Coldwater Reservoir Ecology

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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 sonar surveys on Blue Mesa, Elevenmile, Granby, Green Mountain, McPhee, Vallecito, and Williams Fork reservoirs.

Segment Objective 2: Perform sonar surveys on Taylor Park, Ridgeway, Horsetooth and Carter Reservoirs, as needed or feasible.

INTRODUCTION

Appendix A provides a review of the development of the hydroacoustic program for mobile surveys on Colorado's reservoirs. This review presented on 7 February 2007 was provided to Colorado Division of Wildlife fishery personnel involved with management and research on the state's coldwater reservoir fisheries, particularly kokanee and their egg source waters. Other topics included the utility of sonar in assessing predator-prey dynamics and trout populations in smaller waters, including backcountry cutthroat trout lakes (K. Rogers, personal communication). Part of the purpose of this review was to inform key personnel that I would be cutting back on the number of sonar surveys performed by my crew in 2007 to make time for data analyses and manuscript preparation. In addition, zooplankton, *Mysis,* limnological profile, and kokanee spawn run sampling and analyses would also be largely suspended beginning in 2007 (Appendix A). Thus, continuing sonar surveys and the other sampling on coldwater reservoirs would fall to other personnel.

METHODS and MATERIALS

Sonar surveys were performed on 11 reservoirs in 2006. These included: Blue Mesa (24-25 July), Carter (12 September), Elevenmile (21 August), Granby (22 August), Green Mountain (24 August), Horsetooth (11 September), McPhee (August 1), Taylor Park (July 26), Vallecito (2 August), Vega (29 September), and Williams Fork (23 August). This represented the greatest number of reservoirs receiving sonar surveys since Colorado began performing standardized sonar surveys in 1994 (Appendix A). Most surveys were performed at night, and were scheduled around the new moon, with the exception of conducting both night and day surveys at Vallecito Reservoir and the daytime survey at Vega Reservoir. 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 Yamaha outboard during the surveys. In addition, a six-degree, side-looking transducer was multi-plexed with the down-looker for surveys at Carter, Horsetooth and Vega Reservoirs (Appendix A) Standardized transects (Appendix B) were followed using a Garmin 165 GPS that also fed latitude and longitude coordinates to the PC every five seconds. Data analysis was performed by Kevin Rogers, CDOW Aquatic Researcher. Due to the emerging use of side-looking sonar in Colorado, the analysis of surveys for those waters which included side-looking data (Carter, Horsetooth and Vega) will be delayed as Kevin develops a program for analyzing the data acquired with the side-looking transducer.

RESULTS and DISCUSSION

Numbers of pelagic fish estimated in sonar surveys of reservoirs in 2006 were: Blue Mesa, 573,827; Elevenmile, 63,303; Granby, 207,097; Green Mountain, 88,450; McPhee, 521,983; Taylor Park, 20,323; Vallecito, 140,791; and Williams Fork, 101,541. Key concerns from these 2006 data were the lower estimates of pelagic fish than those in 2005 for Blue Mesa (623,274) and Granby (323, 418). Because Blue Mesa and Granby are the key sources of kokanee egss in Colorado (Martinez 2005), downward trends in pelagic fish abundance, indicative of primarily fewer kokanee, may foretell lower egg production.

A recent concern in the collection of sonar data may influence pelagic fish estimates. While collecting sonar data, it appears that the computer ceases recording trackable fish target into the FSH file upon exceeding about 60,000 to 80,000 echoes. This threshold is typically reached in deeper water, >50m, in more productive coldwater reservoirs, such as Blue Mesa (Table 1), which may result in more “noise” at depth. While transects lengths vary, acoustic data is typically derived from 4,000-7,500 pings (Table 1), with the number of pings being partly influenced by the effects of water conditions and driver experience on boat speed consistency. Regardless, once the apparent “limit” of echoes is exceeded, what appear to be tracked fish on the computer screen pass from the echogram without being recorded in the FSH file as fish. Examining suspect FSH files reveals that, indeed, only the number of fish shown as counted on the screen once processing is stopped at the end of a transect are captured as tracked fish. Efforts are underway to resolve this problem.

Table 1. Sonar data acquisition (pings, echoes and fish) from standardized transects (T#) at Blue Mesa, Granby, McPhee, Taylor Park, and Vallecito reservoirs, Colorado, 2003-2006. Shaded cell denote ≥ 60,000 echoes.

T#	**2003**			**2004**			**2005**			**2006**		
	Ping	**Echo**	**Fish**	**Ping**	**Echo**	**Fish**	**Ping**	**Echo**	**Fish**	**Ping**	**Echo**	**Fish**
Blue Mesa												
01	6,990	67,698	296	6,510	29,864	515	9,128	43,606	838	6,299	63,223	214
02	6,913	148,114	183	7,083	127,164	111	7,882	134,440	243	7,479	149,925	127
03	5,080	54,517	645	5,296	49,343	612	6,540	5,822	231	5,614	99,273	842
04	5,875	103,519	34	6,509	105,491	163	7,471	4,779	262	6,460	126,664	60
05	5,585	121,143	297	5,829	68,542	990	6,554	5,529	275	6,268	111,191	277
06	5,082	69,680	949	5,082	26,922	445	6,856	5,933	309	5,333	67,479	86
07	5,452	30,554	1,839	5,748	24,812	907	5,987	37,795	2,172	7,491	73,141	806
08	5,788	19,774	991	5,819	7,974	423	5,796	39,205	1,523	7,033	17,495	371
09	5,730	32,847	2020	6,248	19,177	869	5,706	24,572	1504	7,157	43,623	1,383
10	5,136	51,421	1,485	5,366	22,772	1,279	5,734	10,174	286	6,053	41,857	530
11	5,485	18,345	1,115	6,305	11,215	654	5,264	29,604	472	6,597	27,166	722
12	8,673	4,312	159	9,639	4,162	263	8,510	2,939	208	10,146	6,048	293
13	5,824	868	36	5,991	761	61	4,634	315	25	6,066	3,300	238
14	5,866	159	6	5,192	1080	113	5,292	443	46	5,917	3,439	294
15	4,120	3,211	154	6,231	276	18	5,316	1,657	83	5,189	1,712	149
Sum	87,599	726,162	10,209	92,848	499,555	7,423	96,670	346,813	8,477	99,102	835,536	6,392
Granby												
01	2.428	1,243	89	3,133	1,027	131	3,663	1,219	114	3,710	1,189	108
02	4,478	11,421	710	5,644	657	63	5,545	2.259	116	6,265	1,109	79
03	2,092	15,004	1,090	6,220	1,440	104	5,693	7,227	333	5,795	1,301	79
04	4,402	32,210	996	5,692	1,657	48	5,297	12,652	457	6,114	2,569	107
05	4,654	84,364	1,019	5,824	16,815	1,035	5,042	41,072	144	5,388	2,339	104
06	3,820	46,618	900	5,104	2.076	49	4,923	17,377	594	4,943	7,781	429
07	3,262	18,334	780	4,319	1,056	41	4,012	4,465	204	4,319	2,441	154
08	4,903	19,385	944	6,558	1,739	108	6,348	10,591	372	6,415	3,165	203
09	4,776	7,946	225	6,027	1,572	132	5,600	4,551	203	5,724	1,942	71
10	4,320	16,183	514	5,780	360	19	5,863	2,908	148	5,394	1,713	61
Sum	36,709	252,708	7,267	54,301	26,325	1,730	51,986	102,064	2,685	54,067	25,549	1,395
McPhee												
01	5,919	139,303	3	8,023	74,756	3,078	6,195	112,544	237	7,494	109,605	929
02	4,630	60,912	2,499	5,162	21,610	1,173	7,516	105,999	636	5,146	52,732	2,376
03	6,034	26,556	1,523	6,504	4,072	193	5,055	34,279	1,416	6,875	14,832	784
04	5,441	1,761	108	1,357	263	19	6,786	13,934	489	6,100	1,670	143
05	9,369	1,278	75	6,053	1,731	96	5,842	2,442	217	6,872	1,223	116
06	5,356	1,405	117	5,680	2061	205	6,857	2,173	163	5,924	3,208	294
Sum	36,749	231,215	4,325	32,779	104,493	4,764	38,251	271,371	3,158	38,411	183,270	4,642
Taylor Park												
01	4,583	40,255	2,784	6,977	350	15	5,806	2,653	52	6,043	5,101	108
02	5,418	11,135	661	7,654	676	25	6,866	955	40	6,631	899	50
03	5,127	1,831	34	6,124	?	55	5,952	335	26	5,900	369	23
04	5,546	1,626	15	5,933	8,634	328	6,250	99	10	6,581	251	23
Sum	20,674	54,847	3,494	26,688		423	24,874	4,042	128	25,155	6,620	204
Vallecito												
01	5,440	8,373	515	6,877	3,576	239	5,763	6,279	484	5,843	5,117	464
02	4,588	2,394	213	7,739	5,877	357	5,309	1,842	145	5,274	5,866	606
03	4,962	2,394	99	5,253	1,419	103	4,437	419	23	4,418	797	74
04	5,855	208	14	6,550	2,848	224	5,543	708	66	5,604	3,511	367
Sum	20,845	13,369	841	26,419	13,720	923	21,052	9,248	718	21,139	15,291	1,511

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: Measure lengths and weights, and collect otoliths from mature kokanee at Blue Mesa, Elevenmile, Granby, McPhee, Shadow Mountain, Vallecito, and Williams Fork Reservoirs; and in Green Mountain if feasible.

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). Validation of kokanee ages, determined by surface aging of otoliths, had been underway via tetracycline marking of kokanee fry at the Roaring Judy Hatchery prior to their release into Blue Mesa Reservoir. Previously, validation of annuli in kokanee otoliths had been confirmed by three kokanee specimens that were six years old at time of their collection from McPhee Reservoir in 1993. These individuals were identified by their semi-mature appearance and larger size resulting from their having been treated with methyltestosterone to impart sterility and longevity prior to their stocking in 1988 (Martinez 1994). In addition to age validation, tetracycline marking of kokanee was performed to help determine if mature kokanee bypassing the Roaring Judy Hatchery and ascending further up the drainage into Slate Creek near Crested Butte were from hatchery stocks or if they were a sub-population sustained by natural reproduction.

METHODS and MATERIALS

Length, weight, and both otoliths (occasionally only one otolith could be found) were collected from mature kokanee at several spawn runs in 2006. Samples were taken from the Blue Mesa Reservoir spawn run at the Roaring Judy Hatchery on six dates (3, 11, 17, 24, and 30 October, and 7 November) and in Slate Creek on 12 October. At Elevenmile Reservoir, samples were collected on five dates: 11, 17, 24 and 30 October, and 2 November. Typically, these samples are obtained randomly, but at Elevemile a shortage of male kokanees required that those available be retained for egg fertilization, thus the 2006 sample contained disproportionately few males. The spawn run from Granby Reservoir was sampled at the kokanee trap on the Colorado River below the dam at Shadow Mountain Reservoir on six dates: 2, 6, 13, 20 and 27 November, and on 5 December. Kokanee were sampled in the Dolores River spawn run from McPhee Reservoir at the Old Dolores Hatchery site on two dates, 1 and 9 November. At Vallecito Reservoir, kokanee were sampled on one date only in the spawn run in Grimes Creek, 24 October, due to a limited run. Williams Fork Reservoir was sampled on three dates: 12, 16 and 23 October. The procedure for determining the age of these otoliths is described in Martinez (2002).

Table 2 provides details (from Dan Brauch, Colorado Division of Wildlife, Fishery Biologist) of marking kokanee by feed-administered tetracycline at Roaring Judy Hatchery in 2002 and 2003. Prior to stocking, kokanee were inspected for marks and mark intensity (Martinez 2002, 2003) and ranked as described in Table 2. Of the kokanee examined for marks in 2002, 99% had “excellent” marks. In 2003, 85% of the kokanee examined displayed “good” to “excellent” marks. To detect marks, carcasses of about 500 mature kokanee were examined each year in the spawn runs of 2005 and 2006. Technicians used a Morech Model 0224-01 Autopsy Saw fitted with a Part no. BD0224-02 Round Blade to cross-section frozen to partially-thawed carcasses along the spine for examination for tetracycline marks fluoresced with a black light.

Table 2 also describes the method of examining carcasses for the presence and intensity of tetracycline marks, however, presence or absence of a mark was the primary criteria. Kokanee stocked in 2002 would have entered the 2005 spawn run as mature fish at 4 years old in 2005 and as 5 year-olds if they survived into 2006. Kokanee stocked in 2003 could have entered the 2005 spawn run at age 3 or the 2006 spawn run as age 4 fish. Technicians were uninformed about the years in which the kokanee had been marked so that they were examining the carcasses “blind” of that information. As indicated in Table 2, two technicians examined marks and conferred on mark presence and intensity.

RESULTS and DISCUSSION

Length frequencies, mean lengths, and sex and age composition of mature kokanee sampled in spawn runs in 2005 are found in Tables 3-16. Martinez (2006a) described the utility of examining the size and age structure in kokanee spawn runs as it relates to population trends and egg production. Additionally, knowing the age of kokanee cohorts is also proving useful in documenting the trend or fate of annual kokanee plants. For example, CDOW Senior Fishery Biologist, Mike Japhet, was preparing a response in June 2006 for local anglers regarding the recently poor angling success for kokanee in Vallecito Reservoir. Below is the information I provided to him, illustrating how kokanee size and age structure data can contribute to providing insight (or hindsight) into past events affecting kokanee year class strength.

1.) All indices suggest that the kokanee population in Vallecito is presently low compared to past years. Furthermore, this information coincides with an abrupt drop in kokanee numbers in 2003.

2.) Sonar surveys in the late 1990s would average 80,000 to 100,000 targets (primarily kokanee). In the early 2000s, this number was close to 60,000 pelagic fish. In 2004 and 2005, we have seen the lowest numbers of kokanee in the annual sonar to date, between about 20,000 to 30,000 fish. We performed a sonar survey in 2003, just before the die-off and documented kokanee numbers similar to the surveys in 2000 and 2001, about 60,000.

Table 2. Descriptions of procedures for tetracycline-marking of kokanee at Roaring Judy hatchery prior to their release into Blue Mesa Reservoir in 2002 and 2003, including the examination and ranking of mark intensity before stocking and upon return of mature kokanee to the hatchery subsequent spawn runs in 2005 and 2006.

2002
- Treated kokanee at a size of 400-600/lb. - Feed contained 4g of active OTC per pound of feed. Treatment was four days with treated feed, one day on regular feed, and then an additional four days on treated feed. - First batch treated at 16 g active OTC / 100 lbs of fish or 4% feed rate per day (352 mg/kg/day). Treated at a rate of 10 g active OTC / 100 lbs fish or 2.5% feed rate per day for all other batches (220 mg/kg/day). - Fish treated in production tanks with 100,000 to 130,000 kokanee each. - 230 kokanee assessed for marks prior to release (at 1 to 20 days post treatment). 227 were rated to have “excellent” mark (99%), 3 were rated to have “poor” mark, and 0 had no mark.
2003
- Treated kokanee at a size of 500-1000/lb. - Feed contained 4g of active OTC per pound of feed. Treatment was four days with treated feed, one day on regular feed, and then an additional four days on treated feed. - First batch treated at 5 g active OTC / 100 lbs of fish or 1.25% feed rate per day (110 mg/kg/day). - Fish treated in production tanks with 100,000 to 130,000 kokanee each. - 420 kokanee assessed for marks prior to release. 4 were rated to have “excellent” mark (1%, standard of “excellent” was mark strength from most kokanee treated in 2002), 353 were rated to have “good” mark, 63 were rated to have “poor” mark (15%) and 0 had no mark. Strength of mark was not at all correlated to size at date of treatment for this group of kokanee (at a size of 500-1000 / lb). - We did have four small troughs with a very thin density of kokanee that we marked with much less success (most kokanee were marked, but most had a “poor” rating). It was felt that they just did not feed very well during the treatment.
Rating of detected tetracycline marks (Christina Santana, personal communication)
- 0 are fish that had absolutely no marks at all - 1 are fish that had few visible marks and the marks that were found were extremely faint - 2 are fish that had faint marks visible throughout the spine OR fish that had medium strength marks in only a few visible locations - 3 are fish that had strong marks visible throughout the spine - Two technicians double-checked each other’s work on a regular basis throughout the identification process to make sure that we were consistent in our classification. He and I discussed the possibility of marks appearing differently depending on the precision of the cut through the spine. We questioned the accuracy of the scale that we used because some marks may appear lighter or darker depending on the exact location of the spinal cut. I think that 3 categories may have been better, lumping 1&2 together. The 3’s were obvious and the 0’s were obvious, but the 1’s and 2’s weren’t as clear.

Table 3. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 3, 11, 17, 24 and 30 October, and 7 November 2006 in the Roaring Judy Hatchery spawn run from Blue Mesa Reservoir.

Roaring Judy Hatchery 2006										
Age	**Statistic (total length in mm)**	**3 October**			**11 October**			**11 October (second sample)**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	33	30	63	26	30	56	40	27	67
	Mean length	406	428	416	401	437	420	419	432	424
	Length range	363-470	377-453	363-453	365-442	391-473	365-473	379-470	409-455	379-470
	Percent	34%	31%	64%	27%	31%	58%	40%	27%	67%
4	**n**	17	18	35	26	15	41	15	18	33
	Mean length	440	462	451	436	466	447	445	479	464
	Length range	415-463	414-491	414-491	433-480	417-509	417-509	420-477	434-588	420-588
	Percent	17%	18%	36%	27%	15%	42%	15%	18%	33%
All	**n**	50	48	98	52	45	97	55	45	100
	Mean length	417	440	429	419	447	432	426	451	437
	Length range	363-470	377-491	363-491	365-480	391-509	365-509	379-477	409-588	379-588
	Percent	51%	49%	100%	54%	46%	100%	55%	45%	100%

Age	**Statistic (total length in mm)**	**17 October**			**24 October**			**30 October**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	32	28	60	29	34	63	27	40	67
	Mean length	411	427	419	398	424	412	390	422	409
	Length range	350-479	388-458	350-458	318-432	380-492	318-492	340-435	393-452	340-452
	Percent	32%	28%	60%	31%	37%	68%	27%	40%	67%
4	**n**	18	22	40	16	14	30	12	21	33
	Mean length	446	460	453	438	458	448	420	449	438
	Length range	420-475	423-491	420-491	420-465	400-497	400-497	361-442	410-486	361-486
	Percent	18%	22%	40%	17%	15%	32%	12%	21%	33%
All	**n**	50	50	100	45	48	93	39	61	100
	Mean length	424	441	433	412	434	423	399	431	419
	Length range	350-479	388-491	350-491	318-465	380-497	318-497	340-442	393-486	393-486
	Percent	50%	50%	100%	48%	52%	100%	39%	61%	100%

Table 3. (CONTINUED) Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 3, 11, 17, 24 and 30 October, and 7 November 2006 in the Roaring Judy Hatchery spawn run from Blue Mesa Reservoir.

Roaring Judy Hatchery 2006							
Age	**Statistic (total length in mm)**	**7 November**			**All Dates**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	37	39	76	224	228	452
	Mean length	403	430	416	404	429	417
	Length range	336-479	337-489	336-489	318-479	337-492	318-492
	Percent	37%	39%	76%	33%	33%	66%
4	**n**	13	11	24	117	119	236
	Mean length	429	452	439	436	461	449
	Length range	386-461	432-475	386-475	361-465	400-509	361-509
	Percent	13%	11%	24%	17%	17%	34%
All	**n**	50	50	100	341	347	688
	Mean length	409	435	422	415	440	428
	Length range	336-479	337-489	336-489	318-479	337-588	318-588
	Percent	50%	50%	100%	50%	50%	100%

Table 4. Length frequency, age (determined from otolith) and sex composition of mature kokanee collected in the Roaring Judy Hatchery spawn run from Blue Mesa Reservoir on 3, 11, 17, 24 and 30 October, and 7 November 2006.

Blue Mesa 2006					
Total length (mm)	**Age 3 - 66%**		**Age 4 - 34%**		**Totals**
	Female	**Male**	**Female**	**Male**	
320	1				1
330					
340	2	1			3
350	3				3
360	1				1
370	9		1		10
380	15	2			17
390	22	2	2		26
400	51	11		1	63
410	42	13	2	1	58
420	30	47	14	5	96
430	15	57	23	5	100
440	16	42	23	15	96
450	7	29	26	9	71
460	4	16	17	23	60
470	4	5	6	22	37
480	2	1	3	17	23
490		1		9	10
500		1		5	6
510				4	4
520				2	2
530					
540					
550					
560					
570					
580					
590				1	1
Total fish	**224**	**228**	**117**	**119**	**688**
	452		**236**		
Mean length (mm)	**405**	**428**	**437**	**461**	**428**
	417		**449**		

Table 5. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 12 October 2006 from the Slate River spawn run from Blue Mesa Reservoir.

Slate River 2006				
Age	**Statistic (total length in mm)**	**12-Oct-06**		
		Female	**Male**	**Both**
3	**n**	26	36	62
	Mean length	399	420	411
	Length range	363-478	376-472	363-478
	Percent	27%	38%	65%
4	**n**	23	11	34
	Mean length	433	465	444
	Length range	396-479	445-503	396-503
	Percent	24%	11%	35%
All	**n**	49	47	96
	Mean length	415	431	423
	Length range	363-479	376-503	363-503
	Percent	51%	49%	100%

Table 6. Length frequency, age (determined from otolith) and sex composition of mature kokanee collected in the Slate River spawn run from Blue Mesa Reservoir on 12 October 2006.

Slate River 10/12/06					
Total length (mm)	**Age 3 -**	**65%**	**Age 4 -**	**35%**	**Totals**
	Female	**Male**	**Female**	**Male**	
370	3				3
380	2	2			4
390	7	3			10
400	3	3	1		7
410	4	5	1		10
420	3	5	2		10
430	2	4	10		16
440	1	5	2		8
450		6	3	2	11
460		2	2	3	7
470			1	3	4
480	1	1	1	1	4
490				1	1
500					
510				1	1
Total fish	**26**	**36**	**23**	**11**	**96**
	62		**34**		
Mean length (mm)	**399**	**420**	**433**	**465**	**423**
	411		**444**		

Table 7. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 11, 17 and 30 October, and 2 November 2006 in the South Platte River spawn run from Elevenmile Reservoir. Note deliberate selection against males on dates during the middle of the spawn run in an effort to preserve male numbers for fertilization of eggs. This selection obviously eliminated randomness of these samples on those dates and thus, this overall data set does not accurately reflect the sex ratio in this spawn run.

Elevenmile 2006										
Age	**Statistic (total length in mm)**	**11 October**			**17 October**			**24 October**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	45	38	83	97	3	100	99	1	100
	Mean length	444	477	459	447	500	449	449	478	449
	Length range	393-501	427-535	393-535	384-498	474-538	384-538	378-495	478	378-495
	Percent	54%	46%	100%	97%	3%	100%	99%	1%	100%
All	**n**	45	38	83	97	3	100	99	1	100
	Mean length	444	477	459	447	500	449	449	478	449
	Length range	393-501	427-535	393-535	384-498	474-538	384-538	378-495	478	378-495
	Percent	54%	46%	100%	97%	3%	100%	99%	1%	100%
Age	**Statistic (total length in mm)**	**30 October**			**2 November**			**All Dates**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
2	**n**					3	3		3	3
	Mean length					366	366		366	366
	Length range					348-381	348-381		348-381	348-381
	Percent					2%	2%		1%	1%
3	**n**	100		100		135	135	341	177	518
	Mean length	450		450		471	471	358	385	456
	Length range	400-505		400-505		368-532	368-532	378-505	427-538	378-538
	Percent	100%		100%		98%	98%	65%	34%	99%
All	**n**	100		100		138	138	341	180	521
	Mean length	450		450		469	469	358	385	455
	Length range	400-505		400-505		348-532	348-532	378-505	427-538	378-538
	Percent	100%		100%		100%	100%	65%	35%	100%

Table 8. Length frequency, age (determined from otoliths) and sex composition of mature kokanee collected in the spawn run at Elevenmile Reservoir on 11, 17, 24 and 30 October and 2 November 2006.

