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1997-99 Evaluation of Juvenile Fall Chinook Stranding on The Hanford Reach 1997 Interim Report

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1997-99 Evaluation of Juvenile Fall Chinook Stranding on The Hanford Reach

1997 Interim Report

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EXECUTIVE SUMMARY

Pilot work was conducted in 1997 to aid in the development of the study plan for the 1998 Evaluation of Juvenile Fall Chinook Stranding on The Hanford Reach. The objectives of the 1997 work were to: 1) identify juvenile chinook production and rearing areas and to assess and classify the type and amount of habitat present in these areas, 2) identify sampling sites and develop the statistical parameters necessary to complete the study, 3) develop a study plan to determine the effects of power peaking on the benthic community of the Hanford Reach, 4) conduct field sampling activities under normal power peaking operations throughout the fall chinook emergence and rearing period and on two controlled river elevation reduction test days, and 5) determine specific schedules for controlled river elevation reduction tests.

Equipment and supplies were purchased or borrowed and personnel were recruited, hired, and trained for the 1997 work. Field sampling of entrapment and nearshore areas began on May 7 and concluded on July 28. Resident fish and chinook were captured with seines, identified, counted, and measured. Microhabitat surveys of entrapment areas were conducted in conjunction with the United States Geological Survey Biological Resource Division (BRD) from September 4 through October 23. An unsteady flow model was created by Pacific Northwest National Laboratories (PNNL) and used to determine the stage/discharge relationship between Priest Rapids Dam and all points located downstream on the Hanford Reach. Historical hourly discharge data for Priest Rapids Dam, redd count data, and juvenile chinook capturing records were obtained and analyzed. The feasibility of conducting an evaluation of diel water fluctuation effect on benthic macroinvertebrates was assessed by Streamside Programs Consultation (SPC) and the University of Idaho Department of Fish and Wildlife (Uof I).

The Hanford Reach was stratified into six gross habitat categories for the purpose of establishing 1998 sampling sites (Objective 1). Juvenile chinook production areas were identified. Identification of chinook rearing areas is in progress. Specific sample site selection (Objective 2) is also in progress and will be based upon review of historical rearing information and preliminary field sampling activities conducted in 1998. A benthic macroinvertebrate evaluation was determined to be feasible and a study plan was drafted (Objective 3). Both resident fish and juvenile chinook appeared to be susceptible to stranding and entrapment (Objective 4). Due to exceptionally high spring river flows, the two controlled river elevation reduction tests were not completed (Objective 4) and the opportunity to assess stranding in cobble substrate did not occur. A 50 kcfs controlled river elevation reduction test schedule and protocol were developed to be implemented in 1998 each Saturday beginning April 11 and concluding June 27 (Objective 5).

Chinook appeared to be most susceptible to entrapment at the earliest stages of rearing and less so as they increased in size. A size threshold (81 mm) was identified at which chinook susceptibility essentially ends. Thermal stress and thermal shock appeared to be the primary source of chinook mortality in entrapment areas. Chinook and resident fish demonstrated evidence of specific habitat preference and were generally segregated. Some species of resident fish appeared to be most susceptible as spawning adults or newly hatched fry. Fish, mammal, and bird predation in entrapment areas was minimal.

Based upon the results of the 1997 pilot work it is recommended that: 1) sampling should be conducted in 1998 under both controlled conditions and normal operations throughout the fall chinook emergence and rearing period, 2) thermal profiling of entrapment areas should be conducted, 3) the BRD should be subcontracted to assess the effect of both delayed mortality and reduced performance ability of juvenile fall chinook exposed to warm water and thermal shock in entrapment zones, 4) micro-habitat map surveys should continue to augment the database begun by BRD, 5) field sampling should continue in 1998 throughout the northern pikeminnow spawning and hatching period to determine nearshore use of newly hatched pikeminnow fry, 6) PNNL should assume the lead role in the completion of the susceptibility model in coordination with other agencies such as the BRD and the USFWS, 7) Uof I and SPC should continue with the benthic macroinvertebrate evaluation in 1998 in accordance with the workplan developed in 1997, and 8) field work in 1998 should be conducted in coordination with Public Utility District of Grant Count (GCPUD) staff, BRD predator sampling efforts and ongoing juvenile chinook research in the Hanford Reach, and WDFW predator work in the Yakima River Basin.

