beginning of the year to clear the stillings basins of all fish present at that time (initial draining) and one towards the end of the year to

evaluate escapement that occurred either during the annual spill or during outlet releases (evaluation draining). Access to the river was blocked below the spillway basin for the entire study; however, this was not the case for the outlet basin. Fish were able to move freely between the outlet basin and the river.

Crews began the evaluation in 2002 and were able to successfully complete initial and evaluation drainings in the outlet basin in both 2002 and 2004. Crews attempted initial and evaluation drainings of the spillway basin in 2002, 2004, and 2005 and were not entirely successful until 2005, the only year that Starvation Reservoir had a significant spill. Because of this, escapement rates of the target species were calculated only for 2005. The reservoir spilled from 16 June to 11 July in 2005 and spilled a total of 15,533 acre-feet (AF). Rates of escapement based on 2005 sampling were as follows: smallmouth bass - 0.0028 fish/AF; walleye – 0.0005 fish/AF; yellow perch – 0.0006 fish/AF.

Given these low escapement rates over the spillway and the self-sustaining nature of smallmouth bass in both the Green and Duchesne rivers, screening the reservoir may not be the most cost-effective means of limiting their escapement from the reservoir, especially in light of other management options. In order to best evaluate cost and benefit, the Program must decide whether or not this rate of escapement is acceptable given the effort expended on reducing smallmouth bass and walleye populations throughout the Green River drainage through nonnative removal efforts.

Walleye escape from the reservoir and while they are occasionally encountered in the middle Green River during other Program efforts, there is little evidence of them successfully spawning in the river. One 25mm walleye was found during nonnative cyprinid removal work in the lower Green River in 2000 (Snyder 2000); however, as of 2006, this has been the only young

of year walleye captured in the Green River. This year, 2006, does however mark the year with the largest number of walleye captured in the Green River since nonnative removal efforts began in 2001 (Table 1). There is no evidence, however, to suggest that these fish originally came from Starvation Reservoir, though it is a likely source for walleye captured in the middle Green River. A more likely source for walleye captured in the lower Green River is Lake Powell. Though we do not know the source of these fish at this time, the Colorado Division of Wildlife is currently conducting a study to pinpoint sources of key nonnative species in the upper Colorado River Basin mainstem rivers. Thus the source of these fish should be identified within the next few years. If the Program believes that walleye will eventually successfully spawn and recruit in the Green River, screening or another management alternative may be necessary to minimize risk.

In addition to walleye and smallmouth bass, yellow perch, though not originally identified as a target species, have a high potential for escapement from the reservoir after having been introduced into Starvation Reservoir prior to 2002. This species was shown to escape the reservoir at approximately the same rate as walleye. Yellow perch are not often encountered in the Green River, nor have young-of-year yellow perch been observed. They are not as piscivorous as walleye and thus they may not need to be targeted; however, given they are new to the reservoir, they are included herein as a target species.

INTRODUCTION

The Upper Colorado River Endangered Fish Recovery Program (Program) has determined that control of nonnative fishes is necessary for recovery of the four big river endangered fishes, Colorado pikeminnow, razorback sucker, bonytail, and humpback chub. Escapement of nonnative fishes from reservoirs or other impoundments and dispersal into endangered fish occupied riverine habitats where they potentially pose a significant predatory or competitive threat has been identified as a problem (U.S. Fish and Wildlife Service 2002). Screening of reservoir outflow to reduce escapement of target nonnative fishes, a costly procedure, has been implemented at Highline Reservoir and attempted at Elkhead Reservoir (Miller and Laiho 1997; Colorado Division of Wildlife 2005). Another option for controlling escapement of nonnatives is to make recommendations to reservoir managers to limit spills and/or releases that may also allow for escapement of nonnatives or to chemically treat the reservoir's stilling basins following spills and/or releases. Each of these options has its drawbacks and limitations and the need for such nonnative fish control measures needs to be evaluated on a case-by-case basis. Starvation Reservoir, in northeastern Utah, was identified in the March 2000 Recovery Implementation Program Recovery Action Plan for such an evaluation beginning in 2002.

Presently, northern pike (*Esox lucieus*) are of great concern in the Yampa and middle Green rivers. However, other highly piscivorous species, including walleye and smallmouth bass, began increasing in abundance in the middle Green River around 2001 or 2002, likely in response to warmer water temperatures associated with drought conditions (Bestgen et al. 2006). Starvation Reservoir was identified as a very likely source for escapement of both walleye and smallmouth bass. The reservoir is located in the Strawberry River drainage and receives inflow

from the Strawberry and Duchesne rivers (Figure 1), though Duchesne River flows are diverted into the reservoir at the Knight Diversion and would not normally flow into the reservoir. The reservoir is primarily a walleye, smallmouth bass, and brown trout fishery. Yellow perch were recently introduced into the reservoir and are now abundant.

Locating major sources of these nonnatives to the river system was identified as the first step in controlling the spread of these species and the negative impacts these species have on recovery efforts for endangered fish species, particularly Colorado pikeminnow and razorback sucker.

Operation records for the reservoir show that spills have occurred regularly from 1985 through 2006 (13 of 22 years). The reservoir is operated to return to maximum capacity every spring as a result of spring peak flows. This operational plan essentially means that spills are likely to occur in years where spring flows are high enough to return reservoir levels to the active storage elevation even after compensating for drawdowns over the previous summer and fall. Spills generally occur in June with a duration ranging from one week to one month.

This four-year study identified locations (spillway or outlet) and rates of escapement of nonnative fish from Starvation Reservoir during releases (which are manually operated from the outlet located below the reservoir surface) and spills (which occur naturally when the reservoir is full and surface water passes over the spillway). This report presents the results of this work in addition to a synthesis of recent data and literature on fish populations in the Duchesne River and Strawberry River adjacent to Starvation Reservoir as an aid in the evaluation of impacts of escapement.

GOAL AND OBJECTIVES

Study Goal

This study was designed to obtain an estimate of the rate of escapement of walleye and smallmouth bass from the spillway and outlet works of Starvation Reservoir and to bring together recent data and literature on fish populations in the Duchesne and Strawberry rivers adjacent to Starvation Reservoir, in an effort to aid in the evaluation of impacts to native, endangered fishes.

Objectives

1. *Review and synthesize available data and reports on smallmouth bass populations and other fish species of the Duchesne River adjacent to Starvation Reservoir.*
2. *Complete an initial draining of the outlet basin prior to the irrigation season.* Theoretically, an effective initial draining would allow crews to clear the stilling basin of all fish so that the only fish present during the next draining, the evaluation draining, were those that escaped from the reservoir during releases. This is not exactly true in this case as the outlet basin was not blocked off from the river, thus fish were able to move freely back and forth between the outlet basin and the river.
3. *Complete an initial draining of the spillway basin prior to a spill.* Again, this was done to clear the spillway basin of fish prior to a spill so that the evaluation draining would turn up only those fish that escaped over the spillway during a spill. While the spillway basin was blocked from the river with a mesh block for the entire study, this initial clearing proved difficult due to the spawning of fish in the stilling basin.
4. *Complete an evaluation draining of the spillway basin following a spill.* Because all fish would theoretically have been cleared out of the spillway basin during the initial

evaluation, the only fish remaining should have been those that escaped during a spill. Thus the evaluation draining served to evaluate escapement over the spillway.

