Coldwater Reservoir Ecology

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Patrick J. Martinez
Principal Investigator

Tom Remington, Director

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Bill Ritter, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

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Paula Nichols, Federal Aid Coordinator
Kay Knudsen, Librarian

Prepared by: ____
Patrick J. Martinez, General Professional V

Approved by: ____
Mark S. Jones, Aquatic Wildlife Research Leader

Date: ______________________________

The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Division of Wildlife policy by the Director or the Wildlife Commission.

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Project No. F-242-R17

Title: Coldwater Reservoir Ecology

Period Covered: July 1, 2009 to June 30, 2010

Principal Investigator: Patrick J. Martinez

STUDY OBJECTIVE: To investigate factors which influence or might affect the stability of sport fisheries in Colorado's large (>1,000 surface acres), coldwater (>6,500 feet in elevation) reservoirs and to provide recommendations for the management and monitoring of these, and similar reservoirs.

OBJECTIVE 1: Hydroacoustic Surveys of Kokanee and Piscivore Abundance Existing and Proposed Broodwaters

Perform standardized hydroacoustic surveys to estimate pelagic fish abundance in established (Blue Mesa, Granby, McPhee, Vallecito,and Williams Fork) and proposed (e.g. Elevenmile and Green Mountain) kokanee brood stock waters, and in other reservoirs as resources allow.

Segment Objective 1: Perform standardized sonar survey at Blue Mesa

INTRODUCTION

Blue Mesa Reservoir was the only water scheduled to be surveyed by scientific sonar in 2009 under this project due to time constraints necessary for data analyses and manuscript preparation. However, due to demand for surveys by Colorado Division of Wildlife's (CDOW) Area Fishery Biologists, a limited number of sonar surveys were performed in 2009, as in 2008 (Martinez 2009). This was accomplished due to the long-term experience of CDOW Research Technician Estevan Vigil, the sonar expertise of CDOW Aquatic Researchers Kevin Rogers and Harry Crockett, and the assistance of Area Fishery Biologists at their respective waters. The results of the 2009 surveys are reported here. Sampling of kokanee spawn runs was not performed by this project in 2009.

METHODS and MATERIALS

Sonar surveys were performed on six large, coldwater reservoirs in 2009. As in 2008, the reservoirs surveyed in 2009 represented key sources of kokanee eggs. (Martinez 2009). These included: Blue Mesa (19 August), Elevenmile (20 August and 15 September), Granby (17 September), McPhee (17 August), Vallecito (18 August), and Williams Fork (16 September). Elevenmile Reservoir was surveyed on two dates to compare the detection and distinction of maturing kokanee that would contribute to the fall spawn run versus kokanee that would mature and spawn the follow year (Kevin Rogers, CDOW Aquatic Researcher, personal communication). Surveys were performed at night, and were scheduled around the dates of the new moon. A PC-controlled HTI 243 digital split-beam scientific echosounder with its 15^{o} down-looking transducer mounted in towed vehicle and deployed using the apparatus described in Martinez (2005) was operated from a 22 foot Hewes SeaRunner powered by an 8-hp, four-stroke Yamaha outboard during the surveys. Standardized transects were followed using a Garmin 165 GPS. Data analysis was performed by Kevin Rogers.

RESULTS and DISCUSSION

Numbers of pelagic fish estimated in sonar surveys of reservoirs in 2007 were: Blue Mesa, 111,427; Elevenmile 21,968 (August) and 19,557 (September); Granby, 122,121; McPhee, 118,679; Vallecito, 28,667; and Williams Fork, 33,038. The ongoing decline in pelagic fish abundance in Blue Mesa Reservoir in 2009 deepened concern about excessive predation on kokanee in the reservoir (Martinez 2009; Martinez et al. 2009).

OBJECTIVE 2: Population Demographics of Kokanee and Lake Trout and Other Piscivores Threatening Kokanee

Survey key population demographics for kokanee (size and age at maturity) in established and potential brood stock waters, and for lake trout and other piscivores (relative weight and growth rate) where they pose a threat to kokanee populations and their egg production (e.g. Blue Mesa and Granby).

Segment Objective 1: Continue analysis of long-term data for Granby kokanee spawn run.

INTRODUCTION, METHODS and DISCUSSION

Long-term data for reservoir storage, physicochemical profiles, zooplankton, *Mysis*, and kokanee stocking and spawner trends have been analyzed for Lake Granby by Dr. Brett Johnson (Colorado State University) to refine the interrelationship among some of these factors reported by Martinez and Wiltzius (1995). The draft manuscript entitled Hydro-climate Mediates Effects of a Keystone Species in a Montane Reservoir documents and discusses the findings of these analyses. Climate change is a growing concern for water supplies and it has implications for sport fisheries (Ficke et al. 2007; Kinsella et al. 2008). As historic patterns of water use and management become altered in response to climate change, changes in reservoir operations may occur that would affect the food webs supporting valuable fishery resources. Improving our understanding of how distant water demand in response to climate change affects local reservoir conditions would help managers anticipate the likelihood and potential magnitude of climate induced ecological impacts to sport fisheries.

Segment Objective 2: Prepare draft manuscript on lake trout management in western U.S. incorporating input from co-authors and reviewers and submit to peer-reviewed outlet.

RESULTS

Western Lake Trout Woes, was published in the American Fisheries Society's Fisheries magazine.

Martinez, P. J., P. E. Bigelow, M. A. Deleray, W. A. Fredenberg, B. S. Hansen, N. J. Horner, S. K. Lehr, R. W. Schneidervin, S. A. Tolentino, and A. E. Viola. 2009. Western lake trout woes. Fisheries 34(9):424-442.

I provided peer review for:

Gresswell, R. E. 2009. Scientific Review Panel Evaluation of the National Park Service Lake Trout Suppression Program in Yellowstone Lake, August 25-29, 2008. USGS Northern Rocky Mountain Science Center Final Report, Bozeman, Montana.

OBJECTIVE 3: Zooplankton Composition and Density and Mysis Density in Selected Waters

Estimate zooplankton composition and density in established and proposed kokanee brood sources, and Mysis density in reservoirs where they are an important food-web component (Granby, Taylor Park) and in other waters where Mysis have been introduced as resources allow.

Segment Objective 1: Collect and analyze crustacean zooplankton and measure temperature and dissolved oxygen at Granby reservoirs.

INTRODUCTION

Crustacean zooplankton monitoring has aided the understanding of trends in reservoir food webs. Long-term sampling of crustacean zooplankton also provides a baseline of species composition, abundance and size structure for comparison to potential changes induced by climate change or invasive species (e.g. cladocerans, mollusks or fish). Crustacean zooplankton has been performed as part of this project for 19 years, from 1991-2009

METHODS and MATERIALS

Crustacean zooplankton was sampled in four reservoirs in 2009. Blue Mesa on 9 June, 15 July and 12 August; Dillon on 21 July; Granby on 10 June; 23 July and 13 August; and Taylor Park on 16 July. Zooplankton was sampled by oblique tows in the 0-10m stratum with a Clarke-Bumpus metered sampler (153 µm net). Samples were placed in 4 oz. Whirl-Pac bags and preserved in 70% ethanol. Processing of samples, zooplankter measurements and estimates of density were performed as described by Martinez (1992). Temperature and dissolved oxygen profiles were also measured on the dates of zooplankton sampling with a YSI Model-57 meter. Secchi depths were measured to the nearest centimeter. Water temperature and dissolved oxygen profiles, and Secchi depth, were measured at a single station (#1) in Highline Lake (Martinez 2000) on 1 June, 2009.

RESULTS and DISCUSSION

Tables 1-12 provide crustacean zooplankton densities and size structures in samples collected from reservoirs in 2009. Water temperature and dissolved oxygen profiles, and Secchi depths measured on the dates of zooplankton sampling (and in Highline Lake) are provided in Appendix A. Blue Mesa Reservoir had a high *Daphnia* density of 20.5/L when sampled in July, 2009, even outnumbering the copepod *Diacyclops thomasi* (formerly *Diacyclops bicuspidatus thomasi*; Table 1). The *Daphnia*, particularly *D. pulicaria* (formerly *Daphnia pulex*; Martinez 2009), in these samples were large, averaging 1.3 mm to 1.5 mm (Tables 2-4). *Daphnia* in Dillon Reservoir were rare (<0.1L; Table 5), and small (averaging <1.0 mm; Table 6) when sampled in July, 2009, and epilimnetic temperatures offered little refuge from predation by *Mysis diluviana* (Martinez and Bergersen 1991; Table A-4). *Daphnia* were scarce in Granby Reservoir (< 1.0/L) when sampled in June and July, 2009, but were more abundant in August (8.9/L; (Table 7) when epilimnetic water temperatures were warmest (Tables A-5 - A-7). *D. pulicaria* was present on all dates sampled and averaged 1-1.2 mm (Tables 8-10). *Daphnia* were scarce in samples collected in Taylor Park Reservoir in mid-July, 2009 (Table 11). *D. pulicaria* was present in samples and averaged 1.2 mm (Table 12). Stratification was weak at the time of sampling, likely providing little refuge from predation by *Mysis.*

Table 1. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Blue Mesa Reservoir, 9 June, 15 July and 12 August 2009.**

Blue Mesa - 09 June 2009 - Mean *Daphnia* density = 5.8/L										
Zooplankton Species	Sapinero (0-10m)			Cebola (0-10m)			Iola (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	4.4	4.6	4.5	2.8	2.6	2.7	1.7	2.0	1.8	3.0
unindentified *Daphnia spp.*	0.4	0.3	0.3	1.2	1.5	1.3	0.8	0.8	0.8	0.8
Daphnia mendotae	2.1	2.3	2.2	1.4	1.8	1.6	1.7	1.6	1.6	1.8
Daphnia pulicaria	2.8	2.9	2.9	2.3	3.8	3.1	5.0	6.9	5.9	4.0
Diacyclops thomasi	11.0	8.5	9.8	6.4	3.8	5.1	8.4	10.5	9.4	8.1
Leptodiaptomus nudus	1.6	1.8	1.7	1.3	2.2	1.7	0.6	0.4	0.5	1.3
Mean total no./L	19.6			13.8			19.6			17.7
Blue Mesa – 15 July 2009 - Mean *Daphnia* density = 20.5/L										
Zooplankton Species	Sapinero (0-10m)			Cebola (0-10m)			Iola (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	0	0	0	0	0.3	0.2	0	0	0	< 0.1
unindentified *Daphnia spp.*	3.8	4.1	3.9	3.9	2.8	3.3	4.3	2.2	3.3	3.5
Daphnia mendotae	5.7	4.1	4.9	2.8	0.6	1.7	1.2	0.7	0.9	2.5
Daphnia pulicaria	14.4	11.6	13	16.4	12.5	14.4	14.9	17.3	16.1	14.5
Diacyclops thomasi	12.1	14.3	13.2	15.8	15	15.4	6.7	10.5	8.6	12.4
Leptodiaptomus nudus	6.2	3.9	5	6.7	4.4	5.6	5.5	5.6	5.6	5.4
Mean total no./L	35			35			28.9			33
Blue Mesa - 12 August 2009 - Mean *Daphnia* density = 6.0/L										
Zooplankton Species	Sapinero (0-10m)			Cebola (0-10m)			Iola (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Ceriodaphnia quadrangula	0.0	0.0	0.0	0	0.4	0.2	0.2	0.5	0.4	0.2
Bosmina longirostris	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.0	< 0.1
unindentified *Daphnia spp.*	2.5	2.8	2.7	2.0	2.4	2.2	2.0	3.9	2.9	2.6
Daphnia mendotae	1.7	1.7	1.7	0.5	1.2	0.9	1.6	1.2	1.4	1.3
Daphnia pulicaria	6.8	4.0	5.4	2.9	5.4	4.1	4.4	4.9	4.7	4.7
Diacyclops thomasi	11.3	10.9	11.1	13.2	14.1	13.6	6.0	7.7	6.9	10.5
Leptodiaptomus nudus	11.6	14.4	13.0	19.8	19.4	19.6	9.2	11.4	10.3	14.3
Mean total no./L	20.8			21.2			16.3			19.4

