Lake and Reservoir Food Web Ecology

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General Professional IV

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROJECT STATEMENT

State: Colorado

Study No. Non-Federal funding

Title: Lake and Reservoir Food Web Ecology

Period Covered: July 1, 2012 to June 30, 2013

Project Objective: To address problems facing lake and reservoir managers throughout Colorado with a focus on important sport fisheries; to collect data and conduct experiments to provide information to managers that will improve fisheries and fish communities in lakes and reservoirs throughout Colorado.

STUDY PLAN A: Select Several Research Priorities to Address Based on Input from Senior Aquatic Staff and Area Biologists

Job A.1. Identify research priorities to address.

Objectives:

The objective of this job was to finalize the selection of research priorities to address based on the list of priorities developed with the input from Colorado Parks and Wildlife Aquatic Senior Staff and Area Biologists.

Introduction:

A large portion of recreation days in Colorado are generated by lakes and reservoirs. Thus, research related to lakes and reservoirs is crucial for supporting these resources and their subsequent management. There are many challenges facing lake and reservoir systems and the organisms within them. A priority list of these issues has been determined by Senior Aquatic Staff members. In 2012-2013 a portion of these priorities have been selected for research efforts.

Methods:

Research priorities were selected based on importance, feasibility, probability of success or benefit, and opportunity.

Results and Discussion:

Research priorities selected for study in the near term are highlighted in grey in the following Tables:

Table 1. East Slope research priorities

Rank	Priority (East Slope)
1	Walleye and wiper fry vs. fingerling stocking success
2	Are shad causing year-class failure of other desirable species
3	Walleye vs. wiper stocking density balance
4	Low Hg and stable forage alternatives to shad
5	Tiger muskie, splake, brown trout etc. as sucker/carp control
6	Increasing crappie angling opportunities
7	Potentials for altering/balancing nutrient fluxes
8	Teeth/anglers/competition limitations on piscivore densities
9	Sterile (99.X%) predator (warmwater) stocking options
10	Investigating/altering edible zooplankton composition
11	Sucker impacts on trout and other species
12	Increasing yellow perch angling opportunities
13	Carp/sucker removal methods (commercial fishery, virus, etc.)
14	Carp impacts on other species
15	Escapement and blocking methods
16	Investigate removal of nutrients in the form of sediments (dredging)
17	A "universal" warmwater reservoir model
18	Increased salinity/absence of fish (can something survive)

Table 2. West Slope research priorities

Rank	Priority (West Slope)
1	Sonar/KOK egg take prediction and population estimates
2	Tiger muskie, splake, brown trout etc. as sucker/carp control
3	What is the influence of gill lice at the population level in KOKs
4	Sterile (99.X%) predator (warmwater) stocking options
5	Alternative forage species
6	Sucker impacts on trout and other species
7	Potentials for altering/balancing nutrient fluxes
8	Crayfish impacts and crayfish control
9	Standardizing sampling methods (walleye and lake trout netting)
10	Female lake trout/splake stocking for "sterility" and good growth
11	Sterile (99.X%) predator (Onchorhynchus/coldwater) stocking options
12	Escapement (WAL, SMB, NPK)
13	Simplify KOK (etc) aging, (weighing otoliths, sectioning to confirm)
14	A "universal" coldwater reservoir model
15	Pike control methods
16	Zooplankton/mysis density and composition quantification
17	Basic limnology, draw from CDPHE and do our own
18	How do we eliminate mysis

STUDY PLAN B: Addressing Walleye Fry Versus Fingerling Stocking Success and Walleye Versus Wiper Stocking Density Balance

Job B.1. Select an appropriate fish marking technique and apply it to assess fish stocking success and balance between sympatric fish populations.

<u>Objectives:</u>

The objective of this experiment was to determine the most appropriate and safe fish marking method while balancing efficiency, effectiveness, and cost and to apply it to assess stocking success and balance between sympatric fish populations.

<u>Introduction:</u>

Marking fish (individually or in groups) is a crucial component for answering many questions related to fisheries. For example, batch marking and recapturing fish can help determine the prevalence of natural reproduction, population size and population growth. Marking fish with individual identifiers can help determine individual growth, movement, survival and other demographic characteristics at the individual and population level. I was asked to investigate fish marking techniques to aid in the assessment of walleye (*Sander vitreus*) fry versus fingerling success after stocking, wiper (*Morone saxatilis* x *M. chrysops*) stocking success, and balancing walleye and wiper stocking in systems in an effort to support sympatric populations. In general, these questions can be addressed completely or in some part by marking single or multiple batches of fish for later recapture and analysis. My goal was to determine the most appropriate and safe fish marking method while balancing efficiency, effectiveness, and cost.

I initially considered three different emersion techniques for batch marking fish (alizarin red, calcein and oxytetracycline (OTC)). Both walleye and wiper fry are often stocked soon after hatching, so holding fish and marking them using feeding techniques was considered less desirable. Further, walleye and wiper fry (especially wiper fry) are sensitive to handling stress which makes marking by emersion preferable to manually marking individuals through physical manipulation out of water. Both walleye and wiper have the potential of being consumed by anglers after stocking. This eliminated alizarin red as a marking technique because it is not approved for use on fish by the United States Food and Drug Administration (FDA). Calcein is approved by the FDA for use on fish, but only on fish up to 2 g. This is near, or potentially slightly below the weight of a walleye fingerling generally stocked in Colorado. Calcein is also expensive to properly dispose of because of its limited approval by the FDA. Thus, after consulting with many CDOW personnel and personnel from external agencies and institutions; FDA approved OTC seemed to be the most flexible and potentially effective means for marking walleye and wiper.

An additional benefit of using OTC as a tool to mark fish is that we may be able to assess whether fish are marked or not using non-lethal techniques. Hawkins (2002) investigated the potential for using spines marked with OTC to differentiate between marked and unmarked fish. This technique has been refined in walleye such that marks from OTC can be detected in spines without the need for the lethal technique of extracting and examining otoliths. This would allow us to determine whether fish have, or have not been marked with OTC without the need to sacrifice the fish for mark evaluation.

Methods:

Marking procedure (multi-species)
This project was conducted and written with the assistance of C. Nathan Cathcart. We collected yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus dolomieu*), and bluegill sunfish (*Lepomis macrochirus*) from College Lake (Fort Collins, CO) by beach seine on 26 June 2011. Fish were transported by truck in a cooler with approximately 45 L of lake water to the Foothills Fisheries Facility (Colorado State University Foothills Campus, Fort Collins, CO). The temperature of the water in the transport cooler was 21.2°C. Fish were later placed in two coolers (treatment and control) with 30 L of well water from the Bellvue Hatchery (Bellvue, CO) with temperatures of 21.0°C. An aeration stone was placed in each cooler to ensure adequate levels of dissolved oxygen. A silicon-based surfactant (ProLine® defoamer) was added to each cooler at a concentration of 0.013 mL/L to prevent foaming.

We used an OTC marking protocol developed by Brooks et al. (1994) and refined by the Minnesota Department of Natural Resources (see Logsdon et al. 2004). Briefly, this method involves adding OTC (Pennox® 343 soluble powder; 76% OTC) to the treatment water at 700 mg/L and then bringing the pH of the solution up to approximately 6.8 using an appropriate amount of sodium phosphate, dibasic, anhydrous buffer depending on the water alkalinity. The ratio of buffer to OTC should be near or less than 1:1. Fish are then placed in the solution for six hours and removed after treatment. For this preliminary testing, we kept fish densities low in order to decrease mortality that may occur due to crowding.

Identical numbers of individuals of the same species were randomly divided between the two coolers (control and treatment) and remained there for six hours. Fish were then netted and clipped (treatment = right pelvic fin and control = left pelvic fin) for later identification. Fish were held together in an aluminum pen in a research pond at the Foothills Fisheries Facility for eight days, and then transferred to the Colorado Parks and Wildlife (CPW) Lake and Reservoir Research Laboratory. Fish were held in an aerated cooler (with the lid partially closed) and fed a variety of prey items including fathead minnows (*Pimephales promelas*), earth worms, blood worms and brine shrimp depending on their preference.

Mark identification (multi-species)
At the completion of this preliminary experiment, we used multiple techniques to differentiate marked and unmarked individuals using multiple hard structures. Based on our ability to use these various techniques and hard structures to distinguish marked from unmarked fish, we evaluated the usefulness of OTC marking in the future.

Yellow perch otoliths and spines were excised, mounted in epoxy and sectioned. These sections were inspected using an ultraviolet light coupled with a microscope provided by Dr. Kevin Bestgen at Colorado State University. We struggled using this equipment, and were not able to differentiate between marked and unmarked individuals. However, we were confident that we had marked the fish successfully using the technique described by Brooks et al. (1994) and refined by the Minnesota Department of Natural Resources (see Logsdon et al. 2004).

After some trial and error, we discovered that the most effective method for detecting OTC marks was using two ultraviolet lamps with no other light sources. The lamps were manufactured by Ultra-violet Products Incorporated located in San Gabriel, California. The lamps were equipped with 100 watt Sylvania mercury spot lights. This method allowed us to examine individuals without the use of a microscope and visually assess whether or not they were marked.

