

Moses Lake Fishery Restoration Project

**Annual Report
2000 - 2001**



DOE/BP-00006320-3

February 2003

This Document should be cited as follows:

Burgess, Dave, "Moses Lake Fishery Restoration Project", Project No. 1995-02800, 55 electronic pages, (BPA Report DOE/BP-00006320-3)

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

Factors Affecting the Recreational Fishery in Moses Lake, Washington

**Formerly, The Moses Lake Fishery Restoration Project
Project Number: 199502800
Contract: 00006320**

FY 2001 Annual Report

Prepared for Submission to the Bonneville Power Administration

Acknowledgments

We would first like to thank the Bonneville Power Administration (BPA) for funding the Moses Lake Project (DOE/BP-00006320-3). We also thank our BPA appointed contracts officer Ron Morinaka for all the effort he has put forth. Office and logistical support was provided by WDFW region 2 staff Kathy Ballinger the region 2 office manager and Wendy Bilodeau the region 2 customer service representative. Other WDFW Regional staff that offered assistance during this reporting period included, Joe Foster, Dennis Beach and Richard Smith. The collection of data would not have been possible if not for the efforts of WDFW field employees Bruce Bolding, William Meyer, Steve Caromile, Marc Divens, Marc Peterson, Randy Osborne, Larry Philips. Chris Donely who was the original project lead provided support during the transition period of his departure from the project.

With respect to technical support, members of the Lake Roosevelt project, Casey Baldwin and Matt Polacek were of great value. Once again members of the community such as Ron Sawyer and the Columbia Basin Walleye Club offered both time and logistical support during this reporting period. Jim Lemieux of The Kalispel Tribe also lent assistance in the form of GIS generated maps used in the annual report as well as coordinates for sampling regimes. We thank Eastern Washington University for the technical support and identification of zooplankton samples. A huge contributor to the continuation and success of this project has been Dr. David Bennett of the University of Idaho. His guidance and expertise is much appreciated and we look forward to working with him in the future. Finally, we would like to acknowledge Central Washington University and more specifically the Department of Biological Sciences Dr. David Hosford and Professor Dr. Paul James for providing us the facilities to conduct laboratory analysis. Once again we would like to thank everyone for their efforts and assistance during all stages of this project.

Moses Lake Project Staff

Dave Burgess
Tammy Vilante
Katrina Anderson

Moses Lake Project Support Staff

Jeff Korth, WDFW district biologist / BPA contact
Dr. David Bennett, University of Idaho, Advisor

Table of Contents

List of Tables.....	4
List of Figures.....	5
Introduction.....	6
Methods	
Original Scope of Work.....	6
Revised Scope of Work.....	16
Results	
Original Scope of Work.....	22
Revised Scope of Work.....	27
References.....	30
Appendices	
Appendix 1.....	33
Appendix 2.....	38

List of Tables

Table 1. Concentrations of chlorophyll a collected from multiple sites.....	23
Table 2. Percent of volume of zooplankton during each sample session.....	23
Table 3. Mean size in millimeters (mm) of zooplankton.....	24
Table 4. During the creel survey conducted on Moses Lake	25

List of Figures

Figure 1. Map of Moses Lake.....	7
----------------------------------	---

Introduction

The Moses Lake Project (project # 199502800) was first funded by Bonneville Power Administration during the FY 99. Work commenced and proceeded through September 2001 when questions arose on the Scope of Work. Due to funding issues at the beginning of FY 2001 we were unable to secure monies to continue with our proposed scope of work.

Consequently, the Moses Lake Project was reduced to one full-time employee. An extension of fifty thousand dollars was granted in which the project with one remaining member by October 2001 continued to operate. By December 2001 the NWPPC granted an additional 20K in spending to secure an advisor that could assist in providing a proposal that the ISRP would find amenable. By Jan 2002, the Moses Lake staff put Dr. David Bennett, from the University of Idaho on payroll. With the guidance of Dr. Bennett the Moses Lake project staff was successful in turning in a new version of the proposal and ultimately received funding by July of 2002. Consequently, the lack of manpower and time spent revising and resubmitting said proposal hampered progress.

Consequently, this report covers work conducted on the original Scope of Work (SOW) to July 2002 and then follows the new and accepted SOW from July 2002 through September 2002. Work on the tasks within the newest proposal began prior to official acceptance so as not to lose the window of opportunity to collect data during the summer field season. As of July 2000 we moved forward and began the appropriate tasks outlined in our scope of work. Therefore, portions of the FY 2001 annual report address tasks outlined in the original (appendix 1, original FY2000 SOW) and newest scope(s) of work (Appendix 2, new FY 2000 SOW).

Methods: Original SOW

Objective 1: Implementation of study design.

Task 1.1: Fish diet study

Monthly surveys for fish diet samples were conducted on Moses Lake starting in October of 2000 until January 2002. Fish were collected during daylight and night hours using boat electrofishing, gill netting and angling. Using multiple gear types minimizes gear sampling bias and allows for the collection of multiple species and size classes of fish. Fish were sampled from randomly selected areas within each of the four lake sections (Figure 1).

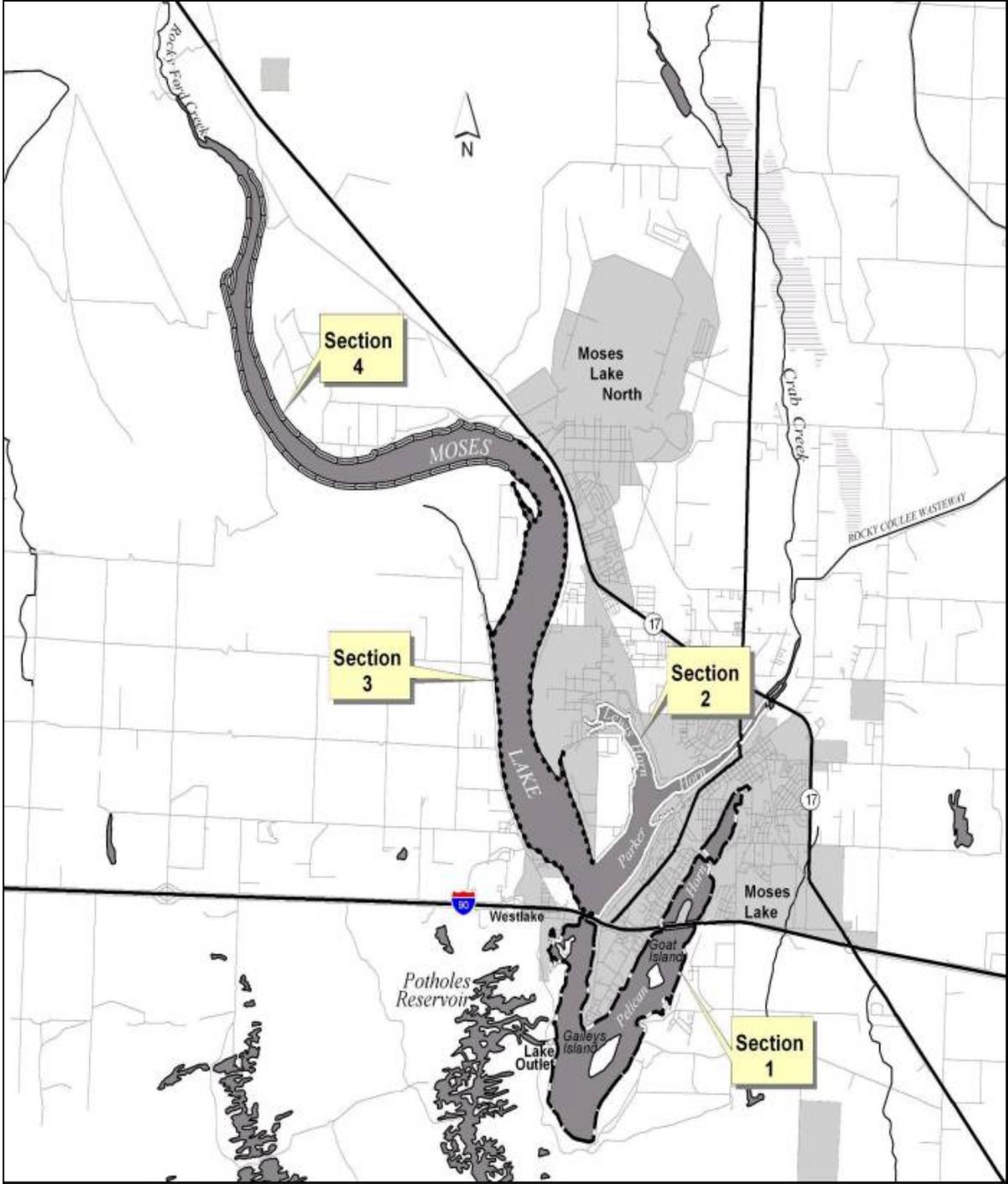


Figure 1. Map of Moses Lake designating sections 1-4.

Three individuals for each age group, young of year, juvenile and adult were collected from each of the four Moses Lake sections. For each species a total of 36 individuals were sampled monthly within Moses Lake for night and day samples. A total of 72 fish were sampled each month from the species of interest (walleye, black crappie, bluegill yellow perch, smallmouth bass, largemouth bass and rainbow trout. All other fish will be secondary species of interest. The sample size for secondary species did exceed a maximum of 20 individual fish sampled per month.

Stomach contents will be collected via gastric lavage methods. Upon capture, a fish's stomach will be pumped using a modified handheld pesticide sprayer with an elongated hose that is inserted into the stomach orally. Once in place water pressure will be pumped into the subject fish emptying the contents into a tray. The fish will then be released and the contents preserved in 95% alcohol to be identified at a later date. The method of gastric evacuation (GR) has been used successfully on a variety of sizes and species of fish (Singh-Renton and Bromley 1996; Ruggerone 1989; Brown 1995; Hartleb and Moring 1995). It is important that stomach contents are removed rapidly from captured fish as soon as possible to prevent the loss of food items via digestion or regurgitation due to increased stress levels. Therefore, gill nets will need to be checked hourly, fish removed and contents preserved.

Stomach contents will be identified to order for macroinvertebrates, order for zooplankton and to species for fish whenever possible. Zooplankton and macroinvertebrate size and wet weight will be measured, for each individual, from each order detected in the sample. Contents will be identified using Pennack's key, freshwater invertebrates of the United States (1989) for invertebrates and Wydoski and Whitney's Inland Fishes of Washington Key for fish (1979) as well as a WDFW generated bone key.