Elevenmile 2006					
Total length (mm)	**Age 2 - 1%**		**Age 3 - 99%**		**Totals**
	Female	**Male**	**Female**	**Male**	
340					
350		1			1
360					
370		1		1	2
380			1		1
390		1	1	2	4
400			5		5
410			13	3	16
420			21	1	22
430			33	5	38
440			49	7	56
450			54	10	64
460			67	24	91
470			42	32	74
480			26	20	46
490			16	29	45
500			11	15	26
510			2	12	14
520				8	8
530				4	4
540				4	4
Total fish		**3**	**341**	**177**	**521**
	3		**518**		
Mean length (mm)		**366**	**448**	**473**	**456**
	366		**457**		

Table 9. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 2, 6, 13, 20, 27 November and 5 December 2006 in the Colorado River spawn run from Granby Reservoir.

Granby 2006										
Age	**Statistic (total length in mm)**	**2 November**			**6 November**			**13 November**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	14	56	70	34	33	67	46	26	72
	Mean length	350	378	364	360	375	367	353	369	361
	Length range	301-386	334-442	301-442	322-407	322-422	322-422	318-399	337-426	318-426
	Percent	15%	62%	77%	34%	33%	67%	46%	26%	73%
4	**n**	1	20	21	18	15	33	12	15	27
	Mean length	391	412	401	395	417	406	395	423	409
	Length range	391	377-435	377-435	374-420	394-448	374-448	317-416	391-491	317-491
	Percent	1%	22%	23%	18%	15%	33%	12%	15%	27%
All	**n**	15	76	91	52	48	100	58	41	99
	Mean length	371	395	383	378	396	387	374	396	385
	Length range	301-386	334-442	301-442	322-420	322-448	322-448	317-416	337-491	317-491
	Percent	77%	23%	100%	52%	48%	100%	59%	41%	100%

Age	**Statistic (total length in mm)**	**20 November**			**27 November**			**5 December**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	24	29	53	28	29	57	35	17	52
	Mean length	374	372	373	356	368	362	350	367	358
	Length range	341-415	347-413	341-415	315-390	315-393	315-393	308-397	331-400	308-400
	Percent	24%	29%	53%	28%	29%	57%	35%	17%	52%
4	**n**	35	12	47	22	21	43	38	10	48
	Mean length	393	421	407	397	419	408	389	413	401
	Length range	351-428	384-472	351-472	360-423	363-452	360-452	335-442	386-446	335-446
	Percent	35%	12%	47%	22%	21%	43%	38%	10%	48%
All	**n**	59	41	100	50	50	100	73	27	100
	Mean length	384	397	390	377	394	385	370	390	393
	Length range	341-428	347-472	341-472	315-423	315-452	315-452	308-442	331-446	308-446
	Percent	59%	41%	100%	50%	50%	100%	73%	27%	100%

Table 9. (continued) Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 2, 6, 13, 20 and 27 November, and 5 December 2006 in the Colorado River spawn run from Granby Reservoir.

Age	**Statistic (total length in mm)**	**All dates**		
		Female	**Male**	**Both**
3	**n**	181	190	371
	Mean length	357	371	364
	Length range	301-415	315-442	301-442
	Percent	31%	32%	63%
4	**n**	126	93	219
	Mean length	393	417	405
	Length range	317-442	363-491	317-491
	Percent	21%	16%	37%
All	**n**	307	283	590
	Mean length	376	395	387
	Length range	301-442	315-491	301-491
	Percent	52%	48%	100%

Table 10. Length frequency, age (determined from otoliths) and sex composition of mature kokanee collected in the Colorado River spawn run from Granby Reservoir on 2, 6, 13, 20 and 27 November, and 5 December 2006.

Granby 2006

Total length (mm)	**Age 3 - 63%**		**Age 4 - 37%**		**Totals**
	Female	**Male**	**Female**	**Male**	
310	2				2
320	4	1			5
330	11				11
340	22	6	1		29
350	31	13	1		45
360	43	28	4		75
370	24	46	8	1	79
380	16	49	15	1	81
390	14	18	19	5	56
400	10	11	36	11	68
410	3	4	22	17	46
420	1	6	16	18	41
430		5	2	19	26
440		2	1	12	15
450		1	1	5	7
460				2	2
470					
480				1	1
490					
500				1	1
Total fish	**181**	**190**	**126**	**93**	**590**
	371		**219**		
Mean length (mm)	**357**	**373**	**393**	**417**	**379**
	365		**403**		

Table 11. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected on 1 and 9 November 2006 in the Dolores River spawn run from McPhee Reservoir.

McPhee 2006										
Age	**Statistic (total length in mm)**	**1 November**			**9 November**			**All Dates**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
2	**n**		1	1	2	2	4	2	3	5
	Mean length		260	260	268	275	271	268	268	268
	Length range		260	260	249-286	249-300	249-300	249-286	249-300	249-300
	Percent		1%	1%	1%	1%	2%	1%	1%	2%
3	**n**	30	44	74	35	119	154	65	163	228
	Mean length	309	331	320	312	324	322	311	328	322
	Length range	279-342	295-396	279-396	256-394	284-365	256-394	256-394	284-396	256-396
	Percent	30%	44%	74%	18%	60%	77%	22%	54%	76%
4	**n**	17	8	25	17	25	42	34	33	67
	Mean length	330	359	344	323	341	334	327	350	343
	Length range	309-353	338-394	309-394	290-347	320-380	290-380	290-347	320-394	290-394
	Percent	17%	8%	25%	9%	13%	21%	11%	18%	29%
All	**n**	47	53	100	54	146	200	101	199	300
	Mean length	316	334	325	314	324	323	315	329	325
	Length range	279-353	295-396	279-396	249-394	249-380	249-394	249-394	249-396	249-396
	Percent	47%	53%	100%	27%	73%	100%	34%	66%	100%

Table 12. Length frequency, age (determined from otoliths) and sex composition of mature kokanee collected in the Dolores River spawn run from McPhee Reservoir on 1 and 9 November 2006.

McPhee 2006							
Total length (mm)	**Age 2 - 2%**		**Age 3 - 76%**		**Age 4 - 22%**		**Totals**
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	
250	1	1					2
260		1	1				2
270							
280			2				2
290	1		5	1	1		8
300		1	10	7			18
310			17	24	4		45
320			16	30	4	1	51
330			7	39	11	6	63
340			4	32	9	7	52
350			1	22	4	7	34
360			1	3	1	7	12
370				2		2	4
380				1		2	3
390				1			1
400			1	1		1	3
410							
Total fish	**2**	**3**	**65**	**163**	**34**	**33**	**300**
	5		**228**		**67**		
Mean length (mm)	**268**	**270**	**310**	**326**	**327**	**345**	**324**
	269		**322**		**336**		

Table 13. Comparison of length, age (determined from otoliths) and sex composition of kokanee collected 12, 16 and 23 October 2006 in the Williams Fork River spawn run from Williams Fork Reservoir.

Williams Fork 2006													
Age	**Statistic (total length in mm)**	**12 October**			**16 October**			**23 October**			**All Dates**		
		Female	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
3	**n**	47	49	96	64	34	98	64	36	100	175	119	294
	Mean length	406	429	418	395	426	405	395	428	407	399	428	410
	Length range	362-474	352-465	352-474	356-495	380-483	356-495	360-470	402-457	360-470	356-495	352-483	352-495
	Percent	47%	49%	96%	64%	34%	98%	64%	36%	100%	58%	40%	98%
4	**n**	1	3	4		2	2				1	5	6
	Mean length	378	502	471		428	428				378	465	450
	Length range	378	496-510	378-510		420-435	420-435				378	420-510	378-510
	Percent	1%	3%	4%		2%	2%				0%	2%	2%
All	**n**	48	52	100	64	36	100	64	36	100	176	124	300
	Mean length	405	434	420	395	426	406	395	428	407	398	429	411
	Length range	362-474	352-510	352-510	356-495	380-483	356-495	360-470	402-457	360-407	356-495	352-510	352-510
	Percent	48%	52%	100%	64%	36%	100%	64%	36%	100%	58%	42%	100

Table 14. Length frequency, age (determined from otoliths) and sex composition of mature kokanee collected in the Williams Fork River spawn run from Williams Fork Reservoir on 12, 16 and 23 October 2006.

Williams Fork 2006					
Total length (mm)	**Age 3 - 98%**		**Age 4 - 2%**		**Totals**
	Female	**Male**	**Female**	**Male**	
360	2	1			3
370	19				19
380	20	1	1		22
390	25	3			28
400	46	2			48
410	28	15			43
420	17	18		1	36
430	3	22			25
440	2	31		1	34
450	4	13			17
460	2	10			12
470	5	2			7
480	1				1
490		1			1
500	1			2	3
510				1	1
Total fish	**175**	**119**	**1**	**5**	**300**
	294		**6**		
Mean length (mm)	**398**	**428**	**378**	**472**	**411**
	410		**456**		

Table 15. Comparison of age (determined from otoliths) and sex composition of mature kokanee collected in the Grimes Creek spawn run from Vallecito Reservoir 24 October 2006.

Vallicito 2006				
Age	**Statistic (total length in mm)**	**24-Oct-06**		
		Female	**Male**	**Both**
2	**n**		1	1
	Mean length		402	402
	Length range		402	402
	Percent		1%	1%
3	**n**	8	18	26
	Mean length	382	428	414
	Length range	358-417	396-516	358-516
	Percent	10%	22%	32%
4	**n**	14	14	28
	Mean length	448	489	469
	Length range	395-492	430-544	395-544
	Percent	17%	17%	35%
5	**n**	13	13	26
	Mean length	460	491	476
	Length range	425-498	430-535	425-535
	Percent	16%	16%	32%
All	**n**	35	46	81
	Mean length	437	464	452
	Length range	358-417	396-544	358-544
	Percent	43%	57%	100%

Table 16. Length frequency, age (determined from otoliths) and sex composition of mature kokanee collected in the Grimes Creek spawn run from Vallecito Reservoir 24 October 2006.

Vallecito 10/24/2006									
Total length (mm)	**Age 2 - 1%**		**Age 3 - 32%**		**Age 4 - 35%**		**Age 5 - 32%**		**Totals**
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	
360			1						1
370			2						2
380			2						2
390			1						1
400				2	1				3
410		1	1	1					3
420			1	2					3
430				7	2	1	1	1	12
440				4	1	1	2	1	9
450				1	4		2		7
460					3	1	2		6
470					2		2		4
480						2	1	1	4
490						3	1	2	6
500					1	1	2	4	8
510						2		2	4
520				1		1			2
530								1	1
540						1		1	2
550						1			1
Total fish		**1**	**8**	**18**	**14**	**14**	**13**	**13**	**81**
	1		**26**		**28**		**26**		
Mean length (mm)	**402**		**382**	**428**	**448**	**489**	**460**	**491**	**452**
	402		**414**		**469**		**476**		

3.) In 2003, we sampled just a few fish from the spawn run, but there were 39% age-3 and 61% age-4 kokanee, a typical age structure for Vallecito. In 2004, our sample from the spawn run was 33% age-2, 65% age-3, and only 1% age-4 kokanee. A reduction of kokanee numbers in 2003 likely allowed the remainder of the population to mature earlier, thus the age-2 and 3 age structure of spawners in 2004. It appears that the 2002 year class which resulted in 77% age-4 fish in 2005 (and which was the age-3 year class in 2004) was much stronger than the 2003 year class, which resulted in only 23% age-3 fish in 2005 (and which was the age-2 year class in 2003). Thus, it appears that many of the kokanee stocked in 2003 that would have been age-1 by the end of that year did not survive. As a result, the 2003 year class would be expected to produce few age-4 kokanee in 2006. Since kokanee fisheries tend to exploit the largest fish in the maturing year classes most heavily, the fishery would see an abrupt decline if one of these year classes, especially the older one, was weak. This evidence coincides with the documented fish kill of 2003, but it may have been more difficult to observe the loss of large numbers of the smallest kokanee.

4.) While the mean size of kokanee spawners has fluctuated in Vallecito over the years, it did show an increase in size in 2004 and 2005 compare to 2003. In 2005, the mean size of spawners was 427 mmTL, which is large for Vallecito and indicative of a reduced kokanee population in the reservoir.

5.) Zooplankton, particularly *Daphnia pulex*, the favorite food of kokanee, was plentiful and large in 2004 and 2005. In both years, the *D. pulex* averaged 1.3 mm with a portion of the *Daphnia* exceeding 2.0 mm in length, a size not typically seen in an over-grazed kokanee water. All *Daphnia* species were especially plentiful in 2005 at over 20/l. A more common value in Vallecito would be around 10/l or less. The key point for the public is that the food base of the kokanee is not broken.

In summary, all evidence points to a massive loss of kokanee in Vallecito in 2003, especially those fish stocked that year. This would manifest in a reduced number of these oldest and largest-sized fish in the maturing population which would support the bulk of the summer fishery in 2006. This situation may improve a bit as the summer passes and the age-3 kokanee grow and begin to fill this void, but overall, anglers should be advised that the kokanee fishery in 2006 will likely suffer throughout the season. We should also be mindful of this come egg-take season.

Making predictions requires confidence and validation that the annuli detected by surface examination of the otoliths from mature kokanee accurately correspond to fish age. Tables 17 and 18 compare the detection of tetracycline marks to ages determined by surface examination of otoliths from mature kokanee. Comparing the incidence of marked to unmarked fish (up to 21%, Table 19) may indicate loss of mark or the presence of naturally spawned kokanee, but this would be difficult to discern in this study.

Table 17. Summary of mature kokanee collected at Roaring Judy Hatchery in the spawn run from Blue Mesa Reservoir and examined for tetracycline marks in 2005.

Length (TLmm)	Age 3 No mark, possible	Age 3 Marked 2003	Age 4 No mark, possible	Age 4 Marked, 2002	Age 5 No mark, expected	Age 5 Marked, ERROR	Total
320		1					1
330			1	2		1	4
340		1		1			2
350							
360		1				1	2
370		1	2	3			6
380		2	3	8		1	14
390	1	5	5	15		1	27
400	2	8	5	26	1		42
410		10	7	30		1	48
420	1	4	12	52			69
430		1	12	54		1	68
440		4	8	58		3	73
450		2	8	43		3	56
460		1	5	20		2	28
470			2	13		5	20
480			1	7		3	11
490		1		3		5	9
500				2		2	4
510							
520				1			1
530				1			1
540							
550		1					1
Total	**4**	**43**	**71**	**339**	**1**	**29**	**487**
Percent	**0.8%**	**9%**	**15%**	**69%**	**0.2%**	**6%**	**100%**
Mark vs. no mark	**9%**		**21%**		**3%**		
Error between marked age 4 & marked, but mis-aged age 5			**8%**				

Table 18. Summary of mature kokanee collected at Roaring Judy Hatchery in the spawn run from Blue Mesa Reservoir and examined for tetracycline marks in 2006.

Length (TLmm)	**Age 3 No mark, expected**	**Age 3 Marked ERROR**	**Age 4 No mark, possible**	**Age 4 Marked, 2003**	**Total**
320	1				1
330					
340	3				3
350	3				3
360	1				1
370	9			1	10
380	14	1			15
390	22		1	1	24
400	52	2		1	55
410	41	3		2	46
420	64	3	5	13	85
430	59	5	5	22	91
440	40	2	5	27	74
450	24	3	4	26	57
460	13	2	2	29	46
470	5	1	5	20	31
480	1	2		17	20
490	1			7	8
500	1		1	4	6
510				2	2
Total	**354**	**24**	**28**	**172**	**578**
Percent	**61%**	**4%**	**5%**	**30%**	**100%**
Mark vs. no mark	**7%**		**16%**		
Error between marked, but mis-aged age 3 and marked age 4,			**14%**		

Examining the percentage of those fish known to be in error compared to fish possessing marks (age 3 in 2005 @ 9% and age 4 vs. 5 @ 8% in 2005 @ 8%, Table 17; and age 3 fish @ 7% and age 3 vs. age 4 fish @ 14% in 2006, Table 18) suggests that assigning ages to kokanee by surface examination of otolith for annuli is acceptably accurate with an average error rate of about 10%. Maceina et al. (2007) considered 80% agreement with known ages to offer a minimum level of quality consistent with many standard fishery assessments.

Further illustrating the confidence in and utility of tracking the age structure of mature kokanee is the relative abundance of 2003 cohort in the spawn runs in 2005 and 2006. Martinez (2006a) showed that the sonar survey in 2003 showed an abrupt dip in pelagic fish numbers, indicative of a decline in kokanee abundance. In 2005, only 9% of the spawn run consisted of age 3 kokanee that would have been from the 2003 plant. In 2006, the year when the bulk of the 2003 plant would have been expected to mature at age 4, only 33% of the spawn run was age 4. These observations indicate that the 2003 kokanee plant likely survived poorly, accounting for the dip in pelagic fish numbers in 2003 and the low percentage of fish from this cohort in the 2005 and 2006 spawn runs.

Table 19 provides statistics for the 2005 and 2006 spawn runs from Blue Mesa Reservoir for mature kokanee sampled at the Roaring Judy Hatchery and in Slate Creek. The similarity of these data in both years support the scenario that the kokanee bypassing the hatchery and ascending the drainage into Slate Creek are simply a subset of the spawn run from Blue Mesa Reservoir rather than a distinct sub-population sustained by natural reproduction. In both years, the mean lengths for both locations differed by only 5-mm, the percentage of fish in the dominant age class was nearly identical, and the percentage of tetracycline marked individuals was very similar.

Table 19. Comparison of statistics for the 2005 and 2006 spawn runs from Blue Mesa Reservoir for mature kokanee sampled at the Roaring Judy Hatchery and in Slate Creek.

Sample statistics	**2005**		**2006**	
	Roaring Judy	Slate Creek	Roaring Judy	Slate Creek
Number of fish	499	100	688	96
Total length (mm)	433	428	428	423
Percent age 3	9	7	66	65
Percent age 4	85	84	34	35
Percent age 5	6	9	none	none
Percent tetracycline-marked	84	83	34	37

Segment Objective 2: Collect and analyze lake trout and brown trout otoliths and stomach samples from Blue Mesa and Granby Reservoirs, as needed or feasible.

INTRODUCTION

Lake trout are apical predators in several of Colorado’s largest coldwater reservoirs. Their intense predation on salmonids of hatchery origin, primarily kokanee and rainbow trout, can severely reduce the numbers of these prey, reducing overall fishery quality for all anglers (Johnson and Martinez 2000). Periodically examining the age structure of lake trout in key waters can provide valuable data for monitoring their growth in relation to their prey supply, response to fishing regulations, and the inherent influence of individual reservoir productivity.

METHODS and MATERIALS

Lake trout and brown trout were sampled by CDOW fishery biologist Dan Brauch in Blue Mesa Reservoir on several dates (30 April, and 1, 8, 10, 12, 15, 16, 17, 19 and 22 May 2006). Lake trout were sampled by CDOW Fishery Biologist Billy Atkinson in Granby (16 May and Green Mountain (15 May) reservoirs in 2006. Otoliths from these fish were mounted in Epofix®, transversely sectioned with an Isomet1000®, finished with an Ameritool, Inc.® polisher. Otolith thin sections were viewed through WESCO® WS-Stereo Trinocular Microscope, 0.65-4.5 zoom , doubled, fitted with a PixeLINK Megapixel® camera with digital images fed to a computer hosting Image-Pro Plus® image enhancing software, version 4.5.1. Aging was determined by the double-blind method, with disputed ages being resolved by a third reader.

RESULTS and DISCUSSION

Figure 1 compares age and growth of brown trout and lake trout sampled in Blue Mesa Reservoir in 2006. Brown trout generally appear to grow at a slower rate than lake trout, and in this small sample, older brown trout approaching 10 years of age may remain at less than 500 mmTL. In contrast, most of the lake trout in this sample exceeded 500 mm TL by age 5, although there is a wide range of sizes in each age class (Figure 1). Historic data shows lake trout in Blue Mesa reaching 760 mmTL (30 inches) by age 10 (Martinez 2006a). While there were no lake trout of that age in this sample, it appears that some lake trout retain or exceed this potential to attain 760 mmTL by age 10.

Figure 2 compares the growth of lake trout in Granby and Green Mountain reservoirs. In contrast to the lake trout sampled in Blue Mesa (Figure 1), lake trout in the 2006 sample from Granby were generally below 500 mmTL until age 9 or 10 (Figure 2). This comparatively slow growth of lake trout in Granby has been discussed extensively and regulation adjustments at Granby have been made to improve the growth and body condition of lake trout there, as well as to relieve predation pressure on the kokanee in an effort to improve kokanee egg production (Martinez 2005, 2006a). These management adjustments have provided evidence of improved condition in the fish population in Granby with reports of higher relative weights for lake trout and the collection of 3 million kokanee eggs in 2006 (Billy Atkinson, CDOW, personal communication).

Lake trout in Green Mountain Reservoir were also below 500 mmTL at age 5, but at least one specimen exceeded 500 mmTL at age 6 (Figure 2). It appears that lake trout in Green Mountain possess a steeper growth trajectory, and at present, their growth rate would be expected to exceed that in Granby, but it would not be expected to exceed that in Blue Mesa. This would have to be confirmed by removing otoliths from a sample of lake trout exceeding 500 mmTL in Green Mountain.

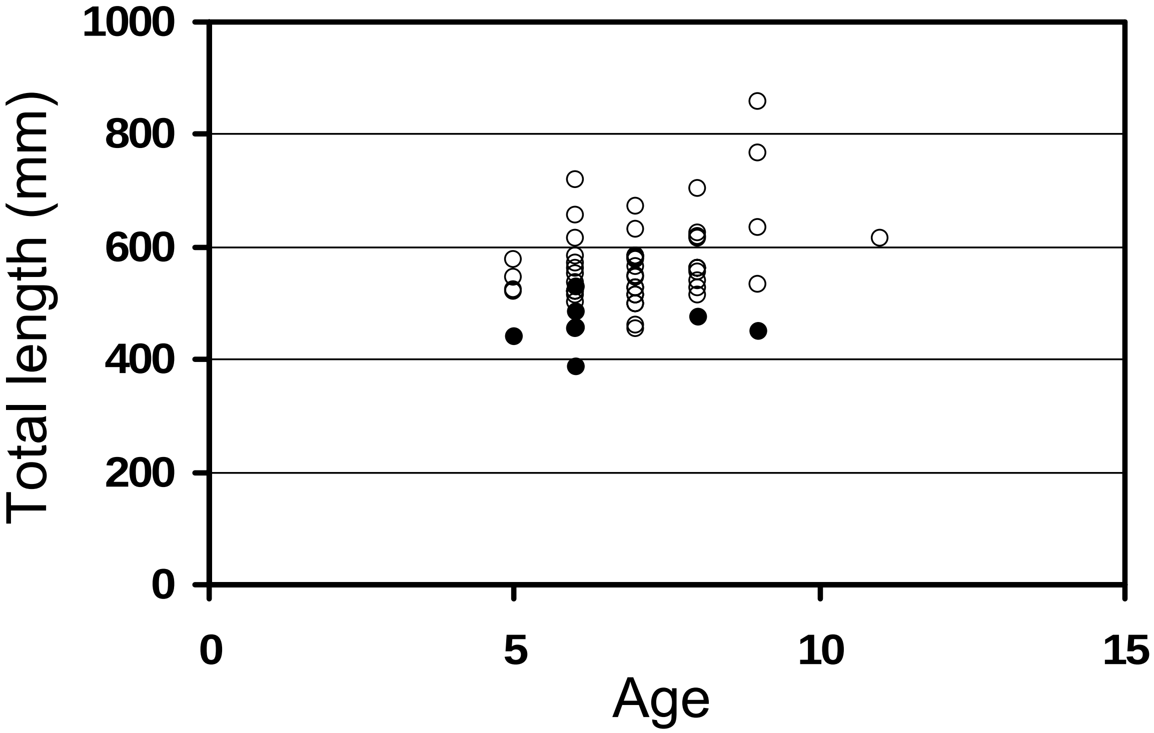

Figure 1. Ages for lake trout and brown trout, determined from transversely sectioned otoliths, captured in Blue Mesa Reservoir on 30 April, and 1, 8, 10, 12, 15, 16, 17, 19 and 22 May, 2006 (black dots, n=7, are brown trout; open circles, n=50, are lake trout).