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INTRODUCTION

The impact of diel water fluctuations on rearing salmonids as a result of power peaking activities has been assessed on numerous Columbia River tributaries and other river systems with hydropower development (Thompson 1970, Witty and Thompson 1974, Phinney 1974a and 1974b, Bauersfeld 1978, Tipping et al. 1978 and 1979, Becker et al. 1981, Woodin 1984, and Beck 1989) but limited research has been conducted on the Hanford Reach (Page 1976, Becker et al. 1981). Historical discharge records for the 1987 through 1996 time period indicate that water elevations in the Priest Rapids Dam tailrace can fluctuate in excess of ten vertical feet with four foot fluctuations common during the fall chinook rearing season. In past years, stranded or entrapped[1] juvenile fall chinook have been observed on a number of occasions as a result of diel water fluctuations on the Hanford Reach (Page 1976, Becker et al. 1981, DeVore 1988, Geist 1989, Wagner 1995, Ocker 1996). This section of the Columbia River, which extends 51 miles downstream of Priest Rapids Dam to Richland, Washington (Figure 1), is the last free flowing (unregulated) stretch of the mid-Columbia and supports the largest population of naturally reproducing wild fall chinook in the Columbia Basin (Huntington et al. 1996, Dauble and Watson 1997). A quantitative assessment of the impacts of diel or periodic water fluctuations on rearing wild fall chinook in the Hanford Reach is needed before corrective measures can be implemented. In 1996, the Northwest Power Planning Council (NPPC) approved funding for the “1997-99 Evaluation of Juvenile Fall Chinook Stranding on The Hanford Reach” to address this need. This evaluation was given high priority status to receive funding through the Bonneville Power Administration (BPA). Cost sharing with the Public Utility District of Grant County (GCPUD) was also identified as a goal at that time. As a result, this work is co-funded by both BPA and GCPUD.

This evaluation is a cooperative effort between the Washington Department of Fish and Wildlife and the United States Geological Survey Biological Resource Division (BRD), Pacific Northwest National Laboratory (PNNL), United States Fish and Wildlife Service (USFWS), The University of Idaho Department of Fish and Wildlife (Uof I), and Streamside Programs Consultation (SPC). The first year (1997) of this evaluation was a pilot assessment in preparation for the full-scale evaluation to begin in 1998. This report summarizes the pilot work conducted in 1997.

OBJECTIVES

The specific objectives of the 1997 pilot work were:

1) Identify juvenile chinook production and rearing areas and to assess and classify the type and amount of habitat present on the Hanford Reach in the production and rearing areas.

2) Identify sampling sites and develop the statistical parameters necessary to complete the study.
    Task 2.1) Stratify Hanford Reach by habitat class.

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[1]Terminology Note: "Stranding" is defined as trapping of fish on or beneath the unwatered substrate as a result of receding river level. "Entrapment" is defined as separation from the main channel of the river in enclosed backwater zones as a result of receding river level. The two terms describe two phases of the same phenomenon. For example, fish caught in depressions which drain completely are first "entrapped" and then "stranded".