With the stomach contents of individual fish collected and identified, further determination of the percentage of food items for each individual species will be compiled. This could be achieved using percentage method (Marreo and Lopez-Rojas 1995). Further analysis will include parametric tests, such as the *t* and ANOVA. Tests will be conducted to determine differences between species and monthly changes within species. A correlation between the zooplankton

and macroinvertebrate data and diet data will be performed. Some studies point to a positive correlation between zooplankton abundance and fish diets (Bremigan and Stein 1994), other studies do not (Westerlund et al. 1998). This data will be incorporated into the bioenergetics model to determine total consumption of prey items in Moses Lake.

Subtask 1.1.1: During the duration of the Moses Lake project scales were collected to determine age and expected growth rates of fishes. However, concern regarding the accuracy of scales has resulted in the collection of otoliths as a primary indicator of age.

Task 1.2: Zooplankton samples were collected from 12 pelagic sites distributed throughout Moses Lake using a Clarke-Bumpus plankton sampler. Vertical plankton tows were conducted from substrate to surface. Sampling the entire water column will reduce the probability of missing zooplankton that migrate vertically (De Stasio 1993).

To calculate the number of zooplankton for a given volume of water passed through the sampling device, the volume of water sampled will be calculated using the following formula:

$$V=D*A$$

Where D is the distance traveled, and A is the area of the opening of the sampling device.

The total density of zooplankton (D_z) will be calculated using the following equation:

$$D_z=n/V$$

Where n is the number of zooplankton and V is the volume of water sampled.

At the end of each tow, zooplankton samples were preserved in Lugol's solution and held in whirl packs to be processed at a later date.. Zooplankton samples will be processed at EWU by a contracted limnologist to determine species composition, density, and estimated biomass.

Monitoring the zooplankton abundance on a monthly basis will allow for temporal analysis. Analysis of these data will include a Chi square to test whether or not a change in abundance is significant. An analysis of variance (ANOVA) will be used to investigate whether significant differences exist in the abundance of the various genera sampled during each season. These data will be incorporated into the bioenergetics model to determine total consumption of prey items in Moses Lake.

Task 1.3: Moses Lake is 6,800 acres and has multiple accesses, which hinders an absolute creel survey (Bain 1987). Hence it is neither economically nor logistically feasible to strictly adhere to either a roving or access point creel design. An access point creel survey requires a clerk to remain at an access and interview anglers as they leave (Hayne 1991). Due to the multiple access sites on Moses Lake this is not a practical method. When a clerk moves through a fishery following a prescribed route and interviews anglers this is called a roving creel survey (Robson 1991). Within this survey type, there are several dimensional parameters such as time and distance and random start time, which are quantified and used in calculating the creel estimate. For large bodies of water, such as Moses Lake, the bus stop survey method may be the most applicable. This survey requires the clerk to move along a predefined route, interview anglers for a set amount of time, and then move to the next site (Hahn et al. 2000). For the purposes of the Moses Lake Fisheries Restoration Project, much of the same protocol will be used as in previous surveys. Consistency of protocol will allow for comparative analysis between different sampling dates. The three main components that are consistent for the previous and future creel surveys are index counts, creel data, and effort (Korth 2000). The methods described in the following text are the survey protocol to be used on Moses Lake.

Angler Harvest and Effort Sampling

- Interviews will be conducted on four weekdays and four weekend/holidays per month.
- Each day will be divided into two sample periods. Each sample period is one half of the total daylight for the day.
- Ideally a minimum of 10 complete angler trips is required per day.

Expansion Methods

- Index counts will be conducted twice during each creel-surveying period: Once during the half of the shift and once during the second half of the shift. Index times will be randomly selected. Below is a list of index sampling sites that will be adhered to.
- Total counts will be conducted twice a month (one week day and one weekend) via an aircraft. Counts will not be done simultaneously with interviews. Total count days will be randomly selected.
- Total counts will be done in conjunction with additional index counts.
- All types of recreation watercraft and activities will be counted and separated into either fishing or other types of activities.

The selection of angler interview days, 8 hour sampling periods within each day, time of index and day and time for total counts will be randomized with the following qualifications:

- Sampling periods will be divided evenly between morning and afternoon periods for both weekday and weekend strata within a given month.
- Sampling periods will occur only once each weekend and once each week.
- Index counts during any single angler interview day will be at least two hours apart.
- Scheduled survey periods, which are missed due to unavoidable circumstances, will shift to the next available day or time within a given month.

Index Sites. Moses Lake

1. Airman's Beach- Located off of highway 17. Boat, shore and vehicle counts.
2. Cascade Valley- Located on Valley Rd. within Lewis Horn. Boat, shore and vehicle counts.
3. Moses Lake Park (formerly state park)- Located off of I-90 exit 174. Shore and vehicle. Shore anglers on I-90 Bridge will be included within this site.
4. Peninsula Drive Boat ramp- Located on the west side of Pelican Horn. Shore (minimal), and vehicle.
5. Alder St. Bridge- Shore.

Data from each creel survey will be collected using the WDFW angler survey form. Data collected will include:

1. Party size.
2. Time checked or finished.
3. Determine age of party members.
4. Hours fished.
5. Satisfied or dissatisfied with trip.
6. Angler type: boat, shore, and float tube, ice.
7. Gear type: lure, bait, flies.
8. Species caught: Abbreviations will be consistent with state protocol.
9. Number and species of fish kept.
10. Number and species of fish released
11. Length (mm)
12. Counts: The number of boats and shore anglers fishing.

Compiling total count, and data from the assigned index sites will permit the expansion of total anglers at any given time.

Other data collected will include air and water temperatures, barometric pressure and current weather conditions (raining, clear, cloudy, windy). If anglers are cooperative, scale samples, lengths and weights will be collected from fish that are kept which in turn will permit the development of a length and age frequencies for angled fish.

Creel and expansion data will permit such calculations as how many fish of which species are caught per a given amount of time by boat and shore anglers, (the total number of fish harvested and the total effort that was expended in doing so). With these data, managers will receive an accurate census of the current status of angling on Moses Lake and combined with relevant data mitigation measures may be employed if it is deemed necessary.

The start date for this creel survey commenced on the 1st of April 2001 and concluded the 15th of April 2001.

Task 1.4: Due to funding constraints the initiation and completion of a valid population estimate was not possible. However, as outlined in the revised FY 2001 SOW, we are planning on addressing this issue.

Task 1.5: At high water Moses Lake has 60.5 miles of shoreline and considerably less at low water. Consequently there may be a sharp change in available habitat between the low and high water seasons. The objective of this portion of the project is to determine the type and amount of available habitat in the littoral zone of Moses Lake during both high and low water periods. Below in tabular format, are the classifications used in categorizing the littoral zone.

***Shoreline Development:**

1. agricultural
2. industrial/business
3. residential
4. undisturbed
5. Bulkhead
 - a. Presence or absence: If “present”, length of affected area in meters

*The total number of meters of shoreline that is occupied with each one of these categories will be established. This will be compared to a similar survey done in 1991 by the Bureau of Reclamation to track changes and/or habitat loss since the last survey.

Shoreline vegetation: vegetation that is growing on or adjacent to the shoreline.

1. tree
2. shrub
3. reed/bulrush
4. grass/forbes
5. sparse vegetation
6. exposed soil or bedrock (none)

7. Total linear meters of shoreline occupied by the dominant shoreline vegetation or lack thereof.

Submerged Aquatic macrophytes: aquatic macrophytes visible along the shoreline and offshore. Assessments will divide macrophytes into offshore and near-shore.

1. present yes or no.
2. dominant species
3. density: high, medium, low
4. Total number of square meters occupied by the dominant submerged aquatic macrophyte.

Substrate type: substrate type that is visible from shoreline to end of visibility in the water.

1. silt
2. sand
3. gravel: less than 4 inches in diameter
4. cobble: 4 to 12 inches in diameter
5. boulder: greater than 12 inches in diameter
6. bedrock
7. Total number of linear meters along the shoreline dominated by the substrate type.

Fish presence:

1. Detail any spawning activity noted during survey
2. Detail any fish observed, species and approximate number of individuals

The aforementioned information will be used to develop GIS coverage maps detailing habitat types, fish density and fish distribution to detect trends in habitat use during different times of the year, and thus habitat types can be quantified. This will be useful to infer potential areas of habitat competition or critical habitat for panfish rearing or reproduction.

The entire shoreline of Moses Lake was examined in 2001 and the habitat type recorded. We had anticipated surveying during lake drawdown in the winter of 2001, however faulty camera

gear did not allow us to obtain the necessary aerial photos. Shortly thereafter, funding questions halted the continuation of this task

Task 1.6, 1.7: Sample processing and data analysis was subsequently halted during the uncertainties surrounding the continued funding of the Moses Lake Project. However once funding was granted at the end of July 2002 another technician was hired and there are plans to hire a fulltime biologist.

Methods: Revised SOW

Objective 1: Quantify secondary production in Moses Lake.

Task 1.1 & 1.2- Zooplankton sampling began in April and continued through October 2002. Three replicates were collected biweekly at each of three sites along a randomly selected transect in each of the four sections (Section I Figure 1) using a ½ m Wisconsin net (n = 72/month). The three sites will be approximately 20 m from each shoreline and in mid-reservoir along each transect. Each sample will be taken ½ m from the bottom to the surface. Depth of sampling will be recorded to calculate volume of water strained. Samples were preserved with buffered formalin (4% sucrose; Haney and Hall 1973), and in the laboratory, one of the samples from each of the two randomly selected sections will be sorted by taxon, identified, and enumerated. Remaining samples will be weighed. Lengths and weights (collective) of the first 20 individuals for commonly occurring species will be collected from each sample. Mean lengths will be computed and effects of grazing evaluated by methods described by Mills et al. (1987).

Task 1.3-Benthic macroinvertebrates were sampled seasonally (spring, summer and fall) starting in spring 2002 along a randomly selected transect in each of the four sections of Moses Lake using a Ponar dredge. Three replicates at each of three sites (similar to the zooplankton

sampling) along the transect provided 36 samples/season. Samples were sieved through a 0.595 mm screen bucket and preserved in buffered formalin containing rose bengal dye (Mason and Yevich 1967). Samples will be sorted and identified to family or order and weighed as a group to estimate density and standing crop.

Objective 2. To quantify the influence of predation on target fishes in Moses Lake.