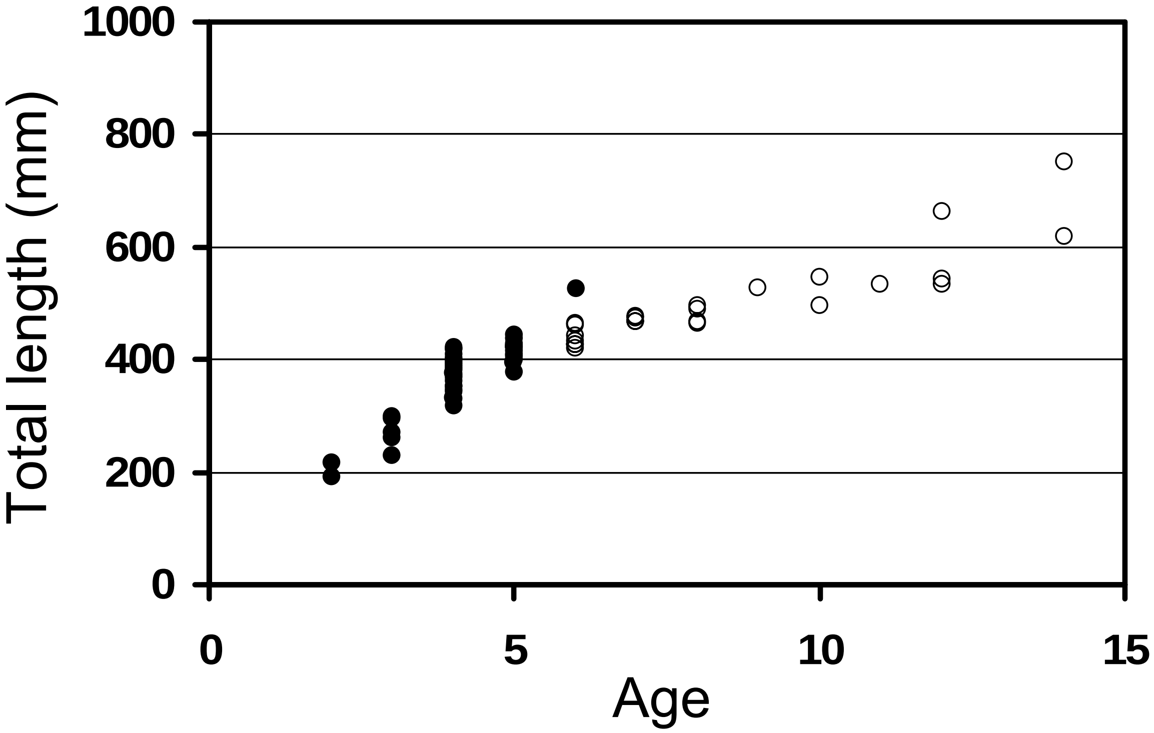

Figure 2. Ages for lake trout, determined from transversely sectioned otoliths, captured in Granby (open circles, n= 24, 16 May) and Green Mountain (black dots, n=46, 15 May) reservoirs, 2006.

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 from Blue Mesa, Elevenmile, Granby, Green Mountain, McPhee, Shadow Mounatin, Taylor Park, Vallecito, and Williams Fork Reservoirs; and in Carter, Dillon, Ridgeway, Ruedi or Vega Reservoirs as needed or feasible.

INTRODUCTION

Crustacean zooplankton monitoring facilitates tracking trends in reservoir food webs. Annual or periodic collection of zooplankton data has proven valuable in helping recommend management strategies for sport fisheries and kokanee egg production, particularly in reservoirs containing *Mysis relicta*.

METHODS and MATERIALS

Crustacean zooplankton was sampled in 11 coldwater reservoirs in 2006. Blue Mesa was sampled on 17 May and 18 July, Dillon on 14 August, Elevenmile on 22 August, Granby on 27 June and 15 August, Green Mountain on 8 August, McPhee on 1 August, Taylor Park on 17 July, Vallecito on 3 August, Vega on 25 May, 13 June, 11 August and 19 October, Williams Fork on 8 August, and Wolford Mountain on 8 August. Sampling on multiple dates in Vega was performed in cooperation with CDOW Fishery Biologist, Anita Martinez, as part of her evaluation of its trout fishery. The results for samples from two waters sampled in 2005 that were not reported in Martinez (2006a), Avery and Grand, are also reported herein.

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 also measured to the nearest centimeter. Temperature and dissolved oxygen were also measured in Shadow Mountain Reservoir on 26 June 2006. These profiles for Avery and Grand lakes are reported in Martinez (2006a).

RESULTS and DISCUSSION

Crustacean zooplankton densities and size structures from samples collected in coldwater reservoirs in 2006 are presented in Tables 20-45. These data for Avery and Grand lakes sampled in 2005 are in Tables 46-49. Temperature, dissolved oxygen profiles, and Secchi depths measured on the dates of zooplankton sampling, and for Shadow Mountain Reservoir, are provided in Appendix B.

Blue Mesa Reservoir had a high *Daphnia* density, >10/l on 18 July (Table 20), dominated by large *D. pulex* averaging 1.4 mm (Table 22). Dillon contained a surprising amount of *Daphnia* on 14 August, 5.7/l (Table 23), mostly small *D. galeata mendotae* averaging 0.8 mm, but some measured at 1.6 mm (Table 24). This stark increase in *Daphnia* abundance in contrast to past years coincides with a drastic dip in *Mysis* density, down to 88.5/m^2 (Table 50), and the presence of warm epilimnetic water temperatures exceeding 14^{o}C above 10m depth (Appendix Table B-3) limiting *Mysis* predation on *Daphnia* in the reservoir's surface waters (Martinez and Bergersen 1991). The samples from Elevenmile Reservoir on 22 August had extremely low zooplankton abundance overall and minimal *Daphnia* (Table 25), although the *D. pulex* in the samples were large, averaging 1.5 mm with individuals up to 2.7 mm (Table 26). This scarcity of zooplankton was likely due to excessive clogging of the sampling net due to a bloom of *Volvox* algae which also precluded measuring Secchi depths (Appendix Table B-4). The Secchi depth could be measured two weeks later on 22 August (Appendix Table B-5).

Granby Reservoir had a very low *Daphnia* density, 0.1/l, on 27 June (Table 27), which coincided with the onset of thermal stratification and epilimnetic temperatures just exceeding 14-15^{o}C (Appendix Table B-6). The *Daphnia* population was of moderate density on 15 August, >5/l (Table 27), and included primarily *D pulex* of large size, averaging 1.7 mm (Table 29). These large *Daphnia* occurred during a period of strong thermal stratification (Appendix Table B-7), despite a high density of *Mysis* >500/m^2 (Table 52). Green Mountain Reservoir had a *Daphnia* density of >7/l, consisting of about equal densities of *D. pulex* and *D. g. mendotae* (Table 30), with some large *D. pulex*, >2 mm, being present (Table 31). *D. pulex* were both abundant in the reservoir in 2005, and sampling for *Mysis* in 2005, not reported in Martinez (2006a), revealed that *Mysis* were not present in samples collected at 10 stations, although they were present historically (Martinez and Bergersen 1991). Thus, it is not surprising that the reservoir is capable of producing higher numbers of *Daphni*a.

McPhee Reservoir had a *Daphnia* density of 7.1/l when sampled on 1 August (Table 32). McPhee typically displays a high diversity of cladocerans, but its zooplankters are characteristically small with the *Daphnia* averaging 1.1 mm when sampled in 2006 (Table 33). Taylor Park Reservoir had a low *Daphnia* density of 3.7/l on 17 July (Table 34), but some of the *D. pulex* in the sample were large, > 2 mm (Table 35). Thermal stratification was not pronounced at the time of sampling in 2006, with temperatures < 14^o C occurring in the upper 10m of the reservoir (Appendix Table B-12). *Daphnia* were low in number (2.9/l) in Vallecito Reservoir on 3 August (Table 36) with few exceeding 2 mm (Table 37).

Daphnia displayed high densities (>10/l) on all sampling dates in Vega Reservoir in 2006, except the earliest date sampled, 25 May (Tables 38 and 40). *D. pulex* was the most abundant daphnid on all sample dates and displayed a large size structure favorable for consumption by trout, particularly on the date of peak abundance (25/l) on 11 August (Tables 39 and 41). Overall zooplankton density was low in Williams Fork Reservoir when sampled on 8 August (Table 42), but the *D. pulex* in the sample were very large, averaging 1.6 mm, up to 3 mm (Table 43). Overall zooplankton density was also low in Wolford Mountain Reservoir when sampled on 8 August, but technicians identified an unusually high variety of *Daphnia* species, including *D. g. mendotae, D. pulex, D. rosea, and D. schoedleri* (Table 44). All four species included larger specimens > 1.5 mm (Table 45) facilitating examination of distinguishing characteristics, thus increasing confidence in their identification.

Lake Avery, a reservoir in the White River drainage, contained a high density of *Daphnia*, > 20/l, when sampled on 21 June 2005 (Table 46). These daphnids were dominated by *D. pulex*, nearly 20/l, averaging 1.2 mm (Table 47). Grand Lake contained a very low density of zooplankton, 3/l, consisting solely of copepods on 30 June 2005 (Table 48).

Table 20. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations at Blue Mesa Reservoir, 17 May and 18 July 2006.

Zooplankton species	Cebolla (0-10m)			Iola (0-10m)			Sapinero (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Blue Mesa – 17 May 2006 - Mean *Daphnia* density = 5.7/L										
Bosmina longirostris	0.4		0.2		0.5	0.3	0.3	1.1	0.7	0.4
Unidentified Daphnia spp.	1.5	1.1	1.3	0.6		0.3	6.0	5.4	5.7	2.4
Diacyclops bicuspidatus thomasi	47.3	28.9	38.1	37.0	36.9	36.9	23.1	21.8	22.4	32.5
Daphnia galeata mendotae	1.8	1.6	1.7	0.9	0.8	0.8	7.0	4.6	5.8	2.8
Daphnia pulex	0.4	0.6	0.5	0.3			1.3	0.9	1.1	0.5
Leptodiaptomus nudus								0.3	0.1	
Mean total no./L	59.0			43.2			39.3			47.1

Blue Mesa - 18 July 2006 - Mean *Daphnia* density = 11.9/L										
Bosmina longirostris	0.3		0.2	1.9	0.5	1.2				0.5
Ceriodaphnia megalops		1.8	0.9	1	1	1	4.3	1.9	3.1	1.7
Unidentified Daphnia spp.	3	1.4	2.2	1.5	1	1.2	2.6	0.7	1.7	1.7
Diacyclops bicuspidatus thomasi	5.7	6.9	6.3	12.1	14.1	13.1	9.5	13.4	11.4	10.3
Daphnia galeata mendotae	3.7	2.5	3.1	1.5	2.9	2.2	2.2	3.7	2.9	2.7
Daphnia pulex	6.4	7.2	6.8	4.4	5.3	4.8	6.1	4.8	5.4	5.7
Daphnia schodleri							0.4		0.2	0.1
Leptodiaptomus nudus	11.7	10.5	11.1	10.6	5.3	8	15.6	18.2	16.9	12
Mean total no./L	30.6			31.5			41.7			34.6

Table 21. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Blue Mesa Reservoir, 17 May 2006. Bl = *Bosmina longirostris*, *D. ssp.* = Unidentified daphnia species, Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**Blue Mesa – 17 May 2006**					
	Bl	**Dp spp**	**Dbt**	**Dgm**	**Dp**	**Ln**
0.4			25			
0.5	1	1	25			1
0.6		1	30	6		
0.7		3	27	18	4	
0.8		3	22	7	3	
0.9			13	6	4	
1.0			9	1	7	
1.1			9	4	1	
1.2		1	6	4	2	
1.3			2	1	3	
1.4		1		2		
1.5			1	2	1	
1.6				1		
1.7						
1.8						
1.9					1	
2.0						
2.1						
2.2						
2.3					1	
Totals	1	10	169	52	27	1
Mean length	0.5	0.7	0.7	0.8	1.0	0.4

Table 22. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected on Blue Mesa Reservoir, 18 July 2006. Bl = *Bosmina longirostris*, Cdm = *Ceriodaphnia megalops, D. spp.*= Unidentified Daphnia species, Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dp = *Daphnia pulex*, Ds = *Daphnia schoedleri,* Ln = *Leptodiaptomus nudus*.

Length class in mm	**Blue Mesa - 18 July 2006**							
	BL	**Cdm**	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Ds**	**Ln**
0.4	1	4		14				7
0.5	1	6		18				12
0.6		2	1	6				8
0.7		7	2	11	3			15
0.8		3	3	3	2	2		10
0.9		2	1	6	7	4		4
1.0			4	2	9	10		6
1.1			3		2	8		3
1.2			3		6	22		2
1.3			1		2	7		
1.4			2		4	6		
1.5			2		4	5		
1.6			1		2	4		
1.7			1			5		
1.8			1		1	2		
1.9						3		
2.0			1			1		
2.1						4		
2.2						2	1	
2.3						1		
Totals	2.0	24.0	26.0	60.0	42.0	86.0	1.0	67.0
Mean length	0.5	0.6	1.2	0.6	1.1	1.4	2.2	0.7

Table 23. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Dillon Reservoir, 14 August 2006.

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**	
Dillon - 14 August 2006 - Mean *Daphnia* density =5.7/L																
Bosmina longirostris	10.8	10.6	10.7	8.3	6.2	7.2	15.3	10.4	12.8	13.8	28.6	21.2	15.5	10.6	13.0	13.0
unidentified *Daphnia spp.*	0.3	0.8	0.5	1.3	0.5	0.9	0.2	0.2	0.2	1.6	0.7	1.1	1.3	1.9	1.6	0.9
Diacyclops bicuspidatus thomasi	10.8	9.3	10.1	11.3	13.7	12.5	12.5	8.7	10.6	16.9	16.1	16.5	23.2	23.1	23.2	14.6
Daphnia galeata mendotae	6.0	6.1	6.0	1.5	1.4	1.4	0.8	0.6	0.7	5.2	2.7	4.0	11.8	11.7	11.8	4.8
Daphnia rosea	0.3		0.1													
Mean total no./L	27.5			22.1			24.3			42.8			49.6			33.2

Table 24. Length frequency of crustacean zooplankton (measured to the nearest 0.1mm) collected in Dillon Reservoir on 14 August 2006. Bl = *Bosmina longirostris*, Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dr = *Daphnia rosea, D.spp.= Unidentified Daphnia species.*

Length class in mm	**Dillon - 14 August 2006**				
	Bl	**Dbt**	**Dgm**	**Dr**	**D. spp.**
0.1					
0.2	12				
0.3	58	1	1		
0.4	70	7	1		5
0.5	10	17	14		6
0.6		39	34		10
0.7		43	16		2
0.8		30	33		3
0.9		26	22		7
1.0		14	9		
1.1		1	10		1
1.2			12	1	1
1.3			1		
1.6			1		
Totals	150	178	154	1	35
Mean length	0.4	0.7	0.8	1.2	0.7

Table 25. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at two stations at Elevenmile Reservoir, 22 August 2006.

Zooplankton Species	**Station #1 (10m)**			**Station #4 (10m)**			**Mean no./L**
	a	b	mean	a	b	mean	
Elevenmile- 22 August 2006- Mean *Daphnia* density = 0.9/L							
Bosmina longirostris	0.4	0.2	0.3	0.2	0.0	0.1	0.2
Ceriodaphnia megalops	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Unidentified *Daphnia spp.*	0.3	0.1	0.2	0.1	0.1	0.1	0.2
Diacyclops bicuspidatus thomasi	2.5	2.3	2.4	2.4	1.7	2.0	2.2
Daphnia galeata mendotae	0.3	0.3	0.3	0.1	0.2	0.1	0.2
Daphnia pulex	0.7	0.4	0.6	0.6	0.3	0.4	0.5
Daphnia schoedleri	0.1	0.0	0.1	0.0	0.1	0.0	0.1
Leptodiaptomus nudus	0.3	0.3	0.3	0.4	0.6	0.5	0.4
Mean total no./L	4.2			3.4			3.8

Table 26. Length frequency of crustacean zooplankton (measured to the nearest 0.01mm) collected on Elevenmile Reservoir, 22 August 2006. Bl = *Bosmina longirostris*, Cdm = *Ceriodaphnia megalops*, *D. spp.* = Unidentified Daphnia species, Dbt= *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, Ds = *Daphnia schoedleri*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**Elevenmile - 22 August 2006**							
	Bl	**Cdm**	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Ds**	**Ln**
0.3	4							
0.4	4	1		1				1
0.5				14				4
0.6				8				1
0.7			1	11				2
0.8				11	2			
0.9			1	18	10			2
1.0			2	2	6	3		1
1.1			4	1		5		
1.2						7		1
1.3						5		
1.4				1		4	1	
1.5			3	2		5	1	
1.6					1	1		
1.7						4	1	
1.8						3		
1.9			1			4		
2.0			1			1		
2.1						1	1	
2.3						1		
2.4							1	
2.6			1					
2.7						1		
Totals	8	1	14	69	19	45	5	12
Mean length	0.4	0.4	1.4	0.8	1.0	1.5	1.8	0.7

Table 27. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Granby Reservoir, 27 June and 15 August 2006.

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	
Granby - 27 June 2006 - Mean *Daphnia* density = 0.1/L																
Bosmina longirostris		0.3	0.2					0.3	0.2	0.8		0.4	0.3	0.4	0.4	0.2
Unidentified *Daphnia* spp.				0.2		0.1										
Diacyclops bicuspidatus thomasi	39.4	46.8	43.1	39.1	30.2	34.6	51.0	36.7	43.8	43.0	61.8	52.4	62.3	50.9	56.6	46.1
Daphnia galeata mendotae	0.4		0.2													
Daphnia pulex								0.3	0.2							
Leptodiaptomus nudus	3.9	2.8	3.4	1.5	0.3	0.9	1.0	3.0	2.0	2.5	0.5	1.5	2.6	0.4	1.5	1.8
Mean total no./L	46.8			35.6			46.2			54.3			58.4			48.3

Granby - 15 August 2006 - Mean *Daphnia* density = 5.2/L																
Bosmina longirostris				0.2		0.1					1.3	0.6				0.1
Unidentified *Daphnia* spp.		0.2	0.1	0.2	0.5	0.3	0.7	0.6	0.6	0.6	0.9	0.7	1.8	1.7	1.7	0.7
Diacyclops bicuspidatus thomasi	12.7	17.2	15.0	12.0	14.9	13.4	13.0	21.3	17.2	21.9	17.9	19.9	21.6	19.8	20.7	17.2
Daphnia galeata mendotae	0.5	1.8	1.1	1.3	1.2	1.2	0.9	0.8	0.9	0.9	0.9	0.9	2.2	1.9	2.0	1.2
Daphnia pulex	6.3	4.5	5.4	0.4	0.2	0.3	2.2	2.1	2.1	1.7	5.6	3.6	4.4	4.4	4.4	3.2
Daphnia rosea				0.2		0.1	0.2		0.1				0.4	0.2	0.3	0.1
Leptodiaptomus nudus	2.3	0.9	1.6		0.2	0.1	0.7	0.2	0.4		1.3	0.6	0.2	0.6	0.4	0.6
Mean total no./L	23.2			15.6			21.4			26.4			29.6			23.2

Table 28. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Granby Reservoir, 27 June 2006. Bl = *Bosmina longirostris*, D.spp. Unidentified Daphnia spp. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dp = *Daphnia pulex,* Ln = *Leptodiaptomus nudus*.

Length class in mm	**Granby- June 27 2006**					
	Bl	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Ln**
0.3	2					
0.4		1	5			1
0.5			24			
0.6			49			1
0.7			75			2
0.8			63			1
0.9			20	1		2
1.0			14		1	2
1.1			1			3
1.2			15			7
1.3			1			4
1.4			1			2
1.5						2
1.6						1
Totals	2	1	268	1	1	28
Mean length	0.3	0.4	0.7	0.9	1.0	1.1

Table 29. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Granby Reservoir, August 15, 2006. Bl = *Bosmina longirostris*, D. spp.= Unidentified Daphnia spp. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dp= *Daphnia pulex*, Dr = *Daphnia rosea,* Ln = *Leptodiaptomus nudus*.

Length class in mm	**Granby- 15 August 2006**						
	Bl	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Dr**	**Ln**
0.2	1						
0.3	2				1		
0.4	1	3	3	3			
0.5		3	4	2			
0.6		6	27	3	1		
0.7		3	42	3			
0.8		2	59	6			4
0.9		3	68	4	1		4
1.0			28	1	2		2
1.1		1	10	2	2	1	
1.2			3	8	3	2	
1.3				2	4		
1.4		2		7	7	1	
1.5				1	11		
1.6		2		3	23		
1.7		1		4	8		
1.8				2	13		
1.9		3		1	19	1	
2.0				1	7		
2.1					14		
2.2					10		
2.3		1			2		
2.4				1			
2.7					1		
Totals	4	30	244	54	129	5	10
Mean length	0.3	1.0	0.8	1.2	1.7	1.4	0.9

Table 30. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at two stations in Green Mountain Reservoir, 8 August 2006. Data collected at only two of five stations due to missing GPS coordinates.

Zooplankton species	**Station #1 (0-10m)**			**Station #2 (1-10m)**			**Mean no./L**
	a	b	mean	a	b	mean	
Green Mountain Reservoir - 8 Aug 2006 - Mean *Daphnia* density = 7.3/L							
Bosmina longirostris	0.3	0.2	0.3	0.1	0.3	0.2	0.3
Unidentified Daphnia spp.	1.2	1.4	1.3	0.6	0.5	0.5	0.9
Diacyclops bicuspidatus thomasi	5.2	8.5	6.8	12.1	12.1	12.1	9.5
Daphnia galeata mendotae	4.4	3.7	4.0	1.9	2.0	2.0	3.0
Daphnia pulex	3.0	3.6	3.3	3.0	3.8	3.4	3.4
Leptodiaptomus nudus	8.0	5.8	6.9	4.0	5.7	4.8	5.9
Mean total no./L	**22.7**			**23.1**			**22.9**

Table 31. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Green Mountian Reservoir, August 2006. Bl = *Bosmina longirostris*, D.spp.= unidentified Daphnia spp. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp= *Daphnia pulex*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**Green Mountain - 8 August 2006**					
	Bl	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Ln**
0.4	1		1			
0.5			2	2		9
0.6		1	8			8
0.7		1	28	2	1	4
0.8		1	17	11	4	5
0.9		6	15	20	11	5
1.0		4	8	10	13	7
1.1		4		5	11	2
1.2		1		8	8	7
1.3				1	4	
1.4		4		11	6	3
1.5		1		6	7	
1.6		2			5	
1.7		1			5	
1.8				1	3	
1.9					4	
2.0					4	
2.1					2	
2.2					1	
Totals	1	26	79	77	89	50
Mean length	0.4	1.1	0.8	1.1	1.3	0.8

Table 32. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in McPhee Reservoir, 1 August 2006.

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	
McPhee - 01 Aug 2006 - Mean *Daphnia* density = 7.1/L																
Bosmina longirostris	2.0	1.7	1.9	0.5	1.0	0.8	0.4	0.83	0.6	2.0	6.8	4.4	1.2	0.6	0.9	1.7
Ceriodaphnia megalops	7.2	6.6	6.9	10.3	14.0	12.1	12.4	11.25	11.8	19.3	18.1	18.7	4.7	9.5	7.1	11.3
Unidentified *Daphnia spp.*	0.7	1.1	0.9		0.5	0.3	0.9	2.50	1.7	4.4	2.0	3.2		0.9	0.4	1.3
Diaphanosoma birgei		0.9	0.4				0.9	0.42	0.6					0.6	0.3	0.3
Diacyclops bicuspidatus thomasi	11.9	8.6	10.2	12.7	14.2	13.5	12.8	11.25	12.0	36.9	25.7	31.3	13.2	10.9	12.0	15.8
Daphnia galeata mendotae	1.6	1.1	1.4	2.9	3.8	3.4	15.0	13.75	14.4	1.6	2.0	1.8	2.6	3.2	2.9	4.8
Daphnia pulex	0.2	1.1	0.7	1.0	0.8	0.9	0.9		0.4	4.0	1.6	2.8				1.0
Leptodiatomus nudus	4.0	4.9	4.5	3.4	4.8	4.1	6.0	5.0	5.5	3.6	1.6	2.6	6.1	6.9	6.5	4.6
Mean total no./L	26.8			35.0			47.1			64.9			30.1			40.8

Table 33. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in McPhee Reservoir, 1 August 2006. Bl = *Bosmina longirostris*, Cdm = *Ceriodaphnia megalops*, *D. spp.*= Unidentified Daphnis spp. Db = *Diaphansoma birgei,* Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**McPhee - 01 August 2006**							
	Bl	**Cdm**	**D. spp.**	**Db**	**Dbt**	**Dgm**	**Dp**	**Ln**
0.3	5	4						
0.4	9	33	1		6			
0.5	1	35	6		18			2
0.6		72	2		57	2	1	6
0.7		38	8	1	32	3	1	11
0.8		9	6	1	12	14	1	11
0.9		1	3	1	7	15	4	10
1.0		1	1	2	3	19	4	10
1.1			3	2	2	12	6	9
1.2			4	1		16	1	5
1.3			1		1	12	3	1
1.4						13	3	
1.5			1			9	3	
1.6						2		
Totals	15	193	36	8	138	117	27	65
Mean length	0.4	0.6	0.8	1.0	0.7	1.1	1.1	0.9

Table 34. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations at Taylor Park Reservoir, 17 July 2006.

