Lake and Reservoir Food Web Ecology

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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.

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State: Colorado

Title: Lake and Reservoir Food Web Ecology

Period Covered: July 1, 2011 to June 30, 2012

Principal Investigator: Dr. Jesse M. Lepak

Study Objective: To identify problems facing lake and reservoir managers throughout Colorado with a focus on important sport fisheries; to identify lakes and reservoirs where research is needed to address these problems; to examine past research in Colorado and other areas related to the current problems facing Colorado lake and reservoir managers; to begin data collection to address research priorities in Colorado lakes and reservoirs.

STUDY PLAN A: IDENTIFY PROBLEMS FACING LAKE AND RESERVOIR MANAGERS THROUGHOUT COLORADO

Job A.1. Develop a priority list of fisheries problems with Colorado Parks & Wildlife Aquatic Senior Staff and Area Biologists

Objectives

The objective of this job was to develop a list of issues facing Colorado lake and reservoir fishery managers and to prioritize this list to best address the problems observed in the field by Senior Aquatic staff and Area Biologists.

Introduction

Colorado has a variety of highly managed waters with respect to fisheries, recreation and municipal uses. As such, this project was developed to evaluate the potential of various management strategies to influence/improve valuable sport fishing opportunities. Currently, sport fish managers are facing issues related to different fish stocking regimes, angling regulations, global climate change, introduced species, etc. It has become apparent to Colorado Division of Wildlife personnel that research is needed to address these and other dynamic issues in Colorado lakes and reservoirs as they develop and transform. Working with Senior Aquatic Staff and Area Biologists to develop a priority list of research topics is essential for structuring this project to best address issues relevant to fisheries managers. This job will ensure that research is appropriately focused on the most important fisheries issues facing Colorado managers.

Methods

A Progress Report was not requested for this Study in 2011 because it has been redefined (now Lake and Reservoir Food Web Ecology) and there was a new Principal Investigator (Dr. Jesse M. Lepak) assigned to the Study in October 2010. Thus, Job A.1. was completed in the previous Period. As a result, a research priority list has been developed, and a subset of this list will be selected and finalized as a focus for the next Study year. The approach for Job A.1. was to obtain input and feedback from Senior and Area Aquatic Biologists and develop a research priority list for both the East and West Slopes in Colorado.

Results and Discussion

On November 3rd, 2010 in Colorado Springs, Colorado, a meeting was held with several Aquatic Biologists. Both Senior Aquatic Biologists on the East Slope (Doug Krieger and Ken Kehmeier) and five other aquatic biologists were present. At this meeting every Biologist had the opportunity voice their opinion on research concerns in their waterbodies and others. Every Biologist that wasn’t present was provided the opportunity to voice concerns via phone or email. Eighteen individual research priorities were determined during the meeting and through email and phone conversations.

On December 1st, 2010 in Grand Junction, Colorado, a meeting was held with several Aquatic Biologists. Both Senior Aquatic Biologists on the West Slope (John Alves and Sherm Hebein) and eight other aquatic biologists were present. At this meeting every Biologist had the opportunity voice their opinion on research concerns in their waterbodies and others. Every Biologist that wasn’t present was provided the opportunity to voice concerns via phone or email. Similar to the East Slope meeting, eighteen individual research priorities were determined during the meeting and through email and phone conversations.

A prioritized research list was completed on April 15th, 2011 (Table 1.). All Senior Aquatic Biologists provided input on the final priority list of research topics. It is important to note that the order in which the topics will be addressed may not follow their priority ranking due to feasibility, opportunity and research value. The rankings were based on Biologist input, however, a subset of these topics will be selected to address in upcoming Study years based on feasibility, opportunity and research value.

Table 1. Research priority list developed for the East and West Slopes in Colorado.

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)

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	Zoolpankton/mysis density and composition quantification
17	Basic limnology, draw from CDPHE and do our own
18	How do we eliminate mysis

STUDY PLAN B: IDENTIFY LAKES AND RESERVOIRS WHERE RESEARCH IS NEEDED TO ADDRESS PROBLEMS FACING LAKE AND RESERVOIR MANAGERS THROUGHOUT COLORADO

Job B.1. Develop a priority list of study systems with Colorado Parks & Wildlife Aquatic Senior Staff and Area Biologists

Objectives

The objective of this job was to develop a list of study systems that can provide the most information about each of the problems facing Colorado lake and reservoir fishery managers.