Task 2.1- Population estimation will commence in spring 2003. We will employ single and multiple census estimators to quantify largemouth and smallmouth bass and walleye population abundance and size distribution. Sampling will entail shoreline electrofishing and trap nets set in known spawning habitat for bass and walleye. Fish will be marked with Floy anchor tags and released. As many fish > 175 mm as possible will be marked prior to spawning. Following spawning when walleye and bass are actively foraging, random locations throughout Moses Lake will be sampled by nighttime electrofishing to quantify the ratio of marked fish in the populations. Ratios of recaptured fish also will be quantified in the sports fishery (Task 3.4) and at the scheduled Walleye Tournament in June and the Bass tournament in July. Total instantaneous mortality will be estimated by catch curve and numbers of marked fish available in the marked population will be adjusted for mortality.

Task 2.2-2.3 Quantification of monthly diets of predatory fishes will be conducted on Moses Lake starting in Spring 2003 and continue for a complete year. Fish will be collected during daylight and night hours to assess diel changes in feeding. Water temperatures will be collected at the inception of each collecting effort. Fish will be primarily collected by boat electrofishing, but gill netting and angling, including creel fish (Task 3.4), will also be employed. Diet samples collected from October 2000 through November 2001 will be analyzed in 2002. These samples will enable us to determine if section differences exist among predatory fishes in Moses Lake and any existing data gaps must be filled in 2003. Sample sizes of 100/month/species will be the desired number.

Stomach contents will be collected on live fish via gastric lavage methods whereas entire stomachs will be removed from sacrificed fish. Food items will be removed and placed in buffered formalin for analysis. Gill nets will be checked hourly, fish removed and contents preserved. Contents will be identified to species for fish, order for macroinvertebrates, and order for zooplankton when possible. Unidentified bony parts will be identified using established bone keys (Hansel et al. 1988). Food items will be weighed and percentages of live food items determined. Predatory inertia will be examined for each of the predator fishes similar to that of Stewart et al. (1981). This analysis will determine the overall impact of each of the cohorts of each of the predatory fishes in Moses Lake.

Objective 3. To quantify mortality of selected fishes in Moses Lake.

Task 3.1- Standardized beach seining (30.5 x 2.4 m, 6.35 mm knotless mesh with a 2.4 x 2.4 x 2.4 m bag with 15 m) would be conducted along the shoreline at random locations in Moses Lake. This sampling is standardized and covers 462 m² area/haul; this technique has been highly effective on juvenile resident fishes in numerous systems (Bowles 1985; Bennett and Hatch 1991; Bennett and Liter 1991). Sampling would occur in the spring 2003 immediately following water rises in the lake and in the fall 2002 before drawdown to assess cohort abundance and mortality. During each of the fall and spring sampling periods, we would randomly select about 150 locations along the shoreline that would provide a sample of approximately 10% of the shoreline. Fishes collected would be identified and measured for length and released. Length frequency distributions for each species would be compared between fall and spring periods to assess mortality among different size classes to assess size related mortality. Estimates of abundance would be expanded to estimate shoreline abundance based on proportional allocation (Scheaffer et al. 1986).

Task 3.2- Water quality determinations will begin in spring 2002 and continue through March 2003 at established transects in each of the four sections of Moses Lake (Figure 1). Use of

standard transects will enable temporal and spatial comparisons among sections of the lake. Water quality data including dissolved oxygen, water temperature, and turbidity will be collected at each of the four sections at an established transect. In addition, hourly recording thermographs will be deployed at 2 m intervals from the surface to the bottom in three sections (sections 1,2, and 3-Figure 1) of Moses Lake throughout the entire study period.

Task 3.4- We will use a combination of cluster and stratified random sampling designs (Scheaffer et al. 1986) to quantify angler use. Anglers will be enumerated and interviewed on the lake and at selected access points (Appendix Table 7). Equal effort will be apportioned between weekend/holidays and weekdays. One of the key items of information collected will be associated with the recovery of marked fishes. We will also obtain stomachs from creel predator fishes to obtain additional stomach samples (Task 2.2). Creel census will be conducted concurrently with the tagging for population quantification and stomach analysis sampling (2003). To estimate the significance of fishing mortality, exploitation will be estimated from recovery of tagged fish ($E = r/m$ where: r = number of recaptured fish and m = number of marked fish available). Estimation of total mortality (Task 2.1) will enable us to partition mortality into fishing and natural.

Task 3.5- We will sample predator fishes in the winter 2003 - 2004 at monthly intervals to assess the influence of predation on over-wintering mortality of potential prey fishes. Gill nets and nighttime electrofishing will be used. Gill nets will be checked at short time intervals to minimize digestion and mortality. Food habits sampling will be conducted similarly to procedures in Tasks 2.1 and 2.3.

Task 3.6- To assess entrainment losses we installed a trap at the outlet dam and sample both day and night to quantify fishes emigrating from Moses Lake during drawdown in 2002 (early FY2003). Sampling began in October 2002 and continued through November 2002. A stratified randomized sampling design (day and night) would be used where day and night sampling times would be randomized. Numbers of each species and size of fishes collected will be quantified and expanded to estimate total emigration losses using the partial count estimator (Lackey and Hubert 1976).

Objective 4. To assess effects of habitat changes from shoreline development and carp on the fish community in Moses Lake

Effects of carp on the Moses Lake ecosystem will be assessed through potential interaction with game fishes. Carp can directly compete for food and space resources, preclude other fishes access to those resources, and/or alter the existing habitat (e.g. physical destruction of littoral zone, turbidity to reduce reactive distances and primary and secondary productivity). Carp comprised about 70% of the biomass in spring 2000 samples, thus, their role in the Moses Lake ecosystem needs to be better understood.

Task 4.1-Data on water quality measurements at standardized sites (Task 3.2) will be supplemented with turbidity sampling at 1/2 km intervals along the shoreline in each of two randomly selected sections. Turbidity (NTU) will be measured approximately 15 m from shore on two randomly selected days within a month (week 1 and week 3) from April through October 2002.

Task 4.2-The food web in Moses Lake will be determined using traditional food habits sampling and stable isotope analysis. Traditional diet analyses will be made from samples collected from October 2000 through November 2001 using similar techniques as indicated in Task 2.3 in the summer of 2002. If additional samples are necessary based on high temporal and spatial variability, additional samples will be taken in 2003. For stable isotope analysis (SIA) tissue samples will be collected from all fishes including carp using beach seining, gill netting or electrofishing in 2002. Fish would be iced in the field until processing. We will separate fishes into one or more size classes depending upon ontogenetic changes in food habits based on regional literature and results from previous samples (2000-2001 samples) from Moses Lake. For SIA, 10 individuals/size group will be analyzed. In the laboratory, a small sample of white muscle (~ 10 mm) will be removed from below the dorsal fin and above the lateral line. Small

fishes may be filleted and a strip of white muscle tissue taken as a sample. The sample then will be frozen until processing.

Sample preparation may be conducted by a consulting laboratory (e.g. UC-Davis, Univ. of Idaho) or conducted internally. Processing entails drying the sample for 12 hours in a 65 °C oven, and grinding it to a flour consistency with a mortar and pestle. Approximately 1 mg of the dried sample will be packaged in a tin cup and analyzed for ¹³C and ¹⁵N signatures. Analyses are made using a mass spectrometer with a CE Instrument's NC 2500 elemental analyzer. Output from the mass spectrometer is δ values, per mil (‰) deviations from standards (atmospheric nitrogen or Pee Dee Belemnite carbon), where:

$$\delta^{15}\text{N or } \delta^{13}\text{C} = [(R_{\text{SAMPLE}} - R_{\text{STANDARD}})/R_{\text{STANDARD}}] \times 1000$$

R_{SAMPLE} = the isotopic ratio of the sample and,

R_{STANDARD} = the isotopic ratio of the standard.

We shall develop a food web diagram from the results of the traditional food habits studies and the stable isotope analysis. To compare results of isotope analysis with those of our traditional diet analysis of Moses Lake fishes, we will use a static mixing model (Harvey and Kitchell 2000). In the model, a consumer's expected δ value is equal to the weighted average δ values of its prey items (weighted by proportion of stomach contents) plus a trophic enrichment value of 3.4 ‰ for nitrogen and 1 ‰ for carbon (Harvey and Kitchell 2000). Predicted and observed values can be statistically compared to assess differences.

Task 4.3- Shoreline development and water level fluctuations have altered the rearing habitat for fishes in Moses Lake. As a potential causative or contributing factor to the low abundance of game fishes, habitat loss and habitat quality will be quantified from aerial photographs and ground truthing during both spring and fall 2002. Aerial photographs will be incorporated into GIS and physical habitat characteristics of the shoreline related to abundance of fishes as determined from spring and fall beach seining and electrofishing. We would also conduct hydroacoustic surveys to evaluate potential over-wintering cover for gamefishes.

Task 4.4- Lastly, we would use radiotelemetry to assess behavior of carp. Radiotransmitters will be surgically implanted into 25 carp, with a minimum of six carp collected in each of the four sections of Moses Lake. Transmitters would be implanted in carp during the summer and movements of carp determined from a minimum of weekly findings through the winter. Tagging would commence in late fall 2002 and terminate in spring 2003.

Results: Original SOW

Objective 1: Implement study design developed for Phase 2 of the Moses Lake Fishery Restoration Project.

Task 1.1 Implement fish diet study.

Collection of stomachs was completed during the reporting period at which time 600 more stomachs were collected. However, the majority of analysis will be completed during the FY 2002. Data collected from the analysis of contents will undergo power analysis to determine an adequate sample size during the FY 2002 when fish diet sampling will continue.

Subtask1.1.1 Collect age and growth structures.

This is an ongoing process and will continue through the next fiscal year.

Task 1.2 Implementation of zooplankton/phytonplankton sampling.

Due to the multi-agency work between the Department of Ecology, Eastern Washington University and the WDFW, analysis is on-going. Chlorophyll 'a' concentrations indicated highest levels of primary productivity in October 2000 and March 2001 (Table 1).

Secondary productivity was also monitored via zooplankton tows. Throughout the surveys as many as 19 species were identified within collected water samples. Generally, the most abundant groups of zooplankton sampled were *Daphnia* (Table 2). As well as being most abundant, *Daphnia* were also the largest zooplankton on average within the collected samples (Table 3).

Based on historical data as well as recently collected data, there is no indication that primary production is a limiting factor. However, more work is being conducted on water quality parameters as well as the collection of secondary productivity data.

Table 1. Concentrations of chlorophyll a collected from multiple sites throughout Moses Lake.

