Coldwater Reservoir Ecology

Federal Aid Project F-242-R16

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Federal Aid in Fish and Wildlife Restoration

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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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

State: Colorado

Project No. F-242-R

Title: Coldwater Reservoir Ecology

Period Covered: July 1, 2008 to June 30, 2009

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 in 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 surveys at Blue Mesa and Granby reservoirs.

Introduction

The number of sonar surveys performed in 2008 was reduced to allow time for data analyses and manuscript preparation. At the request of biologists, several reservoirs surveyed by sonar in recent years were surveyed in 2008 via assistance from this project. The results of these surveys are reported here. Sampling of kokanee spawn runs was not performed by this project in 2008.

Methods and Materials

Sonar surveys were performed on six reservoirs in 2008; about half the number performed in 2007 (Martinez 2008). These included: Blue Mesa (28-30 July), Elevenmile (3 September), Granby (4 September), McPhee (6 August), Vallecito (7 August), and Williams Fork (2 September). 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, CDOW Aquatic Researcher.

Results and Discussion

Numbers of pelagic fish estimated in sonar surveys of reservoirs in 2007 were: Blue Mesa, 159,183; Elevenmile 14,472; Granby, 137,172; McPhee, 117,363; Vallecito, 42,082; and Williams Fork, 49.924. The decline in pelagic fish abundance in Blue Mesa Reservoir in 2008 (Figure 1) deepened concern about excessive predation on kokanee in the reservoir. This and other data pertinent to this topic was discussed at the Colorado Division of Wildlife's (CDOW) 2009 Kokanee Workshop held in Silverthorne, 5-6 April (Appendix A).

OBJECTIVE 2: Populations Demographics of Kokanee, 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: Begin analysis of long-term data sets for kokanee spawn runs to detect relationships among kokanee size, age or egg production.

Introduction

The size and age structure of mature kokanee in Colorado's fall spawn runs has been examined in relation to trends in kokanee populations and egg production (Martinez 2004). Further, these attributes of spawning kokanee have also been examined for possible responses to reservoir operations that might influence entrainment, reservoir thermal conditions and growing seasons or other environmental or ecological effects to reservoir food webs.

Methods and Materials

Long-term and available data for reservoir storage, physicochemical profiles, zooplankton, *Mysis*, and kokanee are being examined in detail for Granby Reservoir. Dr. Brett Johnson at Colorado State University has initiated comparisons of more recent data with the former long-term analyses and interpretation of the interrelationship among some of these factors by Martinez and Wiltzius (1995).

Results and Discussion

Climate change is a growing concern for water management in the west and it has implications for sport fisheries. As historic patterns of water use and management that influence in-reservoir conditions change in response to recent weather patterns, changes could also 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 environmental and 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.

Introduction, Methods, Results and Discussion

The manuscript, Western Lake Trout Woes , was submitted to the American Fisheries Society's Fisheries magazine for peer review. Appendix A contains information from this manuscript, which was discussed at the CDOW 2009 Kokanee Workshop. A draft version of this manuscript was provided to participants in the A Comprehensive Appraisal of Long-Term Suppression of Lake Trout in Yellowstone Lake, a panel on which I was a member, 25-29 August 2009, Chico, Montana. The manuscript has been accepted for publication by Fisheries magazine (Martinez et al. 2009).

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 Blue Mesa and 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).

Methods and Materials

Crustacean zooplankton was sampled in five reservoirs in 2008. Blue Mesa was sampled on 1 July; Dillon on 27 August; Granby on 4 July and 28 August; Rifle Gap on 4 June, 19 August, and 9 October; and Taylor Park on 2 July. Rifle Gap Reservoir was sampled in conjunction with an evaluation of the existing fishery and concerns about illegally stocked fish species (Johnson et al. 2009). Zooplankton was sampled by oblique tows in the 0-10 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.

Results and Discussion

Recent efforts to validate zooplankton species identifications and close inspection of micrographs of *Daphnia* specimens formerly classified as *Daphnia pulex* revealed that this limnetic form in Colorado's western reservoirs sampled as part of this project are actually *Daphnia pulicaria*. This identification was confirmed by the presence of elongated reticulations within the structure of the rostrum of *Daphnia pulicaria* (Figure 1) as opposed to the shorter, polygonal reticulations characteristic of *Daphnia pulex* (Brandalova et al. 1972). Crustacean zooplankton densities and size structures from samples collected in reservoirs in 2008 are presented in Tables 1-16. Temperature, dissolved oxygen profiles, and Secchi depths measured on the dates of zooplankton sampling are provided in Appendix B.

Blue Mesa Reservoir had *Daphnia* densities of 16/L when sampled in July (Table 1). The *Daphnia*, particularly *D. pulex*, in these samples were large, averaging >1.0 mm (Table 2). *Daphnia* in Dillon Reservoir were rare (<0.5L; Table 3), and small (<1.0 mm; Table 4) when sampled in August, and epilimnetic temperatures offered little refuge from predation by *Mysis* (Martinez and Bergersen 1991; Table B-2). No *Daphnia* were recorded in samples from Granby Reservoir in early July (Table 5) when epilimnetic temperatures did not exceed 15^{o}C (Table B-3). The *Daphnia* density was low, 2.4/L, in late August (Table 7) when epilimnetic temperatures exceeded 14-15^{o}C, but suggested that the period of a thermal refuge in 2008 was short (Table B-4). *Daphnia* in Rifle Gap displayed moderate densities on all dates sampled in 2008, ranging from 6.2/L in October to 15.3/L in August (Tables 9, 11, and 13). *Daphnia pulicaria* was present on all dates sampled, with an average length of 1.4 mm (Tables 10, 12, and 14). Another cyclopoid species, *Mesocyclops edax*, was identified from Rifle Gap by detailed examination of micrographs, but samples will have to be re-checked to quantify its density in these samples. *Daphnia* were scarce in samples collected in Taylor Park Reservoir in early July, 2008 (Table 15). The few specimens available for measuring in these samples, on average, were small at <1.0 mm in length (Table 16). Stratification was weak at the time with water temperatures exceeding 14-15^o C only at the reservoir's surface (Table B-8) 11), providing little refuge from predation by *Mysis relicta*.

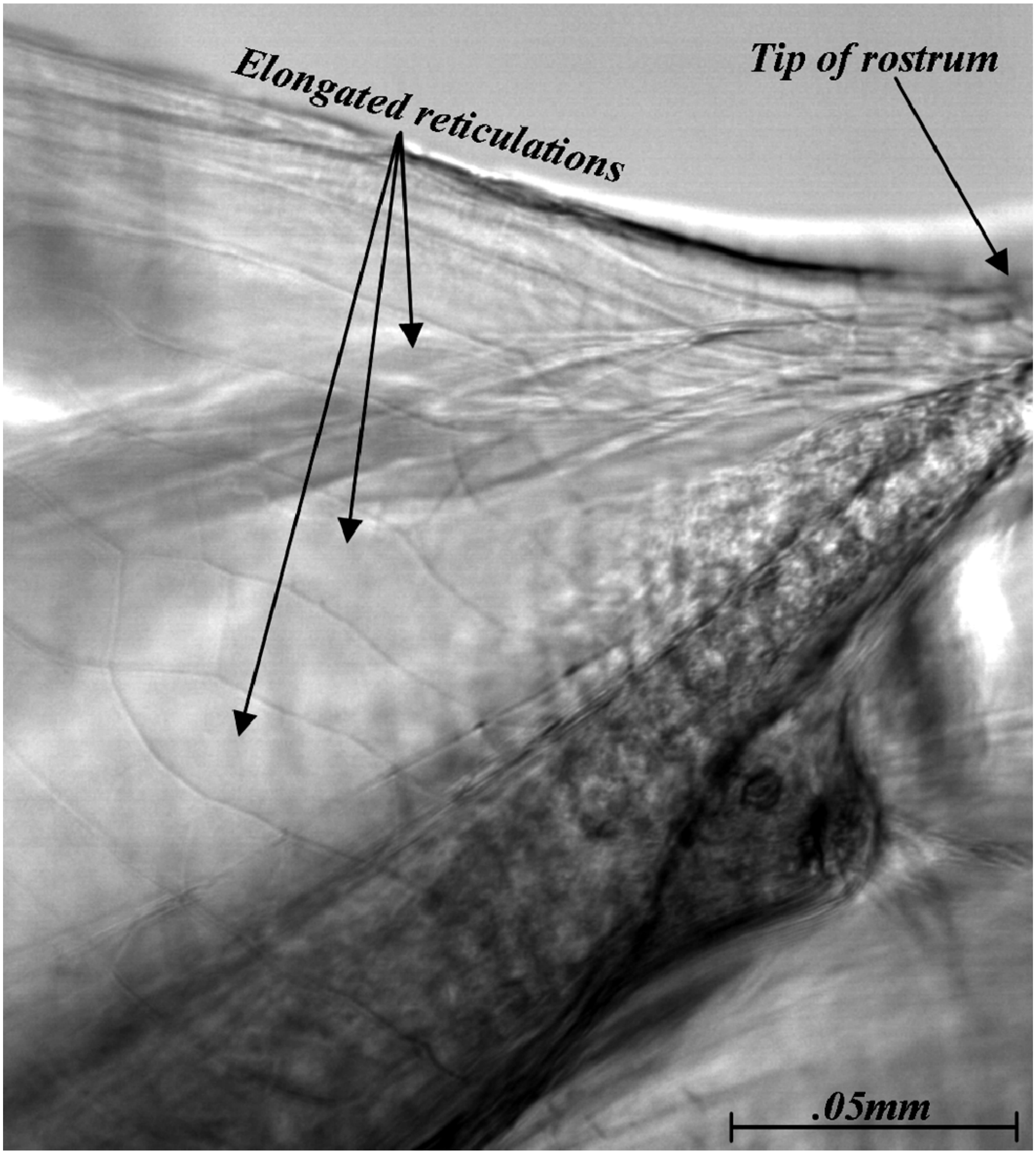

Figure 1. **Micrograph showing elongated reticulations in rostrum of *Daphnia* specimen characteristic of *Daphnia pulicaria* (Brandalova et al. 1972)**

Table 1. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Blue Mesa Reservoir, 01 July 2008.**

Blue Mesa - 01 July 2008 - Mean *Daphnia* density = 16.0/L										
Zooplankton species	Sapinero (0-10m)			Cebola (0-10m)			Iola (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	0.3	0.8	0.6	2.6	1.6	2.1	4.7	11.0	7.8	3.5
unindentified *Daphnia spp.*	3.7	3.9	3.8	1.8	2.4	2.1	0.7	2.7	1.7	2.5
Dapnia mendotae	12.1	10.2	11.2	8.0	7.0	7.5	4.5	5.1	4.8	7.8
Daphnia pulicaria	14.8	11.2	13.0	7.8	6.5	7.2	3.6	5.2	4.4	8.2
Diacyclops b. thomasi	30.0	25.2	27.6	24.3	17.9	21.1	15.9	25.5	20.7	23.1
Leptodiaptomus nudus	0.3	0.0	0.2	0.3	0.5	0.4	0.7	0.4	0.5	0.4
Mean total no./L	56.1			40.0			39.4			45.2

Table 2. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Blue Mesa Reservoir on 01 July 2008. Bl= *Bosmina longirostris*, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm= *Daphnia galeata mendotae*, Dp= *Daphnia pulicaria*, Dp spp.= unidentified *Daphnia* species, Ln= *Leptodiaptomus nudus*.**

Length class in mm	Blue Mesa - 01 July 2008					
	Bl	Dbt	Dgm	Dp	Dp spp.	Ln
0.1						
0.2	13					
0.3	13	1				
0.4	2	2				
0.5	5	23				1
0.6	1	53	2			1
0.7		37	2			2
0.8		25	16	3	6	2
0.9		25	23	12	3	
1.0		11	23	20	2	
1.1		5	23	20		1
1.2		6	23	30	2	
1.3		1	12	8		
1.4			4	7		
1.5			6	5		
1.6			2	4		
1.7			1	4		
1.8			1	5		
1.9				3		
2.0				7		
2.1			1	2		
2.2				3		
2.3				5		
2.4				1		
2.5			1	1		
2.6				2		
Totals	34	189	140	142	13	7
Mean length	0.4	0.8	1.1	1.4	1.0	0.8

Table 3. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Dillon Reservoir, 27 August 2008.**

Dillon - 27 August 2008 - 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	
Bosmina longirostris	N/A	4.2	4.2	N/A	3.8	3.8	N/A	3.3	3.3	N/A	5.1	5.1	7.9	2.0	4.9	4.3
Daphnia galeata mendotae	N/A	0.0	0.0	N/A	0.0	0.0	N/A	0.0	0.0	N/A	0.4	0.4	3.2	1.6	2.4	0.5
Diacyclops bicuspidatus thomasi	N/A	15.7	15.7	N/A	8.6	8.6	N/A	27.7	27.7	N/A	13.2	13.2	33.9	18.5	26.2	18.3
Mean total no./L	19.9			12.4			30.9			18.6			33.5			23.1

Table 4. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Dillon Reservoir on 27 August 2008. Bl= *Bosmina longirostris*, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm= *Daphnia galeata mendotae*.**

Length class in mm	Dillon - 27 August 2008		
	Bl	**Dbt**	**Dgm**
0.1			
0.2	28	2	
0.3	30	11	
0.4	14	28	7
0.5		48	9
0.6		69	4
0.7	1	53	1
0.8		77	4
0.9		30	2
1.0		11	
1.1		1	
Totals	73	330	27
Mean length	0.3	0.7	0.6

Table 5. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Granby Reservoir, 04 July 2008.**

Granby - 04 July 2008 - Mean *Daphnia* density = 0.0/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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.3	0.2	0.2	0.0	0.1	0.1
Diacyclops bicuspidatus. thomasi	2.4	36.5	19.4	5.4	22.3	13.8	11.6	19.0	15.3	9.7	39.7	24.7	39.9	22.7	31.3	20.9
Mean total no./L	19.4			13.8			15.3			24.7			31.3			20.9

Table 6. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Granby Reservoir on 4 July 2008. Dbt= *Diacyclops bicuspidatus thomasi*, Ln= *Leptodiaptomus nudus*.**

Length class in mm	Granby - 4 July 2008	
	Dbt	Ln
0.1		
0.2	1	
0.3	3	
0.4	38	
0.5	102	
0.6	84	
0.7	100	
0.8	66	
0.9	50	
1.0	23	
1.1	13	1
1.2	10	
1.3	8	1
1.4	2	1
1.5		
1.6		
1.7		
1.8		
1.9		1
Totals	500	4
Mean length	0.7	1.5

Table 7. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Granby Reservoir, 28 August 2008.**

Granby - 28 August 2008 - Mean *Daphnia* density = 2.4/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.*	0.3	0.3	0.3	0.9	1.3	1.1	1.0	0.8	0.9	0.5	0.4	0.4	1.3	0.9	1.1	0.7
Bosmina longirostris	1.5	1.0	1.3					0.2	0.1							0.3
Daphnia mendotae	1.2	1.3	1.3	1.5	0.6	1.1	1.0	0.4	0.7	0.8	0.7	0.8	0.5	0.7	0.6	0.9
Daphnia pulicaria	0.8	0.3	0.5	1.1	1.7	1.4	1.0	1.4	1.2	2.9	2.4	2.6	1.5	2.2	1.9	1.5
Diacyclops bicuspidatus thomasi	25.9	26.5	26.2	18.9	17.9	18.4	24.0	28.4	26.2	32.3	25.8	29.0	32.3	20.7	26.5	25.3
Leptodiaptomus nudus	2.7	4.8	3.8	2.1	1.5	1.8	2.9	2.2	2.5	2.6	0.9	1.2	0.8	1.3	1.0	2.1
Diaphanosoma brachyurum	0.5		0.3	1.3	1.7	1.5	2.4	1.0	1.7	4.3	0.7	2.5	0.8	1.1	0.9	1.4
Mean total no./L	33.5			25.1			33.3			36.7			32.0			32.1

Table 8. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Granby Reservoir on 19 August 2008. Bl= *Bosmina longirostris*, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm= *Daphnia galeata mendotae*, Dp= *Daphnia pulicaria*, Dp spp.= unidentified *Daphnia* species, Ln= *Leptodiaptomus nudus*, Db= *Diaphanosoma brachyurum*.**

Length class in mm	Granby - 19 August 2003						
	Bl	**Dbt**	**Dgm**	**Dp**	***Dp* spp.**	**Ln**	**Db**
0.1							
0.2							
0.3	4	2					3
0.4		7	1		1		1
0.5		58	4				3
0.6		114	6		1		2
0.7		109	2	2	1	2	1
0.8		62	6	3		10	1
0.9		25	3	2	1	7	
1.0		5	4	10		6	
1.1		1	1	3		6	
1.2		1		5	1	1	
1.3			2	3		2	
1.4			1	4			
1.5			4	6			
1.6				4	2		
1.7			1	6	1		
1.8			2	9			
1.9				2			
2.0				4			
2.1				2			
2.2							
2.3				1			
Totals	4	384	37	66	8	34	11
Mean length	0.4	0.7	1.0	1.5	1.1	1.0	0.5

Table 9. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Rifle Gap Reservoir, 04 June 2008.**

Rifle Gap 04 June 2008 - Mean *Daphnia* density = 7.3/L										
Zooplankton species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	0.1	0.2	0.2	0.3	0.1	0.2	0.1	0.4	0.3	0.2
Diacyclops b. thomasi	6.8	7.4	7.1	12.2	10.3	11.2	3.4	4.2	3.8	7.4
Dapnia galeata mendotae	0.5	0.5	0.5	0.8	0.3	0.6	0.1	0.7	0.4	0.5
Daphnia pulicaria	8.7	10.1	9.4	5.2	7.6	6.4	3.1	6.1	4.6	6.8
Leptodiaptomus nudus	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.0
Mean total no./L	17.2			18.5			9.1			14.9

Table 10. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Rifle Gap Reservoir on 4 June 2008. Bl=** ***Bosmina longirostris*****, Dbt=** ***Diacyclops bicuspidatus thomasi*****, Dgm=** ***Daphnia galeata mendotae*****, Dp=** ***Daphnia puicaria*****, Ln=** ***Leptodiaptomus nudus*****.**

Length class in mm	Rifle Gap 4 June 2008				
	Bl	**Dbt**	**Dgm**	**Dp**	**Ln**
0.1		1			
0.2		1			
0.3		2			
0.4	1	3			
0.5	2	5			
0.6	1	14			
0.7	0	21	2	1	
0.8	0	41	10	12	
0.9	1	46	5	6	
1.0		26	2	15	
1.1		24	2	15	
1.2		7	3	15	
1.3		0	2	21	
1.4		1	3	13	1
1.5			0	12	
1.6			1	19	
1.7			1	10	
1.8			2	12	
1.9			0	4	
2.0			1	2	
2.1			1	2	
Totals	5	192	35	159	1
Mean length	0.6	0.9	1.2	1.4	1.5