Introduction

Lakes and reservoirs throughout Colorado have varying characteristics with respect to morphology, nutrient loading, fish community structure, elevation, etc. As such, these characteristics must be considered when lakes and reservoirs are selected as study systems in order to maximize their potential to fully address individual and possibly multiple research questions. Selecting appropriate study systems was essential to adequately address the research priorities designated by Senior Aquatic Staff and Area Biologists. If selected carefully, study systems will help address multiple research objectives and reduce the amount of time, travel and effort required to adequately investigate research priorities. This job will ensure that research is conducted efficiently and sampling effort provides the highest amount of information for the highest number of research priorities possible.

Methods

Consultations with Senior Aquatic Staff and Area Biologists were conducted from October 2010 to the present to determine potential study system candidates. Based on these consultations and the amount of information available on candidate systems from previous studies, lakes and reservoirs which have the highest potential to address fishery problems were selected as study systems.

Results and Discussion

A set of lakes and reservoirs have been identified that will help address at least 5 research priorities from the East and West Slope Biologists:

1) Tiger muskellunge and brown trout as sucker control agents: Big Creek, Clear Creek, De Weese, Parvin and Pinewood reservoirs
2) Investigating/altering edible zooplankton composition: Blue Mesa, Carter, Dillon, Eleven Mile, Granby, Horsetooth, McPhee, Taylor Park and Vallecito reservoirs
3) Sucker impacts on trout and other species: Big Creek, Clear Creek, De Weese, Dillon, Lake John, North Delaney, Parvin, Pinewood and South Delaney reservoirs

4) SONAR/KOK egg take prediction and population estimates: Blue Mesa, Carter, Cheesman, Dillon, Elevenmile, Horsetooth, Granby, Green Mountain, McPhee, Vallecito, Williams Fork and Wolford Mountain reservoirs
5) Standardizing sampling methods: Blue Mesa Reservoir
6) Simplify KOK (etc) aging (weighing otoliths and sectioning to confirm): Blue Mesa, Granby, Shadow Mountain and Williams Fork reservoirs
7) Zooplankton/mysis density and composition quantification: Blue Mesa, Carter, Dillon, Eleven Mile, Granby, Horsetooth, McPhee, Taylor Park and Vallecito reservoirs

Other research is also taking place at the Research Hatchery (Bellvue, CO). This research is related to oxytetracycline as a fish marking technique for walleye and wiper. Other systems may be added to this list as research develops and more data is gathered in the coming years.

STUDY PLAN C: EXAMINE PAST RESEARCH IN COLORADO AND OTHER AREAS RELATED TO THE CURRENT PROBLEMS FACING COLORADO LAKE AND RESERVOIR MANAGERS

Job C.1. Examine previous research

Objectives

The objective of this job is to evaluate previous research efforts addressing similar fisheries management obstacles facing Colorado Senior Aquatic Staff and Area Biologists.

Introduction

A wide variety of research has been conducted to address fisheries management problems. Once research topics were identified and prioritized, it was necessary to determine what research has already been conducted to address these specific topics. Evaluating previous research is a vital component of the scientific process in all cases. Duplicating or ignoring previous research is counterproductive to scientific progress. Understanding how others have addressed research questions similar to those designated as priorities by Colorado Senior Aquatic Staff and Area Biologists will help in the appropriate design and focus of future experiments and research in Colorado lakes and reservoirs.

Methods

Essentially this Job required reviewing literature related to the research topics described by the Senior and Area Aquatic Biologists. Biologists were consulted and joined during their sampling efforts to understand their perspectives on these issues and the data being collected. For the topics that are likely to be addressed, short summaries were developed describing these issues, and when necessary, relevant previous research done to address these issues. These summaries are presented here.