Date	Min. μL	Mean μL	Max. μL
10/23/00	34.1	36.9	39.7
1/30/01	7.5	9.7	16.0
2/19/01	14.3	15.7	16.9
3/26/01	35.3	37.1	39.9
5/8/01	1.3	9.7	24.3
7/12/01	3.5	8.5	19.4
10/11/01	5.5	11.2	20.2
12/5/01	11.2	16.2	19.5

Table 2. Percent of total sample volume of zooplankters during each sample session from Moses Lake.

	5/8/01	6/27/01	7/12/01	9/17/01	10/11/01	12/5/01	Grand Total
Alona sp.	0.00	0.53	7.73	23.21	10.80	7.39	9.06
B. longirostris	46.23	20.64	5.67	1.13	10.24	10.27	13.12
D. longiremis	5.62	2.20	4.20	8.50	10.38	1.66	5.79
D. pulex	13.18	33.73	19.12	27.86	20.66	18.66	21.08
Hesperodiaptomus franciscanus	0.73	5.19	12.44	6.17	7.14	2.56	6.33
Bicuspidatus thomasi	2.20	2.23	0.98	1.27	6.56	4.35	3.28
Mescocyclops edax	0.38	2.70	6.32	9.52	10.06	0.60	5.52
Kellocottia longispina	0.15	0.22	0.00	2.08	0.00	0.03	0.33
Asplanchna brightwelli	11.65	1.09	3.04	2.65	3.63	1.24	3.64
Keratella cochlearis	0.37	0.22	0.04	0.43	0.00	0.66	0.26
Keratella quadrata	1.47	1.23	0.20	0.00	0.00	0.35	0.39
Synchaeta pectinata	0.93	0.00	0.00	0.00	0.07	40.30	8.19
(immature) calanoid nauplii	4.31	13.44	3.48	1.35	3.16	1.50	3.60
Polyarthra vulgaris	2.65	8.96	26.12	9.32	8.58	4.05	10.96
(immature) cyclopoid (male) Daphnia	0.00	0.00	1.73	0.00	0.30	3.04	1.06
(male) Daphnia	9.37	7.63	6.03	5.69	7.15	3.28	6.23
Ceriodaphnia sp.	0.00	0.00	0.41	0.82	0.00	0.00	0.20
Notholca sp.	0.78	0.00	1.93	0.00	1.26	0.06	0.83
	0.00	0.00	0.58	0.00	0.00	0.00	0.13

Table 3. Mean size (mm) of zooplankters by sampling time and their overall mean size. Empty cells are a result of no individuals sampled.

	5/8/01	6/27/01	7/12/01	9/17/01	10/11/01	12/5/01	mean
Alona sp.	0.33	0.33	0.32	0.31	0.30	0.32	0.32
B. longirostris	0.40	0.37	0.35	0.31	0.35	0.35	0.35
D. longiremis	1.11	0.84	1.05	1.18	0.96	0.90	1.03
D. pulex	1.63	1.40	1.61	1.58	1.34	1.30	1.49
Hesperodiaptomus franciscanus	1.22	1.22	1.21	1.09	1.05	1.12	1.14
Bicuspidatus thomasi	1.18	1.24	1.01	0.97	0.76	0.96	0.96
Mescocyclops edax	1.36	1.26	1.12	1.06	0.94	1.04	1.08
Asplanchna brightwelli	0.46	0.32	0.46	0.45	0.42	0.52	0.46
Kellocottia longispina		0.62				0.37	0.50
Keratella cochlearis		0.12	0.19	0.16		0.38	0.27
Keratella quadrata	0.28	0.23	0.24			0.22	0.24
Synchaeta pectinata						0.29	0.29
(immature) calanoid	0.55	0.64	0.56	0.71	0.50	0.43	0.55
nauplii	0.29	0.38	0.30	0.30	0.30	0.25	0.30
(immature) cyclopoid	0.60	0.63	0.49	0.55	0.45	0.43	0.51
(male) Daphnia			0.81	1.01			0.94
Ceriodaphnia sp.	0.58		0.59		0.44	0.71	0.54
Notholca sp.			0.19				0.19
Polyarthra vulgaris	0.12		0.13		0.20		0.16

Task 1.3 Implement creel survey for Moses Lake.

Creel survey data analysis has not yet been completed. However, preliminary analysis has begun. We found that the top three targeted species on Moses Lake during the survey was anything, yellow perch and rainbow trout (Table 4). Consequently, greatest percentage of time was also spent targeting these three species.

Table 4. Angler responses the question “what species they were targeting and time spent doing so (n =1595).

Species	% of anglers targeting a species	% of time spent targeting a species
Anything	30.54	27.0
Yellow Perch	28.88	28.0
Rainbow Trout	21.73	22.0
Walleye	9.60	13.0
Black Crappie	4.04	4.8
Bass spp.	1.73	2.1
Warmwater	1.59	1.5
Carp	0.36	<1
Smallmouth Bass	0.36	<1
Tiger Muskie	0.36	<1
CAT spp.	0.29	<1
Bluegill	0.22	<1
Largemouth Bass	0.14	<1
Brown Bullhead	0.07	<1

Task 1.4 Estimate fish population size using mark and recapture methods.

No work was conducted on this task this FY. It will be addressed during the 2002 FY

Task 1.5 Development of GIS coverage to document habitat quantity and quality.

Due to the multiple agencies involved with the products from this task, it has not yet been completed. However, we have collected the summer data and aerial photos. Data has been turned over to the Washington Department of Ecology and the City of Moses Lake to develop a GIS overlay of Moses Lake. Due to unfavorable winter weather conditions and funding uncertainties we have not yet obtained the aerial photos of Moses Lake during drawdown.

However, we have already arranged our flyover and all pictures will be in digital format, which will expedite the analysis portion of tasks 1.5.

Task 1.6 Process samples from Tasks 1.1 and 1.2.

Task 1.7 Analyze data collected, compile and review literature related to the implementation of Tasks 1.1,1.2,1.3,1.4,1.5 and subtask 1.1.1.

Tasks 1.6 and 1.7 are being addressed and will be completed shortly into the beginning of the 2002 FY. It is necessary for these tasks to be completed in a timely manner due to the fact we will need the analyzed data to proceed with the proposed data collections.

Objective 2: Keep database up to date.

Task 2.1 Enter data from field sampling activities.

All collected data has been entered into spreadsheets and backed-up with triple electronic redundancy as well as multiple hard copies.

Objective 3: Attend training and agency meetings for efficiency in project implementation.

Task 3.1 Track Bonneville process and submit required documents to maintain project.

Task 3.2 Attend agency meetings for coordination of project implementation.

Task 3.3 Attend training pertinent to the implementation of the project.

A considerable amount of time has gone into the tracking of both BPA and WDFW meetings regarding the projects funding status. However, a minimal amount of time has been dedicated to training programs due to funding uncertainties encountered the past fiscal year.

Objective 4: Reporting to Bonneville Power Administration.

Task 4.1 Quarterly reports to BPA

Task 4.2 Annual report to BPA

Personnel from the Moses Lake Project are moving forward with the completion of all contract deliverables.

Results: Revised SOW

Objective 1. To quantify secondary production in Moses Lake.

Task 1.1- To sample zooplankton during the rearing season for game fishes in Moses Lake.

Sampling began in July 2002 and continued through to the end of November. Samples have been preserved and will be identified during the winter months 2003.

Task 1.2- To quantify the size composition of zooplankters that are consumed by game fishes in Moses Lake.

Work has not begun on this task.

Task 1.3- To sample the benthic macroinvertebrate community during the rearing season for game fishes in Moses Lake.

Sampling began in July 2002 and continued through to the end of November. Samples have been preserved and will be identified during the winter months.

Objective 2. To quantify the influence of predation on target fishes in Moses Lake.

Task 2.1- To estimate the abundance of predatory fishes (smallmouth bass, largemouth bass and walleye).

This task will commence during the spring of 2003.

Task 2.2- To estimate diet composition of predatory fishes in Moses Lake.

Stomach analysis of previously collected fish has begun. Data from these samples will undergo analysis to determine an adequate sample size to be collected concurrently with task 2.1.

Task 2.3- To estimate fish consumption by predatory fishes and assess predatory inertia in Moses Lake.

No work has begun on this task.

Objective 3. To quantify mortality of selected fishes in Moses Lake.

Task 3.1- To conduct spring and fall standardized shoreline sampling to quantify abundance of age 0 fishes.

All fall beach seining was completed. A total of 127-100' sites were beach seined on Moses Lake. Additionally, popnets were deployed at 13 randomly selected vegetated littoral sites. Captured fish were identified, weighed and lengths recorded. Analysis will begin in the coming months.

Task 3.2- To monitor critical water quality parameters during the rearing season for fishes in Moses Lake.

Water quality samples have continued and will continue well into the next fiscal year.

Task 3.4- To conduct a creel survey to quantify angler exploitation.

Task 3.5- To quantify winter predation losses.

No work has begun on tasks 3.4 and 3.5.

Task 3.6- To quantify entrainment losses from Moses Lake.

We are currently in the data collection stage and managed to complete the fall sample. Data has been entered with minimal analysis conducted.

Objective 4. To assess effects of habitat changes from shoreline development and carp on the fish community in Moses Lake

Task 4.1. To sample turbidity.

Turbidity sampling of the littoral zone began on schedule and will continue through the end of March 2003

Task 4.2. To identify the food web of Moses Lake.

No work has begun on this task.

Task 4.3. To quantify and assess quality of littoral habitat.

Work has continued on this task and it will be completed within this fiscal year.

Task 4.4. Identify summer, fall and winter concentrations of carp.

Transmitters have been successfully planted in 21 carp and tracking will begin January 2003. A duty cycle of 20 on and 4 off have been assigned to the transmitters to increase battery longevity.

References

- Bain R.C. Jr., 1987. Moses Lake Clean Lake Project, Final Stage 3 Report. Moses Lake Conservation District. Moses Lake, WA.
- Bennett, D.H. and D.R. Hatch. 1991. Factors limiting the fish community with largemouth bass in Long Lake, Spokane County, Washington. Completion Report. Washington Water Power, Spokane. Project No. 4
- Bennett, D.H. and M. Liter. 1991. Water quality, fish and wildlife characteristics of Box Canyon Reservoir, Washington. Completion Report. Section 3: Fish. Public Utility District No. 1 of Pend Oreille County, Newport, WA.
- Bremigan M.T., R.A. Stein. 1994. Gape-dependent Larval foraging and zooplankton size: Implication for fish recruitment across systems. Canadian Journal of fisheries and aquatic Sciences. Vol. 51.
- Bowles, E.C. 1985. Recruitment and survival of young-of-the-year largemouth bass (*Micropterus salmoides*) in the Coeur d' Alene Lake system, Idaho. Master's Thesis, University of Idaho, Moscow.
- Brown T.G. 1995. Stomach contents, distribution, and potential of fish predators to consume juvenile chinook salmon (*Oncorhynchus tshawytscha*) in the Nechako and Stuart Rivers, B.C. Canadian Technical Report of Fisheries and Aquatic Sciences 2077:1-39.
- De Stasio B.T. Jr. 1993. Diel vertical and horizontal migration by zooplankton: population budgets and the diurnal deficit. Bulletin of Marine Science. 53(1):44-64
- Hahn P., S. Zeylmaker, S. Bonar. 1993. WDFW methods manual: Creel information from sport fisheries. Washington Department of Fish and Wildlife, Fish Program. Technical Report # 93-18.