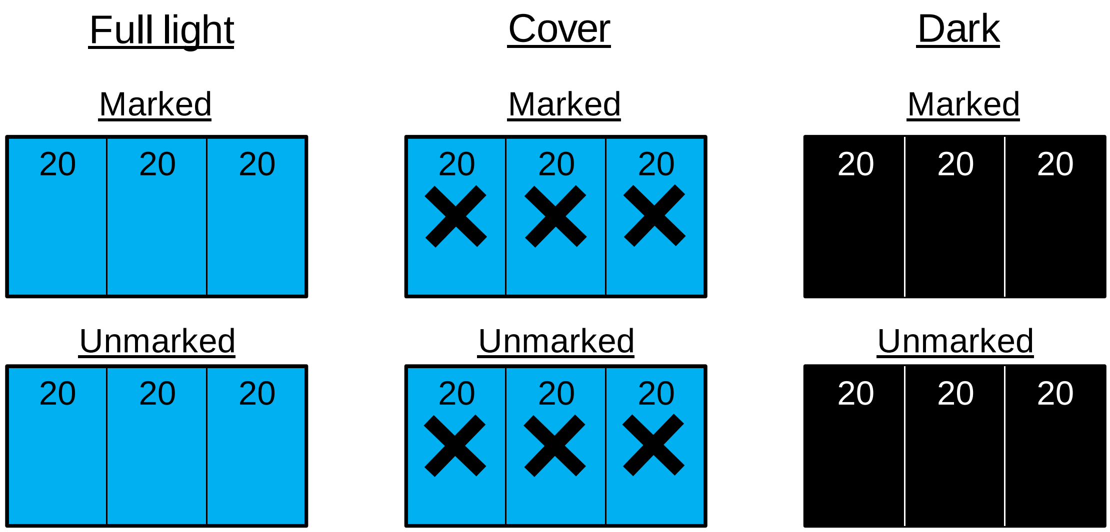
Fish used for mark identification using the ultraviolet lamps were sacrificed on July 25th, 2011 (yellow perch), August 5th, 2011 (smallmouth bass). We were able to keep bluegill sunfish alive in the lab with the available space and marks were assessed on live individuals. Marks were evaluated on September 14th, 80 days after marking. Marks were assessed as present or absent by two independent readers. We examined whole fish, dorsal spines, ventral spines, anal spines, vertebrae and scales for marks for all individuals with the exception of vertebrae and scales of bluegill sunfish that we did not sacrifice. Vertebrae were examined by taking a cross section of individual fish using a bone saw and scales were removed for analysis. All other structures were examined while still attached to the individual fish.

We did experience fish mortality throughout the experiment, however, this mortality was unrelated to the marking procedure (during which no mortality was observed). Fish were moved multiple times during the experiment and lab space and aeration were sometimes lacking due to other concurrent experiments. This resulted in some mortality, but it should be noted that during these events, mortality was the same or higher in the control relative to the treatment fish for all species. However, we had little power to detect differences between the mortality of marked and unmarked individuals due to low sample sizes, given that this experiment was only a preliminary study.

Walleye trial

After the preliminary work described above, we evaluated juvenile walleye mark retention. We used the same marking technique as described above. We placed 20 marked walleye in each section of 20 gallon tanks divided into thirds. (60 fish total per tank). We also had the same number and design for control (unmarked) walleye. To evaluate mark retention, we had a full light treatment, a covered treatment (some refuge from light offered by blacking out the bottom of the tanks and providing floating structure (plastic garden edging material), and a treatment that remained in the dark (See the following Figure for study design). Whole fish were analyzed for marks by two readers, and given a rank between 0 (no mark) and 5 (excellent mark).

Figure 1. Walleye trial design (overhead view with N's listed in each tank section).



Rainbow trout trial
Briefly, we attempted marking rainbow trout fry with the procedure described above. Mark retention was poor after only a few days. These results are not presented or discussed, but we suspect that the lack of hard structures on these young fish limited OTC uptake.

Results:

Multi-species
Though there were some differences in the intensity of the OTC marks, all individuals that were marked were easily discernable from those that were not. This held true in the case of whole fish, dorsal spines, ventral spines, anal spines, and vertebrae. However, we were unable to differentiate marked individuals using scales alone (Table 1). In the case of bluegill sunfish, vertebrae and scales were not evaluated because they were still alive. Perhaps the most definitive evidence showing the effectiveness of OTC marking was provided by the images displayed in Figures 1 and 2. Based on the results of the preliminary experiment described here, we feel it is relatively straightforward to differentiate between OTC marked and unmarked fish structures we evaluated with the exception of fish scales. Though all fish parts showed some reflection of the ultraviolet lights used, the distinctive yellow-green color of marked structures is apparent versus the blue or white hue (depending on what was examined) of the structures from unmarked individuals. Marks on facial structures (whole body) were particularly evident.

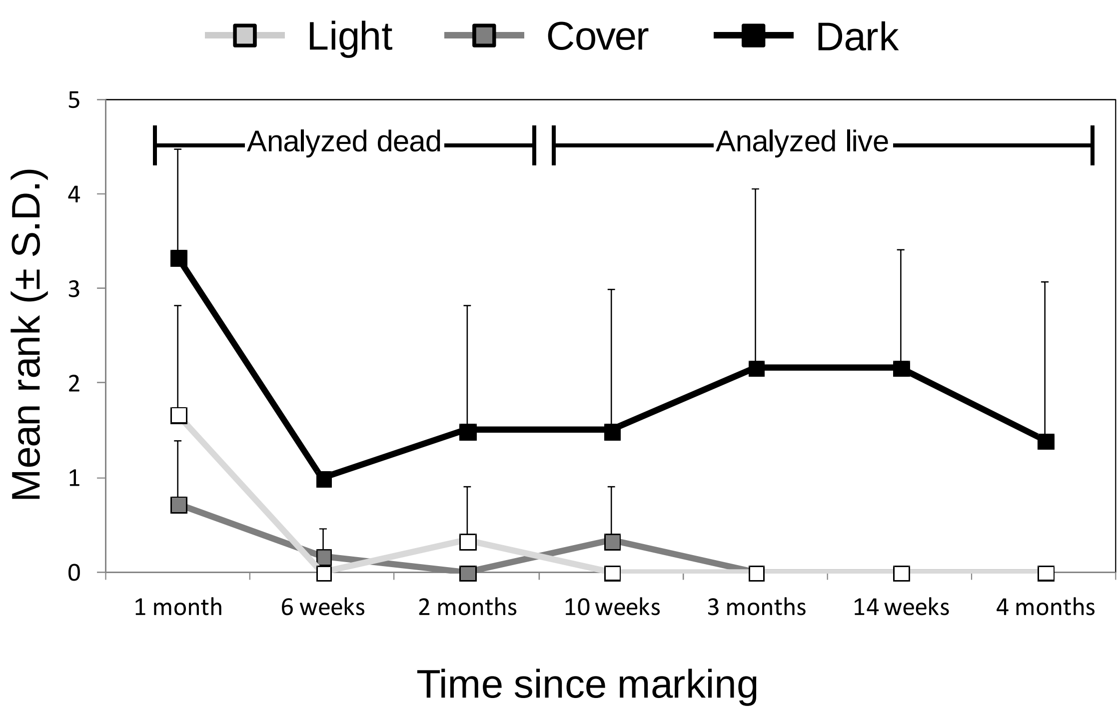
Table 1. Percent of correctly identified marked and unmarked individuals by fish species and structure evaluated. The number of each fish by species that were marked and unmarked are provided and NA indicates a structure that was not evaluated.

Species	Marked	Unmarked	Whole fish	Dorsal spine	Ventral spine	Anal spine	Vertebrae	Scales
YPE	7	5	100%	100%	100%	100%	100%	0%
SMB	2	2	100%	100%	100%	100%	100%	0%
BGL	3	1	100%	100%	100%	100%	NA	NA

The amounts of chemicals used for the treatments using 30 L of water were as follows:
1) 30 L of well water from the Bellvue Hatchery (alkalinity ~ 80 mEq/L)
2) 27.63 g of Pennox® 343 soluble powder (76% OTC)
3) 25.0 g of sodium phosphate, dibasic, anhydrous buffer (added until pH = 6.8)
4) 0.4 mL of ProLine® defoamer

Walleye trial
At first walleye were sacrificed and brought back to the Lake and Reservoir Laboratory for inspection. However, it became apparent that this was unnecessary and fish were examined live. One fish was collected from each tank section (three marked fish and three unmakred fish for each treatment; light, cover, dark) for the first three collections and after that, five fish from each tank section were inspected for marks and returned. Mean rankings for marked fish from treatments with light exposure diminished relatively quickly. However, marks remained visible on fish kept in the dark for the duration of the four month trial (Figure 2). Few false positives were identified in control fish (4 in total with ranks ≤ 1).

Figure 2. Walleye OTC mean OTC rankings and standard deviations through time.



Discussion:

Based on the results described here, we feel OTC marking shows promise for use in the future. The benefits of this technique include its non-lethal, non-invasive, and relatively easy to distinguish nature. We believe the technique could be applied to answer questions posed by biologists related to walleye and wiper stocking success, survival and competition. Given the right circumstances, millions of fish could be marked during transport or in the hatchery, (as is the case with the Minnesota Department of Natural Resources) and hundreds or thousands of fish could be collected from the wild in a single day, and analyzed for OTC marks either at night or in a portable enclosure (e.g., an ice house) where external light sources would be at a minimum.

We believe that two factors were influential in the outcome of the OTC emersion technique. During my consultation with personnel at Minnesota Department of Natural Resources, it was made clear that source water alkalinity and oxygen were important factors influencing the success any OTC marking effort. The importance of maintaining adequate oxygen levels during marking is obvious, however, using source water with the correct alkalinity is more complex. When emersion water alkalinity is elevated (>60 mEq/L; Minnesota Department of Natural Resources, pers. comm.), it requires less buffer to increase the emersion solution to the desired pH of 6.8. This is important because an excess of buffer (> 1:1 buffer to OTC) will precipitate OTC out of solution, leaving little for fish uptake. We paid close attention to this variable during this experiment, making sure alkalinity exceeded 60 mEq/L (~ 80 mEq/L). Waters in Colorado tend to be relatively low in alkalinity, thus, we caution that source water alkalinity should be quantified and exceed 60 mEq/L prior to any marking efforts. Fortunately, little water is required to mark large batches of fish, and this water could be obtained from suitable sources and transported to distant locations.

Walleye represent an excellent species for this marking technique because they tend to prefer low light conditions and they have adequate hard structures at small sizes relative to rainbow trout. Our next step is to take this technique and apply it in the field with walleye fingerlings. This research is set to take place in the coming field season.

Acknowledgements:

We thank Steve Brinkman, Kevin Bestgen, and the Minnesota Department of Natural Resource's hatchery personnel for their assistance and input throughout this project. We also thank Ben Swigle, Chris Craft, Estevan Vigil and Michael Avery for logistic support.

References:

Brooks, R.C., Heidinger, R.C., and Kohler, C.C. 1994. Mass-marking otoliths of larval and juvenile walleye by immersion in oxytetracycline, calcein, or calcein blue. North American Journal of Fisheries Management. 14:143-150.

Hawkins, M.J. 2002. Use of high pressure liquid chromatography to detect and quantify oxytetracycline marks in walleye otoliths and dorsal spines. M.S. Thesis. South Dakota State University, Brookings, South Dakota.

Logsdon, D.E., Pittman, B.J., and Barnard, G.C. 2004. Oxytetracycline marking of newly hatched walleye fry. North American Journal of Fisheries Management. 24:1071-1077.