Results and Discussion

Summaries:

Addressing Walleye Fry Versus Fingerling Stocking Success and Walleye Versus Wiper Stocking Density Balance

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. Various Biologists were interested in 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. Selecting an appropriate fish marking technique is essential to assess walleye fry versus fingerling success after stocking, wiper stocking success, and balancing walleye and wiper stocking in systems in an effort to support sympatric populations.

Tiger Muskellunge and Brown Trout as Sucker Control Agents

Suppression of undesirable fish species that negatively influence preferred species is common (e.g., Hayes et al. 1992; Ruzycki et al. 2003; Weidel et al. 2007). 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 (Barton and Bidgood 1979), and decreased growth rates of stocked rainbow trout in the presence of suckers have been observed (Bidgood and Barton 1982). Reduced rainbow trout survival has been attributed to reductions in available benthos following the introduction of white suckers (Alexander 1975a, 1975b), and rainbow trout yield has been shown to decrease in systems where white suckers have been introduced (Barton 1980). Additionally, white sucker introduction or colonization has resulted in changes in the spatial distribution and/or feeding habits of brook trout in response to increased interspecific competition for resources (Magnan 1988; Lachance and Magnan 1990; Tremblay and Magnan 1991; Lacasse and Magnan 1992). These niche shifts were correlated to significant decreases in mean annual brook trout yield, relative abundance, and biomass (Magnan 1988; Lachance and Magnan 1990). Furthermore, the extent of resource partitioning has been related to white sucker density (Bourke et al. 1999). This type of information, combined with anecdotal evidence, has made white sucker control a common management practice in systems where they are common while salmonid species are desired by anglers.

Removals of white suckers have been conducted across the United States and Canada. Mass mechanical removal of white suckers was evaluated by Brodeur et al. (2001) in five temperate lakes in Quebec. These authors demonstrated that removals may induce compensatory responses in white suckers (e.g., increased individual growth rates, decreased age at maturity, increased mean adjusted fecundity). Results from this study indicate that these compensatory responses were related to the intensity of the removal effort; the more intense the removal, the more intense the response (Brodeur et al. 2001). Further, the compensatory responses observed for white suckers occurred more rapidly than any population gains observed for brook trout present within the five study systems. Thus, if suppression of white suckers is considered as a management strategy, the responses described by Brodeur et al. (2001) 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 (Kerr and Lasenby 2001) and have been widely introduced (Wingate 1986). Tiger muskellunge have been stocked in lakes and reservoirs in Colorado, Idaho, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Mexico, New York, Ohio, Pennsylvania, Washington, West Virginia, and Wisconsin (Kutcha 2004). 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.

Quantifying Zooplankton (Community Structure and Density) and Mysis (Density) Populations

Some species of zooplankton represent the base of food webs in a variety of lakes and reservoirs. Edible zooplankton are essential to many larval, juvenile and even adult sport fish species. Further, *Mysis diluviana*, or freshwater opossum shrimp, are a competitor of these fish species for zooplankton as forage. Specifically, kokanee salmon (*Oncorhynchus nerka*), economically important sport fish species in Colorado, (representing ~$30 million dollars in revenue annually) are highly dependent upon zooplankton (particularly large *Daphnia* species) as forage. Understanding the interactions between Mysis and zooplankton is crucial to determine the potential of a given system to support sport fish that rely on these species as prey.

Investigating Sucker Impacts on Rainbow Trout

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 (Barton and Bidgood 1979), and decreased growth rates of stocked rainbow trout in the presence of suckers have been observed (Bidgood and Barton 1982). Reduced rainbow trout survival has been attributed to reductions in available benthos following the introduction of white suckers (Alexander 1975a, 1975b), and rainbow trout yield has been shown to decrease in systems where white suckers have been introduced (Barton 1980). Additionally, white sucker introduction or colonization has resulted in changes in the spatial distribution and/or feeding habits of brook trout in response to increased interspecific competition for resources (Magnan 1988; Lachance and Magnan 1990; Tremblay and Magnan 1991; Lacasse and Magnan 1992). These niche shifts were correlated to significant decreases in mean annual brook trout yield, relative abundance, and biomass (Magnan 1988; Lachance and Magnan 1990). Furthermore, the extent of resource partitioning has been related to white sucker density (Bourke et al. 1999).

