DRAFT STUDY PLAN FOR THE

ASSESSMENT OF PREDATION ON JUVENILE SALMON IN THE OKANOGAN RIVER, WA

Prepared for:
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1.0 INTRODUCTION

The Confederated Tribes of the Colville Reservation (CCT) requested the development of a study plan to assess the extent of predation on juvenile salmon (Chinook, Sockeye, and Steelhead) by resident fish and birds of the Okanogan River (i.e., Predation Assessment Program, or PAP). The development of this study is a component of the Okanogan Basin Monitoring and Evaluation Program (OBMEP) designed for providing population scale status data for all anadromous fish species and their habitats.

Predation by fish and birds on juvenile salmon has been intensively studied in the Columbia River Basin (Fritts and Pearsons, 2006; Naughton and Bennett 2003; Antolos et. al 2005; Ruggerone 1986) to ascertain the relative impact on early life-history survival in the hydro-system. Listing of several basin stocks under the Endangered Species Act (ESA) and the substantial funding directed toward rebuilding depressed runs has resulted in a concerted effort to evaluate predatory mortality. In some cases, management actions have included the direct take of predators in an attempt to minimize the impact on juvenile salmon populations (Jerald 2003; Jerald 2005; Turner et al. 2005; Turner et al. 2006). Similarly, the impact of predators on juvenile salmon populations in the Okanogan River is of interest to managers, however a comprehensive study has never been conducted in that region. To address this gap in information, the CCT have proposed to conduct a study to assess the relative magnitude of predation on juvenile salmon stocks of the Okanogan Basin.

The Okanogan River Basin and the adjacent waters of Wells Dam Reservoir (Columbia River) are inhabited by a variety of potential fish and bird predators. There are select species of high enough abundance to potentially consume a substantial number of juvenile salmon. In particular, piscivorous fish include smallmouth bass (SMB), northern pikeminnow (NPM), and walleye and birds include gulls and cormorants (Douglas PUD, 2006). The primary objective of PAP is to quantify the consumption of juvenile salmon so that it may be assessed relative to juvenile salmon abundance. Therefore, the general hypothesis for the program is that juvenile salmon are being consumed by fish and birds in the area extending from Wells Dam to McIntyre Dam on the Okanogan River. More specifically, PAP will quantify and evaluate the magnitude of predation on juvenile salmon.

The approach to achieving the objective of PAP is to partition the study area into geo-hydraulic strata and the predators by class (fish, birds) so that manageable and directed effort can be prioritized. The program is to be implemented in stages as based on funding, information needs, and logistical considerations. For the purpose of this study, and potential future studies, there are three primary strata in the study area; 1) Wells Reservoir (including the inundation portion of the Okanogan River up to Chilliwist Creek), 2) Okanogan River at Chilliwist Creek to Zosel Dam and the Similkameen River to Enlow Dam, and 3) Okanogan River at Zosel Dam to McIntyre Dam (Canada) (Figure 1).

There are five primary tasks of PAP:

1. Determine a reach stratified population estimate and size distribution for predators (fish, birds) of juvenile salmon.

2. Assess the reach stratified abundance of juvenile salmon by year class (young of year and yearling) in the stomachs of predators in order to assess the presence and timing of salmon and other food items in their diet.

3. Apply reach stratified predator stomach content analysis to the reach stratified predator population estimate to determine the relative consumption of juvenile salmon.

4. Compare estimated total juvenile consumption to juvenile population estimates to assess the relative take by predators.

5. Provide recommendations for management of predator species.

6. Identify potential data gaps related to evaluating predation of juvenile salmon within Okanagan River.

This document presents the overarching goals of PAP and details the implementation activities of stage one to be conducted in the summers of 2010, 2011, and 2012. More specifically, a pilot study in Strata 2 will occur in the first year with focused research activities in the second and third years. The rationale for beginning in this area and with this class of predator is based on the assumption that the populations of predator and salmon are the most concentrated and likely to overlap in space and time. Juvenile salmon production in the Okanogan Basin originates in Strata 2 and 3, and anecdotal evidence suggests two primary fish predators, SMB and NPM, reside in Strata 2 (Johnson et. al 2008; Colville Tribes, 2001, 2002). Consumption by other predatory fish is negligible and will not be considered in this strata. Research on fish predators and research in Strata 1 and 3 will take place in the future as separate stages, as will research on bird predators in all three strata.

2.0 TECHNICAL PROPOSAL

Stage one of PAP, as defined above by geo-hydraulic strata, class of predator, and biological rationale will address the hypothesis that juvenile salmon are being consumed by piscivorous fish in Strata 2 of the study area. The relative effect of data resulting in acceptance of this hypothesis will be evaluated by comparing total predation (number of juveniles) to estimates of their respective population estimate. It is anticipated that juvenile salmon predation will be assessed by species and year class. While there does not exist rigorous estimates of the juvenile salmon populations, best estimates will be derived from existing information on spawner populations and their potential production.

In each year of the study, specific objectives and questions will be addressed. The focus of the pilot year to asses methods and gather qualitative population and consumption data in order to fine tune effort, procedures, and schedule for use in the following years. With each year, increasing focus will be placed on areas of the river with a high population of predator in order to increase precision of population and consumption estimates. Objectives and questions to be addressed in stage one are as follows:

Pilot year - 2010

1. Assess population of NPM and SMB within Strata 2.
    - What is the relative abundance and distribution of predators?
    - Which reaches have the greatest relative abundance of predators?
    - What is the extent of predator movement?
2. Observe stomach contents of NPM and SMB within Strata 2.
    - When do the predators begin consuming juvenile salmon?
    - What other animals are being consumed?
    - What is the frequency of observing a predator with an empty stomach?
3. Determine effectiveness of proposed methods and schedule within Strata 2.
    - Is electroshocking sufficiently effective during times of increased flow and turbidity?
    - Will other gears be necessary?
    - Are there periods of time throughout the study period when sampling for population and/or stomach content assessment is not feasible?
    - What level of effort is required to adequate sample Strata 2?
    - Based on the collected data, will an adequate number of fish be caught to facilitate population and consumption estimates in 2011 when focus on specific reaches are altered.
    - What is the extent of predator movement and will the proposed population estimate methods need to be altered accordingly?

Study year one - 2011

1. Assess population of NPM and SMB within Strata 2.
    - What is the estimated abundance and distribution of predators?
    - Which reaches have the greatest estimated abundance of predators?
    - With what habitat features do the predators associate?
2. Examine stomach contents of NPM and SMB within Strata 2.
    - What is the estimated consumption of juvenile salmon?
    - Is there a preference by the predators to salmon year class?
    - When do the predators begin consuming juvenile salmon?
    - What other animals are being consumed?

