FINAL REPORT

Elkhead Reservoir Escapement
Recovery Program Project No.: 118
Investigation of nonnative fish escapement from Elkhead Reservoir.

By:

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Executive Summary

An escapement study was conducted during 2003 and 2004 during periods of high spill rates associated with snowmelt runoff at Elkhead Reservoir near Craig, Colorado. Nets were placed and monitored at strategic locations on the spillway and outlet structure. Fish escapement was confirmed at all locations, but was greatest during periods of high discharge at the spillway. Relative abundance data indicated that bluegill and black crappie are the species that escape with the greatest frequency; however, they have been captured infrequently in slackwater habitats in the Yampa River downstream from Elkhead Reservoir. A diel pattern of escapement was also observed.

The recommended screening for the reservoir to minimize escapement includes installation of screens on all controlled outlets of the enlarged reservoir. To the extent practicable, the controlled outlets should be used to the maximum release capacity during runoff when flows are released over the spillway. This operational adjustment should shorten the magnitude and duration of flows exiting the reservoir by way of the spillway.

This screening option recognizes that there could be some escapement during highest flows. The species that are of most concern are northern pike and smallmouth bass. Based on the data collected in 2003 and 2004, few smallmouth bass and no northern pike were captured during this study.

Key words: catch rate; diel; entrainment; escapement; outlet structure; outflow; spillway; reservoir; runoff.

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INTRODUCTION

Escapement of non-native fish from Elkhead Reservoir has been identified as a potential impact to listed fish in the Yampa River. Fish escapement from the reservoir was included in the 2001 work plan for Elkhead Reservoir enlargement studies conducted by Miller Ecological Consultants, Inc. Miller and Laiho (1997) recommended study of escapement prior to the selecting an escapement control device. The potential cost of building and installing a flexible, Kevlar-like net, suspended in the water column to minimize fish escapement from Elkhead Reservoir is estimated near $1 million. It is presumed that annual operating and maintenance of this screen will also be significant. These potential costs compel an evaluation of fish escapement as a pre-requisite task to justify this investment in both the recovery of the endangered Colorado River fishes and the reservoir sportfishery.

Miller Ecological Consultants, Inc. collected aquatic resource information in fall of 1995 on Elkhead Creek for fish and macroinvertebrates (Miller and Rees 1996). Two sites were studied, one downstream of the reservoir and one upstream of the reservoir. The data provided baseline information for the stream aquatic resources downstream and upstream of Elkhead Reservoir. Results of this survey demonstrated the presence of small numbers black crappie and bluegill, and relatively abundant smallmouth bass in the creek near the dam outlet. Most bass were 30-95 mm in length with only four of 192 fish exceeding 100 mm.

Colorado Division of Wildlife collected data on the reservoir fishery in 1999 (Bill Elmblad, CDOW personal communication). They sampled with electrofishing and gill nets. The results of that survey showed that approximately 80% of the fish captured were nonnative game species. Nonnative white sucker made up the largest segment of nongame fish (15%). No native fish were collected in the reservoir. The reservoir was again sampled in 2001 (Miller Ecological 2004), and results on relative abundance confirmed those of CDOW, showing smallmouth bass, black crappie and bluegill to be the most common species.

Miller Ecological Consultants conducted a preliminary escapement study during the summer and fall of 2001 but due to the short runoff period, data were not collected during runoff (Miller Ecological 2004). It was hypothesized that the potential for escapement is greatest during the snowmelt runoff period from May through June. This study provides results from monitoring escapement during runoff in 2003 and 2004.

Elkhead Reservoir represents the largest reservoir in the Yampa Valley with potential and opportunities for warmwater fishing recreation. Due to its size, it offers considerable capacity to serve as a receiving water for nonnative gamefish species targeted for control and removal from the Yampa River. Relocation of adult gamefish from the river to the reservoir could potentially serve a net benefit of both reducing their impacts on native riverine fish populations (including the federally endangered fish species), and providing sportfishery potential in the reservoir. A habitat suitability rating projected for an enlarged Elkhead Reservoir based on a pattern judgement model using physical factors indicated suitable habitat for smallmouth and largemouth bass would remain low, similar to conditions at the existing reservoir (Bergersen and Martinez 2003). Despite the apparent biological limitations based on reservoir habitat modeling, the local populace regards this reservoir as a desirable fishery for these species. Interaction with the local bass-fishing club demonstrated members were generally satisfied with the current productive capacity of the reservoir for producing desirable-sized bass (Tom Nesler, Colorado

Division of Wildlife, personal communication). The procedures used in this escapement study allow for the capture and subsequent monitoring of resident fish as well as "relocated" fish within the reservoir.

Study Area

Elkhead Dam and Reservoir is located approximately 10 miles northeast of the city of Craig, Colorado. The dam is located on Elkhead Creek and was constructed in 1974. The current capacity of the Reservoir is approximately 13,000 acre feet. Annual operational hydrology is dominated by snowmelt runoff during April through June when approximately 90% of the annual 20,000 to 100,000 acre feet of water occurs as inflow to the Reservoir (Miller and Laiho 1997).

The spillway is a U-shaped ogee crest structure, 41 meters long, and the primary outlet works are located submerged in the Reservoir and has a maximum capacity of 180 cfs (Figure 1). The outlet at the dam has not been regularly operated since the dam was constructed. The outlet was not operated, other than seepage flow, during the study. There is an auxiliary outlet on the east side of the spillway to release to an irrigation ditch that releases 10 cfs.