- Haney, J.F. and D.J. Hall. 1973. Sugar-coated *Daphnia*: A preservation technique for Cladoceran. *Limnology and Oceanography* 18:331-333.
- Hansel, H.C., S.D. Duke, P.T. Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. *Transactions of the American Fisheries Society* 117:55-62.
- Hartleb C.F., J.R. Moring. 1995. An improved gastric lavage device for removing stomach contents from live fish. *Fisheries Research*. 24:261-265.
- Harvey, C.J. and J.F. Kitchell. 2000. A stable isotope evaluation of the structure and spatial heterogeneity of a Lake Superior food web. *Canadian Journal of Fisheries and Aquatic Sciences* 57:1395-1403.
- Hayne D.W. 1991. The access point creel survey: Procedures and comparison with the roving-clerk creel survey. *American Fisheries Society Symposium*. 12:123-138.
- Korth J. 2000. Washington Department of Fish and Wildlife. Personal communications related to the past and future of creel surveys on Moses Lake.
- Lackey, R.T. and W. A. Hubert. 1976. Analysis of exploited fish populations. Sea Grant Division, Virginia Polytechnic Institute and State University, Blacksburg.
- Marrero C., H. Lopez-Rojas. 1995. Quantitative evaluation of the point method for fish stomach contents analysis. *Journal of Fish Biology*. 47:914-916.
- Mason, W.T., Jr. and P.P. Yevich. 1967. The use of phloxine B and rose Bengal stains to facilitate sorting benthic samples. *Transactions of the American Fisheries Society* 86 (2):221-223.

- Mills, E. L., D.M. Green, and A. Schiavone, Jr. 1987. Use of zooplankton size to assess the community structure of fish populations in freshwater lakes. *North American Journal of Fisheries Management* 7(3): 369-378.
- Pennak, R.W. 1989. *Freshwater invertebrates of the United States*, 3rd ed. John Wiley and Sons, New York, NY.
- Robson D.S. 1991. The roving creel survey. *American Fisheries Society Symposium*. 12:19-24.
- Ruggerone G.T. 1989. Gastric evacuation of single and multiple meals by piscivorous coho salmon (*Oncorhynchus kisutch*). *Environmental Biology of Fishes*. 26:143-147.
- Scheaffer, R.L., W. Mendenhall, and L. Ott. 1986. *Elementary survey sampling*. Duxbury Press, Boston, MA., 3rd Edition.
- Sing-Renton S., P.J. Bromley. 1996. Effects of temperature, prey type and prey size on gastric evacuation in small cod and whiting. *Journal of Fish Biology*. 49:702-713.
- Stewart, D.J., J.F. Kitchell, and L.B. Crowder. 1981. Forage fishes and their salmonid predators in Lake Michigan. *Transactions of the American Fisheries Society* 110 (6): 751-763.
- Westerlund J.E., P.C. Jacobson, H.K. Van Offelen, J.K. Hirsch. 1998. Use of limnetic zooplankton sampling in assessments of fish community structure in Minnesota bass-panfish lakes. Minnesota Department of Natural Resources, Investigational Report, 467 pp.1-21.
- Wydoski, R.S., and R.R. Whitney. 1979. *Inland Fishes of Washington*. University of Washington Press. United States. 220 pp.

Appendix 1. Original scope of work; began FY 2002 until June 2002 at which time the project shifted to the revised proposal.

Washington Department of Fish and Wildlife
Moses Lake Fishery Restoration Project
Project Number: 9502800
Scope of Work, Timeline and Budget for FY 2000 Contract
September 27, 2000 to September 26, 2001

Scope Of Work

Phase 1 of the project had the primary objectives of:

1. Collection and synthesis of all pertinent information in regards to Moses Lake.
2. The development and testing of preliminary hypotheses.
3. Analysis of historical and current data.
4. The development of refined hypotheses.

The refined hypotheses are as follows:

- a. Recruitment of panfish is limited by interspecific and/or intraspecific competition.
- b. Recruitment of panfish is limited by primary productivity.
- c. Recruitment of panfish is limited by predation.
- d. Recruitment of panfish is limited by habitat quality and quantity.
- e. Recruitment of panfish is limited by angling exploitation.

The development of refined hypotheses lead to creation of a study design to test and prove or disprove the hypotheses.

Phase 2 implements the study design and tests the refined hypotheses developed in Phase 1.

Phase 2 will start with this contract year and continue through FY 2002.

Objective 1: Implement study design developed for Phase 2 of the Moses Lake Fishery Restoration Project.

Task 1.1 Implement fish diet study. Investigate diets for all major species of fish present in Moses Lake. Collect stomach contents from fish using live lavage or collection of stomachs from deceased fish. All contents will be collected monthly to capture seasonal diet shifts and preferences. Contents will be identified to species for fish, and genus for zooplankton and macro-invertebrates. This will be ongoing through the next contract period.

Duration: Sept. to Sept.

Level of Effort: 1160 hours

Subtask1.1.1 Continued collection of scales and collection of otoliths for large predators to determine age frequency for large predators and ground truth accuracy of aging done previously.

Duration: Sept. to Sept.

Level of Effort: 200 hours

Task 1.2 Implement zooplankton seasonal density, size and species delineation study in Moses Lake. Using a Clarke-Bumpus plankton tow, dedicated index sites will be monitored monthly for collection of zooplankton. This will be ongoing through the next contract period.

Duration: Sept. to Sept.

Level of Effort: 200 hours

Task 1.3 Implement creel survey for Moses Lake. An in depth twelve month creel survey to document seasonal and annual angling use will be conducted. This will be ongoing through the next contract period.

Duration: April to Sept.

Level of Effort: 1056 hours

Task 1.4 Estimate fish population size using mark and recapture methods. Using open model mark and recapture methods to determine size of predator and prey populations. This will be ongoing through the next contract period.

Duration: Sept. to Sept.

Level of Effort: 1200 hours

Task 1.5 Development of GIS coverage to document habitat quantity and quality. Maps will include spawning and rearing areas, critical habitat areas and shoreline development. This will be ongoing through the next contract period.

Duration: Sept. to Sept.

Level of Effort: 200 hours

Task 1.6 Process samples from Tasks 1.1 and 1.2.

Duration: Dec. to Sept.

Level of Effort: 1600 hours

Task 1.7 Analyze data collected, compile and review literature related to the implementation of Tasks 1.1,1.2,1.3,1.4,1.5 and subtask 1.1.1.

Duration: Dec. to Sept.

Level of Effort: 800 hours

Objective 2: Keep database up to date.

Task 2.1 Enter data from field sampling activities.

Duration: Dec. to Sept.

Level of Effort: 320 hours

Objective 3: Attend training and agency meetings for efficiency in project implementation.

Task 3.1 Track Bonneville process and submit required documents to maintain project.

Duration: Sept. to Sept.

Level of Effort: 160 hours

Task 3.2 Attend agency meetings for coordination of project implementation.

Duration: Sept. to Sept.

Level of Effort: 96 hours

Task 3.3 Attend training pertinent to the implementation of the project.

Duration: Sept. to Sept.

Level of Effort: 120 hours

Objective 4: Reporting to Bonneville Power Administration.

Task 4.1 Quarterly reports to BPA

Duration: Sept. to Sept.

Level of Effort: 80 hours

Task 4.2 Annual report to BPA

Duration: Sept. to Sept.

Level of Effort: 120 hours

Task	Staff Days	Duration	Products
1.1	145	Sept. – Sept.	Understanding of diets of warmwater fish.
1.1.1	25	Sept. – Sept.	Ground truth ages of large predators using otoliths vs. scales
1.2	25	Sept. – Sept.	Understand seasonal size, densities and species for zooplankton. This will be initial investigations to potentially develop a larger more in depth study.
1.3	132	Sept. – Sept.	Complete creel survey to define angler use and harvest. Including angling mortality for warmwater fish.
1.4	150	Sept. – Sept.	Estimate populations to best determine total number of warmwater fish of all species in population.
1.5	25	Sept. – Sept.	GIS maps generated that document habitat quantity and quality, spawning

			and rearing areas.
1.6	200	Dec. - Sept.	Preparation and processing of field samples.
1.7	100	Dec. - Sept.	Analysis of data collected from Tasks 1.1 – 1.5
2.1	40	Dec. - Sept.	Keep database up to date.
3.1	20	Sept. – Sept.	Up to date with pertinent process.
3.2	12	Sept. – Sept.	Keep current with agency activities and requirements
3.3	15	Sept. – Sept.	Attend training to enable more efficient implementation of the project.
4.1	10	Sept. – Sept.	Submission of quarterly reports.
4.2	15	Sept. – Sept.	Submission of annual report.

Moses Lake Fishery Restoration Project
Project # 9502800
Budget for FY 2000
September 27, 2000 to September 26, 2001

ITEM

Personnel	Salary	Fringe	Total
Fish Biologist 3	\$48,000	\$13,440	\$61,440
Fish Biologist 1	\$34,368	\$9,623	\$43,991
Fish Biologist 1	\$34,368	\$9,623	\$43,991
.5 Scientific Tech 2	\$13,500	\$3,780	\$17,280
			\$166,702
Travel	per mile	total miles	
Mileage, per annum	\$0.315	5,000	\$1,575
Per diem	per day	total days	
Agency workshops and training	\$94	10	\$940
Professional/coordination meeting	\$100	25	\$2,500
Airfare	per trip	# trips	
	\$400	5	\$2,000
	\$200	5	\$1,000
			\$8,015
Goods and Services	per item	total items	
Rain gear	\$150	3	\$450
Foul weather clothing (jacket, pants, gloves)	\$200	3	\$600
Mustang suit	\$400	3	\$1,200
16" rubber boot	\$75	3	\$225
Hip boots	\$100	3	\$300
Floy tags and tagging equipment			\$6,000
Office and storage rent	per month	# months	
	\$350	12	\$4,200
Air conditioner, including installation			\$1,200
Office phone and utilities			\$1,500
Office Supplies			\$500
Vehicle fuel, repair and maintenance			\$2,250
Boat fuel, repair and maintenance			\$3,000
Service and modifications, other equipment (e.g. ropes, floats, connectors)			\$2,000
			23,425
WDFW Overhead(20.8%)			41,214
Subtotal			239,356
Equipment	per item	total items	
Software	321	1	321
Trap nets	1,200	6	7,200
Gill nets	220	6	1,320
Measuring Board	160	2	320
Sample containers	per box		
	60	5	300
	18	10	180
Gastric Lavage equipment (pumps, hoses)			300
			9,641
Enhancement Project Account	per Item	Total Items	
Fish Barriers	\$5,300	3	\$15,900
Broodstock (Crappie/Bluegill)	per fish	# fish	
	\$1	3000	\$3,000
Total			\$18,900
GRAND TOTAL			267,897
	Less unspent 1999 funds		-34,500
	New 2000 Funds needed		233,397

Appendix 2: Newest SOW started in July 2002 to continue through FY 2002.