Table 11. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Rifle Gap Reservoir, 19 August 2008.**

Rifle Gap 19 August 2008 - Mean *Daphnia* density = 15.3/L										
Zooplankton species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	3.2	0.0	1.6	0.2	0.0	0.1	0.5	0.8	0.6	0.8
unindentified *Daphnia spp.*	5.3	2.1	3.7	2.2	3.7	2.9	0.5	0.4	0.5	2.4
Daphnia pulicaria	6.8	7.3	7.0	5.5	4.9	5.2	4.3	3.2	3.8	5.3
Diacyclops b. thomasi	34.2	19.0	26.6	6.4	13.5	9.9	5.0	8.1	6.6	14.4
Dapnia galeata mendotae	10.0	3.8	6.9	6.2	12.8	9.5	5.9	6.8	6.4	7.6
Leptodiaptomus nudus	12.1	10.7	11.4	6.4	7.0	6.7	3.8	6.4	5.1	7.8
Mean total no./L	57.2			34.4			22.9			38.2

Table 12. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Rifle Gap on 19 August 2008. Bl= *Bosmina longirostris*, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm= *Daphnia galeata mendotae*, Dp= *Daphnia pulicaria*, Dp spp.= unidentified *Daphnia* species, Ln= *Leptodiaptomus nudus*.**

Length class in mm	Rifle Gap 19 August 2008					
	Bl	Dbt	Dgm	Dp	Dp spp.	Ln
0.1						
0.2	2	2				
0.3	2	5	13			1
0.4		14	13		2	9
0.5		15	16			8
0.6		14	16		1	12
0.7		4	24	2	2	4
0.8		14	20	6		5
0.9		9	9	10	1	4
1.0		4	7	12	1	2
1.1			2	7		1
1.2		1	7	8		3
1.3		1	2	8	1	1
1.4		2	1	9		
1.5				6	1	1
1.6				7	1	
1.7				12		
1.8				8		
1.9				9		
2.0				2		
Totals	4	85	130	106	10	51
Mean length	0.3	0.7	0.7	1.4	1.0	0.7

Table 13. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Rifle Gap Reservoir, 09 October 2008.**

Rifle Gap - 09 October 2008 - Mean *Daphnia* density = 6.2/L										
Zooplankton species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	0.0	0.0	0.0	0.0	0.2	0.1	0.3	0.4	0.4	0.1
unindentified *Daphnia spp.*	1.2	2.1	1.7	1.6	1.2	1.4	1.0	1.7	1.4	1.5
Daphnia pulicaria	3.4	2.1	2.8	2.9	1.9	2.4	2.5	4.9	3.7	2.9
Diacyclops b. thomasi	10.6	8.2	9.4	4.5	5.1	4.8	11.3	9.4	10.4	8.2
Dapnia galeata mendotae	2.4	2.1	2.3	1.8	1.9	1.8	0.9	1.6	1.2	1.8
Leptodiaptomus nudus	4.1	1.4	2.8	1.1	0.7	0.9	1.4	0.7	1.1	1.6
Mean total no./L	18.9			11.4			18.0			16.1

Table 14. **Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Rifle Gap on 09 October 2008. Bl= *Bosmina longirostris*, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm= *Daphnia galeata mendotae*, Dp= *Daphnia pulicaria*, Dp spp.= unidentified *Daphnia* species, Ln= *Leptodiaptomus nudus*.**

Length class in mm	Rifle Gap 09 October 2008					
	Bl	**Dbt**	**Dgm**	**Dp**	**Dp spp.**	**Ln**
0.3	4					
0.4		15				
0.5		13	1			
0.6		16				
0.7		15	7		2	
0.8		25	13	4	1	1
0.9		8	7	7	4	2
1.0		6	4	8		10
1.1		1	2	4		1
1.2		1	5	9	1	3
1.3		1	7	14	2	
1.4		1	6	9		
1.5			3	12	4	
1.6			3	11	2	
1.7				1	1	
1.8			1	7		
1.9				2		
Totals	4	102	59	88	17	17
Mean length	0.4	0.7	1.1	1.4	1.2	1.1

Table 15. **Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Taylor Park Reservoir, 02 July 2008.**

Taylor Park - 02 July 2008 - 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	
Dapnia mendotae		0.1											0.1		0.1	<0.1
Daphnia pulicaria		0.1														<0.1
Leptodiaptomus nudus	0.3	0.3	0.3	0.1		0.1	0.2	0.1	0.1	0.2		0.1	0.1	0.2	0.2	0.2
Diacyclops b. thomasi	3.4	18.5	10.9	3.5	7.6	5.5	7.5	4.7	6.1	16.5	2.0	9.3	14.0	6.4	10.2	8.4
Mean total no./L	10.9			5.5			6.1			9.3			10.2			8.4

Table 16. Length frequency of crustacean zooplankton (measured to nearest 0.01mm) collected in Taylor Park Reservoir on 02 July 2008. Dbt= *Diacyclops bicuspidatus thomasi*, Ln= *Leptodiaptomus nudus*, Dgm= *Daphnia galeata mendotae*, Dp= *Daphnia pulicaria*.

Length class in mm	Taylor Park - 02 July 2008			
	Dbt	Ln	Dgm	Dp
0.2	1			
0.3	1			
0.4	10			
0.5	33			1
0.6	73		1	
0.7	85	1		
0.8	75		1	
0.9	76			
1.0	47	1		
1.1	31			
1.2	37			
1.3	16	1		
1.4	1	3		
1.5		2		
1.6		1		1
Totals	486	9	2	2
Mean length	0.9	1.4	0.8	1.1

Segment Objective 2: Sample *Mysis* in Granby and Taylor Park reservoirs.

Introduction

Mysis prey on *Daphnia* and can be a complicating factor in reservoir fishery management. Periodic examination of reservoirs for the presence of *Mysis*, or to estimate *Mysis* abundance provides information that aids fishery managers.

Methods and Materials

Sampling for *Mysis* was performed on four reservoirs in 2008. Sampling was performed at Blue Mesa on 18 June, at Dillon on 27 August, at Granby on 3 July and 28 August, and at Taylor Park on 2 July. Sampling was performed at night, near the date of the new moon. 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 by GPS and retrieved at 0.37 m/s with an anchor windlass. Only three stations were sampled at Blue Mesa Reservoir due boat mechanical problems. These stations were all in Sapinero Basin (BMMY13, BMMY14 and BMMY15). Samples collected in Blue Mesa were inspected in the field for *Mysis* and were not preserved. 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

No *Mysis* were collected in Blue Mesa at the three stations sampled in 2008, which were all over deep water (48.5, 59 and 54.2 m). Estimated *Mysis* densities and size structures for the other reservoirs sampled in 2008 are given in Tables 17-24. The estimated *Mysis* density in Dillon in 2008, 205/m^2 (Table 17), was similar to that in 2007, 229/m^2 (Martinez 2008). The estimated density of *Mysis* in Granby in June 2008, 682/m^2 (Table 19), was lower than the 28 August estimate of 892/m^2 (Table 21). In the interest of long term monitoring, sampling dates later in the season after thermal stratification is pronounced likely ensures that the bulk of the *Mysis* population has migrated to deeper water where they become available to the vertical tow net. The density of Mysis in Granby remained high in 2008, likely contributing to the low densities of Daphnia (Tables 5 and 7; Martinez 2008). The estimated density of *Mysis* in Taylor Park on 2 July 2008, 205/m^2 (Table 23), was less than half that reported for 16 July 2007, 470/m^2 (Martinez 2008). Proportionately, there were fewer large mysids in 2007 (Martinez 2008), which may have contributed to reduced reproduction in 2008.

Table 17. **Summary of nighttime *Mysis* sampling at ten stations in Dillon Reservoir on 27 August 2008, using a vertical meter net (0.785m^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 - 27 August 2008 - 10 Stations - Mean *Mysis*/m^2 = 204.7											
Sample number	Sampling stations (water depth in meters)										Data summary
	Stratum I		Stratum II				Stratum III				
	1A - 51.2	1B- 53.3	2A- 33.7	2B- 38.4	2C- 35.1	2D- 36.7	3A- 9.2	3B- 11.5	3C- 18.3	3D- 12.4	
#1	55	291	141	197	360	93	74	127	256	94	1688
#2	42	262	122	262	216	55	119	197	171	80	1526
Sum	97	553	263	459	576	148	193	324	427	174	3214
Mean	48.5	276.5	131.5	229.5	288	74	96.5	162	213.5	87	160.7

Table 18. *Mysis relicta* **length frequency for specimens collected from nighttime vertical meter-net tows for Dillon Reservoir, 27 August 2008.**

Dillon Reservoir- 27 August 2008														
Station - sample #	***Mysis* total length (mm)**													
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Total**
DN1A-2			2	2	4	5	4	1	7	8	7	2		42
DN1B-2	1		7	30	31	20	21	14	33	74	25	5	1	262
DN2A-1		2	11	20	11	6	21	29	7	14	12	5	3	141
DN2B-2		3	30	56	28	27	21	18	14	35	22	8		262
DN2C-1	1	5	34	94	68	41	19	11	19	44	23			360
DN2D-1		1	3	9	3	6	5	8	22	26	9		1	93
DN3A-2	1			3	5	33	51	25	1					119
DN3B-2	1	7	31	45	63	39	11							197
DN3C-2	1	12	28	39	41	34	12	2	1	1				171
DN3D-1		2	1	5	18	41	18	6	1	1	1			94
Totals	4	32	147	303	272	252	183	114	105	203	99	21	5	1741
Percent	0.2%	1.8%	8.4%	17.4%	15.6%	14.5%	10.5%	6.5%	6.0%	11.7%	5.7%	1.2%	0.3%	100.0%

Table 19. **Summary of nighttime *Mysis* sampling at ten stations in Granby Reservoir on 03 July 2008, using a vertical meter net (0.785m^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 - 03 July 2008 - 10 Stations - Mean *Mysis*/m² = 682.2											
Sample number	**Sampling stations (water depth in meters)**										Data summary
	Stratum I		**Stratum II**				**Stratum III**				
	1A-53.4	1B-52.1	2A-29.6	2B-28.4	2C-31.7	2D-22.9	3A-18.5	3B-12.4	3C-16.2	3D-18.8	
#1	765	757	1238	187	511	159	662	270	322	132	5003
#2	1165	884	1334	128	447	138	811	228	389	183	5707
Sum	1930	1641	2572	315	958	297	1473	498	711	315	10710
Mean	965	820.5	1286	157.5	479	148.5	736.5	249	355.5	157.5	535.5

Table 20. ***Mysis relicta*** **length frequency for specimens collected from nighttime vertical meter-net tows for Granby Reservoir, 03 July 2008.**

Granby Reservoir- 03 July 2008																			
Station - sample #	***Mysis*** **total length (mm)**																		**Totals**
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	
GR1A-1	21	56	145	103	39	7		3	50	147	104	54	15	7	9	5			765
GR1B-1	24	39	79	76	26	6	2	3	48	176	177	78	13	6	3	1			757
GR2A-2	31	105	336	318	131	16	4	2	21	106	148	83	27	3	2			1	1334
GR2B-2	13	8	13	8	1	1			14	32	23	12	2	1					128
GR2C-1	33	61	113	74	20	2	1	3	32	76	57	25	9	3	1		1		511
GR2D-1	14	24	27	34	16	1	2		4	14	13	7	1	2					159
GR3A-2	8	44	116	134	91	21	2	5	35	117	125	78	24	9	2				811
GR3B-2	13	32	46	41	16	8		1	2	21	32	14	2						228
GR3C-2	18	37	76	59	23	7	2		18	63	59	23	2		2				389
GR3D-1	9	11	23	8	23	9	1		1	18	16	10	1	2					132
Totals	184	217	974	855	386	78	14	17	225	770	754	384	96	33	19	6	1	1	5214
Percent	3.53%	4.2%	18.7%	16.4%	7.4%	1.5%	0.3%	0.3%	4.3%	14.8%	14.5%	7.4%	1.8%	0.6%	0.4%	0.1%	0.0%	0.0%	100.0%

Table 21. **Summary of nighttime *Mysis* sampling at ten stations in Granby Reservoir on 28 August 2008, using a vertical meter net (0.785m^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 - 28 August 2008 - 10 Stations - Mean *Mysis*/m² = 891.8											
Sample number	Sampling stations (water depth in meters)										Data summary
	Stratum I		Stratum II				Stratum III				
	1A- 53.8	1B- 48.2	2A- 28	2B- 24.8	2C- 31.0	2D- 22.5	3A- 16.3	3B- 12.1	3C- 15.2	3D- 18.0	
#1	2792	154	1213	152	321	1083	225	45	110	594	6689
#2	3780	125	1078	131	390	1076	214	50	44	424	7312
Sum	6572	279	2291	283	711	2159	439	95	154	1018	14001
Mean	328	139.5	1145.5	141.5	355.5	1079.5	219.5	47.5	77	509	700.1

Table 22. ***Mysis relicta*** **length frequency for specimens collected from nighttime vertical meter-net tows for Granby Reservoir, 28 August 2008.**

Granby Reservoir- 28 August 2008																			
Station - sample #	*Mysis* total length (mm)																		Totals
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	
GR1A-2		8	64	166	282	318	158	81	58	168	668	846	580	254	85	30	11	3	3780
GR1B-1	1	2	8	17	10	6	3	7	13	35	36	13	1	2					154
GR2A-2	3	21	91	207	179	74	44	23	46	153	160	57	17	3					1078
GR2B-1		2	5	9	14	13	15	8	10	31	29	9	6	1					152
GR2C-1		1	7	23	22	12	7	6	21	85	88	36	8	3	2				321
GR2D-2		2	42	93	128	200	76	58	44	65	134	130	68	20	9	7			1076
GR3A-1	1	4	22	44	39	30	30	20	4	7	15	6	3						225
GR3B-2		1	3	4	8	8	5	4	5	1	7	3	1						50
GR3C-2		1	1	12	10	9	4	2	1	1		3							44
GR3D-1		9	22	57	80	80	68	84	56	37	53	36	11	1					594
Totals	5	51	265	632	772	750	410	293	258	583	1190	1139	695	284	96	37	11	3	7474
Percent	0.07%	0.7%	3.5%	8.5%	10.3%	10.0%	5.5%	3.9%	3.5%	7.8%	15.9%	15.2%	9.3%	3.8%	1.3%	0.5%	0.1%	0.0%	100.0%

Table 23. **Summary of nighttime *Mysis* sampling at ten stations in Taylor Park Reservoir on 02 July 2008, using a vertical meter net (0.785m^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 Reservoir - 02 July 2008 - 10 Stations - Mean *Mysis*/m² = 159.7											
Sample number	**Sampling stations (water depth in meters)**										Data summary
	Stratum I		**Stratum II**				**Stratum III**				
	1A-40.1	1B-40.5	2A-27.9	2B-30.4	2C-18.8	2D-23.5	3A-7.0	3B-9.15	3C-12.9	3D-10.4	
#1	184	95	118	174	180	228	29	11	85	136	1240
#2	194	103	177	127	157	149	65	44	104	147	1267
Sum	378	198	295	301	337	377	94	55	189	283	2507
Mean	189	99	147.5	150.5	169	189	47	28	94.5	141.5	125.4

Table 24. ***Mysis relicta*** **length frequency for specimens collected from nighttime vertical meter-net tows for Taylor Park Reservoir, 02 July 2008.**

Taylor Park Reservoir- 02 July 2008																	
Station - sample #	**Mysids Size (mm)**																**Totals**
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	
TY1A-1	17	14	29	38	23	2			6	12	23	12	5	2	1		184
TY1B-2	10	20	16	19	6	1			2	13	9	7					103
TY2A-2	16	7	31	47	12				8	21	24	10					176
TY2B-2	18	5	27	19	10	1			2	13	18	10	3	1			127
TY2C-1	13	18	31	19	11	1			5	29	33 14		6	2	3		185
TY2D-1	23	19	14	22	7			1	17	39	43	21	6	6	6	4	228
TY2D-2	19	6	12	19	3	2		1	3	21	39	15	2	2	2	3	149
TY3A-1	11	7	1	6	4												29
TY3B-2	5	7	2	12	14	2					1				1		44
TY3C-1	6	6	6	18	17	9	1			2	8	3	4	2		1	83
TY3D-1	5	9	22	23	14	2		1	4	17	21	9	7	1	1		136
Totals	143	118	191	242	121	20	1	47	167	219	101	33	16	14	8	1	444
Percent	9.90%	8.2%	13.2%	16.8%	8.4%	1.4%	0.1%	0.2%	3.3%	11.6%	15.2%	7.0%	2.3%	1.1%	1.0%	0.6%	100.0%

Segment Objective 3: Collect and analyze crustacean zooplankton and measure temperature and dissolved oxygen at Blue Mesa and Granby reservoirs.

Introduction

Some species of crustacean zooplankton represent the cornerstone of reservoir food webs, being an important food of larval, juvenile or adult fish. Reservoir fluctuation limits the development of productive littoral zones and aquatic plants, leaving the open-water limnetic zone as a primary energy pathway for sustaining sport fish populations. While all reservoirs and lakes contain a variety of crustacean zooplankton species that are consumed by fish, the seasonal presence and abundance of *Daphnia* is of particular interest. Among the largest zooplankters, *Daphnia* often serve as an important food of some coldwater and warmwater fish species. In coldwater reservoirs in particular, *Daphinia pulicaria* is often the primary food of kokanee and rainbow trout. *Daphinia* is also a primary food of introduced *Mysis relicta*, and *Mysis* can be a potent competitor for this food resource, eliminating *Daphnia* or truncating their seasonal abundance.

Methods, Results and Discussion

Efforts are underway to complete A Compendium of Crustacean Zooplankton Collections from Selected Colorado Reservoir and Lakes: 1991-2009. This document is intended to summarize data associated with the collection of crustacean zooplankton performed as part of research on Colorado's large coldwater reservoirs and lakes, and some of its lower elevation warmwater reservoirs. The sampling at 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 Coldwater Reservoir Ecology, from 1992 to 2010. Collections from 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 Westslope Warmwater Fisheries 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 Westslope Warmwater Fisheries. Data for Rifle Gap, a warmwater reservoir, appears in this 2009 Coldwater Reservoir Ecology annual report.