5. *Complete three fish sampling passes through the three-mile river reach below Starvation Reservoir.* This was done to determine presence/absence of target species immediately below the reservoir in the Strawberry River. This was done in fall and spring, 2002.

6. *Complete an evaluation draining of the outlet basin following the irrigation season.* This draining served to evaluate escapement of fish from the outlet basin, though as mentioned above, there were problems with effectively evaluating escapement here due to the absence of a block weir between the basin and the river.

7. *Obtain an estimate of the rate of escapement of target fish species through the spillway and outlet works of Starvation Reservoir.* Due to the difficulty mentioned above, this calculation was only done for the spillway basin and only done with data collected during 2005.

STUDY AREA

Starvation Reservoir is located in the Strawberry River drainage of northeastern Utah. It is approximately 3,310 surface acres (and approximately 167,000 AF) at capacity and receives inflow from the Strawberry and Duchesne rivers. The primary study areas were the reservoir's outlet basin and spillway basin and a three-mile reach of river beginning at the base of the stilling basins (Figures 2 and 3). These stilling basins connect to the river, thus any fish that is able to escape from the reservoir may also easily access the river. This access was blocked between the spillway basin and the river for the purposes of this study; this was not done between the outlet basin and the river. In addition to sampling the Strawberry River, portions of the Duchesne River (below the Knight and Myton diversions – Figure 1) were also sampled to add information on smallmouth bass and walleye distribution downstream of Starvation Reservoir.

METHODS

Initial draining of the stilling basins

Sampling in the outlet basin was done in 2002 and 2004. In 2002, pumping of the outlet basin began on 4 March and was completed on 8 March. In 2004, pumping of the outlet basin began on 15 March and was completed on 17 March. All fish were removed using a seine, identified, and enumerated. A representative sample of fish was measured and weighed.

In 2002, pumping of the spillway basin began on 12 March and was terminated prematurely as the reservoir began to spill on 28 March. Because of the incomplete pumping, removal of all fishes was difficult. Despite not being able to remove all fish, crews were able to use multiple sampling techniques (electrofishing, trammel netting, seining) to remove as many fish as possible. In 2004, pumping of the spillway basin began on 18 March and was completed 7 April. This was the only draining in 2004, as no spill occurred this year. In 2005, the spillway basin was drained beginning 8 June and ending 14 June prior to the spill and was intensively sampled to evaluate presence and relative abundance of fish.

In order to keep fish from downstream sections of the river from moving into the spillway basin, a block net weir (weir) was installed downriver from the basin. This weir was in place from the beginning of the study in 2002 through the end of the study in 2005 (Figure 3). The spillway basin weir was constructed using stock panels for a rigid frame overlaid with ½" mesh screening and was anchored to the riverbank using gabion baskets. The center of the weir was also anchored to a gabion basket. The weir below the spillway basin was placed, monitored, and cleaned daily during the spill period. Crews were asked by the Central Utah Water Conservancy District to refrain from setting up a separate weir between the outlet basin and the river in order to keep the outlet works clear for water releases.

Evaluation draining of the stilling basins

The next step consisted of again draining and sampling the outlet and spillway basins, this time after the irrigation season (outlet works) or after a spill (spillway). The outlet basin was drained following the irrigation season in 2002 and 2004. In 2002, evaluation draining of the outlet basin began on 3 December. Sampling was completed on 6 December. All fish were removed using a seine. In 2004, the evaluation draining of the outlet basin began on 1 November and was completed on 3 November.

The spillway basin was sampled following spills in 2002 and 2005. In 2002, pumping of the spillway basin began on 22 October and was completed on 15 November. The spillway basin evaluation draining in 2002 was thought to be successful at removing fish remaining from the initial sampling in the spring and thus served to clear the spillway basin for the next spill (which did not occur until 2005). The spillway basin was sampled after draining using both electrofishing and gill nets. No spill occurred in 2004, thus only an initial sampling occurred during that year.

In 2005, the spillway basin was pumped for three weeks in September to allow an evaluation of fish escapement over the spillway. Toward the end of the pumping period, river flows were increased to aid sampling efforts in the lower Duchesne River. Though the releases from the outlet into the spillway channel approximately 900 feet downstream of the spillway basin, the backflow was large enough to completely refill the spillway basin. It then became necessary to evaluate escapement using other methods in the stilling basin. Gill nets, fyke nets, and electrofishing were employed in an effort to sample and collect as many fish as possible and evaluate escapement. All walleye and smallmouth bass collected in both the stilling basins were lethally removed.

River sampling

Strawberry River sampling was done in 2002. Species presence in areas downstream of the stilling basins was monitored by electrofishing the three-mile section of river directly below the weir before and following runoff. A canoe equipped for electrofishing using a generator and a Coffelt 2-C electrofishing unit was used to electrofish the entire width of the stream channel as crews waded upstream (Figure 4). In addition to sampling this three-mile section of the Strawberry River, using the same sampling technique, crews also electrofished parts of the Duchesne River around the Knight Diversion (located approximately 5 miles upstream from the town of Duchesne) and Myton Diversion (approximately 20 miles east of Duchesne on Highway 40) in 2004 to evaluate the presence of target species (Figure 1).

Reservoir sampling

In 2005, the reservoir near the spillway was sampled using gill nets to evaluate escapement potential. Gill nets were set for three nights at the beginning of the spill.

Escapement rates

Following field activities, an estimate of the rate of escapement was calculated by dividing the number of fish captured in the spillway basin relative to the volume of water (AF) discharged over the spillway (e.g., 46 fish/15,533 AF = 0.0003 fish/AF). This discharge data was available from dam operation records at the Central Utah Water Conservancy District. This calculation was not done for results in the outlet basin due to the inability to prevent fish from moving back and forth between the stilling basin to the river.

RESULTS[1]

Starvation Reservoir spills

No spill occurred in 2003 or 2004. In 2002, spilling began on 2 April and ended on 8 April. Only 109 AF of water spilled with a peak spill of 16 cfs. The depth of water over the spillway during this time was not measured; however, during the 2002 spills, the water going over the spillway was observed to be a thin sheet, not more than a few inches. In 2005, the final year of the evaluation, the reservoir began spilling on 16 June; spills continued through 11 July for a total of 15,533 AF and a peak spill of 494 cfs (Figure 5). Water depth over the spillway during this spill was at least six inches, though again, depth was not physically measured, only observed.

2002

Initial draining of stilling basins

Fish removed after pumping of the outlet basin included predominantly brown trout and mountain whitefish (*Prosopium williamsoni*), though some centrarchids and catostomids were also found. Target species included one smallmouth bass and four walleye (Table 3).