The east side of the spillway is in close proximity with the natural topography and provides habitat connected closely to the east spillway area (Figure 2). The west side of the spillway is concrete and riprap and does not have the same configuration as the east side. It may provide different habitat and different attraction than the east side of the spillway (Figure 3). The spillway release goes over the ogee crest and down a flume shaped concrete spillway to a plunge pool. The controlled outlet works exits about two-thirds of the way down that spillway chute when it is in operation (Figure 4).

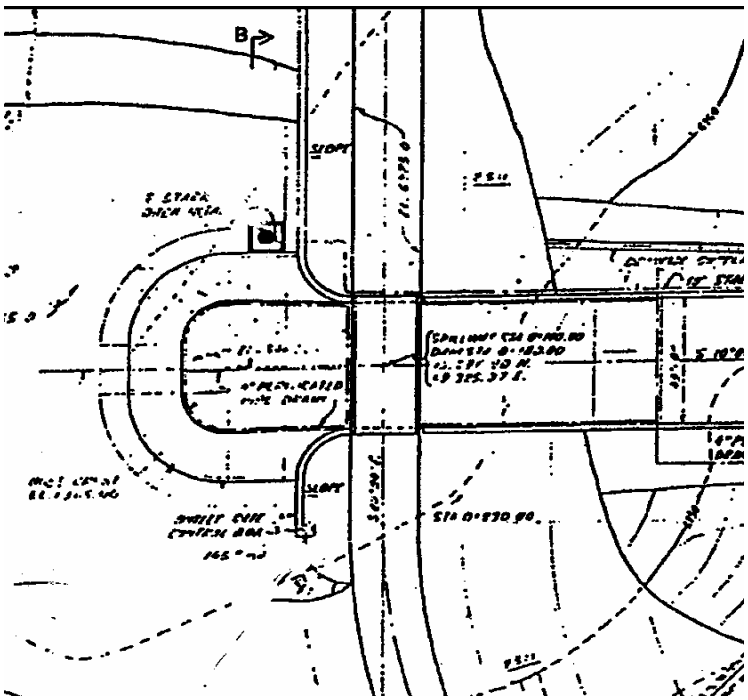


Figure 1. Plan view of spillway.

Figure 2. View of Elkhead spillway looking east.

Figure 3. View of Elkhead spillway looking west.

Figure 4. View of outlet net and spillway.

Study Goals and Objectives:

The study goal was to document magnitude and characteristics of escapement of nonnative fishes from Elkhead Reservoir to guide design and operational criteria for potential screening, refine sportfishery management, and evaluate translocation of nonnative fish from Yampa River removal actions. Escapement of fish eggs and larval forms were not included in the study due to the obvious impracticalities in preventing escapement through screening devices.

The objectives of this study were: 1) Quantify escapement of fishes from Elkhead Reservoir by species and size during spring runoff; 2) Recommend the design and operational criteria for screening reservoir outflows that would be most effective for minimizing escapement; and 3) Evaluate escapement rates of nonnative gamefish relocated from the Yampa River to the reservoir.

METHODS

This study relied solely on nets placed in the spillway and on the reservoir outlet during high flows associated with the spring runoff to determine escapement. The nets used in this study were tailrace nets normally designed for hydroelectric projects. These nets consisted of a face

frame (0.91m x 0.91m) and an inner and outer net similar to a fyke net in design. The nets had 6.3 mm mesh with a 3 m long bag. During 2003, one net was used on the outlet structure and one net was used on the east side of the spillway. These nets were used again in 2004, but an additional net was also used on the west side of the spillway. Escapement was calculated by the following equation:

Escapement (Fish per hour) = ((spillway width/net width) x (number of fish per hour per net))

2003: Total fish per hour = 45 x (Fish per hour)

2004: Total fish per hour = 22.5 x (Fish per hour)

Sampling was conducted during four weeks during April through early June each year. Sampling during 2003 was conducted during the weeks of April 28, May 5, May 19 and June 2 (Table 1). During 2004 sampling was conducted during the weeks of May 3, May 18, May 25 and June 1. One net was always set to capture the entire release from the outlet (Figure 5). A second net was used on the top of the spillway adjacent to the east retaining wall (Figure 6 and Figure 7). A third net was set on the spillway adjacent to the west retaining wall during sampling conducted in 2004 (Figure 8). Each net was anchored with a metal frame and ropes to the spillway chute retaining wall. The nets were left in place during sample sessions and checked for fish every two hours. The nets were set during three or four days of each monitoring week. All fish captured were identified, weighed and measured. All live fish were marked (fin clip for small fish and individual floy tag for large fish) and returned to the reservoir. Live fish were released on the east side of the reservoir approximately 100 meters from the dam. Discharge during sampling was obtained from USGS Gage 9246400.

Table 1. Sampling dates for the Elkhead Reservoir escapement study, 2003 and 2004.

Week	Days sampled
April 28, 2003	April 29, April 30, May 1
May 5, 2003	May 6, May 7, May 8
May 19, 2003	May 19, May 20, May 21, May 22
June 2, 2003	June 2, June 3, June 4, June 5
May 3, 2004	May 3, May 4, May5
May 18, 2004	May 18, May 19, May 20
May 25, 2004	May 25, May 26, May 27,
June 1, 2004	June 1, June 2, June 3

Figure 5. Elkhead Reservoir outlet capture net.