Table 2. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Blue Mesa Reservoir, 9 June 2009. Bl = *Bosmina longirostris*, Dt = *Diacyclops thomasi*, Ln = *Leptodiaptomus nudus*. Dp = *Daphnia pulicaria*, Dgm = *Daphnia galeata mendotae*, D. spp. = Unidentified *Daphnia*.**

Length class in mm	Blue Mesa - 09 June 2009					
	Bl	Dt	Dgm	Dp	D. spp.	Ln
0.1						
0.2	9					
0.3	12	6				1
0.4	13	12	1			8
0.5	6	17	3	3		5
0.6		25	7	1		3
0.7		13	7	1		1
0.8		13	18	6		2
0.9		5	6	9	1	2
1.0		7	1	13		1
1.1		2	1	8		
1.2			2	8		
1.3			4	3		
1.4			1	3		
1.5				1		
1.6				10		
1.7			1	5		
1.8				9		
1.9				2		
2.0				3		
2.1				1		
Totals	40	100	52	86	1	23
Mean Length	0.38	0.75	0.89	1.31	0.93	0.60

Table 3. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Blue Mesa Reservoir 15 July 2009. Bl = *Bosmina longirostris*, Dp spp. = Unidentified *Daphnia*, Dt = *Diacyclops thomasi*, Dp = *Daphnia pulicaria*, Ln = *Leptodiaptomus nudus*, Dgm = *Daphnia galeata mendotae*.**

Length class in mm	Blue Mesa - 15 July 2009					
	Bl	**Dt**	**Dgm**	**Dp**	**Dp spp.**	**Ln**
0.1						
0.2						
0.3	1	6				2
0.4		22				1
0.5		21				3
0.6		17				5
0.7		12	3	2		3
0.8		7	8	3	1	6
0.9		6	11	13	2	4
1.0		5	8	22	2	5
1.1		2	9	16	2	5
1.2		1	7	21	1	1
1.3			6	13	2	
1.4			2	17	1	
1.5				4	0	
1.6				12	3	
1.7				5	1	
1.8			1	3		
1.9				2		
2.0				5		
2.1				4		
2.2				4		
2.3				2		
2.4				2		
Totals	1	99	55	150	15	35
Mean Length	0.32	0.65	1.08	1.38	1.27	0.84

Table 4. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Blue Mesa Reservoir 12 August 2009. Bl = *Bosmina longirostris*, Dp spp. = Unidentified *Daphnia,* Dt = *Diacyclops thomasi,* Dp = *Daphnia pulicaria*, Ln = *Leptodiaptomus nudus*, Dgm = *Daphnia galeata mendotae,* Cdq = *Ceriodaphnia quadrangula.***

Length class in mm	Blue Mesa - 12 August 2009						
	Bl	Dt	Dgm	Dp	Dp spp.	Ln	Cdq
0.1							
0.2							
0.3		2					
0.4	1	17				13	
0.5		19				46	2
0.6		22			1	30	
0.7		18	3	1	1	15	
0.8		13	5		2	6	
0.9		6	4	4		6	
1.0		1	4	13	1	6	
1.1		1	2	7	3	2	
1.2			4	16	3	2	
1.3			4	10	0		
1.4			4	13	1		
1.5				10	2		
1.6				12	1		
1.7				11	1	1	
1.8			1	15			
1.9				9			
2.0				2			
2.1				4			
2.2				1			
Totals	1	99	31	128	16	127	2
Mean Length	0.4	0.7	1.1	1.5	1.2	0.7	0.5

Table 5. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Dillon Reservoir, 21 July 2009.**

Dillon - 21 July 2009 - Mean *Daphnia* density = < 0.1/L																
Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	0.8	0.2	0.5	0.1	0.2	0.2	7.2	6.5	6.8	0.4	0.4	0.4	9.8	7.4	8.6	3.3
Daphnia mendotae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	< 0.1
Daphnia pulicaria	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	< 0.1
Diacyclops thomasi	7.6	4.0	5.8	13.2	8.0	10.6	19.5	18.0	18.8	7.2	7.4	7.3	13.5	18.7	16.1	11.7
Mean total no./L	6.2			10.8			25.6			7.7			24.8			15.0

Table 6. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Dillon Reservoir, 21 July 2009. Bl = *Bosmina longirostris*, Dt = *Diacyclops thomasi*, Dp = *Daphnia pulicaria*, Dgm = *Daphnia galeata mendotae*.**

Length class in mm	Dillon - 21 July 2009			
	Bl	Dt	Dgm	Dp
0.1	1			
0.2	22			
0.3	27	2		
0.4	9	15		
0.5	2	34	1	
0.6		99		
0.7		101		
0.8		98		
0.9		24		
1.0		1		
1.1				
1.2				1
Totals	61	374	1	1
Mean Length	0.3	0.7	0.5	1.3

Table 7. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Lake Granby, 10 June, 23 July and 13 August 2009.**

Granby - 10 June 2009 - Mean *Daphnia* density = < 0.1/L

Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
Leptodiaptomus nudus	0.2	0.2	0.2	0.1	0.0	0.1	0.3	0.3	0.3	0.1	0.0	0.0	0.8	0.5	0.6	0.3
Diacyclops thomasi	4.1	2.9	3.5	4.5	7.8	6.1	15.8	12.8	14.3	7.6	15.2	11.4	33.3	29.3	31.3	13.3
Daphnia pulicaria	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1
Mean total no./L	3.7			6.2			14.6			11.4			31.9			13.6

Granby - 23 July 2009 - Mean *Daphnia* density =0.5 /L

Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
unindentified *Daphnia spp.*	0.2	0.3	0.3	0.0	0.0	0.0	0.3	0.0	0.1	0.3	0.3	0.3	0.8	0.4	0.6	0.3
Bosmina longirostris	1.0	1.3	1.2	0.4	0.0	0.2	0.3	0.0	0.1	0.0	0.0	0.0	0.2	0.6	0.4	0.4
Daphnia mendotae	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.8	0.4	0.1
Daphnia pulicaria	0.2	0.0	0.1	0.0	0.3	0.2	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.6	0.3	0.1
Diacyclops thomasi	39.9	33.9	36.9	42.5	41.6	42.0	19.2	46.9	33.1	47.9	56.5	52.2	22.9	31.7	27.3	38.3
Leptodiaptomus nudus	1.0	1.3	1.2	3.9	2.5	3.2	5.1	3.6	4.4	6.2	7.1	6.7	6.3	6.6	6.5	4.4
Mean total no./L	39.7			45.5			37.7			59.4			35.5			43.6

Granby - 13 August 2009 - Mean *Daphnia* density = 8.9/L

Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
unindentified *Daphnia spp.*	3.6	1.4	2.5		1.9	1.9	1.9	1.6	1.8	1.6	1.4	1.5	4.1	2.7	3.4	2.2
Bosmina longirostris	0.0	0.0	0.0		0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.2	0.5	0.3	0.1
Daphnia mendotae	2.5	2.6	2.5		2.1	2.1	1.9	3.3	2.6	3.5	2.7	3.1	9.7	8.8	9.3	3.9
Daphnia puicaria	2.5	1.6	2.0		2.7	2.7	1.7	1.6	1.6	2.1	0.9	1.5	6.4	5.9	6.2	2.8
Diacyclops thomasi	26.2	24.5	25.3		24.7	24.7	15.8	20.0	17.9	19.0	20.6	19.8	12.4	13.4	12.9	20.1
Leptodiaptomus nudus	1.6	1.2	1.4		0.4	0.4	1.2	1.2	1.2	1.2	2.5	1.8	2.3	14.3	8.3	2.6
Diaphanosoma brachyurum	0.9	0.5	0.7		3.1	3.1	2.1	1.9	2.0	2.1	1.8	2.0	3.9	5.4	4.7	2.5
Mean total no./L	34.4			34.9			27.3			29.7			45.1			34.3

Table 8. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Lake Granby, 10 June 2009. Dt = *Diacyclops thomasi*, Ln = *Leptodiaptomus nudus*, and Dp = *Daphnia pulicaria*.**

Length class in mm	Granby - 10 June 2009		
	Dt	Ln	Dp
0.1	2		
0.2	0		
0.3	3		
0.4	38	1	
0.5	123	1	
0.6	154	6	
0.7	56		
0.8	82	1	
0.9	66		
1.0	25		1
1.1	21	1	
1.2	9	1	
1.3	4	4	
1.4		2	
1.5	1	1	
1.6			
1.7		1	
1.8			
1.9	1		
Totals	585	19	1
Mean Length	0.7	1.0	1.1

Table 9. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Lake Granby, 23 July 2009. Bl = *Bosmina longirostris*, Dt = *Diacyclops thomasi*, Dp = *Daphnia pulicaria*, Dgm = *Daphnia galeata mendotae*, D. spp. = Unidentified *Daphnia*, and Ln = *Leptodiaptomus nudus*.**

Length class in mm	Granby - 23 July 2009					
	Bl	**Dt**	**Dgm**	**Dp**	***D.* spp.**	**Ln**
0.1						
0.2		5				
0.3	1	21				1
0.4	1	54	1			6
0.5		123	2	1	1	14
0.6		127		1		4
0.7		55				5
0.8		52	1	1		6
0.9		9				5
1.0				2		7
1.1						2
1.2			1	1		3
1.3						3
1.4				1		1
Totals	2	446	5	7	1	57
Mean Length	0.4	0.6	0.7	1.0	0.5	0.8

Table 10. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Lake Granby, 13 August 2009. Bl = *Bosmina longirostris*, Dt = D*iacyclops thomasi*, Dp = *Daphnia pulicaria*, Dgm = *Daphnia galeata mendotae*, D. spp. = Unidentified *Daphnia*, Ln = *Leptodiaptomus nudus*, and Db = *Diaphanosoma brachyurum*.**

Length class in mm	Granby - 13 August 2009						
	Bl	Dt	Dgm	Dp	*D.* spp.	Ln	Db
0.1							
0.2	2						
0.3		1					3
0.4		10					8
0.5		33	2		2		8
0.6		40	5	5	5		5
0.7		37	27	8	2	1	4
0.8		65	30	13	1		4
0.9		62	18	13		1	1
1.0		30	11	18	4		1
1.1		4	5	10	2	3	
1.2			10	11		4	
1.3			4	4	1	2	
1.4			6	6	1	1	1
1.5				6			
1.6			5	1	1		
1.7			5	1			
1.8			2	2	1		
1.9				7			
2.0				2			
2.1					1		
2.2				2			
2.3				1			
Totals	2	282	130	110	21	12	35
Mean Length	0.3	0.8	1.0	1.2	1.0	1.2	0.6

Table 11. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Taylor Park Reservoir, 16 July 2009.