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	
Taylor Park - 17 July 2006 - Mean *Daphnia* density = 3.7/L																
Unidentified *Daphnia spp.*	0.3	0.5	0.4	0.2	0.1	0.2	0.3	0.4	0.4	0.8	0.8	0.8	1.2	0.6	0.9	0.5
Diacyclops bicuspidatus thomasi	18.2	13.8	16.0	17.5	16.9	17.2	23.4	15.8	19.6	15.3	16.6	16.0	17.5	16.0	16.7	17.1
Daphnia galeata mendotae	0.4	1.5	1.0	0.5	0.2	0.4	0.3	0.9	0.6	0.3	1.0	0.7	0.8	1.0	0.9	0.7
Daphnia pulex	2.4	1.9	2.1	1.6	0.8	1.2	4.9	3.5	4.2	2.6	1.0	1.8	3.5	2.2	2.9	2.4
Leptodiaptomus nudus	0.7	1.4	1.1	0.6	1.9	1.3	1.2	1.2	1.2	1.2	0.8	1.0	1.0	0.6	0.8	1.1
Mean total no./L	20.6			20.2			26.0			20.3			22.2			21.9

Table 35. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Taylor Park Reservoir, 17 July 2006. D.spp.= Unidentified Daphnia spp. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dp = *Daphnia pulex*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**Taylor Park- 17 July 2006**				
	D. spp.	**Dbt**	**Dgm**	**Dp**	**Ln**
0.4		5			
0.5	1	29		1	1
0.6		50	1		2
0.7	4	88	3	1	1
0.8	2	25	13	6	1
0.9	8	31	19	17	3
1.0	1	7	3	16	
1.1	3	1	1	11	2
1.2	1			20	3
1.3	2			5	
1.4	2			13	
1.5	4		1	4	5
1.6	2			8	2
1.7				8	1
1.8				5	
1.9	1			4	
2.0				7	
2.1	1			5	
2.2			1	3	
2.3				3	
2.4				4	
2.5				5	
2.7				1	
Totals	32	236	42	147	21
Mean length	1.1	0.7	0.9	1.4	1.1

Table 36. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimates from duplicate samples collected at three stations in Vallecito Reservoir on 3 August 2006.

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	
Vallecito - 03 August 2006- Mean *Daphnia* density = 2.9/L										
Bosmina longirostris	1.2	1.3	1.2	2.5	1.2	1.9	4.3	1.7	3.0	2.0
Ceriodaphnia megalops					0.2	0.1				<0.1
Unidentified *Daphnia spp.*	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.1	0.2	0.2
Diacyclops bicuspidatus thomasi	3.0	2.8	2.9	2.9	4.1	3.5	6.7	3.6	5.2	3.8
Daphnia galeata mendotae	0.2	0.4	0.3	1.2	0.6	0.9	0.6	0.7	0.7	0.6
Daphnia pulex	1.8	1.3	1.6	1.1	0.9	1.0	4.4	2.4	3.4	2.0
Daphnia rosea								0.1	0.1	<0.1
Leptodiaptomus nudus	0.1	0.3	0.2	0.2	0.2	0.2	0.5	0.2	0.4	0.2
Mean total no./L	6.4			7.8			12.9			9.0

Table 37. Length frequency of crustacean zooplankton (measured to the nearest 0.1mm) collected in Vallecito Reservoir on 3 August 2006. D. spp.= Unidentified Daphnia spp. Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, Dr = *Daphnia rosea*, Dbt = *Diacyclops bicuspidatus thomasi*.

Length class in mm	**Vallecito - 03 August 2006**				
	D. spp.	Dgm	Dp	Dr	Dbt
0.3					1
0.4					7
0.5					3
0.6	1	2			15
0.7	5	17	1		23
0.8	4	24	2		25
0.9	2	39	8		20
1.0	2	16	12		2
1.1	2	10	17		1
1.2	2	5	10		3
1.3	1		3		
1.4		2	7		
1.5		4	4		
1.6		3	3	2	
1.7	1	2	1		
1.8			2		
1.9			2		
2.0	1		7		
2.1			1		
Totals	21	124	80	2	100
Mean length	1.0	0.9	1.3	1.6	0.7

Table 38. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations at Vega Reservoir, 25 May and 13 June 2006.

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	
Vega - 25 May 2006 - Mean *Daphnia* density = 4.4/L										
Diacyclops b. thomasi	13.2	11.4	12.4	8.6	6.1	7.4	10.0	9.2	9.6	9.8
Unindentified *Daphnia spp.*		0.580	0.3	0.103		0.1				0.1
Daphnia galeata mendotae	2.7	1.9	2.3	2.0	1.5	1.7	0.7	0.4	0.6	1.5
Dapnia pulex	3.5	2.9	3.2	5.3	3.6	4.5	0.8	0.6	0.7	2.8
Leptodiaptomus nudus	3.5	2.1	2.8	4.0	2.3	3.1	0.8	0.3	0.5	2.1
Mean total no./L	20.9			16.8			11.4			16.4
Vega - 13 June 2006 - Mean *Daphnia* density = 12.7/L										
Diacyclops b. thomasi	16.2	32.2	24.2	11.2	18.6	14.9	20.2	25.0	22.6	20.6
Unindentified *Daphnia spp.*		0.542	0.3	0.135		0.1				0.1
Daphnia galeata mendotae	1.1	2.2	1.6	1.4	1.6	1.4	2.6	2.1	2.3	1.8
Dapnia pulex	8.2	17.4	12.8	7.5	8.2	7.9	10.7	12.7	11.7	10.8
Leptodiaptomus nudus	1.3	3.5	2.4	0.9	1.6	1.2	1.9	1.6	1.7	1.8
Mean total no./L	41.3			25.5			38.3			35.0

Table 39. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations at Vega Reservoir, 11 August and 19 October 2006.

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	
Vega - 11 August 2006 - Mean *Daphnia* density = 25.1/L										
Diacyclops b. thomasi	7.6	7.9	7.7	9.4	9.2	9.3	23.9	n/a	23.9	13.6
Unindentified *Daphnia spp.*		0.2	0.1	0.2	0.3	0.2		n/a		0.1
Daphnia galeata mendotae	13.5	9.8	11.6	8.5	8.9	8.7	6.8	n/a	6.8	9.0
Dapnia pulex	19.0	10.5	14.8	15.0	17.3	16.2	16.8	n/a	16.8	15.9
Leptodiaptomus nudus	2.8	1.7	2.2	2.2	3.1	2.7	1.9	n/a	1.9	2.3
Mean total no./L	36.5			37.1			49.4			41.0

Vega - 19 October 2006 - Mean *Daphnia* density = 10.0/L										
Diacyclops b. thomasi	2.6	5.8	4.2	1.5	2.8	2.1	1.6	1.8	1.7	2.7
Unindentified *Daphnia spp.*	0.076									0.01
Daphnia galeata mendotae	2.0	3.7	2.8	0.9	0.6	0.8	0.4	0.4	0.4	1.3
Dapnia pulex	6.1	14.2	10.1	6.5	3.5	5.0	1.1	1.0	1.1	5.4
Ceriodaphnia	2.7	3.2	3.0	3.3	3.2	3.3	3.4	3.4	3.4	3.2
Leptodiaptomus nudus	1.1	1.5	1.3	0.3	0.1	0.2	0.2	0.3	0.2	0.6
Bosmina longirostris	1.7	6.4	4.1	1.5	1.1	1.3	0.5	0.7	0.6	2.0
Mean total no./L	25.6			12.7			7.4			15.2

Table 40. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected on Vega Reservoir, 25 May and 13 June 2006. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, D. spp. = Unknown Daphnia spp. Ln = *Leptodiaptomus nudus.*

Length class in mm	**Vega- 25 May 2006**					**Vega- 13 June 2006**				
	Dbt	**Dgm**	**Dp**	**D. spp.**	**Ln**	**Dbt**	**Dgm**	**Dp**	**D. spp.**	**Ln**
0.2						1				
0.3	1					8				
0.4	14	1	1			34	1			
0.5	40	11	1		2	51				
0.6	48	35	1	1	2	41	4	3		
0.7	25	12	2	1	4	13	4	3		
0.8	18	19	18		9	16	13	15		
0.9	15	7	21		9	5	15	14	2	
1.0	3	1	5	3	4	1	13	20		
1.1	2		6	2	1		7	19	1	2
1.2	6		16		3			20		2
1.3		1	9		1			21		2
1.4		1	5					7		3
1.5			6					5		6
1.6			10					4		2
1.7			4		1			5		4
1.8			3					2		
1.9			4					3		1
2.0			1					4		
2.1			2					2		
2.2			3					2		
2.3										
2.4								1		
Totals	172	88	118	7	36	170	57	150	3	22
Mean length	0.69	0.74	1.26	0.96	0.9	0.59	0.93	1.26	1.04	1.4

Table 41. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected on Vega Reservoir, 11 August and 19 October 2006. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*, Dp = *Daphnia pulex*, D. spp. = Unknown Daphnia spp. Ln = *Leptodiaptomus nudus*

Length class in mm	**Vega- 11 August 2006**					**Vega- 19 October 2006**						
	Dbt	**Dgm**	**Dp**	**D. spp.**	**Ln**	**Dbt**	**Dgm**	**Bl**	**Cdm**	**Dp**	**D. spp.**	**Ln**
0.2								2				
0.3	5					1		7				
0.4	10	1			1	1	2	35				
0.5	24	21				19	7	3	5			
0.6	9	23	1	1		16	15		30			
0.7	5	21	3			5	18		43		1	
0.8	5	22	7	1		12	30		14	13		
0.9	7	13	13		4	13	12			22		
1.0		9	11	1	1	3	6			20		2
1.1		5	10		1					22		2
1.2		2	9		3		1			35		5
1.3		1	8		2					14		1
1.4		1	6		1		1			2		4
1.5			4		1		1			1		
1.6		1	9							2		
1.7		1	9							3		
1.8			12							2		
1.9			12							1		
2.0			5							4		
2.1			3							3		
2.2			2							1		
2.3			1									
2.4												
Totals	65	121	125	3	14	70	93	47	92	145	1	14
Mean length	0.62	0.81	1.45	0.85	1.1	0.73	0.81	0.42	0.72	1.21	0.77	1.3

Table 42. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Williams Fork Reservoir, 8 August 2006.

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	
William's Fork - 8 August 2006 - Mean *Daphnia* density =3.8/L																
Alona spp.				0.2		0.1										0.0
Bosmina longirostris	0.2		0.1					0.16	0.1				0.2	0.5	0.3	0.1
Leptodiaptomus nudus	2.2	2.8	2.5	5.3	4.3	4.8	4.3	3.11	3.7	3.1	5.0	4.1	6.3	2.9	4.6	3.9
Ceriodaphnia megalops														0.2	0.1	0.0
Unidentified *Daphnia spp.*	0.3	0.6	0.5	0.4	0.4	0.4	0.7	0.98	0.8	0.3	0.6	0.4	1.3	0.9	1.1	0.6
Diacyclops bicuspidatus thomasi	4.7	7.9	6.3	4.4	4.4	4.4	7.0	5.73	6.4	3.6	3.4	3.5	3.9	3.8	3.9	4.9
Daphnia galeata mendotae	1.0	0.7	0.8	0.4	0.6	0.5	0.6	0.98	0.8	0.4	0.6	0.5	1.7	0.2	1.0	0.7
Daphnia pulex	2.4	1.7	2.0	3.3	3.8	3.5	2.4	2.46	2.4	1.2	2.2	1.7	1.7	2.0	1.9	2.3
Daphnia rosea				0.1												0.0
Daphnia schoedleri		0.1		0.2		0.1	0.5		0.2							0.1
Mean total no./L	12.3			13.8			14.4			10.2			13.0			12.7

Table 43. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Williams Fork Reservoir, 8 August 2006. *Al* = *Alona spp*, Bl = *Bosmina longirostris*, *Cdm = Ceriodaphnia megalops,D. spp.= Unidentified daphnia spp.* Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae*,Dp = *Daphnia pulex,* Dr = *Daphnia rosea, Ds = Daphnia schoedleri,* Ln = *Leptodiaptomus nudus*.

Length class in mm	**Williams Fork - 8 August 2006**								
	Al	**Bl**	**Cdm**	**D. spp.**	**Dbt**	**Dgm**	**Dp**	**Ds**	**Ln**
0.2									
0.3					1				1
0.4	1		1		10				2
0.5					17				20
0.6		1			19				18
0.7					37				9
0.8	1			1	37		1		8
0.9				5	20	2	1		6
1.0				5	11		6	1	9
1.1				3	2	1	7		5
1.2				4		12	19		10
1.3				2		6	8		3
1.4				1	1	7	20		4
1.5				3	1	7	26	2	4
1.6				6		7	14		3
1.7				4	1	5	16	2	
1.8				1		3	8		
1.9				2		1	9	1	1
2.0				2		3	5		
2.1				4		1	4		
2.2						1	5		
2.3							2	1	
2.4				1			5		
2.5							7		
2.6				1			2		
2.7							1		
2.8							1		
2.9				2			1		
3.0							1		
Totals	**2**	**1**	**1**	**47**	**157**	**57**	**169**	**7**	**113**
Mean length	**0.6**	**0.6**	**0.4**	**1.5**	**0.7**	**1.5**	**1.6**	**1.7**	**0.9**

Table 44. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations in Wolford Reservoir, 8 August 2006.

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	
Wolford - 08 August 2006 - Mean *Daphnia* density = 1.5/L																
Unidentified *Daphnia spp.*	0.1	0.2	0.2	0.2		0.1	0.1	0.3	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.2
Diacyclops bicuspidatus thomasi	6.5	7.5	7.0	5.1	5.3	5.2	6.2	6.1	6.1	9.8	7.0	8.4	3.5	4.0	3.8	6.1
Daphnia mendotae	0.3	0.3	0.3	0.4	0.3	0.4	0.1	0.1	0.1	0.6	0.3	0.4	0.2	0.3	0.2	0.3
Daphnia pulex	0.6	0.4	0.5	0.5	1.1	0.8	0.5	0.6	0.5	1.5	1.5	1.5	0.7	0.8	0.8	0.8
Daphnia rosea				0.1	0.1	0.1		0.1		0.1		0.1				0.1
Daphnia schodleri	0.4	0.3	0.3	0.1			0.3	0.3	0.3		0.1		0.5		0.3	0.2
Leptodiaptomus nudus	2.3	0.8	1.5	1.2	1.5	1.4	0.9	1.2	1.1	5.3	4.5	4.9	0.7	0.6	0.6	1.9
Mean total no./L	9.8			8.0			8.4			15.5			5.9			9.5

Table 45. Length frequency of crustacean zooplankton (measured to the nearest 0.1mm) collected in Wolford Reservoir, August 8, 2006. D. spp. = Unidentified Daphnia spp. Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata mendotae,* Dp = *Daphnia pulex,* Dr = *Daphnia rosea,* Ds = *Daphnia schoedleri*, Ln = *Leptodiaptomus nudus*.

Length class in mm	**Wolford- 08 August 2006**						
	D. spp.	Dbt	Dgm	Dp	Dr	Ds	Ln
0.4		3					
0.5		19	2				4
0.6		32	1				6
0.7	1	58	3		1		8
0.8	1	57	4	3			5
0.9	1	48	12	4			7
1.0	2	17	6	8		2	5
1.1	1	2	1	13			3
1.2	2			14		3	5
1.3	1		1	6			4
1.4	2		1	13		1	5
1.5	1			5		1	8
1.6	3		1	1		1	1
1.7	2			3			4
1.8			1	2		2	
1.9	2		4	9		5	
2.0	2		1	7	2	3	
2.1			2	3	3	3	
2.2	1			2		4	
2.3	1			5		5	
2.4	1			8	1	1	
2.5	1			5		2	
2.7				1			
Totals	25	236	40	112	7	33	65
Mean length	1.6	0.8	1.1	1.6	1.9	1.9	1.1

Table 46. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at five stations at Lake Avery, 21 June 2005.

Zooplankton species	**Station #1 (0-10m)**			**Station #2 (0-10m)**			**Station #3 (0-10m)**			**Station #4 (0-10m)**			**Mean no./L**
	a	**b**	**mean**	**a**	**b**	**mean**	**a**	**b**	**mean**	**a**	**b**	**mean**	
Avery - 21 June 2005 - Mean *Daphnia* density = 23.5/L													
Bosmina longirostris	0.0	0.0	0.0	0.2	0.0	0.1	0.5	0.9	0.7	0.3	0.0	0.2	0.2
Unidentified *Daphnia* spp.	1.9	0.4	1.2	0.7	1.9	1.3	1.9	1.9	1.9	1.7	3.8	2.7	1.8
Diacyclops b. thomasi	4.0	7.4	5.7	3.5	6.6	5.0	11.7	11.8	11.8	7.9	8.5	8.2	7.7
Daphnia galeata mendotae	0.9	0.2	0.6	0.2	1.3	0.8	4.7	2.8	3.8	2.7	3.8	3.3	2.1
Daphnia pulex	8.7	8.5	8.6	15.1	11.2	13.2	30.9	35.5	33.2	24.3	23.2	23.8	19.7
Mean total no./L	16.0			20.4			51.4			38.1			31.5

Table 47. Length frequency of crustacean zooplankton (measured to the nearest 0.1 mm) collected in Lake Avery on 21 June 2005. Bl = *Bosmina longirostris*, D. spp. = Unknown Daphnia, Dbt = *Diacyclops bicuspidatus thomasi*, Dgm = *Daphnia galeata Mendotae*, Dp = *Daphnia pulex*.

Length class in mm	**Avery- 21 June 2005**				
	Bl	**D. spp.**	**Dbt**	**Dgm**	**Dp**
0.3	1				
0.4	1		1		
0.5	1		13	1	
0.6		1	10	4	
0.7		8	3	10	3
0.8		9	5	24	6
0.9		8	16	4	28
1.0		5	8	4	43
1.1		8	5	1	29
1.2		3	8		42
1.3		2	2		3
1.4		3	2		9
1.5				1	5
1.6		1			3
1.7		1			5
1.8					6
1.9					11
2.0					5
2.1					2
Totals	3	49	73	49	200
Mean Length	0.4	1.0	0.8	0.8	1.2

Table 48. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at four stations at Grand Lake on 30 June 2005.

Zooplankton species	**Station #1 (0-10m)**			**Station #2 (0-10m)**			**Station #3 (0-10m)**			**Station #4 (0-10m)**			**Mean no./L**
	a	**b**	**mean**	**a**	**b**	**mean**	**a**	**b**	**mean**	**a**	**b**	**mean**	
Grand - 30 June 2005 - Mean *Daphnia* density = 0.0/L													
Diacyclops bicuspidatus thomasi	2.3	3.6	3.0	2.4	2.5	2.5	2.0	4.8	3.4	4.0	4.9	4.4	3.3
Leptodiaptomus nudus							0.1						
Mean total no./L	3.0			2.5			3.4			4.4			3.3

Table 49. Length frequency of crustacean zooplankton (measured to the nearest 0.1mm) collected on Grand Lake on 30 June 2005. Dbt = *Diacyclops bicuspidatus thomasi*, Ln = *Leptodiaptomus nudus.*

Length class in mm	**Grand- 30 June 2005**	
	Dbt	**Ln**
0.4	5	
0.5	23	
0.6	37	
0.7	34	
0.8	33	
0.9	35	1
1.0	22	
1.1	11	
1.2	24	
1.3	8	
1.4	3	1
Totals	235	2
Mean length	0.8	1.2

Segment Objective 2: Sample *Mysis* in Granby and Taylor Park Reservoirs; and in Dillon, Jefferson or Ruedi Reservoirs as needed or feasible.

INTRODUCTION

Mysis predation on zooplankton, particularly *Daphnia*, can be a complicating factor in the fishery management of several reservoirs in Colorado. Periodic, preferably annual, data on *Mysis* abundance has assisted fishery managers in understanding or predicting fishery responses to various management actions.

METHODS and MATERIALS

Quantitative sampling for *Mysis* was performed on four reservoirs in 2006. Sampling was performed in Dillon on 14 August, in Granby on 23 August, in Horsetooth on 16 August, and in Taylor Park on 17 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. Duplicate samples collected at each station 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 to the nearest millimeter from the tip of the rostrum to the tip of the telson, excluding setae.

RESULTS and DISCUSSION

Estimated *Mysis* densities and size structures for waters sampled in 2005 are given in Tables 50-57. A summary of mysid densities for Dillon, Granby and Tarlor Park reservoirs from 1991-2006 are provided in Table 58. Note that Table 58 corrects an error in the long-term mean for Taylor Park reported in Martinez (2006a).

Compared to the estimated density of *Mysis* in Dillon Reservoir in 2005, 451/m^2 (Table 58), the density in 2006, 88.5/m^2 (Table 50), indicates an abrupt crash in the mysid population. Conspicuously, larger mysids, > 15 mm, were essentially absent in the 2006 sample (Table 51). *Mysis* in Granby Reservoir showed an increase to over 500/m2 in 2006 (Table 52), a density associated with reductions in *Daphnia* abundance in years of delayed or weak thermal stratification. The mysids sampled in Horsetooth Reservoir 2006 were low in number, 2.6/m2 (Table 54), but all size classes were present (Table 55), similar to the observations in 2005 (Martinez 2006a). The density of *Mysis* in Taylor Park in 2006, 387/m^2 (Table 56), exceeded the reservoir's long-term mean *Mysis* density of 300/m^2 (Table 58).

Table 50. Summary of nighttime *Mysis* sampling at ten stations in Dillon Reservoir on 14 August 2006, using vertical meter net (0.785m^2 bridle opening). Estimate of corrected lake wide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.

Dillon Reservoir - 14 August 2006 - 10 Stations - Mean *Mysis*/m^2 = 88.5											
Sample number	**Sampling stations (water depth in meters)**										**Data summary**
	Stratum I		**Stratum II**				**Stratum III**				
	1A (52.8)	1B (55.0)	2A (34.7)	2B (38.3)	2C (33.9)	2D (38.0)	3A (9.5)	3B (10.8)	3C (11.5)	3D (14.2)	
#1	15	24	156	196	158	18	16	113	22	11	**729**
#2	13	26	152	147	119	22	60	93	23	6	**661**
Sum	28	50	308	343	277	40	76	206	45	17	**1390**
Mean	14	25	154	171.5	138.5	20	38	103	22.5	8.5	**69.5**

Table 51. *Mysis relicta* length frequency for specimens collected from nighttime vertical meter-net tows in Dillon Reservoir on 14 August 2006. *Mysis* total length in mm (tip of rostrum to tip of telson, excluding setae).

Dillon Reservoir - 14 August 2006

Station number	**Juvenile Mysids**							**Maturing and adult mysids**					**Total**
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	
1A-1					1	5	2	2	1	2	2		**15**
1B-1						1	4	7	7	5			**24**
2A-2			4	6	9	23	23	33	33	15	6		**152**
2B-1	1	2	13	18	12	23	21	48	41	14	2	1	**196**
2C-2		3	3	14	13	18	17	32	19				**119**
2D-2					1	1	3		9	3	1		**18**
3A-1	1			2	2	5	5	1					**16**
3B-1		3	6	28	36	32	8						**113**
3C-2		2	2	4	7	4	3	1					**23**
3D-1						3	5	3					**11**
Totals	2	10	28	72	81	115	91	127	110	39	11	1	**685**
Percent	0.29	1.46	4.09	10.51	11.82	16.79	13.28	18.54	16.06	5.69	1.61	0.15	**100.0**

Table 52. Summary of nighttime *Mysis* sampling at ten stations in Granby Reservoir on 23 August 2006, using a vertical meter net (0.785 m² bridle opening). Estimate of corrected lake wide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.