Figure 6. Net on east edge of spillway.

Figure 7. View from above spillway net.

Figure 8. View of placement of east and west spillway nets used in 2004.

RESULTS

2003

A total of 282 fish in 117 hours of netting was captured leaving the spillway of Elkhead Reservoir in 2003 (Table 2). Depth over the spillway was estimated at less than one foot. The escapement per hour per net ranged from zero to 12.5 fish/hr with an average of 2.41 fish/hr. The net captured 0.91 m of the 41 m total spillway width (Table 2). The per net captures were multiplied to estimate the range of escapement per hour and per day for the total spillway width. Eight fish species were captured during the 2003 sampling. The most abundant fish were black crappie and bluegill, which comprised 78% and 16% of the escapement respectively (Table 3). Largemouth bass (n=1 273 mm TL), smallmouth bass (n=1 230 mm TL) and rainbow trout (n=1 346 TL) escapement was less than 1% of the total. Fish total lengths ranged from 50 mm to 350 mm (Figure 9). The majority of the black crappie was approximately 125 mm total length. The majority of the bluegill was 75 mm total length. The smallest fish captured were sand shiner and speckled dace. No fish bearing finclips or Floy tags were recaptured.

No fish were captured in 112 hours of netting on the outlet (Table 2). Total release capacity of the outlet is 180 cfs. The outlet release during the sampling was estimated at less than 5 cfs.

The highest hourly escapement rate occurred just after sunset (Figure 10), while the highest weekly escapement rates occurred during weeks of higher discharge (Figures 11-12, Table 4). The stream flow was approximately 600 cfs the week of April 28th, 2003, peaked at approximately 1000 cfs during the week of May 19th, 2003 and dropped to approximately 350 cfs the week of June 2, 2003. Highest diel escapement rates in all weeks sampled occurred between 8:00 pm to 10:00 pm in the evening.

2004

Lower snow pack resulted in lower flows in Elkhead Creek during May and June of 2004. It is likely that the lower volume of water passing over the spillway contributed to a lower catch rate. A total of 60 fish were captured moving through the spillway (249.5 hours of netting). The per net captures were multiplied (based on two nets during 2004) to estimate the range of escapement per hour and per day for the total spillway width (Table 2). The estimated total hourly escapement estimates assumed an equal rate of escapement for the entire spillway width. This may over or under estimate the escapement if the rate of escapement varies across the spillway. Conditions at the spillway precluded safe sampling at locations other than the east and west ends. Based on the data from 2004, the rate of escapement varies and is higher on the east side than the west side.

Five fish species were captured during the 2004 sampling. The most abundant fish were bluegill and black crappie, which comprised 47.6% and 45.9% of the escapement respectively (Table 3). Smallmouth bass, rainbow trout and fathead minnow were also collected in low numbers during the 2004 season.

One fish, a 55 mm TL smallmouth bass, was captured at the outlet structure (118.17 hours of netting). The outlet release in 2004 was similar to 2003. Depth of the water over the outlet in the reservoir at the time of capture was 10 meters.

Fish captured in the spillway during 2004 were generally smaller than those captured in 2003. Fish sizes in 2004 ranged from 27 mm to 297 mm (Figure 9). Total length for black crappie ranged from 29 mm to 109 mm, while bluegill sizes ranged from 27 mm to 110 mm. The majority of the fish captured during the 2004 season were less than 100 mm. One smallmouth bass (98 mm) was captured in the spillway.

The time of escapement in 2004 did not reflect a consistent diel pattern, but the rate of escapement did seem to be influenced by stream flow. The highest escapement rates at the spillway were recorded between 6:00 am and 8:00 am on 5 May, and between 6:00 pm and 8:00 pm on 18 May (Figure 10). Discharge at these times was recorded at 344 cfs and 193 cfs, respectively. However, overall catch rate was highest during the week with the highest discharge. Of the 61 fish captured, 60 were collected during the first two weeks when flows were greater than 170 cfs. Only one fish was captured during the last two weeks when discharge fell below 110 cfs. In addition, the majority of the fish were captured in the east spillway net. A total of 48 fish were captured in the east side spillway net as compared to 12 fish in the west side spillway net.

All fish captured in 2003 and except for rainbow trout and possibly one 98 mm TL smallmouth bass in 2004 were wild spawned fish. The reservoir was not stocked with bluegill or black crappie in 2003 and 2004. Bluegill has not been stocked since 1986 (B. Elmblad, CDOW personal communication).

No tagged smallmouth bass from the Yampa River relocation were captured during the escapement study. In 2003, smallmouth bass were first transferred to Elkhead Reservoir on June 18 after the escapement study sampling ended (Table 5). In 2004, smallmouth bass were transferred beginning on May 4 until July 8. This period coincides with the escapement study but no tagged fish were captured at the spillway.

Table 2. Summary of escapement netting at Elkhead Reservoir, 2003 and 2004.