**2002-2003 Factors Affecting the Recreational Fishery in Moses Lake,
Washington**
(Formerly “Restore Moses Lake Recreational Fishery”)
Statement of Work

**Washington Department of Fish and Wildlife
Natural Resource Building
111 Washington St. SE
Olympia WA 98501**

A. Administrative Summary:

Project Contact: Jeff Korth *korthjwk@dfw.wa.gov*
Project Leader: Dave Burgess *burgedsb@dfw.wa.gov*
Telephone: 509-754-4624 ext. 40
Address: 1550 Alder St. NW, Ephrata, WA 98823
Project Headquarters: Same as above
Project Advisor: Dr. David Bennett, University of Idaho
Project Period: September 27, 2002 – September 26, 2003
Administrative Contact: Dianna Neiswanger (contracts office)

B. Relationship to the Columbia River Fish and Wildlife Program

The objective for the Moses Lake Project as stated in the sub-basin summary (WDFW Sub Basin Summary) is to, “Maintain and enhance a balanced and productive Moses Lake warmwater recreational fishery to near historical records as off-site resident fish substitution for the loss of anadromous fish above Chief Joseph and Grand Coulee Dams.”

Section 10.1 of the 1994 NWPPC’s Fish and Wildlife Program Resident Fish Goal states, The program goal for resident fish is to recover and preserve the health of native resident fish injured by the hydropower system, where feasible, and, where appropriate, to use resident fish to mitigate for anadromous fish losses in the system (NWPPC 1994).

The Washington Department of Fish and Wildlife’s ability to provide fishing for native fishes has continued to decline, in large part due to the changing face of the habitats in which those fishes reside. As species are listed under the Endangered Species Act or their status is scrutinized, other associated fisheries are also lost due to their proximity to the listed populations and the potential for anglers to impact the listed populations. Those waters and habitats which are best suited to the propagation of non-native fisheries, such as Moses Lake, and where those non-native fishes have little or no impact on native fish resources, should be developed for recreational opportunities as a substitute for those native natural resources. Much like the NWPPC’s opinion on

resident fishes, our goal as managers and researchers is to maintain and improve the integrity of our native fauna while maintaining and enhancing the inland fishing opportunities within Washington State via aggressive and scientifically sound methods.

Coordination and Connection to Other Projects

The Moses Lake Project is directly related to two other BPA funded projects; the Lake Roosevelt Fisheries Evaluation Program (199404300) and the Banks Lake Fishery Evaluation Project. Moses Lake receives water and probably fish through entrainment from Lake Roosevelt and Banks Lake. These projects have objectives to quantify warmwater fish populations and how determine how best to provide for sustainable recreational fisheries for these warmwater fishes. The projects will exchange information, and compliment one another regarding the management recreational fisheries in similar and contiguous habitats. Furthermore, there will be a considerable amount of work sharing, logistical and technical support between the mentioned projects.

The project is also related to the Joint Stock Assessment above Chief Joseph and Grand Coulee Dams Project (JSAP #199700400). All data collected is sent to the project to be entered on the unified “blocked area” database. The data is available for analysis and will be contained on the database developed by the JSAP project. JSAP GIS capabilities will be used for spatial analysis of data collected on the Moses Lake Project.

Abstract

During the 1950s to the late 1970’s Moses Lake was the premier fishery for resident fishes in central Washington, including black crappie *Pomoxis nigromaculatus*, bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, and yellow perch *Perca flavescens*. Beginning in the late 1970's and throughout the 1980's, these fisheries experienced a gradual decline probably a result of several events including changes in species composition and abundance, over-harvest, and changes in habitat. To mitigate for depressed panfish abundance the Washington Department of Fish and Wildlife began to supplement the population with panfish brood stock in 1995 in the hopes of increasing production. Likewise, a rainbow trout *Oncorhynchus mykiss* net pen rearing program was also initiated to mitigate for lost recreational fishing opportunities. Therefore, the BPA funded Moses Lake Project relates directly to the WDFW stocking project.

The Moses Lake Project will assess factors affecting the Moses Lake fish community based on data attained through sound objective, scientific assessment. The long-term goal of the proposed work is the formulation of management recommendations that would enhance the sport fishery and economic benefit to the Moses Lake community and the state of Washington as mitigation for lost recreational fishing opportunities for anadromous species in the blocked portion of the Columbia River (Moses Lake Project Proposal, 2002). The current proposal (Phase I) briefly summarizes the results of

historical investigations of the fishery, species complexes, and habitat of Moses Lake and presents the study plan for partitioning the sources of mortality to target species (black crappie, bluegill, yellow perch, walleye, rainbow trout, largemouth and smallmouth bass), examining competitive interactions, and assessing habitat quantity and quality in Moses Lake.

The sources of mortality investigated include predation, angling, and entrainment. Competitive interactions include grazing impacts and dietary overlap among the target species and with common carp. Habitat assessments include secondary productivity, impacts due to winter draw down, and water quality variability especially as impacted by common carp.

The proposal culminates in identifying and ranking limiting factors by degree of impact to the fishery and implementing an action plan with the most feasible management actions (e.g. regulations, habitat enhancements, carp removal). Future direction would implement the action plan in conjunction with fisheries managers and provide for the monitoring and evaluation of the implemented recommendations (Phase II).

Performance Work Statement

Introduction and Implementation of the Proposal

Due to complications with the funding approval process, the Moses Lake Project was initially only minimally funded (\$70K) for FY 01. Fall funding was not approved until May 2002. Consequently, the tasks of hiring personnel and procuring equipment as well as tasks outlined within the approved proposal were recently started. The following objectives and tasks have been taken directly from the submitted proposal and include those started in FY 02 (FY 01 funding) but not necessarily completed within this fiscal year as well as tasks expected to be started and completed in FY 03 (FY 02 funding). The tasks that are not listed will be carried out the following years.

Recent recommendations by the ISRP has accounted for approximately an additional thirty four thousand dollars to be spent on a project advisor (Dr. David Bennett) and various other types of sampling gear during FY 02 and twenty thousand dollars each year after. Furthermore, there will be an increase in one FTE demand due to the increased required workload.

Overall Project Goal

The goal of this project is to identify factors affecting the Moses Lake sport fishery with the aim of enhancing the sport fishing recreational opportunities and the economic return to the Moses Lake community and Washington State.

**Logic Tree for Moses Lake Project
Phase I**

Project Goal: Assess factors affecting the Moses Lake fish community

Partition the sources of mortality.

Examine species interactions.

Assess habitat quality and quantity.

Assess the influence of angling.

Assess the influence of predation.

Quantify entrainment losses.

Assess secondary production and its influence on inter-specific interactions.

Assess impacts of carp.

Monitor critical water quality parameters.

Estimate the mortality of cohorts.

Assess competitive interactions of target fishes.

Identify factors with the greatest impacts on the Moses Lake fish community. Identify the most feasible management actions in conjunction with fisheries managers (e.g. regulations, stocking, habitat enhancements, carp removal).

Phase II – Future Research

Implement appropriate management actions based on Phase I results.

Evaluate the role of the management actions on the sport fishery.

Management actions are successful.

Management actions are not successful.

Objective 1. To quantify secondary production in Moses Lake.

Hypotheses:

1. Production of zooplankton is not limiting food abundance of planktivorous life stages of fishes
2. Size composition of zooplankton indicates interspecific interactions for food is not affecting survival of age 0 and older fishes.
3. Benthic macroinvertebrate production is adequate to provide food for game fishes in Moses Lake.
4. Primary productivity is sufficient to support sufficient secondary production.

Tasks:

Task 1.1- To sample zooplankton during the rearing season for game fishes in Moses Lake. **(Started June 2002, and will continue through May 2003)**

Task 1.2- To quantify the size composition of zooplankters that are consumed by game fishes in Moses Lake.

Task 1.3- To sample the benthic macroinvertebrate community during the rearing season for game fishes in Moses Lake. **(Started June 2002 and will continue through October 2003)**

Methods:

Task 1.1 & 1.2- Zooplankton sampling will begin in April and continue through October 2002. Three replicates will be collected biweekly at each of three sites along a randomly selected transect in each of the four sections (Section I Figure 1) using a ½ m Wisconsin net ($n = 72/\text{month}$). The three sites will be approximately 20 m from each shoreline and in mid-reservoir along each transect. Each sample will be taken ½ m from the bottom to the surface. Depth of sampling will be recorded to calculate volume of water strained.

Samples will be preserved with buffered formalin (4% sucrose; Haney and Hall 1973), and in the laboratory, one of the samples from each of the two randomly selected sections will be sorted by taxon, identified, and enumerated. Remaining samples will be weighed.

Lengths and weights (collective) of the first 20 individuals for commonly occurring species will be collected from each sample. Mean lengths will be computed and effects of grazing evaluated by methods described by Mills et al. (1987).

Task 1.3- Benthic macroinvertebrates will be sampled seasonally (spring, summer and fall) starting in spring 2002 along a randomly selected transect in each of the four sections of Moses Lake using a Ponar dredge. Three replicates at each of three sites (similar to the zooplankton sampling) along the transect will provide 36 samples/season. Samples will be run through a 0.595 mm sieve bucket and preserved in buffered formalin

containing rose bengal dye (Mason and Yevich 1967). Samples will be sorted and identified to family or order and weighed as a group to estimate density and standing crop.