The last days of pumping in the spillway basin were windy, which created large waves on the reservoir thus causing a spill and filling the stilling basin. Because of this, the crew used an electrofishing boat, trammel nets, and seines to get as many fish out as possible before the stilling basin completely refilled. As a result, not all of the fish were removed during the initial draining of the spillway basin. Fish removed from the stilling basin during this effort resulted in the capture of predominantly carp (*Cyprinus carpio*), green sunfish (*Lepomis cyanellus*), and

[1] Because this evaluation is looking at problematic nonnative fishes, this report will not discuss native fishes captured during this evaluation. Numbers are included in information tables; however, it is presumed that these fishes are not a problem and thus are not discussed. Table 2 lists whether species mentioned are native or nonnative to the drainage.

Utah chub (*Gila atraria*). Target species captured included 184 smallmouth bass and 48 walleye (Table 4).

Evaluation draining of stilling basins

Fish removed after the evaluation draining of the outlet basin were again predominantly brown trout and mountain whitefish, though carp, young-of-year (YOY) green sunfish, and rainbow trout were captured in small numbers. Target species included 2 walleye (Table 3).

Starvation Reservoir spilled for a period of seven days in 2002, beginning on 2 April. Knowing that the spill in the spring was short and that little chance of escapement existed, it is assumed that none of the fish removed during the evaluation draining escaped from the reservoir during the 2002 spill. Therefore, the evaluation draining served to remove the fish missed during the initial draining due to the spill before the draining was complete. Fish assemblage removed during this effort was similar to the initial draining effort: predominantly carp, green sunfish, and Utah chub. Target species included 158 smallmouth bass and 8 walleye (Table 4).

River reach monitoring

Within the three-mile section of river directly below the weir, fish sampled before spring irrigation releases were similar to those found in the outlet stilling basin: predominantly brown trout and mountain whitefish, but also carp, cutthroat trout (*Oncorhynchus clarki*), rainbow trout, and Utah chub (Table 5). Species assemblage was similar in the fall except crews did not see any cutthroat trout, though they did see mountain sucker (*Catostomus platyrhynchus*) (Table 5). No walleye, smallmouth bass, or green sunfish were observed during spring or fall electrofishing efforts. Given the connection that existed between the outlet basin and the river, it is not surprising that the two samples (river and outlet basin) were so similar.

2003

Fieldwork for 2003 was postponed due to Starvation Reservoir not spilling.

2004

Initial draining of stilling basins

Fish collected after draining the outlet basin were predominantly brown trout. Additional species included largemouth bass (*Micropterus salmoides*), mountain sucker, mountain whitefish, and numerous mottled sculpin (*Cottus bairdii*). Target species included two walleye and two yellow perch (Table 3).

Fish removed after draining the spillway basin were predominantly centrarchids, though a few cyprinids and salmonids were caught during this effort. Target species included 96 smallmouth bass and one walleye (Table 4). Note in Table 4 that though the 2002 drainings were considered successful at removing fish, a few fish remained in the spillway basin (one brown trout, 10 carp, two Utah chub, one walleye, and many smaller green sunfish and smallmouth bass). These fish are believed to have eluded the removal effort from the 2002 drainings as even though the draining was successful, it was not possible to completely drain the basin (the pumps used for this project become much less effective when the depth of water is less then four inches). Instead, the spillway basin was drained down to the concrete flooring of the basin as far as possible and then seined to remove as many fish as possible.

Evaluation draining of stilling basins

Fish removed after draining of the outlet basin were again predominantly brown trout and mountain whitefish. Crews also captured white sucker (*Catostomus commersonii*), mountain sucker, and carp. Target species included one walleye and 48 yellow perch (Table 3).

Starvation Reservoir did not spill in 2004; therefore, an evaluation draining of the spillway basin could not be completed.

River reach monitoring

Fish species collected below the Knight Diversion (upper Duchesne drainage), which is above the confluence with the Strawberry River, included flannelmouth sucker, brown trout, and carp. Fish collected below the town of Myton (lower Duchesne drainage) included white sucker, flannelmouth sucker (*Catostomus latipinnis*), carp, black bullhead (*Ameiurus melas*), and smallmouth bass.

2005

Initial draining of stilling basins

Sampling in the spillway basin prior to the spill resulted in the capture of predominantly green sunfish, which were primarily YOY likely produced within the basin. Other species included brown trout, carp, and adult green sunfish. Target species included nine smallmouth bass (Table 4). The brown trout and carp were likely fish that avoided removal during the previous draining. Again, although the 2004 and 2005 initial drainings were considered successful at removing fish, crews could not be entirely effective at removing every fish due to equipment limitations.

Evaluation draining of stilling basins

Sampling in the spillway basin in October following the spill again resulted in the capture of predominantly green sunfish; however, crews also captured brown trout, white sucker, and Utah chub. Target species included 43 smallmouth bass, eight walleye, and nine yellow perch (Table 4). In considering the numbers and species collected prior to the spill, all fish collected

with the exception of the green sunfish (of which, abundant YOY were collected) likely escaped from the reservoir during the spill. Length frequencies for smallmouth bass, walleye, and yellow perch throughout the study effort are given in Figures 6, 7, and 8.

Reservoir sampling

Sampling near the spillway resulted in the capture of six smallmouth bass, 20 walleye, and 52 yellow perch (Table 4). Other species captured during this effort were brown trout and Utah chub. The brown trout, smallmouth bass, and Utah chub were large adults. The walleye and yellow perch were primarily age-1 and age-2 juveniles (Figure 9).

Other Duchesne River sampling

The U.S. Fish and Wildlife Service's Vernal Colorado River Fishery Project (CRFP) sampled the Duchesne River to remove smallmouth bass and channel catfish (*Ictalurus punctatus*). Results of the effort in 2005 resulted in the capture and removal of 100 smallmouth bass and 61 channel catfish. Smallmouth bass were predominantly encountered in the upper sampling reaches (RM 17 - RM 41). Length frequencies for smallmouth bass over all four removal passes are given in Figure 10 (figure reproduced with permission from CRFP). The species assemblage during removal efforts was similar to that found during the 2004 Duchesne River effort: carp, white sucker, channel catfish, smallmouth bass, and brown trout. No walleye or yellow perch were captured during 2005.

DISCUSSION

Outlet Stilling Basin

In 2002 and 2004, brown trout were captured in quite similar numbers during both drainings (2002: 120 initial/114 evaluation; 2004: 293 initial/349 evaluation). Given that brown trout numbers remained high and that their population is considered stable within the Strawberry River drainage, the most likely explanation is that most are moving into the outlet basin from the river where they are established (though some probably do escape from the reservoir). Influx from the river is especially likely given that no weir was set up between the outlet basin and the river.