	Outlet				**Spillway**	
2003	Total			Total		
hours set	112			117		
fish captured	0			282		
	Average	Max	Min	Average	max	min
fish/hr/net	0	0	0	2.41	12.5	0
total fish per hour (fish/hr*spillway length)	0	0	0	108.6	562.5	0
Total fish per day (total fish*24)	0	0	0	2606.9	13500	0
2004	Total			Total		
hours set	120.17			247.5		
fish captured	1			60		
	Average	Max	Min	Average	max	min
fish/hr/net	0.01	0.5	0	0.24	5.5	0
total fish per hour (*spillway length)	0.01	0.5	0	10.9	247.5	0
Total fish per day (total fish*24)	0.2	12	0	261.8	5940	0

Table 3. Total number of fish collected during 2003 and 2004 escapement study.

Species	**Grand Total**	**Percent**	**Average escapement number per hour**	**Average escapement number per day**
2003				
Bluegill (*Lepomis macrochirus*)	45	16.0%	17.3	416.0
Smallmouth bass (*Micropertus dolomieu*)	1	0.4%	0.4	9.2
Largemouth bass (*Micropterus salmoides*)	1	0.4%	0.4	9.2
Sand shiner (*Notropis stramineus*)	6	2.1%	2.3	55.5
Rainbow trout (*Oncorhynchus mykiss*)	1	0.4%	0.4	9.2
Fathead minnow (*Pimephales promelas*)	7	2.5%	2.7	64.7
Black crappie (*Pomoxis nigromaculatus*)	220	78.0%	84.7	2033.5
Speckled dace *(Rhinichthys osculus*)	1	0.4%	0.4	9.2
Grand Total (2003)	282	100%	108.6	2606.9
2004				
Bluegill (*Lepomis macrochirus*)	29	47.6%	5.2	124.6
Smallmouth bass (*Micropertus dolomieu*)	2	3.3%	0.3	8.6
Rainbow trout (*Oncorhynchus mykiss*)	1	1.6%	0.2	4.3
Fathead minnow (*Pimephales promelas*)	1	1.6%	0.2	4.3
Black crappie (*Pomoxis nigromaculatus*)	28	45.9%	5.0	120.3
Grand Total (2004)	61	100%	10.9	262.0

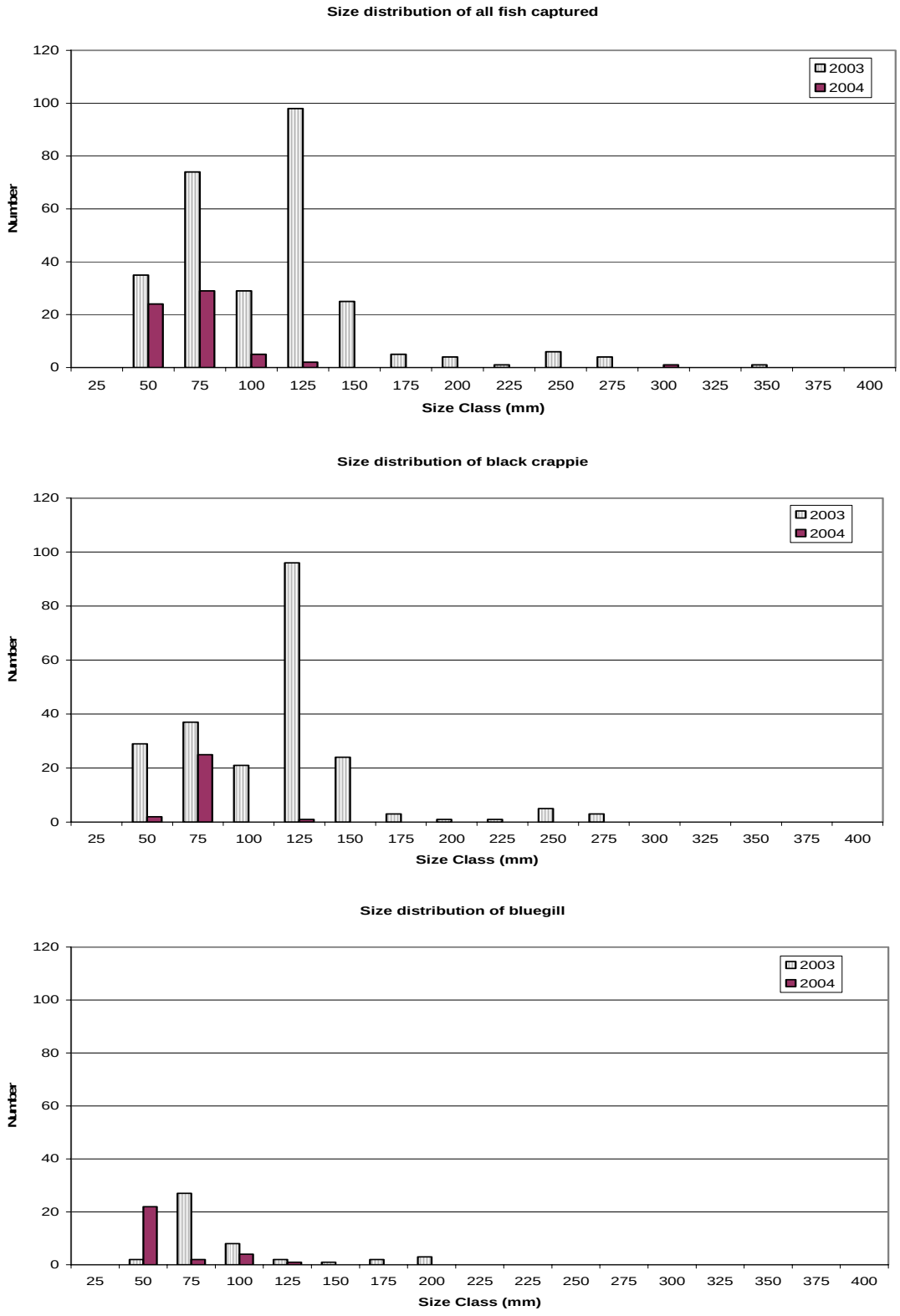
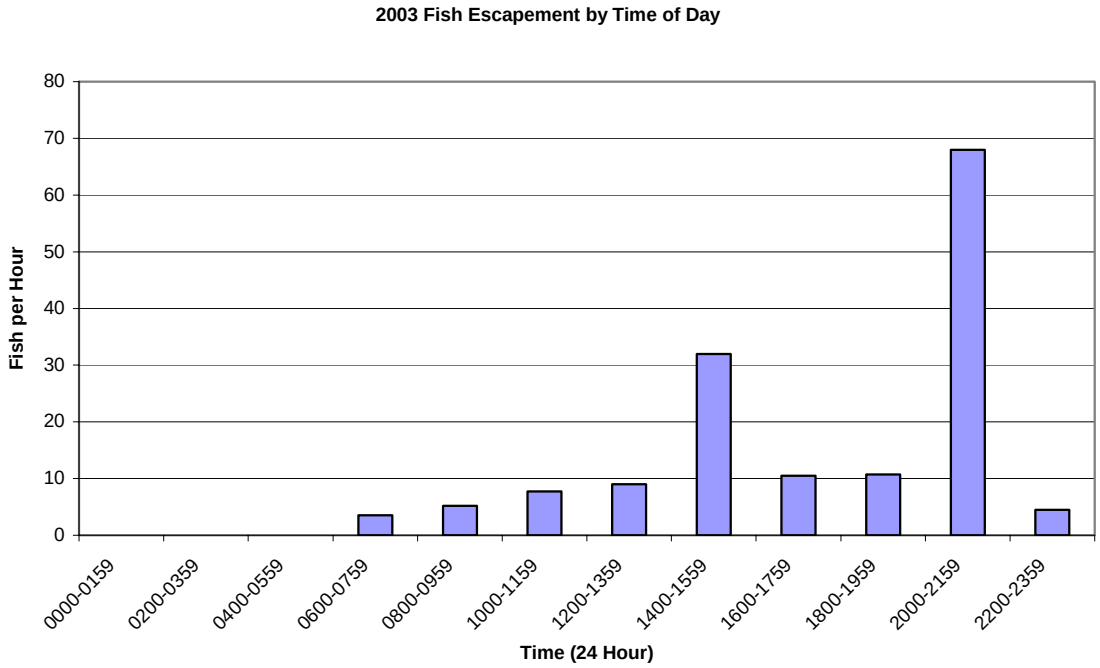