Taylor Park - 16 July 2009 - Mean *Daphnia* density = 0.5/L																
Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
unindentified *Daphnia spp.*	0.4	0.3	0.3	0.0	1.1	0.5	0.0	0.0	0.0	0.0	0.4	0.2	0.4	0.2	0.3	0.3
Daphnia mendotae	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.6	0.3	0.2	0.0	0.1	0.2	0.3	0.3	0.2
Daphnia pulicaria	0.4	0.2	0.3	0.0	0.0	0.0	1.0	0.0	0.5	0.6	0.0	0.3	0.4	0.3	0.4	0.3
Leptodiaptomus nudus	0.9	0.2	0.5	0.0	0.0	0.0	1.7	0.0	0.9	0.6	0.2	0.4	0.2	0.3	0.3	0.4
Diacyclops thomasi	26.8	34.4	30.6	75.1	101.1	88.1	64.7	68.2	66.5	36.7	39.5	38.1	25.7	23.3	24.5	49.5
Mean total no./L	31.9			88.6			68.1			39.1			25.7			50.7

Table 12. **Length frequency of crustacean zooplankton (measured to nearest 0.01 mm) collected in Taylor Park Reservoir, 23 July 2009. Dt = *Diacyclops thomasi*, Dp = *Daphnia pulicaria*, Dgm = *Daphnia galeata mendotae*, Dp spp. = Unidentified *Daphnia*, Ln = *Leptodiaptomus nudus*.**

Length class in mm	Taylor Park - 16 July 2009				
	Dt	Ln	Dgm	Dp	Dp spp.
0.1	1				
0.2	1				
0.3	14				
0.4	65				
0.5	136	2	2		1
0.6	179		5	1	
0.7	72				
0.8	80				1
0.9	36		1	3	
1.0	10			3	
1.1	3				
1.2				1	
1.3					
1.4		1		1	
1.5		1		1	
1.6					
1.7		1			
1.8				1	
Totals	597	5	8	11	2
Mean Length	0.7	1.2	0.7	1.2	0.7

Segment Objective 2: Sample *Mysis* in Granby Reservoir.

INTRODUCTION

Mysis diluviana, formerly *Mysis relicta* (Vainola 1986, Vainola et al. 1994; Audzijonyte and Vainola 2005; Dooh et al. 2006), was widely introduced into Colorado lakes and reservoirs (Finnell 1977; Nesler 1986; Martinez and Bergersen 1989). *Mysis* is presently known or believed to occur in 18 waters in Colorado, with populations establishing following purposeful introductions or through passive (downstream) transport from adjacent waters or via transmountain diversion. *Mysis* prey on *Daphnia* and can complicate reservoir fishery management (Martinez and Bergersen 1989, Nesler and Bergersen 1991; Martinez and Wiltzius 1995) by reconfiguring the food webs that support coldwater sport fishes (Martinez et al. 2009). Periodic examination of reservoirs for the presence of *Mysis*, or to estimate *Mysis* abundance provides information that aids fishery managers in understanding sport fishery trends.

Table 13. Lakes and reservoirs in Colorado known or believed to contain established populations of *Mysis diluviana* as a result purposeful introductions or through passive (downstream) transport from adjacent waters or via transmountain diversion (CBT = Colorado-Big Thompson Project).

Lake or reservoir	County	Surface acres	Elevation in feet	Depth in feet	Date of *Mysis* introduction	Most recent sampling for *Mysis*
Big Creek	Jackson	350	8,997	57	1969-1972	1992
Carter	Larimer	1,445	5,781	160	passive (CBT)	2003
Chalk	Eagle	15	11,230	22	1972	1983
Chambers	Larimer	254	9,153	91	1971-1974	2003
Dillon	Summit	3,000	9,017	240	1970	2009
Estes	Larimer	185	7,468	44	passive (CBT)	1981
Granby	Grand	7,280	8,280	220	1971	2009
Grand	Grand	506	8,367	266	1969-1971	1994
Gross	Boulder	412	7,287	280	1971-1974	1994
Horsetooth	Larimer	1,899	5,430	203	passive (CBT)	2006
Jefferson	Park	145	10,687	100	1972	2005
Marys	Larimer	42	8,046	32	passive (CBT)	1984
Mt. Elbert	Lake	200	9,500	90	pump-back	2004
Ruedi	Eagle	1,000	7,766	279	1970	2003
Shadow Mountain	Grand	1,356	8,367	36	passive (CBT)	2005
Taylor Park	Gunnison	2,009	9,330	150	1973-1974	2009
Turquoise	Lake	1,650	9,869	128	1972	1992
Twin Lakes	Lake	3,137	9,200	100	1957	2004

METHODS and MATERIALS

Sampling for *Mysis* was performed at Granby as scheduled under this 2009 segment, and at two additional waters due to CDOW Fishery Biologist interest. Sampling was performed at Dillon on 21 July, at Granby on 22 July, and at Taylor Park on 15 July. Sampling in 2009 had to be performed outside the new moon due to time constraints. Samples were collected using a 1-m diameter x 3-m long conical net with 0.5 mm mesh lowered to the reservoir bottom at standardized stations, located at night using a GPS unit, and retrieved at 0.37 m/s with an anchor windlass. Duplicate samples collected at each station in the other reservoirs were placed in 18 oz. Whirl-Pac bags, identified with a rag paper label, and preserved in 70% ethanol. In the lab, all samples were enumerated with one sample from each station being randomly chosen for measurement of individual mysids. Mysids were measured for total length to the nearest millimeter from the tip of the rostrum to the tip of the telson, excluding setae.

RESULTS and DISCUSSION

The estimated *Mysis* density in Dillon in July 2009, 207/m^2 (Table 14), was similar to that in 2007, 229/m^2 (Martinez 2008), and 2008, 205/m^2 (Martinez 2009). The estimated density of *Mysis* in Granby in July 2009, 314/m^2 (Table 16), was considerably lower than those in 2007, 1,184/m2 (Martinez 2008) or 2008, 892/m^2 (Martinez 2009). The estimated density of *Mysis* in Taylor Park in July 2009, 433/m^2 (Table 23), was similar to that reported in 2007, 470/m^2 (Martinez 2008) and double that in 2008, 205/m^2 (Martinez 2009). Tables 15, 17 and 19 provide length frequencies for the mysids sampled in these reservoirs in 2009. These variable trends in *Mysis* abundance in these three reservoirs illustrate the need to monitor mysid populations to better understand the effects of this keystone species on the food webs sustaining lake and reservoir sport fish populations.

Table 14. **Summary of nighttime *Mysis diluviana* sampling at ten stations in Dillon Reservoir, 21 July 2009, using a vertical meter net (0.785 m^2 bridle opening). Estimate of corrected lakewide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.**

Dillon Reservoir - 21 July 2009 - 10 Stations - Mean *Mysis*/m² = 206.9											
Sample number	Sampling stations (water depth in meters)										Data summary
	Stratum I		Stratum II				Stratum III				
	1A - 52.0	1B- 55.0	2A- 32.0	2B- 39.0	2C- 35	2D- 37.0	3A- 9.3	3B- 12.0	3C- 15.0	3D- 13.0	
#1	53	85	354	234	320	133	50	123	395	56	1803
#2	56	118	290	117	492	67	43	76	137	50	1446
Sum	109	203	644	351	812	200	93	199	532	106	3249
Mean	54.5	101.5	322	175.5	406	100	46.5	99.5	266	53	162.45

Table 15. ***Mysis diluviana*** **length frequency for specimens collected from nighttime vertical meter-net tows for Dillon Reservoir, July 2009.**

Dillon Reservoir- 21 July 2009																		
Station - sample #	Mysid Size (mm)																	Totals
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
GR1A-1	15	3	8	4	3	5	5	7	2	1								53
GR1B-1	10	5	8	23	7	1	6	9	13	3								85
GR2A-1	4	11	51	71	48	24	21	30	19	4	8	18	25	14	5	1		354
GR2B-2	2	5	14	31	22	8	5	7	3	1	3	10	5		1			117
GR2C-1	7	17	45	72	54	35	22	7		3	24	22	11		1			320
GR2D-1		4	7	13	10	12	8	8	1	5	11	31	10	11	2			133
GR3A-1				1	7	16	14	8	4									50
GR3B-2		1	4	16	23	11	13	8				1	1	1				79
GR3C-2	31	68	23	12	2		1											137
GR3D-1		9	10	21	10	2	1	1	2									56
Totals	69	104	170	264	186	114	96	85	44	17	46	82	52	26	9	1	0	1384
Percent	4.99%	7.5%	12.3%	19.1%	13.4%	8.2%	6.9%	6.1%	3.2%	1.2%	3.3%	5.9%	3.8%	1.9%	0.7%	0.1%	0.0%	100.0%

Table 16. **Summary of nighttime *Mysis diluviana* sampling at ten stations in Lake Granby, 22 July 2009, using a vertical meter net (0.785 m^2 bridle opening). Estimate of corrected lakewide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.**