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.

Routine Kokanee Population Assessments and Improvement of SONAR Methodology for Estimating Fish Abundance

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 these surveys will continue 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, SONAR can be refined, and it is possible to adapt its capabilities to better suit the 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.

Standardizing Gillnetting Techniques

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. 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.

The American Fisheries Society and the Ontario Ministry of Natural Resources is leading an effort to develop standardized gillnetting techniques across North America that will be comparable to previous data collected there and throughout Europe. This type of approach could aid in the development and assessment of management goals in a variety of Colorado waters depending on the need. Specifically, they have developed a technique known as SPIN (summer profundal index netting) for lake trout (*Salvelinus namaycush*) populations. This quantitative gillnet sampling method could provide "instantaneous" lake trout population estimates comparable to other systems across North America. The power of this particular method is the use of data from hundreds of systems as a calibration tool to quantify 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.

In addition, 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 (*Sander vitreus*) index netting (FWIN) which focuses on walleye population estimation. Finally, 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. These techniques will be explored as standardized gillnetting methods in Colorado.

Using Otolith Weights for Age Determination of Kokanee Salmon

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 (Francis and Campana 2004). 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 (Johnson and Martinez 2000; Martinez et al. 2009). 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 (Worthington et al. 1995; Francis and Campana 2004), yet use of otolith weights to determine fish age is a relatively underutilized approach. The majority of examples in the literature of using otolith weight to determine fish age have focused on economically important saltwater fishes (Worthington et al 1995; Vallisneri et al. 2008). 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 (Worthington et al. 1995; Steward et al. 2009).

Using otolith weights to determine kokanee salmon will greatly reduce the man-hours spent training personnel and embedding, sectioning and imaging otoliths for age interpretation. It should also decrease the amount of subjectivity and inaccuracy of aging fish by otolith surface analysis. Typically, for fish aging that relies on sectioned otoliths, the process of embedding takes 24 h and then sectioning, polishing, and imaging requires an additional 5-15 min per otolith. Then, multiple interpreters are required to agree on the age of the fish. The surface aging method is less labor-intensive, but is not considered as accurate, requires multiple interpreters, and relies on interpreter subjectivity as well. Using otolith weights (calibrated using a subset of sectioned otoliths) removes subjectivity from fish aging entirely and an untrained technician can "age" approximately 300-350 fish in one, 8 h day (using mean weights of 600-700 otoliths). This relatively rapid method of aging fish could provide managers with nearly “real-time” assessments of individual fish ages and population age structure. These data would assist Senior Aquatic Staff and Area Biologists in deciding which management actions are appropriate and timely with respect to kokanee population age structure, harvest regulations and spawning operations. Finally, this method might prove useful for aging other freshwater species in Colorado. Thus, the utility of using kokanee salmon otolith weights as a non-subjective and rapid method for determining kokanee age will be investigated.

STUDY PLAN D: BEGIN DATA COLLECTION TO ADDRESS RESEARCH PRIORITIES DESIGNATED BY COLORADO PARKS & WILDLIFE SENIOR AQUATIC STAFF AND AREA BIOLOGISTS

Job D.1. Data Collection

Objectives

The objective of this job is to initiate data and sample collection pertinent to addressing research priorities designated by Colorado Parks & Wildlife Senior Aquatic Staff and Area Biologists.

Introduction

Colorado Aquatic Area Biologists conduct routine sampling efforts and these have continued simultaneously with the overall project described here. To maximize the usefulness of these efforts, pertinent data and samples were compiled by the Principal Investigator as deemed necessary to address various research priorities.

Methods

The methods for this job vary depending on the particular effort. Data collection has started on several research priorities. These collections are incomplete, and work will continue into the feature. With the data already collected, reports are being prepared based on what has been observed thus far. When data collection and analyses are complete, and these reports are finalized they will be included in future Progress Reports. Coincident with preliminary data collection, previous collaborations related to Research Priorities were finalized. Historic SONAR surveys were also conducted. The results of these efforts are described below.