In addition to compiling these crustacean zooplankton data, some of the trends in species composition, abundance or size structure are examined in more depth. As an aid to the identification of these species, micrographs with labels showing the key distinguishing features of the various species will be provided. The resolution of these images has facilitated the verification of species' identifications, and in some cases, errors in prior records were detected (Figure 1). These identifications will be corrected in the data that is included in the Compendium, to the extent possible. The locations of sampling stations in individual waters will also be included, and where possible, coordinates will be provided. Preparation of a document summarizing the status of limnetic zooplankton populations in these waters during this two-decade period will contribute to a baseline of zooplankton condition during a timeframe in which the presence or impacts of exotic invertebrates had not been detected or documented.

Segment Objective 4: Begin analysis of long-term *Mysis* data sets.

Introduction

Mysis display certain distribution patterns in large lakes which have not been closely examined in smaller, artificial reservoir environments. Colorado's reservoirs containing *Mysis* are quite shallow (<100 m) compared to many of the lakes (>100 m) where these distributional observations have been made for both native and introduced *Mysis* populations. There is a tendency for *Mysis* to be more abundant in deeper, offshore locations than in shallower, nearshore waters during summer (Lehman et al. 1990; McDonald et al.; Pothoven et al. 2000; Shea and Makarewicz 1989). Further, there is a tendency for there to be larger adult mysids in deeper water compared to smaller juvenile mysids in shallower water (Johannsson, O. E. 1995; Morgan and Threlkeld 1982). The presence of these distribution patterns in Colorado reservoirs would have implications for fish predation on *Mysis* (Lehman et al. 1990; Martinez and Bergersen 1991; McDonald et al. 1990), entrainment of *Mysis* into tailrace fisheries (Nehring 2001; Wright 2009), and mechanical harvest of *Mysis* (Martinez 2001; 2002).

Methods

Abundance and length frequency data for mysids collected from Granby Reservoir since 1997, and from Dillon and Taylor Park reservoirs since 1998 were used to examine *Mysis* distribution trends. All mysids collected in these years were measured for total length, which is the body length from the tip of the rostrum to the tip of the telson (Pothoven et al. 2000). Typically, ten stations were sampled each year on a single date from mid- to late-summer. Data for the shallow depth category consisted of the five shallowest stations and the data from the five deepest stations were used for the deep category. In those few cases where fewer than 10 stations were sampled or duplicate depths occurred, the available data was assigned to the shallow or deep categories based on how the depth for each station was related to the depth of the other stations sampled on that date. Cumulative-frequency distributions provide an alternate view of length-frequency histograms (Neumann and Allen 2007). This type of data presentation was used to compare where the shallow vs. the deep station lines reached 100% for each year, facilitating visual comparison of *Mysis* size in each reservoir on each sampling date.

Results and Discussion

Figures 2-7 provide cumulative frequency graphs of mysid size in shallow and deep stations for Dillon, Granby and Taylor Park Reservoirs. In nearly all of these comparisons, the largest mysids were found in the deeper stations. However, in several cases in Dillon and Granby, the mean size of mysids in the smaller size classes was larger in the shallow stations (Figures 2 and 4). Only one deep station was sampled in Granby in 2002 (Martinez 2003), and it was the only year in which the largest mysids were consistently found in the shallow stations (Figure 4). The cumulative frequency comparisons for Taylor Park most consistently showed the largest mysids occurring in the samples from the deeper stations (Figures 6 and 7).

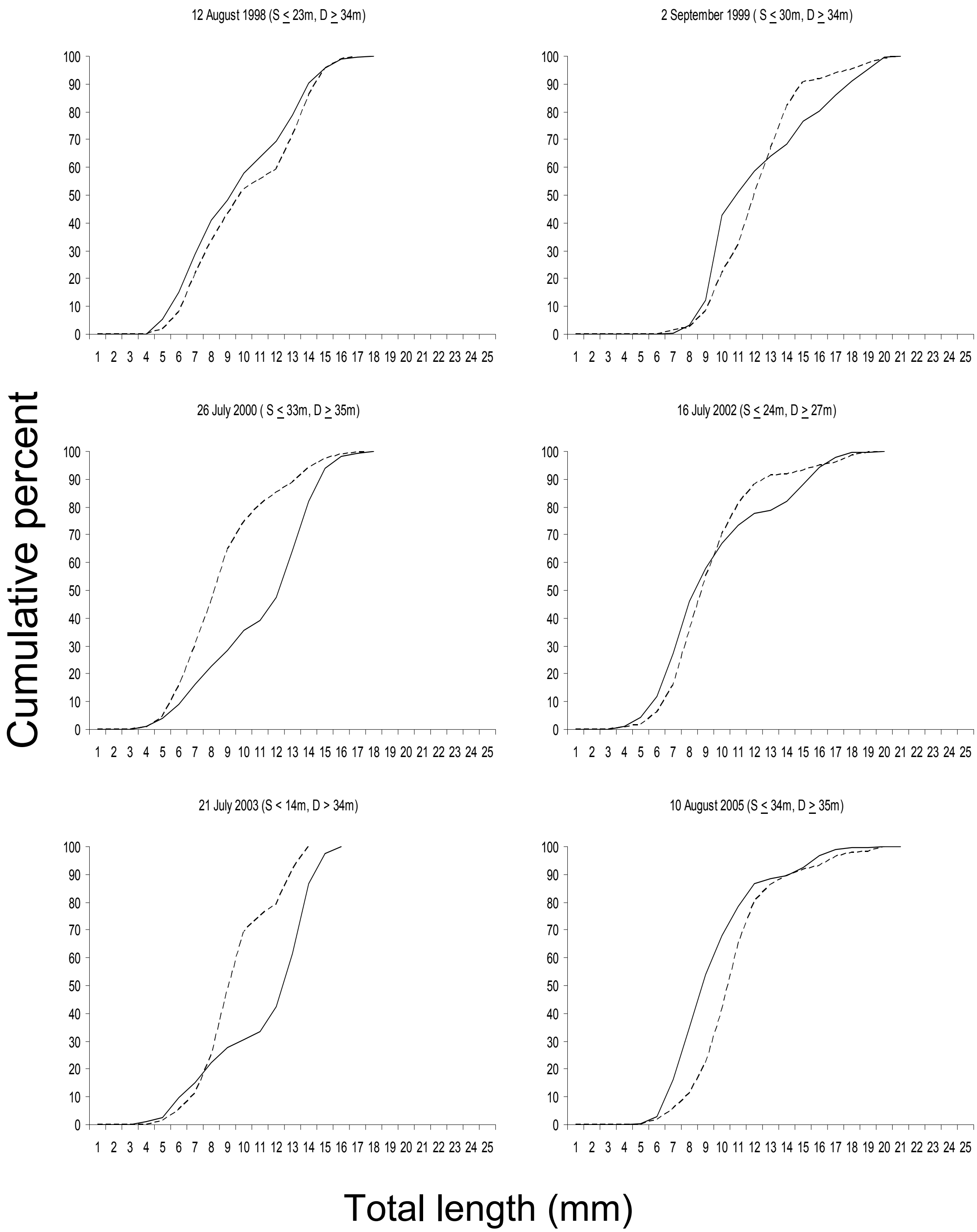

Figure 2. **Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Dillon Reservoir from 1998 through 2005. *Mysis* was not sampled in 1997, 2001 or 2004.**

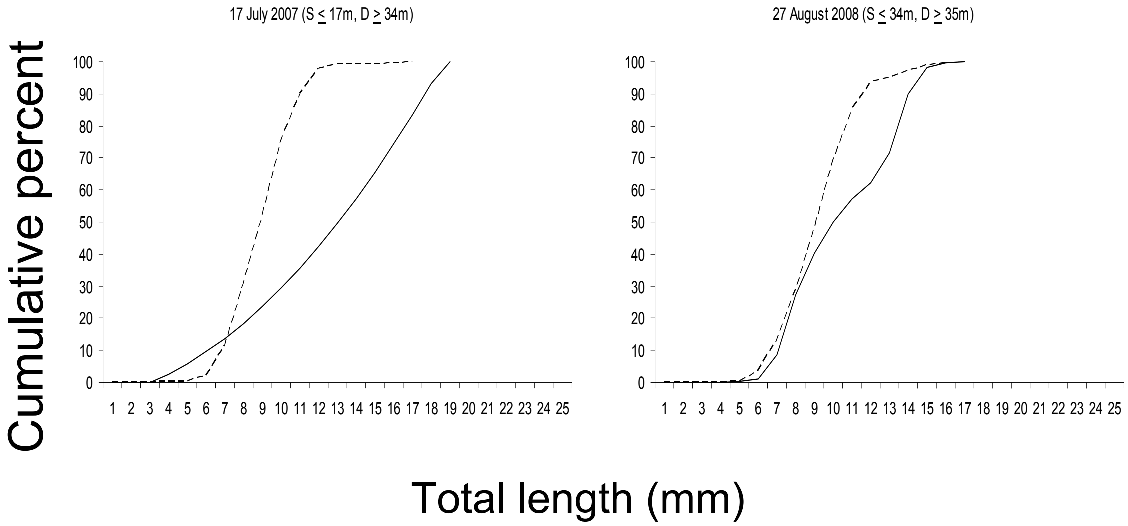

Figure 3. **Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Dillon Reservoir in 2007 and 2008. *Mysis* was not sampled in 2006.**

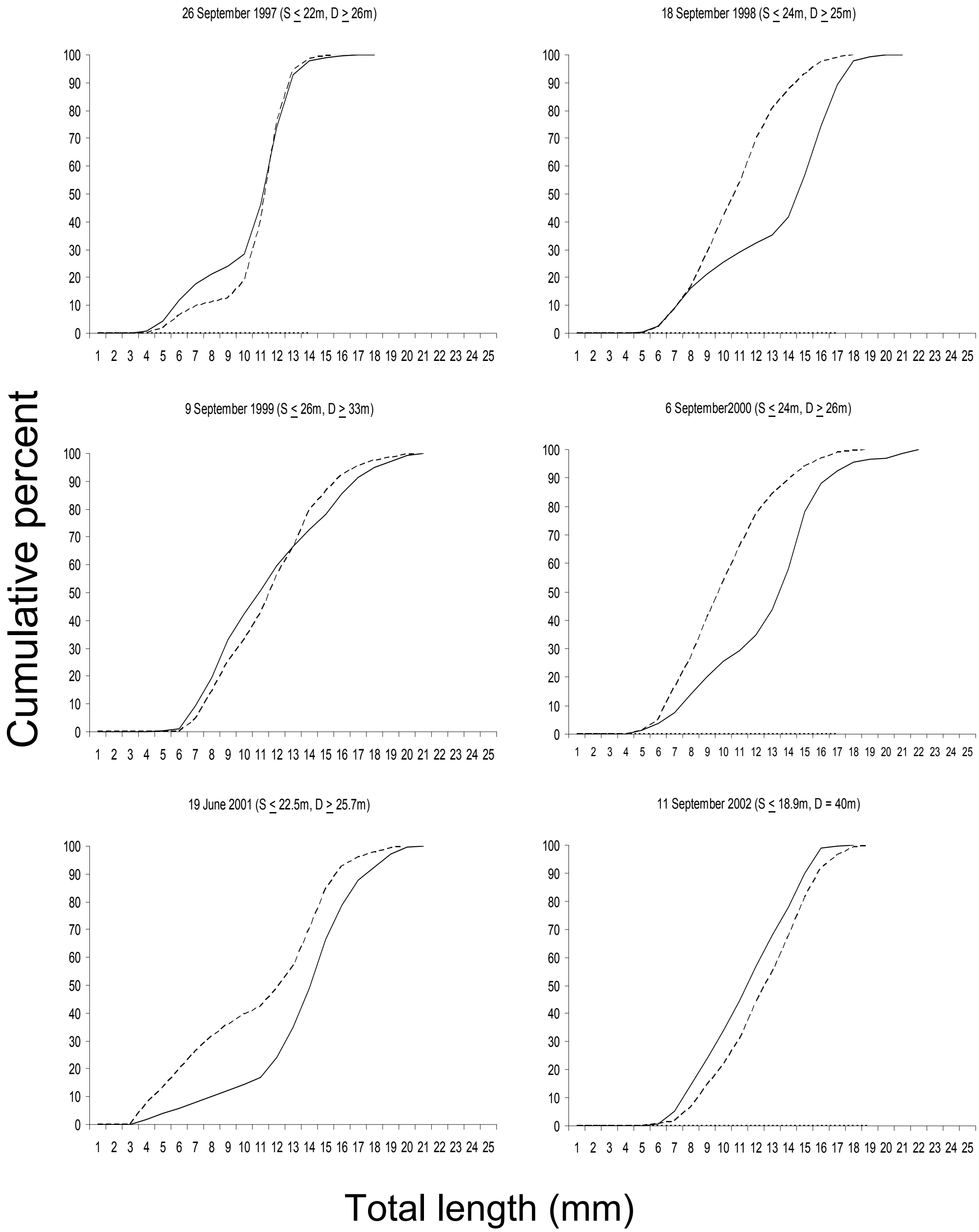

Figure 4. **Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Granby Reservoir from 1997 through 2002.**

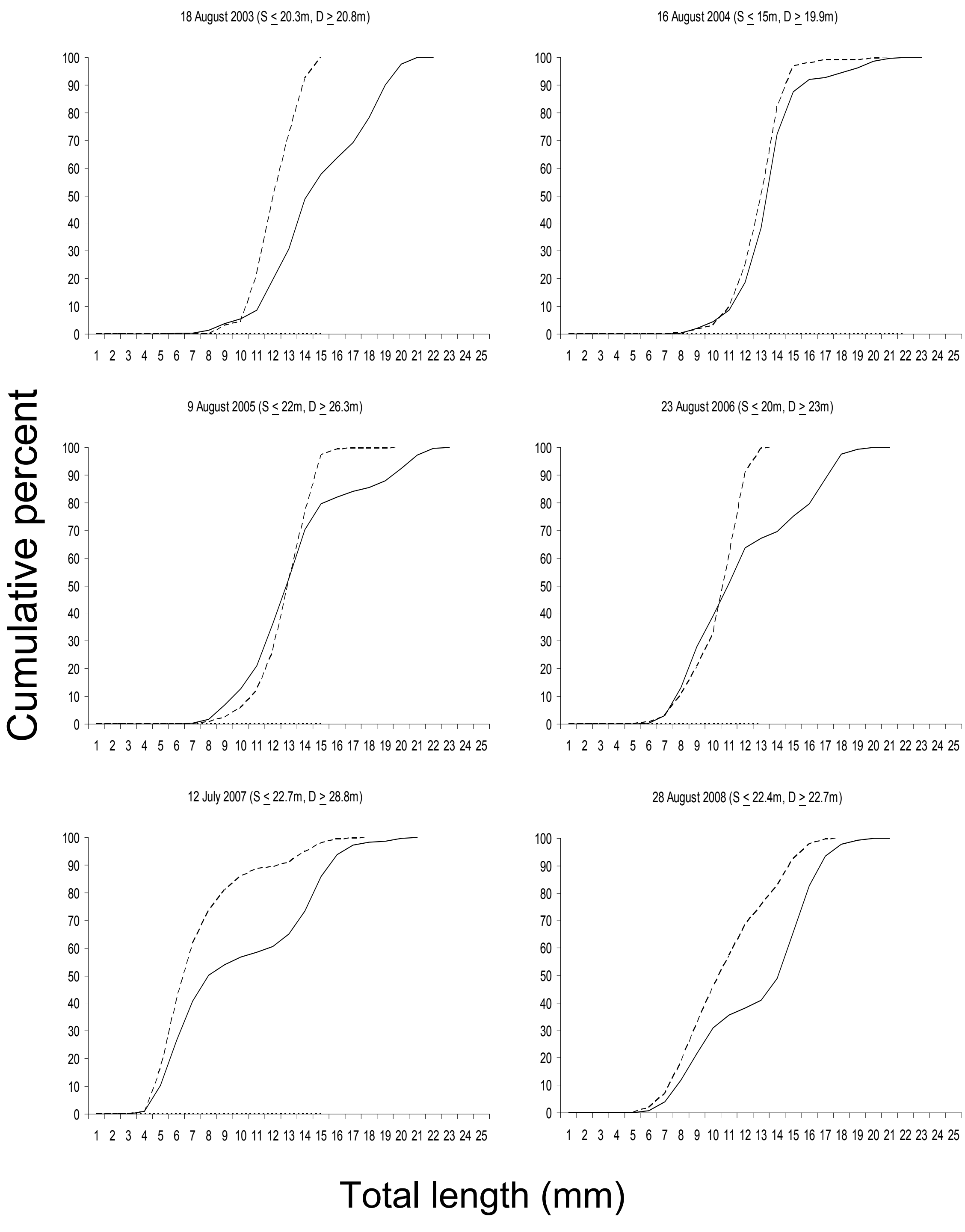

Figure 5. Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Granby Reservoir from 2003 through 2008.