Largemouth bass were captured in the outlet basin in 2004, though they are rarely encountered in either the reservoir itself or the river downstream of the reservoir (Utah Division of Wildlife Resources 2003). Also beginning in 2004, crews began catching yellow perch in relatively high numbers. Perch were introduced into the reservoir prior to 2002 and are now established in the reservoir. While it is unlikely that walleye, smallmouth bass, and yellow perch are moving from the river into the outlet basin (these species were not found in the river during electrofishing surveys), it is possible that these species escape from the outlet and continue downstream into the Duchesne River. If this were occurring, escapement rates (based on the data collected during this study) through the outlet would be underestimated. Additionally, escapement of the target species may be underestimated as a result of our inability to characterize predation by brown trout in the outlet basin. Given these uncertainties, it was virtually impossible to get a definitive rate of escapement through the outlet works.

The outlet drain (capacity = 2,400 cfs) is 117 feet below the reservoir surface when the reservoir is full (5,712 feet elevation). Reservoir operation records from the Central Utah Water

Conservancy District indicate that from 1986 and 2006, the reservoir regularly filled to the active storage level during the spring and then was drawn down over the remainder of the year. These drawdowns were extensive in dry water years (sometimes as much as 80,000AF, with an average of around 40,000AF). These amounts translate into an elevation reduction of sometimes 10, sometimes nearly 40 feet of overall water elevation in the reservoir. These water level fluctuations could have significant ramifications on the species assemblage escaping from the reservoir with cold water species escaping during spring releases and a cool water assemblage escaping as the reservoir elevation is reduced over the year. Therefore, although study results indicate that escapement rates for smallmouth bass and walleye through the outlet are low (only one smallmouth bass in 2002; six walleye in 2002 and three in 2004), the potential is there for these species to escape and the potential is also there to underestimate their rate of escapement.

Spillway Stilling Basin

Comparing the 2005 spillway escapement numbers (not rates) with escapement numbers from the outlet evaluation drainings, smallmouth bass and walleye appear to escape over the spillway in higher numbers than through the outlet. Yellow perch escape from both the outlet works and the spillway, but they appear to escape from the outlet in greater numbers.

Given the difficulties with the study, the initial and evaluation drainings in 2002 were considered an effective “initial” draining. In addition, the evaluation draining in 2004 and the initial draining in 2005 were nearly complete at removing all fishes. Thus, the evaluation draining in 2005 was thought to be a valid evaluation of escapement of target species over the spillway. Despite this fact, the spillway basin did refill before crews were able to clear it of all fish, thus there is potential for underestimation of escapement even during the 2005 evaluation draining. Another key feature in the evaluation of escapement, the weir placed in between the

spillway basin and the river, was known to be effective throughout all but the largest spills from the reservoir. During the 2005, water overtopped a small portion of the weir (estimated to be approximately four to six inches and about one to two feet wide). Because it was such a small section of the spillway channel and because it was on the very top of the water, it is highly unlikely that any fish were able to escape from the spillway basin to the river; however, it is possible and therefore, final escapement numbers in 2005 may be an underestimate of actual escapement.

Based on the life stages present in the spillway basin, it is likely that each of the species escaped from the reservoir between drainings except for green sunfish, which are apparently established in the spillway basin. It is also possible that smallmouth bass are established in the spillway basin as there was no spill in 2004 and a number of smallmouth bass between 150 and 200mm were captured during the initial draining of 2005. These fish could have been YOY in 2004 and thus would have resulted from spawning in the spillway basin. It is also possible, however, that temperatures in the spillway basin are low enough to prohibit normal growth of smallmouth bass. If this were the case, these 150 – 200mm fish could have been older than YOY in 2004. Whatever the source of these smaller smallmouth bass (escapement or spawned in the spillway basin), these fish are not likely to be the source of YOY fish seen in the Duchesne River. It is more probable that smallmouth bass, in addition to reproducing in the reservoir and the spillway basin are also reproducing in the Duchesne River.

Escapement Rates

The target species (smallmouth bass, walleye) were found during the initial draining of the spillway basin in 2002 and in almost every subsequent sampling effort. Because it is difficult to differentiate a fish that has escaped from the reservoir from a fish that was spawned in the

spillway basin, rates of escapement were calculated with the assumption that all fish from the evaluation draining escaped from the reservoir after the initial draining (43 smallmouth bass, five walleye, eight yellow perch). The authors felt this assumption was warranted, as it would provide a conservative estimate of escapement. In addition, it was the only objective way to establish escapement rates given all of the unknowns associated with the study. Given this assumption, in 2005, smallmouth bass were observed to escape at a rate of 0.0028 fish/AF of spill; walleye escaped at a rate 0.0005 fish/AF of spill; and yellow perch at a rate of 0.0006 fish/AF of spill (total spillage in 2005 was 15,533 AF). Thus, these species do appear to escape, but at low rates.

It is important to remember that this is likely an underestimate of true escapement; however, upon comparing escapement at Starvation Reservoir with that observed at Elkhead Reservoir, even an underestimate of escapement would be a relatively small amount. Studies at Elkhead Reservoir have estimated escapement of smallmouth bass at 0.02 fish/AF (Miller et al. 2005), meaning that Starvation Reservoir escapement rates are an order of magnitude smaller than those observed at Elkhead Reservoir. For rates of escapement at Starvation Reservoir to be similar to those seen at Elkhead, at least 310 smallmouth bass would have had to escape the spillway in 2005 compared with the 43 fish that actually did. The largest number of smallmouth bass seen during the study was 184 fish during the initial draining in 2002. This suggests that though escapement over the spillway was probably underestimated, escapement rates at Starvation Reservoir are not likely to be as high as at Elkhead Reservoir.

Smallmouth bass escape at slightly higher rates that may be considered problematic for endangered fish recovery; however, considering its probable self-sustaining population status in the Duchesne River and its definite self-sustaining status in the Green River, escapement from Starvation Reservoir is only part of the overall picture.

Strawberry and Duchesne River Sampling

Sampling in the Strawberry River suggests a species assemblage dominated by brown trout. Given the assemblage in the Strawberry River and its similarity to the assemblage collected from the outlet evaluations, brown trout are most likely moving upstream into the outlet basin and there is likely very little escapement of brown trout through the outlet, though it probably does occur.

Sampling in the Duchesne River in 2004 and 2005 by various agencies revealed a species assemblage dominated by nonnative fishes in both the upper and lower stretches of the river. The only native fish encountered in any of these surveys was flannelmouth sucker. Smallmouth bass were found in sampling efforts beginning around the Myton Diversion (RM 41). Figure 10 shows length frequency information for smallmouth bass sampled during removal efforts from RM 0 to RM 41. This information is courtesy the CRFP.

Summary

At this point, it is certain that smallmouth bass, walleye, and yellow perch are escaping from Starvation Reservoir and that they are the predominant escapees from the reservoir via the spillway (does not include white sucker which may be increasing in abundance and green sunfish which is apparently established in the spillway basin). Smallmouth bass are currently established in both the Duchesne and Green rivers, though active removal is occurring in the Green River and results from that project suggest that catch rates of certain size classes appear to be declining from 2004 through 2006 data (Upper Colorado River Recovery Implementation Program 2005 annual report, Project No. 123). If the goal of the removal efforts is to eventually reduce the numbers of smallmouth bass to a level where only minimal removal efforts are needed each year, the decision on the appropriate management for Starvation Reservoir then becomes whether or

not the Recovery Program believes this goal would be cost effective given the rate of escapement of smallmouth bass from the reservoir.