STUDY PLAN C: Tiger Muskellunge and Brown Trout as Sucker Control Agents

Job C.1. Determine the effectiveness of tiger muskellunge and brown trout as sucker control agents.

Objectives:

The objective of this job is to evaluate the utility of tiger muskellunge and brown trout populations to suppress undesirable white sucker populations.

Introduction:

Suppression of undesirable fish species that negatively influence preferred species is common. One species often targeted for suppression is the white sucker (*Catostomus commersonii*). White suckers have been shown to compete with salmonid species including popular sport fish such as rainbow trout (*Oncorhynchus mykiss*), an important sport fish in Colorado. Rainbow trout diets have been found to overlap considerably with white suckers, and decreased growth rates of stocked rainbow trout in the presence of suckers have been observed. Reduced rainbow trout survival has been attributed to reductions in available benthos following the introduction of white suckers, and rainbow trout yield has been shown to decrease in systems where white suckers have been introduced. This type of information, combined with anecdotal evidence, has made white sucker control a common management practice in systems where they are abundant while salmonid species are desired by anglers.

Removals of white suckers have been conducted across the United States and Canada. A mass mechanical removal of white suckers was evaluated in five temperate lakes in Quebec. It was demonstrated that removals may induce compensatory responses in white suckers (e.g., increased individual growth rates, decreased age at maturity, increased mean adjusted fecundity). This indicates that these compensatory responses were related to the intensity of the removal effort; the more intense the removal, the more intense the response. Further, the compensatory responses observed for white suckers occurred more rapidly than any population gains observed for brook trout present within the five systems. Thus, if suppression of white suckers is considered as a management strategy, these potential responses should be considered, given that suppression attempts may result in the growth of white sucker populations without continuous effort or complete eradication.

Fish removal efforts can be costly and time-consuming; an alternative management practice to suppress undesirable fish species efficiently is to introduce piscivores that have the potential to effectively control the undesirable population. For example, sterile esocids such as tiger muskellunge (hybrids of northern pike *Esox lucius* and muskellunge *E. masquinongy*) are often stocked as biological control agents to suppress white sucker populations. Brown trout (*Salmo trutta*) have also been considered as a means to control white sucker populations in Colorado. Biological control (i.e., tiger muskellunge and brown trout introductions) of undesirable species has the benefit of being less labor intensive compared to mechanical removals. Suppression can occur across days, seasons and even years following stocking because effort (predation on white suckers) is essentially continuous. Perhaps one drawback to this approach is the potential for predation by tiger muskellunge and brown trout on desirable sport fish species like rainbow trout, rather than the intended, undesirable species. In this context, the effectiveness of tiger muskellunge and brown trout as white sucker control agents have not been thoroughly evaluated.

Methods:

A pond study was conducted to determine esocid prey preference, a study including five reservoirs was conducted to evaluate tiger muskellunge consumption of white suckers and stocked salmonids and a study is currently underway to evaluate brown trout consumption of white suckers and stocked salmonids. Detailed methodology of the esocid pond study can be found in the manuscript referenced below. A brief methodology is described for the tiger muskellunge-specific below and will be made fully available upon publication.

Results and Discussion:

One manuscript related to this job has been published in the peer reviewed scientific journal, Lake and Reservoir Management:

- **Lepak, J.M.**, Fetherman, E.R., Pate, W.M., Craft, C.D. and Gardunio, E.I. 2012. An experimental approach to determine esocid prey preference in replicated pond systems. Lake and Reservoir Management. 28:224-231

This manuscript describes the pond study with the following Abstract:

ABSTRACT: Competitive interactions between salmonids and white suckers (*Catostomus commersonii*) often result in poor salmonid growth, condition, and ultimately angler catch-per-unit-effort. Fisheries managers frequently introduce hybrid northern pike (*Esox lucius*) and muskellunge (*E. masquinongy*), known as tiger muskellunge, as biological control agents to reduce the abundance of undesirable species including white suckers, while simultaneously attempting to create viable recreational fisheries with stocked salmonids. In this study, northern pike were used to evaluate esocid prey preference between naïve, hatchery-reared rainbow trout (*Oncorhynchus mykiss*) and wild white suckers. Enclosures containing northern pike were stocked with rainbow trout and white suckers at 2 densities (50:50 and 20:80, respectively) to represent different ratios of forage. Weekly sampling by beach seine was used to determine rainbow trout and white sucker mortality. When the experiment was complete, enclosures were drained to determine overall survival of the forage species. Rainbow trout numbers declined precipitously to zero, while 60 to 75% of white suckers remained across all treatments. This study demonstrated a clear difference in survival of rainbow trout and white suckers (rainbow trout having lower survival) in the presence of northern pike under these conditions. We suggest fisheries managers consider these findings when stocking or managing for piscivores to control undesirable fish species, or to create recreational fisheries, while simultaneously stocking naïve sport fish vulnerable to predation.

Another manuscript related to this job is complete and will be submitted to Lake and Reservoir Management as a sister piece to the manuscript mentioned above within this reporting period.

- **Lepak, J.M.,** Cathcart, C.N., and Stacy, W.L. Tiger muskellunge predation upon stocked sport fish intended for recreational fisheries. Intended for submission to Lake and Reservoir Management.

This manuscript describes tiger muskellunge prey preference in five Colorado reservoirs. Stable isotope analyses were used to evaluate tiger muskellunge (northern pike, *Esox lucius* L., x muskellunge, *E. masquinongy*) predation on stocked salmonids, *Oncorhynchus* spp. relative to naturally reproducing white suckers, *Catostomus commersonii*, in five Colorado (USA) reservoirs. Stable isotope analyses indicated that tiger muskellunge consumed primarily stocked salmonids (53–84% by mass). Economic analyses indicated that an average individual tiger muskellunge surviving from age-3 to age-14 consumed approximately 70,000 grams of stocked salmonids during that time period. These results suggest that stocking salmonids into systems that contain tiger muskellunge (and potentially other predators) may result in losses of stocked fish to predation.

STUDY PLAN D: Collect and Archive Zooplankton (for Community Structure and Density Information when Needed) and Mysis (for Density and Biomass Information when Needed) samples

Job D.1. Collect, measure and archive zooplankton and Mysis samples from important Colorado waters.

<u>Objective:</u>

Collect and measure and identify zooplankton from Blue Mesa Reservoir, Granby Reservoir, Taylor Park Reservoir, and Vallecito Reservoir. Collect and measure Mysis samples from Granby Reservoir and Taylor Park Reservoir. Archive any other samples collected.

Introduction:

Zooplankton and Mysis data provide valuable information about the interactions between zooplankton, Mysis and kokanee salmon populations. Understanding these interactions allow us to determine the impacts that these species have on each other and how these will in turn affect overall community structure, kokanee population size and individual growth. These collections also provide a baseline for understanding the potential influence of natural and anthropogenic perturbations including climate change, introduced species and community shifts. These sorts of events often act at the base of food webs first and work upwards. Thus, evaluating the potential changes associated with these perturbations is vital for making appropriate management decisions in the face of ecosystem changes.

Methods:

Zooplankton were collected during the day from standardized sites in lakes and reservoirs that contain Mysis and kokanee salmon populations (and other potentially important reservoirs). We used oblique tows from depths of 0-10 m with a Clarke-Bumpus metered sampler (153 µm mesh net) with two replicates per site. Samples were preserved in 70% ethanol and held in 4 ounce Whirl-Pak bags. Zooplankton identification and individual and density measurements were conducted as described in Coldwater Reports prepared by P. Martinez.

Mysis were collected at night on the new moon in standardized sites in lakes and reservoirs of interest (those with Mysis and kokanee salmon populations). Collections were conducted with a 1 m diameter, 3 m long conical net with 500 µm mesh. The net was lowered to the bottom at every site and retrieved at 0.37 m/s with a battery-powered winch. Duplicate samples were be collected at each site and preserved in 70% ethanol and held in 18 ounce Whirl-Pak bags. Mysis densities were calculated from these samples and individuals were measured from the tip of the rostrum to the tip of the telson, excluding setae.

Results and Discussion:

The zooplankton and Mysis data obtained in 2012 can be found in Tables 1 – 12 below. In each length frequency table the abbreviations are: Bl = *Bosmina longirostris*, Cdq = *Ceriodaphnia quadrangular*, Dgm = *Daphnia mendotae*, Dp = *Daphnia pulicaria*, Dp spp. = unidentified *Daphnia spp.*, Dbt = *Diacyclops b. thomasi*, and Ln = *Leptodiaptomus nudus*. All other samples not presented here were archived for later identification if necessary.

Table 1. Blue Mesa Reservoir zooplankton density data.

Blue Mesa - 20 August 2012 - Mean *Daphnia* density = 10.2/L										
Zooplankton Species	Sapinero (0-10m)			Cebola (0-10m)			Iola (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Ceriodaphnia quadrangula	4.6	5.5	5.0	4.7	3.4	4.1	6.52	4.87	5.7	4.9
Bosmina longirostris	0.8	1.6	1.2	3.4	2.6	3.0	13.4	16.7	15.0	6.4
unidentified *Daphnia spp.*	1.9	1.1	1.5	3.8	0.6	2.2	2.1	6.6	4.3	2.7
Daphnia mendotae	1.9	0.5	1.2	0.5	0.6	0.5	0.0	1.0	0.5	0.8
Daphnia pulicaria	2.3	1.6	1.9	4.6	4.5	4.6	15.4	11.8	13.6	6.7
Diacyclops b. thomasi	6.0	12.1	9.0	6.3	4.9	5.6	7.9	10.4	9.2	7.9
Leptodiaptomus nudus	3.3	6.3	4.8	3.4	5.7	4.6	3.4	0.4	1.9	3.7
Mean total no./L	19.8			19.9			48.4			29.4

Table 2. Blue Mesa Reservoir zooplankton length frequency data.

length class in mm	**Blue Mesa - 20 August 2012**						
	Bl	**Dbt**	**Dgm**	**Dp**	**Dp spp.**	**Ln**	**Cdq**
0.1							
0.2	17						1
0.3	10	8		1	2	4	4
0.4	5	14	1	2		3	5
0.5	2	13	2			6	13
0.6		10	2	3		10	5
0.7		6		2		6	
0.8		2	2	3		6	3
0.9		7	2	2	1	4	
1.0		2		9	1	2	
1.1		1		9			1
1.2				8	1		
1.3			1	7			
1.4				3	1		
1.5				3			
1.6				3			
1.7				5			
1.8				16	1		
1.9				4			
2.0				6			
2.1				2			
2.2				3			
2.3							
2.4							
2.5							
2.6							
2.7							
2.8							
2.9							
Totals	34	63	10	91	7	41	32
Mean Length	0.3	0.6	0.8	1.4	1.0	0.7	0.6

Table 3. Granby Reservoir zooplankton density data.