Study year two - 2012

1. Assess population of NPM and SMB throughout Strata 2
    - What is the estimated abundance and distribution of predators?
    - Does the population of predators change throughout the sampling period?
2. Observe consumption habits of NPM and SMB
    - What are the consumption estimate by reach and section?
    - When do the predators begin consuming juvenile salmon and how does their diet change over the sampling period?
    - What other animals are being consumed?

2.1 STUDY AREA

The Okanogan River in Strata 2 is partitioned into 33 reaches based on physical and biological characteristics (Figure 2) for EDT sampling and analysis. The total length of Strata 2 is 118.70 km and individual reaches range from 0.34 to 15.55 km in length. Parameters used to define these reaches included water depth and velocity; substrate gradient and type; riparian structure and slope; and presence of riffles, structure, holding areas, islands, tributaries, and impassable rapids and falls (Table 1). The reaches for this study were derived from GIS attribute data information collected and compiled by OBMEP. No major flooding events or construction resulting in changed physical and biological river characteristics have occurred since this survey and it is assumed to still be accurate. Each reach is partitioned into five equal length sections for the purpose of predator population sampling. Having the river separated into heterogeneous reaches (i.e., relatively homogenous within reaches) and sections will result in more accurate statistical results and allow for comparison of predator density and salmon consumption between portions of the river.

2.2 JUVENILE SALMON

There are three species of salmon that inhabit the Okanogan River and sustain juvenile production including Chinook, sockeye and steelhead. Within these species are specific classes of fish including natural origin sub-yearling Chinook, hatchery origin yearling Chinook, natural origin sockeye, hatchery origin sockeye, natural origin steelhead, and hatchery origin steelhead. Each of these classes have population characteristics that define their life history in the Okanogan River (Table 2).

All of these juvenile salmon are of an appropriate size for consumption by SMB and NPM and can be anticipated to be present in the diet of those predators. However, the smaller sized fish are likely more susceptible to predation.

2.3 TIMING OF SAMPLING

The proposed sampling period for Strata 2 is April 5 – Aug 20, 2010, April 4 – Aug 19, 2011, and March 30 – Aug 14, 2012 (Table 2). Based on underwater video monitoring at Zosel Dam from prior years, starting the sampling period at the beginning of April coincided with SMB migration from wintering habitats. Northern pikeminnow begin actively moving in May (John Arterburn, Colville Confederated Tribes, Pers. Comm.). Also, salmon alevin have already emerged from the gravel at the beginning of April (Rayton and Arterburn 2008) and consequently become a potential food source. All juvenile salmon appear to complete their out-migration before the end of July when water temperature in the Okanogan River exceeds criteria for survival (John Arterburn, Colville Confederated Tribes, Pers. Comm.). Commencing sampling with the redistribution of predators from wintering habitats and ending sampling with the cessation of migration ensures that predators are assessed throughout the entire period they are feeding on juvenile salmon in Strata 2.

2.4 RADIO TAGGING PREDATORS

The primarily goal of the radio tracking performed in the pilot study (2010) is to document the extent of SMB and NPM movement throughout the Okanogan River and adjust the population and consumption estimate procedures if needed. This portion of this study has been designed and will be conducted by Ed Zaple as part of his Ph.D. thesis with the University of Washington. Mr. Zaple will also investigate real-time correlated foraging routes, preferred foraging locations, and flow velocity-related behaviors as documented by frequent observations in particular areas. Mr. Zaple will also perform analysis of stomach contents which will inform as to the relative success of particular foraging behaviors exhibited by individual fish. From these data, it’s hoped that strong correlations might be drawn regarding preferred foraging behaviors by NPM and SMB in the Okanogan River. This data will possible be utilized in the continuing development of a predator fish bioenergetics and behavior model that may be applied to more generalized sites, both in the Okanogan River and throughout the Columbia River system.

For the purpose of Mr. Zaple’s research, tracking data collection will focus efforts, to the extent practical, within river segments in which there are known bathymetric and velocity data. Of particular interest will be the river segments immediately downstream of Zosel Dam (Figure 2), near the cross channel confluence of the Okanogan River and the Similkameen Rivers, and downstream of two major steelhead smolt producing tributaries (Keith Kistler, Colville Confederated Tribes, Pers. Comm.). When not available, velocity data will be collected over a range of outflow conditions.

SMB and NPM will be captured initially using electrofishing, seine, or hook and line methods from the aforementioned radio tag segments. A minimum of six healthy fish, each greater than 300 mm in length, from each segment will be sampled. NPM are the preferred species, but if insufficient numbers are available, SMB will be substituted. Each candidate fish will be anesthetized with carbon dioxide, weighed, measured, have a radio tag surgically inserted into their body cavity, have the wound sutured, and, last, be placed into a recovery tank for monitoring over a period of no less than 1 hour.. Upon recovery, each tagged fish will be returned to the approximate location in which it was captured.

Movement of these tagged fish will be observed using a network of stationary receivers as well as periodically utilized boat-mounted or automobile-mounted radio receivers. Fixed radio receivers will be positioned in optimal locations for relative position at the three segments identified. Up to four receivers will be deployed at each segment. The receiver network will be calibrated using a manually controlled radio tag which is recorded at regular intervals and moved throughout the sampling area by a boat with known horizontal position. Radio tag tracks will be recorded continuous by the fixed receivers and during biweekly site visits by portable receivers in boats or automobiles. Individual tag tracks will be unique to the particular fish in which the tags were implanted.

At bi-weekly intervals, during each site visit to the three sample segments, tagged fish will be recaptured during the fish capture activities associated with the population and stomach content assessments. They will be physically separated from the other untagged fish and have their stomach contents purged using the lavage technique. Samples will be individually stored for later analysis. Sampled fish will be placed into the on-board recovery tank following the procedure, then released back the river in the same general location as they were captured. Again, unhealthy fish or those not recovering quickly will be rejected if necessary to maintain future sample viability.

Also during the bi-weekly sampling site visits, flow velocity will be recorded throughout the study area using a portable Acoustic Doppler Velocimeter (ADV) and highly accurate GPS locating unit suitable for use in moving boats. These velocity data will be correlated with current conditions of flow as recorded by available gages along the river. Up to 50 individual measurement points may be specified within each of the three study reaches. Also, river flow and water temperature data will be collected from existing gauge and data sites operated by the USGS, the Washington Department of Ecology, and/or other entities.

At the conclusion of the study, radio tag tracking data will be evaluated with the velocity and water temperature data, as well as stomach contents, to determine the particular foraging habits and behavior of the tagged fish.