Products:

- Collection of data to later estimate zooplankton abundance and size structure during the rearing season for game fishes.
- Collection of data to later estimate benthic macroinvertebrate abundance and comparison with other systems geographically similar

Objective 2. To quantify the influence of predation on target fishes in Moses Lake.

Hypotheses:

- 1) Fish predation is affecting survival of panfishes in Moses Lake.
- 2) Fish predation is responsible for the significant decrease in age 1 and older fishes in Moses Lake.
- 3) Fish predation structures the current Moses Lake fish community.

Tasks:

Task 2.1- To estimate the abundance of predatory fishes (smallmouth bass, largemouth bass and walleye).

Task 2.2- To estimate diet composition of predatory fishes in Moses Lake. **(Preliminary analysis of previous samples started July 2002 and will continue through October 2003)**

Task 2.3- To estimate fish consumption by predatory fishes and assess predatory inertia in Moses Lake.

Methods:

Task 2.1- Population estimation will commence in spring 2003. We will employ single and multiple census estimators to quantify largemouth and smallmouth bass and walleye population abundance and size distribution. Sampling will entail shoreline electrofishing and trap nets set in known spawning habitat for bass and walleye. Fish will be marked with Floy anchor tags and released. As many fish > 175 mm as possible will be marked prior to spawning. Following spawning when walleye and bass are actively foraging, random locations throughout Moses Lake will be sampled by nighttime electrofishing to quantify the ratio of marked fish in the populations. Ratios of recaptured fish also will be quantified in the sports fishery (Task 3.4) and at the scheduled Walleye Tournament in

June and the Bass tournament in July. Total instantaneous mortality will be estimated by catch curve and numbers of marked fish will be adjusted for mortality.

Task 2.2-2.3 Quantification of monthly diets of predatory fishes will be conducted on Moses Lake starting in Spring 2003 and continue for a complete year. Fish will be collected during daylight and night hours to assess diel changes in feeding. Water temperatures will be collected at the inception of each collecting effort. Fish will be primarily collected by boat electrofishing, but gill netting and angling, including creel fish (Task 3.4), will also be employed. Diet samples collected from October 2000 through November 2001 will be analyzed in 2002. These samples will enable us to determine if section differences exist among predatory fishes in Moses Lake and any existing data gaps must be filled in 2003. Sample sizes of 100/month/species will be the desired number.

Stomach contents will be collected on live fish via gastric lavage methods whereas entire stomachs will be removed from sacrificed fish. Food items will be removed and placed in buffered formalin for analysis. Gill nets will be checked hourly, fish removed and contents preserved. Contents will be identified to species for fish, order for macroinvertebrates, and order for zooplankton when possible. Unidentified bony parts will be identified using established bone keys (Hansel et al. 1988). Food items will be weighed and percentages of live food items determined. Predatory inertia will be examined for each of the predator fishes similar to that of Stewart et al. (1981). This analysis will determine the overall impact of each of the cohorts of each of the predatory fishes in Moses Lake.

Products: (note: overlap between 02-04 sampling years, analysis completed in 04)

- Collection of data to estimate abundance and size structure of predatory fishes.
- Collect data to determine the significance of dietary items to predatory fishes.
- Estimate the influence of predatory fishes on other game fishes in Moses Lake

Objective 3. To quantify mortality of selected fishes in Moses Lake.

Hypotheses:

- 1) Year class strength is being determined after the first rearing season.
- 2) Spawning and rearing habitat are adequate for good year-class production.
- 3) Water quality is sufficient for successful spawning and rearing.
- 4) Angler harvest is not structuring the Moses Lake fish community.
- 5) Winter mortality is largely a result of predation.

Tasks:

Task 3.1- To conduct spring and fall standardized shoreline sampling to quantify abundance of age 0 fishes.

- Task 3.2-** To monitor critical water quality parameters during the rearing season for fishes in Moses Lake. **(Started June 2000, modified data collection started (June 2002 and continuing through May 2003)**
- Task 3.4-** To conduct a creel survey to quantify angler exploitation **(This task will extend through 04)**
- Task 3.5-** To quantify winter predation losses **(collection of data only 03, extending through 04).**
- Task 3.6-** To quantify entrainment losses from Moses Lake **(collection of data only 03, extending through 04).**

Methods:

Task 3.1- Standardized beach seining (30.5 x 2.4 m, 6.35 mm knotless mesh with a 2.4 x 2.4 x 2.4 m bag with 15 m) would be conducted along the shoreline at random locations in Moses Lake. This sampling is standardized and covers 462 m² area/haul. And has been highly effective on juvenile resident fishes in numerous systems (Bowles 1985; Bennett and Hatch 1991; Bennett and LITER 1991). Sampling would occur in the spring 2003 immediately following water rises in the lake and in the fall 2002 before drawdown to assess cohort abundance and mortality. During each of the fall and spring sampling periods, we would randomly select about 150 locations along the shoreline that would provide a sample of approximately 10% of the shoreline. Fishes collected would be identified and measured for length and released. Length frequency distributions for each species would be compared between fall and spring periods to assess mortality among different size classes to assess size related mortality. Estimates of abundance would be expanded to estimate shoreline abundance based on proportional allocation (Scheaffer et al. 1986).

Task 3.2- Water quality determinations will begin in spring 2002 and continue through March 2003 at established transects in each of the four sections of Moses Lake (Figure 1). Use of standard transects will enable temporal and spatial comparisons among sections of the lake. Water quality data including dissolved oxygen, water temperature, and turbidity will be collected at each of the four sections at an established transect. In addition, hourly recording thermographs will be deployed at 2 m intervals from the surface to the bottom in three sections (sections 1,2, and 3-Figure 1) of Moses Lake throughout the entire study period.

Task 3.4- We will use a combination of cluster and stratified random sampling designs (Scheaffer et al. 1986) to quantify angler use. Anglers will be enumerated and interviewed on the lake and at selected access points (Appendix Table 7). Equal effort will be apportioned between weekend/holidays and weekdays. One of the key items of information collected will be associated with the recovery of marked fishes. We will also obtain stomachs from creel predator fishes to obtain additional stomach samples (Task 2.2). Creel census will be conducted concurrently with the tagging for population quantification and stomach analysis sampling (2003). To estimate the significance of

fishing mortality, exploitation will be estimated from recovery of tagged fish ($E = r/m$ where: r = number of recaptured fish and m = number of marked fish available). Estimation of total mortality (Task 2.1) will enable us to partition mortality into fishing and natural.

Task 3.5- We will sample predator fishes in the winter 2003 - 2004 at monthly intervals to assess the influence of predation on over-wintering mortality of potential prey fishes. Gill nets and nighttime electrofishing will be used. Gill nets will be checked at short time intervals to minimize digestion and mortality. Food habits sampling will be conducted similarly to procedures in Tasks 2.1 and 2.3.

Task 3.6- To assess entrainment losses we would install a trap at the outlet dam and sample both day and night to quantify fishes emigrating from Moses Lake during drawdown in 2002 (early FY2003). A stratified randomized sampling design (day and night) would be used where day and night sampling times would be randomized. Numbers of each species and size of fishes emigrating would be quantified and expanded to estimate total emigration losses using the partial count estimator (Lackey and Hubert 1976).

Products:

- Estimates of mortality associated with different cohorts.
- Density of age 0 fishes during fall and spring to assess year-class strength.
- Over-winter survival/mortality for age 0 fishes.
- Comparison of year-class strength with those from other waters.
- Measures of key water quality parameters that could affect survival and growth of game fishes.
- Collect data to partition of mortality between natural and fishing causes. This will be completed upon the completion of the creel survey.
- Quantified estimates of entrainment losses.

Objective 4. To assess effects of habitat changes from shoreline development and carp on the fish community in Moses Lake

Hypotheses:

1. Carp are increasing turbidity in Moses Lake.
2. Carp are adversely affecting habitat for target fishes.
3. Carp are competing with desired game fishes for food.
4. Carp are predators on eggs and larval game fishes.
5. Shoreline development, water level fluctuations, and sedimentation adversely affect spawning and rearing habitat.

Tasks:

Task 4.1. To sample turbidity. (Started July 2002 and will continue through May 2003)

Task 4.2. To identify the food web of Moses Lake. **(Begin in 03 and continuing through 04)**

Task 4.3. To quantify and assess quality of littoral habitat.

Task 4.4. To identify summer, fall and winter concentrations of carp.

Methods:

Effects of carp on the Moses Lake ecosystem will be assessed through potential interaction with game fishes. Carp can directly compete for food and space resources, preclude other fishes access to those resources, and/or alter the existing habitat (e.g. physical destruction of littoral zone, turbidity to reduce reactive distances and primary and secondary productivity). Carp comprised about 70% of the biomass in spring 2000 samples, thus, their role in the Moses Lake ecosystem needs to be better understood.

Task 4.1-Data on water quality measurements at standardized sites (Task 3.2) will be supplemented with turbidity sampling at 1/2 km intervals along the shoreline in each of two randomly selected sections. Turbidity (NTU) will be measured approximately 15 m from shore on two randomly selected days within a month (week 1 and week 3) from April through October 2002.

Task 4.2-The food web in Moses Lake will be determined using traditional food habits sampling and stable isotope analysis. Traditional diet analyses will be made from samples collected from October 2000 through November 2001 using similar techniques as indicated in Task 2.3 in the summer of 2002. If additional samples are necessary based on high temporal and spatial variability, additional samples will be taken in 2003. For stable isotope analysis (SIA) tissue samples will be collected from all fishes including carp using beach seining, gill netting or electrofishing in 2002. Fish would be iced in the field until processing. We will separate fishes into one or more size classes depending upon ontogenetic changes in food habits based on regional literature and results from previous samples (2000-2001 samples) from Moses Lake. For SIA, 10 individuals/size group will be analyzed. In the laboratory, a small sample of white muscle (~ 10 mm) will be removed from below the dorsal fin and above the lateral line. Small fishes may be filleted and a strip of white muscle tissue taken as a sample. The sample then will be frozen until processing.

Sample preparation may be conducted by a consulting laboratory (e.g. UC-Davis, Univ. of Idaho) or conducted internally. Processing entails drying the sample for 12 hours in a 65 °C oven, and grinding it to a flour consistency with a mortar and pestle. Approximately 1 mg of the dried sample will be packaged in a tin cup and analyzed for ¹³C and ¹⁵N signatures. Analyses are made using a mass spectrometer with a CE Instrument's NC 2500 elemental analyzer. Output from the mass spectrometer is δ values, per mil (‰) deviations from standards (atmospheric nitrogen or Pee Dee Belemnite carbon), where:

$$\delta^{15}\text{N} \text{ or } \delta^{13}\text{C} = [(R_{\text{SAMPLE}} - R_{\text{STANDARD}})/R_{\text{STANDARD}}] \times 1000$$

R_{SAMPLE} = the isotopic ratio of the sample and,
 R_{STANDARD} = the isotopic ratio of the standard.