Granby - 18 September 2012 - Mean *Daphnia* density = 0.6 /L																
Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
unidentified *Daphnia spp.*	0.0	0.0	0.0	0.6	0.1	0.4	0.0	0.0	0.0	0.3	0.0	0.2	0.1	0.0	0.1	0.1
Daphnia mendotae	0.2	0.0	0.1	0.2	0.1	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Daphnia pulicaria	0.2	0.2	0.2	0.6	1.3	1.0	0.4	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.4
Diacyclops b. thomasi	7.2	2.8	5.0	9.4	9.7	9.5	16.4	6.3	11.3	3.1	4.1	3.6	8.3	6.5	7.4	7.4
Leptodiaptomus nudus	2.8	1.2	2.0	0.0	2.1	1.1	6.4	2.2	4.3	0.6	0.7	0.6	1.8	2.5	2.1	2.0
Diaphanosoma brachyurum	0.3	0.1	0.2	0.2	1.2	0.7	0.8	0.1	0.4	0.0	0.0	0.0	0.2	0.1	0.1	0.3
Mean total no./L	7.5			12.8			16.5			4.7			10.0			10.3

Table 4. Granby Reservoir zooplankton length frequency data.

length class in mm	Granby - 18 September 2012					
	Dbt	**Dgm**	**Dp**	***Dp* spp.**	**Ln**	**Db**
0.1	1					
0.2	0				1	
0.3	3				1	
0.4	9				2	
0.5	32		1		7	1
0.6	75		1		10	2
0.7	61	1	1		2	1
0.8	35	3	5	1	7	
0.9	22	1	2		12	1
1.0	2		4		7	3
1.1		1	1		3	
1.2		1	2		4	
1.3			2		6	
1.4			1			
1.5						
1.6						
1.7			1			
1.8			1			
1.9						
2.0			2			
2.1			1			
2.2			2			
2.3			1			
2.4			1	1		
2.5			1			
2.6			1			
2.7			1			
Totals	240	7	32	2	62	8
Mean Length	0.7	1.5	1.5	1.6	0.9	0.8

Table 5. Taylor Park Reservoir zooplankton density data.

Taylor Park - 19 August 2012 - Mean *Daphnia* density = 2.8/L																
Zooplankton Species	Station 1 (0-10m)			Station 2 (0-10m)			Station 3 (0-10m)			Station 4 (0-10m)			Station 5 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	a	b	mean	a	b	mean	
unidentified *Daphnia spp.*	0.3	0.8	0.5	0.6	1.1	0.8	0.1	0.1	0.1	0.9	1.7	1.3	0.4	0.1	0.2	0.6
Daphnia mendotae	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.3	0.1	0.0	0.0	0.1
Daphnia pulicaria	2.5	1.9	2.2	0.6	0.6	0.6	2.9	2.9	2.9	4.2	2.9	3.6	1.9	0.7	1.3	2.1
Bosmina longirostris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Leptodiaptomus nudus	24.5	16.8	20.7	5.8	11.3	8.6	1.6	2.9	2.3	1.1	2.4	1.8	7.1	4.2	5.6	7.8
Diacyclops b. thomasi	1.1	3.7	2.4	1.6	0.8	1.2	0.7	0.7	0.7	1.4	1.4	1.4	3.7	2.3	3.0	1.7
Mean total no./L	25.8			11.2			5.9			8.4			10.3			14.4

Table 6. Taylor Park Reservoir zooplankton length frequency data.

length class in mm	Taylor Park - 19 August 2012					
	Dbt	**Ln**	**Dgm**	**Dp**	**Bl**	**Dp spp.**
0.1						
0.2						
0.3	3				1	
0.4	17	5				
0.5	19	31		1		
0.6	9	20				
0.7	4	27		1		
0.8	1	7	3	1		1
0.9	1	21		2		
1.0		19		4		1
1.1		8		7		1
1.2		11		3		
1.3		6		7		2
1.4		8		8		1
1.5		7	1	9		
1.6		9		15		2
1.7	1	2		13		1
1.8		3		17		3
1.9		3		11		3
2.0		6		20		2
2.1		1	1	12		
2.2				7		2
2.3				1		2
2.4		1		1		
2.5						
2.6						1
Totals	55	195	5	140	1	22
Mean Length	0.6	1.0	1.3	1.7	0.3	1.8

Table 7. Vallecito Reservoir zooplankton density data

Vallecito - 18 August 2012 - Mean *Daphnia* density = 7.2/L										
Zooplankton Species	P1 (0-10m)			P2 (0-10m)			P3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Bosmina longirostris	1.4	0.6	1.0	2.0	0.5	1.3	2.5	2.5	2.5	1.6
unidentified *Daphnia spp.*	0.0	2.4	1.2	1.6	1.4	1.5	1.1	0.6	0.8	1.2
Daphnia mendotae	9.3	4.8	7.0	7.3	6.2	6.8	3.3	4.8	4.0	6.0
Daphnia pulicaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diacyclops b. thomasi	2.5	2.1	2.3	1.6	1.9	1.8	0.6	1.6	1.1	1.7
Leptodiaptomus nudus	36.9	36.5	36.7	26.2	29.6	27.9	10.3	6.4	8.3	24.3
Mean total no./L	11.5			11.3			8.5			10.4

Table 8. Vallecito Reservoir zooplankton length frequency data.

length class in mm	**Vallecito - 18 August 2012**				
	Bl	**Dbt**	**Dgm**	**Dp spp.**	**Ln**
0.1	1				
0.2	18				2
0.3	14				4
0.4		1	1		38
0.5		2	5	1	53
0.6			15		41
0.7		4	12		19
0.8		5	19	1	30
0.9		4	25		20
1.0			29	2	5
1.1			15		2
1.2			9	1	5
1.3			6		1
1.4			1		
Totals	33	16	137	5	220
Mean Length	0.3	0.8	0.9	0.9	0.7

Table 9. Granby Reservoir Mysis density data.

Granby Reservoir - 22 July 2009 - 10 Stations - Mean *Mysis* /m² = 630.32										
Sample number	Sampling stations (water depth in meters)									Data summary
	Stratum I		Stratum II				Stratum III			
	1A- 49.5	1B- 48	2A- 25	2B- 21.5	2C- 29.0	2D- 18.5	3A- 14.5	3B- 8.0	3C- 12.0	3D-13	
#1	2104	330	246	65	428	212	167	15	9	155	3731
#2	4167	383	265	119	420	299	228	15	24	245	6165
Sum	6271	713	511	184	848	511	395	30	33	400	9896
Mean	3135.5	356.5	255.5	92	424	255.5	197.5	15	16.5	200	494.8

Table 10. Granby Reservoir Mysis length frequency data.

Granby Reservoir- 22 July 2009																		
Station - sample #	Mysids Size (mm)																	Totals
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
GR1A-1				5	64	276	301	208	200	258	296	215	147	56	48	25	5	2104
GR1B-2			1	12	15	31	35	31	45	60	52	42	25	25	2	4	1	381
GR2A-2				2	11	28	22	26	37	50	31	19	15	16	7	1		265
GR2B-1				1	1	1	3	4	9	21	16	7	1		1			65
GR2C-1			1	17	43	57	27	22	37	39	62	41	29	23	18	9	3	428
GR2D-1					5	19	16	15	18	42	61	25	7	4				212
GR3A-1						4	5	9	35	63	41	10						167
GR3B-1						2	4	3	4	1	1							15
GR3C-1						1	2	2	2	2								9
GR3D-1				5	12	12	9	17	36	36	25	3						155
Totals	0	0	2	42	151	431	424	337	423	572	585	362	224	124	76	39	9	3801
Percent	0.00%	0.0%	0.1%	1.1%	4.0%	11.3%	11.2%	8.9%	11.1%	15.0%	15.4%	9.5%	5.9%	3.3%	2.0%	1.0%	0.2%	100.0%

Table 11. Taylor Park Reservoir Mysis density data.

Taylor Park - 19 August 2012 - 6 Stations - Mean *Mysis* /m² = 327.49										
Sample number	Sampling stations (water depth in meters)									Data summary
	Stratum I		Stratum II				Stratum III			
	1A - 24	1B- 36	2A- 20.5	2B- 24	2C- 13	2D- 19	3A-	3B-	3C-	3D-	
#1	267	216	255	281	189	282	N/A	N/A	N/A	N/A	1490
#2	196	235	276	345	253	290	N/A	N/A	N/A	N/A	1595
Sum	463	451	531	626	442	572	0	0	0	0	3085
Mean	231.5	225.5	265.5	313	221	286	0	0	0	0	257.08

Table 12. Taylor Park Reservoir Mysis length frequency data.

Taylor Park Reservoir- 19 August 2009																			
Station - sample #	Mysids Size (mm)																		Totals
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
GR1A-1				1	7	15	15	26	44	54	41	17	13	14	16	2	2		267
GR1B-1			3	10	11	7	5	11	8	14	22	15	32	35	22	15	5	1	216
GR2A-2				1	6	27	30	38	37	53	44	26	12	2					276
GR2B-1				1	16	24	25	26	46	55	53	21	4	7	2	1			281
GR2C-2				6	12	11	26	41	54	67	29	4			1	2			253
GR2D-2				6	14	28	28	40	47	65	48	13		1					290
Totals	0	0	3	25	66	112	129	182	236	308	237	96	61	59	41	20	7	1	1583
Percent	0.00%	0.0%	0.2%	1.6%	4.2%	7.1%	8.1%	11.5%	14.9%	19.5%	15.0%	6.1%	3.9%	3.7%	2.6%	1.3%	0.4%	0.1%	100.0%

STUDY PLAN E: Investigating Sucker Impacts on Rainbow Trout

Job E.1. Collection of rainbow trout and white suckers for growth and stable isotope analyses to quantify the importance of diet overlap.

Objective:

The objective of this job is to collect rainbow trout and white sucker samples from a variety of Colorado waterbodies to estimate growth and diet of these species using otolith, fin ray and stable isotope analyses.