2.5 PREDATOR POPULATION ASSESSMENT

Predatory fish populations will be assessed using boat electrofishing (400 volts at 3-5 amps, and 30 Hz, Erick Van Dyke, Oregon Department of Fish and Wildlife, Pers. Comm.) according to a sampling regime stratified by reach and section. A survey will be conducted using two boats, one on each bank, and fishing downstream in tandem. Each boat will have a GPS unit with an uploaded map of sections. Alternative methods (seine, tangle net) may be used for specific types of habitat where electrofishing is not sufficiently effective, although hook and line methods will be avoided for NPM due to this species tendency to regurgitate stomach contents (Erick Van Dyke, Oregon Department of Fish and Wildlife, Pers. Comm.). Observance of other predator fish species (of which there are expected to be few, John Arterburn, Colville Confederated Tribes, Pers. Comm.), percentage of habitat type (pool, riffle, run, substrate, cover) within a section, and seconds of electrofishing pedal time will be recorded. A specific electroshocking procedure will be developed and electroshocking rules and regulations will be investigated at a later time.

A WDFW scientific fish collection permit will be obtained for sampling activities and sample collection. ESA summer steelhead juveniles and adults will likely be in the study area during sampling, so protocols will be adjusted according to the terms of the permit.

During the pilot study (2010), every reach of the Okanogan River will be examined uniformly in order to determine the reaches with a large population of predators (Table 1). Over the course of 10 sampling days, the northern most of the five sections (section one) within each of the 33 reaches will be sampled. The next ten sampling days will consist of the adjacent southern section (section 2) of each reach. Systematically sampling among groups of identically numbered sections will continue for 50 sampling days until all five sections within each reach are complete. Twenty percent of the river is sampled with each pass of the river and, after five passes, the entire river is sampled.

Previous redd surveys have determined ten portions of the river which can be covered in a day's time (Table 1). Each area is a different length as certain portions of the river take a longer time than others to pass due to variable velocity and depth (John Arterburn, Colville Confederated Tribes, Pers. Comm.). The sections also differ in length between reaches and therefore the number of sections sampled in a day will vary. The access points do not fall directly on reach boarders and GPS units will be used to find reach and section borders. Sampling areas begin and end with an access point (Brian Miller, Colville Confederated Tribes, Pers. Comm.) and will be used in this study for logistical purposed with no biological significance. During the redd surveys, many suspected spawning SMB beds were observed and it is believed that feeding may be concentrated at these locations. Catch at these beds will be noted in order to investigate whether the observed depressions overlap with catch of bass.

Sampling will occur according to an "every other" Monday through Friday schedule (Table 1) or a "two week on, two week off" schedule in which fish are sampled Monday through Friday over two consecutive weeks followed by two weeks of no sampling. Both schedules would allow for non-sampling periods to organize supplies, review previously collected data, and provide an opportunity make up sampling effort missed due to unforeseen circumstances. The "every other" schedule would provide a greater spread of sampling days throughout the study period than the "two week on, two week off" schedule. Therefore, the "every other" schedule would leave less chance of missing and important biological event such as fish migration or a shift in predator diet. The "two week on, two week off" schedule would result in more simultaneous data collection from reaches than the "every other" schedule. Also, the "two week on, two week off" schedule results in a lower probability than the "every other" schedule of having to fill an entire block of non-sampling days (two weeks versus one week) with make-up sampling days. The schedule to be used will be determined at a later time.

It is assumed that multiple reaches sampled in the pilot study (2010) will produce very few fish. In the first study year (2011), these reaches will be excluded with a threshold developed upon data analysis. With less reaches to be sampled, data precision and accuracy can be improved by increasing the number of sampling sessions within reaches and sections with a larger number of predators. For instance, if half of the 33 reaches sampled in the pilot study have very few predators and are omitted in the first study year (2011), then each reach can be sampled twice creating roughly the same amount of effort as in the pilot study (2010). Systematically sampling among groups of identically numbered sections will still occur as in the pilot study (2010) but will be repeated twice in this scenario. With this schedule, no section will be sampled twice within five days (Fresh et al. 2003).

During the second study year (2012), precision and accuracy will be increased even further. Specific section in each reach with the greatest number of predators will be chosen as index sections and receive a greater sampling effort. The number of index sections and sampling events at sections will be determined upon first study year (2011) data analysis. For example, if two index sections are chosen per reach, then they may be sampled 16 times while the non index sites are sampled six times. The overall number of sampling events has not changed from the previous year but the focus has shifted. Another systematic sampling schedule will have to be developed for this year as there are no longer a consistent number of sampling events at all sections. This new schedule will involve frequent and consistent sampling of index sites and provide fish data for a temporal examination of population and consumption changes.

Mark and recapture will be the primary method for estimating predator population abundance. The Bayes sequential model (Gazey and Staley 1986) will be applied to the time and space stratified mark-recapture data to estimate mean and 95% Highest Probability Density bounds. Mark-recapture estimates may not be robust in a study such where fish movement is potentially extensive (Karl English, LGL Limited, Pers. Comm.) or the population is sparse, but the model can be adjusted for these conditions. Model assumptions will be evaluated by assessment of the successive posterior distributions. Alternative models will be considered depending on the distribution and abundance of the predator populations.

Catch rate (length-of-shoreline based surveys) of SMB and NPM will be used as the secondary method to index predator population abundance. Catch rate will be calculated as the number of predators captured (by species), divided by the distance of river sampled and will be presented as the number of fish per kilometer. Catch data by section will be combined where appropriate as based on variance and extrapolated to the sampling area. Further, catch rate as based on sampling effort (electrofishing time on) will also be evaluated. These methods have the advantage of not requiring tags and do not need to meet the assumptions of using mark-recapture models. However, this method does use the fundamental assumption that the observed densities of predators at sampled locations are representative of the areas to which the densities are extrapolated.

Target fish will include smallmouth bass longer than 100 mm and NPM longer than 200 mm as these are the approximate lengths at which each species become piscivorous (Poe et al. 1991; Fritts and Pearson 2006; Vigg et al. 1991; Naughton 2004). Target fish will be measured for length and weight to obtain information on size distribution. Size selectivity of electrofishing will assumed to be negligible over the targeted fish size range (Erick Van Dyke, Oregon Department of Fish and Wildlife, Pers. Comm.).

Full-duplex PIT tags will be used for marking predators. Tagged fish will be released in proximity to the location in which they were captured. Fish will be marked continuously over the study period and previously marked fish will be recorded as recaptures. These types of tags have the added benefit of being observable in video collected at Zosel Dam.

For both SMB and NPM, a minimum of 780 tags will be targeted for release and a minimum of 766 marked fish will be recaptured. These targets for marks applied and fish examined were determined based on sample size formulas for mark-recapture experiments (Robson and Regier, 1964). The targets are based on population estimates of 25,000 for both SMB and NPM in Strata

2 and an accuracy goal of ±50% on 95% precision confidence bounds. The SMB population estimate is based on the estimated number of bass per mile (>150 mm) in the lower Yakima River, WA (Fritts and Pearsons, 2006). The NPM population estimate is based on the estimated number of pikeminnow (>300 mm) per mile in the lower Chehalis River, WA (Fresh et al. 2003). These two rivers are comparable to the Okanogan River in maximum and minimum discharge profiles and support salmon populations. A specific tagging procedure will be developed at a later time.