Granby Reservoir - 22 July 2009 - 10 Stations - Mean *Mysis*/m² = 314											
Sample number	Sampling stations (water depth in meters)										Data summary
	Stratum I		Stratum II				Stratum III				
	1A- 49.5	1B- 53	2A- 31.5	2B- 28.0	2C- 33.0	2D- 26.0	3A- 19.0	3B- 15.0	3C- 19.0	3D- 21.5	
#1	171	78	491	219	52	106	783	216	250	172	2538
#2	278	60	346	165	33	92	757	184	254	222	2391
Sum	449	138	837	384	85	198	1540	400	504	394	4929
Mean	224.5	69	418.5	192	42.5	99	770	200	252	197	246.45

Table 17. ***Mysis diluviana*** **length frequency for specimens collected from nighttime vertical meter-net tows for Lake Granby, 22 July 2009.**

Granby Reservoir- 22 July 2009																		
Station - sample #	Mysid Size (mm)																	Totals
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
GR1A-2		31	41	34	14	11	5	1	3	14	51	33	23	4	7	6		278
GR1B-1					2	1	2	2	18	18	12	9	6	2	3	1	2	78
GR2A-1	12	42	74	53	28	5	6	3	3	31	123	69	28	10	4			491
GR2B-1	34	19	25	27	23	20	23	11	15	12	8	1						218
GR2C-2	11		1		4	4	5	1	2	2	2							32
GR2D-2		1	2	7	4	11	7	5		3	14	12	8	7	5	6		92
GR3A-1	475	153	56	34	16	10	14	8	8	8	1							783
GR3B-2	34	35	39	27	11	6	1	12	9	7	3							184
GR3C-2	36	27	28	31	26	13	10		5	6	13	5	2	2				204
GR3D-1		2	1	12		12	15	10	13	28	21	25	14	10	6	1	2	172
Totals	602	237	267	225	128	93	88	53	76	129	248	154	81	35	25	14	4	2532
Percent	23.78%	9.4%	10.5%	8.9%	5.1%	3.7%	3.5%	2.1%	3.0%	5.1%	9.8%	6.1%	3.2%	1.4%	1.0%	0.6%	0.2%	100.0%

Table 18. **Summary of nighttime *Mysis diluviana* sampling at ten stations in Taylor Park Reservoir, 15 July 2009, using a vertical meter net (0.785 m^2 bridle opening). Estimate of corrected lakewide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.**

Taylor Park - 15 July 2009 - 10 Stations - Mean *Mysis*/m² = 433.3											
Sample number	**Sampling stations (water depth in meters)**										Data summary
	Stratum I		**Stratum II**				**Stratum III**				
	1A - 38.5	1B- 41.5	2A- 25.0	2B- 29.5	2C- 19	2D- 24.0	3A- 7.4	3B- 9.6	3C- 13.0	3D- 11.0	
#1	137	73	126	405	578	425	169	460	538	341	3252
#2	159	50	154	185	546	479	192	744	661	381	3551
Sum	296	123	280	590	1124	904	361	1204	1199	722	6803
Mean	148	61.5	140	295	562	452	180.5	602	599.5	361	340.15

Table 19. ***Mysis diluviana*** **length frequency for specimens collected from nighttime vertical meter-net tows for Taylor Park Reservoir, 15 July 2009.**

Taylor Park Reservoir- 15 July 2009																		
Station - sample #	Mysid Size (mm)																	Totals
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
GR1A-2				7	37	57	46	7			2	1	2					159
GR1B-2				1	10	16	11	1			1	4		2	2	2		50
GR2A-1				10	23	52	29	3	2		2	2	1	1		1		126
GR2B-1	1	4	10	46	79	65	39	7	1	4	37	47	28	25	9	4		406
GR2C-1	7	25	54	93	101	76	40	11		5	33	54	37	32	8	1	1	578
GR2D-1		8	13	37	79	87	77	14		4	9	31	32	21	12	1		425
GR3A-2		3	8	22	58	61	35	5										192
GR3B-1	3	6	24	60	112	127	104	18	4				2					460
GR3C-1		5	16	62	119	211	119	35	1		1		2	1	1			573
GR3D-2		4	9	75	109	103	46	5		1	3	10	8	8				381
Totals	11	55	134	413	727	855	546	106	8	14	88	149	112	90	32	9	1	3350
Percent	0.33%	1.6%	4.0%	12.3%	21.7%	25.5%	16.3%	3.2%	0.2%	0.4%	2.6%	4.4%	3.3%	2.7%	1.0%	0.3%	0.0%	100.0%

Segment Objective 3: Complete compendium of crustacean zooplankton collections.

INTRODUCTION, METHODS, RESULTS and DISCUSSION

The results from 19 years of crustacean zooplankton sampling, including information regarding the sampling details for individual reservoirs was compiled for inclusion in a compendium. A draft version of <u>A Compendium of Crustacean Zooplankton and *Mysis diluviana* Collections from Selected Colorado Reservoirs and Lakes: 1991-2009</u>, coauthored with Research Technicians Michael Gross and Estevan Vigil, was completed during this segment. This document, which will become CDOW Special Report No. 82, summarizes data associated with the collection of crustacean zooplankton performed as part of research on Colorado's large coldwater lakes and reservoirs and includes data from some smaller or lower elevation reservoirs. Sampling in coldwater reservoirs and lakes was performed under Federal Aid in Fish and Wildlife Restoration Projects F-89, F-85, and F-242 from 1991 to 2009 and reported in annual progress or final reports, entitled <u>Coldwater Reservoir Ecology</u>, from 1992 to 2010. Collections from the warmwater reservoir Highline Lake were made under Federal Aid in Fish and Wildlife Restoration Project F-325 from 1999 to 2002 and reported in annual progress reports entitled <u>Westslope Warmwater Fisheries</u> from 2000 to 2003. Additional data from Highline Lake in 2005 and 2006 was included in the 2007 Great Outdoors Colorado annual report also entitled <u>Westslope Warmwater Fisheries</u>. Data for Rifle Gap Reservoir, a mid-elevation reservoir, appeared in the 2009 Coldwater Reservoir Ecology annual report. Updates and corrections to zooplankton species nomenclature were incorporated into historic sampling records. Diagnostic features for identifying selected species of crustacean zooplankton were provided with anatomical descriptions and micrographs showing key structures.

In addition, *Mysis* was sampled in 14 Colorado lakes and reservoirs from 1991 to 2009. At some waters, sampling was performed primarily to document the establishment or persistence of mysid populations. In several larger reservoirs, mysids were more frequently monitored to study their population dynamics and potential impacts to *Daphnia* and sport fish populations. The results from 19 years of *Mysis* sampling was included in the draft of <u>A Compendium of Crustacean Zooplankton and *Mysis diluviana* Collections from Selected Colorado Reservoirs and Lakes: 1991-2009</u>. A summary of some of this information was provided in a presentation entitled <u>*Mysis diluviana*: Observations from its Introduction in Western North America and Population Trends in Selected Colorado Reservoirs</u> at the February 2010 CDOW Kokanee Workshop in Kremmling, CO.

<u>OBJECTIVE 4:</u> **WATER AND OTOLITH MICROCHEMISTRY AS A FORENSIC TOOL TO TRACE AND PROSECUTE ILLEGAL MOVEMENTS OF FISH**

Initiate, facilitate and participate in water and otolith microchemical investigations to identify the utility of this technique as a potential forensic tool for tracing and combating illicit fish stocking by sampling at hatcheries (state, federal and private) and in select large reservoirs and their satellite waters.

Segment Objective 1: Promote microchemical techniques as forensic tool for aquatic resources.

INTRODUCTION, METHODS, RESULTS and DISCUSSION

Collecting otoliths and preparing thin sections to reveal their annuli has provided the capability to age long-lives fishes and/or to perform microchemical analyses to track the origins and movements of fish (Whitledge et al. 2006; Maceina et al. 2007; Whitledge et al. 2007; Johnson et al. 2008; Gibson-Reinemer et al. 2009). <u>Instructions for Capturing, Cropping and Enhancing Otolith Thin Section Images</u> (Appendix B) by Wildlife Technican Michael Gross, provides instructions for obtaining high quality digital images of otolith thin sections using digital microscopy equipment and computer programs.

During this segment, interest was expressed by CDOW Law Enforcement about the utility of microchemical analyses to identify the origins of crayfish. After providing preliminary information to Law Enforcement personnel, the matter was referred to Dr. Brett Johnson at Colorado State University for analyses. Dr. Johnson provided a memo summarizing the isotopic analyses and results (edited to remove investigation details; Appendix C).

<u>OBJECTIVE 5:</u> **TECHNICAL AND COOPERATIVE SUPPORT IN OTHER RESEARCH INVESTIGATIONS AND IN RESERVOIR MANAGEMENT**

Provide technical and cooperative support in other research investigations (e.g. strobes at Vallecito, yellow perch Perca flavescens in Blue Mesa) and in reservoir management including selecting angling regulations, fish stocking, and information dissemination, to help perpetuate fishery productivity and stability.

Segment Objective 1: Participate in efforts to advance agency and public response to combat illicit fish introductions in western Colorado.

INTRODUCTION, METHODS, RESULTS and DISCUSSION

The article Are we Doing All we can to Stem the Tide of Illegal Fish Stocking? was published in Fisheries (Johnson et al 2009).

Several opportunities allowed discussion of illegal introductions of aquatic species. The implications of illegal fish introductions was discussed in a presentation, Nonnative Species in the Upper Colorado River Basin: Incorporating Community Ecology Concepts and Invasive Species Deterrents into Native Fish Restoration and Conservation, to the Upper Colorado River Basin (UCRB) Endangered Fish Researchers Meeting held in Grand Junction in January 2010. The opportunity also arose to discuss the illegal introduction of yellow perch in Blue Mesa Reservoir at the CDOW Kokanee Workshop held in Kremmling in February 2010. In March 2010, I participated in discussions with CDOW personnel and the Colorado Fish Health Board regarding the illegal introduction of rusty crayfish into the Yampa River basin. In April 2010, I presented information to CDOW Aquatic Section personnel regarding native and nonnative fish research and management in western Colorado. This included discussion of the implications of various fish species which have been illegally introduced in coldwater and warmwater reservoirs (Table 20) and the relative invasion risk posed by these species based on the frequency of their illegal introduction in the past two decades (Table 21).

Segment Objective 2: Participate in dissemination of information, as needed or feasible, to facilitate lake trout reduction and kokanee increase at Blue Mesa Reservoir.

INTRODUCTION, METHODS, RESULTS and DISCUSSION

I worked with CDOW's Southwest Region fishery biologists to produce summaries for Blue Mesa Reservoir comparing 1) angler harvest and preference, and the estimated monetary value of the kokanee, rainbow trout, and lake trout fisheries, and 2) lake trout population trends and implications of a potential lake trout population reduction program on the lake trout fishery (Appendix D).