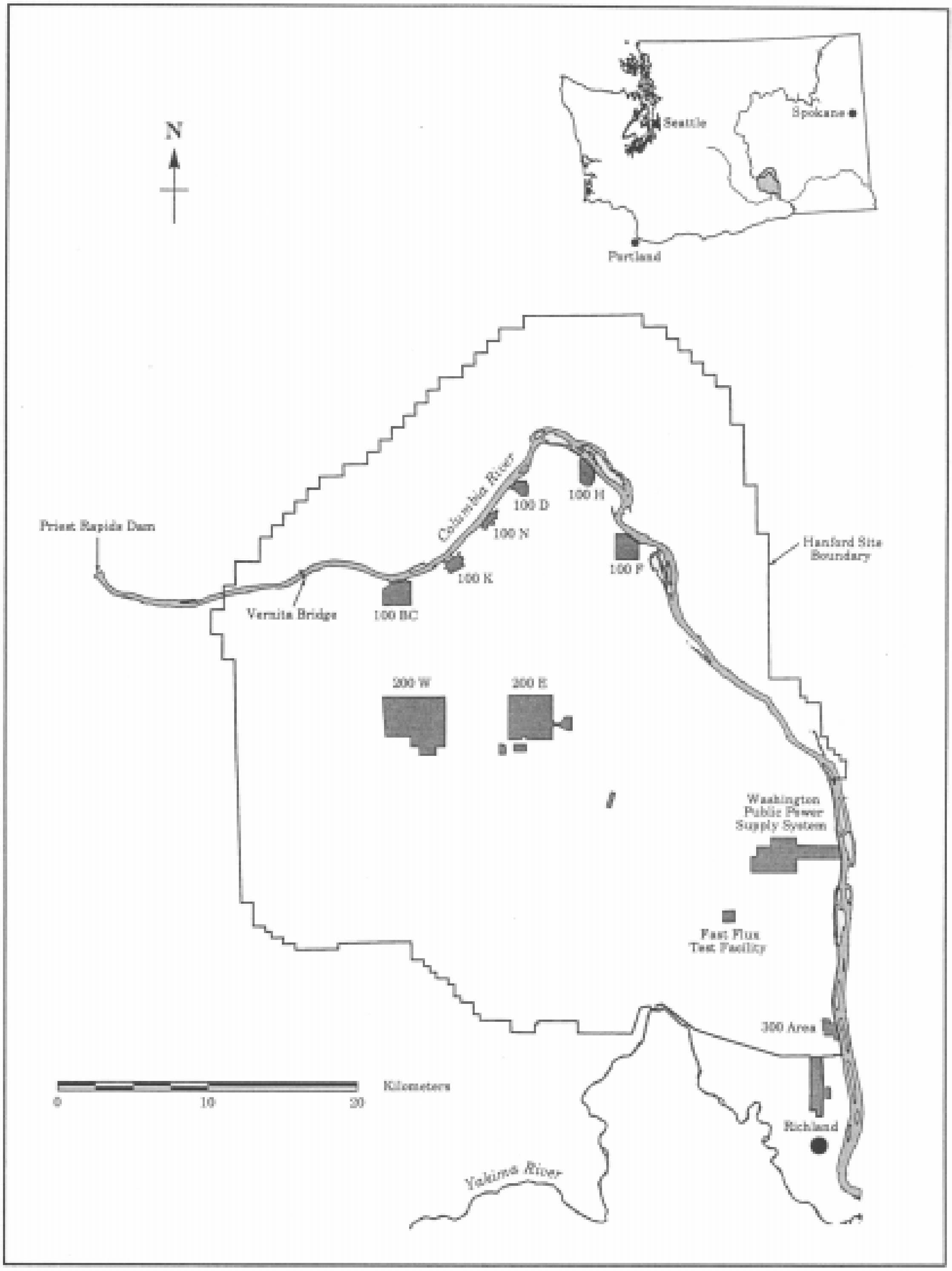

Figure 1. The Hanford Reach of the Columbia River, Washington.

Figure 1. The Hanford Reach of the Columbia River, Washington.

Task 2.2) Establish sampling sites within each stratum.

3) Develop a study plan to determine the effects of power peaking on the benthic community of the Hanford Reach.

4) In coordination with GCPUD and through the use of an unsteady flow model provided by PNNL, conduct field sampling activities under normal power peaking operations throughout the fall chinook emergence and rearing period and on two controlled river elevation reduction test days.

Task 4.1) Collect information on stranding and entrapment of juvenile fall chinook.

Task 4.2) Collect information on stranding and entrapment of resident fish.

Task 4.3) In coordination with USFWS and BRD, perform habitat-mapping surveys.

5) Determine specific schedules for controlled river elevation reduction tests.

Task 5.1) Review historical Priest Rapids hourly discharge profiles (provided by GCPUD).

Task 5.2) Work with GCPUD personnel and study coordination group to determine specific schedules for controlled river elevation reductions planned for 1997 and 1998.

METHODS

Equipment/Personnel/Personnel Training

A 19-foot Alumaweld jet boat, 133 horsepower Mercury jet outboard motor, 15 horsepower Mercury auxiliary outboard motor, and boat trailer were purchased for the study to conduct fieldwork. A dual wheel Chevrolet pickup truck was leased through the General Service Association (GSA) Government Fleet Services and used to haul the boat. Miscellaneous boat (life jackets, flares, fire extinguisher, tools, outboard motor oil, etc.) and field equipment (waders, waterproof field books, magnifying glasses, polarized sunglasses, etc.) were also purchased as needed. An OxyGuard Handy MKII Portable DO meter was purchased to measure water temperature and dissolved oxygen (DO) concentrations and saturation levels in the river and entrapment areas. A Gateway G6-200 Pentium microcomputer was purchased for data entry and analysis. Three cellular phones and two hand radios were also purchased for the program to aid in field communication.