Figure 9. Size distribution of all fish, black crappie and bluegill, 2003 and 2004.



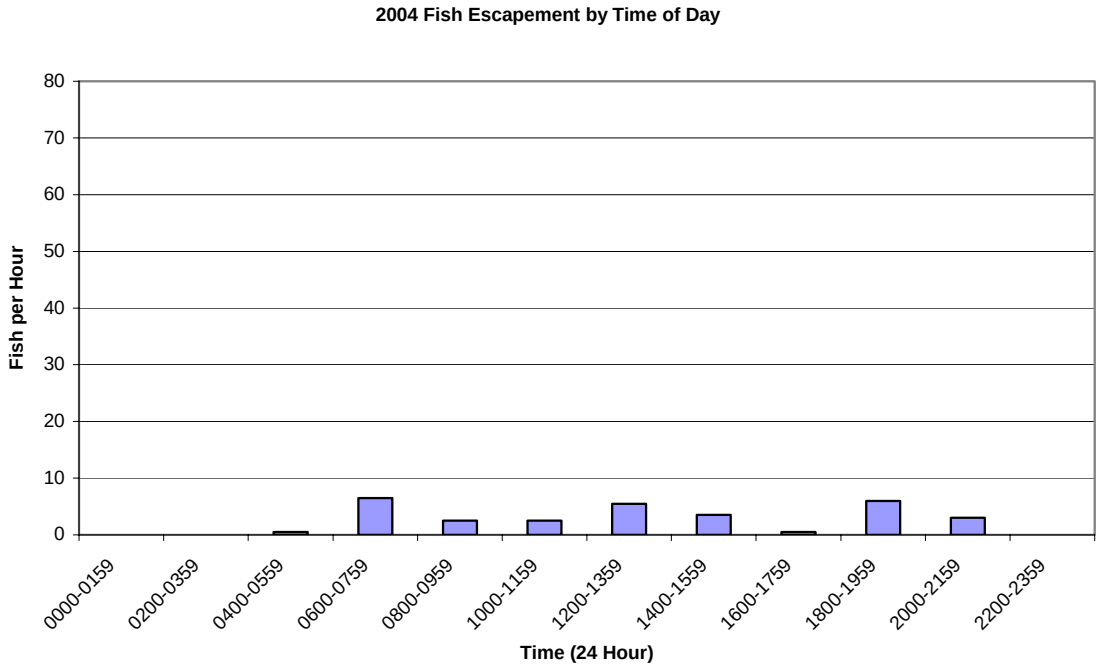


Figure 10. Fish escapement by time of day sampled for 2003 and 2004.