Table 20. **Summary of illegally introduced fish and crayfish species in western Colorado during the 1980s, 1990s, and 2000s, in higher elevation (shaded; n = 12)) and lower elevation reservoirs (unshaded; n = 9). BCR = black crappie *Pomoxis nigromaculatus*, BGL = bluegill *Lepomis macrochirus*, GSH = golden shiner *Notemigonus crysoleucas*, GSF = green sunfish *Lepomis cyanellus*, LMB = largemouth bass *Micropterus salmoides*, NOP = northern pike *Esox lucius*, RSS = redside shiner *Richardsonius balteatus*, RCF = rusty crayfish *Orconectes rusticus*, SMB = smallmouth bass *Micropterus dolomieu*, WLY = walleye *Sander vitreus*, and YLP = yellow perch *Perca flavescens*.**

Reservoir or pond name	Decade of illegal introduction			Totals
	1980	1990	2000	
Avery			**GSF, BCR**	2
Blue Mesa		**YPE**	NOP, SMB, **RSS**	4
Catamount			**RCF**	1
Connected Lakes		WLY		1
Duke			**SMB**	1
Elkhead	**BCR**			1
Granby			NOP	1
Crawford		**BCR, NOP**, WLY	SMB	4
Juniata	**SMB**	**WLY**	**BGL**	3
Harvey Gap	**NOP**	**YPE**, WLY		3
Highline	**YPE, BCR**		**SMB**	3
Kenney	**BCR**, BGL, LMB, NOP		WLY	5
Ruedi			**YPE**	1
Ridgeway		**YPE**	SMB	2
McPhee		NOP, **WLY**		2
Rifle Gap		**BCR, NOP, YPE**	**GSH**	4
Stagecoach		**NOP**	**WLY**	2
Wolford Mtn.			**NOP**	1
Steamboat			NOP	1
Vallecito	SMB		**YPE**	2
Vega			NOP	1
21 waters	10	15	19	**45**
9 lower elevation waters (warmwater); 12 higher elevation (coldwater)				

Table 21. Summary of illegally introduced fish and crayfish species in western Colorado during the 1980s, 1990s, and 2000s showing that incidence of this activity per decade has increased and that northern pike, smallmouth bass, yellow perch, and walleye have been the species most frequently transplanted illegally in the past two decades.

Nonnative & invasive species		No. per decade			Total
Family	**Species**	**1980**	**1990**	**2000**	
Cambaridae	Rusty crayfish			1	1
Cyprinidae	Redside & golden shiners			2	2
Esocidae	Northern pike	2	4	5	**11**
Centrarchidae	Bluegill	1		1	2
	Green sunfish	1		1	2
	Black crappie	3	2	1	6
	Largemouth bass	1			1
	Smallmouth bass	1	1	5	**7**
Percidae	Yellow perch	1	4	2	**7**
	Walleye		4	2	**6**
Total	8	10	15	20	45
Number per year >>>		**1.0**	**1.5**	**2.0**	**1.5**

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APPENDIX A

TEMPERATURE AND DISSOLVED OXYGEN PROFILES, AND SECCHI DEPTHS MEASURED IN RESERVOIRS IN 2009

Table A-1. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Blue Mesa Reservoir on 9 June 2009. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Blue Mesa 09 June 2009					
	SAP (95m)		CEB (20m)		IOLA (24m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	12.5	7.6	13.5	7.1	13.0	7.5
1	12.5	7.7	13.5	7.1	12.9	7.5
2	12.5	7.7	13.3	7.2	12.8	7.6
3	12.3	7.9	13.2	7.3	12.8	7.7
4	12.2	7.8	13.2	7.3	12.8	7.7
5	12.1	7.8	13.1	7.4	12.8	7.8
6	12.0	7.8	13.1	7.4	12.8	7.7
7	12.0	7.7	13.0	7.4	12.8	7.8
8	11.7	7.8	12.8	7.4	12.8	7.7
9	11.2	7.7	12.6	7.3	12.7	7.7
10	10.8	73.7	12.2	7.3	12.7	7.7
11	10.3	7.5	12.1	7.3	12.7	7.7
12	10.1	7.5	11.8	7.2	12.7	7.6
13	10.0	7.5	11.6	7.2	12.6	7.6
14	9.9	7.5	11.3	7.1	12.3	7.5
15	9.8	7.6	11.1	7.1	11.9	7.6
16	9.7	7.7	10.8	7.1	11.6	7.6
17	9.5	7.8	10.5	7.0	11.2	7.6
18	9.3	7.9	10.2	7.0	10.7	7.6
19	9.1	7.9	9.7	7.0	10.6	7.5
20	9.0	7.9	9.4	7.1	10.5	7.4
25	8.4	8.1				
30	7.7	8.1				
35	7.3	8.2				
40	6.4	8.2				
45	5.7	8.2				
50	5.4	8.3				
55	5.3	8.3				
60						
Secchi (m)	2.50		2.64		2.70	

Table A-2. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Blue Mesa Reservoir on 15 July 2009. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Blue Mesa 15 July 2009					
	SAP (95m)		CEB (60m)		IOLA (25m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	19.9	7.0	19.6	8.0	18.8	6.8
1	19.2	6.9	19.1	7.1	18.8	6.5
2	18.8	6.9	19.0	7.0	18.7	6.4
3	18.5	6.9	18.9	6.8	18.6	6.4
4	18.4	6.8	18.9	6.8	18.5	6.2
5	18.3	6.8	18.8	6.7	18.4	6.3
6	17.6	6.5	18.8	6.8	18.4	6.3
7	17.2	6.4	18.8	6.6	18.4	6.2
8	16.3	6.2	17.6	6.0	18.4	6.3
9	15.5	5.9	17.0	5.9	17.6	6.0
10	14.7	5.9	15.6	5.6	16.6	5.9
11	14.6	6.0	14.5	5.5	15.9	5.8
12	13.9	5.9	14.2	5.4	15.2	5.6
13	13.6	6.0	13.9	5.4	14.5	5.5
14	13.3	6.1	13.6	5.5	14.1	5.3
15	13.0	6.0	13.3	5.4	13.5	5.3
16	12.8	6.0	13.1	5.4	13.3	5.2
17	12.3	6.0	12.7	5.4	12.9	5.2
18	11.8	6.2	12.5	5.4	12.7	5.2
19	11.5	6.2	12.2	5.4	12.6	5.2
20	11.4	6.1	11.8	5.4	12.4	5.2
25	10.4	6.3	10.6	5.7	11.1	4.2
30	9.8	6.8	10.0	5.1		
35	9.1	6.8	9.1	5.1		
40	8.3	6.7	8.3	5.0		
45	7.5	6.9	7.5	4.9		
50	6.8	6.5	6.9	4.9		
55	6.1	6.6	6.5	4.7		
60	5.8	6.9	6.5	4.6		
Secchi (m)	6.92		6.96		7.26	

Table A-3. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Blue Mesa Reservoir on 12 August 2009. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Blue Mesa 12 August 2009					
	SAP (96m)		CEB (58m)		IOLA (24m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	18.4	6.6	19.2	6.5	18.8	7.1
1	18.3	6.6	19.0	6.5	18.7	6.9
2	18.2	6.5	18.9	6.3	18.6	6.9
3	18.2	6.4	18.9	6.4	18.6	6.8
4	18.2	6.5	18.9	6.4	18.6	6.7
5	18.2	6.6	18.8	6.4	18.5	6.8
6	18.2	6.6	18.8	6.3	18.5	6.7
7	18.1	6.4	18.7	6.3	18.5	6.8
8	18.1	6.5	18.7	6.3	18.5	6.8
9	18.0	6.2	18.6	6.0	18.5	6.8
10	17.8	6.0	18.5	6.0	18.5	6.8
11	17.6	5.6	17.7	5.5	18.4	6.6
12	15.9	4.8	16.9	4.9	18.3	6.5
13	15.3	4.9	15.7	4.3	16.8	5.7
14	14.8	4.9	15.1	4.3	15.7	5.0
15	14.4	5.1	14.8	4.4	14.8	4.3
16	14.0	5.1	14.1	4.4	14.6	4.3
17	13.6	5.2	13.9	4.5	14.0	4.1
18	13.4	5.3	13.5	4.6	13.7	3.9
19	13.2	5.4	13.2	4.6	13.2	3.8
20	12.8	5.4	12.9	4.6	13.0	3.6
25	11.4	5.8	11.7	4.5		
30	10.7	6.0	10.9	4.4		
35	9.8	6.0	10.1	3.6		
40	8.9	6.1	9.1	3.3		
45	7.7	5.9	7.8	3.6		
50	6.8	5.9	7.1	3.3		
55	6.1	6.2	6.7	3.4		
60						
Secchi (m)	6.74		6.73		6.31	

Table A-4. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Dillon Reservoir on 21 July 2009. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Dillon 21 July2009									
	P1 (67m)		P2 (33m)		P3 (18m)		P4 (15m)		P5 (13m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	15.8	6.3	16.0	6.1	16.2	6.6	15.5	6.1	16.5	7.2
1	15.6	6.5	15.7	6.2	16.1	6.3	15.4	6.1	16.4	7.1
2	15.1	6.6	15.5	6.3	15.5	6.2	15.2	6.2	16.4	7.0
3	14.9	6.7	15.1	6.4	15.4	6.2	15.0	6.3	15.9	7.1
4	14.9	6.7	15.0	6.5	15.3	6.2	14.8	6.3	15.8	7.0
5	14.8	6.7	13.4	6.5	15.3	6.2	14.8	6.3	15.7	7.0
6	14.6	6.8	11.2	6.4	15.1	6.3	14.7	6.3	15.0	6.9
7	14.5	6.7	10.1	6.6	13.4	6.4	14.4	6.3	14.0	6.9
8	10.8	7.0	9.5	6.7	12.4	6.5	13.5	6.4	12.6	6.9
9	9.0	7.0	8.9	6.7	11.3	6.6	10.8	6.5	11.6	6.9
10	8.2	7.0	8.2	6.7	10.1	6.7	9.2	6.6	10.9	6.8
11	7.7	7.0	8.0	6.7	9.8	6.7	8.5	6.5	9.3	6.7
12	7.5	6.9	7.4	6.6	9.5	6.6	7.9	6.5	8.7	6.4
13	7.0	6.9	7.1	6.6	9.0	6.6	7.5	6.5	7.5	6.4
14	6.8	6.8	6.7	6.6	8.4	6.6	6.9	6.4		
15	6.6	6.8	5.9	6.5	8.1	6.5	6.7	6.4		
16	6.4	6.8	5.7	6.5	7.8	6.4				
17	6.2	6.9	5.5	6.5	6.8	6.3				
18	6.1	6.8	5.4	6.4	6.4	6.2				
19	6.0	6.7	5.3	6.4						
20	5.8	6.7	5.2	6.3						
25	4.8	6.7	4.9	6.3						
30	4.6	6.6	4.7	6.3						
35	4.4	6.6								
40	4.1	6.5								
45	4.0	6.4								
50	4.0	6.3								
55	3.9	6.2								
Secchi (m)	3.44		3.52		3.55		3.42		3.30	