Granby Reservoir- 23 August 2006 - 10 Stations - Mean Mysis/m = 515.8											
Sample number	**Sampling stations (water depth in meters)**										**Data summary**
	Stratum I		**Stratum II**				**Stratum III**				
	A-50.5	B-47.5	A-26.0	B-23.5	C-28.5	D-20.0	A-13.3	B-10.0	C-13.0	D-16.0	
#1	1110	439	601	314	244	513	387	13	47	179	**3847**
#2	1468	469	585	318	194	587	296	10	36	287	**4250**
Sum	2578	908	1186	632	438	1100	683	23	83	466	**8097**
Mean	1289.0	454.0	593.0	316.0	219.0	550.0	341.5	11.5	41.5	233.0	**404.9**

Table 53. *Mysis relicta* length frequency for specimens collected from nighttime vertical meter-net tows in Granby Reservoir on 23 August 2006. *Mysis* total length in mm (tip of rostrum to tip of telson, excluding setae).

Granby Reservoir - 23 August 2006																	
Station number	**Juvenile mysids**							**Maturing and adult mysids**									**Total**
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	
1A-1		5	25	108	151	95	92	84	29	28	85	69	169	142	22	6		**1110**
1B-2	1		18	68	91	60	41	36	9	12	29	32	21	34	9	8		**469**
2A-2		2	25	69	101	82	100	104	22	7	11	5	20	34	2	1		**585**
2B-1			1	12	28	37	69	94	34	11	12	2	5	7	2			**314**
2C-2			2	16	22	22	15	22	6	2	11	17	17	28	8	5	1	**194**
2D-1		1	7	27	43	52	136	177	68	2								**513**
3A-1	1	3	20	48	53	61	117	75	9									**387**
3B-2					2		2	3	3									**10**
3C-2				2	6	6	9	13										**36**
3D-1		1	1	5	14	13	54	67	22	2								**179**
Totals	2	12	99	355	511	428	635	675	202	64	148	125	232	245	43	20	1	**3797**
Percent	0.05	0.32	2.61	9.35	13.46	11.27	16.72	17.78	5.32	1.69	3.90	3.29	6.11	6.45	1.1	0.53	0.03	**100.0**

Table 54. Summary of nighttime *Mysis* sampling at eight stations in Horsetooth Reservoir on 16 August 2006, using a vertical meter net (0.785 m² bridle opening). Estimate of corrected lake wide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter.

Horsetooth Reservoir- 16 August 2006- Mean Mysis/m^2 = 2.7								
Sample number	**Sampling stations (water depth in meters)**							**Data summary**
	HTMY1 (31.2)	HTMY2 (36.4)	HTMY3 (22.2)	HTMY4 (37.0)	HTMY5 (35.0)	HTMY6 (32.0)	HTMY7 (32.5)	
#1	0	0	2	0	1	5	5	**13**
#2	0	0	3	6	3	5	3	**20**
Sum	0	0	5	6	4	10	8	**33**
Mean	00	0	2.5	3	2	5	4	**2.1**

Table 55. *Mysis relicta* length frequency for specimens collected from nighttime vertical meter-net tows in Horsetooth Reservoir on 16 August 2006. *Mysis* total length in mm (tip of rostrum to tip of teslon, excluding setae).

Horsetooth Reservoir - 16 August 2006																		
Station number	**Juvenile mysids**								**Maturing & adult mysids**									**Total**
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
HTMY3-1	1		1															**2**
HTMY3-2	1		2															**3**
HTMY4-2								1	1		2				1		1	**6**
HTMY5-1									1									**1**
HTMY5-2			1												1	1		**3**
HTMY6-1					1		1	1					1			1		**5**
HTMY6-2							1			1		1				1	1	**5**
HTMY7-1									1		2	1			1			**5**
HTMY7-2								1	1			1						**3**
Totals	2		4		1		2	3	4	1	4	3	1		3	3	2	**33**
Percent	6.0		12.1		3.0		6.0	9.1	12.1	3.0	12.1	9.1	3.0		9.1	9.1	6.1	**100**

Table 56. Summary of nighttime *Mysis* sampling at nine stations at Taylor Park Reservoir on 17 July 2006, using a vertical meter net (0.785 m² bridle opening). Estimate of corrected lake wide mean *Mysis* density derived from duplicate samples at each station expressed as number per square meter. No sample taken from Station 3B due to shallow water depth.

Taylor Park - 17 July 2006 - 9 Stations - Mean Mysis/m^2 = 387.5											
Sample number	**Sampling stations (water depth in meters)**										**Data summary**
	Stratum I		**Stratum II**				**Stratum III**				
	1A-(38)	1B-(39)	2A-(27)	2B-(28)	2C-(18)	2D-(22)	3A-(9)	3B	3C-(11)	3D-(7)	
#1	214	186	213	462	345	508	214	N/A	243	156	**2541**
#2	156	186	391	445	314	532	375	N/A	282	253	**2934**
Sum	370	372	604	907	659	1040	589	N/A	525	409	**5475**
Mean	185.0	186.0	302.0	453.5	329.5	520.0	294.5	N/A	262.5	204.5	**304.2**

Table 57. *Mysis relicta* length frequency for specimens collected from nighttime vertical meter-net tows in Taylor Park Reservoir on 17 August 2006. *Mysis* total length in mm (tip of rostrum to tip of telson, excluding setae).

Taylor Reservoir - 17 July 2006																	
Station number	**Juvenile Mysids**								**Maturing and adult mysids**								**Total**
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
DN1A-2			1	13	39	38	35	16	3		3	4	3		1		**156**
DN1B-2			7	28	38	27	15	12	4	13	16	17	6	3			**186**
DN2A-1			2	20	39	52	44	23	2	2	11	10	7		1		**213**
DN2B-2	1	11	43	45	45	28	34	20	11	28	80	68	24	6	1		**445**
DN2C-2		7	30	32	44	66	66	39	5	4	11	7	3				**314**
DN2D-2	1	16	75	62	52	47	49	28	10	25	79	68	12	5	2	1	**532**
DN3A-2		4	14	33	50	99	127	44	4								**375**
DN3C-2		9	23	41	51	75	60	21	2								**282**
DN3D-1		3	22	29	25	41	23	9	3	1							**156**
Totals	2	50	217	303	383	473	453	212	44	73	200	174	55	14	5	1	**2659**
Percent	0.1	1.9	8.2	11.4	14.4	17.8	17.0	8.0	1.7	2.7	7.5	6.5	2.1	0.5	0.2	0.0	**100**

Table 58. Summary of the estimated densities of *Mysis relicta* in three of the largest reservoirs in Colorado containing *Mysis*. Dillon, Granby, and Taylor Park, which also have the longest records of sampling for this introduced species during the period from 1991 to 2006.

Year	***Mysis* density (number/m²)**		
	Dillon	**Granby**	**Taylor Park**
1991	572	162	437
1992	352	178	456
1993	341	231	165
1994	270	541	170
1995	372	674	93
1996	235	1365	182
1997	no data	382	
1998	246	294	196
1999	236	566	197
2000	223	843	366
2001	no data	378	262
2002	336	460	504
2003	25	30	241
2004	no data	238	399
2005	451	215	447
2006	89	516	387
No. years	13	16	15
Minimum	25	30	93
Maximum	572	1365	504
Mean no./m²	**288**	**442**	**300**

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:	Collect water and otolith samples from Blue Mesa, Taylor Park, Crawford, and Paonia Reservoirs to evaluate utility of microchemical techniques to identify origins of illicitly stocked fishes in Blue Mesa.

INTRODUCTION, METHODS, RESULTS and DISCUSSION

Martinez (2006b) discussed concern about the escalating rate of illicit fish introduction in western Colorado, including the threat that this activity poses to established sport fisheries, consequences for native fish preservation and endangered fish recovery, strategies to combat this illicit activity, and the potential utility of water and otolith microchemistry as a forensic tool to discourage and prosecute illegal movements of fish by the public. While this Segment Objective was originally specific to the illicit movement of yellow perch among reservoirs in the Gunnison River Basin (Martinez 2006a), this work will now be addressed on a larger geographic scale under my GOCO funded West Slope Warmwater Fisheries research. This effort, Project C18/19 funded by the Colorado River Recovery Program, is entitled Chemically Fingerprinting Nonnative Fishes in Reservoirs (Martinez 2006b). Progress for this work will be reported in Recovery Program annual reports produced cooperatively with Colorado State University personnel including Phil Brinkly, Master's Candidate, and Dr. Brett Johnson in the Department of Fish, Wildlife and Conservation Biology.

Segment Objective 2:	Participate in water and otolith collection and analyses from hatcheries and receiving water to facilitate development of forensic tool for identifying source of illicitly stocked fishes.

INTRODUCTION, METHODS and DISCUSSION

Martinez (2005) discussed the impetus to initiate research on potential forensic application of "fingerprinting" water sources and identifying these distinct microchemical compositions in the otoliths of fish to track their illicit transfer among waters by the public and private sectors. Appendix C summarizes research by Dan Gibson-Reinemer, Masters Candidate at CSU, initially funded in part by CDOW and then by a grant from the Whirling Disease Initiative, Montana State University.

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 research on fish escapement at Vallecito Reservoir, as needed or feasible.

INTRODUCTION

Martinez (2005) described the background and rationale for conducting a preliminary examination of the utility of strobe lights at the Vallecito Reservoir outlet to reduce and control escapement of kokanee. My crew assisted this effort by performing additional hydroacoustics in 2006 to determine the distribution of kokanee in the reservoir in relation to the outlet.

METHODS and MATERIALS

In addition to the standardized annual hydroacoustic survey performed at night in Vallecito in early August 2006 (Table 1), these same standardized transects were also surveyed during daytime to compare the vertical distribution of kokanee in the reservoir. Kevin Rogers, CDOW Aquatic Researcher, processed these data.

RESULTS and DISCUSSION

Martinez (2005) described the configuration of the penstock at Vallecito Dam through which kokanee might become entrained in relation to the fluctuation of the reservoir. At full capacity, the penstock is 25.5 m (83 feet) below the water surface. In 2004, when the preliminary evaluation of kokanee response to a strobe light in Vallecito Reservoir was performed, the average depth of water above the penstock intake during the months of April through September was 20 m (66 feet). Table 59 compares the numbers of tracked fish, presumed to be almost entirely kokanee (Martinez 1995) in the sonar survey during the day and at night on 29 August 2005 and 2 August 2006 in Vallecito. There is a drastic difference in fish density as seen by sonar during the day vs. night due to the daytime schooling behavior of kokanee in surface waters. Of greater interest is the increase in the proportion of fish below 10 m at night, especially the 376% to 1,774% increase in fish below 20 m from day to night. This diel migratory behavior of kokanee places them in closer proximity, depth-wise, to the intake of the penstock at night when they concentrate at depth around 20-m. The greater density of kokanee in 2006 may exacerbate this problem, but is unknown if population effects would be similar during years of lower kokanee abundance as observed in 2005 (Table 60).

Table 59. Comparison of daytime versus nighttime numbers of fish, primarily kokanee, determined from hydrocacoustics along four standardized transects in three strata in Vallecito Reservoir on 29 August 2005 and 2 August 2006.

Water depth (m)	**Daytime**		**Nighttime**		**From day to night**	
	Number	**Percent**	**Number**	**Percent**	**Difference**	**% change**
29 August 2005						
2-10	2,531	16	1,266	3	1,265	- 50%
10-20	10,285	63	19,538	53	-9,253	+ 90%
>20	3,467	21	16,521	44	-13,054	+ 376%
Total	**16,283**	**100**	**37,325**	**100**	**-21,042**	**+130**
2 August 2006						
2-10	5,353	36	2,141	1	3,212	-60%
10-20	8,798	60	129,148	92	-120,350	+1,368%
>20	507	4	9,502	7	-8,995	+1,774%
Total	**14,658**	**100**	**140,791**	**100**	**-126,133**	**+860**

Segment Objective 2: Participate in yellow perch investigations at Blue Mesa Reservoir, as needed or feasible.

INTRODUCTION

Illicitly introduced yellow perch in Blue Mesa Reservoir continue to be viewed as a serious threat to the quality of the reseservoir's coldwater salmonid fishery. The basis for this perceived threat is the potential for yellow perch to exert intense predation on kokanee fry or to compete for the *Daphnia* and invertebrate prey base.

METHODS and MATERIALS

Appendix D contains provides the methodology utilized at CSU to identify gut contents of brown trout, lake trout and yellow perch collected in Blue Mesa Reservoir in 2005. In addition, Appendix D also describes the use of available data to perform a bioenergetics analysis of yellow perch in Blue Mesa. Lacking age data, surrogate growth data for yellow perch from the Dakotas was used. In 2005 and 2006, otoliths were removed from yellow perch captured in Blue Mesa by CDOW Fishery Biologist, Dan Brauch. Yellow perch otoliths were processed and aged as described earlier in this report for brown trout and lake trout.

RESULTS and DISCUSSION

Appendix D summarizes the preliminary bioenergetics results and demonstrates that yellow perch do indeed pose a threat to kokanee in Blue Mesa Reservoir. Figure 3 summarizes age and growth of yellow perch sampled in the reservoir in 2005 and 2006. There are a wide range of sizes in the older cohorts, but the rate of growth appears to be slow. This growth is slower than the surrogate rate for yellow perch used in the bioenergetics simulation.

Segment Objective 3: Participate in dissemination of information, as needed or feasible.

INTRODUCTION, METHODS, MATERIALS, RESULTS and DISCUSSION

In addition to the review of Colorado's hydroacoustic program (Appendix A), work under this objective focused primarily on preparation of the draft manuscript Western Trout Woes (Martinez 2006a). I completed a preliminary draft and sent it to coauthors in six states on 16 January 2007. I received the last of the feedback from these coauthors on 17 April 2007. The goal will be to incorporate this input into a final draft for submission to Fisheries magazine.

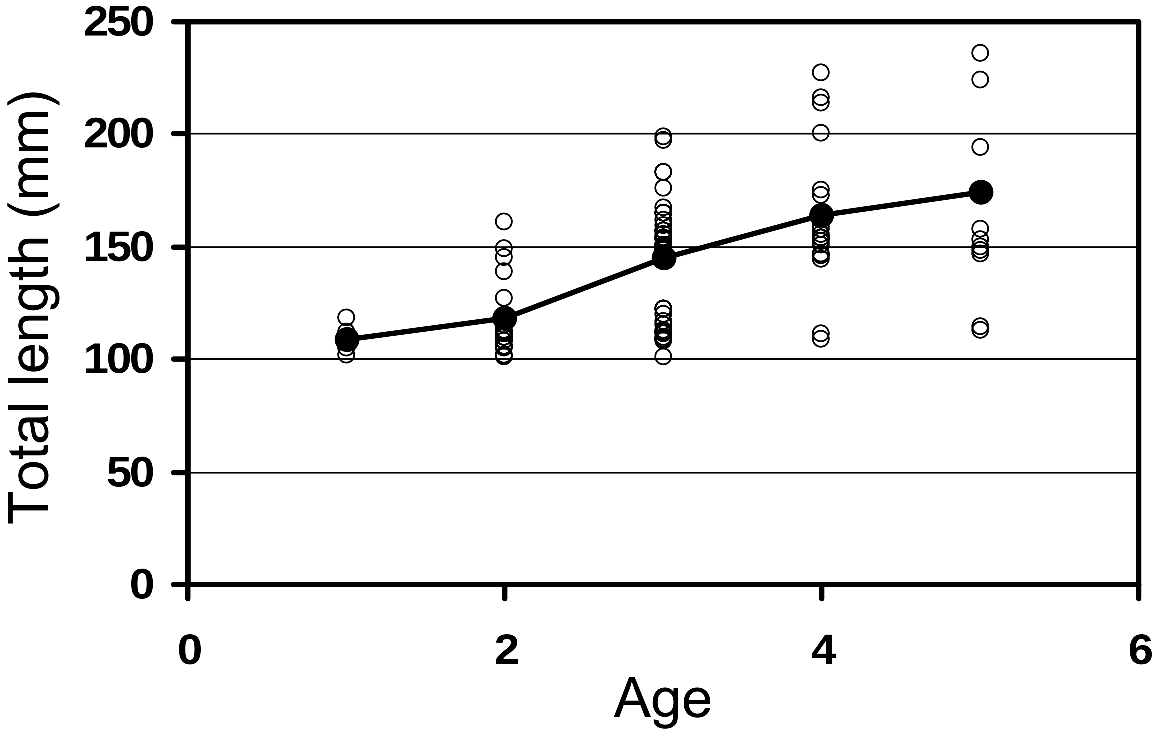

Figure 3. Ages for yellow perch collected in Blue Mesa Reservoir 11 November 2005 (n=9), and 9 and 15 August 2006 (n=89). Open dots are represent individual fish (n=96). The black dots and line indicate the mean length for each age class.

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Maceina, M. J., J. Boxrucker, D. L. Buckmeier, R. S. Gangl, D. O. Lucchesi, D. A. Isermann, J. R. Jackson, and P. J. Martinez. 2007. Current Status and Review of Freshwater Fish Aging Procedures Used by State and Provincial Fisheries Agencies with Recommendations for Future Directions. Fisheries 32:329-340.

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Martinez, P. J., and E. P. Bergersen. 1991. Interactions of zooplankton, *Mysis relicta*, and kokanees in Lake Granby, Colorado. American Fisheries Society Symposium 9:49-64.

APPENDIX A

POWERPOINT: ***HISTORY OF HYDROACOUSTICS PROGRAM IN CO***, PRESENTED 7 FEBRUARY 2007AT KOKANEE MEETING IN SILVERTHORNE, CO

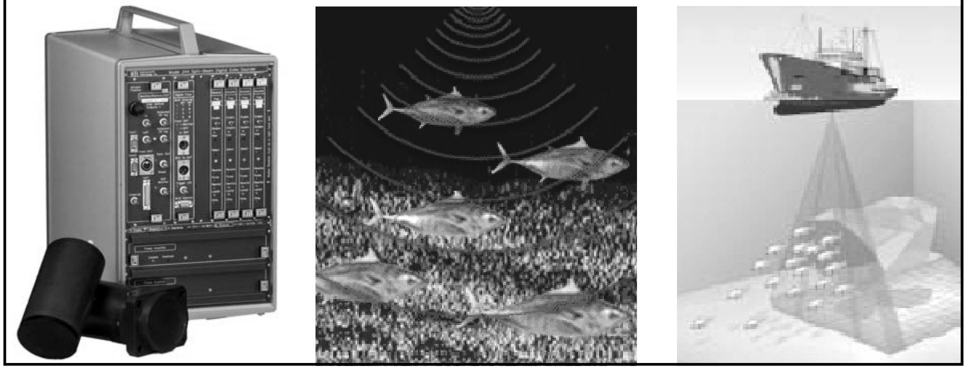
History of Hydroacoustics Program in CO

1991

- evaluate scientific sonar for use in CO waters (FED-AID F-89)

1992

- Lake Mead (NV) & Buffalo Bill Reservoir (WY) sonar with USBR



History of Hydroacoustics Program in CO

1993

- visit Hydroacoustic Technology, Inc. (HTI), BioSonics, and SIMRAD in Seattle, WA to review scientific sonar systems
- HTI training "Using Hydroacoustics for Fishery Assessments"
- purchased HTI 240-200 kHz Digital Split-beam Echosounder
- training at nighttime sonar survey at FGR with Dan Yule, WG&F
- preliminary sonar transects in 4 waters: HTR, GRR, TWL, VCR
- transects identified by barricade blinkers on floats or shoreline
- transducer deployed by shaft mounted in Minn-Kota bracket

History of Hydroacoustics Program in CO

1994

- Sam Johnston, HTI, provided post-processing training in FC
- sonar surveys in 5 waters; blinkers & SONY-GPS for transects
- begin use of sonar for predator-prey abundance & bioenergetics

1995

- comparison of USBR SIMRAD single-beam vs. CDOW HTI split-beam estimates of pelagic fish abundance in Blue Mesa & Twin Lakes favorable
- comparison of CSU BioSonics dual-beam vs. CDOW HTI split-beam estimates of pelagic fish abundance in Blue Mesa favorable; **questions raised about -55db cutoff for *Mysis***
- Steve Johnson M.S. research on *Mysis* TS at CSU (B. Johnson)

History of Hydroacoustics Program in CO

1996

- data post-processed by S. Johnson
- lake-wide pelagic fish population derived area vs. volume for whole reservoir, in 3-strata & by 5-m strata (5-m used in CO)
- *Mysis* TS in situ, volume backscatter & theoretical modeling

1997

- Johnson, S. K. 1998. Acoustic Target Strength Estimates of Opossum Shrimp (*Mysis relicta*). Master's thesis. CSU.
- S. Johnson & J. Stockwell attend Mysid Workshop in NY;
- boat accident at Blue Mesa during sonar survey

History of Hydroacoustics Program in CO

1998

- Kevin Rogers begins participation in sonar surveys; Horsetooth
- K. Rogers writes LabView sonar analysis program for MAC & takes over sonar post-processing

1999

- Draft: Johnson, Johnson & Martinez. Acoustic target strength estimates of opossum shrimp (*Mysis relicta*) using a split-beam echo sounder = -74.6 db @ 11.1mm & 200 kHz
- Gal, G., Rudstam, L. G. & C. H. Greene. 1999. Acoustic characterization of *Mysis relicta*. Limnology & Oceanography 44:371-381. = -73.1 db @ 13.7mm & 420 kHz dual-beam.
- D. Yule (WY G&F) & P. Martinez (CDOW) conduct sonar training for Saskatchewan Environment, Regina

History of Hydroacoustics Program in CO

2000

- HTI Model 240 upgraded to Model 243 with Windows operating system, EchoScape software & lap-top command
- Jill Hardiman M.S. research on YOY-KOK distribution in Blue Mesa using scientific sonar (CSU - B. Johnson)
- Johnson B. M. & P. J. Martinez. 2000. Trophic economics of lake trout management in reservoirs of differing productivity. NAJFM 20:127-143. (MAC abundance via TS & target depth)
- desire to verify rapid-assessment potential of sonar surveys for predator-prey components in reservoirs

History of Hydroacoustics Program in CO

2001

- Harry Crockett M.S. research to use sonar to estimate MAC size & abundance in Blue Mesa (CSU - B. Johnson)
- **Sonar Workshop**: Advanced Mobile Survey Short Course: Dutch John UT
- HTI 243- repair of computer in sounder – failed to track quadrant in split-beam transducer – compromised size, but not abundance estimation

History of Hydroacoustics Program in CO

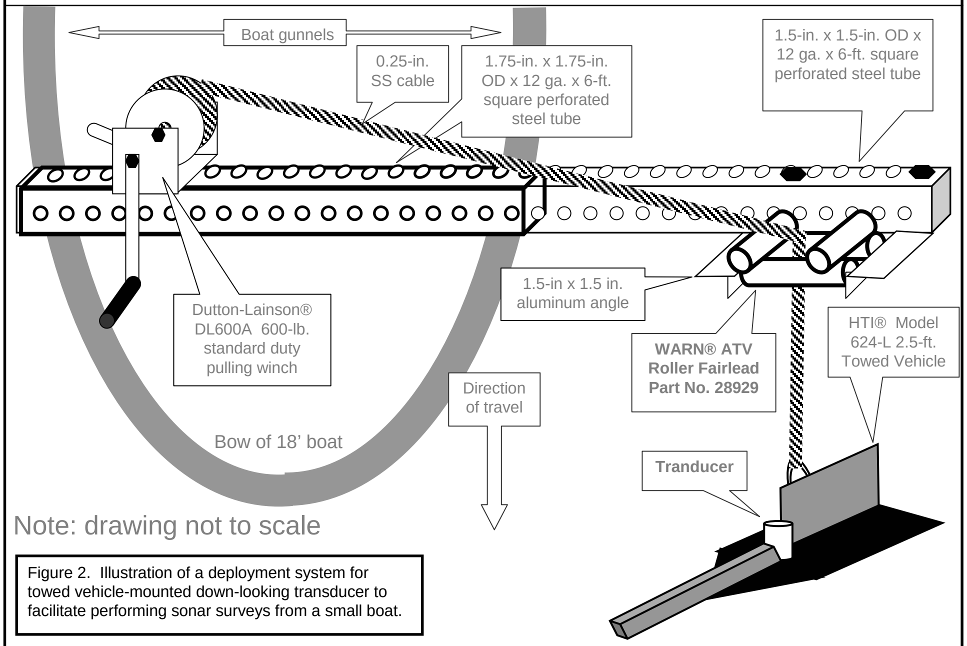
2002

- methods to examine MAC acoustic target strength
- New laptop with improved network connections for sonar (RJ-45) & towed-fin for deployment of down-looking transducer
- drought prevented access to Taylor Park & Vallecito

History of Hydroacoustics Program in CO

2003

- Martinez, P., K. Rogers, H. Crockett, B. Johnson. 2003. Discerning prey & piscivore targets in hydroacoustic surveys of pelagic salmonids in Colorado reservoirs *in* P. Martinez, 2003, Coldwater Reservoir Ecology, Project F-242-R10, Progress Report. (use of kokanee spawn run length frequency to identify TS cutoff for predators sized targets in sonar surveys)
- **Sonar Workshop** in Grand Junction
- strobe light examination at Vallecito – USBR, K. Keisling, MSC
- Hardiman, J. M. 2003. Predation risk & limnological conditions drive seasonal distribution of YOY kokanee in a Colorado reservoir. Master's thesis. CSU.
- assemble hardware to deploy towed-fin & down-looker



Note: drawing not to scale

Figure 2. Illustration of a deployment system for towed vehicle-mounted down-looking transducer to facilitate performing sonar surveys from a small boat.