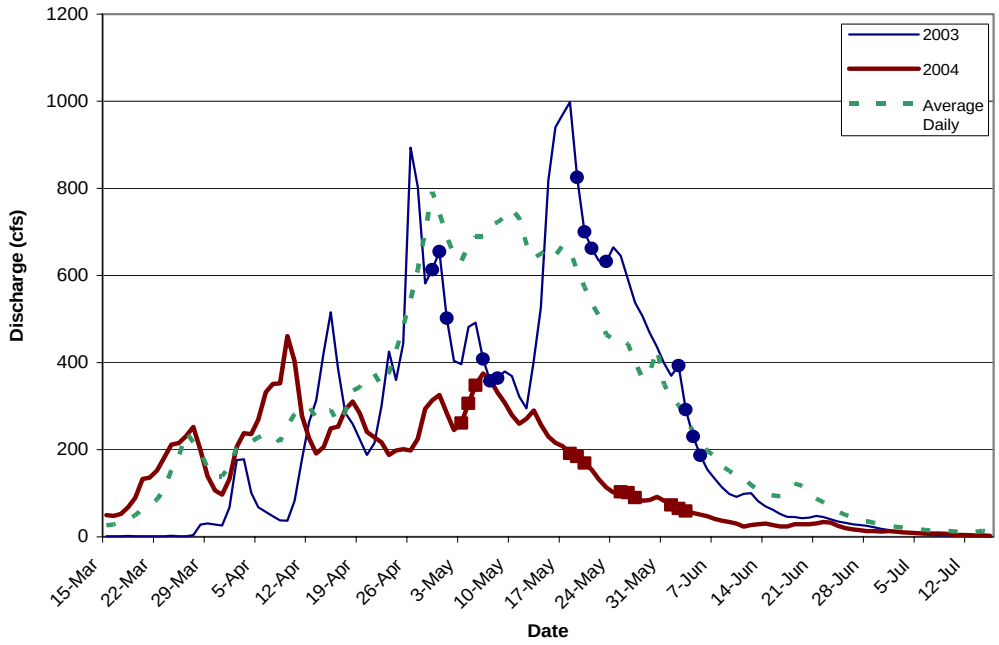


Figure 11. Hydrograph for Elkhead Creek during the 2003 and 2004 sampling seasons based on data from USGS Gage 9246400, Maynard Gulch. Sample dates are marked as solid data point on each line. Average daily flow are taken from the period of record from 1995-2004.

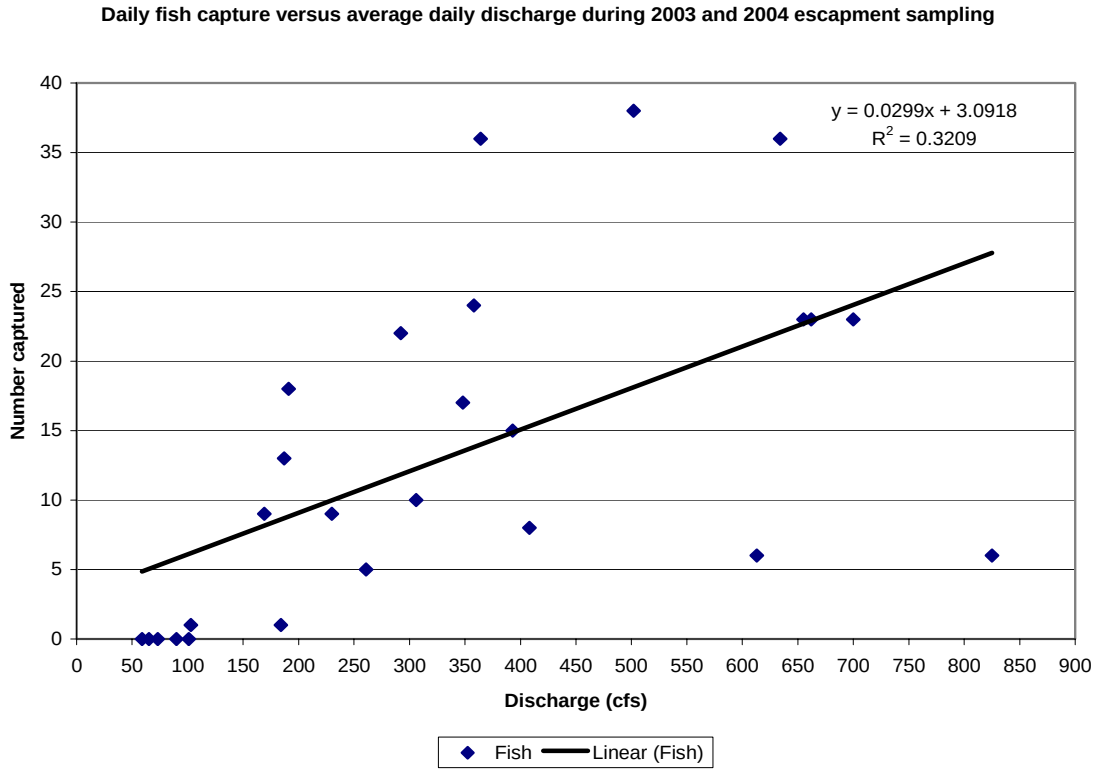


Figure 12. Number of fish captured versus average daily discharge for 2003 and 2004 escapement sampling.