Table A-5. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Granby Reservoir on 10 June 2009. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Granby 10 June 2009									
	P1 (19.0m)		P2 (10m)		P3 (29m)		P4 (37m)		P5 (30m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	11.7	7.4	11.8	7.6	11.2	7.5	11.2	7.4	11.3	7.8
1	11.2	7.7	11.4	7.5	11.2	7.7	11.0	7.4	11.3	7.7
2	10.9	7.6	11.1	7.5	11.2	7.7	10.9	7.3	11.2	7.6
3	10.9	7.6	11.2	7.4	11.2	7.8	10.9	7.2	11.2	7.3
4	10.7	7.5	11.0	7.3	11.1	7.9	10.9	7.2	11.2	7.3
5	10.4	7.4	10.9	7.3	11.1	7.9	10.9	7.2	11.2	7.4
6	10.3	7.4	10.9	7.3	11.1	7.9	10.9	7.2	11.2	7.4
7	10.3	7.4	10.9	7.4	11.0	7.9	10.9	7.2	11.2	7.4
8	10.2	7.5	10.8	7.3	11.0	7.9	10.9	7.2	11.2	7.4
9	10.1	7.3	10.8	7.3	10.9	7.9	10.9	7.2	11.2	7.4
10	10.0	7.5	10.7	7.2	10.8	7.7	10.2	7.3	11.1	7.3
11	10.0	7.5			10.7	7.7	9.5	7.1	10.6	7.3
12	9.9	7.5			10.6	7.7	9.1	7.0	8.8	7.0
13	9.0	7.3			9.6	7.5	8.4	7.0	8.3	7.0
14	7.6	7.2			8.9	7.5	6.9	7.9	7.8	7.0
15	7.4	7.1			8.7	7.4	7.8	7.0	7.6	7.0
16	7.1	7.0			8.1	7.4	7.4	6.9	7.0	7.1
17	6.9	7.0			7.6	7.5	7.2	7.0	6.5	7.0
18	6.9	7.0			7.1	7.5	7.1	7.0	6.3	7.1
19					6.8	7.6	7.1	6.9	6.2	7.0
20					6.6	7.5	6.9	6.9	6.2	7.0
25					5.9	7.7	6.3	7.1	5.9	7.1
30							6.1	7.2	5.8	6.9
35							6.1	7.1		
Secchi (m)	2.42		2.26		1.11		3.23		3.26	

Table A-6. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Granby Reservoir on 23 July 2009. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Granby 23 July 2009									
	P1 (23m)		P2 (15m)		P3 (23m)		P4 (34m)		P5 (34m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	17.1	6.6	18.4	7.2	18.3	6.4	18.4	6.9	18.8	6.6
1	17.1	6.6	17.9	6.5	18.0	6.3	17.8	6.5	18.9	6.3
2	17.1	6.5	17.7	6.4	17.9	6.3	17.7	6.3	18.7	6.4
3	17.1	6.4	17.6	6.4	17.6	6.0	17.6	6.4	18.5	6.4
4	17.1	6.3	17.5	6.2	17.6	6.0	17.5	6.3	18.4	6.4
5	17.0	6.2	17.4	6.1	17.6	6.0	17.4	6.3	18.3	6.2
6	16.9	6.1	17.3	6.0	17.4	6.0	17.3	6.3	17.3	5.9
7	16.9	6.1	17.2	6.0	17.3	6.0	17.1	6.1	16.4	5.6
8	16.8	6.0	16.5	5.6	15.9	5.3	16.5	5.7	14.9	5.2
9	16.2	5.6	15.7	5.4	15.0	4.9	15.8	5.3	12.9	4.9
10	14.9	5.1	14.5	4.9	13.6	4.8	14.3	4.9	12.0	4.9
11	13.2	4.9	13.1	4.7	12.7	4.8	13.0	4.8	10.9	5.1
12	12.5	4.9	12.5	4.6	12.2	4.9	11.9	4.8	10.2	5.4
13	11.9	4.9	12.0	4.6	11.5	4.9	11.2	4.9	9.9	5.3
14	11.5	4.9	11.5	4.6	10.6	5.0	10.7	5.0	9.5	5.3
15	11.0	4.9			9.9	5.1	9.8	4.9	9.0	5.3
16	10.6	4.9			9.5	5.1	9.4	5.0	8.6	5.2
17	9.8	5.0			9.0	5.2	9.3	4.9	8.6	5.2
18	9.2	4.9			7.9	5.2	8.5	5.0	7.9	5.3
19	8.7	4.8			7.8	5.2	8.0	5.0	7.7	5.2
20	8.5	4.8			7.7	5.2	7.6	5.0	7.4	5.2
25							7.4	5.1	7.0	5.4
30							7.2	5.2	6.9	5.2
Secchi (m)	2.97		3.14		3.45		2.81		3.64	

Table A-7. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Granby Reservoir on 13 August 2009. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Granby 13 August 2009									
	P1 (23m)		P2 (16m)		P3 (15m)		P4 (46m)		P5 (34m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	17.1	7.0	17.0	6.8	17.4	7.2	17.2	6.6	17.6	7.0
1	17.1	6.7	17.0	6.5	17.4	6.8	17.2	6.8	17.6	6.7
2	17.1	6.6	17.0	6.6	17.3	6.8	17.2	6.8	17.6	6.7
3	17.1	6.7	17.1	6.4	17.4	6.7	17.2	6.8	17.6	6.7
4	17.3	6.7	17.1	6.4	17.4	6.7	17.1	6.7	17.6	6.5
5	17.3	6.7	17.1	6.4	17.4	6.7	16.9	6.7	17.6	6.5
6	16.9	6.8	17.0	6.4	17.4	6.6	16.7	6.3	17.6	6.6
7	16.7	6.7	17.0	6.3	17.3	6.6	16.5	6.3	17.3	6.4
8	16.8	6.7	16.8	6.1	17.0	6.4	16.4	6.2	16.9	6.1
9	16.6	6.8	15.8	5.4	15.2	5.2	16.3	6.2	16.0	5.2
10	16.5	6.7	15.3	5.0	14.0	4.8	16.0	6.1	14.5	4.7
11	15.8	6.4	13.7	4.4	13.6	4.8	13.7	4.6	12.4	4.6
12	13.1	4.6	12.6	4.4	12.5	4.8	13.0	4.6	11.0	5.2
13	12.5	4.7	11.6	4.6	11.3	5.0	10.5	5.0	10.2	5.0
14	11.4	4.7	11.4	4.5	10.6	5.0	10.0	5.2	9.7	5.0
15	10.8	4.7	10.9	4.7	10.1	5.2	9.6	5.2	8.9	5.5
16	10.5	4.8					9.0	5.2	8.7	5.6
17	10.0	4.8					8.7	5.2	8.2	5.5
18	9.3	4.8					8.3	5.3	8.0	5.6
19	8.9	4.6					8.1	5.4	7.8	5.6
20	8.6	4.5					8.0	5.4	7.7	5.7
25							7.7	5.2	7.4	5.5
30							7.4	5.3	7.3	5.6
35							7.3	5.4		
40							7.2	5.4		
45							7.1	5.4		
Secchi (m)	5.69		5.51		5.42		5.85		7.74	

Table A-8. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at one station at Highline Reservoir on 1 June 2009. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	**Highline 01 June 2009**	
	P1 (10m)	
	°C	mg/l
0	18.4	8.0
1	18.3	9.0
2	18.2	9.7
3	18.1	9.9
4	17.5	10.1
5	16.0	8.2
6	14.9	6.5
7	14.2	5.3
8	13.4	4.1
9	12.9	0.5
10	12.7	1.1
Secchi (m)	0.85	

Table A-9. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Taylor Park Reservoir on 16 July2009. Values in parenthesis denote maximum water depth at station.

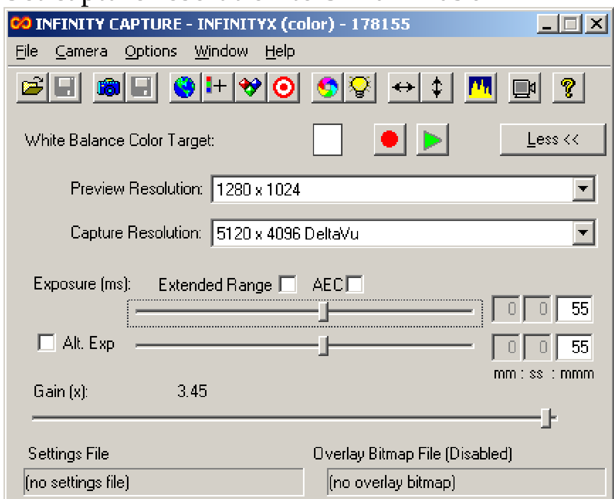
Water Depth (m)	Taylor Park 16 July 2009									
	P1 (14m)		P2 (9m)		P3 (33m)		P4 (14m)		P5 (12m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	16.1	6.8	15.6	6.6	15.5	8.0	16.5	6.8	16.4	8.3
1	16.1	6.7	15.6	6.9	15.6	7.7	15.9	6.9	16.3	8.3
2	16.1	6.6	15.4	7.0	15.5	7.5	15.9	6.7	16.1	7.9
3	16.1	6.5	15.3	7.0	15.5	7.3	15.8	6.7	15.9	7.6
4	16.0	6.5	15.6	6.9	15.5	7.2	15.7	6.7	15.7	7.5
5	16.0	6.5	15.2	6.9	15.5	6.9	15.6	6.6	15.5	7.2
6	15.1	6.6	15.2	6.8	15.5	6.9	15.4	6.5	14.7	7.2
7	14.8	6.7	15.2	6.9	15.5	6.8	13.8	6.5	13.8	6.8
8	14.0	6.4	15.2	6.8	13.5	6.4	13.2	6.3	13.1	6.5
9	13.4	6.4			12.6	6.5	12.0	5.9	12.7	6.4
10	13.2	6.3			11.6	6.2	11.6	5.8	12.3	6.2
11	12.3	6.1			11.1	6.0	11.5	5.7	11.8	5.9
12	11.2	5.8			10.8	5.9	11.1	5.5		
13	11.0	5.7			10.6	5.8	10.7	5.5		
14	10.8	5.7			10.4	5.8	10.4	5.5		
15					10.0	5.8				
16					9.5	5.7				
17					9.3	5.5				
18					9.2	5.5				
19					9.1	5.5				
20					9.0	5.4				
25					8.8	5.2				
30					8.5	5.2				
Secchi (m)	4.91		4.67		4.50		4.16		N/A	