Walleye and yellow perch are also escaping over the spillway, in fact, sampling in the reservoir near the spillway showed both walleye and yellow perch had a high potential for escapement over the spillway as captures of these fish were higher than any others in the reservoir sampling. Interestingly, while crews from the Utah Division of Wildlife Resources in Vernal (Division) tend to capture walleye at similar rates each year (Table 1), they have not yet observed reproduction of walleye below Starvation Reservoir. The Division's Moab office, however, found one 25mm walleye during nonnative cyprinid removal in the lower Green River in 2000 (Snyder 2000). This has been the only YOY walleye captured in the Green River to date. This year (2006), during other sampling in the Green River, capture rates of walleye in the lower Green River increased from prior years. It is unknown whether these fish came from Starvation Reservoir, though the number of potential sources is limited to only Starvation Reservoir and Lake Powell in Utah. The actual source of these fish will hopefully be identified through the isotope study currently being conducted by the Colorado Division of Wildlife. Because of this uncertainty, it may be premature to screen or manage spills at Starvation Reservoir.

The decision to manage Starvation Reservoir to prevent walleye escapement thus becomes whether or not the Recovery Program believes the risk that walleye will someday successfully spawn and recruit in the drainage is greater than the cost associated with screening or altering management of the reservoir. In the meantime, crews are removing walleye as they are found in the Green River and the Colorado Division of Wildlife is continuing to collect nonnative fish specimens throughout the drainage to identify isotopic signatures that will pinpoint sources of the various target nonnative species.

Yellow perch were not identified as a target species for this study; however, with their introduction to the reservoir, they have become a species with a high potential for escapement. In comparison with the other target species, yellow perch are not as piscivorous though they are known to be dietary generalists and to eat smaller fish as adults and thus may pose a threat to certain life stages of the endangered fishes (Knight et al. 1984; Graeb et al. 2005).

CONCLUSIONS

- Smallmouth bass, walleye, and yellow perch are escaping from Starvation Reservoir. Given the information collected in 2005, it appears all three species are escaping from the reservoir at a rate of less than 0.01 fish/AF (0.0028 fish/AF for smallmouth bass, 0.0005 fish/AF for walleye, and 0.0006 fish/AF for yellow perch). Since 1985, the reservoir has spilled an average of 5,017 AF/year for an average escapement of less than 20 fish each year (14 smallmouth bass, 3 walleye, and 3 yellow perch) based on information collected in 2005.
- Fish captured from the outlet basin were predominantly those of a coldwater species assemblage similar to those found in the Strawberry River (though escapement here could be underestimated), whereas those captured from the spillway basin were predominantly of a cool water assemblage similar to those found lower in the Duchesne River drainage (beginning around RM 41).
- It is likely that smallmouth bass currently reproduce in the Duchesne River below the Myton Diversion and it is certain that they reproduce in the middle Green River. Smallmouth bass removal efforts conducted by the Recovery Program may offset the need to prevent escapement of nonnatives from Starvation Reservoir. However, with the increased emphasis on removing smallmouth bass beginning in 2007, it may be more important now to eliminate the reservoir as a potential source of smallmouth bass.
- The Division normally sees a few adult walleye each year during sampling efforts in the Green River. In 2006, however, Division crews working in the lower Green River captured 48 walleye during the spring Colorado pikeminnow abundance estimates. While

this is not significantly greater than in other years, 2006 does represent the largest catch of walleye in the Green River since nonnative removal efforts began in 2001 (Table 1).

- In reservoir sampling near the spillway in 2005, yellow perch and walleye were the most abundant species gill netted in seven gill net sets, suggesting that these species may have the highest potential to escape over the spillway.

RECOMMENDATIONS

- Do not screen the spillway of Starvation Reservoir. Reservoir screening options are expensive and are not always guaranteed, and with such a low rate of escapement of the target species, other more cost-effective options should be evaluated (see #3 below).
- Take no management action in the outlet basin. Given that it was not possible to determine whether fish escaped from the outlet drain or moved in from the river (though the target species most likely came through the outlet), it would be beneficial to determine escapement rates through the outlet before managing it for escapement.
- Continue to explore the option of managing Starvation Reservoir to limit the volume of spills. Starvation Reservoir is managed to spill every year and though this will likely continue, lower capacity spills may be better at containing fish in the reservoir. During the Elkhead Reservoir study, spills less than 200 cfs seemed to be associated with minimal escapement (Miller et al. 2005).
- If able to develop a better way to characterize escapement (i.e., determine escapement at different spill volumes), explore the feasibility of chemically treating the stilling basin after a spill to eliminate potential for downstream movement of target species. This could be done by blocking the spillway channel with the block weir again during a spill and then pumping and treating the spillway basin after the spill is completed. This would prevent all adult fish in the spillway basin from moving downriver.
- Continue isotope studies to identify sources of nonnative fishes throughout the Green River drainage. This project will help determine where the large number of walleye in the lower Green River is coming from and whether Starvation Reservoir is a bigger source of both walleye and smallmouth bass than initially perceived.

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Table 1. Number and size of walleye captured and removed from the middle and lower (in parentheses) Green River, 2001-2006. Note that sampling effort in 2004 and 2005 was lower than for other years.

Year	Middle Green River Locations	Size Range (mm)	Number (lower Green totals)
2001	Duchesne River (RM 248), Jensen (RM 309), Split Mountain (RM 319)	495 - 675	40 (14)
2002	Jensen, Wyasket Outlet (RM 255)	419 - 570	15 (37)
2003	Ouray (RMs 251-260), Cliff Creek (RM 303), Duchesne River, Jensen, RZB Bar (RM 311), Bonanza Bridge (RM 289.6)	439 - 560	12 (25)
2004	Stirrup (RM 275), Johnson (RM 264), Bonanza Bridge, Brennan 264), Leota Bottom (RMs 257-260)	355 - 643	9 (3)
2005	Jensen, Cliff Creek	474 - 716	13 (1)
2006	Thunder Ranch (RMs 303.5-311), Split Mountain, Jensen, Red Wash (RM 298)	465 - 680	13 (48)

Table 2. Native and nonnative species mentioned in the text.	
Native Species	
Colorado pikeminnow	*Ptychocheilus lucius*
Razorback sucker	*Xyrauchen texanus*
Humpback chub	*Gila cypha*
Bonytail	*Gila elegans*
Mountain whitefish	*Prosopium williamsoni*
Cutthroat trout	*Oncorhynchus clarki*
Mountain sucker	*Catostomus platyrhynchus*
Mottled sculpin	*Cottus bairdii*
Flannelmouth sucker	*Catostomus latipinnis*
Nonnative Species	
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
Brown trout	*Salmo trutta*
Utah chub	*Gila atraria*
Yellow perch	*Perca flavescens*
Green sunfish	*Lepomis cyanellus*
Carp	*Cyprinus carpio*
Rainbow trout	*Oncorhynchus mykiss*
Northern pike	*Esox lucius*
Largemouth bass	*Micropterus salmoides*
White sucker	*Catostomus commersonii*
Black bullhead	*Ameiurus melas*
Channel catfish	*Ictalurus punctatus*

Table 3. Number of fish caught by species in the outlet stilling basin of Starvation Reservoir during initial and evaluation draining: 2002 and 2004.