Introduction:

White suckers (*Catostomus commersonii*) have been shown to compete with salmonid species including popular sport fish such as rainbow trout (*Oncorhynchus mykiss*), an important sport fish in Colorado. Rainbow trout diets have been found to overlap considerably with white suckers, and decreased growth rates of stocked rainbow trout in the presence of suckers have been observed. Reduced rainbow trout survival has been attributed to reductions in available benthos following the introduction of white suckers, and rainbow trout yield has been shown to decrease in systems where white suckers have been introduced.

Although these relationships have been established in systems outside of Colorado, little work has been to quantify these relationships within Colorado waterbodies. Further, in some systems, rainbow trout and white suckers coexist and both species experience growth at the individual level. The differences between these systems and others in Colorado that contain white suckers where rainbow trout experience poor growth are not well understood.

Methods:

Rainbow trout and white suckers will be collected in a variety of Colorado waterbodies with various methods. Rainbow trout and white sucker growth will be evaluated using aging structures (otoliths and fin rays respectively) and tissue samples will be analyzed for stable isotopes of carbon and nitrogen (indicators of diet composition). Morphological and limnological data for comparisons across systems are currently available from previous sampling efforts by Colorado Parks and Wildlife personnel. Using these measurements we will determine the importance of diet overlap and waterbody characteristics on rainbow trout growth in the presence of white sucker stable isotope analyses and Bayesian mixing models will be used to evaluate diet overlap.

Results and Discussion:

This project is not complete, but samples have been collected from Big Creek Reservoir, Clear Creek Reservoir, DeWeese Reservoir, Dillon Reservoir, Lake John, Parvin Reservoir, Pinewood Reservoir, and South Delaney Butte. Analyses are currently underway.

STUDY PLAN F: Routine Kokanee Population Assessments and Improvement of SONAR Methodology for Estimating Fish Abundance

Job F.1. Conduct and refine SONAR surveys throughout Colorado waters to estimate kokanee salmon population size and annual egg take.

Objective:

The objective of this job is to continue historical SONAR surveys (for detection of trends in kokanee salmon abundance) and to improve our ability to estimate kokanee salmon egg take and abundance.

Introduction:

An economically important component of many Colorado fisheries is the kokanee salmon (*Oncorhynchus nerka*). This species (representing ~$30 million dollars in revenue annually to the state of Colorado) must be sustained by the annual collection of eggs and raising kokanee salmon in the state hatchery system until they are stocked as fry. Since they represent such a large portion of the state's economy, significant effort is put towards the collection and propagation of kokanee salmon eggs. In order to maximize the cost/benefit of these efforts, it is crucial to estimate the numbers of adult kokanee salmon that will be spawning in a given system in a given year, and to subsequently estimate the potential number of eggs that these salmon will supply to the hatchery system.

The most effective and widespread method for estimating kokanee salmon population size in Colorado waters is the use of SONAR (sound navigation and ranging) surveys, otherwise known as hydroacoustic surveys. These surveys use sound waves projected from a transducer to enumerate the number of fish within the water column. These surveys are non-invasive, less labor intensive and reduce sampling bias when compared to more traditional gear types (e.g., gillnets, electrofishing, trapping, etc.). Hydroacoustic surveys are used extensively to assess marine fish stocks, and their application to lake and reservoir systems is increasing in conjunction with research and advances in SONAR technology.

Colorado uses hydroacoustic surveys to estimate kokanee salmon population size in many waterbodies. The aim of hydroacoustic surveys is to determine the relative abundance of kokanee salmon to predict future egg take. These surveys have been conducted successfully historically, and I intend to continue these surveys as they are currently designed because the historical hydroacoustic data collection design has value for present and future kokanee salmon population and egg take predictions. However, we are still in the process of refining this technique and adapting its capabilities to better suit our needs in Colorado. For example, hydroacoustic surveys are excellent for enumerating fish numbers, however, verifying species composition must be done by other means such as trawl samples, *in-situ* measurements or autonomous underwater vehicle (AUV) video recordings. Currently, the ability to distinguish individual fish species with SONAR technology is obscured by the variation in target strength (the strength of a returning sound echo) among species and within the same species and individuals. Target strength of returning sound echoes depends on internal fish physiology (i.e., the shape and orientation of the swimbladder) as well depth, stomach fullness, fish length and species. Thus, it is important to improve hydroacoustic survey design and data collection through a better understanding of fish species target strength variability. Specifically, the need for precise estimates of target strength values/ranges of kokanee salmon in the wild is paramount for reducing uncertainty in abundance and future egg take estimates. In the past this has proven difficult, primarily because lake and reservoir systems in Colorado contain more species then just kokanee salmon.

Continuing hydroacoustic surveys will allow us to detect, and prepare for, increasing or decreasing trends in annual kokanee salmon abundance and egg take. Data collected will be summarized and provided to Area Biologists to aid in various management decisions (e.g., kokanee salmon stocking density, harvest regulations and egg take effort allotment). Refining SONAR surveys through a better understanding of target strength variability will allow us to reduce the amount of uncertainty associated with our estimates of kokanee salmon abundance and future egg take.

Methods:

Procedure 1. Conduct historical SONAR surveys

SONAR surveys have been conducted historically throughout Colorado in waters that contain kokanee salmon. These surveys continued for comparison with data collected in the past. Nighttime surveys were conducted when lakes and reservoirs are thermally stratified (corresponding to the summer months) during the new moon phase. Stratification aids in the separation of hydroacoustic targets by fish species because of their differing thermal preferences. Furthermore, kokanee salmon tend to school based on visual cues, and during low-light conditions they are dispersed spatially which makes them easier to enumerate (i.e., fish are spread out and easier to differentiate from one-another).

Surveys were conducted using a personal computer-controlled Hydroacoustic Technology Inc. (HTI) 243 split-beam scientific echosounder with a 15 degree down-looking transducer mounted in a towed fin. This equipment was operated from a 22 foot Hewes Craft Sear Runner. Historical standardized transects were followed using a Garmin 165 global positioning system. Data are then processed using Echoscape (HTI Inc.) coupled with program HACH (developed by Dr. Kevin Rogers, Colorado Parks and Wildlife).

Procedure 2. Refine SONAR surveys to better develop a kokanee salmon target strength to length relationship.

A new reservoir named Lake Nighthorse, located near Durango, Colorado, presented a unique opportunity to evaluate estimates of target strength values/ranges of kokanee salmon in the wild. This reservoir has just been filled, and currently has a limited number of fish species present. Unlike this system, most other Colorado waterbodies contain many fish species, making it difficult to conclusively differentiate kokanee salmon from the other species present. As of 2011, Lake Nighthorse has only been stocked with "catchable" (~300 mm) rainbow trout and ~75,000 kokanee salmon (~50 mm). These two species are relatively simple to differentiate using hydroacoustics because of their large size difference and behavior. Gill netting efforts were conducted in conjunction with hydroacoustic surveys to verify kokanee salmon lengths

Results and Discussion:

Procedure 1 (historical surveys) were completed and the annual report describing these results has been made available to Aquatic Biologists on the Colorado Parks and Wildlife Q-drive.

Procedure 2 (refining target strength to length relationship) is underway. With our sampling in Lake Nighthorse, we will be able to determine kokanee salmon-specific target strength and variability. Through repeated surveys, we will be able to track these fish through time as they grow in length, and develop kokanee salmon-specific target strength and variability across a range of kokanee lengths. Hydroacoustic survey data coupled with netting data to verify fish length to target strength data can then be applied to better differentiate between kokanee salmon and other fish species in lakes and reservoirs throughout Colorado.

STUDY PLAN G: Standardizing Gillnetting Techniques

Job G.1. Conduct SPIN lake trout netting in Blue Mesa Reservoir.

Objective:

The objective of this job is to explore the potential of SPIN (summer profundal index netting) as a standardized lake trout sampling technique in Colorado waterbodies.

Introduction:

Estimating fish population size is an essential part of fisheries management. Often, harvest regulations and other management decisions that influence fish community and food web structure rely heavily on the knowledge of how many fish are present within a given system. Capture-mark-recapture studies are one of the most common and reliable methods for estimating fish population sizes and answering other questions related to fisheries. Although this method is useful, it can be extremely labor intensive, and to obtain precise estimates, one must often mark a large proportion of the fish in a population in order to have recapture rates at or above 30%. In some systems, this may take a period of years depending on the life history of the species of interest.

To avoid labor-intensive sampling that is often constrained by available time, personnel and resources, fisheries biologists and researchers have developed methods to estimate what is referred to as "relative abundance". These approaches can be conducted using several gear types (e.g., gillnets, electrofishing, trapping, etc.) and generally involve a standardized effort. Using the catch rates from these methods, a "catch-per-unit-effort" (CPUE) can be calculated for comparison over time and across systems. Thus, comparisons of CPUE can indicate whether a particular system has more or less fish in a given year or whether a particular system has more or less fish relative to another. Although this can be useful, these types of approaches do not provide an estimate of the number of individuals in a system. Thus, although these qualitative sampling methods offer guidance for fisheries managers, they do not provide quantitative measures on which to base management decisions.

I was asked to investigate the potential for using standardized sampling techniques for developing fish population indices in Colorado. The biologists across the state use a variety of methods to sample fish and obtain CPUE's for comparison across systems and time. However, since several methods and gear types are used for fish sampling in many cases, it can be difficult to compare CPUE's across the landscape. At the same time, it can be very important to continue standardized historic sampling efforts in a given system for comparison to previous data. When new methods are developed and implemented, one can lose the ability to compare these methods to past efforts unless the new and old methods are conducted simultaneously for calibration. Thus, although I have explored a new technique for fish sampling, I do not recommend forgoing any historical long-term data collection without serious consideration. However, new, alternative methods may provide additional information not formerly available using other techniques.

Methods:

I explored the utility of a quantitative method for sampling lake trout (*Salvelinus namaycush*) developed by the Ontario Ministry of Natural Resources. Specifically, this method is referred to as summer profundal index netting, (SPIN) and focuses on capturing lake trout in such a way that allows us to utilize lake trout data from 700-800 other systems to estimate population size, rather than obtaining relative abundance data. Briefly, the method involves using 64 m X 1.8 m gill nets with eight panels with stretch mesh sizes of 57, 64, 70, 76, 89, 102, 114 and 127 mm in random order. Nets are set along the bottom in random orientation and sites are depth stratified and selected at random. The SPIN manual has an interchangeable rope design which allows for nets to be set in 2, to over 80 m of water which was useful and versatile, and may be used for other netting efforts. Sampling is conducted when surface temperatures exceed 18°C and nets are set for two hours. Netting for this project was conducted from 8 to 12 August, 2011. For further sampling details, see Sandstrom and Lester (2009). The power of this particular method is the use of data from hundreds of systems as a calibration tool to characterize lake trout densities that can then be used to estimate lakewide abundance, versus techniques that provide estimates of relative abundance through time and across systems.