Table 4. A comparison of fish captured (by week) during each year of the Elkhead escapement study.

		Total Fish Collected	
		2003	2004
APRIL	Week 4	67	No sampling
MAY	Week 1	68	32
	Week 2	No sampling	No sampling
	Week 3	88	28
	Week 4	No sampling	1
JUNE	Week 1	59	0

Table 5. Summary of smallmouth bass stocked in Elkhead Reservoir from the Yampa River that could have been captured during the escapement study (Source: John Hawkins, CSU, summary data).

	Sample					All Fish	All Fish	Not tagged Fish	Not tagged Fish	Tagged Fish	Tagged Fish
Year	trip	dates stocked	tagged	not tagged	number stocked	TL-range (mm)	mean TL (mm)	TL-size range (mm)	mean TL (mm)	TL-size range (mm)	mean TL (mm)
2003	4	6/18/2003	54	2	56	62-450	242.27	62-136	99	142-450	247.57
2003	4.5	7/1-7/2/03	198	9	207	91-495	230.56	91-130	112.33	122-495	230.96
2004	2	5/4-5/11/04	431	72	503	67-463	251.62	67-170	131.93	152-463	271.62
2004	3	5/18-5/25/04	308	52	360	65-432	240.95	65-180	124.38	143-432	260.63
2004	4	6/1-6/7/04	335	149	484	61-440	199.35	61-166	93.36	115-440	246.48
2004	5	6/18-6/22/04	286	273	559	60-510	201.91	60-214	148.9	153-510	252.52
2004	6	7/1-7/2/04	131	219	350	71-434	199.15	71-230	147.43	160-434	285.6
2004	7	7/7-7/8/04	110	399	509	63-366	163.49	63-250	140.85	137-366	245.58

DISCUSSION

The species relative abundance for the escapement study was notably different for smallmouth bass escaping the reservoir in comparison with reservoir relative abundance. Relative abundance collected in 1999 showed that 15% of the fish captured were smallmouth bass in the reservoir by CDOW collections. In 2001, smallmouth bass comprised 45% of the relative abundance of species collected in the reservoir. Black crappie made up 54% of the relative abundance in 1999 and 29% of relative abundance in 2001 in the reservoir (Tables 6 and 7). This compares with 78% relative abundance in the 2003 escapement study and 45.9% escapement in 2004 (Table 3). Bluegill made up 8% of the relative abundance in 1999 in the reservoir (Table 6) and 15% of the relative abundance in 2001 (Table 7). Relative abundance of bluegill in escapement was 16% in 2003 and 47.6% in 2004. It appears that the small bluegill and crappie may be leaving the reservoir at higher rates due to the fact that they are caught in the high velocities before they can react to those and swim to areas of low velocities and safe habitat. It has been noted by others that fish in low velocities tend to stay in those, especially in reservoir and lake situations, and will avoid areas of higher velocities (Bell 1991).

Table 6. Species relative abundance in Elkhead Reservoir 1999 (CDOW 1999).

Species	Number collected	Percent abundance
White sucker	42	15%
Smallmouth bass	42	15%
Bluegill	22	8%
Northern pike	3	1%
Largemouth bass	15	5%
Black crappie	151	54%
Channel catfish	3	1%
Total	278	100%

Table 7. Elkhead Reservoirs' species relative abundance 2001 (Miller Ecological 2004).

Species	Elkhead Reservoir-2001	
	Number	Relative abundance
White sucker	11	3.1
Flannelmouth sucker	1	0.3
Northern pike	1	0.3
Channel catfish	6	1.7
Bluegill	52	14.9
Smallmouth bass	159	45.4
Largemouth bass	17	4.9
Black crappie	103	29.4

The escapement sampling in 2003 and 2004 confirmed that fish leave Elkhead Reservoir during periods of high flows associated with runoff. The majority of the fish captured during netting were less than 150 mm in total length during 2003 and less than 100 mm total length in 2004. The rate of escapement (and size of fish) appeared to be positively related to the level of discharge (Figure 12). Most of the fish that were captured each year were acquired during periods of relatively high outflow from the reservoir. In 2003 (a year with higher sustained runoff from snowmelt) the rate of escapement was consistently greater than escapement found in 2004 (Table 4). During each year the rate of escapement was also greatest during weeks with higher outflow.

Escapement was dominated by black crappie and bluegill with crappie dominating the early season catch and bluegill becoming dominant in subsequent weeks. Species composition results from other fish sampling investigations within critical habitat on the Yampa River have demonstrated captures of black crappie to be sporadic and relatively minor, and those of bluegill to be almost nonexistent despite the numbers of these species evident in outflow escapement (Anderson 2003, 2004; Bestgen and Hawkins 2004, Nesler 1995). There may be a seasonal influence on escapement related to species composition, but this was difficult to detect given the short duration of this study. An outflow from the reservoir that persisted through the month of June would be necessary to provide accurate information regarding the seasonal influence on species composition.

The results of this study suggested that several other physical and biological processes may also influence escapement. Much of the data indicated a diel pattern to escapement with the majority of the fish moving through the spillway near sunrise, sunset or after dark. This may be related to fish becoming more active with the onset of darkness thus increasing the potential for entrainment in the outflow. Wave action at the spillway may also result in an increase in the rate of escapement. Very few large individual fish were captured during the study. The swimming ability of larger size classes may provide an advantage in the avoidance of entrainment (Bell 1991). This ability may not yet be realized in younger fish of smaller size classes.