APPENDIX B

INSTRUCTIONS FOR CAPTURING, CROPPING AND ENHANCING OTOLITH THIN SECTION IMAGES

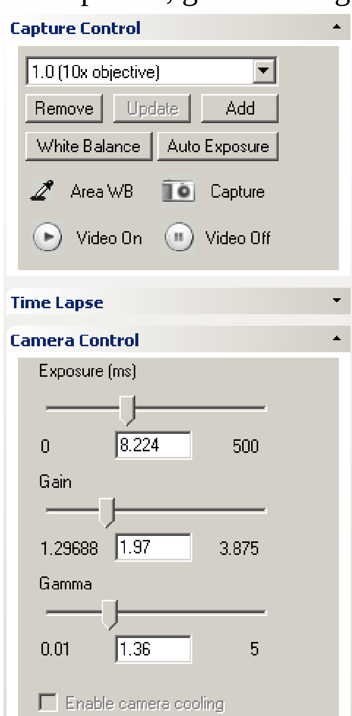
Instructions for capturing, cropping and enhancing otolith thin section images:

1. **Set Infinity X camera resolutions:**
   - Open Infinity Capture software
   - Set preview resolution to 1280 x 1024
   - Set capture resolution to 5120 x 4096

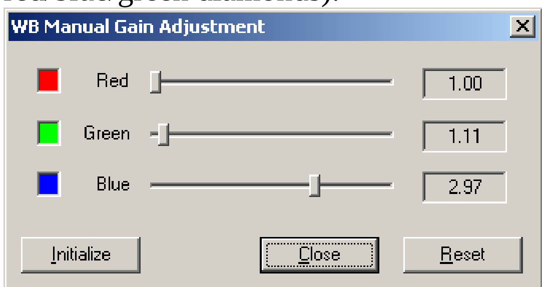


   - Minimize Infinity Capture

2. **Adjusting camera settings and using preset settings:**
   - Open Infinity Analyze software
   - In the box labeled "Capture Control," browse through preset settings to find the most optimum camera settings or create a new preset by adjusting the exposure, gain and/or gamma and then hitting the "add" button.



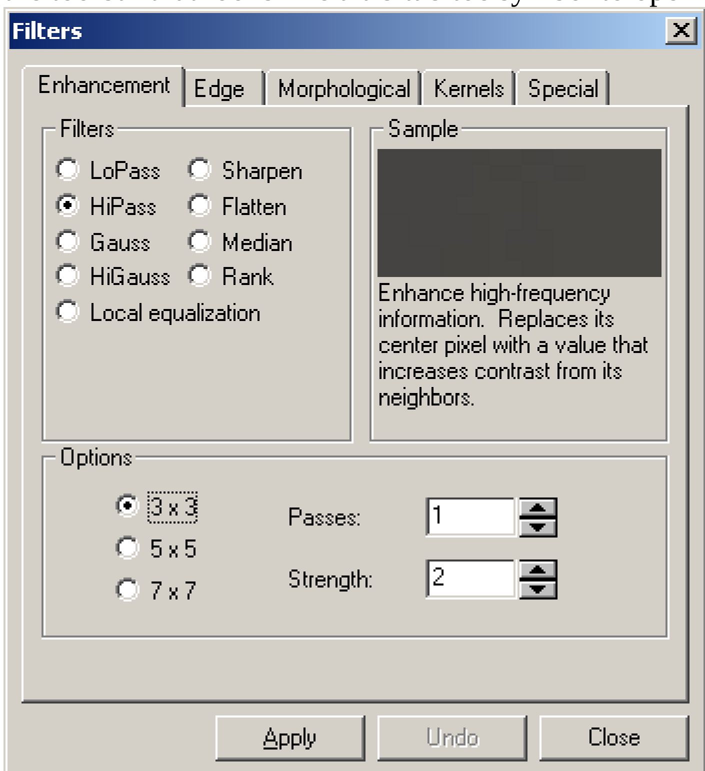
- If you are going to take measurements, make sure your preset is properly calibrated for the microscope magnification being used. Instructions and tutorials for calibrating presets can be found at: www.lumenera.com/support/download.php
- If the colors still need adjusting, maximize Infinity Capture and adjust the coloration manually via the "WB Manual Gain Adjustment" (button with red/blue/green diamonds).



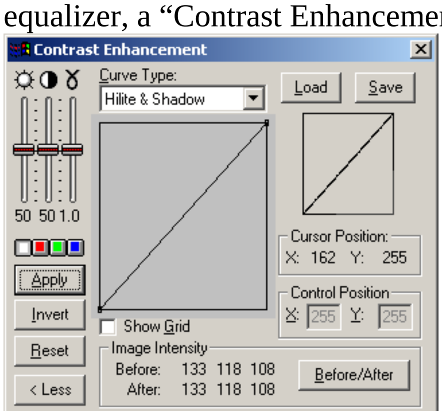
3. **Capturing and saving the images:**
   - To capture the image using Infinity Analyze, click the camera icon at the top of the screen or double click the image. After the image has been captured, it is often useful to click the "toggle preview" icon (next to camera icon). This will help to reduce the computer lag while analyzing the captured image.
   - If the captured image is acceptable, save the image to a designated file or desktop. File name should include: where sample is from, species, date, sample number, and preferably a brief description.
     ex. BMR-KOK-102209.001(460mm Age4).jpg
   - The image should be saved as a .jpg or as a .bmp. A .jpg file will take up less memory on the hard drive than a .bmp file, but .bmp may have a slightly higher quality that may be preferred for publication use.
4. **Cropping the saved images:**
   - Open and minimize Image Pro Plus data imaging software.
   - Drag saved image onto minimized Image Pro Plus icon on the toolbar and into the application.

- To crop image: click the square box at the top of the screen, and then surround your target with the box.
- Click Edit > Duplicate/Crop to AOI (the cropped picture will appear)
- Generally, the cropped image should be saved as the same file name as the uncropped version and replaced.

5. **Enhancing the saved images:**
    - Once the images are cropped and saved, Image Pro Plus software may be used to modify and/or enhance the images with filters. Click the icon on the toolbar that looks like a tic-tac-toe symbol to open the "Filters" box.



    - There are numerous filters to choose from that all have a specific utility. The filters that will be most useful when reading otoliths are: Hipass, Local Equalization, Phase, Sharpen, Laplace, and Sculpt. Hipass, Local Equalization and Phase seem to work especially well.
    - Also in Image Pro Plus, if you press the button that looks like a stereo equalizer, a "Contrast Enhancement" box will appear.



- The brightness, contrast, and gamma settings can all be adjusted from here. Adjusting these settings may help to reveal annuli. Also in the "Contrast Enhancement" box, clicking "invert" can be a useful tool in revealing annuli.

6. **Tutorials on the internet:**
    - **T**here are numerous tutorials online for Infinity software at www.lumenera.com/support/download.php . It is recommended that all new users do the tutorials in order to avoid unnecessary frustrating complications.

APPENDIX C

SUMMARY OF MICROCHEMICAL ANALYSIS OF CRAYFISH

Colorado State University
Department of Fish, Wildlife and Conservation Biology
Fort Collins, CO 80523-1474
(970) 491-5020
FAX: (970) 491-5091

August 25, 2010 - We have completed the chemical analysis of the crayfish samples you provided. We sent two crayfish carapaces from each of four locations to the Woods Hole Oceanographic Institute for strontium isotope ratio analysis ($^{87}Sr/^{86}Sr$). The isotope laboratory at Woods Hole was constructed by Dr. Simon Thorrold, one of the world's experts in strontium isotope analysis. The instruments at this laboratory are used to analyze fish otoliths, coral, mollusk shells, and other calcareous materials found in aquatic organisms. Although we are not aware of any other scientists that have looked at strontium isotopes in crayfish before, the scientist that performed the analysis on our crayfish developed a methodology that he said worked quite well and he said crayfish carapaces contain more than enough strontium to obtain very accurate estimates of their strontium ratio.

In our work with fish we have found that this isotope ratio has quite low variability among species of fish within a location (typically sample CV<0.02%). We have examined up to four different species representing up to three families of fish within a given location and there have been no statistically significant differences in the strontium ratio. We have also learned that strontium ratio does vary considerably by location. Virtually all of the 12 or so reservoirs we have examined in the Upper Colorado River basin have distinct strontium isotope signatures.

While we have not studied crayfish in detail, the crayfish samples we sent to Woods Hole also showed extremely low variability within a location (average CV=0.007%) and large differences across locations (Figure 1). The difference in strontium ratio of crayfish between [the suspect samples] (Sr ratio= 0.714277) and Wolford Mountain Reservoir (Sr ratio= 0.708576) was about 0.005702. This is an enormous difference, especially considering the low standard errors of each sample. I did not include results from a pair of crayfish I sent in from Chatfield Reservoir, near Denver, because the value there was so high (0.721262) it would obscure the comparisons among the three samples above.

Based on the information at hand and assuming 1) that what we know about fish is transferable to crayfish, and 2) that the crayfish [in the suspect samples] had very recently been collected from the wild and at a similar in time to when the Wolford sample was collected, I conclude that it is extremely unlikely that the [suspect] samples of crayfish you confiscated ….originated from Wolford Mountain Reservoir (nor Stagecoach Reservoir). We cannot say where the [suspect samples of] crayfish did originate from without more sampling to characterize the strontium ratio of suspect waters.