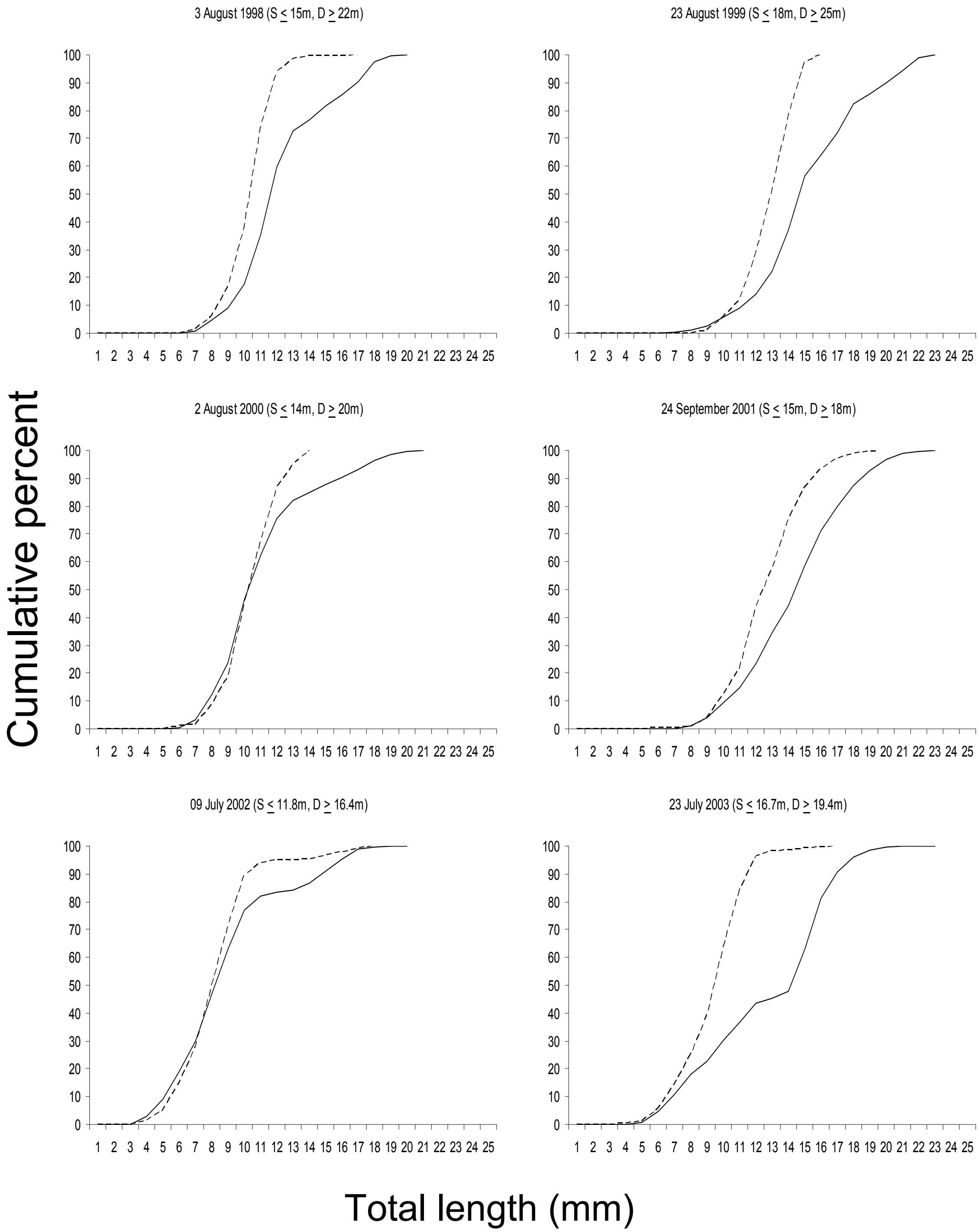

Figure 6. **Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Taylor Park Reservoir from 1998 through 2003. *Mysis* was not sampled in 1997.**

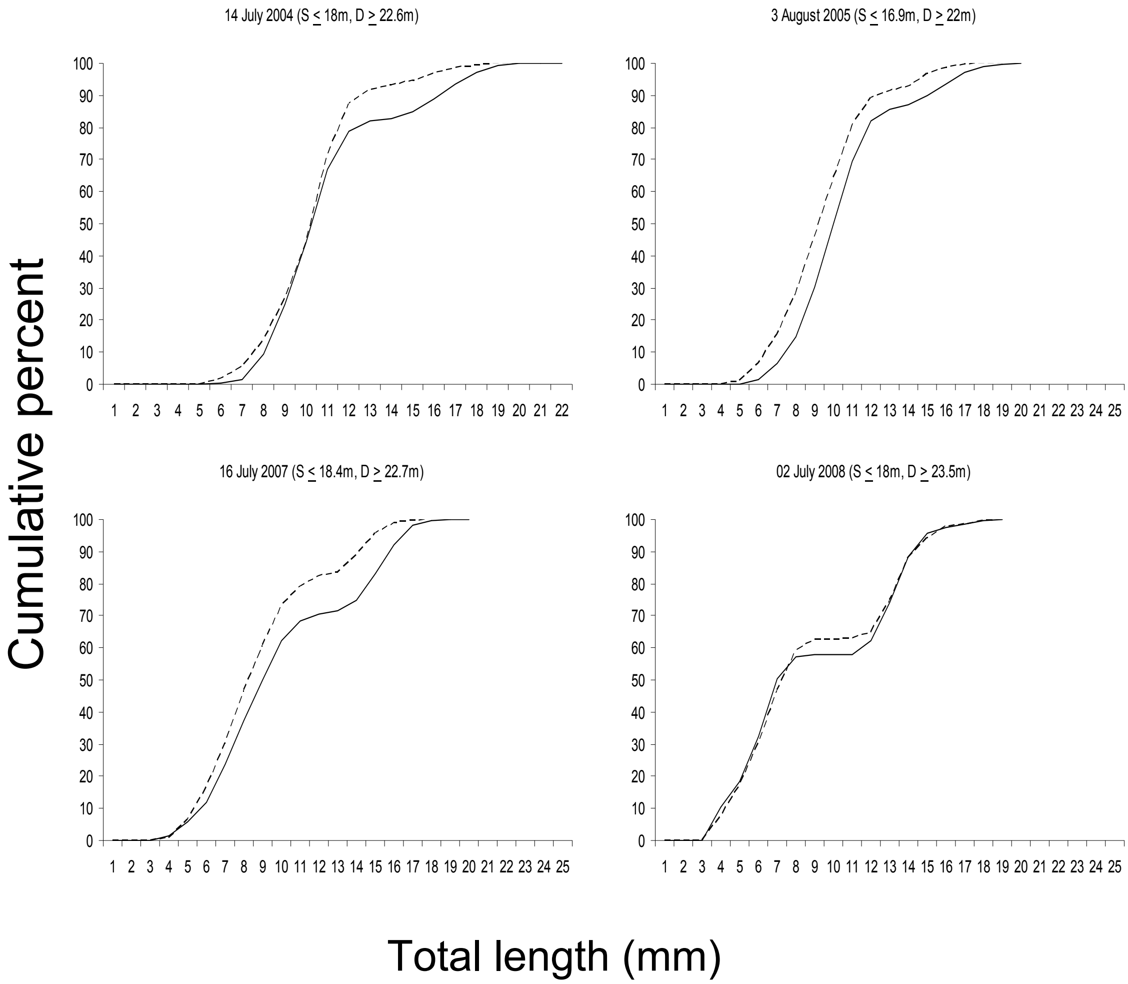

Figure 7. Cumulative-frequency distribution for *Mysis relicta* collected from shallow (dotted line) and deep (solid line) stations in Taylor Park Reservoir from 2004 through 2008. *Mysis* was not sampled in 2006.

Tables 25-27 summarize mysid abundance and size comparisons in shallow and deep stations in Dillon, Granby and Taylor Park reservoirs. The pattern of more and larger mysids occurring in deeper water appears consistent in these comparisons. *Mysis* densities were higher in the deeper stations by 79% in Dillon, by 161% in Granby, and by 91% in Taylor Park. The pattern of larger mysids in deeper water was also present. In all three reservoirs, the mean body length of *Mysis* was 0.8 mm to 1.36 mm longer in the samples from deeper water compared to those from shallower water (Table 25-27).

Another pattern that seemed evident was likely related to the productivity of these reservoirs. Granby is considered more productive than Taylor Park (Johnson and Martinez 2000), while Dillon is the least productive, likely suffering, in part, from cultural oligitrophication (Martinez 1996 and 2001; Ney 1996). The density of *Mysis* was higher in Granby in both shallow and deep stations than in either Dillon or Taylor Park (Table 25-27). In shallower water in Granby, *Mysis* density was 55% higher than in Dillon and 14.2 % higher than in Taylor Park. The shallow water *Mysis* density in Taylor Park was 35% higher than in Dillon. In the deeper stations, the *Mysis* density in Granby was 128% higher than in Dillon and 56% higher than in Taylor Park. The density of *Mysis* in the deeper station in Taylor Park was 45% higher than in Dillon. The size of *Mysis* in these three reservoirs also corresponded to their rank in productivity, with the mean mysid size being larger according to higher productivity. In the shallow water stations, the mean body length of *Mysis* over the number of years examined was 10.33 in Dillon, 10.96 in Taylor Park, and 11.54 in Granby. Similarly, in the deep stations, the mean body length of Mysis increased with productivity: 11.21 in Dillon, 11.92 in Taylor Park and 12.9 in Granby.

Both Granby and Taylor Park contain lake trout, a primary predator on *Mysis*. While *Mysis* densities appear to fluctuate in these reservoirs irrespective of apparent lake trout densities, the overlap of *Mysis* and lake trout in deeper, cooler waters during summer stratification may expose more adult mysids to consumption by lake trout. While this predation does not appear to control *Mysis* density, the loss of adults via entrainment into the tailraces below their dams may represent a more consistent source of *Mysis* mortality in Dillon and Taylor Park. The tailrace trout fisheries below both reservoirs are renowned for the presence of large rainbow which feed heavily on *Mysis* entrained through the outlets of these reservoirs (Wright 2009). While reservoir productivity may ultimately control maximum *Mysis* densities in Dillon and Taylor Park, the concentration of more, larger mysids in the depths of these reservoirs may contribute to a steady loss of adult, reproductive *Mysis* compared to Granby which does not pose the same entrainment scenario.

The concentration of more and larger mysids at depth in these reservoirs would suggest that if mechanical removal were implemented to reduce their abundance, harvest should focus over deeper waters to increase the catch of adult *Mysis*, possibly inflicting reproductive and generational losses on the population. If sustained harvest of *Mysis* was desired, perhaps focusing mechanical methods in shallower waters would remove proportionately fewer adult mysids, thereby sustaining reproductive capacity and a harvestable surplus.

Table 25. Summary of shallow and deep water *Mysis relicta* samples used to compare *Mysis* density and size structure in Dillon Reservoir, 1998-2008. Sampling was not conducted in 2001, 2004, or 2006.

Parameter	Dillon Reservoir - 1998-2008: Shallow								Total, range or mean
	1998	1999	2000	2002	2003	2005	2007	2008	
Number of samples	5	5	5	5	3	5	4	5	37
Depth range (m)	4--23	8--30	10--33	10--24	12--14	9--34	9--17	9--34	4--34
mean Depth (m)	12.6	14.6	16.4	13.4	13.3	16.4	12.8	16.8	14.54
Mysis/m^2 range	7.6--315.9	90.4--234.4	62.4--217.8	101.9--652.2	12.7--51.0	98.1--738.9	24.2--231.8	119.7--251.0	7.6--652.2
mean *Mysis*/m^2	106.8	160.5	137.6	254.5	30.6	295.8	144.3	183.9	164.25
Total length (mm) range	5--17	7--21	4--18	4--20	5--14	6--20	4--17	5--17	4--21
Mean total length (mm)	10.7	12.7	9.2	9.8	9.9	11.2	9.4	9.7	10.33

Parameter	Dillon Reservoir - 1998-2008: Deep								Total, range or mean
	1998	1999	2000	2002	2003	2005	2007	2008	
Number of samples	5	5	5	5	6	5	6	5	42
Depth range (m)	34--53	34--54	35--54	27--45	34--53	35--54	34--53	35--54	27--54
Mean depth (m)	41.2	42.6	42.8	34.8	35.8	43.2	40.7	43	40.51
Mysis/m^2 range	22.9--847.1	76.4--569.4	59.9--240.8	214--686.6	10.2--84.1	61.1--1365.6	168.2--671.3	53.3--458.6	10.2--1365
Mean *Mysis*/m^2	366.8	294	159.2	387	35.5	545	304.2	259.6	293.91
Total length (mm) range	5--18	7--21	4--18	4--20	4--16	5--21	4--19	5--17	4--21
Mean total length (mm)	10.1	12.7	11.6	9.9	11.7	9.9	12.9	10.9	11.21

Table 26. Summary of shallow and deep water *Mysis relicta* samples used to compare *Mysis* density and size structure in Granby Reservoir, 1997-2008.

Parameter	Granby Reservoir - 1997-2008: Shallow												Total, range or mean
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Number of samples	5	5	4	5	5	2	4	3	5	5	6	6	54
Depth range (m)	8--22	15--24	17--23	13--24	12--22.5	10--18.9	13--20.3	10.2--19.9	11--22	10--20	11.8--22.7	12.2--22.4	8--24
Mean depth (m)	16.2	16.1	20.3	17.8	16.5	14.5	16.6	15	16.3	14.72	18	16.7	16.56
Mysis/m^2 range	49.7--276.4	1.3--135.0	115.9--570.7	196.2--208.3	76.4--328.7	43.3--438.2	1.3--79.0	65--779.6	29.3--137.6	45.9--653.5	286.6--1039.5	56.1--756.7	1.3--1039.5
Mean *Mysis*/m^2	169.2	66.8	386.9	312.1	229.6	240.8	20.7	334.1	81.8	286.6	673.5	271.3	256.12
Total length (mm) range	5--17	6--18	7--21	4--20	4--21	4--19	9--15	4--21	8--20	5--14	4--20	5--18	4--21
Mean total length (mm)	11.3	11.2	12.1	10.5	11.4	12.9	12.6	13.4	13.3	10.8	7.8	11.2	11.54

Parameter	Granby Reservoir - 1997-2008: Deep												Total, range or mean
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Number of samples	5	5	6	5	5	1	4	4	5	5	4	5	54
Depth range (m)	26--50	25--53	26--53	26--51	25.7--49	40	20.8-48.0	21.6--42.1	26.3--48.3	23--50	28.8--52.6	22.7--55.0	20.8--55
Mean depth (m)	37.6	38.4	37.2	38.6	36.5	40	35	31.9	35.9	34.6	40.5	36.9	36.93
Mysis/m^2 range	318.5--1194.9	68.8--1406.4	434.4--1769.4	179.6--577.1	211.5--1277.7	475.2	26.8--332.5	2.5--775.8	96.8--750.3	247.1--1414.0	707.0--3854.8	196.2--4815.3	2.5--4815.3
Mean *Mysis*/m^2	570.2	508.8	699.4	226.5	597.5	475.2	128.7	332.9	341.4	680.8	1836	1632.9	669.19
Total length (mm) range	4--18	5--21	5--21	4--22	4--21	6--18	6--22	7--23	6--23	5--21	4--21	5--21	4--23
Mean total length (mm)	10.8	13.7	12	13.2	14	11.9	15.4	14	13.9	12.3	10.3	13.3	12.9

Table 27. **Summary of shallow and deep water *Mysis relicta* samples used to compare *Mysis* density and size structure in Taylor Park Reservoir, 1998-2008. Sampling was not conducted in 2001, 2004, or 2006.**

Parameter	Taylor Park Reservoir - 1998-2008: Shallow										Total, range or mean
	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	
Number of samples	4	5	4	5	5	5	4	5	3	5	45
Depth range (m)	6--15	10--18	8--14	6--15	8.9--11.8	10--16.7	9.8--18	6.5--16.9	9.8--18.4	7--18	6--18.4
Mean depth (m)	9.6	12.6	9.5	8.8	9.6	12.8	11.9	10.1	13.1	11.6	10.96
Mysis/m^2 range	2.5--280.3	1.3--461.1	5.1--229.3	65.0--280.3	115.9--588.5	30.6--1110.8	128.7--620.4	31.8--468.8	360.5--682.8	36.9--229.3	1.3--1110.8
Mean *Mysis*/m^2	72.6	177.8	108.6	154.9	250.4	365.4	336.9	160.8	494.7	120.8	224.29
Total length (mm) range	7--17	9--20	6--14	6--20	4--19	4--20	6--20	5--19	4--18	4--19	4--20
Mean total length (mm)	10.7	13.3	10.8	13.1	8.7	9.7	10.8	9.9	9.4	9.3	10.57

Parameter	Taylor Park Reservoir - 1998-2008: Deep										Total, range or mean
	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	
Number of samples	5	5	5	5	5	5	5	5	5	5	50
Depth range (m)	22--38	25--41	20--37	18--37	16.4--33.6	19.4--37	22.6--40.5	22--39.3	22.7--40.2	23.5--41.3	16.4--41.3
Mean depth (m)	30	33.2	27.8	28.4	21.6	28.5	31.7	30	31.3	32.7	29.52
Mysis/m^2 range	140.1--512.1	47.1--248.4	91.7--681.5	220.4--719.7	337.6--1236.9	356.7--811.5	174.5--770.7	382.2--1201.3	258.6--560.5	161.8--290.4	47.1--1236.9
Mean *Mysis*/m^2	313.6	218.9	277.2	431.6	700.6	598.7	461.9	655.8	413	208.7	428.00
Total length (mm) range	6--20	7--23	6--21	8--23	4--20	4--23	5--22	5--20	4--20	4--19	4--23
Mean total length (mm)	12.7	15.6	11.4	14.8	9.3	13.1	11.5	10.9	10.5	9.4	11.92

OBJECTIVE 4: **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: Participate in publication of hatchery water and otolith microchemical study.

Introduction, Methods, Results and Discussion

The Master's thesis by Gibson-Reinemer (2008) and the report by Johnson et al. (2008) contributed to a manuscript on the results of research on hatchery water and otolith microchemistry. This manuscript, entitled Elemental Signatures in Otoliths of Hatchery Rainbow Trout (*Oncorhynchus mykiss*): Distinctiveness and Utility for Detecting Origins and Movement was published in the Canadian Journal of Fisheries and Aquatic Sciences (Gibson –Reinemer et al. 2009). The findings from this research will contribute to other studies in Colorado on reservoir microchemical signatures (Johnson and Martinez 2008) and the growing potential of this technique as a forensic tool for prosecuting perpetrators of illegal transplants of fish.

OBJECTIVE 5: **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.

Segment Objective 2: Participate in dissemination of information, as needed or feasible.

Introduction, Methods and Discussion

Segment Objectives 1 and 2 are discussed here together. Efforts to inform and alert fishery personnel about the growing and festering problems associated with illegal fish introduction in Colorado included a presentation to Dr. Brett Johnson's FW401 Fishery Science class at CSU in November, 2008. This presentation entitled "A Collision of

Religions: Conflicts between Sport Fish and Native Aquatic Species Management" included examples of the concerns and potential consequences of illegally introduced fishes. The manuscript "Are We Doing All We Can to Stem the Tide of Illegal Fish Introductions?" co-authored by Brett Johnson, Robert Arlinghaus, and Pat Martinez was accepted for publication in Fisheries (Johnson et al. 2009). The issue of illegal fish introductions was also discussed at an internal CDOW meeting regarding endangered fish recovery held in Grand Junction in April, 2008.