No tagged nonnative gamefish relocated to Elkhead Reservoir were documented in the escapement, however, one smallmouth bass in the same size class as those stocked but not tagged in Elkhead Reservoir in 2003 and 2004 was captured in the nets. Since other adult nonnative gamefish were captured it is possible that relocated fish could escape from the reservoir. The escapement of relocated fish is most likely low based on the low numbers of bass captured in the escapement study.

Screen Options

Screen options for Elkhead Reservoir range from fixed screens to kevlar nets in front of the spillway. Several options were considered in this study based on prior feasibility evaluations of structures to control escapement (Miller and Laiho, 1997). Structures that may work at Elkhead to control escapement include traditional fixed screens in front of the spillway. This would be a steel wedgewire to screen all flow from the spillway and outlet works. A second option is a kevlar net placed in front of the spillway and work in conjunction with screens on the low level outlet works. A third option is to screen the low level outlet works or operate the release from the reservoir to minimize spill.

The traditional screening in the service spillway, which also acts as the flood spillway, would present a problem for passing flood flows. There is no precedent for screens on structures of this type (Miller and Laiho 1997). The alternative is to place a floating screen out in front of the spillway such as a kevlar net. This could be feasible but there are likely problems that will occur with maintenance and operation especially during periods of flows higher than the average runoff. Based on observations made during this study, debris may become a problem and become entangled in a net and compromise the integrity of the net itself. Large debris, such as large trees, was observed moving through the reservoir and over the spillway during the study period. The spillway nets also have problems with fouling from algae growth and other organic debris coming through the reservoir.

In addition to fish escapement, large woody debris, was observed exiting the reservoir at the spillway. Some of this debris was over 20 feet long and 1 foot in diameter. Debris this size would pose a danger to any surface screen (fixed or net) installed at the spillway and require additional maintenance on the screens. The debris load should be considered when determining screen type and location for the reservoir.

The selected alternative for this application to minimize escapement from the reservoir without compromising structural integrity of the dam is a screen on the low level outlet works of the enlarged reservoir and operation of the outlet works to maximum capacity.

Enlargement of the reservoir will place the outlet capacity at nearly 600 cfs which would allow screening of approximately 80% of the flow at the average peak. Average peak flow is approximately 800 cfs (Figure 11) based on USGS data for gage 09246400. The proposed outlet works would release up to nearly 600 cfs. Data from this study shows that there is minimal escapement at flows less than 175 cfs which would be the flow over the spillway during average peak flow. This condition would exist based on the data shown for less than three weeks for an average year.

Approximately 200 cfs would be released from the spillway in average years for approximately three weeks. Currently flows greater than 200 cfs pass the spillway for nearly two months. The peak discharge occurs in mid-May (Figure 11). Based on the timing of the peak flow, smallmouth bass spawning would likely not have taken place in mid-May. Graham and Orth (1986) report peak spawning for smallmouth to occur after runoff and when water temperatures are between 15 ^{o}C to 20^{o}C.

CONCLUSIONS AND RECOMMENDATIONS

This study documented fish escapement from Elkhead Reservoir during runoff in 2003 and 2004. The capture techniques quantified the escapement from the spillway and reservoir outlet. The study objectives were: 1) quantify escapement of fishes from Elkhead Reservoir by species and size during spring runoff; 2) recommend the design and operational criteria for screening reservoir outflows that would be most effective for minimizing escapement; and 3) evaluate escapement rates of nonnative gamefish relocated from the Yampa River to the reservoir.

The following conclusions can be made from the study (Note: the controlled outlet was not operated during the study and therefore conclusions are based on escapement from the reservoir spillway):

- The data collected does quantify escapement by species and size.
- The majority of the escapement was small bluegill and black crappie.
- The highest numbers of fish were captured during the highest runoff period in both years.
- Low numbers of adult fish were captured in both years.
- No tagged fish from the relocation were captured.
- Rates of smallmouth bass escapement, including stocked bass, were low relative to reservoir abundance.

The following recommendations are made to minimize escapement from the reservoir. These recommendations are made with the assumption that the proposed reservoir enlargement and dam reconstruction will occur. The draft results from this project were presented to the Upper Colorado River Basin Biology Committee in early 2004. The discussions at that meeting and final results of the study were used to develop the following recommendations:

- All controlled outlets (gated) from the enlarged reservoir should be screened using a conventional fixed metal screen.
- The screen opening should exclude adult and juvenile size classes for smallmouth bass.
- The screen should be designed for exclusion with no fish bypass incorporated into the design.
- Cleaning mechanisms as needed should be installed on the screens.
- The primary release mechanism from the reservoir should be the controlled outlet structure and secondarily the uncontrolled spillway.
- The controlled outlets should be operated at the maximum capacity practicable during runoff to minimize the magnitude and duration of spill from the reservoir.
- If possible, and in coordination with annual reservoir operations, a drawdown of the reservoir to further curtail spill should be considered.
- Reservoir escapement monitoring post-Elkhead enlargement should be conducted to evaluate operational releases.
- Adaptive management should used after reservoir reconstruction to adjust the above recommendations as needed to minimize escapement.

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