	Brown trout	Mountain whitefish	Smallmouth bass	Walleye	Largemouth bass	Yellow perch	Green sunfish	Mountain sucker	Rainbow trout	Utah chub	Carp	White sucker
March 2002 Initial	120	143	1	4	0	0	3	5	7	9	30	0
December 2002 Evaluation	114	38	0	2	0	0	3	0	2	0	2	0
March 2004 Initial	293	8	0	2	3	2	0	1	0	0	0	0
November 2004 Evaluation	349	16	0	1	0	48	0	4	0	0	9	1

Table 4. Number of fish caught by species in the spillway stilling basin of Starvation Reservoir (2002 - 2005) and near the dam and spillway in the reservoir (June 2005).

	Brown trout	White sucker	Carp	Green sunfish	Smallmouth bass	Utah chub	Walleye	Yellow perch
March 2002 Initial	6	0	230	501	184	139	48	0
October 2002 Evaluation	4	0	12	521+	158	20	8	0
March 2004 Initial	1	0	10	Abund. YOY	96	2	1	0
June 2005 Reservoir	9	0	0	0	6	9	20	52
June 2005 Initial	1	0	2	168	9	0	0	0
October 2005 Evaluation	2	12	0	69	43	3	8	9

Table 5. Number of fish by species captured during electrofishing efforts in approximately three river-miles of the Strawberry River below Starvation Reservoir during the spring and fall: 2002.

	Brown trout	Carp	Cutthroat trout	Mountain whitefish	Mountain sucker	Rainbow trout	Utah chub
Spring	1584	2	1	13	0	28	1
Fall	1779	0	0	57	9	21	0

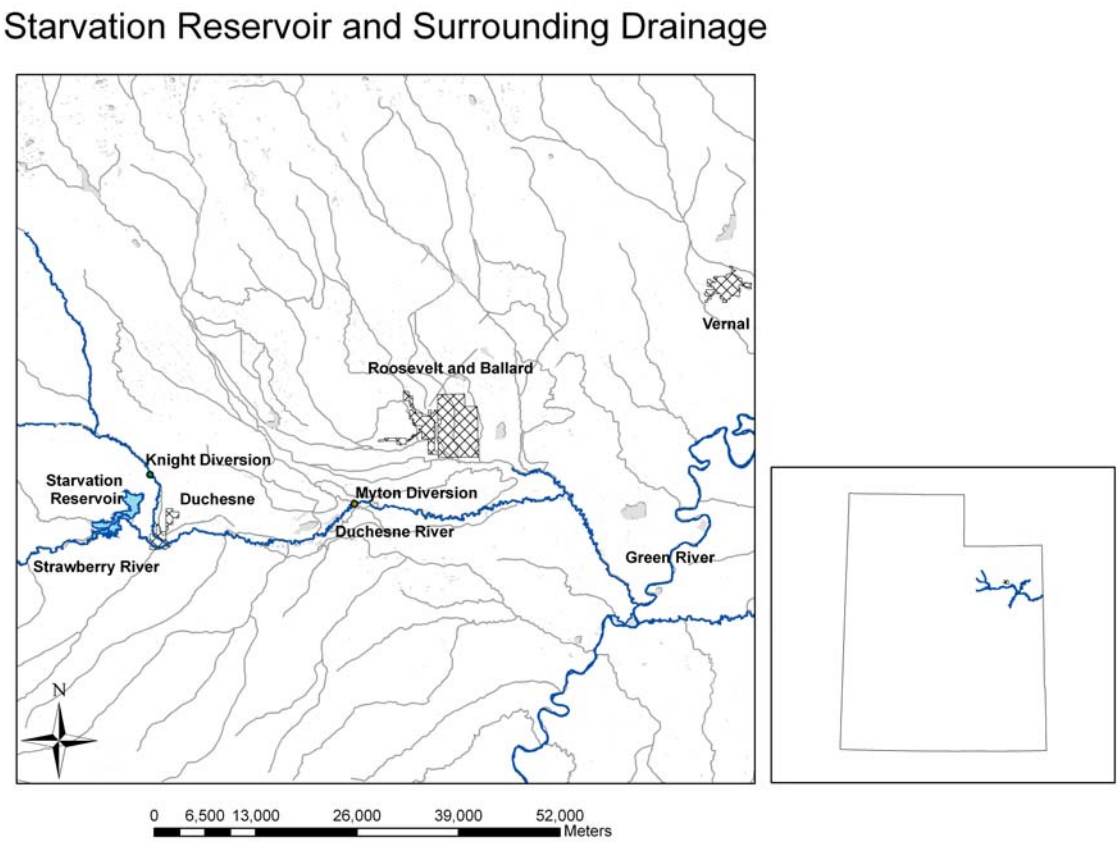

Figure 1 – Select features in the Duchesne and Strawberry River drainages, including Starvation Reservoir.