History of Hydroacoustics Program in CO

2004

- acquire 6^o side-looking transducer & inverter for DC power
- perform down-looking surveys with 15^o transducer mounted in towed-fin
- collect side-looking sonar data with 6^o transducer mounted on shaft (Elkhead)
- Crockett, H. J. 2004. Assessment of lake trout abundance & ecology in a Colorado reservoir using hydroacoustic & mark-recapture techniques. Master's thesis. CSU.
- Hardiman, J. M., B. M. Johnson & P. J. Martinez. 2004. Do predators influence the distribution of age-0 kokanee in a Colorado reservoir? TAFS 133:1366-1378.

History of Hydroacoustics Program in CO

2005

- Martinez, P., K. Rogers & H. Crockett. 2005. Used of a towed-vehicle for deployment of a down-looking tranducer during mobile surveys in lakes & reservoirs. **Sonar Workshop** in Yellowstone

- K. Rogers requires new data form for sonar surveys

- acquire & rig new sonar boat – Hewes Sea Runner 22

- set-up for deployment of down- & side-looking transducer from small jon-boat at Trapper’s Lake

- K. Rogers adapts small boat set-up for raft

HYDROACOUSTIC SURVEY DATA SHEET Page ____ of ____

Water__________________ **Date**_____________ Personnel_____________________________

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Transect number______ UTM zone __ __ __

S	Mil time __ __ __ __	**S**	Mil time __ __ __ __
T	Waypoint ________	**T**	Waypoint ________
A	UTM X 0 __ __ __ __ __ __	**O**	UTM X 0 __ __ __ __ __ __
R	UTM Y __ __ __ __ __ __ __	**P**	UTM Y __ __ __ __ __ __ __
T	DAT (or count) ________		DAT (or count) ________ PNO ____
	File __ __ __ __ __ __ __ __		Fish ______ T.S. ______ Pings ____

Comments/Art:

Waves: none 0-1 ft 1-2 ft >2 ft Wind: none 0-5 mph 5-15 mph >15 mph

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Transect number______ UTM zone __ __ __

S	Mil time __ __ __ __	**S**	Mil time __ __ __ __
T	Waypoint ________	**T**	Waypoint ________
A	UTM X 0 __ __ __ __ __ __	**O**	UTM X 0 __ __ __ __ __ __
R	UTM Y __ __ __ __ __ __ __	**P**	UTM Y __ __ __ __ __ __ __
T	DAT (or count) ________		DAT (or count) ________ PNO ____
	File __ __ __ __ __ __ __ __		Fish ______ T.S. ______ Pings ____

Comments/Art:

Waves: none 0-1 ft 1-2 ft >2 ft Wind: none 0-5 mph 5-15 mph >15 mph

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Transect number______ UTM zone __ __ __

S	Mil time __ __ __ __	**S**	Mil time __ __ __ __
T	Waypoint ________ **T**	Waypoint ________	
A	UTM X 0 __ __ __ __ __ __	**O**	UTM X 0 __ __ __ __ __ __
R	UTM Y __ __ __ __ __ __ __	**P**	UTM Y __ __ __ __ __ __ __
T	DAT (or count) ________		DAT (or count) ________ PNO ____
	File __ __ __ __ __ __ __ __		Fish ______ T.S. ______ Pings ____

Comments/Art:

Waves: none 0-1 ft 1-2 ft >2 ft Wind: none 0-5 mph 5-15 mph >15 mph


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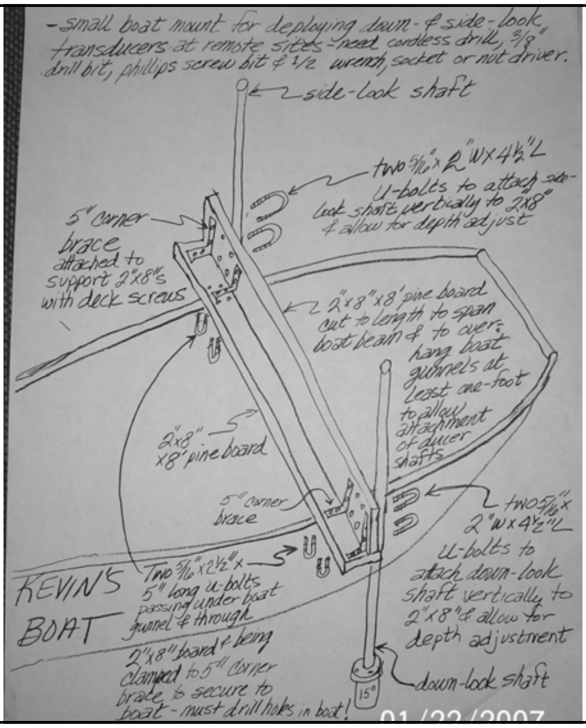


History of Hydroacoustics Program in CO

2006

- Crockett, H. J., B. M. Johnson, P. J. Martinez & D. Brauch. 2006. Modeling target strength distributions to improve hydroacoustic estimation of lake trout population size. TAFS 135:1095-1108.
- compare HTI 241 (WY G&F–Andy Dux) with CDOW HTI 243 & re-run transects 4x to assess repeatability at Williams Fork
- K. Rogers horse-pack sonar into Little Trappers lake
-
-

History of Hydroacoustics Program in CO

2007

- Sonar workshop in Yellowstone

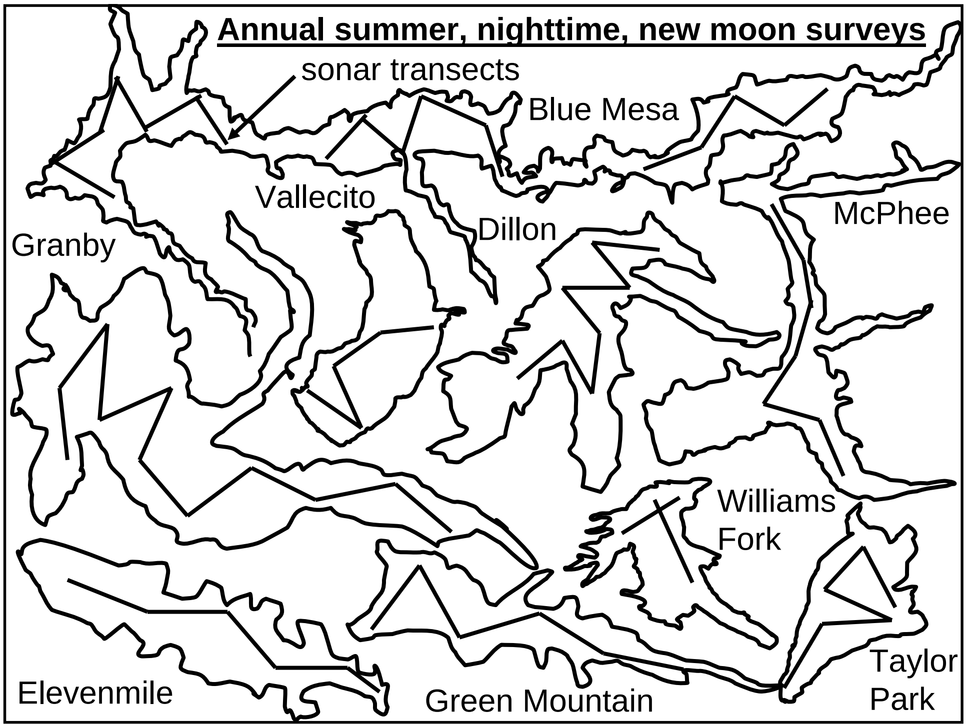
It’s time again for the biennial Hydroacoustic Lake Survey Workshop, a forum to promote discussion and exchange ideas between researchers using mobile survey hydroacoustic techniques to monitor fish populations. The meeting emphasizes issues-of-concern to current users of HTI *Model 241/244 Split-Beam Hydroacoustic System*s, including various aspects of mobile survey data collection and analysis.

This workshop is the fourth in a continuing series of “*Advanced Mobile Survey Hydroacoustic Techniques*” meetings intended to address shared challenges faced by biologists involved in freshwater hydroacoustic assessment applications. Previous workshops have taken place in Dutch John, Utah (Utah Department of Natural Resources) in 2001, Grand Junction, Colorado in 2003 (Colorado Department of Wildlife) and Yellowstone Park in 2005 (National Park Service). We’ve typically had attendance by 20-25 researchers from across the US, the Caribbean, Europe and even Australia.

The 2007 workshop is scheduled for June 13-15, 2007 on Yellowstone Lake in Yellowstone National Park (Lake Village), the same location as in 2005. There’s no charge to attend the workshop, but attendees will be responsible for their own lodging, transportation and food costs.

Reservoir name	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**		**05**		**06**	
	Down-looking=D (Side-looking=S)										**D**	**S**	**D**	**S**	**D**	**S**
Large (~1,000 SA), high elevation (>6,500’asl) salmonid reservoirs																
Blue Mesa	A	J	A	A	A	A	A	A	A	A	A		A		A	
Dillon				S	S	S	S	S	A	A			A			
Elevenmile		j											A		A	
Granby	S	S	S	S	S	S	S	S	A	A	S	S	S		S	
Green Mtn.													S		S	
McPhee	A	S			A	A	A	j A	j	A	J		A		A	
Ruedi										A						
Stagecoach								A								
Taylor Park	A	A	A	S	A	S	S	S		A	A		A		A	
Twin Lakes	J															
Vallecito		S			A	A	A	A		A	J		A		A	
Vega															O	O
Williams Fk.								A	A	A	A		A		A	A
Wolford Mtn.								A								

Reservoir name	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**		**05**		**06**	
	Down-looking=D (Side-looking=S)										**D**	**S**	**D**	**S**	**D**	**S**
Assorted low elevation (<6,500’ asl) reservoirs																
Carter						S	S								S	S
Cherry Creek							S									
Elkhead											O	O				
Horsetooth					O	O				S			O	O	S	S
Small (< 200 SA), high elevation (>9,000 ft. asl) cutthroat trout lakes																
Fern														S		
Big Cow (2007)																
Lawn (2007)																
Little Trapper																S
Trappers													S	S		



Sonar, KOK/MAC & Limnology

- **trends in pelagic fish abundance (KOK)**
- **rapid assessment of prey vs. predator (MAC)**
- **Front Range reservoirs; *Mysis* target strengths**
- **target strength & age-0 KOK distributions (CSU)**
- **fish escapment; Vallecito strobe examination**
- **transducer deployment; transect repeatability**
- **side-looking surveys; remote lake cutthroat trout**
- **sonar workshops; 13-15 Jun 2007, Yellowstone**

Sonar, **KOK/MAC** & Limnology

- length (weight) frequency of kokanee spawn runs
- age composition of kokanee spawn runs
- MAC bioenergetics & trophic economics
- KOK broodstock guideline (199?) & designation?
- KOK/MAC/*MYSIS* food web (stable isotopes)
- MAC otolith aging & validation (tagged fish)
- KOK otolith aging & validation (chemical markers)
- "Western Lake Trout Woes"

Sonar, KOK/MAC & **Limnology**

- crustacean zooplankton species, density & lengths
- *Mysis* density, length frequency & biomass
- temperature & dissolved oxygen profiles, & Secchi
- zooplankton vs. *Mysis* vs. reservoir operations
- *Mysis* commercial fishery considerations

APPENDIX B

TEMPERATURE AND DISSOLVED OXYGEN PROFILES, AND SECCHI DEPTHS MEASURED IN COLDWATER RESERVOIRS IN 2006

Table B-1. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations at Blue Mesa Reservoir on 17 May 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Blue Mesa 17 May 2006**					
	Sapinero (87.3m)		**Cebolla (54m)**		**Iola (19.4m)**	
	°C	mg/l	°C	mg/l	°C	mg/l
0	13.6	6.7	14.8	5.8	13.7	7.0
1	10.8	6.9	12.4	6.2	12.5	6.9
2	10.6	5.3	11.8	6.1	12.3	7.2
3	10.0	5.1	11.5	5.9	12.2	7.5
4	9.6	5.3	11.3	5.4	12.0	7.5
5	9.3	5.4	11.2	5.0	11.6	7.4
6	9.2	5.2	11.0	5.1	11.1	7.4
7	8.9	5.2	9.9	5.0	11.0	7.3
8	8.7	5.3	9.5	4.9	10.6	7.6
9	8.3	5.4	9.2	4.8	10.1	7.3
10	8.1	5.4	8.7	4.9	9.7	7.5
11	7.9	5.3	8.0	5.0	9.2	7.5
12	7.5	5.2	7.8	5.2	9.0	7.7
13	7.2	4.9	7.7	5.2	8.9	7.4
14	7.0	4.3	7.3	5.3	8.5	7.1
15	6.8	3.8	7.0	5.3	7.4	6.2
16	6.6	3.7	6.9	5.3	6.9	6.2
17	6.4	3.7	6.6	5.4	6.5	5.8
18	6.2	3.6	6.4	5.3	6.5	5.4
19	6.0	3.4	6.1	5.7	6.5	5.4
20	5.8	3.2	5.7	5.8		
25	5.3	2.3	5.4	4.9		
30	4.6	2.1	5.2	4.4		
35	4.4	1.9	4.9	4.2		
40	4.3	1.8	4.8	4.5		
45	4.2	1.8	4.8	4.1		
50	4.1	1.7	4.8	4.6		
55	4.0	1.8				
Secchi (m)	3.21		3.31		2.35	

Table B-2. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations at Blue Mesa Reservoir on 18 July 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Blue Mesa 18 July 2006**					
	Sapinero (95.1m)		**Cebolla (58.2m)**		**Iola (20.8m)**	
	°C	mg/l	°C	mg/l	°C	mg/l
0	20.1	6.5	20.6	6.5	21.3	6.7
1	19.6	7.0	20.1	6.7	20.1	6.9
2	19.6	6.9	19.8	6.8	19.9	7.0
3	19.4	7.1	19.8	6.9	19.7	7.1
4	19.3	7.0	19.7	7.0	19.6	7.0
5	19.3	7.2	19.5	7.0	19.4	6.8
6	19.2	7.1	19.4	6.9	19.2	6.7
7	19.2	7.3	18.7	6.6	18.9	6.7
8	19.1	7.3	18.2	6.7	17.9	6.3
9	18.2	7.3	17.6	6.5	17.4	6.1
10	17.4	6.9	16.8	6.0	16.2	5.9
11	17.0	6.9	16.0	6.0	15.8	5.8
12	16.5	6.9	15.1	5.9	15.1	5.6
13	15.1	6.7	14.9	5.8	14.6	5.6
14	14.1	6.8	14.1	5.9	14.4	5.4
15	13.4	6.9	14.0	6.0	13.7	5.5
16	13.0	7.0	12.9	6.2	13.4	5.3
17	12.4	6.9	12.5	6.3	12.6	5.2
18	11.9	7.1	12.1	6.5	12.2	4.9
19	11.5	7.3	11.4	6.6	11.7	4.4
20	10.8	7.4	10.8	7.0	10.9	4.4
25	9.1	8.3	8.7	7.2		
30	7.6	8.8	7.2	7.4		
35	6.8	8.4	6.8	7.2		
40	6.1	8.2	6.2	7.4		
45	5.6	8.3	5.7	7.6		
50	5.3	8.5	5.6	7.8		
55	5.0	8.4	5.4	7.7		
Secchi (m)	3.59		5.10		4.55	

Table B-3. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations in Dillon Reservoir on 14 August in 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Dillon 14 August 2006**									
	P1 (65.0m)		**P2 (27.0m)**		**P3 (18.1m)**		**P4 (21.1m)**		**P5 (12.0m)**	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	17.4	6.8	18.0	6.5	17.9	6.6	17.6	6.5	18.3	6.4
1	17.4	6.8	18.0	6.6	17.9	6.7	17.7	6.5	18.3	6.4
2	18.3	6.9	17.7	6.6	17.9	6.7	17.4	6.5	18.2	6.6
3	17.0	7.0	17.4	6.7	17.7	6.8	17.3	6.5	17.8	6.7
4	16.9	7.0	17.3	6.9	17.4	6.9	17.1	6.5	17.5	6.8
5	16.8	7.1	17.1	6.9	17.4	6.9	17.0	6.5	16.9	6.6
6	16.8	7.0	17.1	6.9	17.2	6.9	16.8	6.6	16.9	6.5
7	16.8	7.1	16.5	6.8	16.3	6.8	16.6	6.5	16.6	6.3
8	16.7	7.0	15.7	6.8	15.9	6.7	16.1	6.5	16.2	6.1
9	15.2	6.8	15.1	6.8	15.4	7.2	15.2	6.3	15.5	6.1
10	14.1	6.7	14.9	6.8	14.9	6.8	13.9	6.5	15.3	6.0
11	13.6	6.6	14.1	6.7	14.2	6.7	13.1	6.4	14.7	5.8
12	12.9	6.6	13.7	6.4	13.7	6.3	12.6	6.2		
13	12.2	6.4	12.6	6.4	13.6	6.0	11.8	6.3		
14	11.5	6.4	11.9	6.3	12.8	5.9	11.5	6.3		
15	11.2	6.4	11.1	6.2	12.2	5.7	11.1	6.4		
16	11.0	6.3	11.0	6.1	11.5	5.7	10.7	6.2		
17	10.5	6.3	10.0	6.2	11.1	5.7	10.0	6.3		
18	10.0	6.4	9.9	6.2	10.5	5.6	9.7	6.4		
19	9.6	6.4	9.5	6.2			9.6	6.4		
20	9.4	6.5	9.4	6.2			9.3	6.4		
25	8.3	6.8	8.4	6.4						
30	7.4	6.9								
35	6.4	7.1								
40	5.9	7.0								
45	5.4	6.8								
50	5.2	6.7								
55	5.1	6.5								
Secchi (m)	12.47		4.51		3.67		4.32		4.57	

Table B-4. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Elevenmile Reservoir on 9 August 2006. Values in parenthesis denote maximum water depth at station. Secchi depths not available due to extremely high density bloom of a *Volvox* species.

Water depth (m)	**Elevenmile 9 August 2006**									
	P1 (28.8m)		**P2 (16.4m)**		**P3 (13.3m)**		**P4 (14.5m)**		**P5 (11.7m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	19.3	6.7	18.6	6.1	18.7	5.4	18.7	5.5	18.5	5.3
1	19.3	6.4	18.8	6.3	18.6	5.4	18.7	5.5	18.3	5.5
2	19.3	6.3	18.7	6.3	18.5	5.4	18.6	5.6	18.2	5.3
3	19.3	6.3	18.5	6.2	18.4	5.5	18.5	5.7	18.2	5.3
4	19.3	6.3	18.4	6.0	18.3	5.5	18.4	5.6	18.2	5.3
5	18.5	6.5	18.3	6.1	18.2	5.4	18.3	5.6	18.2	5.3
6	18.3	6.4	18.3	6.2	18.1	5.3	18.2	5.5	18.1	5.2
7	18.2	6.0	18.2	5.7	18.1	5.2	18.1	5.4	18.1	5.2
8	18.2	5.7	18.1	5.5	17.6	3.9	17.7	4.7	17.9	4.7
9	18.0	5.6	18.0	5.0	17.4	3.5	17.1	3.0	17.0	2.3
10	17.8	5.0	17.7	4.5	17.1	2.9	16.3	1.7	17.0	2.7
11	16.5	2.6	16.4	2.1	15.9	1.5	16.0	1.2	16.4	1.7
12	15.9	1.7	16.1	1.5	15.6	0.9	15.5	0.8		
13	15.6	1.6	15.7	1.2	15.4	0.6	15.3	0.6		
14	15.1	1.3	15.5	0.8						
15	14.9	1.3	15.2	0.7						
16	14.7	1.1	15.1	0.6						
17	14.5	1.1								
18	14.1	1.1								
19	13.8	1.2								
20	13.5	0.9								
25	12.8	0.8								
Secchi (m)	N/A		N/A		N/A		N/A		N/A	

Table B-5. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at two stations on Elevenmile Reservoir on 22 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Elevenmile 22 August 2006**			
	P1 (14.5m)		**P4 (14.5m)**	
	°C	**mg/l**	**°C**	**mg/l**
0	18.2	7.0	19.8	6.8
1	18.0	6.9	19.1	7.0
2	17.9	6.8	18.2	7.4
3	17.8	6.8	18.0	7.4
4	17.8	6.7	17.9	7.0
5	17.8	6.7	17.8	6.9
6	17.8	6.6	17.8	6.6
7	17.8	6.6	17.8	6.4
8	17.7	6.7	17.7	6.2
9	17.7	6.8	17.6	6.2
10	17.7	6.2	17.6	5.4
11	17.6	5.6	17.5	4.7
12	17.3	3.7	16.7	0.7
13	16.3	1.1	15.7	0.3
14	15.8	0.6	15.1	0.2
Secchi (m)	4.42		4.63	

Table B-6. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations in Granby Reservoir on 27 June 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Granby 27 June 2006**									
	P1 (20.0m)		**P2 (11.8m)**		**P3 (25.6m)**		**P4 (38.0m)**		**P5 (30.5m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	16.7	6.5	17.9	6.8	16.5	7.2	17.1	6.5	17.4	6.8
1	16.5	6.6	16.8	6.9	16.5	7.1	16.8	6.7	16.2	7.0
2	16.3	6.5	16.4	7.0	16.3	7.2	16.5	6.8	15.9	7.1
3	16.2	6.4	16.2	7.1	16.1	7.2	16.2	6.9	15.8	7.0
4	16.1	6.6	16.1	6.9	16.1	7.2	16.1	6.9	15.6	7.0
5	16.1	6.5	16.0	6.9	15.9	7.1	16.0	6.8	15.5	7.0
6	15.7	6.7	15.9	6.9	15.8	7.0	15.8	6.7	15.3	6.9
7	15.6	6.4	15.8	6.8	15.7	6.9	15.6	6.5	15.2	6.8
8	15.6	6.4	14.2	6.1	14.8	6.5	15.5	6.4	15.1	6.8
9	15.5	6.2	11.2	5.5	12.6	5.9	15.1	6.3	14.7	6.6
10	14.7	6.2	10.4	5.3	11.5	5.7	11.6	5.7	13.4	6.1
11	9.7	4.7	9.3	5.3	10.1	5.7	9.6	5.6	12.9	5.9
12	8.6	5.0			9.3	5.8	7.4	5.6	12.4	5.9
13	8.1	5.0			8.1	5.9	7.3	5.6	10.7	5.8
14	7.8	5.1			7.9	5.9	7.1	5.6	9.0	6.0
15	7.5	5.0			7.3	6.0	7.0	5.6	8.2	6.0
16	7.1	5.0			7.2	6.0	6.8	5.7	7.8	6.0
17	6.9	5.0			7.2	6.0	6.7	5.7	7.6	6.1
18	6.8	5.1			7.0	6.0	6.7	5.7	7.4	6.1
19	6.7	5.2			6.8	6.0	6.5	5.7	7.2	6.1
20	6.6	5.1			6.8	6.0	6.5	5.7	7.1	6.2
25							6.4	5.7	6.8	6.1
30							6.3	5.8	5.9	6.4
35							6.3	5.8		
Secchi (m)	3.08		3.05		3.12		3.00		3.05	

Table B-7. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations in Granby Reservoir on 15 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Granby 15 August 2006**									
	P1 (17.5m)		**P2 (9.3m)**		**P3 (24.1m)**		**P4 (28.8m)**		**P5 (21.4m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	20.1	6.7	20.2	6.8	19.9	6.8	21.1	6.7	20.6	6.6
1	19.9	6.9	19.2	7	19.6	6.8	20.2	6.8	20.2	6.6
2	19.7	6.9	18.9	7.2	19.4	6.9	19.5	7.1	19.7	6.7
3	19.6	7.0	18.8	7.2	19.2	6.9	19.3	7.0	19.4	6.7
4	19.5	7.0	18.7	7.1	19.1	6.9	19.2	7.0	19.3	6.8
5	19.4	6.9	18.7	7	19.0	7.0	19.2	6.9	19.2	6.9
6	18.8	6.2	18.5	6.9	18.8	6.7	19.1	7.0	19.2	7.0
7	17.8	5.3	18.5	6.9	18.7	6.7	18.2	5.7	19.2	6.9
8	15.5	3.6	17.8	6.3	18.7	6.5	16.5	4.3	18.2	6.0
9	15	3.3	15.8	3.3	16.0	4.1	15.8	3.8	15.5	4.1
10	14.2	3.2			14.2	3.5	15.0	3.7	14.1	3.7
11	13.4	3.3			13.7	3.5	12.9	3.8	13.3	3.6
12	12.8	3.4			13.2	3.4	12.2	4.0	12.0	3.8
13	12.4	3.4			11.3	3.8	11.3	3.8	10.9	4.1
14	11.2	3.3			10.2	3.9	10.8	3.9	10.1	4.3
15	10	2.9			9.2	3.9	10.4	3.7	9.3	4.5
16	8.9	2.9			8.5	4.1	9.8	3.8	8.6	4.7
17	8.5	2.9			8.0	4.2	8.9	3.8	8.1	4.8
18					7.7	4.2	7.8	4.0	7.9	4.9
19					7.5	4.3	7.4	4.2	7.6	5.1
20					7.4	4.3	7.2	4.2	7.4	5.2
25							6.9	4.5	6.9	5.1
Secchi (m)	2.8		2.27		4.37		3.33		4.43	

Table B-8. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at two stations at Green Mountain Reservoir on 8 August 2006. Values in parenthesis denote maximum water depth at station. Data collected at two of five stations due to missing GPS coordinates.