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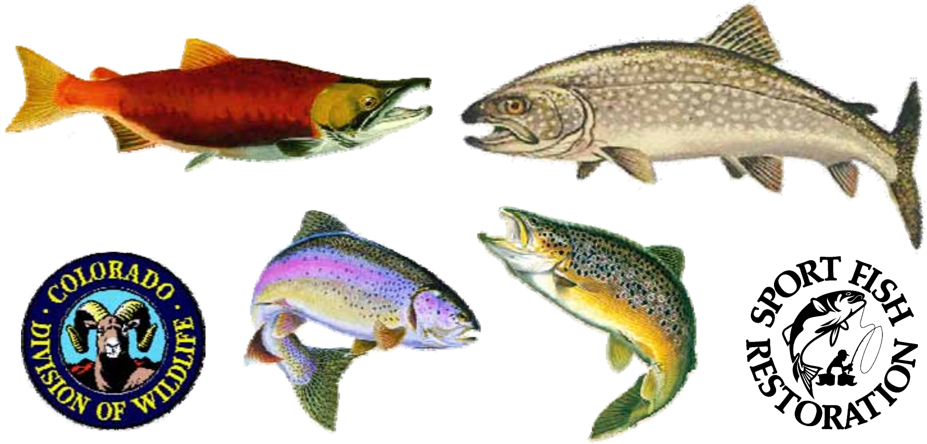
APPENDIX A

POWERPOINT PRESENTATION

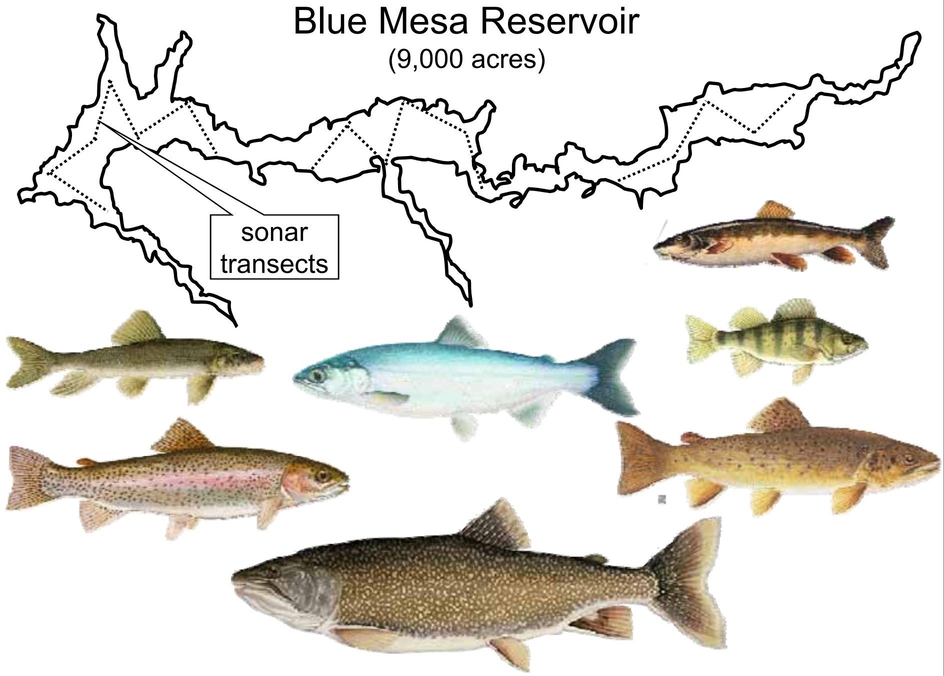
KOKANEE POPULATION & FISHERY TRENDS IN BLUE MESA RESERVOIR: IMPLICATIONS FOR THE SPORT FISHERY, KOKANEE EGG PRODUCTION & LAKE TROUT MANAGEMENT

Kokanee population & fishery trends in Blue Mesa Reservoir: implications for the sport fishery, kokanee egg production & lake trout management

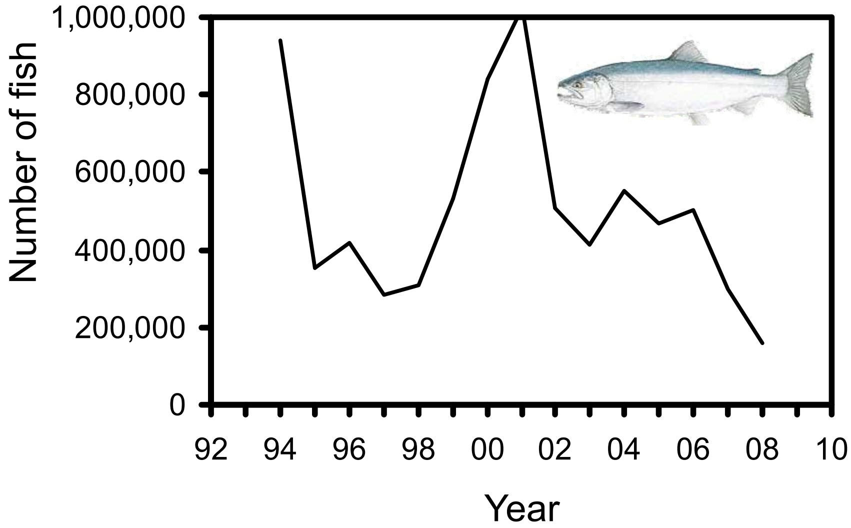
Patrick J. Martinez
Colorado Division of Wildlife, Grand Junction



Blue Mesa Reservoir
(9,000 acres)

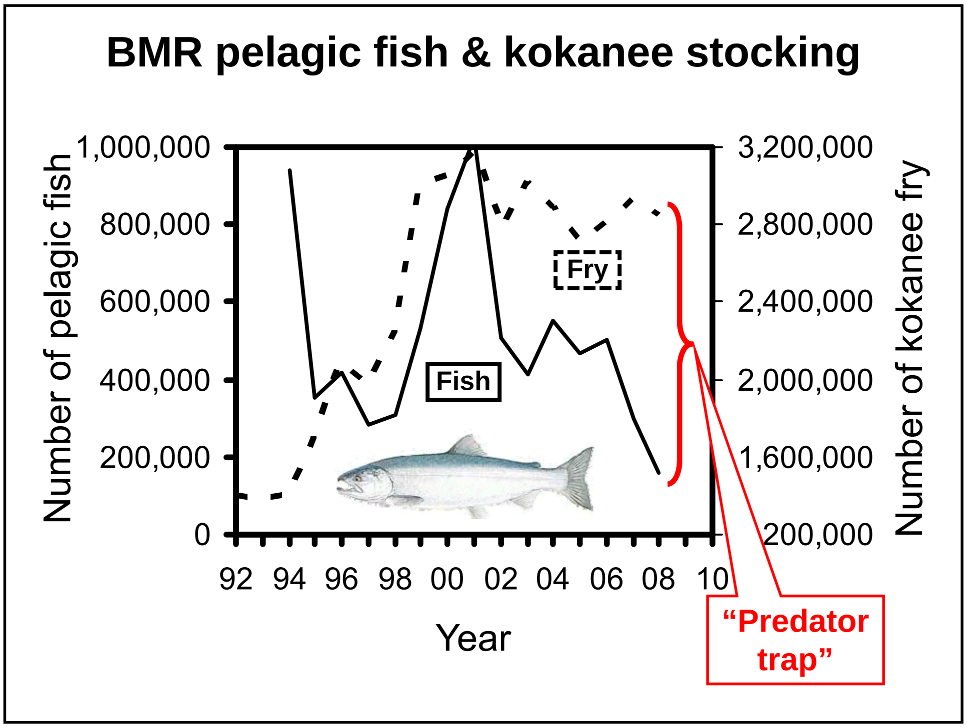


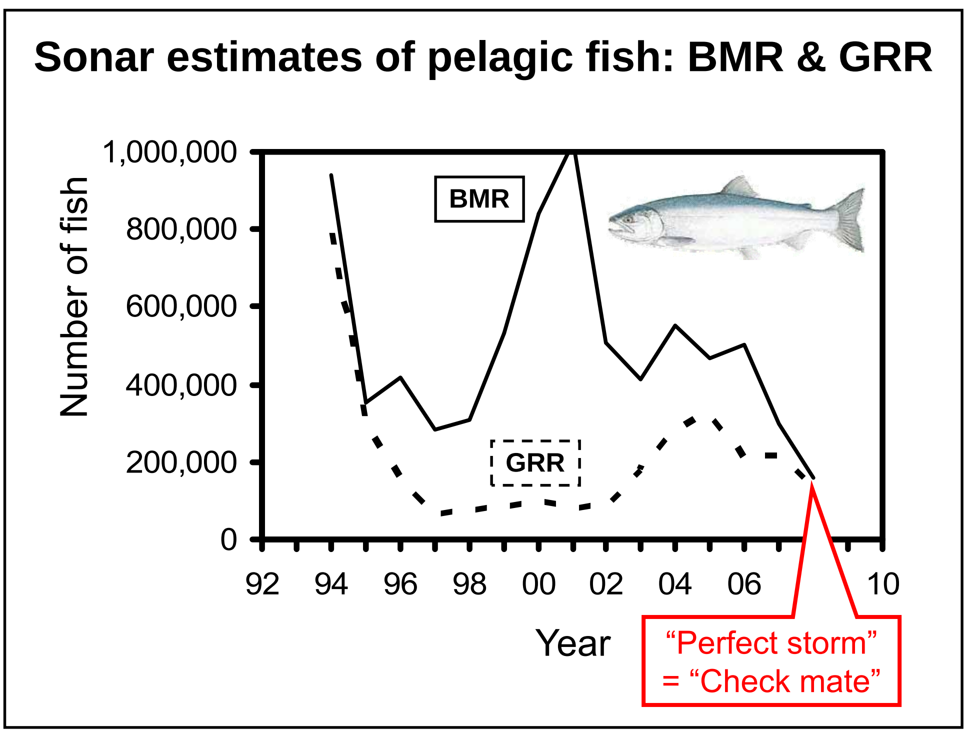
Sonar estimates of pelagic fish: BMR

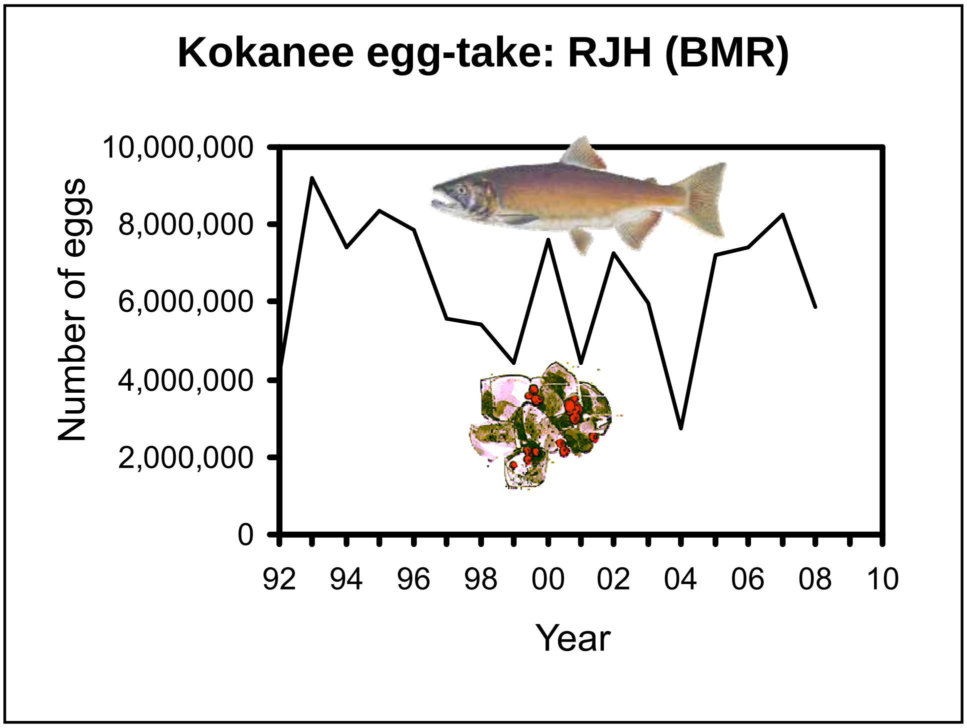


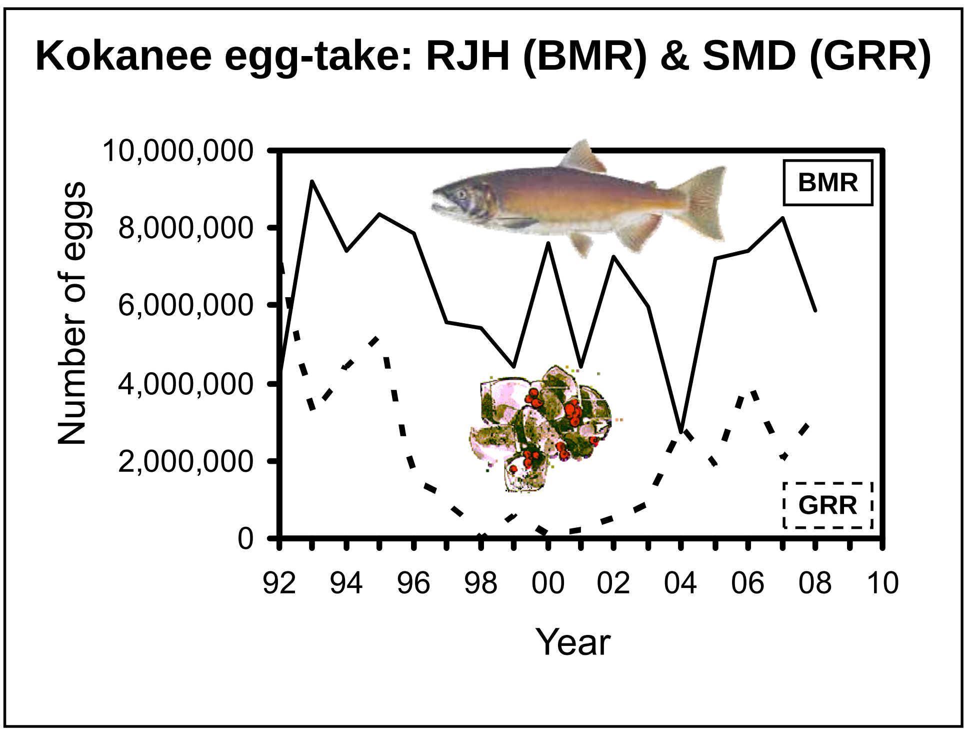
Predator inertia: the capacity of a predator to maintain a high demand for prey despite a severe decline in their preferred or suitable prey. This inertia is highest in piscivores that are long-lived and resistant to starvation. Lake trout, for example, do not die when their key prey declines or disappears Consequently, they can re-exert high rates of mortality on prey populations that somehow reappear or rebound. This predatory inertia can result in a “predator trap”, delaying or preventing the restoration of prey.

Predator trap: a situation in which prey density has declined severely and is unable to rebound due to an overabundance of predators whose piscivory limits recruitment or survival of prey from reproduction or stocking – may become an ecological or economic impediment to food web or fishery restoration.

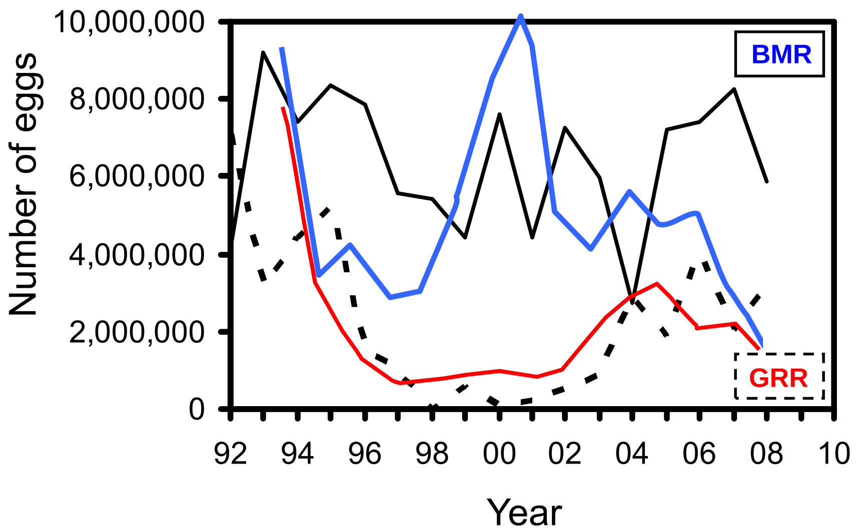

BMR pelagic fish & kokanee stocking
Number of pelagic fish
1,000,000
800,000
600,000
400,000
200,000
0
Number of kokanee fry
3,200,000
2,800,000
2,400,000
2,000,000
1,600,000
1,200,000
Fry
Fish
92 94 96 98 00 02 04 06 08 10
Year
"Predator trap"


Sonar estimates of pelagic fish: BMR & GRR
Number of fish
1,000,000
800,000
600,000
400,000
200,000
0
BMR
GRR
92 94 96 98 00 02 04 06 10
Year
"Perfect storm"
= "Check mate"


Kokanee egg-take: RJH (BMR)
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Number of eggs
92
94
96
98
00
02
04
06
08
10
Year


Kokanee egg-take: RJH (BMR) & SMD (GRR)
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Number of eggs
BMR
GRR
92
94
96
98
00
02
04
06
08
10
Year

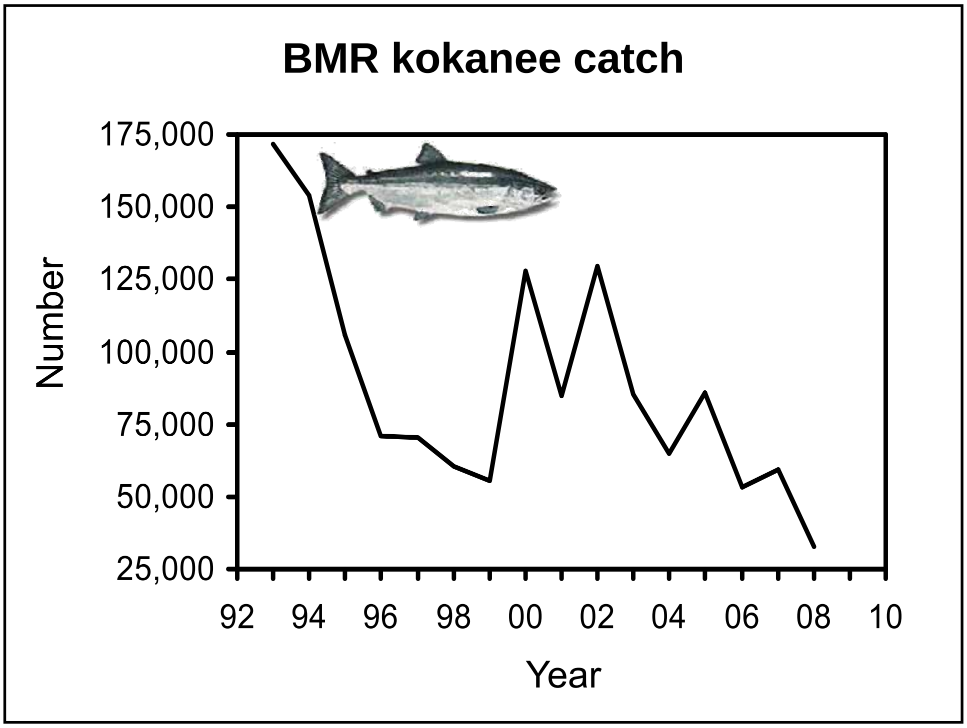
Kokanee egg-take: RJH (BMR) & SMD (GRR)



Compensatory Mortality - Mortality is compensatory when the mortality rate (i.e., proportion of population affected) decreases as the population size decreases. This is in contrast to depensatory mortality, were the rate increases as the size of the population decreases.