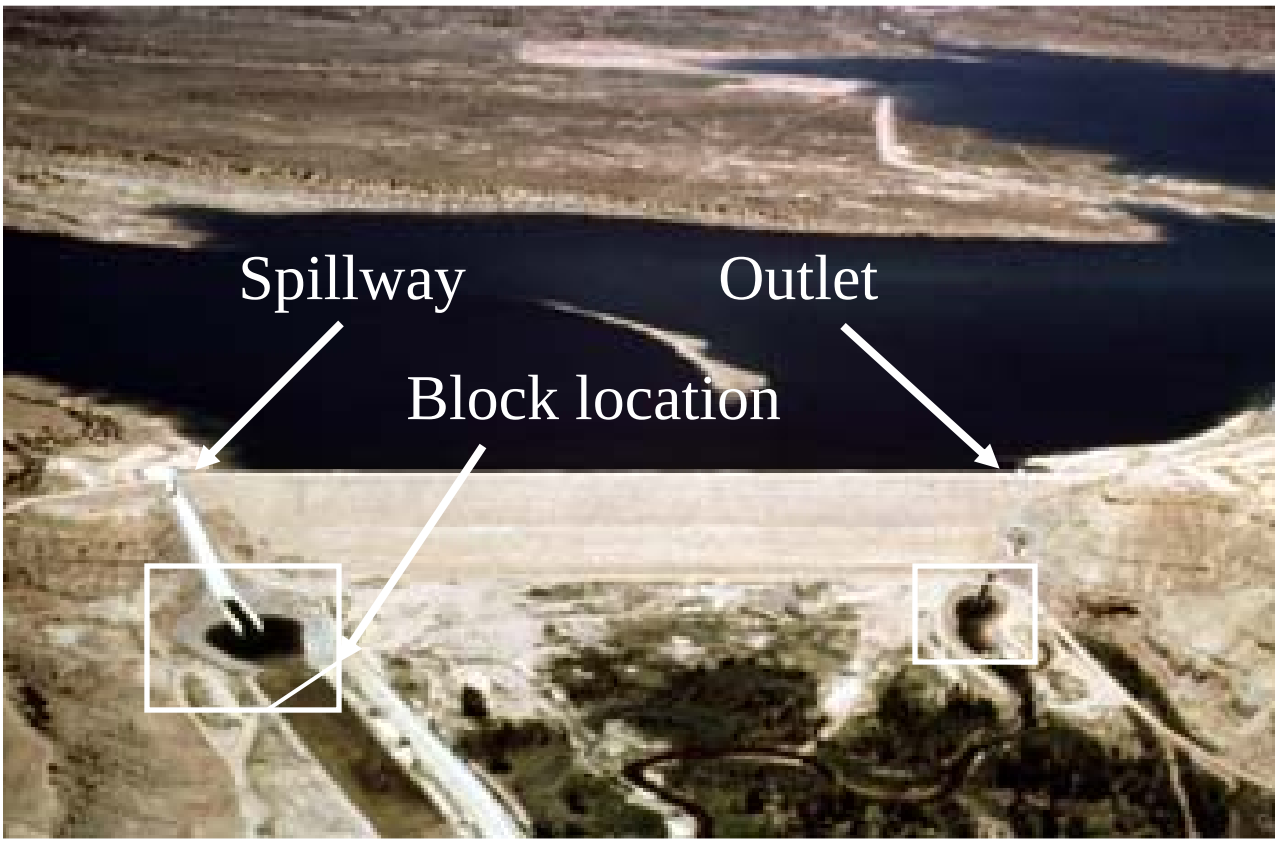

Figure 2 – Starvation Dam and the spillway and outlet locations. The stilling basins are each identified by a white box. Please note that the outlet is a bottom release of water and the spillway spills water from the top of the reservoir. The block net weir was set below the spillway basin, between the stilling basin and the river.

Figure 3 – Picture showing the block net weir between the river and the spillway stilling basin.

Figure 4 – Crews sampling the Strawberry River downstream of the dam.

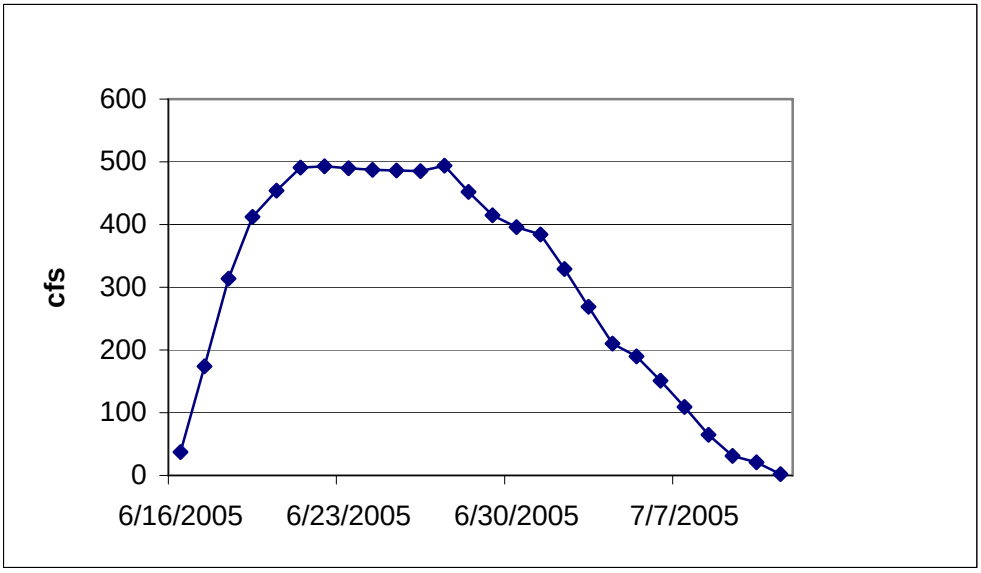

Figure 5 – Daily spill hydrograph for the Starvation Reservoir spill in 2005.

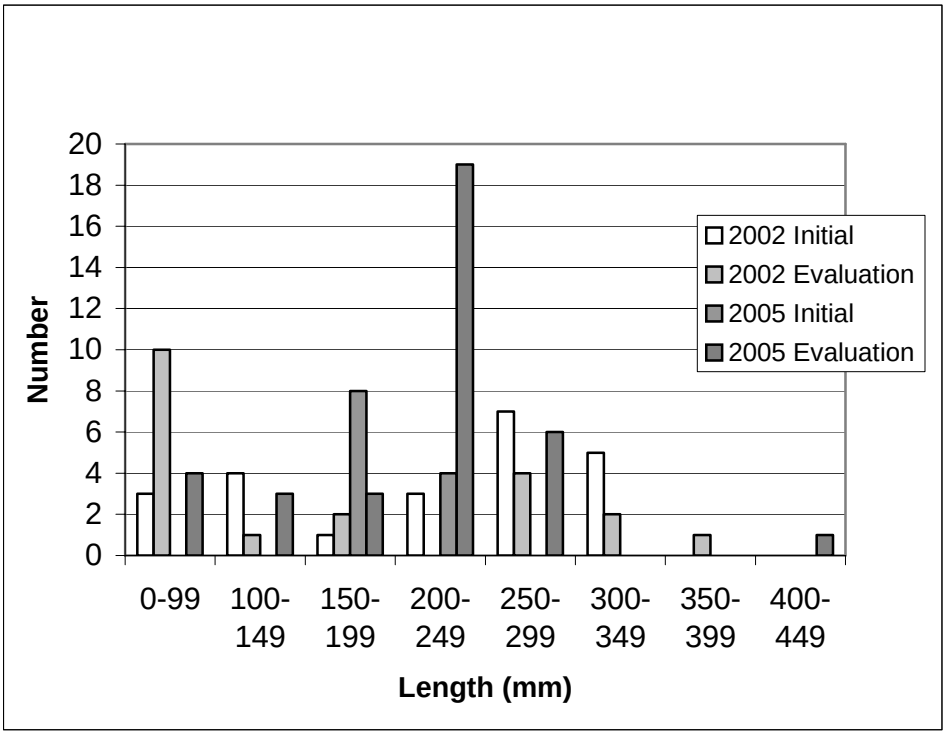

Figure 6 – Length frequencies for all smallmouth bass captured in the spillway basin during the Starvation Reservoir escapement study.