In the pilot study (2010), a minimum of seven fish per species per kilometer will be targeted to mark (780 target tags / 118.70 km Strata 2 = 6.57 tags/km) which equals 831 tagged individuals (6.57 tags/km x 118.70 km Strata 2 = 830.97 target tags). Two hundred and eleven SMB (Fritts and Pearsons, 2006) and NPM (Fresh et al. 2003) are estimated to be in each kilometer of the Okanogan River (25000 fish / 118.70 km = 210.61 fish/km.). It is predicted that roughly 3% (Karl English, LGL, Pers. Comm.) of all fish, or seven fish, per kilometer will be collected through electrofishing efforts (25000 fish x .03 / 118.70 km = 6.32 fish/km.). This estimate of catch is sufficient to facilitate the seven fish per kilometer target. Target tag calculations for the first and second study year (2011 and 2012) cannot be calculated at this time as estimated fish populations and fish per kilometer may be altered based on the previous year's data and the number of kilometers to be sampled may change. Extra sampling days at sections may be required to meet the targeted number of mark and recapture. Additional days will not be incorporated into the pilot data (2010).

Descriptive statistics will be calculated for SMB and NPM populations within Strata 2 of the Okanogan in order to summarize data. Predator size frequency distributions will also be developed for each reach. Habitat type, fishing effort, and number of fish caught will be used to calculate densities of predators. Habitat percentages will also be correlated with fish densities to determine predator substrate preference. Mark and recapture will be analyzed using the Bayes open population models (Gazey and Staley 1986) in Program MARK to confirm the area based population estimates.

2.6 PREDATOR STOMACH CONTENT ASSESSMENT

During the pilot study (2010), one fish per day will be retained for an "in boat" stomach content analysis. These fish will be weighed, have their lengths and weights measured, and then be euthanized in MS222. Body cavities will be cut open and entire digestive tracts contents will be removed and visually examined. Empty stomachs or a percentage of stomach content estimates by phylum will be noted. Presence of salmon by species will also be noted if possible. The lavage technique will not be utilized because food is often left in the stomach and therefore underestimates total consumption. It is predicted that roughly 50% of stomachs will be empty. If this is the case, subsequent fish will be sampled until stomach contents are found within at least one fish. This will ensure sufficient stomach observations to assess contents. A specific stomach sampling procedure will be developed at a later time.

During the first and second study year (2011 and 2012), a minimum sample each year of 200 SMB and NPM will be retained for stomach content analysis. The number of stomach samples to take was derived from previous studies (Karl English, LGL, Pers. Comm.) and has been spread throughout the sampling periods so that a temporal aspect of diet shifts can be investigated. Stomach sampling effort is subject to change based upon pilot year (2010) results. The 200 fish will be divided by the number of kilometers retained from the previous year's study in order to calculate how many stomach samples to obtain per kilometer and section. These stomach samples will be placed in ethanol for analysis at a later time. Again, if all fish sampled for a section have empty stomachs, subsequent fish will be sampled until stomach contents are found within and collected from at least one fish. This will ensure sufficient stomach contents for a thorough diet analysis. If the beginning or end of SMB or NPM's predation on juvenile salmon is not observed during the sampling period, sites may be visited again in September to determine prey in the absence of juvenile salmon.

Stomach contents will be analyzed in a laboratory. Identifiable food items will be sorted and enumerated (to species if possible) and salmon will be measured for length to determine year class. Sub-yearling and swim up Chinook and multiple year class steelheads are anticipated in the samples (John Arterburn, Colville Confederated Tribes, Pers. Comm.). Macroinvertebrates and zooplankton will also be identified and sorted by family with the use of a dissecting scope. Unidentifiable digested matter will be classified as "other". The soft tissue of partially digested unidentifiable food items will be digested in a pancreatin (8x porcine digestive enzyme) solution. With the use of the dissecting scope, characteristics of the remaining diagnostic bones, such as vertebrae, cleithra, dentaries, and opercles shape, can be used to distinguish between salmonid and non-salmonid fish (and between species if possible) (Fritts and Pearsons, 2006; Frost 2000; Hansel et al. 1988). This method is particularly useful for northern pikeminnow as they have a non-acidic digestive system and bones are left undamaged (Frost 2000). A specific stomach content analysis will be developed at a later time.

Salmon length will be characterized weekly from salmon captured in annual rotary trap surveys performed by the CCT. Descriptive statistics of salmon found in predator stomachs and salmon found in rotary trap will be compared to determine if predators have a preference to salmon species and year class. Numerical percentage, weight percentage, and percent frequency of occurrence of salmon found in predator stomachs will be combined into a hybrid index of relative importance to predator diet. This calculation reduces biases associated with each of the individual calculations (Bowen 1983).

2.7 PREDATOR CONSUMPTION ASSESSMENT

The *Bioenergetics Model 3.0 for Windows* from the University of Wisconsin (Hanson et al. 1997) will be used to determine consumption rates of salmon by SMB and NPM. This model utilizes data entered by the user (Table 4) and parameters from the program's database to calculate a variety of values including growth and consumption rate and weight for cohorts and the entire population. Smallmouth bass physiological parameters are already within the database but will be updated if found necessary (Hyslop 1980; Whitledge 2002; Whitledge 2003). Physiological parameters for NPM will be obtained from other sources (Zorich 2004; Petersen 1999) as they are not within the database. Many prey energy densities are not in the database and will have to be found in the existing literature. Sensitivity of this program will be determined with fake data prior to study commencement.

Consumption estimated can be compared to salmon out-migration estimates, as determined from rotary trap surveys performed by the CCT, to assess whether or not a substantial number of juvenile salmon are being consumed by SMB and NPM. In addition, the specific year classes of salmon being consumed and the date at which consumption began can be determined. These results can be used to develop fisheries management strategies for the Okanogan River.

2.8 DATA GAP ANALYSIS

All available information (grey and white literature) on the Okanogan River, including the Canadian portion of the study area, will be complied and reviewed to determine what is known about the abundance, distribution and consumption of juvenile salmon by predatory fish and birds. Additional personal contacts will be made with past and current researchers and agencies in the Okanogan River to identify unpublished data for the region. Data gaps will be identified as critical or non-critical and any assumptions that were made in the collection or processing of data will be identified to aid in the development of standardized sampling protocols.

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4.0 TABLES

Table 1. Reach, section, and sampling area descriptions and "every other" week schedule.