Water depth (m)	**Green Mountain 8 August 2006**			
	P1 (15.5m)		**P2 (39.7m)**	
	°C	**mg/l**	**°C**	**mg/l**
0	18.6	7.0	18.1	6.9
1	18.4	6.9	17.8	6.9
2	18.3	7.0	17.6	7.0
3	18.3	7.0	17.4	6.9
4	18.1	7.1	17.3	6.9
5	17.4	7.1	17.2	6.9
6	17.0	7.1	17.0	6.8
7	16.8	7.0	16.5	6.7
8	16.3	7.0	16.3	6.6
9	15.6	6.8	15.9	6.6
10	15.3	6.9	15.4	6.5
11	14.3	7.1	13.9	6.4
12	13.8	7.2	13.2	6.3
13	13.1	7.1	12.7	6.2
14	12.1	6.9	12.1	6.2
15	11.8	6.7	11.6	6.1
16			11.1	6.2
17			10.9	6.2
18			10.5	6.2
19			10.4	6.2
20			10.2	6.2
25			9.5	6.2
30			8.8	6.3
35			8.3	6.6
Secchi (m)	4.15		4.19	

Table B-9. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at two stations at Green Mountain Reservoir on 28 June 2006. Values in parenthesis denote maximum water depth at station. Data collected at two of five stations due to missing GPS co-ordinates.

Water depth (m)	**Green Mountain 28 June 2006**			
	P1 (14.5m)		**P2 (39.2m)**	
	°C	**mg/l**	**°C**	**mg/l**
0	15.3	6.7	15.9	6.8
1	15.4	6.6	15.6	6.7
2	15.4	6.6	15.1	6.7
3	15.4	6.6	14.9	6.6
4	15.2	6.6	14.9	6.6
5	15.1	6.6	14.8	6.6
6	14.7	6.6	14.6	6.4
7	14.6	6.6	14.5	6.4
8	12.9	6.4	14.2	6.4
9	12.6	6.4	14.0	6.2
10	12.6	6.5	14.0	6.2
11	11.8	6.3	13.7	6.2
12	11.8	6.3	12.8	6.2
13	11.5	6.2	11.6	6.2
14	11.3	6.2	11.1	6.2
15			10.9	6.2
16			10.8	6.1
17			10.6	6.1
18			10.5	6.1
19			10.3	6.1
20			10.2	6.1
25			9.7	6.1
30			9.2	6.1
35			8.5	6.1
Secchi (m)	2.04		2.08	

Table B-10. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations in McPhee Reservoir on 1 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**McPhee 1 August 2006**									
	P1 (12.5m)		**P2 (48.9m)**		**P3 (41.2m)**		**P4 (32.8m)**		**P5 (10.7m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	22.2	6.6	22.2	6.5	21.9	7.6	22.0	6.6	21.7	6.3
1	21.7	6.5	22.0	6.4	21.8	7.2	21.8	6.4	21.5	6.3
2	21.5	6.5	21.8	6.4	21.8	7.1	21.5	6.6	21.1	6.4
3	21.4	6.6	21.5	6.6	21.4	7.1	21.4	6.6	21.0	6.4
4	21.2	6.4	21.3	6.6	21.4	7.0	20.9	6.5	21.0	6.3
5	21.0	6.4	21.6	6.6	21.2	7.1	20.7	6.5	20.9	6.3
6	20.7	6.2	21.0	6.5	21.0	7.1	20.4	6.4	20.9	6.4
7	20.2	6.0	20.7	6.5	20.8	7.0	19.7	6.1	20.8	6.4
8	19.6	5.4	20.3	6.4	20.6	6.9	18.8	5.4	20.7	6.3
9	19.7	5.4	18.7	5.7	19.7	6.4	17.9	5.0	19.0	5.6
10	18.1	4.8	17.2	5.2	18.1	5.8	16.5	4.6	17.3	5.2
11	17.0	4.7	14.4	5.1	15.8	5.2	14.3	3.9		
12	15.6	4.6	13.2	5.3	14.2	5.0	12.0	4.3		
13			11.2	5.9	12.3	5.5	10.4	4.8		
14			10.9	6.4	10.4	6.1	9.4	5.1		
15			9.2	6.8	9.7	6.6	8.5	5.6		
16			8.9	6.9	8.9	6.9	7.9	5.7		
17			8.4	7.2	8.1	7.4	7.6	5.8		
18			7.9	7.5	7.8	7.8	7.4	5.8		
19			7.7	7.5	7.4	8.0	7.0	5.8		
20			7.4	7.6	7.3	8.1	6.9	5.9		
25			6.7	8.0	6.2	8.7	6.2	6.6		
30			6.2	8.3	5.9	8.9	5.9	7.1		
35			5.8	8.4	5.6	9.1				
40			5.6	5.8	5.5	9.0				
45			5.4	8.4						
Secchi (m)	2.10		3.60		3.80		3.16		1.49	

Table B-11. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations in Shadow Mountain Reservoir on 26 June 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Shadow Mountain 26 June 2006**					
	P1 (5.6m)		**P2 (8.7m)**		**P3 (5.5m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	16.8	6.8	16.5	6.9	16.5	7.3
1	16.8	6.8	13.6	7.0	16.2	7.0
2	16.7	6.8	12.6	6.8	15.5	6.9
3	11.8	7.0	11.9	6.8	11.5	6.7
4	11.3	7.0	11.5	6.7	11.2	6.7
5	11.1	6.6	11.2	6.6	10.9	6.6
6			11.0	6.6		
7			10.8	6.5		
8			10.7	6.3		
Secchi (m)	2.36		2.13		2.35	

Table B-12. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Taylor Park Reservoir on 17 July 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	Taylor Park 17 July 2006									
	P1 (11.7m)		P2 (15.1m)		P3 (37.1m)		P4 (14.9m)		P5 (11.8m)	
	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	17.2	7.0	17.0	6.9	16.7	7.0	16.7	6.9	16.5	6.8
1	17.1	7.1	16.9	7.2	16.8	7.1	16.7	7.0	16.6	7.0
2	17.1	7.1	16.9	7.3	16.7	7.0	16.3	7.1	16.6	7.2
3	17.1	7.2	16.9	7.4	16.6	7.1	15.4	7.3	16.6	7.3
4	17.1	7.2	16.9	7.5	16.5	7.1	14.5	7.3	16.6	7.3
5	17.0	7.2	16.9	7.5	16.0	7.4	14.2	7.2	16.5	7.2
6	16.4	7.6	16.9	7.5	15.8	7.2	13.8	7.1	15.0	7.2
7	15.7	7.4	16.9	7.5	14.1	6.8	13.2	6.9	14.2	7.2
8	15.5	7.4	14.7	7.3	13.6	6.5	13.0	6.7	13.2	6.7
9	15.5	7.4	12.5	6.7	13.2	6.2	12.8	6.6	12.6	6.4
10	15.4	7.4	12.0	6.5	12.7	5.9	12.5	6.4	12.4	6.1
11	15.2	7.4	11.5	6.3	12.2	5.8	12.3	6.1	12.3	5.9
12			11.3	6.2	12.0	5.6	12.1	6.0		
13			11.1	6.2	11.5	5.3	11.8	5.9		
14			11.0	6.2	11.4	5.3	11.5	5.6		
15			11.0	6.2	11.2	5.1				
16					11.0	5.1				
17					10.9	5.1				
18					10.6	4.9				
19					10.3	4.9				
20					9.8	4.8				
25					8.4	5.2				
30					8.0	5.2				
35					7.9	5.2				
Secchi (m)	4.5		5.6		6.6		4.4		3.3	

Table B-13. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Vega Reservoir on 25 May 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Vega - 25 May 2006**					
	P1 (18.2m)		**P2 (22.7m)**		**P3 (23.1m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	14.7	3.7	14.5	6.4	13.3	7.5
1	14.3	3.3	13.7	7.6	11.1	7.3
2	11.6	3.6	12.2	6.8	10.3	7.1
3	10.8	3.9	9.9	6.7	9.9	7.1
4	10.3	4.0	9.4	6.7	8.8	7.0
5	9.4	3.3	8.2	6.6	8.2	6.9
6	8.5	2.8	7.4	6.5	7.9	6.8
7	8.0	2.5	6.9	6.5	7.7	6.7
8	7.3	2.6	6.6	6.4	7.3	6.7
9	7.3	2.5	6.6	6.1	7.3	6.7
10	7.1	2.3	6.4	5.8	6.8	6.5
11	7.0	2.1	6.3	5.2	6.3	6.1
12	6.8	1.8	6.3	5.0	6.3	5.8
13	6.6	1.7	6.1	4.4	6.2	5.5
14	6.4	1.6	6.1	4.1	6.2	5.0
15	6.3	1.6	6.0	3.8	6.2	4.6
16	6.2	1.5	6.0	3.3	6.1	4.4
17	6.1	1.4	6.0	3.0	6.0	4.2
18	6.0	1.4	6.0	2.6	6.0	4.0
19			5.9	2.2	6.0	3.7
20			5.9	1.5	5.9	3.4
Secchi (m)	1.70		1.59		1.56	

Table B-14. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Vega Reservoir on 13 June 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Vega - 13 June 2006**					
	P1 (17.7m)		**P2 (22.6m)**		**P3 (28.8m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	17.3	7.5	16.1	7.6	15.8	6.5
1	17.2	7.3	16.0	7.2	15.9	6.3
2	17.0	7.1	14.8	7.2	15.9	6.1
3	15.1	7.1	14.1	7.0	15.9	5.9
4	14.6	7.1	13.3	7.0	15.6	6.1
5	13.2	6.7	12.2	6.6	15.2	6.0
6	12.1	6.5	10.7	6.6	14.8	6.4
7	11.0	6.6	10.0	6.5	14.2	6.1
8	9.6	6.5	9.1	6.6	13.6	6.1
9	9.3	6.5	8.1	6.6	13.5	6.1
10	8.6	6.6	7.8	6.7	13.1	6.1
11	8.2	6.4	7.5	6.4	12.9	6.0
12	8.1	6.4	7.4	6.3	12.6	6.0
13	8.0	6.3	7.2	6.2	12.1	6.3
14	7.9	6.3	7.2	6.1	11.7	6.3
15	7.7	6.3	7.2	6.1	11.4	6.4
16	7.3	6.0	7.2	6.1	11.2	6.4
17	7.2	5.9	7.1	6.1	10.8	6.5
18			7.1	6.0	10.7	6.5
19			7.1	6.0	10.5	6.5
20			7.0	6.0	10.2	6.7
25					9.9	6.6
Secchi (m)	3.32		2.30		2.33	

Table B-15. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Vega Reservoir on 11 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Vega 11 - August 2006**					
	P1 (8.6m)		**P2 (17.5m)**		**P3 (27.5m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	20.4	6.4	21.0	6.7	21.0	7.4
1	20.4	6.4	20.1	6.8	20.9	7.5
2	19.8	6.0	19.5	6.4	20.1	7.8
3	19.5	6.2	19.4	5.8	19.8	7.7
4	19.3	6.0	19.3	5.8	19.7	7.1
5	19.2	5.9	19.2	5.7	19.5	6.3
6	19.2	5.7	19.1	5.6	19.3	6.3
7	18.8	4.8	18.9	5.5	18.2	4.4
8	17.5	2.7	18.2	3.4	17.5	3.0
9			16.3	1.6	16.4	1.8
10			15.0	1.2	15.4	1.2
11			13.6	1.1	14.5	1.1
12			13.2	1.1	13.6	1.1
13			12.8	1.3	13.1	1.2
14			12.6	1.4	12.7	1.3
15			12.0	1.0	12.4	1.2
16			11.9	1.0	11.7	0.9
17			11.7	0.8	11.4	0.8
18					11.0	0.7
19					10.7	0.5
20					10.4	0.4
25					9.9	0.2
Secchi (m)	2.04		2.47		2.09	

Table B-16. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations on Vega Reserviour on 19 October 2006. Values in parenthesis denote maximum water depth at station.

Water Depth (m)	**Vega 19 October 2006**					
	P1 (8.1m)		**P2 (13.5m)**		**P3 (18m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	7.4	8.4	7.3	8.3	7.9	8.3
1	7.3	8.4	7.3	8.4	7.3	8.3
2	7.4	8.4	7.2	8.4	7.3	8.3
3	7.3	8.4	7.1	8.4	7.3	8.3
4	7.2	8.4	7.1	8.3	7.3	8.3
5	7.2	8.4	7.1	8.3	7.2	8.3
6	7.1	8.3	7.0	8.3	7.2	8.3
7	7.1	8.3	7.0	8.3	7.2	8.3
8			7.1	8.3	7.1	8.3
9			7.0	8.3	7.1	8.3
10			7.0	8.3	7.1	8.3
11			7.1	8.1	7.1	8.3
12			7.1	8.0	7.1	8.3
13			7.2	7.9	7.1	8.3
14					7.0	8.3
15					7.0	8.3
16					7.0	8.3
17					7.0	8.3
18						
19						
20						
25						
30						
35						
40						
Secchi (m)	1.80		1.50		1.75	

Table B-17. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations in Williams Fork Reservoir on 8 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Williams Fork 8 August 2006**									
	P1 (13.6m)		**P2 (42.0m)**		**P3 (25.7m)**		**P4 (28.2m)**		**P5 (16.9m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	19.1	6.5	19.0		19.7	6.7	19.7	6.7	20.7	6.4
1	19.1	6.6	19.0		19.4	6.4	19.5	6.6	20.0	6.6
2	19.1	6.6	19.0		19.3	6.5	19.5	6.6	19.8	6.8
3	19.1	6.7	19.0		19.2	6.5	19.4	6.6	19.6	6.6
4	19.0	6.6	18.9		19.2	6.4	19.4	6.4	19.1	6.5
5	19.0	6.7	18.9		19.2	6.5	19.0	6.4	18.7	6.3
6	19.0	6.6	18.9		18.7	6.2	18.7	6.1	18.7	6.2
7	18.8	6.6	18.9		17.8	5.2	18.1	5.8	15.5	6.2
8	18.6	6.3	18.3		17.1	4.8	17.3	5.3	16.8	4.6
9	16.3	4.8	16.5		16.6	4.5	15.8	4.7	15.1	4.3
10	14.5	4.5	14.4		15.7	4.4	14.2	4.4	14.8	4.3
11	13.6	4.6	13.7		14.6	4.3	13.5	4.4	14.2	4.3
12	14.1	4.8	12.7		13.4	4.3	12.7	4.6	13.6	4.4
13	12.6	4.9	12.4		12.5	4.5	12.3	4.6	13.2	4.4
14			11.8		11.7	4.7	12.0	4.7	12.8	4.5
15			11.6		7.2	4.8	11.0	4.9	12.5	4.5
16			11.1		10.7	5.4	10.6	5.0	11.7	4.6
17			10.7		10.3	5.1	10.2	5.2		
18			10.2		9.8	5.3	9.9	5.4		
19			10.0		9.6	5.4	9.7	5.5		
20			9.8		9.5	5.4	9.6	5.5		
25			9.0		8.5	5.7	8.5	5.6		
30			8.3							
35			8.0							
40			7.8							
Secchi (m)	4.45		4.41		4.08		4.80		4.16	

Table B-18: Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at five stations on Wolford Reservoir on 8 August 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	**Wolford 8 August 2006**									
	P1 (23.3m)		**P2 (28.0m)**		**P3 (28.3m)**		**P4 (23.5m)**		**P5 (22.0m)**	
	°C	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**	**°C**	**mg/l**
0	20.2	6.8	20.7	7.1	20.2	7.0	21.0	7.1	22.4	7.0
1	19.7	6.9	20.0	7.1	20.1	7.0	20.1	7.1	20.8	6.9
2	19.4	7.1	19.6	7.1	19.8	6.9	19.8	7.2	20.5	7.0
3	19.3	7.1	19.3	6.9	19.3	6.7	19.7	7.1	20.3	6.9
4	19.2	6.9	19.2	7.0	19.3	6.8	19.6	6.9	19.9	6.8
5	19.2	6.9	19.2	7.1	19.2	6.8	19.5	6.9	19.7	6.7
6	19.1	6.9	19.1	7.2	19.2	6.8	19.4	7.0	19.5	6.4
7	19.0	6.8	18.9	6.6	18.8	6.4	17.8	4.7	18.6	4.8
8	16.7	4.7	16.4	4.6	16.3	3.6	16.2	3.7	17.3	3.7
9	15.1	3.6	15.1	3.7	15.1	3.4	15.4	3.2	16.0	3.0
10	14.0	3.6	13.7	3.7	14.3	3.3	14.4	3.2	14.3	3.0
11	13.5	3.7	13.1	3.8	13.2	3.5	13.3	3.3	13.2	3.4
12	12.7	4.0	12.4	4.0	12.0	4.1	11.5	3.8	12.4	3.6
13	11.2	4.5	11.0	4.6	10.8	4.6	10.6	4.3	11.8	3.8
14	10.4	4.7	10.1	5.0	10.0	5.1	10.2	4.6	11.0	4.1
15	9.9	5.2	9.5	5.4	9.3	5.4	9.4	4.9	10.4	4.2
16	9.3	5.5	9.1	5.7	8.6	5.8	9.0	5.2	9.7	4.4
17	8.8	5.8	8.5	5.8	8.3	5.9	8.6	5.2	9.1	4.5
18	8.4	6.0	8.2	6.0	8.1	5.9	8.3	5.0	8.7	4.6
19	8.0	6.1	7.9	6.1	8.0	5.9	8.0	5.0	8.2	4.7
20	7.9	6.1	7.8	6.1	7.8	5.9	7.9	4.8	8.0	4.8
25			7.3	6.1	7.2	5.8				
Secchi (m)	2.03		2.15		2.59		2.43		2.40	

APPENDIX C

ANNUAL REPORT

FORENSIC APPLICATIONS OF OTOLITH MICROCHEMISTRY FOR TRACKING SOURCES OF ILLEGALLY STOCKED WHIRLING DISEASE POSITIVE TROUT

Interim Report
Reporting Period: 01/01/2006 - 12/31/2006

Forensic Applications of Otolith Microchemistry for Tracking Sources of Illegally Stocked Whirling Disease Positive Trout

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Executive Summary

This project is a continuation of a study funded by the Whirling Disease Initiative during 2004-2005. We are refining methods for determining sources of illegally stocked fishes by chemical analysis of their otoliths. The project was granted a no-cost extension until June 30, 2007 to compensate for delays caused by the analytical laboratories that provided water and otolith data. We are on track to complete the study by its new end date. Our work in 2006 demonstrated the utility of hatchery fingerprinting for determining the origins of stocked fish captured at large. Further, chemical signatures at a hatchery appear to be stable over time scales relevant to the lifespan of rainbow trout.

Introduction

Microchemical analysis of otoliths is emerging as an extremely useful method for tracing origins and movement patterns of fishes (Gao and Beamish 1999; Hobson 1999; Kennedy et al. 2000, 2002; Weber et al. 2002; Wells et al. 2003). The basis of this technique is to identify the microchemical signature of waters the fish has inhabited in its past (Campana and Thorrold 2001; Outridge et al. 2002). These signatures are assimilated into the tissues of the fish and are permanently recorded within the otolith (ear bone) as the fish grows, thus laying down a timeline as a fish is moved among waters having different chemical signatures. Otoliths from fish that are suspected to have been illicitly stocked can be analyzed to determine their microchemical history (Munro et al. 2005). By matching these markers with those of potential sources, it becomes feasible to identify which water source (hatchery) they were formerly reared in, and the approximate time they were moved from one water body to another. In this study, we are investigating the factors that affect the applicability and accuracy of the technique, and we are developing recommendations for its application as a forensic tool for tracking sources of illegally stocked trout.

Goals and Objectives

1. Determine variation in microchemical and isotopic fingerprints of otoliths and water samples obtained from a variety of CDOW hatcheries: do chemical fingerprints of water and otoliths differ across at a broad geographic scale? What is the seasonal variation in water and fish fingerprints?

2. Assess utility of these fingerprints for tracing hatchery origins of fish at large: is there enough variation among hatcheries that the chemical fingerprint of an otolith can be used to trace a fish to its hatchery of origin?

3. Determine variation in microchemical and isotopic fingerprints of otoliths obtained from private hatchery fish and assess utility of these fingerprints for tracing hatchery origins of fish at large: do chemical fingerprints of fish from private hatcheries show sufficient variation to identify the private hatchery of origin?

4. Determine how size at stocking affects detectability of hatchery-derived chemical fingerprint: how small can a stocked fish be and still allow us to trace its origin?

5. Determine if otoliths from marked fish that are stocked from known hatcheries and are at large for a year or more can be used to correctly identify the hatchery of origin: what is the persistence of otolith fingerprints after fish are stocked?

6. Determine if wild fish can be distinguished from stocked hatchery fish, especially in areas that are in close proximity to source hatcheries: is the chemical signature imparted to a fish by a hatchery distinct from that of wild fish in the same drainage?

7. Determine if timing and duration of transfers can be detected from microchemical signatures of otoliths, and if multiple transfers among sites can be detected: how small an area, and hence, timeframe of the fish's life, can be examined within an otolith?

Methods and Materials

We used existing samples and gathered additional samples of otoliths and other tissues from fish from a variety of hatcheries representing a large geographic range. Additional water samples from the same locations were also collected, using ultra-clean techniques (Shiller 2003). In 2006 we collected water samples from CDOW trout hatcheries, giving us a three-year profile of water chemistry at hatcheries.