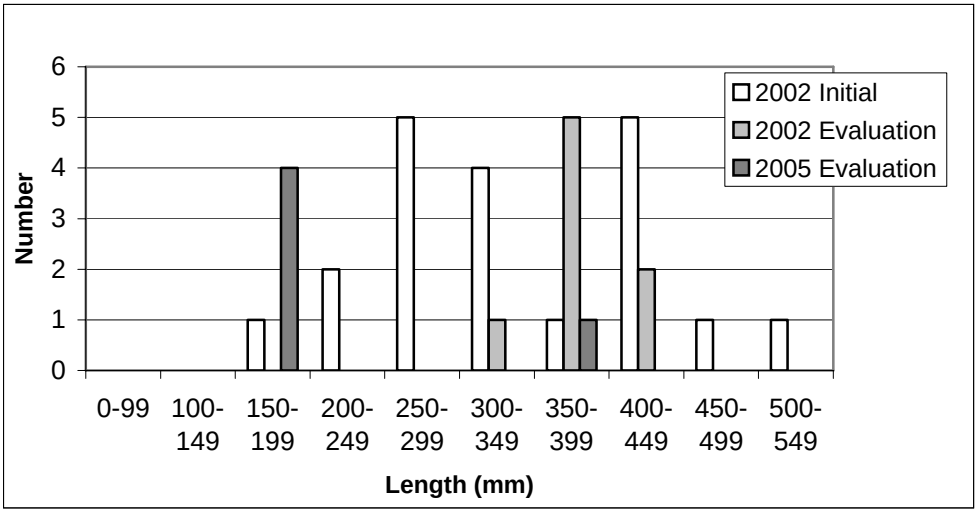

Figure 7 – Length frequencies for all walleye captured in the spillway basin during the Starvation Reservoir escapement study.

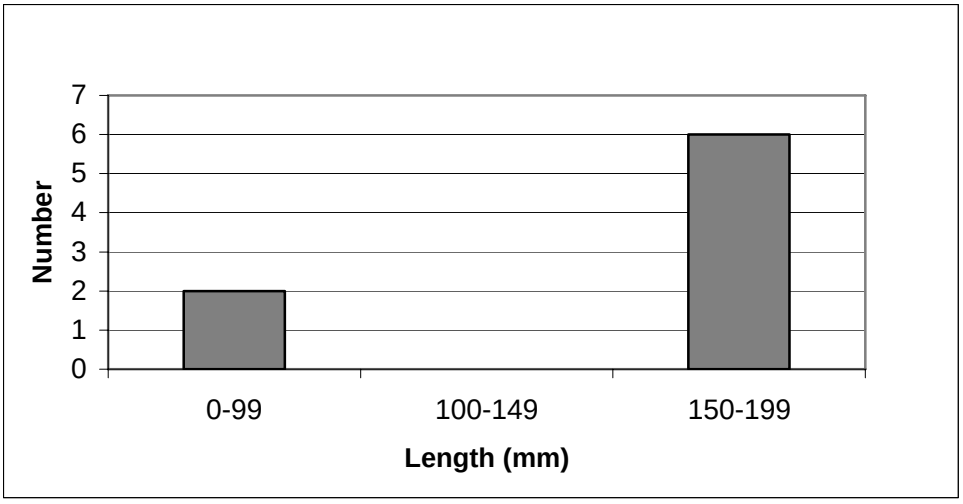

Figure 8 – Length frequencies for all yellow perch captured in the spillway basin during the Starvation Reservoir escapement study (2005 evaluation draining only).

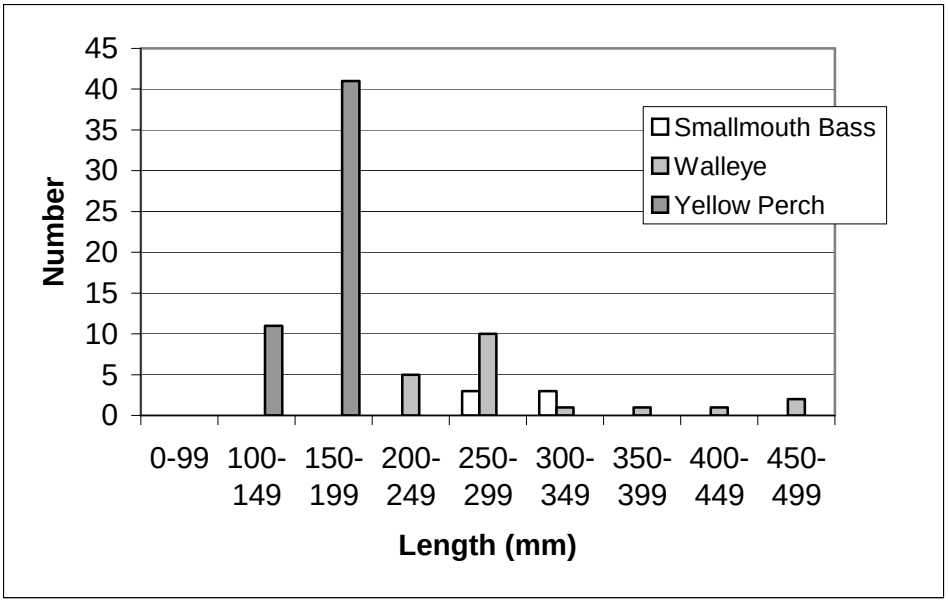

Figure 9 – Length frequencies for all target species captured in 2005 during gill net sampling in the reservoir.

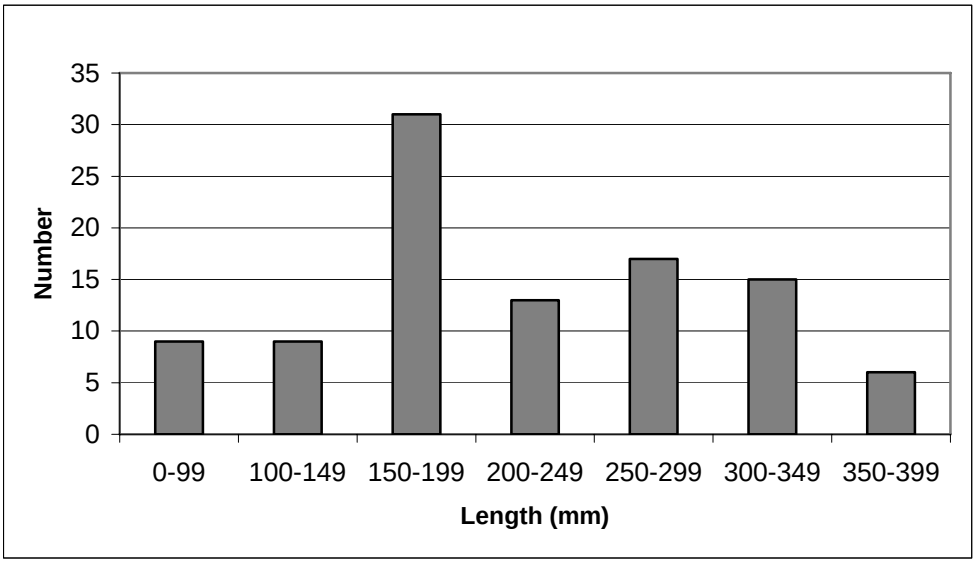

Figure 10 – Length frequencies of smallmouth bass from four removal passes on the Duchesne River (RM 0 – 41; 2005). Figure reproduced with permission from the U.S. Fish and Wildlife Service's CRFP.