Reach Name (in sampling order)	EDT Description	Length (km)	Section length (km)	Target tags per sect per species	Sum of sections within sample (km)	Survey area name	Sampling Schedule				
							Section 1	Section 2	Section 3	Section 4	Section 5
SR05	RR crossing at increased confinement segment to Enloe Falls (not dam yet)	3.311641	0.662328	5							
SR04	Beginning of valley confinement to the RR crossing at increased confinement	1.609087	0.321817	3							
SR03	Kay Street to the beginning of valley confinement (1.5 miles upstream)	1.848910	0.369782	3	3.012404	S1/S2	4/5	5/3	5/31	6/28	7/26
SR02	Just above N. backflow channel to Kay Street (river bend at Peninsula)	2.158104	0.431621	3							
SR01	Confluence with Okanogan to backflow channel	6.134280	1.226856	8							
BF	East end of channel to West end of channel	0.645794	0.129159	1							
OR28b	Backflow channel reach to the confluence of Tonasket creek	1.894257	0.378851	3	1.180378	O7	4/6	5/4	6/1	6/29	7/27
OR28a	Confluence with Okanogan below Eyhott Island to N. backwater channel	3.361840	0.672368	5							
OR27	Below Horseshoe Lake RM 69.5 to the confluence with Similkameen	7.909700	1.581940	10	1.581940	O6	4/7	5/5	6/2	6/30	7/28
OR26b	Okanogan 26h release point to below Horseshoe Lake at RM 69.5	8.441395	1.688279	11							
OR26a	Mouth of Whitestone creek to Okanogan 26h hatchery release point	2.014768	0.402954	3							
OR25	Mouth of Antoine creek to the mouth of Whitestone creek	2.022834	0.404567	3	3.945998	O5*	4/8	5/6	6/3	7/1	7/29
OR24	Mouth of Siwash creek to the mouth of Antione creek	6.317122	1.263424	8							
OR23	Mouth of Bonaparte creek to the mouth of Siwash creek	0.933869	0.186774	2							
OR22	Mouth of Aeneas creek to Bonaparte creek	7.084012	1.416802	9	2.199424	O5	4/9	5/7	6/4	7/2	7/30
OR21	Chewiliken to the mouth of Aeneas creek	3.913109	0.782622	5							
OR20	Janis Rapids to Chewiliken	0.339762	0.067952	1							
OR19	Upper end of mainstem constriction point to Janis Rapids	2.612893	0.522579	4							
OR18	McLouglin Falls to upper end of mainstem constriction point	0.635109	0.127022	1	2.088615	O4	4/19	5/17	6/14	7/12	8/9
OR17	Point of constriction above Barker to McLoughlin Falls	1.928276	0.385655	3							
OR16	Mouth of Tunk creek to point of constriction past orchards above Barker	4.186609	0.837322	6							
OR15	Southermost mid channel island/bar below McAllister rapids to Tunk Creek	0.740426	0.148085	1							
OR14	Wannacut to southermost mid channel island/bar below McAllister rapids	15.554451	3.110890	20	4.081120	O3	4/20	5/18	6/15	7/13	8/10
OR13	Omak Creek Mouth to mouth of Wannacut Creek	4.851150	0.970230	7							
OR12	Sewage disposal site near RM 30 to the mouth of Omak Creek	3.320587	0.664117	5							
OR11	Pumping station by hospital in Okanogan to right bank sewage disposal site	2.055425	0.411085	3							
OR10	Oak St. Bridge in the town of Okanogan to Pumping Station near Hospital	5.062557	1.012511	7	2.928894	O2	4/21	5/19	6/16	7/14	8/11
OR09	Mouth of Salmon Creek to the Oak Street Bridge in the town of Okanogan	0.489445	0.097889	1							
OR08	Cornett roperty to mouth of Salmon Creek	3.716454	0.743291	5							
OR07	Barnholt Loop to the Cornett property	2.871754	0.574351	4							
OR06	Mouth of Tallant Creek to Barnholt Loop	3.592735	0.718547	5	2.112026	O1*	4/22	5/20	6/17	7/15	8/12
OR05	Mouth of Loup Loup to mouth of Tallant Creek	4.095639	0.819128	6							
OR04	Mouth of Chilliwist Creek to Mouth of Loup Loup Creek	3.047200	0.609440	4	0.609440	O1	4/23	5/21	6/18	7/16	8/13
Totals:	**33 Sections**	**118.701194**	**23.740239**	**165**	**23.7402388**	**10 Areas**			**50 Days**		

Table 2. Juvenile Salmon of the Okanogan River. Data from Johnson and Rayton (2007) and Rayton and Arterburn (2008).

Characteristic / Species	**Sub-yearling Chinook**	**Yearling Chinook**	**Sockeye**	**Sockeye**	**Steelhead**	**Steelhead**
Origin	natural origin, summer run, Similkameen	hatchery origin, summer run, Similkameen	natural origin, Osoyoos Lake	hatchery origin, Skaha Lake	natural origin, Okanogan	hatchery origin, Okanogan
Population Size	400k to 1.1 mill	270k	1.5 mill	140k	7k - 14k	97k
Migration Timing	May-June	late April-early June	May	April	mid April-mid June	May
Size (a)	54 mm	133 mm	100 mm	140 mm	155 mm	200 mm
Age	0+	1+	1+	1+	1+, 2+, 3+, 4+	1+

(a) unpublished data, rotary trap catch, Colville Tribes 2008 & 2009

Table 3. Strata 2 project task schedule

	Feb	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
2010										
Organize equipment, schedules, and protocols	X	X								
Abundance estimate										
Mark and recapture			X	X	X	X	X			
Calculate abundance							X	X		
Consumption estimate										
Observe stomach contents			X	X	X	X				
2011										
Organize equipment, schedules, and protocols	X	X								
Abundance estimate										
Mark and recapture			X	X	X	X	X			
Calculate abundance							X	X		
Consumption estimate										
Collect fish for stomach contents			X	X	X	X	X			
Analyzing stomach contents			X	X	X	X	X			
Calculate consumption							X	X	X	
2012										
Organize equipment, schedules, and protocols	X	X								
Abundance estimate										
Mark and recapture			X	X	X	X				
Calculate abundance							X	X	X	
Consumption estimate										
Collect fish for stomach contents			X	X	X	X				
Analyzing stomach contents			X	X	X	X				
Calculate consumption							X	X	X	
Generate report								X	X	X

Table 4. Bioenergetics 3.0 input required from user

Input	**Data Source**
Dates of sampling	Collected in Field
Water temperature for each day of sampling period	Collected in Field
Weight of fish on first day of sampling	Collected in Field
Weight of fish on last day of sampling	Collected in Field
Proportion of each prey species in stomach for each stomach sampling day	Determined in Lab
Prey energy density for each stomach sampling day	Existing literature; Bioenergetics 3.0 manual
Predator energy density for each stomach sampling day	Existing literature; Bioenergetics 3.0 manual

5.0 FIGURES

Figure 1. Three primary strata in the study area.