It was decided that Blue Mesa Reservoir would provide a good testing ground for this technique for two reasons: 1) there are more data available for lake trout in Blue Mesa Reservoir relative to many other lake trout populations in the state, and 2) Blue Mesa Reservoir has a timely issue related to lake trout management and additional information would be useful. The biologist for Blue Mesa Reservoir (Dan Brauch) was able to assemble two crews to conduct the lake trout sampling over the course of one week in August. The results from this effort are described below.

Results and Discussion:

In 81 net sets we captured 129 lake trout ranging for 230 mm to 996 mm and lake trout were captured in all eight mesh sizes (an additional two fish were captured but were swimming freely and could not be associated with a specific mesh size). This corresponded to a lake-wide population estimate (excluding depths of less than 2 m which were not sampled) of 34,071 (lower 68% confidence interval = 27,144; upper 68% confidence interval = 41,929) lake trout over 230 mm. I selected two methods of presenting these data; 1) by age class, and 2) by size class in 50 mm increments starting with the smallest lake trout sampled at 230 mm (Figures 1 and 2 respectively). It was evident that larger numbers of lake trout were present in the younger age class and corresponding smaller size classes as would be expected in most naturally reproducing populations (Figures 1 and 2). Bycatch during this sampling effort included kokanee salmon, (*Oncorhynchus nerka*) brown trout, (*Salmo trutta*) white sucker, (*Catostomus commersonii*) and longnose sucker (*Catostomus catostomus*) (Table 1). Relatively high mortality was observed in most species relative to what is common during SPIN sampling (Sandstrom, pers. comm.). However, we observed 25% mortality in lake trout > 800 mm ($n = 4$).

Table 1. Catches of fish by species and depth strata during SPIN sampling on Blue Mesa Reservoir. Note that mortality was 25% for lake trout captured > 800 mm ($n = 4$).

Species	2-10 m	10-20 m	20-30 m	30-40 m	40-60 m	60-80 m	Total	Mortality
MAC	0	0	34	92	1	2	129	62%
KOK	1	15	15	8	0	0	39	85%
LOC	5	22	45	32	0	0	104	68%
WHS	39	17	7	0	0	0	63	24%
LGS	22	28	18	18	0	0	86	23%

Prior to SPIN sampling, personnel from Colorado Parks and Wildlife, Colorado State University and the Ontario Ministry of Natural Resources discussed our expectations with respect to the lake trout population size in Blue Mesa Reservoir. Based on creel and standardized sampling data, personal experience with lake trout sampling in a variety of systems throughout North America, and expert knowledge of Blue Mesa Reservoir itself, we arrived at a population estimate of 50,000 individuals total. Our SPIN lake trout population estimate of ~34,000 is lower than this number, however, we must consider that our SPIN estimate only includes fish over 230 mm, and it is probable that a large proportion of lake trout in Blue Mesa Reservoir are < 230 mm. This stands to reason given that approximately 6,000 to 9,000 lake trout are harvested from Blue Mesa Reservoir annually and the majority of these fish are between 400 and 600 mm. A large standing stock of smaller lake trout (ages 0-2) must be present to replace these fish that are harvested. However, the catchability of fish < 300 mm is relatively low using the SPIN method, and as such, it is difficult to accurately estimate the number of lake trout in smaller size classes that are present.

Figure 1. Estimated number of lake trout in Blue Mesa Reservoir by age class. Error bars represent 68% confidence intervals.

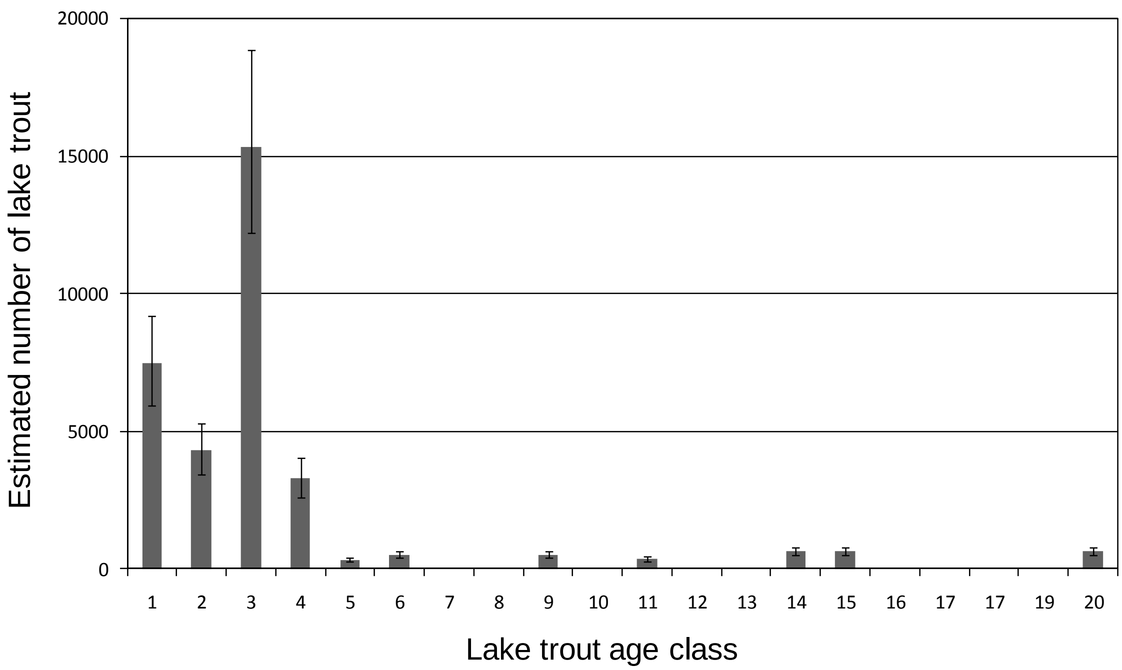
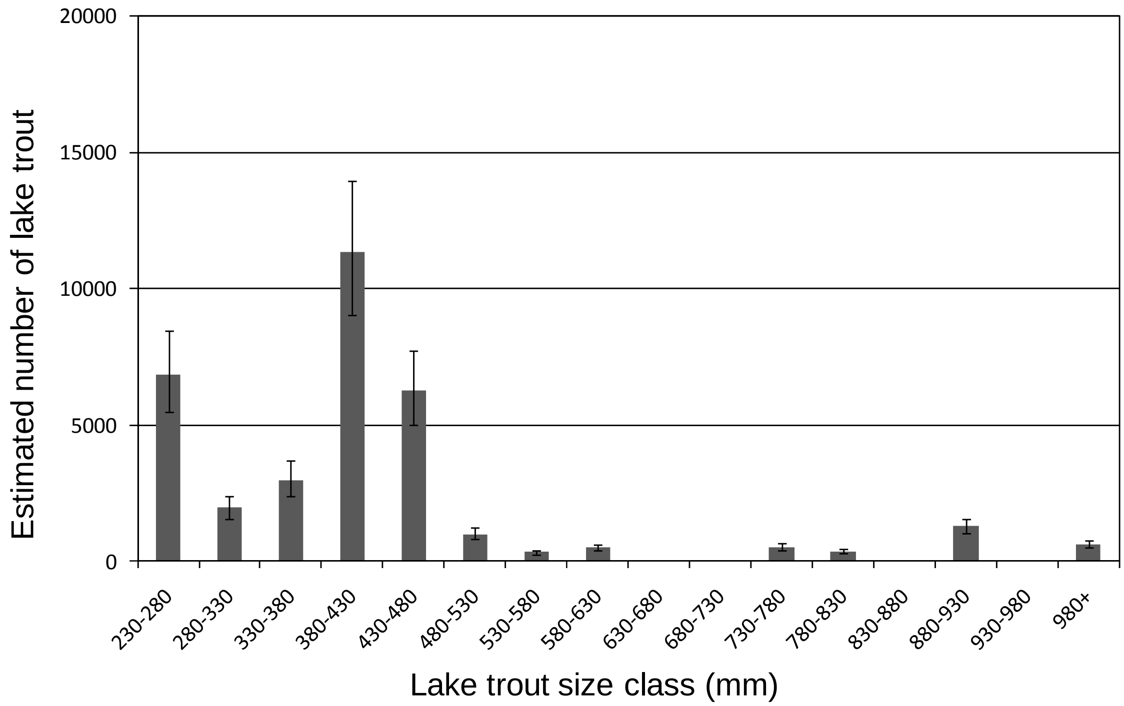


Figure 2. Estimated number of lake trout in Blue Mesa Reservoir by size class. Error bars represent 68% confidence intervals.