Results and Discussion

Previous work conducted by the Principal Investigator was highly applicable to several of the Jobs described here, and these efforts were finalized in the form of peer reviewed manuscripts during this reporting period (submitted previously). These efforts, continued collaboration, and new efforts initiated by the Principal Investigator are described below.

A large collaborative effort examining northern pike predation on rainbow trout and the subsequent changes in mercury concentrations of northern pike (related to Research Priorities 4, 5, and 8 – East Slope and 2 and 5 – West Slope) was completed and published.

ABSTRACT:
Altering food web structure has been shown to influence mercury (Hg) concentrations in sport fish. Here, we describe a whole-system manipulation designed to assess the effectiveness of stocking relatively high quality, low Hg prey (rainbow trout, *Oncorhynchus mykiss*), as means of increasing northern pike (*Esox lucius*) growth to reduce Hg concentrations. A replicated pond experiment served as a reference for the lake experiment, and provided information to parameterize bioenergetics simulations. Results indicate that stocking relatively high quality, low Hg prey is a rapid and effective method to reduce sport fish Hg concentrations by up to 50% through an increase in individual northern pike biomass. Large northern pike, those fish that tend to be the most contaminated, were affected most by the manipulation. The observed declines in northern pike Hg concentrations indicate that stocking might be used to reduce Hg concentrations in sport fish prior to harvest. However, after one year, northern pike Hg concentrations rebounded, suggesting that reductions would be temporary without continuous stocking. Thus, perhaps the most effective method of perpetually reducing sport fish Hg concentrations would be to manage for the development of a naturally reproducing forage fish population with relatively high energy content and low Hg concentrations.

For the full manuscript see:
Lepak, J.M., Kinzli, K.D., Fetherman, E.R., Pate, W.M., Hansen, A.G., Gardunio, E.I., Cathcart, C.N., Stacy, W.L., Underwood, Z.E., Brandt, M.M., Myrick, C.M., and Johnson, B.M. 2012. Manipulation of growth to reduce sport fish mercury concentrations on a whole-lake scale. Canadian Journal of Fisheries and Aquatic Sciences. 69:122-135.

A manuscript related to the collaborative project listed above was also completed and published.

ABSTRACT:
The American Fisheries Society (AFS) student subunits have the potential to train fisheries biologists and to benefit participating faculty as well. In order for this potential to be realized, subunit student and faculty members must demonstrate strong leadership and enthusiasm to encourage and maintain the participation of those around them. Collaboration between student subunit members and fisheries professionals contributes to the core AFS mission of “advancing fisheries and aquatic science and promoting the development of fisheries professionals.” Here we describe how a recent collaboration between the Colorado State University (CSU) subunit and natural resource management agencies from the state of Colorado is helping meet the AFS mission. With the guidance of CSU faculty and the determination of the subunit officers, the research project

facilitated student involvement and professional collaboration that resulted in multiple oral and poster presentations and the development of a manuscript currently in review for a peer reviewed journal.

For the full manuscript see:
Pate, W.M., Stacy, W.L., Gardunio, E.I., and **Lepak, J.M.** 2011. Collaborative research between current and future fisheries professionals: facilitating AFS subunit participation. Fisheries. 36(9):458-460.

A previous collaboration with Cornell University personnel resulted in the publication of a manuscript related to rainbow trout performance in food limited environments (related to Research Priority 11 – East Slope and 6 – West Slope) that is applicable to management in Colorado.

ABSTRACT:
We evaluated performance of rainbow trout in food-limited lake and hatchery environments using whole-body water content as a proxy for fish energy reserves and lipid content. Relative abundance of rainbow trout stocked in an oligotrophic lake from 2002 – 2006 decreased by 88% in 145 days. Whole-body water content of rainbow trout increased following stocking in the lake, and similar increases in water content were observed in fish from a food-deprived hatchery treatment. Water content in the fed hatchery fish was significantly lower than water content observed in stocked lake fish. Traditional metrics of body condition (i.e., Fulton's K and relative weight) based on length-weight relationships were insufficient to detect observed changes in whole body water content for all lake and hatchery treatments. We conclude that depletion of energy reserves contributed to poor survival and low angling returns of stocked rainbow trout in the study lake.