Depensatory Mortality - Mortality is depensatory when its rate (i.e., proportion of population affected) increases as the size of the population decreases. This is in contrast to compensatory mortality where the mortality rate decreases as the population size decreases.

"*Depensatory mortality*" increases as the density of kokanee decreases. This means that at low densities there are higher *per capita* mortality rates. This kind of mortality can result from predators that take a fixed number rather than a fixed percentage of the population.



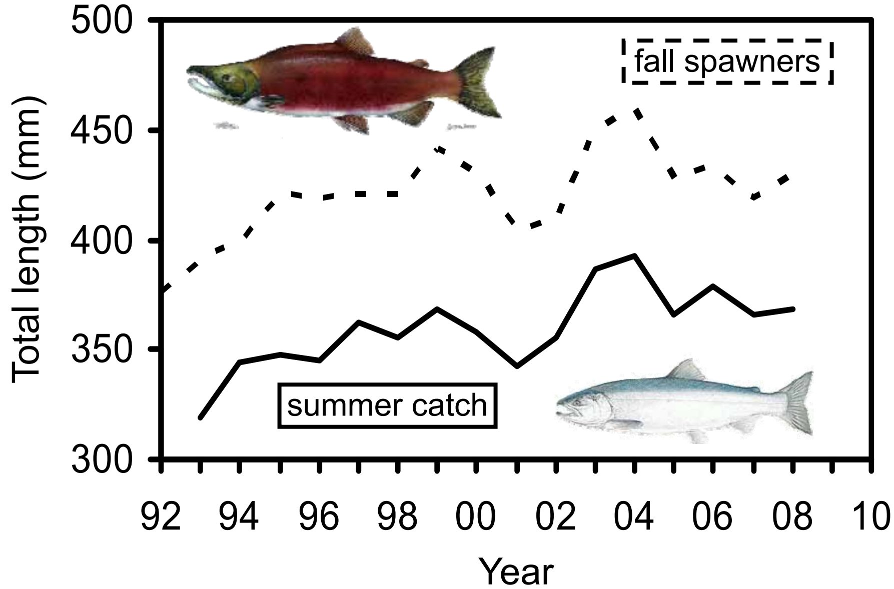
Parkinson, E. A. 1990. Impaired school formation at low density: a mechanism for depensatory mortality in sockeye salmon. B. C. Fisheries Bureau, Fisheries Management Report No. 99.

- school formation may be severely inhibited by a low encounter rate among juvenile sockeye at low densities

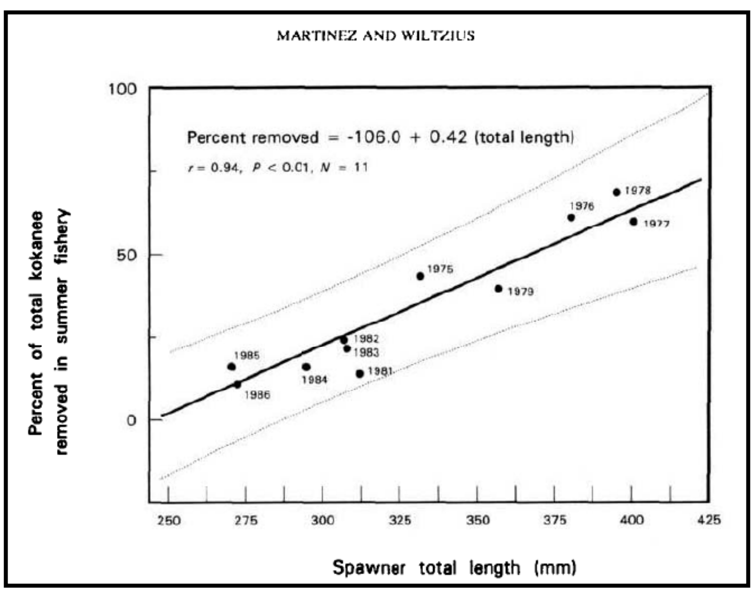
- encounter rates of predators with schools is insensitive to density

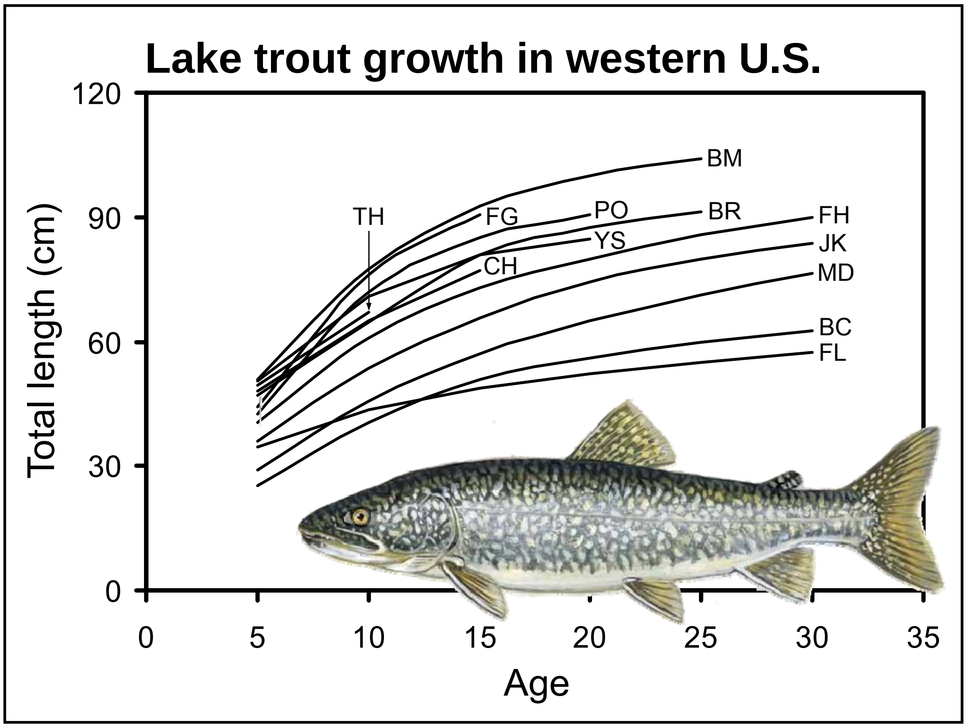
- enhanced school formation at higher sockeye densities may reduce predation risk

BMR kokanee average size



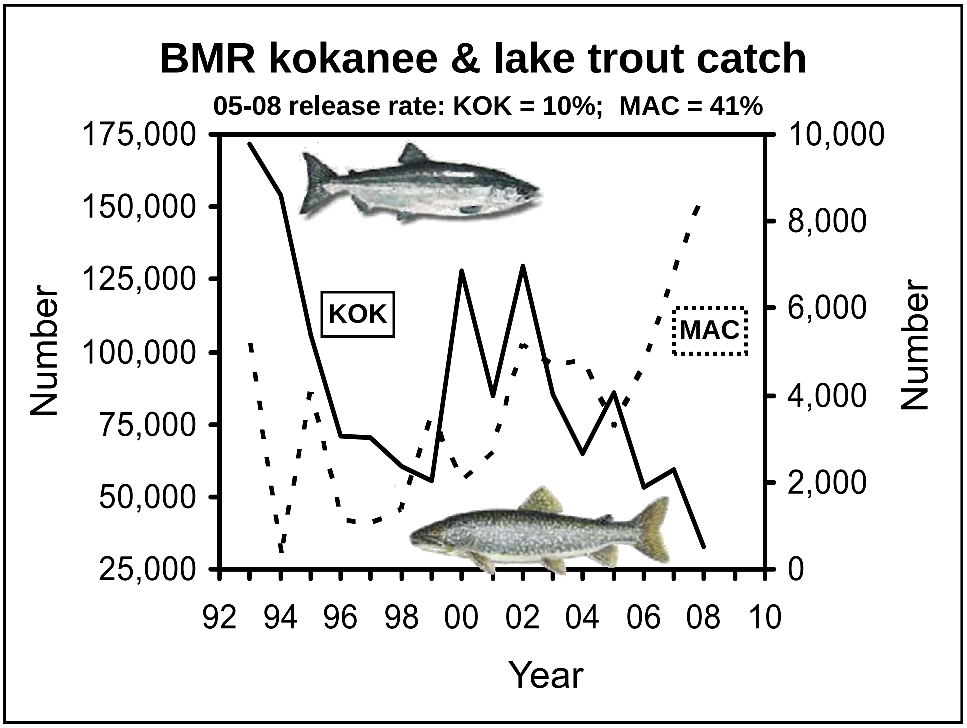
Depensatory angling mortality: GRR kokanee

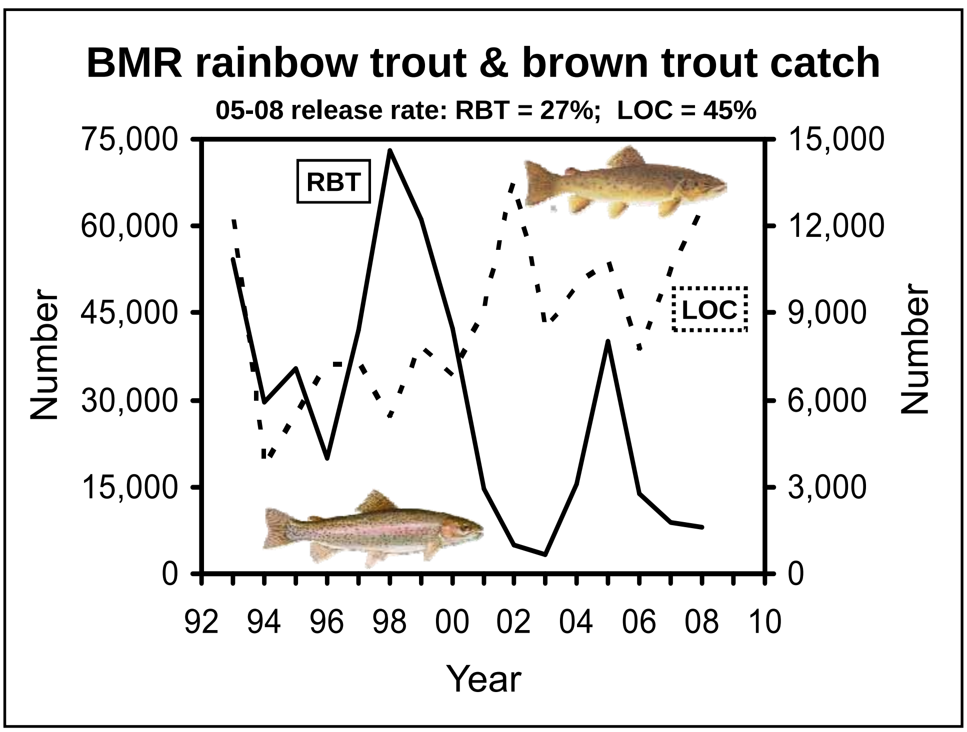




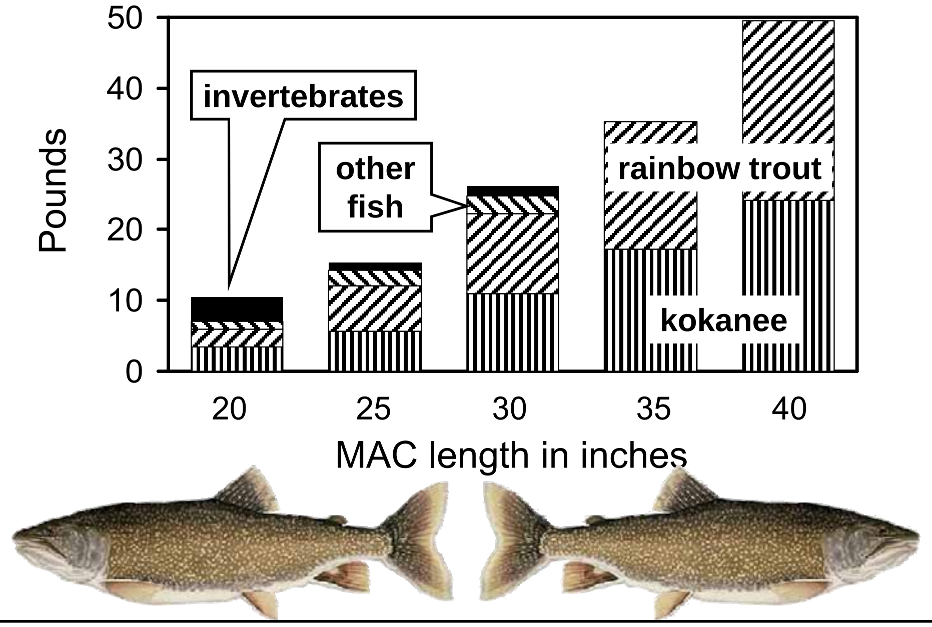
Rieman, B. E. & D. L. Myers. 1991. Kokanee population dynamics: cost, benefits & risks of salmonid predators in kokanee waters. Federal Aid Job Completion Report F-73-R-13. Idaho Department of Fish & Game, Boise.

- predators can impose depensatory mortality (DM) on prey populations, resulting in prey collapse at low densities
- kokanee may be particularly vulnerable to depensatory effects – schooling behavior of kokanee may increase their vulnerability to predators at low kokanee density
- lake trout seem to prefer kokanee – both kokanee in the diet and lake trout growth increase as kokanee numbers increase
- lake trout represent a greater risk of collapsing a kokanee population


BMR kokanee & lake trout catch
05-08 release rate: KOK = 10%; MAC = 41%
KOK
MAC
Number
Number
Year
175,000
150,000
125,000
100,000
75,000
50,000
25,000
10,000
8,000
6,000
4,000
2,000
0
92 94 96 98 00 02 04 06 08 10


BMR rainbow trout & brown trout catch
05-08 release rate: RBT = 27%; LOC = 45%
RBT
LOC
Number
Number
Year
75,000
60,000
45,000
30,000
15,000
0
15,000
12,000
9,000
6,000
3,000
0
92 94 96 98 00 02 04 06 08 10

BMR annual prey eaten per lake trout



Pelagic fish biomass shortfall: SONAR

Year	Pelagic prey fish	Grams/ fish	Mean no.fish	Mean g/fish	Kg of fish	Wt.of fish missing
2000	776,418	92	618,536	91	56,287	37,582 kg Or 82,680 lbs
2001	960,910	66				
2002	710,538	100				
2003	383,253	158				
2004	543,106	71				
2005	456,358	83				
2006	499,170	66				
2007	293,670	73	225,366	83	18,705	
2008	157,062	92				

Number of macs 20-30 in.TL eating ~ 10 lbs of pelagic fish/year that need to be removed immediately to relinquish 82,680 lbs of predation pressure = 8,268

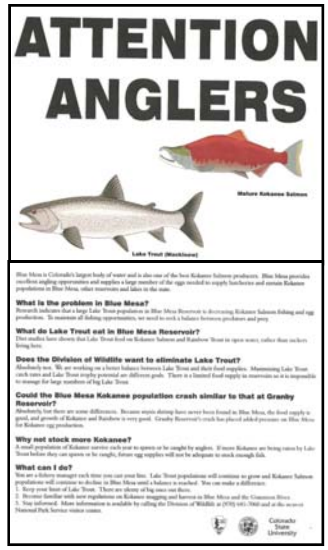
Kokanee biomass shortfall: CREEL

Year	Kokanee catch	Mean TLmm	Mean Wt.(g)	Mean no.fish	Mean g/fish	Kg of fish	Wt.of fish missing
2000	128,117	358	475	96,073	515	49,478	23,828 kg or 52,422 lbs
2001	84,633	342	414				
2002	129,864	355	463				
2003	85,204	387	601				
2004	62,702	393	630				
2005	85,919	366	508				
2006	53,070	379	565	48,396	530	25,650	
2007	59,171	366	508				
2008	32,948	368	517				

Number of macs 20-30 in.TL eating ~10 lbs of kokanee/year that need to be removed immediately to relinquish 52,422 pounds of predation pressure = 5,242

Are kokanee in Blue Mesa Reservoir vital for the fishery & egg production?	**YES**
Is there an ongoing decline in the kokanee population?	**YES**
Are kokanee in Blue Mesa Reservoir threatened by lake trout predation?	**YES**
Can kokanee rebound if lake trout numbers remain at present levels?	**NO**
Is there an ongoing increase in the lake trout population?	**YES**
Has the present approach to suppressing lake trout been effective?	**NO**

Story carried by local & prominent newspapers & CDOW press release



Story not carried by local or prominent newspapers or CDOW press release

Are lake trout capable of eliminating kokanee from the reservoir?	**YES**
Is there an estimate of how many lake trout need to be removed?	**~YES**
Is present angler harvest capable of suppressing the lake trout population?	**NO**
Could incentives increase angler harvest & suppress the lake trout population?	**YES**
Could gill netting suppress the lake trout population?	**YES**
Is there time to spare while deciding what to do?	**NO!**

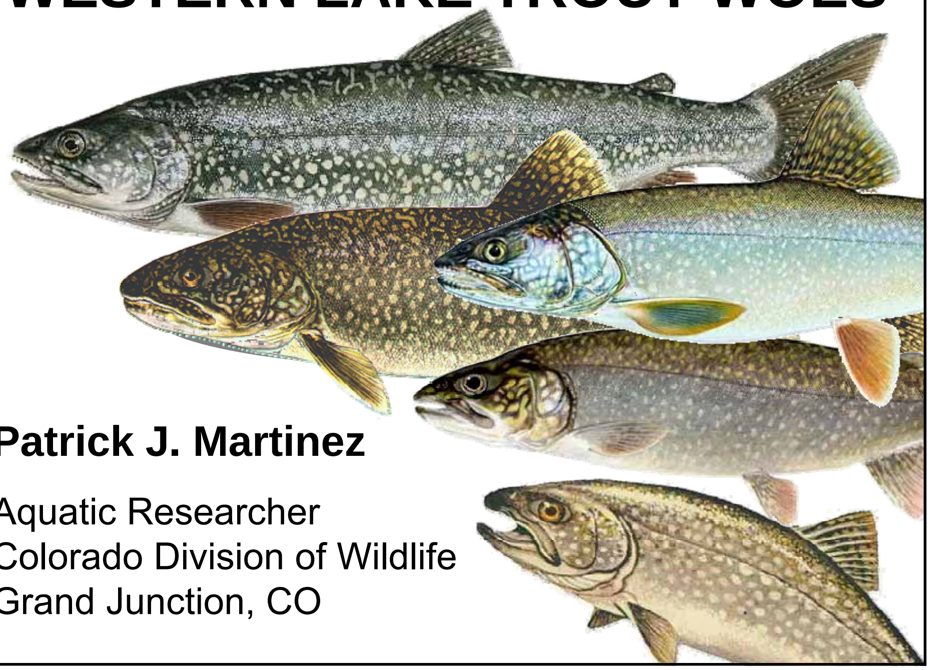
Strategies to reduce & control lake trout abundance & predation in BMR