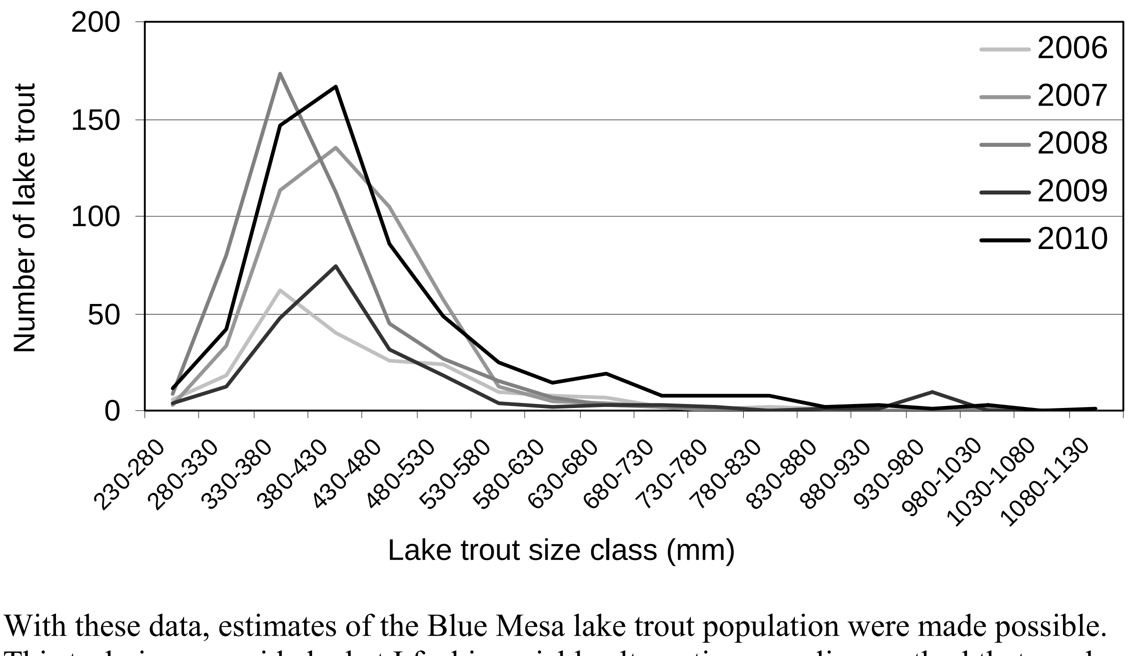


The most recent and comprehensive lake trout population estimate in Blue Mesa Reservoir was conducted by coupling capture-mark-recapture gillnetting surveys (2000-2002) with hydroacoustic surveys (2002) (Crockett et al. 2006). This 3-year effort used multiple approaches to estimate the number of lake trout > 425 mm (n = 4 approaches) and the number of lake trout > 564 mm (n = 2 approaches). Although caution must be used when interpreting the relevancy of these estimates to the SPIN estimate of 2011, I compared these data to qualitatively assess their similarity. The SPIN estimate of lake trout > 425 mm was approximately 11,000, which fell within the 95% confidence intervals of three of the four approaches, and slightly above the 95% confidence intervals for one approach used to estimate this value by Crockett et al. (2006). The SPIN estimate of lake trout > 564 mm was approximately 3,000, which fell within the 95% confidence intervals of both approaches used to estimate this value by Crockett et al. (2006). Though my estimates overlapped relatively well with those obtained by Crockett et al. (2006), two factors should be considered when comparing these values; 1) there is no temporal overlap in these estimates, so changes in the lake trout population may have occurred between these two sampling periods, and 2) Crockett et al. (2006) used Love's equation (Love 1971) to determine the target strength corresponding to these size categories for lake trout, which we now believe may lead to underestimating the number of lake trout within each size category (K. Rogers and H. Crockett pers. comm.).

The Biologist for Blue Mesa Reservoir (Dan Brauch) has data from creel surveys of lake trout anglers conducted for almost two decades. I selected the most recent five years of these data for comparison with the data collected by the SPIN methodology. The creel data represent the total reported catch of measured lake trout by anglers from May to October by year (Figure 3). These data show a relatively large number of lake trout being caught that were centered around 400 mm in length, similar to what was found in the SPIN survey, and the rest of the catches by size class match up well. The largest difference between these data is that the SPIN data show a relatively large number of fish shorter than 300 mm (Figures 2 and 3). This difference is likely attributable to the difference in vulnerability of lake trout to SPIN versus angling gear. Again, caution must be used when comparing these data, however, the pattern of catches of lake trout by size by anglers and those estimated using the SPIN methodology overlap well.

Lake trout (and bycatch) mortality was relatively high during SPIN sampling (Table 1). The mortality that was experienced was greater than what was expected (~25%) based on data obtained by the Ontario Ministry of Natural Resources (S. Sandstrom pers. comm.). This may be related to the size structure of fish captured and the relatively high elevation at which sampling took place, where reduced atmospheric pressure may have increased bladder expansion compared to lower elevation systems sampled in Ontario and other Canadian systems. However, it should be noted that mortality of large lake trout (> 800 mm; $n = 4$; those of highest conservation concern) was 25%, and reflected the expected mortality rate based on data from the Ontario Ministry of Natural Resources.

Figure 3. Number of lake trout caught and measured from May to October in Blue Mesa Reservoir by anglers by size class by year (Dan Brauch; CDOW data).



With these data, estimates of the Blue Mesa lake trout population were made possible. This technique provided what I feel is a viable alternative sampling method that can be considered quantitative. Personnel at the Ontario Ministry of Natural Resources have developed three other techniques that might prove useful in the future, primarily due to their more quantitative nature when compared to catch-per-unit-effort approaches. Similar to SPIN, spring littoral index netting (SLIN) is a nearshore lake trout assessment tool using slightly different nets and sampling design. Another potentially useful technique is fall walleye index netting (FWIN) which focuses on walleye population estimation. These types of approaches could aid in the development and assessment of management goals in a variety of Colorado waters depending on the need. For example, the SPIN results obtained from this preliminary study could be coupled with the bioenergetics model developed by researchers at Colorado State University, (Dr. Brett Johnson and William Pate) to estimate the consumptive demand of the lake trout population on kokanee salmon in Blue Mesa Reservoir. These estimates could then be used to determine the best management practices for balancing the objectives of stakeholders interested in the lake trout and kokanee salmon fisheries Blue Mesa Reservoir.

To reiterate, I was asked to look into *standardization* of lake and reservoir sampling. The SPIN, SLIN, and FWIN approaches allow us to estimate lake trout walleye population size essentially real-time. These methods could prove very useful in the short-term because they are calibrated and standardized for lake and reservoir sampling. However, an initiative to standardize lake and reservoir fish community assessments is currently underway. The American Fisheries Society and the Ontario Ministry of Natural Resources is leading an effort to develop standardized “broad-scale” monitoring methods coupling large and small mesh gillnets to maintain comparability to other methods worldwide (Sandstrom et al. 2011). The large mesh nets have been proposed by the American Fisheries Society as a standard for freshwater species in North America (Bonar et al. 2009) while the small mesh nets are a new standard developed and suggested for use by Ontario researchers, because the combination of the two span a mesh size range that is similar to the Nordic design adopted in Europe (Appelberg 2000). This gear combination was proposed as an optimum compromise between North American and European standards and will be comparable to previous data. Currently, this “broad-scale” method is being calibrated for as many species as possible with a focus on North American freshwater species. If this method proves to be as beneficial and efficient as SPIN, SLIN, and FWIN, it may be wise to adopt this technique, so we have the ability to rely on, and compare our results to the large amount of data that will be collected by fisheries professionals in North America and elsewhere.

The American Fisheries Society and the Ontario Ministry of Natural Resources have initiated a respectable effort to standardize freshwater fish sampling while simultaneously considering comparability to data collected previously at the global level. Weighing the importance of maintaining old sampling techniques against the potential benefits of new approaches is crucial for making an appropriate decision about how to monitor a particular species or system. In light of this, below I have presented what I feel are the benefits, drawbacks and compromises of the SPIN method I experimented with this summer. As a final note, I chose to investigate the SPIN method because I felt I could obtain immediate (because this method is already calibrated) and applicable (because of the importance of Blue Mesa lake trout management) results. The other methods I have discussed above have the potential to provide similar benefits under the appropriate circumstances, so further exploration of these methods is likely going to be a future direction of the Lake and Reservoir Research Laboratory. The benefits and drawbacks of SPIN are listed below:

Benefits of SPIN:
1) Quantitative
2) Comparable to a growing global dataset
3) Relatively low effort (one week with two crews of three and two boats) and low intensity (less than 100 fish can be handled to obtain an estimate) with a versatile and interchangeable rope design
4) Summer sampling when interactions with lake trout anglers are at a minimum
5) Simple and real-time calculations
6) Excellent sources for support

Drawbacks of SPIN:
1) Often not comparable to historic sampling efforts
2) Species-specific (only calibrated for lake trout)
3) Nets are designed with thin monofilament which is susceptible to damage
4) A small window of opportunity for sampling (surface temperatures > 18° C) or warmest period of the summer
5) A "bailing can" is listed as required equipment for this technique

Compromises of SPIN:
1) Mortality (%) was relatively high, but a limited number of lake trout must be handled to obtain a population estimate
2) Numbers of small fish (< 300 mm) are difficult to estimate because of gillnet mesh size resulting in low detectability, however, this is a common problem with most gillnetting procedures, and SPIN methodology accounts for this discrepancy to some degree where other methods fail to do so

Acknowledgements:

I would like to extend my thanks to Dan Brauch and his crew at the Gunnison office. Without their efforts this project would not have been possible. I would also like to thank William Pate, Brett Johnson, Steve Sandstrom, Nigel Lester, C. Nathan Cathcart, Estevan Vigil and Michael Avery for project support, consultation, and efforts during sampling in the field.

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STUDY PLAN H: Using Otolith Weights for Age Interpretation of Kokanee Salmon *Oncorhynchus nerka*

Job H.1. Use otolith weights to develop a predictive model for age interpretation of kokanee salmon.

Objective:

The objective of this job is to evaluate the accuracy, speed and cost-effectiveness of using non-subjective otolith weights to determine kokanee salmon ages.

Introduction:

Estimating ages of individuals in fish populations is crucial for effectively managing sport fisheries. Determining growth rates of sport fish and their prey provides valuable information about the relative success of individuals and populations, and how they interact at the community level within a fishery. Fish ages can be determined using a variety of fish hard parts including otoliths (calcium carbonate structures in the skull), scales, fin rays, and cleithra. These structures produce annuli that can be used to determine fish age much like counting the rings of a tree. However, aging these structures is highly dependent on the interpreter's ability to discern annuli, adding subjectivity to determining fish ages. Currently, the most widely accepted approach for age determination in fish is using thin sectioned otoliths for interpretation. This method is considered to be the most accurate, but is labor-intensive, and requires the interpreter to determine age subjectively.

There is a large amount of effort focused on aging kokanee salmon, (*Oncorhynchus nerka*) in Colorado. The kokanee salmon (*Oncorhynchus nerka*) is one of the most sought after sport fish species in Colorado, (representing ~$30 million dollars in revenue annually) and they are also an important prey species for lake trout (*Salvelinus namaycush*) in many Colorado waterbodies. Thus, understanding their growth is an important aspect of fisheries management in Colorado. Previously, the vast majority of the aging work on kokanee salmon in Colorado has been done by surface aging of otoliths. This method eliminates the time-consuming procedures of embedding otoliths in resin, sectioning them with a diamond blade saw, polishing the thin sections and then imaging them using a compound microscope. Although surface aging is relatively rapid, it is subjective, dependent on the experience of the personnel interpreting the ages, is often inaccurate, and has been largely abandoned for these reasons.