Stocked trout were collected from rivers and reservoirs to examine how size at stocking affects detectability of hatchery signatures and fingerprints, if these markers persist in otoliths after stocking, and also to determine the temporal resolution recorded in otoliths regarding stocking dates and transfers among waters with distinct chemical characteristics. We compared signatures of otoliths from known or suspected hatchery trout collected by Kevin Thompson of CDOW from bodies of water in close proximity to hatcheries in late 2004. Additional at-large sampling of hatchery-reared fish occurred in the summer of 2006. Hatchery recaptures were collected at Vega Reservoir, Granby Lakes, Button Rock Reservoir, and the South Platte River, allowing us to examine the effectiveness of hatchery fingerprinting to identify stocked fish over a wide geographic range.

Otoliths were handled with non-metallic forceps, sectioned in a transverse plane with an Isomet® low-speed saw and polished with lapping film on a lapidary wheel. Thin sections were mounted on acid-washed glass microscope slides, ultrasonically cleaned in ultrapure water, and dried in a laminar flow hood.
We stored the cleaned thin sections in acid-washed polypropylene petri dishes inside a sealed container until they were analyzed.

Water and otolith thin sections were analyzed for elemental concentrations and stable isotope ratios, employing laser ablation inductively coupled mass spectrometry and isotope ratio mass spectrometry (Campana 1999; Campana et al.

1994; Thorrold and Shuttleworth 2000; Weber et al. 2002). Some of the preparatory lab work was conducted at CSU, but most of the chemical analyses were performed by the following laboratories: the U.S.G.S. Mineral Resources Laboratory in Denver; Department of Marine Science, University of Southern Mississippi; and Department of Earth Sciences, University of Melbourne, Australia.

Progress to Date

Our progress has been significantly hampered by slow turnaround time and extremely limited access to analytical instruments in contract labs. Thus, we requested and were granted a no-cost extension for the project, with a new end date of June 30, 2007.

We have been relying on the USGS Mineral Resources Laboratory in Denver for most of our otolith analyses. This is one of the world's top facilities for the kind of analysis we required. However, they were in the process of installing, relocating, and calibrating instruments during much of 2006. We chose not to seek alternative analytical facilities for our elemental abundance analyses during the interim because of issues with differential techniques and subsequent data non-comparability among laboratories. We are pleased to report that we have completed laser ablation analysis of all otolith sections in the Denver lab and we now have all the calibrated, integrated data available for statistical analysis.

We have been able to make significant progress on data analysis despite lab delays. We have analyzed variations in water chemistry at CDOW hatcheries in 2004, 2005, and 2006. The interannual variations within a hatchery tend to be small relative to the differences among hatcheries, indicating hatcheries have distinct water chemistry profiles that persist over time. We see this variation in chemical signatures echoed in the otolith chemistry of fish from the same hatcheries. At hatcheries, differences in otolith signatures between years are small relative to the differences in otolith signatures among hatcheries. Interannual stability of otolith chemistry indicates that forensic determinations regarding hatchery of origin may be made by sampling from hatcheries a year or more after suspected illicit stockings have occurred.

Once all of the data from Denver was acquired, we were able to create models to classify a set of blind samples collected by Kevin Thompson (CDOW research biologist). Using otolith elemental data from the CDOW hatchery fish we collected in 2004 and 2005, we were able to classify the blind samples of fish reared at hatcheries in or prior to 2004 with an overall accuracy of 64 percent. This compares well with the total accuracy rate of 69 percent for fish collected from CDOW hatcheries. In November 2006, we received data for otolith strontium isotope ratios ($^{87}Sr/^{86}Sr$) that we are working to incorporate into our models as another geographical marker that can be used to identify hatchery of origin.

Our work over the past year has also helped us to create a methodology for increasing the classification accuracy of at-large fish. As the number of hatcheries in a model decreases, the overall accuracy of the model increases. Thus, if we are able to eliminate hatcheries from our models based on on-the-ground investigation and traditional stock identification methods, our multivariate models become even more effective in determining hatchery of origin. We have termed this the "eclectic approach to source identification." This approach has the advantage of combining investigative fieldwork and traditional stock identification methods with empirical data from otoliths. We believe this will lead to greater accuracy in identifying hatchery origins as well as greater confidence of management, law enforcement, and private industry regarding the results.

We also presented our latest findings at the following professional conferences:

a. Whirling Disease Symposium, February, 2006
b. Colorado-Wyoming Chapter of the American Fisheries Society, March, 2006
c. National Meeting, American Fisheries Society, September, 2006

Budget

The current balance in our account is approximately $2,800. We will expend about $400 for Dan to attend and present a talk at the Whirling Disease Symposium in February. With the additional analyses we have planned, plus technician salaries and miscellaneous expenses we anticipate expending the entire budget by the project's new end date.

To be completed by end of project

Our work over the coming months will focus on refining our otolith chemistry models, quantifying variation in water chemistry among hatcheries, and determining the utility of Sr isotope analysis as an additional variable to improve model accuracy. We will also:

1. Present our latest findings at the Whirling Disease Symposium, February, 2007.
2. Provide guidance for application of the tool by managers and law enforcement personnel.
3. Prepare manuscripts for publication in peer-reviewed scientific journals.
4. Prepare detailed final report summarizing all aspects of the study, June 30, 2007.

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APPENDIX D

ANNUAL REPORT

ISOTOPIC, ELEMENTAL & BIOENERGETICS STUDIES: APPLICATION OF ISOTOPIC AND ELEMENTAL TECHNIQUES TO IDENTIFY PROVENANCE OF FISHES AND TO FACILITATE BIOENERGETICS PROJECTIONS OF FOOD-WEB IMPACTS OF PISCIVORES RESERVOIRS

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ISOTOPIC, ELEMENTAL & BIOENERGETICS STUDIES: APPLICATION OF ISOTOPIC AND ELEMENTAL TECHNIQUES TO IDENTIFY PROVENANCE OF FISHES AND TO FACILITATE BIOENERGETICS PROJECTIONS OF FOOD-WEB IMPACTS OF PISCIVORES RESERVOIRS.

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INTRODUCTION

An understanding of trophic dynamics is fundamental to effective fishery management. This report summarizes continuing research aimed at developing, refining and applying new methodologies for the study of trophic dynamics in reservoirs in Colorado.

FISH DIET IN BLUE MESA RESERVOIR

The extent of predation by resident salmonids and yellow perch on newly stocked kokanee fingerlings at Blue Mesa Reservoir was unknown, prompting a field study in spring 2005. Results of that investigation are presented here.

METHODS

Fish stomach samples were collected from Blue Mesa Reservoir by Colorado Division of Wildlife biologists on April 18, 2005, concurrent with the release of kokanee fingerlings from the Roaring Judy Fish Hatchery. Species collected were lake trout, brown trout, rainbow trout, yellow perch and kokanee. Stomach contents were analyzed in the Fisheries Ecology Laboratory. Prey organisms were measured after preservation in both formalin and ethanol. Various body measurements were used with regression models to compute live mass of each taxon found in guts. Backbone lengths (BBL) were recorded for fish prey, when complete. We measured head capsule width (HCW) of aquatic insects and carapace length of crayfish. Stomachs containing zooplankton were analyzed using a plankton wheel or in three 1 mL aliquots. Ten individuals of each type of zooplankton were measured and the remainder was counted when using the plankton wheel. We measured 25 of each type of zooplankton and counted the remainder when using the aliquot method; the total number of zooplankton found in a stomach was computed from the number of zooplankton counted in 3 mL aliquots and the dilution volume/3 mL. Unidentifiable salmonids were assumed to be kokanee if TL < 80 mm.

RESULTS AND DISCUSSION

Kokanee fingerlings were very common in stomachs of brown trout (87% contained at least one kokanee) and lake trout (80% contained kokanee) (Table 1). Half of the six yellow perch sampled also contained kokanee in their guts. Kokanee and rainbow trout stomachs contained mainly insects, plankton and amphipods, and no fish remains. Yellow perch were found in 13% and 60% of brown trout and lake trout stomachs, respectively. The average prey: predator TL of the 288 measurable fish prey in predator stomachs was 0.14 (range: 0.09 - 0.32). Thus, predators chose to consume some fishes that were less than 10% of the predator’s length, indicating that despite their small size at stocking, kokanee fingerlings were at risk of predation from even relatively large brown and lake trout.

Translating the diet observations into projections of acute predatory mortality suffered by kokanee fingerlings in Iola Basin would require information on the abundance of piscivores in the area of the reservoir represented by the diet samples. Estimating predation rates over a longer time frame would be more challenging, requiring a larger scale predator sampling program to track the incidence of predation as stocked fingerlings disperse throughout the reservoir. Previous studies have demonstrated that kokanee are a significant fraction of the lake trout diet throughout the growing season (e.g., Johnson and Martinez 2000), but information on the diet (and abundance) of brown trout is scant. Given the high frequency of kokanee in brown trout guts in the present study, it would be prudent to investigate piscivory by brown trout in more detail, and determine if management action (e.g., liberalized harvest) is warranted to protect the kokanee population. The implications of piscivory by yellow perch are considered in the next section of the report.

Table 1. Frequency of occurrence (and percent) of seven prey taxa found in stomachs of kokanee (KOK), brown trout (LOC), lake trout (MAC), rainbow trout (RBT), and yellow perch (YPE) sampled from Iola Basin in Blue Mesa Reservoir, by CDOW on April 18, 2005. Insects included members of the Chironomidae, Coleoptera, Ephemeroptera, Hemiptera, Plecoptera, and Trichoptera. Crustacea included crayfish (CFI), zooplankton (ZP) and amphipods (AMP).

Predator	N	Predator TL (mm)	Fish prey				Crustacea		
			KOK	LGS	YPE	Insects	CFI	ZP	AMP
KOK	5	209	0 (0)	0 (0)	0 (0)	1 (20)	0 (0)	5 (100)	0 (0)
LOC	30	355	26 (87)	2 (7)	4 (13)	9 (30)	4 (13)	0 (0)	1 (3)
MAC	5	474	4 (80)	0 (0)	3 (60)	0 (0)	0 (0)	0 (0)	0 (0)
RBT	2	318	0 (0)	0 (0)	0 (0)	2 (100)	0 (0)	0 (0)	1 (50)
YPE	6	148	3 (50)	0 (0)	0 (0)	4 (67)	0 (0)	0 (0)	0 (0)

BIOENERGETICS PROJECTIONS: Yellow Perch in Blue Mesa Reservoir

Although they are usually classified as generalist feeders, yellow perch are known to be highly piscivorous under some circumstances (Mittelbach and Persson 1998; Graeb et al. 2005; Fullhart et al. 2006). Johnson et al. (1995) observed stocked walleye fingerlings (50-mm TL) in the guts of adult yellow perch sampled near the location of stocking in Lake Mendota, Wisconsin. Predation by yellow perch on stocked kokanee fingerlings has been documented in Blue Mesa Reservoir (above). Thus, concern over the potential predatory impact of yellow perch on kokanee is valid and warrants investigation.

METHODS

Information on the growth of kokanee (Johnson and Koski 2005) and yellow perch (Carlander 1997), and a prey:predator length ratio was used to determine the size/age of kokanee that would be morphologically vulnerable to predation by yellow perch through the growing season at Blue Mesa Reservoir. The maximum prey:predator length ratio reported for yellow perch is approximately 50% (Mittelbach and Persson 1998); this value was used in calculations. The Wisconsin bioenergetics model (Hanson et al. 1997) was used to compute consumption by three age-classes of yellow perch large enough to consume kokanee (Table 1). A “worst case scenario” simulation, assuming perch diet consisted entirely of kokanee during the period when the prey was available, was used to set the upper bound on per capita consumption of kokanee.

RESULTS AND DISCUSSION

Based on the maximum prey:predator length threshold, only age-0 kokanee are morphologically vulnerable to predation by yellow perch up to 225 mm TL in Blue Mesa Reservoir (Figure 1), and kokanee outgrow the window of vulnerability within their first growing season. Based on an assumed growth rate, only perch approximately age-2 and older are large enough to consume any size kokanee. Per capita consumption of kokanee by age-2, 3 and 4 yellow perch together totaled 149 g, which was equivalent to approximately 46 age-0 kokanee. Based on an average annual stocking level of 2.78 x 10^6 fish per year, it would require a population of about 180,000 age-2 and older yellow perch to consume the entire number of kokanee stocked. The number of stocked kokanee that make it to the reservoir and survive is undoubtedly much less implying that far fewer yellow perch would be able to eliminate the entire cohort. It is reasonable to expect that yellow perch abundance in Blue Mesa Reservoir is much larger. For example, in similar-sized Lake Mendota, Wisconsin, the abundance of mature yellow perch was estimated to be approximately 860,000 fish (215 perch/ha; Johnson et al. 1992). Thus, yellow perch do indeed appear to present a significant threat to kokanee recruitment in Blue Mesa Reservoir.

Given what we know about age-0 kokanee growth and dispersal after they reach the reservoir (Hardiman 2003), the most intense period of predation by perch may occur during spring and early summer, in Iola Basin. Later in summer the size of kokanee and reduced spatial overlap with yellow perch may result in a lower risk of predation by perch. These predictions should be evaluated by 1) determining yellow perch growth rate in BMR, and 2) documenting yellow perch spatial distribution and diet during the months of April through July. Estimating the population level consumptive demand will require an estimate of the abundance of perch, but even rudimentary information are lacking. Further, diet information consists of single samples from July 2002 and 2004, and one day in April 2005. There is little information available on yellow perch growth, size structure, recruitment patterns, spatial distribution or abundance indicators. Gathering these demographic and ecological data would be an important component of a monitoring program designed to predict and track effects of yellow perch in the reservoir.

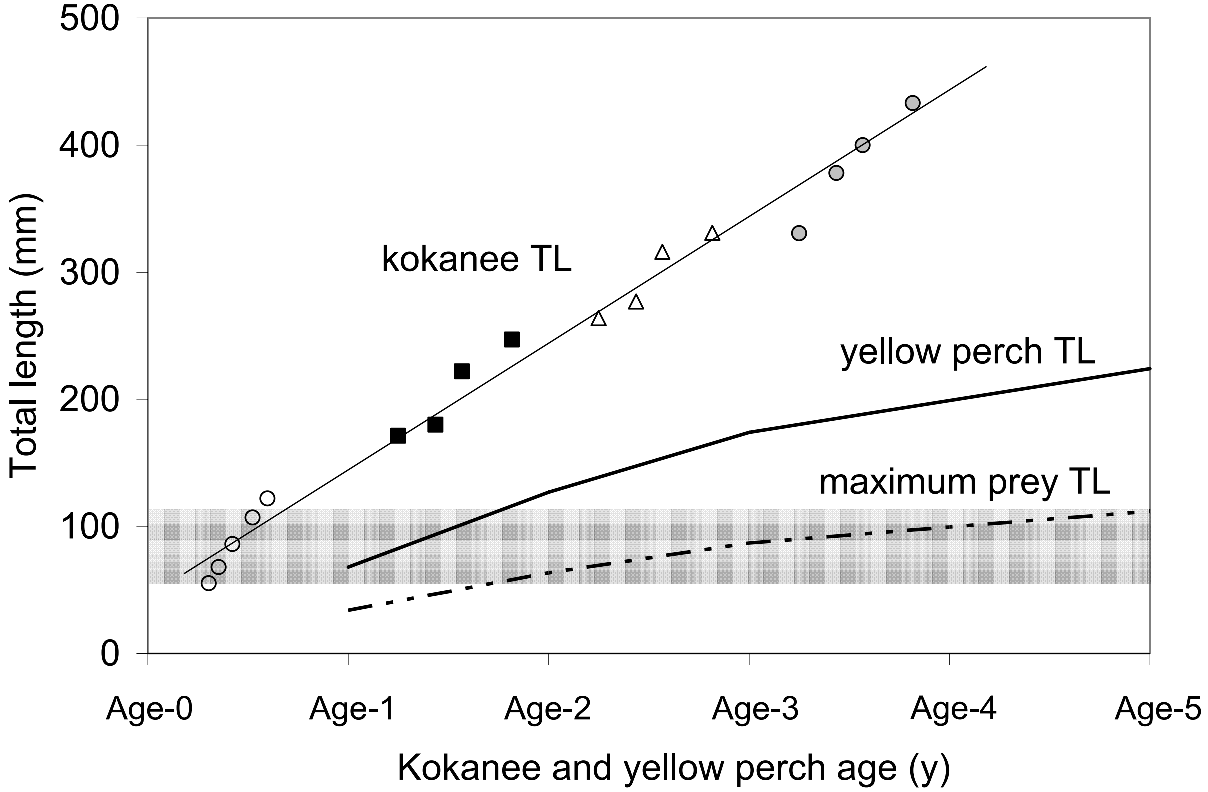

Figure 1. Growth (solid lines) of kokanee and yellow perch and the maximum size kokanee (dashed line) that can be consumed by yellow perch in Blue Mesa Reservoir. Shaded bar shows overlap between available prey sizes/ages based on yellow perch growth trajectory and a prey:predator size ratio of 0.50 (Mittelbach and Persson 1998). Growth data for yellow perch were not available for BMR; data from North and South Dakota reservoirs (Carlander 1997) were used as a surrogate.

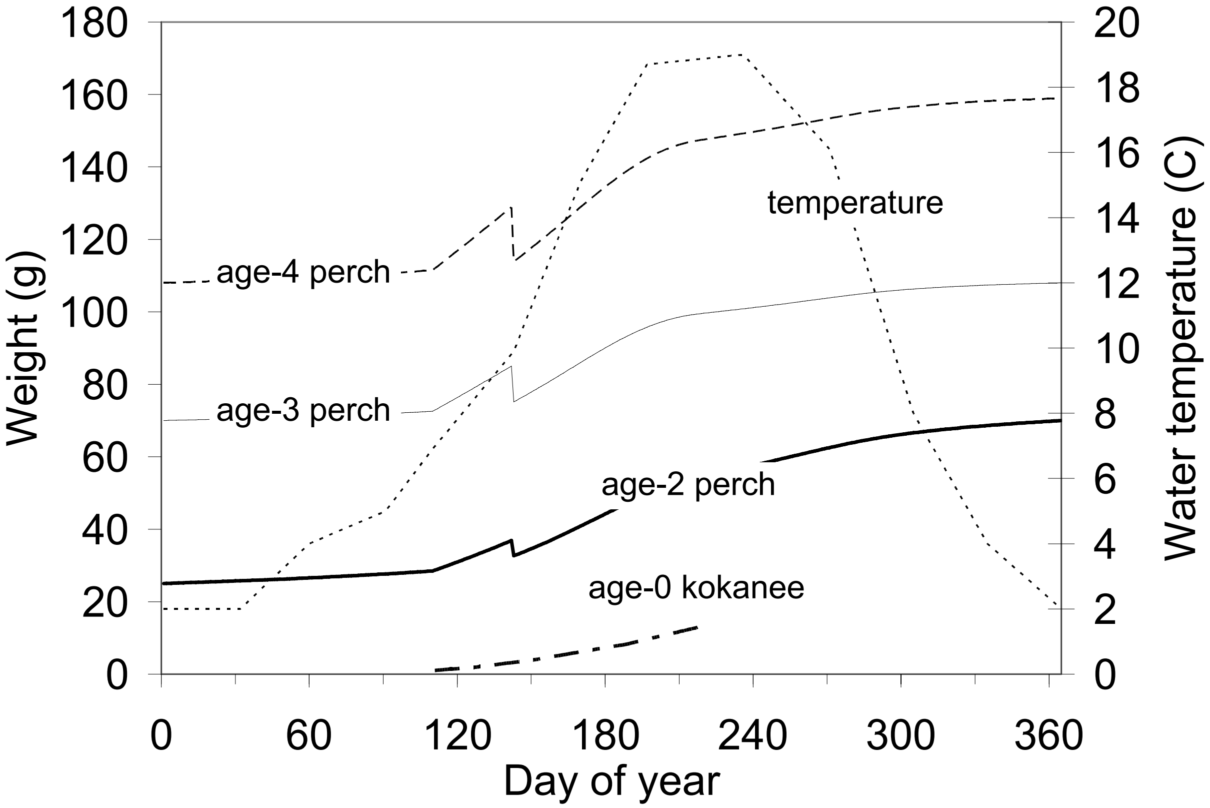

Figure 2. Growth trajectories of three age-classes of yellow perch (Carlander 1997) and age-0 kokanee (Johnson and Koski 2005), and water temperature (at 2 m depth, °C) used in bioenergetics simulations of yellow perch consumptive demand at Blue Mesa Reservoir.

Table 1. Inputs used in bioenergetics model simulations of the potential consumption of invertebrates and kokanee (KOK) by yellow perch in Blue Mesa Reservoir.

Date	Model day	KOK age-0 weight* (g)	Water temperature at 2 m (°C)	Invertebrates		Kokanee		Yellow perch**			
				diet (%)	energy (J/g wet)	diet (%)	energy (J/g wet)	Spawning (%)	Age-2 weight (g)	Age-3 weight (g)	Age-4 weight (g)
1-Jan	1	-	2	100	3,641	0	7,528	-	25	70	108
1-Feb	32	-	2	100	3,641	0	7,528	-			
1-Mar	60	-	4	100	3,641	0	7,528	-			
1-Apr	91	-	5	100	3,641	0	7,528	-			
20-Apr	110	1.05	6.9	0	3,641	100	7,528	-			
9-May	129	2.04	8.6	0	3,641	100	7,528				
23-May	143	3.27	9.9	0	3,641	100	7,528	12			
3-Jun	154	4.31	12	0	3,641	100	7,528				
19-Jun	170	6.14	15.1	0	3,641	100	7,528	-			
10-Jul	191	8.65	17.9	0	3,641	100	7,528				
16-Jul	197	9.61	18.7	0	3,641	100	7,528	-			
6-Aug	218	13.13	18.9	100	3,641	0	7,528				
24-Aug	236	-	19	100	3,641	0	7,528	-			
28-Sep	271	-	16.1	100	3,641	0	7,528	-			
1-Nov	305	-	8	100	3,641	0	7,528	-			
1-Dec	335	-	4	100	3,641	0	7,528	-			
31-Dec	365	-	2	100	3,641	0	7,528	-	70	108	159

* Johnson and Koski 2005

**Carlander 1997

ISOTOPIC AND ELEMENTAL ANALYSES

COLLABORATION ON MANUSCRIPTS

This year one manuscript (abstracted below) was published in the North American Journal of Fisheries Management (Crockett et al. 2006).

1. Crockett, H. J., B. M. Johnson, P. J. Martinez and D. Brauch. 2006. Modeling target strength distributions to improve hydroacoustic estimation of lake trout population size. North American Journal of Fisheries Management 135:1095-1108.

ABSTRACT

Many management agencies use hydroacoustic surveys to estimate pelagic prey fish abundance and population trends. It would be desirable to simultaneously assess piscivore population size and predation demand. However, multiple sources of variation in target strength complicate the target strength—fish size relationship, impairing managers' ability to distinguish among echoes from predators and prey. This uncertainty may substantially bias population size estimates, especially for piscivores that are greatly outnumbered by other species. We used an in situ estimate of target strength variance, combined with fish length-frequency distributions, to estimate the distribution of target strengths for prey-sized kokanee (lacustrine sockeye salmon *Oncorhynchus nerka*), and piscivorous lake trout *Salvelinus namaycush* in Blue Mesa Reservoir, CO. Comparison of the resulting lake trout population size estimates with those obtained from an intensive mark-recapture study showed that this approach substantially improved the precision and accuracy of hydroacoustic estimates. This technique may be especially useful in systems having relatively few species and/or species with discrete size-classes, as is the case for many western U.S. reservoirs.

RECOMMENDATIONS

1. Given the high frequency of kokanee fingerlings observed in brown trout guts in Blue Mesa Reservoir, it would be prudent to investigate piscivory by brown trout in more detail. Fundamental unknowns include abundance and size structure of the population, seasonal diet, and spatial distribution and overlap with kokanee.

2. Anecdotal evidence suggests that the yellow perch population in Blue Mesa Reservoir continues to expand. Predicting their predatory effects on kokanee and on the invertebrate forage base in the reservoir would be prudent; however, the available biological data on yellow perch in BMR are limited. Particularly needed are data on growth rate, spatial distribution and diet during the months of April through July. Funding to support a

graduate study to gather and analyze additional data and to project predatory and competitive impacts should be sought.

3. We should continue to work on manuscripts deriving from this research and submit them to scientific journals.

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