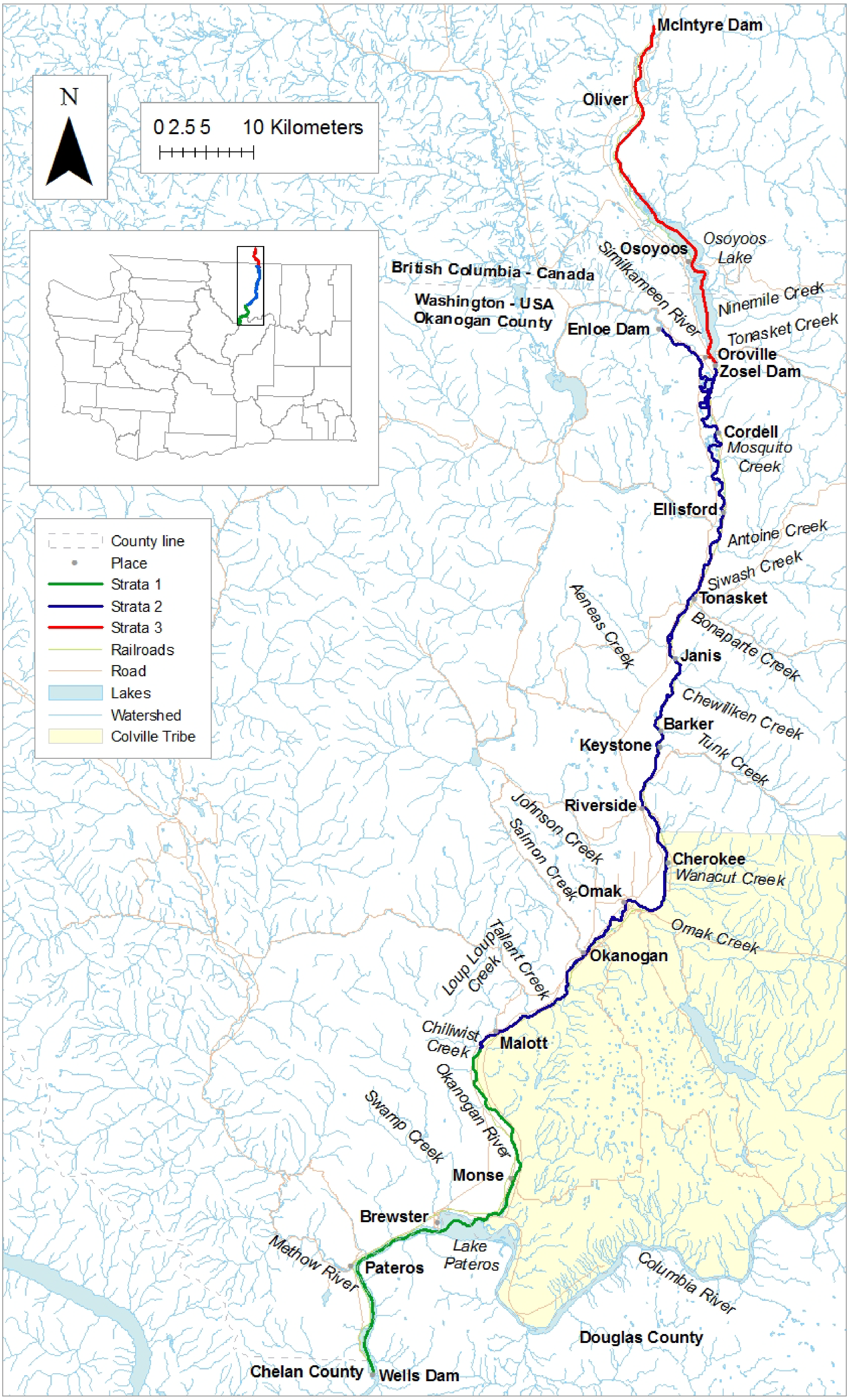

Figure 2. Section 1, Chillowist, WA to Zosel Dam in Oroville, WA, divided and sequentially numbered into sample reaches and sampling areas.