There are several examples from the literature showing otolith mass increases with age, yet use of otolith weights to determine fish age is a relatively underutilized approach. The majority of the examples in the literature of using otolith weight to determine fish age have focused on economically important saltwater fishes. However, determining fish age using otolith weights is an attractive method because it requires relatively little training, is non-subjective, and is much faster when compared to other fish aging techniques.

Methods:

Briefly, otoliths were weighed as indicators of fish age. A machine learning approach (Random Forest) was used to incorporate otolith weight, fish length, fish sex, day of capture, year of capture and system of capture in a model to predict fish age. The model was calibrated with ages interpreted from a small subset of sectioned otoliths.

Results and Discussion:

One manuscript related to this job has been published in the peer reviewed scientific journal, Canadian Journal of Fisheries and Aquatic Sciences:

- **Lepak, J.M.**, Cathcart, C.N., and Hooten, M.B. 2012. Otolith weight as a predictor of age in kokanee salmon (*Oncorhynchus nerka*) from four Colorado reservoirs. Canadian Journal of Fisheries and Aquatic Sciences. 69(10):1569-1575

This manuscript describes the study with the following Abstract:

ABSTRACT: Estimating ages of individuals in fish populations is crucial for determining characteristics necessary to effectively manage sport fisheries. Currently, the most accepted approach for fish age determination is using thin sectioned otoliths for interpretation. This method is labor-intensive, requires extensive training, and subjectively determines age. Several studies have shown that otolith mass increases with age, yet use of otolith weights to determine fish age is relatively underutilized. However, determining fish age using otolith weight requires relatively little training, is relatively non-subjective, and is faster compared to other aging techniques. We collected kokanee salmon (*Oncorhynchus nerka*) in 2004 from four reservoirs, and from 2000 – 2009 in one reservoir, to evaluate the efficacy of using otolith weights to determine fish ages. We used a machine learning technique to predict kokanee salmon ages using otolith weight and various other covariates. Our findings suggest this method has potential to significantly reduce time and financial resources required to age fish. We conclude that using otolith weights to determine fish age may represent an efficient and accurate approach for some species.

TECHNICAL SUPPORT

Essentially all of my research is directly focused on answering questions related to lake and reservoir fisheries issues (e.g., management, community structure, angler satisfaction, etc.) posed by Senior Aquatic Staff and Area Biologists. It has been my responsibility to concentrate my efforts on addressing these issues and subsequently disseminating my findings to the relevant personnel. A large percentage of my time has been devoted to working together with biologists in the field to collect the samples required to characterize lake and reservoir food web structures and interactions within their fisheries. I have also been involved with University personnel advising two graduate level students and a research associate with projects focusing on various overlapping aspects of my research priorities developed by Senior Aquatic Staff and Area Biologists. The final step of the research process is to provide descriptions of the analysis and findings of my work. This includes providing biologists with management options or predictions of potential outcomes of system perturbations (natural and anthropogenic) and also general descriptions of how important processes are influencing lake and reservoir ecosystems. Thus, my efforts in the field and in the laboratory have been combined and communicated through reports, invited presentations and the preparation of manuscripts for publication. These materials were made available to Senior Aquatic Staff and Area Biologists as they are developed. Thus, effectively all of my time has been focused on providing technical support (in the form of help with field work and preparing and disseminating my research findings) for Senior Aquatic Staff and Area Biologists.

ADDITIONAL RESEARCH/COLLABORATION

The Jobs being conducted in the Lake and Reservoir Research Laboratory have resulted in internal collaborations as well as collaborations with several other Agencies/Institutions/Entities in the form of manuscript publishing and development and presentations. Currently Dr. Jesse Lepak is an affiliate faculty member at Colorado State University and is a member of two Graduate Student committees. Dr. Lepak is also supervising three Research Associates at Colorado State University. The outcomes of these collaborations are listed below:

1) Publication:

- **Lepak, J.M.**, Kraft, C.E., and Vanni, M.J. 2013. Clupeid response to stressors: the influence of environmental factors on thiaminase expression. Journal of Aquatic Animal Health. 25:90-97.

ABSTRACT: Over the past five decades, a reproductive failure related to thiamine deficiency, referred to as thiamine deficiency complex (TDC), has been observed in valuable salmonine fishes in the Great Lakes and Finger Lakes in North America and the Baltic Sea in Europe. The cause of TDC has been linked to the consumption of clupeid fish, which contain high levels of a thiamine-destroying enzyme called thiaminase I (hereafter referred to as thiaminase”). High activities of thiaminase have been reported from clupeids such as Alewife Alosa pseudoharengus, Gizzard Shad Dorosoma cepedianum and Atlantic (Baltic) Herring Clupea harengus, but no consistent explanation has accounted for the wide range of observed variation in levels of thiaminase in clupeids. Chronic stress can suppress the immune systems of Alewife and other fishes, thereby reducing the number of circulating white blood cells available to suppress bacteria. Because the presence of thiaminase has been associated with thiaminolytic bacteria isolated from Alewife viscera, we hypothesized that stressful conditions, which can potentially limit clupeid immune response or alter internal physiological conditions, could allow for thiaminase to be produced more efficiently by bacteria or thiaminolytic bacteria could proliferate, or both events could occur, resulting in a subsequent increase in thiaminolytic activity. In this study, Alewives and Gizzard Shad were exposed to severe winter temperatures and low food availability, respectively, in replicated pond experiments to evaluate the influence of stressful conditions on clupeid thiaminase activity. Though responses in circulating white blood cell counts and metrics of fish condition indicated that experimental treatments affected these clupeids, these effects were not related to increased thiaminase activity. The only significant treatment effect on clupeid thiaminase was an increase in mean thiaminase activity in Gizzard Shad from ponds where only high quality energy sources were available. These data indicate that variability in clupeid thiaminase may be related to diet composition.

2) Publication:

- Hargis, L.N., **Lepak, J.M.,** Vigil, E.M., and Gunn, C. 2013. Prevalence and intensity of the parasitic copepod (*Salmincola californiensis*) on kokanee salmon (*Oncorhynchus nerka*) in a Colorado reservoir. In Press: Southwestern Naturalist.

ABSTRACT: Copepods of the genus *Salmincola* (gill lice) parasitize salmonids. We collected kokanee salmon (*Oncorhynchus nerka*) from a Colorado reservoir to identify the species of gill lice present and investigate intensity and prevalence of infestations. We observed increasing intensity and prevalence with fish age. Our study adds to limited knowledge of *Salmincola* infestations in Colorado and the West.

3) Manuscript development:
In collaboration with Dr. Brett Johnson and William Pate at Colorado State University, a manuscript has been developed for submission to a peer reviewed scientific journal. This article focuses on the balance between kokanee and lake trout fisheries in Blue Mesa Reservoir and will be submitted for review in the near future.

4) Manuscript development:
In collaboration with Dr. Brett Johnson and Brian Wolff at Colorado State University, a manuscript has been developed for submission to a peer reviewed scientific journal. The article focuses on fisheries management strategies that could reduce mercury concentrations in sport fish and will be submitted in the near future.

5) Presentations:

External Presentations

- **Lepak, J.M.** Characterizing mercury in Colorado's Sport Fish. Front Range Community College. April 2013. Fort Collins, CO.

- **Lepak, J.M.,** Cathcart, C.N., and Stacy, W. Tiger muskellunge predation on stocked sportfish intended for recreational fisheries. CO-WY American Fisheries Society Meeting. February 2013. Fort Collins, CO (**Best Professional Paper; J. Lepak also received the award as CO-WY AFS Outstanding Mentor at this meeting**).

- Olsen, D., Johnson, B.M., and **Lepak, J.M.** The Arctic char (*Salvelinus alpinus*) of Dillon Reservoir, Colorado: an evaluation of their present status and future management possibilities. CO-WY American Fisheries Society Meeting. February 2013. Fort Collins, CO (**Best Student Paper;** D. Olsen presenter).

- Hargis, L., **Lepak, J.M.**, Vigil, E., **Gunn, C.** Prevalence and Intensity of the Parasitic Copepod (*Salmincola californiensis*) on Kokanee Salmon (*Oncorhynchus nerka*) in a Colorado reservoir. CO-WY American Fisheries Society Meeting. February 2013. Fort Collins, CO (**Best Professional Poster;** poster presented by E. Vigil).

- Marvin-DiPasquale, M., Eagles-Smith, C., Eckley, C., Evers, D., and **Lepak, J.M.** Western North American Mercury Synthesis. Delta Tributaries Mercury Council Meeting. February 2013. Sacramento, CA. (M. Marvin-DiPasquale presenter).

- **Lepak, J.M.** Information presented during the 32nd International Kokanee Salmon Workshop in Fort Collins, CO. Northern Water Conservancy District Meeting. February 2013. Berthoud, CO.

- **Lepak, J.M.**, Hargis, L., Vigil, E., and Gunn C. 32nd Experiences with Gill Lice in Colorado Kokanee Salmon populations. International Kokanee Salmon Workshop. February 2013. Fort Collins, CO. (**J. Lepak: meeting organizer**).

- Pate, W.M., Johnson, B.M., **Lepak, J.M.**, **and Brauch, D. Strategies** for multi-use recreational fisheries: coexistence of lake trout and kokanee in western waters. 32nd International Kokanee Salmon Workshop. February 2013. Fort Collins, CO. (W. Pate presenter).

- Hargis, L., **Lepak, J.M.**, Vigil, E., **Gunn, C.** Prevalence and Intensity of the Parasitic Copepod (*Salmincola californiensis*) on Kokanee Salmon (*Oncorhynchus nerka*) in a Colorado reservoir. 32nd International Kokanee Salmon Workshop. February 2013. Fort Collins, CO (poster presented by L. Hargis).

Internal Presentations

- **Lepak, J.M.** Kokanee Salmon Meeting 2013. Annual Colorado Parks and Wildlife Kokanee Salmon Meeting. February 2013. Fort Collins, CO.

- **Lepak, J.M.** Mercury in Colorado Fish: EAT FISH CHOOSE WISELY. District Wildlife Manager Meeting (in-service). April 2013. Pueblo, CO.

- **Lepak, J.M.** Mercury in Colorado Fish: EAT FISH CHOOSE WISELY. District Wildlife Manager Meeting (in-service). January 2013. Denver, CO.

- **Lepak, J.M.** Lake and Reservoir Research Update. Annual Colorado Parks and Wildlife Aquatic Biologist Meeting. January 2013. Steamboat Springs, CO.