- do not stock lake trout ('92)	**++**
- increase bag limit for lake trout ('96)	**++**
- remove length limit for lake trout ('96)	**++**
- promote lake trout harvest	**+-**
- manage for 2M kokanee stocked/yr	**- -**
- "must-kill" for lake trout ≤ 20 in.TL	**- -**
- remove bag limit for yellow perch	**+-**

Strategies to reduce & control lake trout abundance & predation in BMR

- gill net to remove lake trout	**- -**
- identify & remove lake trout at spawning sites	**- -**
- $$ incentive for angler harvest of lake trout	**- -**
- "must-kill" for illegally or invasively introduced fish	**- -**
- monitor lake trout body condition & Hg burden	**+-**
- do not ignore sonar trends ('07)	**- -**
- "West Mac Woes": CO/WY AFS; CDOW-GJ; CSU Fish Sci.; Bonneville AFS; CSU Student Chapter AFS	**++**

WESTERN LAKE TROUT WOES



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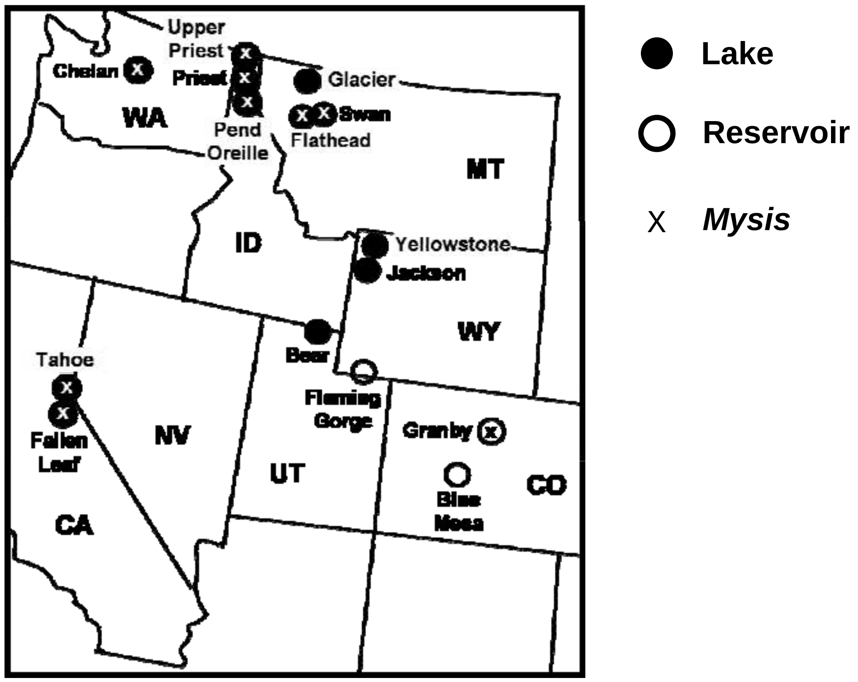


Sequence of strategies to control lake trout abundance & predation

1. Stop stocking lake trout
2. Liberalize restrictive harvest regulations for lake trout
3. Encourage & promote angler harvest of lake trout
4. Provide monetary incentives for angler harvest of lake trout
5. Implement intensive netting to remove lake trout
6. Intensively remove adult lake trout from spawning reefs
7. Permit commercial rod & reel fishery for lake trout
8. Control invasive movements of lake trout

WYOMING GAME & FISH DEPARTMENT

May, 2004
Volume 1, Issue 1

JACKSON REGION ANGLER NEWSLETTER

Future Management

Since 1988, approximately 36,000 lake trout have been stocked annually. Stocked lake trout have a poor return to anglers (10-20%). In addition, the decrease in condition of game fish species has raised concerns that the zooplankton resources in Jackson Lake may be over-utilized. Lake trout stocking will be reduced in upcoming years and phased out in 2007.

Nothing like fishing for 'Macs' on Lake Chelan and these lake trout make a magnificent meal.

By Wayne Kruse, Herald Outdoor Columnist, Published: Sunday, July 27, 2008

- the question of Mackinaw table quality comes up regularly

- scrape out the body fat when you clean the fish, and the other is to be prepared to put the fish on ice immediately after it's in the boat, and all the way home

- Since lakers are an oily species, they don't freeze well for extended periods of time. The upside of that is that they're great smokers.

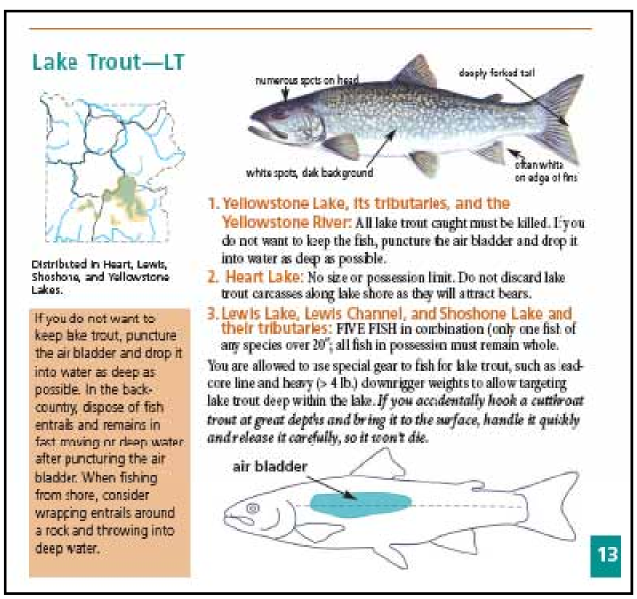
- simply salted and peppered the fillets, placed them in foil with slices of onion and lemon, added ketchup and dollops of butter, wrapped them up and laid them on the coals of a wood fire. They poached in their own juices and came out steaming, tomatoey, buttery, delicious. The best fish I've ever eaten, hands down. Better than halibut or walleye or spring Chinook or lingcod, and that's saying something.

KEEP SMALLER LAKE TROUT IN FLAMING GORGE, PLEASE 12/17/2004
GREEN RIVER -- To help keep Flaming Gorge Reservoir's trophy lake trout potential, now is not the time to be a trophy angler. Fish biologists are encouraging anglers to keep smaller lake trout.
"Fishing for lake trout, especially smaller fish in the 18- to 24-inch size classes should be very good again this year," said Bill Wengert, Game and Fish Department fish biologist in Green River. "An abundance of these fish exists in the reservoir. Every angler is encouraged to keep these smaller lake trout to help keep the lake trout in balance with their most important forage fish - kokanee salmon."

LAKE TROUT vs KOKANEE at FLAMING GORGE August 15, 2005
Utah Division of Wildlife Resources biologists are afraid there are too many lake trout in the reservoir – that the lake trout are preying too heavily on the kokanee. They are proposing fishing regulation changes to protect the kokanee and allow a more liberal harvest of lake trout.

ICE FISHING "HEATS UP" at FLAMING GORGE February 24, 2006
DUTCH JOHN — "There are many small- and medium-sized lake trout in Flaming Gorge, so please take advantage of the new eight-fish lake trout regulation and harvest a limit."

1.) Yellowstone Lake & Heart Lake: All Lake Trout caught must be KEPT & KILLED. Under no circumstances should Lake Trout be returned to the water alive. There is no size or possession limit on Lake Trout caught in Yellowstone Lake or Heart Lake.


Lake Trout—LT

Distributed in Heart, Lewis, Shoshone, and Yellowstone Lakes.

If you do not want to keep lake trout, puncture the air bladder and drop it into water as deep as possible. In the back-country, dispose of fish entrails and remains in fast moving or deep water after puncturing the air bladder. When fishing from shore, consider wrapping entrails around a rock and throwing into deep water.

1. Yellowstone Lake, its tributaries, and the Yellowstone River: All lake trout caught must be killed. If you do not want to keep the fish, puncture the air bladder and drop it into water as deep as possible.
2. Heart Lake: No size or possession limit. Do not discard lake trout carcasses along lake shore as they will attract bears.
3. Lewis Lake, Lewis Channel, and Shoshone Lake and their tributaries: FIVE FISH in combination (only one fish of any species over 20"; all fish in possession must remain whole.

You are allowed to use special gear to fish for lake trout, such as lead-core line and heavy (> 4 lb.) downrigger weights to allow targeting lake trout deep within the lake. *If you accidentally hook a cutthroat trout at great depths and bring it to the surface, handle it quickly and release it carefully, so it won't die.*

13

FISHING EVENT: 2009 SPRING MACK DAYS

Lake Trout Fishing Event/Derby on Flathead Lake

Over $45,000 in cash & prizes available Over $20,000 in cash awards

(up to$30,000 in bonuses for all anglers entering 20 or more lake trout)
plus OVER 1000 tagged lake trout with values from $100-$5,000

March 13th-April 26th

(Fridays, Saturdays, & Sundays)

Dates: March 13,14,15,20,21,22,27,28,29,
April 3,4,5,10,11,12,17,18,19,24,25, & 26

Fish 20 days & pick your best 12 days (the last day will be a separate day with separate prizes) to compete for the top angler prizes or just fish one day & still be eligible for cash & merchandise prizes. All it takes is one fish to win!!

Sponsored by the Confederated Salish and Kootenai Tribes
and sanctioned by Montana Fish, Wildlife, & Parks.
Flathead Lake-Polson, Montana

Lake Pend Oreille, ID

Monetary incentives for angler harvest of lake trout

- 2006: $10/lake trout harvested more effective than rewards based on tagged fish @ $100 -$2,000; removed 6,000 rainbow trout & 11,000 lake trout (total cost = $241,000)

- 2007: $15/lake trout harvested ($500,000 budgeted)

- lake trout are reportedly unable to withstand a total annual mortality higher than 50%

IDAHO FISH & GAME PANHANDLE REGION NEWS RELEASE February 13, 2009

Meeting set to discuss Lake Pend Oreille fishery

The predator problem was identified in 2000. Since then, fishery biologists and anglers have generally come to agree that restoring the rainbow and bull trout fishery will require a significant and immediate reduction in the number of predators, combined with long-term suppression of the lake trout population.

In many ways, 2008 was the most encouraging year in the recovery effort to date. Anglers removed just over 13,000 lake trout and nearly 4,700 rainbow trout. Commercial netters removed an additional 11,761 lake trout. The total harvested since the effort began in 2006 is up to 63,597.

Lake Pend Oreille, ID

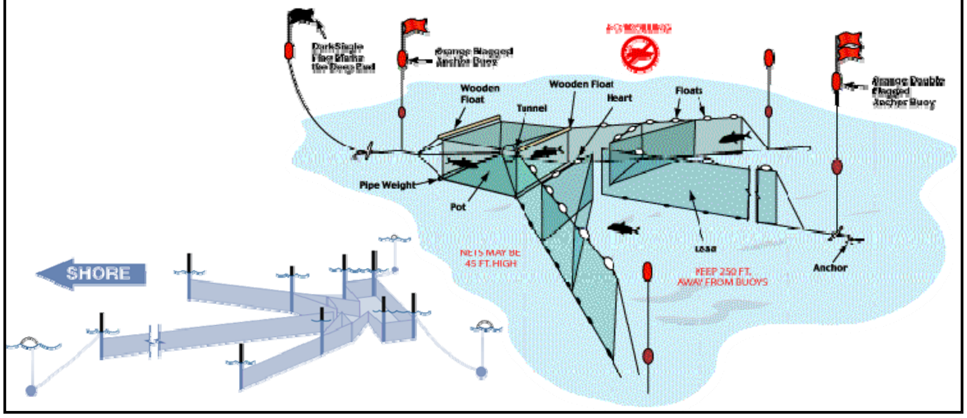
Commercial-scale deep-water trap nets (pound nets)

Harbor Fisheries, Inc. (Bailey's Harbor, Wisconsin)

Large trap nets alone may not be a suitable way to suppress the lake trout population in a short period of time. Trap nets are valuable for collecting lake trout for population estimates and sonic tagging projects without causing high mortality to target or non-target fishes

COMMERCIAL TRAP FISHING NETS

The nets are designed to allow non-target species to be released unharmed. The pots of the nets are set in water 75 to 150 feet deep. The leads extend toward shore into water shallower than 75 feet deep. The nets are anchored on the bottom and may be 45 feet high. Nets are marked with several flags. There is a single orange flag over the pot; a single dark colored flag in deep water off the pot; a pair of single orange flags at the end of the wings and a double orange flag at the end of the shallow lead. There is a flashing amber light above the double orange flag at night. Anchor lines extend beyond the flags 400 to 600 feet away from the net. The single dark flag may be 1200 feet from the pot and so may be difficult to see in foggy conditions.



Lake Pend Oreille, ID

Intensive gill netting

Yellowstone Lake gill netting for lake trout

- ~$300,000 budgeted annually for gill netting
- 2009: contract with professional commercial fishery consultants

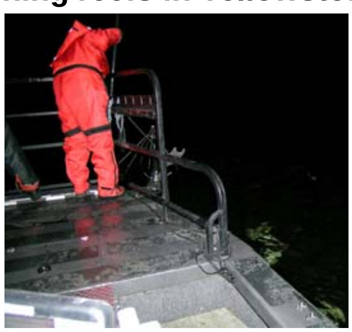
STATUS: COOPERATIVE SWAN LAKE FISHERIES MANAGEMENT PROJECT, March 2008

- biologists are concerned that these predacious fish threaten the popular bull trout & kokanee fishery in the lake
- 2007 fish sampling over a three-week period (September 17-October 4); biologists set a total of 26.5 miles of gill net
- total catch included 2,156 lake trout; 735 mortalities, 30 sonic-tagged & 1,391 tagged & released for population estimate
- based on 2007 information, depletion estimate for 2008 could remove large portion of population, effectively slowing lake trout population growth
- second round of intensive netting to be done 2-19 September 2008; all lake trout caught to be removed from the lake at cost of about $60,000

Swan Lake Fish Sampling Program Meets Goals In 2008; Agencies Propose To Move Ahead With Expanded 3-Year Program 06 January 2009

- interagency project to sample & begin to reduce the lake trout population last fall in Swan Lake came off successfully
- FWP & others contracted with professional commercial fishery consultants to conduct gill netting, using over two linear miles of nets at each setting
- sampling & removal over a three-week period in September yielded a population estimate of about 8,800 lake trout from 7-36 inches in length
- 3,784 lake trout 7-36-in. were removed during netting, including 70 adult fish 20-36; by-catch of other fish species relatively low
- 18 sonic tag implanted adult lake trout identified two major spawning locations where eggs were also located on the rocky substrate
- agencies propose to move forward with an experimental 3-year plan to further reduce the number of predatory lake trout in Swan Lake

Nighttime electrofishing on lake trout spawning reefs in Yellowstone lake



Strategies to prevent kokanee crash in BMR

- **agency-endorsed** education campaign promoting immediate need reduce abundance of & predation by lake trout

- stock "extra" kokanee from lower priority waters (Taylor, Carter, Green Mountain etc. – 2009 - **short term!!**)

- monetary reward for angler harvest of lake trout of target size to provide incentive & hasten lake trout reduction

- allow "sinking" of angler-caught lake trout of target size if angler chooses to not keep catch to faciltate removal

Strategies to prevent kokanee crash in BMR

- "must-kill" regulation for lake trout of target size to provide long-term control of lake trout abundance & predation

- intensive gill netting for lake trout to reduce abundance of target-size fish & monitor population parameters

- remove bag limit on brown trout & encourage harvest to reduce overall predation demand in reservoir

- anticipate illegal stocking: implement & enforce disincentives including "must-kill" regulations & severe monetary penalties

Utah Fishing • 2009

REPORT ILLEGAL STOCKING

Whether it's burbot at Flaming Gorge, gizzard shad at Lake Powell, walleye at Red Fleet or catfish in the Green River, the problem's the same: fish have been illegally introduced into waters across Utah.

A few rogue anglers—individuals who want to introduce the fish into new waters for selfish reasons—have negatively affected fishing for everyone.

What's so terrible about adding a few extra fish? You might be surprised.

Ecosystems in turmoil

There are several reasons why moving fish illegally is bad for a fishery. One of the biggest reasons is that some species affect the stability of other fish populations in the lake or reservoir.

This occurred in Flaming Gorge when someone dumped burbot (a type of freshwater cod) above the reservoir. Burbot reproduce quickly and are notorious egg predators. Now, the burbot population—which feeds on kokanee eggs—threatens the future of Flaming Gorge as a world-class kokanee fishery.

Drew Cushing, warm water fisheries coordinator for the Division, notes that it isn't just burbot. "Yellow perch, smallmouth bass and walleye can wreak havoc too," he notes.

"And although these four species are a challenge, **ANY** fish that's illegally stocked can cause problems and affect fishing."

Invasive species and diseases

Diseases and aquatic invasive species are another reason why fish shouldn't be moved.

"Every year, we hear about a devastating disease or invasive species that's causing problems in another state," Cushing says. "Viral hemorrhagic septicemia, quagga mussels, Eurasian milfoil—we don't want them in our waters."

Cushing is concerned that fish brought into Utah from other states, or fish that are moved from one in-state water to another, will spread diseases and species that will lead to big problems for Utah's anglers.

Endangered and native fish

In addition to affecting sport fish, Cushing says illegal introductions can also affect native and endangered fish.

"If the burbot in Flaming Gorge make their way into the Green River, that could become a big problem for endangered fish in the Green and Colorado river systems."

Native populations of cutthroat trout are also at risk if someone introduces the wrong species—or a disease—into the waters where they live.

High removal costs

In the past, the Division used chemicals such as rotenone to eliminate all of the problem fish. This occurred on a large scale in 1990, when it cost the state $3.8 million to treat Strawberry Reservoir.

That treatment removed nearly all of the fish from the reservoir, not just the invasive species, and allowed the Division to start over with cutthroat trout and sterile rainbows. Although Strawberry is a success story, a rotenone treatment of that scope would not happen today.

Cushing notes that, "Rotenone has gotten very expensive. It costs a huge amount today to treat even a small water. And that high cost means we may never be able to treat the state's larger waters again."