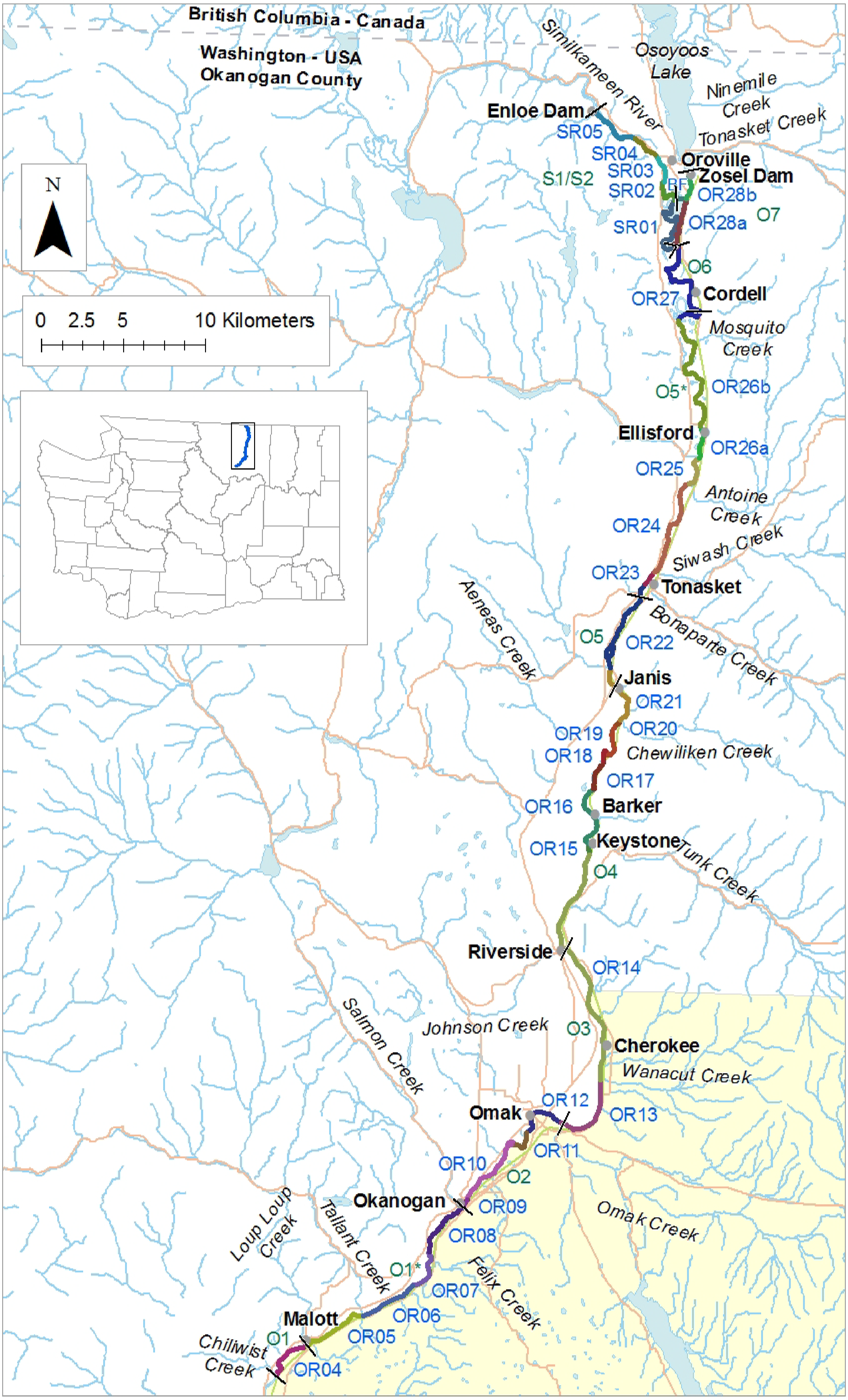

Figure 3. Map legend for Section 1, Chillowist, WA to Zosel Dam in Oroville, WA.

BF01, East end of channel to West end of channel.
OR04, Mouth of Chilliwist Creek to Mouth of Loup Loup Creek
OR05, Mouth of Loup Loup to mouth of Tallant Creek
OR06, Mouth of Tallant Creek to Barnholt Loop
OR07, Barnholt Loop to the Cornett property
OR08, Cornett roperty to mouth of Salmon Creek
OR09, Mouth of Salmon Creek to the Oak Street Bridge in the town of Okanogan
OR10, Oak St. Bridge in the town of Okanogan to Pumping Station near Hospital
OR11, Pumping station by hospital in Okanogan to right bank sewage disposal site
OR12, Sewage disposal site near RM 30 to the mouth of Omak Creek
OR13, Omak Creek Mouth to mouth of Wannacut Creek
OR14, Wannacut to southermost mid channel island/bar below McAllister rapids
OR15, Southermost mid channel island/bar below McAllister rapids to Tunk Creek
OR16, Mouth of Tunk creek to point of constriction past orchards above Barker
OR17, Point of constriction above Barker to McLoughlin Falls
OR18, McLouglin Falls to upper end of mainstem constriction point
OR19, Upper end of mainstem constriction point to Janis Rapids
OR20, Janis Rapids to Chewiliken
OR21, Chewiliken to the mouth of Aeneas creek
OR22, Mouth of Aeneas creek to Bonaparte creek
OR23, Mouth of Bonaparte creek to the mouth of Siwash creek
OR24, Mouth of Siwash creek to the mouth of Antione creek
OR25, Mouth of Antoine creek to the mouth of Whitestone creek
OR26a, Mouth of Whitestone creek to Okanogan 26h hatchery release point
OR26b, Okanogan 26h release point to below Horseshoe Lake at RM 69.5
OR27, Below Horseshoe Lake RM 69.5 to the confluence with Similkameen
OR28a, Confluence with Okanogan below Eyhott Island to N. backwater channel
OR28b, Backflow channel reach to the confluence of Tonasket creek
SR01, Confluence with Okanogan to backflow channel
SR02, Just above N. backflow channel to Kay Street (river bend at Peninsula)
SR03, Kay Street to the beginning of valley confinement (1.5 miles upsteam)
SR04, Beginning of valley confinement to the RR crossing at increased confinement
SR05, RR crossing at increased confinement segment to Enloe Falls (not dam yet)
Railroad
Road
Watershed
Lakes
Colville Tribe Land
County Line
Sampling Area (O1-O7, S1/S2)
Place

6.0 ANNOTATED BIBLIOGRAPHY

Citation

Naughton, G. P., D. H. Bennett, and K. B. Newman. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. North American Journal of Fisheries Management 24:534-544.

Geographic Location

Lower Granite Reservoir, Snake River, is in Southeastern Washington

Purpose

Estimate the number of smallmouth bass and quantify their consumption of juvenile salmon and steelhead in the tailrace and forebay of the lower granite dam, and compare these results with those for the free-flowing to impoundment transitional areas in the Snake and Clearwater River areas of the upper Lower Granite Reservoir.

Relevant facts

Length of smallmouth when they switch from eating insects to fish; explanation of bioenergetics, fish collection, and stomach content analysis

Conclusion

Juvenile salmon were not a major prey of smallmouth bass at any location in either 1996 or 1997. Highest percentage of consumption in smallmouth between the sites diet was 11%. High amount of variability between years due to water temp, flow and tubidity.

Citation

Fritts, A.L., and T.N. Pearsons. 2006. Effects of predation by nonnative smallmouth bass on native salmonid prey: The role of predator and prey size. Transactions of the American Fisheries Society 2006 135:853-860.

Purpose

Provide detailed information about the minimum, average, and maximum sizes of prey fish consumed by smallmouth bass and the per capita and population consumption of salmonids by different sizes of smallmouth bass in the lower Yakima River. Discuss the potential predation risks to salmonids posed by nonnative smallmouth bass and compare these risks to those posed by northern pikeminnow.

Geographic Location

The Yakima River is a Columbia River tributary located in south-central Washington State

Relevant facts

Most of the salmonids were consumed by smallmouth bass smaller than 250 mm, and the vast majority was consumed by smallmouth bass smaller than 300 mm (mean of 83.6% over the 5-year period). Salmonids were less common in the guts of larger smallmouth bass than in the guts of smaller individuals. Length of salmonids consumed by smallmouth bass decreased with increasing predator length. The mean relative length of salmonids consumed by smallmouth bass was 25.0%. The size range of salmonids consumed by smallmouth bass was 22–153 mm, and the mean size consumed was 59 mm. Covered mark-recapture, stomach sampling, and bioenergetics.

Conclusion

After piscivory begins in bass, number of salmon consumed decreased with an increase in predator size. For pikeminnow, these are positively correlated. Smallmouth bass become piscivorous approximately 2 or 3 years earlier than do northern pikeminnow.

Citation

Vigg, S., T. P. Poe, A. L. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Geographic Location

John Day Reservoir on the Columbia

Purpose

Document the feeding ecology of northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, quantifying the diets of these four predators temporally and spatially, and evaluating predation dynamics with respect to out-migrations of juvenile salmonids.