I appreciate your confidence in my lab and I am pleased that some of the isotope research I've done (much with CDOW Aquatic Research support) has provided some utility to a significant field issue. I hope you and your colleagues will feel like you can continue to call on my expertise again in the future.
CC: Patrick Martinez

Table 1. **Strontium isotope ratios ($^{87}Sr/^{86}Sr$) and variability measured in crayfish carapaces (n=2 per site) sampled at four locations in Colorado: confiscated [suspect samples] (Adams County), and sampled at Wolford Mountain Reservoir (Grand County), Stagecoach Reservoir (Routt County), and Chatfield Reservoir (Adams/Jefferson County).**

Sample #	Source location	$^{87}Sr/^{86}Sr$	Average	Coefficient of variation (%)	2*standard error
1A	Suspect sample	0.714238	0.714277	0.007870	0.000112
1B	Suspect sample	0.714317			
2A	Wolford Mtn	0.708564	0.708576	0.002337	0.000033
2B	Wolford Mtn	0.708587			
4A	Stagecoach	0.709244	0.709240	0.000780	0.000011
4B	Stagecoach	0.709236			
7A	Chatfield	0.721338	0.721262	0.015028	0.000217
7B	Chatfield	0.721185			

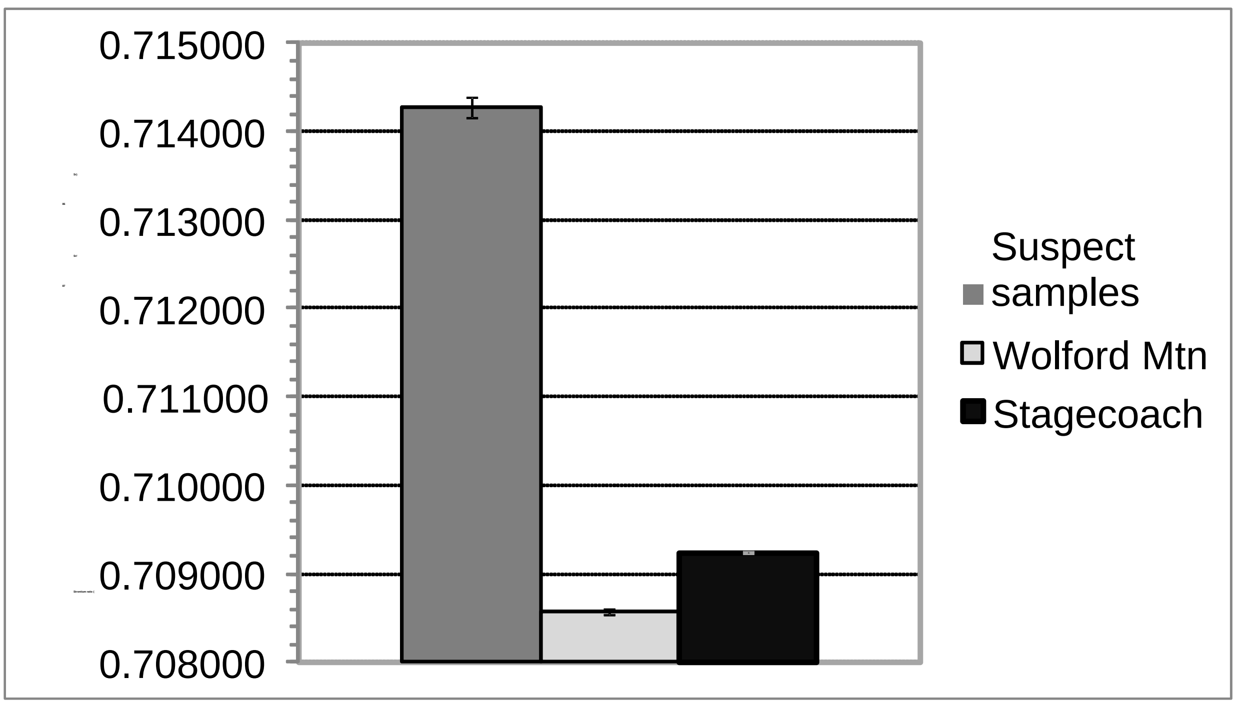


Figure 1. Strontium isotope ratio ($^{87}Sr/^{86}Sr$) measured in crayfish carapaces (n=2 per site) sampled at three locations in Colorado: confiscated [suspect samples] (Adams County), and sampled at Wolford Mountain Reservoir (Grand County) and Stagecoach Reservoir (Routt County). Error bars show ±2*standard error.

APPENDIX D

COMPARISONS OF ANGLER HARVEST & PREFERENCE, & MONETARY VALUE ESTIMATES FOR KOKANEE, RAINBOW TROUT & LAKE TROUT FISHERIES IN BLUE MESA RESERVOIR
and
LAKE TROUT (MAC) POPULATION TRENDS AND IMPLICATIONS OF POTENTIAL CDOW SPONSORED LAKE TROUT POPULATION REDUCTION PROGRAM ON LAKE TROUT FISHERY IN BLUE MESA RESERVOIR (BMR)

Comparisons of Angler Harvest & Preference, & Monetary Value Estimates for Kokanee, Rainbow Trout & Lake Trout Fisheries in Blue Mesa Reservoir

Creel survey data from Blue Mesa Reservoir (BMR) from 1998-2008 was used to develop estimates for comparing angler harvest and preference, and the monetary value for the kokanee (KOK), rainbow trout (RBT), and lake trout (MAC) fisheries in BMR. Since 1998, the creel survey has also collected data to assess perceptions of angler satisfaction regarding their fishing experience and number of fish caught. Creel survey data typically represented two time periods: winter and spring (early), and summer and fall (main) fishing seasons. The data from these two time periods were weighted in accordance with the length of their respective survey periods to normalize the estimates for calculating average values of angler harvest and preference, and fishery satisfaction, which was available from 2000-2008. In addition, comparisons were also made between the early and main fishing seasons to illustrate some of the misconceptions about the prominence of the lake trout fishery among those anglers that target this species earlier in the year.

KOK and RBT, the primary prey of MAC in BMR, represent the mainstays of the reservoir's fishery in terms of angler catch and preference. Neither KOK nor RBT are sustained by reproduction in the reservoir and both are stocked annually. From 1998-2008, KOK, RBT, and MAC accounted for an average of 56%, 22% and 5% of the fish caught during the fishing season. The catch of these species during the early part of the season averaged 4%, 39% and 13%. While many anglers interviewed at BMR from 2000-2008 were seeking to catch any fish species (~30%), most anglers targeted specific species: KOK, 40%; RBT, 15%; and MAC 8%. During the early fishing season, fewer anglers targeted KOK (2%), while more anglers indicated that they were seeking RBT (22%) or MAC (21%). Generally, interest in MAC fishing largely dissipates as larger MAC move to deeper water early in the main fishing season.

In 2004, BMR was estimated to produce about $8M of angling related economic output, of which about 80% ($6.4M) was attributed to anglers pursuing KOK, primarily from boats. The remaining 20% of this economic value ($1.6M) would primarily be due to anglers pursuing trout. Data indicate that out-of-state anglers pursue kokanee at BMR, with anglers from 49 states participating in the fishery since 1993. RBT and MAC are pursued by anglers primarily from CO fishing from both boats and from shore. MAC angling is concentrated in the early season and data from 2004-2007 provides more detailed information about angling activity during this period. The majority of anglers (46%) were after any species and 21% targeted RBT. Of the 30% of early season anglers that targeted MAC, about half of this angling was from boats. Considering the percentages of MAC harvested (5%) and the proportion of anglers targeting MAC (8%) over the fishing season, and the emphasis on MAC angling during the early fishing season, the value of the MAC fishery in BMR is estimated to be about $0.5M.

BMR represents a high quality fishing destination with 87% of anglers being satisfied to highly satisfied with their fishing experience. Similarly, 60% of anglers indicated that they were satisfied to highly satisfied with the numbers of fish they caught at BMR from 1998-2007. This perception changed abruptly in 2008 when only 18% of anglers interviewed were satisfied with their catch and 58% ranked their satisfaction with the numbers of fish caught as poor to very poor. This dissatisfaction in 2008 is attributed primarily to the declines in the number of kokanee and rainbow trout caught by anglers at BMR.

Lake Trout (MAC) Population Trends and Implications of Potential CDOW Sponsored Lake Trout Population Reduction Program on Lake Trout Fishery in Blue Mesa Reservoir (BMR)

Currently, the MAC population is believed to be expanding due to sustained natural reproduction and recruitment of new age classes. Although some harvest of these naturally reproduced MAC occurs (about 4,000 to 6,000 annually), it is insufficient to control or reduce the growth of the population. The expansion of the MAC population is evident in creel survey data which showed significantly higher catch rates of MAC in recent years. Unchecked, this expanding population will overtax available prey sources, largely stocked salmonids. In turn, MAC will experience declines in condition, growth, and therefore trophy potential. Removal of smaller MAC will help maintain rapid growth and good condition of larger MAC. Management action is clearly needed and intended to balance hatchery reared prey source while maintaining trophy MAC potential.

A targeted effort to reduce MAC numbers to sustainable levels will improve the ability of managers to sustain the overall fishery, including the trophy MAC component. MAC reduction efforts would target younger, smaller MAC, while accommodating the return and survival of larger MAC to maintain the trophy component of the fishery. Reduction targets would also ensure that sufficient MAC survive and recruit into older age classes to sustain the trophy fishery. Further research would be needed to fine tune the numbers and sizes of MAC targeted for harvest or removal to ensure maintenance of trophy MAC angling opportunity.

MAC growth in BMR has been near maximum, exceeding the growth documented for the species throughout its native and introduced ranges. This rapid growth rate results in MAC reaching large sizes in a comparatively short time interval: 30 inches in just 10 years. This rapid growth rate, coupled with steady natural reproduction and recruitment of MAC in BMR results in a high potential for MAC abundance, and the predation they exert on the other sportfish, to exceed the capacity of angler harvest alone to control the MAC population.

Efforts at BMR to educate anglers about excessive MAC predation in an attempt to increase angler harvest of MAC began in 2000. These efforts have included discussions at Angler Roundtables, articles in newspapers (Gunnison, Montrose, Grand Junction, and Denver), and educational posters placed at BMR boat ramps. These efforts have not resulted in increased harvest rates of MAC, although the number of MAC harvested has increased in recent years as the MAC population has increased. Anglers continue to release many of the MAC they catch, with 30% to 50% of the MAC caught during the main fishing season being released in recent years.

Survival of piscivorous MAC (lake trout over approximately 17 inches) was estimated to be 76% during a MAC study performed in 2000-2002. This high survival rate likely resulted from many MAC moving into deeper water (100 feet or more) from June through September—most of the main fishing season. Many anglers targeting MAC practice catch and release angling, contributing to low angling mortality. This high survival rate corroborates the expectation and indications that the lake trout population has increased. Given the population characteristics of MAC in BMR, it is expected that the survival rate for MAC must be reduced to at least 55% to begin to reduce MAC populations.

Current MAC harvest by anglers is insufficient to control or reduce the lake trout population in BMR. Efforts to increase MAC harvest in other waters in the western U.S. with similar MAC population and predation issues have included fishing tournaments which promote and reward the harvest of MAC of a certain size. This type of harvest incentive could contribute to the reduction and control of MAC abundance and predation at BMR, but it would likely need to be applied concurrently with targeted agency removal of MAC to reduce the MAC population to a level where KOK and RBT recovery would be possible. Although the primary purpose of such a fishing tournament would be to increase angler harvest of MAC, a secondary purpose would be to educate anglers about the challenges and importance of recovering KOK and RBT, and the prominent role of these species in the overall sport fishery and in producing and perpetuating trophy MAC opportunity at BMR.

Fishing regulations changes should be considered which would encourage and allow increased harvest of MAC. At the same time, modeling should be conducted to assess whether protective harvest regulations are necessary for any size class of MAC to preserve trophy MAC opportunity in BMR.