Managing illegally stocked fish

Going forward, the Division may stop managing fish that were illegally stocked.

According to Cushing, "Fish that are stocked illegally in a water may not be protected by limits. They'll be treated much the same as carp are treated."

How you can help

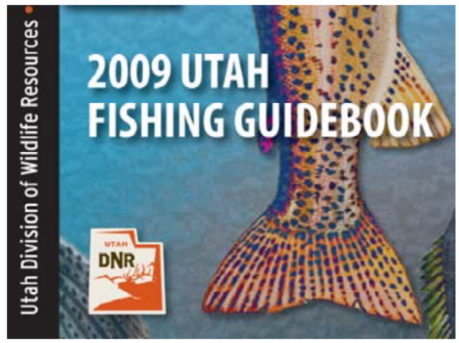
Anglers are the best line of defense in keeping fishing great in Utah for years to come.

If you know that someone has placed fish in a water illegally, please call the Division's Utah Turn in Poachers (UTIP) hotline at 1-800-662-DEER (3337). The line is staffed 24 hours a day, seven days a week. You might even receive a reward for your effort to protect Utah's waters!

If you want to remain anonymous, wildlife officers will honor your request. You can also report illegal fish stocking online at *wildlife.utah.gov/law/hsp/pf.php*.

Fines and jail time

Utah takes illegal fish stocking seriously. Releasing live fish into the wild is a class A misdemeanor. Those who violate this law can receive a fine of up to $2,500, spend up to one year in jail and may be held liable for any damage to the fishery.



Utah Fishing • 2009

WYOMING FISHING REGULATIONS

2008 – 2009

Conserving Wildlife – Serving People

WYOMING GAME AND FISH COMMISSION

YOU CAN HELP PROTECT YOUR FISHERIES

AQUATIC NUISANCE SPECIES

Every water body is a unique ecological system. A fish, aquatic plant, or other aquatic life form that inhabits one stream or lake may cause problems in another. When a new organism arrives it may upset the delicate balance of the system causing ecological or economic harm. The common carp, New Zealand mudsnail, and the whirling disease parasite are well known examples of invasive species that can reduce the quality of Wyoming's fisheries.

There are many harmful plants, fish, amphibians, crustaceans, mollusks, diseases, and parasites, some so small they can travel with you without you even being aware. However, there are simple, precautionary steps you can take every time you leave any body of water to lessen the chance you'll be moving any of them:

- Remove all visible mud, plants, fish, or other animals from equipment.
- Eliminate water from all equipment before you depart.
- Clean and dry anything that came in contact with the water.
- Do not release plants, fish, or other animals into a body of water unless they came out of that water body.

HELP STOP ILLEGAL FISH TRANSPORT!

Due to the significant threat introduced fish species pose to the state's fisheries, the Wyoming Game and Fish Department is increasing enforcement of the laws concerning transportation and introduction of species to new waters. This offense is a misdemeanor that carries a considerable fine and possible jail time.

Wyoming's fisheries have been impacted by illegal introductions in several river basins. Examples include:

- Brook stickleback in the North Platte and Big Horn Rivers.
- Walleye in Lake DeSmet and Casper's Vesness Pond.
- Ling and white suckers in Big Sandy, and Fontenelle Reservoirs, the Big Sandy River, and the Green River below Fontenelle Reservoir.

IT IS UNLAWFUL TO:

- Plant live fish or fish eggs without the consent and supervision of the Wyoming Game and Fish Department.
- Transport live fish or live fish eggs from the water of capture. This includes transporting live fish in the live well of your fishing boat once you are off the water.
- Release aquarium fish or unused baitfish in any Wyoming water!

DRAIN YOUR LIVE WELL!

Large lake trout like this one rely almost exclusively on Kokanee for food.

Kokanee anglers like Morgan Carey will likely see fishing success decline in the future.

The remains of this Kokanee were found in the stomach of a 20 inch burbot this winter.

A large walleye and brown trout captured in Sulphur Creek Reservoir during 2007.

“We’re going to miss kokanee in Colorado”

- typically stocked as fry (< 500/lb @ ~2 in.TL = “put-&-grow”)
- well suited to reasonably productive fluctuating reservoirs
- simple food-web ecology & prey requirements
- highly popular with anglers in many reservoirs
- summer troll, fall snag/fly & winter ice fisheries
- typically high economic impact (boats)
- unique reproductive strategy (imprinting, homing, migration)

“We’re going to miss kokanee in Colorado”

- largely whirling disease resistant

- typically non-invasive; not problematic in adjacent waters

- no threat to native fishes

- no hybridization with native fish or sport fish stocks

- no predation on other fish; generally “play nice”

- highest energy density among coldwater prey

- lowest propensity for contaminant bioaccumulation (e.g. Hg)

APPENDIX B

TEMPERATURE AND DISSOLVED OXYGEN PROFILES, AND SECCHI DEPTHS MEASURED IN RESERVOIRS IN 2008

Table B-1. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Blue Mesa Reservoir on 01 July 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Blue Mesa 01 July 2008					
	P1 (22.0m)		P2 (57.0m)		P3 (93.0m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	17.6	5.1	18.4	5.6	18.7	5.4
1	16.5	5.1	17.8	5.7	17.3	5.4
2	16.2	5.1	17.4	5.8	17.0	5.5
3	16.1	5.1	17.2	5.7	16.9	5.5
4	16.0	5.1	17.0	5.7	16.8	5.6
5	16.0	5.1	16.8	5.5	16.4	5.4
6	15.9	5.1	16.0	5.5	16.2	5.3
7	15.1	5.0	15.3	5.4	14.8	5.2
8	14.8	5.0	14.2	5.3	14.2	5.1
9	14.7	5.1	13.2	5.2	13.1	5.0
10	13.6	5.0	12.7	5.2	12.5	5.1
11	13.4	5.0	12.4	5.2	12.1	5.1
12	13.0	5.0	12.2	5.4	11.8	5.3
13	12.8	5.0	12.0	5.1	11.6	5.4
14	12.6	5.1	11.7	5.2	11.5	5.3
15	12.5	5.0	11.5	5.1	11.3	5.4
16	12.2	4.9	11.3	5.1	11.3	5.4
17	12.0	4.9	11.2	5.1	11.2	5.4
18	11.6	4.8	11.1	5.1	11.1	5.4
19	11.4	4.7	11.0	5.1	11.0	5.4
20	11.3	4.5	11.0	5.1	10.9	5.5
25			10.4	5.0	10.5	5.7
30			10.2	5.0	10.0	5.7
35			8.6	4.8	9.4	5.7
40			6.9	4.7	7.8	5.6
45			6.5	4.5	6.4	5.6
50			6.2	4.4	5.8	5.5
55			6.1	4.2	5.4	5.5
60					5.4	5.1
Secchi (m)	3.62		4.10		4.61	

Table B-2. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Dillon Reservoir on 27 August 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Dillon 27 August 2008									
	P1 (7.9m)		P2 (29.0m)		P3 (17.4m)		P4 (23.9m)		P5 (13.7m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	16.4	6.7	15.3	8.7	16.0	6.9	15.3	6.9	16.2	7.0
1	16.3	6.6	15.3	8.7	16.0	6.9	15.2	7.2	16.1	6.9
2	16.0	6.6	15.3	8.1	15.9	7.0	15.2	7.3	16.1	7.0
3	15.7	6.6	15.2	8.1	15.9	7.0	15.1	6.9	16.1	7.0
4	15.6	6.6	15.2	8.0	15.8	7.0	14.9	6.8	16.1	7.1
5	15.1	6.6	15.2	8.0	15.8	7.0	14.6	6.9	16.1	7.1
6	15.1	6.6	15.2	8.0	15.6	6.9	14.0	6.7	15.9	7.2
7	14.9	6.6	15.0	7.6	14.8	6.8	13.8	6.6	14.7	6.7
8			14.9	8.1	14.6	6.7	13.6	6.5	14.4	6.4
9			14.9	8.2	14.4	6.7	13.2	6.4	13.6	6.0
10			14.4	8.1	14.1	6.4	12.9	6.4	13.1	5.9
11			14.1	7.8	13.8	6.3	12.7	6.4	12.6	5.9
12			13.9	7.7	13.0	6.2	12.4	6.3	12.5	5.8
13			13.6	6.9	12.5	6.2	11.0	6.3	12.0	5.6
14			13.4	6.7	11.7	5.9	10.3	6.2		
15			13.3	6.7	11.0	5.6	10.1	6.1		
16			13.2	6.7	10.2	5.6	9.8	6.0		
17			13.1	6.5	9.9	5.6	9.6	6.1		
18			12.6	6.8			9.6	6.1		
19			12.2	6.7			9.1	6.0		
20			12.0	6.7			8.6	6.1		
25			8.6	6.2						
Secchi (m)	0.65		N/A		4.58		N/A		N/A	

Table B-3. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Granby Reservoir on 04 July 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Granby 04 July 2008									
	P1 (32.0m)		P2 (40.2m)		P3 (22.3m)		P4 (12.4m)		P5 (23.1m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	15.9	7.6	15.8	7.2	15.5	8.1	15.9	7.0	15.7	7.7
1	15.9	7.5	15.7	7.2	15.5	7.8	15.5	7.0	15.7	7.5
2	15.9	7.6	15.6	7.3	15.4	7.7	15.3	7.1	15.7	7.4
3	15.8	7.1	15.6	7.3	15.3	7.6	15.1	7.0	15.6	7.3
4	15.7	7.4	15.5	7.3	15.3	7.4	14.8	6.8	15.4	7.4
5	15.6	7.4	14.8	7.1	15.3	7.3	14.6	6.9	15.3	7.4
6	15.1	7.3	14.0	6.9	15.6	7.2	14.3	6.6	15.0	7.3
7	14.1	7.0	13.5	6.6	14.7	7.0	14.0	6.6	14.2	7.4
8	13.0	6.7	13.0	6.6	13.0	6.7	13.7	6.3	13.1	6.8
9	12.0	6.5	12.4	6.4	12.4	6.4	13.6	6.2	12.6	6.4
10	10.8	6.4	12.0	6.3	11.4	6.2	13.3	6.2	12.2	6.3
11	10.2	6.3	11.1	6.1	11.0	6.0	12.1	6.0	11.9	6.3
12	9.5	6.2	10.3	6.1	10.6	6.1	11.1	5.2	11.5	6.2
13	9.4	6.2	10.0	6.1	10.2	6.1			10.7	6.0
14	9.4	6.1	9.7	6.1	10.0	6.0			10.2	5.9
15	9.1	6.1	9.4	6.1	9.4	5.9			9.8	5.8
16	9.0	6.1	8.9	6.2	9.0	6.1			9.7	5.7
17	8.9	6.0	8.8	6.1	9.1	6.0			9.5	5.7
18	8.6	6.1	8.7	6.1	8.5	6.0			9.2	5.6
19	8.5	6.1	8.6	6.0	8.1	5.9			8.8	5.5
20	8.1	6.0	8.1	5.9	7.8	5.6			8.5	5.4
25	7.2	6.0	7.2	5.9						
30	6.8	5.6	7.0	5.8						
35			6.9	5.7						
Secchi (m)	2.67		2.55		2.13		2.71		2.11	

Table B-4. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Granby Reservoir on 28 August 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Granby 28 August 2008									
	P1 (19.8m)		P2 (11.4m)		P3 (15.5m)		P4 (29.6m)		P5 (32.1m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	16.3	6.9	17.0	6.6	17.0	7.1	17.3	6.6	17.6	6.7
1	16.4	6.7	17.0	6.6	17.0	6.9	17.1	6.5	17.3	6.6
2	16.5	6.6	16.9	6.6	17.0	6.8	16.8	6.4	17.1	6.6
3	16.5	6.6	16.9	6.6	17.0	6.8	16.7	6.3	17.1	6.6
4	16.5	6.5	16.8	6.3	17.0	6.8	16.6	6.2	17.1	6.6
5	16.4	6.4	16.8	6.4	17.0	6.7	16.6	6.2	17.1	6.6
6	16.4	6.4	16.8	6.3	17.0	6.7	16.6	6.2	17.1	6.6
7	16.4	6.4	16.8	6.3	16.9	6.5	16.5	6.1	17.0	6.6
8	16.3	6.3	16.8	6.4	16.2	5.6	16.5	6.0	17.0	6.5
9	16.2	6.3	16.0	5.6	15.2	5.0	16.2	5.8	14.9	4.9
10	15.5	5.8	14.9	4.3	14.8	4.9	15.3	5.1	3.0	4.2
11	15.1	4.9	14.2	4.1	14.1	4.6	14.4	4.5	11.4	4.2
12	14.5	4.7			13.4	4.3	12.9	4.0	11.2	4.2
13	13.0	3.8			12.6	4.0	12.6	4.0	10.4	4.3
14	12.4	3.7			11.4	4.0	10.3	3.9	9.8	4.5
15	11.2	3.6			10.3	4.0	9.8	3.9	9.2	4.6
16	10.2	3.5					9.6	4.1	8.9	4.7
17	9.8	3.4					9.5	4.0	8.6	4.5
18	9.8	3.3					8.8	4.0	8.3	4.4
19	9.5	3.2					8.6	4.0	8.2	4.4
20							8.5	3.9	8.0	4.4
25							8.3	3.9	7.7	4.3
30									7.6	3.7
Secchi (m)	3.45		4.04		4.08		4.48		4.32	

Table B-5. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Rifle Gap Reservoir on 04 June 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Rifle Gap 04 June 2008					
	P1 (16.4m)		P2 (14.6m)		P3 (12.9m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	16.57	7.8	16.1	7.8	16.3	7.3
1	16.4	8.8	16.1	7.7	16.3	7.2
2	15.9	9.5	16.1	7.8	16.3	7.5
3	15.8	9.5	16.1	7.8	16.3	7.3
4	15.7	9.3	16.0	7.9	16.2	7.2
5	15.2	8.8	14.9	7.9	15.6	7.0
6	13.4	8.7	13.5	7.8	13.4	6.4
7	12.3	8.6	12.2	7.6	12.7	6.5
8	12.0	8.2	11.4	7.5	12.0	6.5
9	11.3	7.9	11.1	7.4	11.7	6.5
10	10.7	7.6	10.8	7.2	11.3	6.4
11	10.1	7.1	10.5	7.1	10.5	5.9
12	9.9	6.6	10.3	7.0	9.9	4.5
13	9.7	6.4	10.0	6.3		
14	9.5	6.0	9.7	4.8		
15	9.4	5.4				
16	9.4	5.1				
Secchi (m)	2.04		2.11		2.05	

Table B-6. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Rifle Gap Reservoir on 19 August 2008. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	Rifle Gap 19 August 2008					
	P1 (13.3m)		P2 (11.7m)		P3 (11.6m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	21.0	7.1	21.2	7.6	21.1	7.8
1	20.6	7.1	20.8	7.5	21.0	7.6
2	20.5	7.1	20.7	7.4	20.8	7.6
3	20.4	7.1	20.6	7.2	20.7	7.6
4	20.4	7.1	20.5	7.2	20.6	7.6
5	20.3	7.1	20.5	7.1	20.5	7.4
6	20.3	7.1	20.4	7.1	20.3	7.0
7	20.2	7.2	20.1	6.6	20.0	6.6
8	19.2	6.2	19.6	6.1	19.5	6.1
9	18.6	5.7	18.7	5.3	19.0	5.8
10	17.9	4.7	17.5	4.3	17.7	4.5
11	16.5	3.5	17.0	3.9	16.4	2.9
12	15.4	2.9				
13	13.3	1.2				
Secchi (m)	4.75		4.71		4.43	

Table B-7 **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Rifle Gap Reservoir on 09 October 2008. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Rifle Gap 09 October 2008					
	P1 (12.7m)		P2 (10.3m)		P3 (10.2m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	14.6	8.2	14.7	8.4	14.9	8.9
1	14.6	8.3	14.7	8.5	14.7	8.9
2	14.6	8.3	14.6	8.6	14.6	9.0
3	14.6	8.1	14.6	8.7	14.6	9.0
4	14.5	8.4	14.6	8.6	14.6	9.0
5	14.5	8.4	14.6	8.5	14.6	8.9
6	14.5	8.4	14.5	8.6	14.5	9.1
7	14.5	8.5	14.5	8.6	14.5	9.1
8	14.5	8.2	14.5	8.7	14.4	9.1
9	14.5	8.4	14.5	8.2	14.4	8.9
10	14.4	8.4			14.3	8.6
11	14.4	8.4				
12	14.2	8.3				
Secchi (m)	4.30		4.57		4.56	

Table B-8. **Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Taylor Park Reservoir on 02 July 2008. Values in parenthesis denote maximum water depth at station.**

Water Depth (m)	Taylor Park 02 July 2008									
	P1 (11.8m)		P2 (27.6m)		P3 (35.4m)		P4 (13.6m)		P5 (10.7m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	17.1	8.7	16.4	7.2	16.4	7.0	15.8	7.8	15.3	7.3
1	15.8	8.7	15.7	7.3	15.2	7.1	15.5	7.4	15.4	7.7
2	15.0	8.3	15.5	7.4	15.1	7.2	14.4	7.5	15.3	7.8
3	14.6	8.1	15.2	7.3	14.1	7.2	14.4	7.6	15.1	7.9
4	14.0	8.1	13.9	7.1	12.2	7.3	13.2	7.6	14.3	7.9
5	11.7	8.0	11.6	7.2	11.7	7.1	12.5	7.5	14.1	7.8
6	11.0	7.8	11.1	7.1	11.5	7.1	12.4	7.4	13.0	7.8
7	10.1	7.5	10.7	7.1	11.0	7.1	11.9	7.4	11.9	7.4
8	10.0	7.4	10.5	7.0	10.6	7.1	11.1	7.3	11.1	7.5
9	9.4	7.5	10.4	7.0	10.1	7.1	10.6	7.3	9.8	7.3
10	9.1	7.5	10.1	6.9	9.8	7.1	10.0	7.1	9.3	7.1
11	9.0	7.5	10.0	7.0	9.6	7.1	9.0	7.2		
12			9.9	7.0	9.4	7.1	9.0	7.2		
13			9.8	7.0	9.1	7.1	8.8	6.3		
14			9.7	7.0	8.8	7.1				
15			9.6	7.1	8.7	7.1				
16			9.4	7.1	8.4	7.1				
17			9.3	7.1	8.3	7.1				
18			9.0	7.1	8.1	7.1				
19			8.7	7.0	8.0	6.9				
20			8.4	7.0	7.9	6.9				
25			7.8	7.1	7.7	6.8				
30					7.5	6.7				
35					7.3	6.5				
Secchi (m)	2.66		2.47		2.27		2.39		N/A	