Relevant facts

The importance of fish in northern squawfish diets increased with the predators' length Fish shorter than 200 mm ate mainly ephemeropterans and hymenopterans (41.2-90.5%). As they grew, the predators switched first to crayfish and then to fish. Salmonids composed 21% of the diet of 300-mm northern squawfish and 83% of the diet of the larger fish. Crustaceans (crayfish and amphipods) were the most important food of smallmouth bass 50-100 mm long, accounting for 57% of the diet. Smallmouth bass longer than 100 mm began switching to fish as the major dietary component and the importance of crayfish decreased as predator size increased. Also covered fish sampling and stomach contents analysis.

Conclusion

Of the four predator species studied, only northern squawfish included juvenile salmonids as a dominant food during salmonid emigrations through John Day Reservoir. They also found that the areas near the dams were the locations where northern squawfish predation on juvenile salmonids was most intense. The walleye was the second most important predator on juvenile salmonids, followed by channel catfish. Diet composition indicated that the smallmouth bass was the least important predator on juvenile salmonids (4% by number overall) emigrating through John Day Reservoir. Northern squawfish and, to a lesser degree, channel catfish, were the only predators that preferred juvenile salmonids more during their peak migratory densities. Northern squawfish consistently consumed more juvenile salmonids from the smaller size-groups available, especially in April, May, and August.

Citation

Scholz. 2009. Analysis of walleye, smallmouth bass and burbot food habits in the San Poil River to determine the number of stocked kokanee and naturally produced rainbow trout consumed by their populations. Unpublished.

Purpose

Determine walleye and smallmouth bass population abundance in the inundated section of the San Poil River, determine walleye, smallmouth bass and burbot food habits using traditional methods (numerical percentage, weight percentage, frequency of occurrence, and index of relative importance), determine total consumption of individual types of prey in the diets of walleye, smallmouth bass, and burbot by applying specific bioenergetics models, combine the above data to determine the total biomass (number) of each type of prey consumed by each predator. Particular attention will be focused on the number (biomass) of kokanee and rainbow trout consumed by each predator. Total consumption of kokanee and rainbow trout by all predators combined will be compared to the number of hatchery kokanee released into the San Poil drainage and the number of rainbow trout estimated to have migrated down the San Poil River (data provided by the CCT).

Geographic Location

The inundated section of the San Poil River

Relevant facts

Looked at for study design example. Methods: fish collection, stomach content, fish consumption.

Conclusion

n/a: proposal

Citation

Fresh, K. L. and S. L. Schroder. 2003. Predation by northern pikeminnow on hatchery and wild coho salmon smolts in the Chehalis River, Washington. North American Journal of Fisheries Management, 23:1257-1264

Purpose

Test the hypothesis that northern pikeminnow predation was responsible for the low smolt-to-adult survival rates of Chehalis River coho salmon. A secondary objective was to ascertain if northern pikeminnow predation could account for the 2–4 times higher survival rates that wild coho salmon smolts have compared with those of hatchery coho salmon smolts in the basin.

Geographic Location

Chehalis River basin, Washington

Relevant facts

Methods included Number of smolts eaten calculation, digestive tract analyses, mark-recapture (justification for eaiting 5 days inbetween) with population estimates, and calculating ET90%. Coho salmon smolts were the most frequently occurring fish species in northern pikeminnow digestive tracts and were found in 12.6% of northern pikeminnow in 1988 and 3.5% in 1989.

Conclusion

The results of this study suggest that predation by northern pikeminnow in the Chehalis River below rkm 82 during the April–May smolt migration period was not the primary factor responsible for the low smolt-to-adult survival rates of coho salmon in this basin. The hatchery-produced salmonids are more vulnerable to predation by northern pikeminnow.

Citation

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.

Purpose

To describe the use of diagnostic characteristics of selected bones to identify prey fishes obtained from predator stomachs and to estimate original prey size from measurements of selected bones.

Geographic Location

Fish were collected in John Day Reservoir on the Columbia or were obtained from fish hatcheries.

Relevant facts

The cleithrum was diagnostic for all genera except those of the Salmonidae, in which steelhead could not be distinguished from the three salmon species. The cleithra of salmonids are crescent-shaped and expanded along most of both limbs. Genera within a family can also be distinguished on the basis of the leithra. Dentaries were diagnostic for all genera. Dentaries were useful in distinguishing the three salmon species from steelhead; the dentary was wider and its ventral limb was relatively longer in the steelhead than in the salmons. Other diagnostic characters of dentaries were the general shape, presence, and distribution of teeth (e.g., single row of canine teeth in steelhead versus a cardiform pad in species of Ictalurus). Opercles, though diagnostic for all families and most genera, were less resistant than other bones to digestion. Cleithra and dentaries were more persistent in the stomach contents of predators and served as the best means of identifying prey fishes. The cleithrum, because it is relatively large and is one of the first diagnostic bones to develop, was generally the most useful bone for identifying youngof-year fishes.

Conclusion

Results suggest that the identification and measurement of cleithra, dentaries, opercles, and pharyngeal arches of prey species provide an easy and reasonably accurate method of estimating original length of prey fish in partly digested remains. This method may enable investigators to gain useful information that might otherwise be lost when prey fish lengths cannot be obtained by direct measurement.

Citation

Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L.A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Purpose

Document the feeding ecology of northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, quantifying the diets of these four predators temporally and spatially, and valuating predation dynamics with respect to out-migrations of juvenile salmonids.

Geographic Location

John Day Reservoir of the Columbia River

Relevant facts

Methods include fish sampling and stomach content analysis. The importance of fish in northern squawfish diets increased with the predators' length. Fish shorter than 200 mm ate mainly ephemeropterans and hymenopterans (41.2-90.5%). As they grew, the predators switched first to crayfish and then to fish. Salmonids composed 21% of the diet of 300-mm northern squawfish and 83% of the diet of the larger fish. Smallmouth bass longer than 100 mm began switching to fish as the major dietary component and the importance of crayfish decreased as predator size increased.

Conclusion

As judged by the dietary composition and prey selectivity of the four predators studied, the northern squawnsh was clearly the major predator on juvenile salmonids in John Day Reservoir. Channel catfish were also important in spring in the upper reservoir. Walleyes and smallmouth bass appeared to select salmonids only when their distributions overlapped that of subyearling Chinook salmon. Size-selective predation by northern squawfish may also play an important role in reducing survival of the smaller individuals within each run of out-migrating juvenile salmonids.

Citation

Mesa, M., J. Beeman, T. Counihan and D. Burgess. 2009. Predator-prey interaction of fishes within the Priest Rapids Project. Unpublished.

Purpose

Increase understanding of predator prey interactions within the Priest Rapids project.

Geographic Location

Priest Rapids project area

Relevant facts

Looked at for study design example. Proposing to use mark recapture, bioenergetics modeling (Bioenergetics 3.0), and stable isotopes.

Conclusion

n/a: proposal