For the full manuscript see:
Josephson, D.C., Robinson, J.M., **Lepak, J.M.**, and Kraft, C.E. 2012. Rainbow trout performance in food-limited environments: Implications for future assessment and management. Journal of Freshwater Ecology. 27:159-170.

A previous collaboration with Colorado State University personnel resulted in the publication of a manuscript related to sportfish mercury concentrations and walleye food web dynamics (related to Research Priorities 4 and 8 – East Slope and 5 – West Slope) conducted in Colorado reservoirs.

ABSTRACT:
Mercury (Hg) contamination in sport fish is a global problem. In freshwater systems, food web structure, sport fish sex, size, diet and growth rates influence Hg bioaccumulation. Fish stocking is a common management practice worldwide that can introduce external energy and contaminants into freshwater systems. Thus, stocking can alter many of the factors that influence Hg concentrations in sport fish. Here we

evaluated the influence of external subsidies, in the form of hatchery-raised rainbow trout *Oncorhynchus mykiss* on walleye *Sander vitreus* diet, growth and Hg concentrations in two freshwater systems. Stocking differentially influenced male and female walleye diets and growth, producing a counterintuitive size-contamination relationship. Modeling indicated that walleye growth rate and diet were important explanatory variables when predicting Hg concentrations. Thus, hatchery contributions to freshwater systems in the form of energy and contaminants can influence diet, growth and Hg concentrations in sport fish. Given the extensive scale of fish stocking, and the known health risks associated with Hg contamination, this represents a significant issue for managers monitoring and manipulating freshwater food web structures, and policy makers attempting to develop fish consumption advisories to protect human health in stocked systems.

For the full manuscript see:
Lepak, J.M., Hooten, M.B., and Johnson, B.M. The influence of external subsidies on diet, growth and Hg concentrations of freshwater sportfish: implications for management and fish consumption advisories. Available Online: Ecotoxicology. DOI 10.1007/s10646-012-0921-4.

A new collaboration with Colorado Parks and Wildlife Research Scientist Eric Fetherman resulted in the preparation and submission of a manuscript dealing with fish population size estimation.

ABSTRACT:
Removal abundance estimation methods are commonly used, especially in fisheries, when removal proves to be more feasible than a capture-mark-recapture estimation approach. However, if depletion of the population is not realized, removal estimation is not possible. We describe a method for accurately estimating detection probabilities when population size is known or can be estimated, and calculating true detection probabilities of removal gear or techniques used to conduct removal estimates. The number of individuals not captured during removal, f_0, is used to fix the abundance parameter, N, in traditional closed capture-recapture models to back-calculate detection probability, p. The recapture parameter, c, is fixed to zero in all models as animals are not available for recapture in removal studies. We present two examples where the back-calculation method was used to 1) estimate detection probabilities following removal failure; and, 2) estimate true detection probability of removal gear and deployment techniques. Other possible uses of this technique include microcosm studies in which abundance estimates are needed to estimate survival over time but are difficult to obtain, or obtaining detection probabilities for a given organism in a given habitat at the microcosm level, which can then be applied at larger scales.

Submission details:
Fetherman, E.R., and **Lepak, J.M.** Back-calculation of capture probability and estimating gear efficiency using known population abundances. Submitted March 13th 2012: North American Journal of Fisheries Management.

A new collaboration with a technician at Colorado Parks and Wildlife in the Lake and Reservoir Laboratory resulted in the preparation, submission, and acceptance of a manuscript on walleye mercury contamination and bioenergetics (related to Research Priorities 4 and 8 – East Slope and 5 – West Slope) conducted in Colorado reservoirs.