We shall develop a food web diagram from the results of the traditional food habits studies and the stable isotope analysis. To compare results of isotope analysis with those of our traditional diet analysis of Moses Lake fishes, we will use a static mixing model (Harvey and Kitchell 2000). In the model, a consumer's expected δ value is equal to the weighted average δ values of its prey items (weighted by proportion of stomach contents) plus a trophic enrichment value of 3.4 ‰ for nitrogen and 1 ‰ for carbon (Harvey and Kitchell 2000). Predicted and observed values can be statistically compared to assess differences.

Task 4.3- Shoreline development and water level fluctuations have altered the rearing habitat for fishes in Moses Lake. As a potential causative or contributing factor to the low abundance of game fishes, habitat loss and habitat quality will be quantified from aerial photographs and ground truthing during both spring and fall 2002. Aerial photographs will be incorporated into GIS and physical habitat characteristics of the shoreline related to abundance of fishes as determined from spring and fall beach seining and electrofishing. We would also conduct hydroacoustic surveys to evaluate potential over-wintering cover for gamefishes.

Task 4.4- Lastly, we would use radiotelemetry to assess behavior of carp. Radiotransmitters will be surgically implanted into 25 carp, with a minimum of six carp collected in each of the four sections of Moses Lake. Transmitters would be implanted in carp during the summer and movements of carp determined from a minimum of weekly findings through the winter. Tagging would commence in late spring 2002 and terminate in spring 2003.

Products:

- Estimates of turbidity
- Begin collection to identify the Moses Lake food web.
- Qualitative and quantitative assessment of littoral rearing habitat for game fishes
- Identification of carp concentrations for possible control

F. Budget: See attached spreadsheet(s) summary. FY 01 spreadsheet shows under budget spending (budgeted \$235K) and FY 02 shows over budget spending (budgeted \$223K) as to meet new task requirements.

G. Work Schedule:

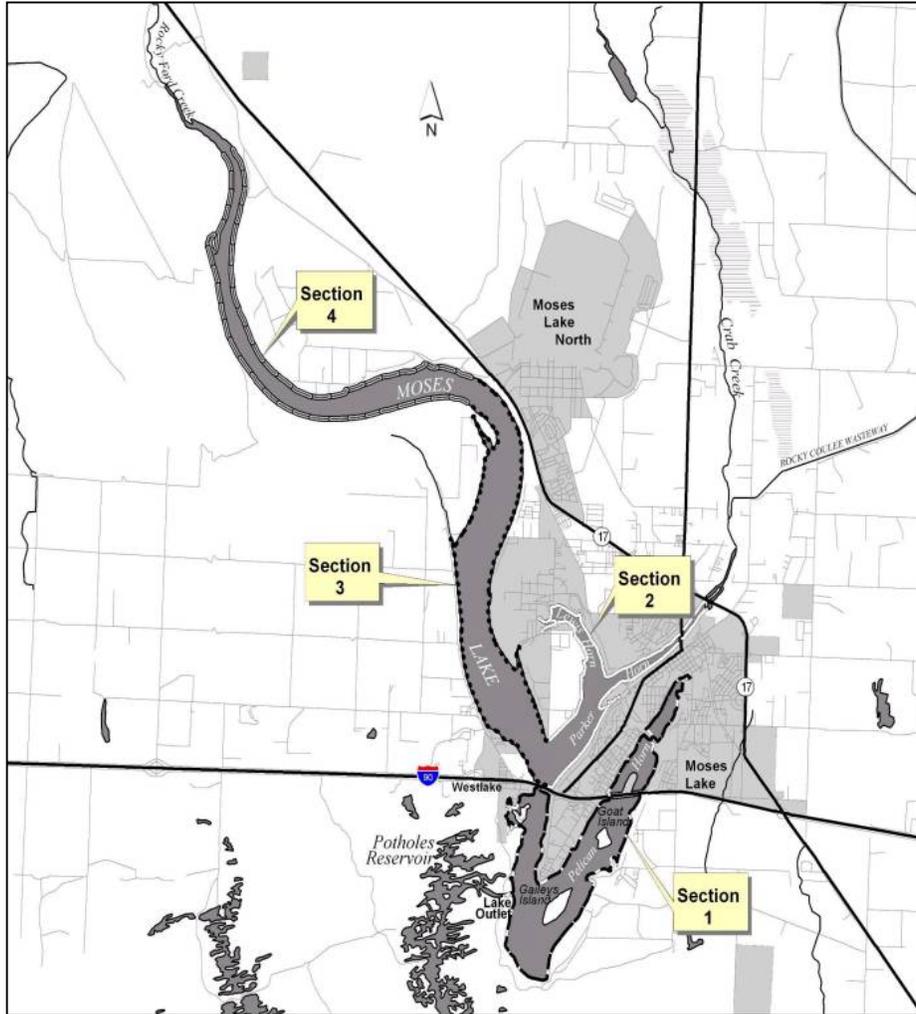
Water quality, zooplankton and turbidity sampling will continue through May, at which time juvenile fish sampling and entrainment netting will commence in October and continue through mid-November. The multi-agency cooperative task of littoral analysis will continue through and be completed in 2003. During the winter months data will be entered, samples will be identified and data analysis performed. Barring no unforeseen circumstances, carp will have been planted with transmitters and tracking will occur

Task	Description	Duration and Effort (actual dates)
1.1	Zooplankton sampling	2 FTE's start June 2002 and continue through May 2003
1.2	Size of consumed zooplankters within the diets of fishes	1-2 FTE's Started July 2002 and continue through 2004
1.3	Benthic macroinvertebrate sampling	2 FTE's Started in June 2002 and continue through October 2003
2.1	Predatory fish abundance	4 FTE's (Banks Lake staff assistance) start April 2003 through October 2004
2.2	Predatory fish diet analysis	3 FTE's previous samples started July 2002 and with new samples continue through Oct 2004
2.3	Predatory fish inertia	2 FTE's start Octo 2002 through November 2004
3.1	Shoreline Seining	4 FTE's (Banks Lake staff assistance). Two sample periods: October 2002-November 2002, April 2003-May 2003
3.2	Water quality monitoring	2 FTE's started June 2002 and will continue March 2003. Thermographs not yet deployed
3.4	Creel survey	1 FTE start April 2003 through November 2004
3.5	Fish predator diets	3 FTE's winter 2003-2004
3.6	Entrainment	2 FTE's start October through November 2003. Fish collection, data analysis conducted 2004.
4.1	Turbidity sampling	2 FTE's start July 2002 through June 2003
4.2	Food web, stable isotope analysis	2 FTE's run in tandem with seining and diet sampling.
4.3	Litoral zone analysis	1 FTE (Cooperative DOE, WDFW, City of Moses Lake) start June 2002 through April 2003
4.4	Radio tracking carp	2 FTE's start date depends on approval to purchase the necessary equipment

H. Facilities and Equipment

Much of the major equipment has been purchased using BPA funds. Major equipment required for the project includes: an electrofishing boat, pickup truck, gill nets, trap nets, microscope and light source, 3 desk top computers, 1 lap top computer, Clarke-Bumpus zooplankton tow and specialized computer software (e.g. bioenergetics model, population assessment models). Future major equipment purchases will include telemetry gear, thermographs. Other materials such as preservatives, sample containers, rent for boat storage; phone service and a variety of smaller items and services will be purchased throughout the project to maintain an efficient operating regime. WDFW has supplied office space and a scale press as part of the overhead operating cost. To remain within WISHA and OSHA safe operating protocol, lab space and chemical hoods at Central Washington University are used when handling and processing chemical samples. Furthermore, Central Washington University has offered the use of their equipment such as multiple dissecting scopes, drying ovens and balances to aid in processing samples.

I. Map of Moses Lake: Section designation made.



References

- Bennett, D.H. and D.R. Hatch. 1991. Factors limiting the fish community with largemouth bass in Long Lake, Spokane County, Washington. Completion Report. Washington Water Power, Spokane. Project No. 4.
- Bennett, D.H. and M. Liter. 1991. Water quality, fish and wildlife characteristics of Box Canyon Reservoir, Washington. Completion Report. Section 3: Fish. Public Utility District No. 1 of Pend Oreille County, Newport, WA.
- Bennett, D.H., J.W. Korth, and D.S. Burgess. 2002. Factors Affecting the Recreational Fishery in Moses Lake, Washington. Project ID:199502800. NWPPC approved project proposal
- Bowles, E.C. 1985. Recruitment and survival of young-of-the-year largemouth bass (*Micropterus salmoides*) in the Coeur d' Alene Lake system, Idaho. Master's Thesis, University of Idaho, Moscow.
- Haney, J.F. and D.J. Hall. 1973. Sugar-coated *Daphnia*: A preservation technique for Cladoceran. *Limnology and Oceanography* 18:331-333.
- Hansel, H.C., S.D. Duke, P.T. Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. *Transactions of the American Fisheries Society* 117:55-62.
- Harvey, C.J. and J.F. Kitchell. 2000. A stable isotope evaluation of the structure and spatial heterogeneity of a Lake Superior food web. *Canadian Journal of Fisheries and Aquatic Sciences* 57:1395-1403.
- Lackey, R.T. and W. A. Hubert. 1976. Analysis of exploited fish populations. Sea Grant Division, Virginia Polytechnic Institute and State University, Blacksburg
- Mason, W.T., Jr. and P.P. Yevich. 1967. The use of phloxine B and rose Bengal stains to facilitate sorting benthic samples. *Transactions of the American Fisheries Society* 86 (2):221-223.
- Mills, E. L, D.M. Green, and A. Schiavone, Jr. 1987. Use of zooplankton size to assess the community structure of fish populations in freshwater lakes. *North American Journal of Fisheries Management* 7(3): 369-378.
- Northwest Power Planning Council (NWPPC) 1994. Resident Fish Goal. Columbia River Basin Fish and Wildlife Program. Council Document 94-55.
- Scheaffer, R.L., W. Mendenhall, and L. Ott. 1986. Elementary survey sampling. Duxbury Press, Boston, MA., 3rd Edition.

Stewart, D.J., J.F. Kitchell, and L.B. Crowder. 1981. Forage fishes and their salmonid predators in Lake Michigan. *Transactions of the American Fisheries Society* 110 (6): 751-763.