ABSTRACT:
Mercury (Hg) bioaccumulation in aquatic food webs has created a human health concern for anglers who consume fish. Variability in sport fish Hg concentration adds to the uncertainty of the amount of fish an angler can safely consume, so predicting where variability arises is useful. We evaluated the relative influence of diet (prey Hg concentration and energy density) and sex on sport fish Hg concentrations using a bioenergetics approach. Our results indicated that sport fish diets (prey Hg concentration followed by energy density) were the most important factors for determining sport fish Hg concentration followed by sex. Although physiological and behavioral differences based on sex may lead to differences in gross growth efficiency, resulting in different Hg concentrations in male and female sport fish, evaluating the relative importance of these differences will require sex-specific parameterization of bioenergetics models. Our results support previous findings that knowledge of sport fish diets (prey Hg concentration followed by energy density) and sex could aid in the prediction of sport fish Hg concentrations. Thus, basic knowledge of system-specific food web structure could provide valuable information for developing sport fish consumption advisories to better protect anglers and their families from Hg contamination.

Submission details:
Stacy, W.L., and **Lepak, J.M.** Relative Influence of Prey Mercury Concentration, Prey Energy Density and Predator Sex on Sport Fish Mercury Concentrations. In Press: Science of the Total Environment.

Historic SONAR surveys were conducted in several Colorado reservoirs (related to Research Priority 1 – East Slope) and resulted in the preparation and dissemination of an annual SONAR survey report prepared by Research Associate (Colorado Parks and Wildlife and Colorado State University) Michael Avery in collaboration with Dr. Jesse M. Lepak (see the Colorado Parks and Wildlife Aquatic Research website; URL: http://wildlife.state.co.us/Research/Aquatic/Publications/Pages/Publications.aspx or http://wildlife.state.co.us/Research/Aquatic/LakesandReservoirs/Pages/LakesAndReservoirs.aspx).

Several presentations were also made as a result of these efforts and collaborations:

1) **Lepak, J.M.** February 2011. Manipulation of sport fish growth to reduce mercury bioaccumulation on a whole-lake scale. Colorado-Wyoming American Fisheries Society Meeting, Fort Collins, CO. (Best Professional Paper Award)

2) Stacy, W., and **Lepak, J.M.** January 2011. Relative importance of growth, prey energy density and prey mercury content in determining walleye mercury concentrations. Midwest American Fisheries Society Meeting, Brookings, SD. (W. Stacy presenter)

3) **Lepak, J.M.** June 2011. Zooplankton from a Fisheries and Mercury Perspective. Colorado Lake and Reservoir Management Association Summer Zooplankton Workshop, Denver, CO. (Invited Presenter/Instructor)

4) **Lepak, J.M.** September 2011. Manipulation of sport fish growth to reduce mercury bioaccumulation on a whole-lake scale. National American Fisheries Society Meeting, Seattle, WA.

5) **Lepak, J.M.** March 2012. Otolith weight as a predictor of age in kokanee salmon (*Oncorhynchus nerka*). Western Division American Fisheries Society Meeting, Jackson, WY.

6) Pate, W.M., and **Lepak, J.M.** March 2012. Boom-and-bust lake trout-kokanee fisheries: turning runaway consumption into sustainable fisheries for both species. Western Division American Fisheries Society Meeting, Jackson, WY. (W. Pate presenter)

7) **Lepak, J.M.** January 2012. Progress on Lake and Reservoir Research Priorities. Annual CPW Biologist Meeting, Fort Collins, CO.

8) **Lepak, J.M.** February 2012. Progress on Kokanee Salmon Research. Annual CPW Kokanee Salmon Meeting, Buena Vista, CO.

STUDY PLAN E: PREPARE A DETAILED FIVE-YEAR PROJECT STATEMENT

Job E.1. Prepare a detailed five-year Project Statement

<u>Objectives</u>

The objective of this job was to incorporate knowledge gained in the first year of this project to develop an appropriate five-year project statement. This will guide research efforts from July 1, 2012 to June 30, 2017.

<u>Introduction, Methods and Results</u>

A great deal was learned, observed and discussed with Colorado Parks and Wildlife Senior Aquatic Staff and Area Biologists during the first year of this project with Colorado Parks and Wildlife. Based on what has been learned, a 5-year Project Statement has been prepared. This document was submitted to the Federal Aid Coordinator in spring, 2012.

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