All field personnel who had not previously received U.S. Coast Guard boat safety training were required to attend a three-day boat safety-training course offered by the BRD Columbia River Research Laboratory. All field personnel received security clearance training and were issued security clearance badges as required by the U.S. Department of Energy for access to the Hanford Site.

The PNNL was subcontracted to develop an unsteady flow model, which describes the stage/discharge relationship between Priest Rapids Dam and all points downstream to Richland, Washington. This was completed and delivered to WDFW in May of 1997. Also, a cooperative agreement was established between the Pacific States Marine Fisheries Commission (PSMFC), WDFW, and PNNL to allow the sharing of a PSMFC Geographic Information System (GIS) specialist between BPA funded PNNL and WDFW studies. All GIS work was conducted at the PNNL office in Richland, Washington. In addition, the jet boat and GSA vehicle were stored at the PNNL office in close proximity to the study area.

All other equipment used in the 1997 fieldwork was borrowed. Prior to the boat purchase and GSA vehicle lease, a 16-foot jet boat and pickup truck were borrowed from the WDFW Columbia River Laboratory and used during the early portion of the field season. A 30 foot stick seine (1/4" stretch mesh), Smith Root

Type VII Electrofisher, batteries, and battery charger were borrowed from the WDFW Region 3 (Yakima) office to allow sampling of small entrapment areas. A 70 foot beach seine (1/4" stretch mesh) was borrowed from the BRD Columbia River Research Laboratory to conduct baseline sampling in the nearshore areas of the Columbia River and in large entrapment zones. A Nikon Top Gun Laser surveying unit, Husky datalogger, Tripod, prism rod, laptop microcomputer, and military issued Rockwell Global Positioning System (GPS) unit were also borrowed from the BRD and used to conduct fall chinook micro-habitat surveys. A BRD biologist with Federal Bureau of Investigation security clearance was hired on intermittent temporary status by WDFW and shared between WDFW and BRD. This was necessary to conduct fieldwork with the military issued GPS because by U.S. military mandate, only a federal employee with proper security clearance is allowed to use the GPS unit. Miscellaneous laboratory equipment (anesthetic and anesthetic dispensers, length frequency boards, hand tabulators, etc.) used in the field was borrowed from the McNary/Lower Monumental Smolt Monitoring Program (SMP).

Biological Data Collection

Stranding/Entrapment Surveys

Actual field surveys were conducted once or twice weekly under prevailing discharge conditions beginning May 7 and concluding July 28. As the field season progressed, the unsteady flow model was used in conjunction with hourly discharge information from Priest Rapids Dam to assist in the coordination of survey scheduling. Hourly discharge information was downloaded daily from the U.S. Army Corps of Engineers North Pacific Region Water Management Division internet web site (http://rcchpl.npd.usace.army.mil).

The pilot work conducted in 1997 was intended to establish the study design framework for 1998. Stranding/entrapment survey work was conducted primarily to: 1) assess equipment requirements, 2) orient field personnel to the study area and equipment usage, 3) collect basic biological information on anadromous and resident fish distribution, general habitat preference, and age and size composition, and 4) collect general information regarding susceptibility to stranding and entrapment due to diel water fluctuations. The impact of diel flow fluctuations on the rearing population of fall chinook is the primary focus of this study. Therefore, less effort was extended to collect resident fish related data in 1997. Resident fish sampling was usually conducted in conjunction with juvenile fall chinook sampling but because of logistical constraints, much of the resident fish data collected were restricted to very basic biological information (species identification, counts, and length measurements) and noted field observations. Resident and anadromous fish were collected via backpack electroshocking, or stick and beach seining from entrapment areas and from the nearshore areas of the river to reference entrapment susceptibility and baseline population structure. Electroshocking was abandoned as a sampling method very early in the field season because stick seining was more efficient and less harmful to the fish. Captured fish were anesthetized, identified, counted, measured, and released. Information pertaining to physical parameters (i.e., water temperature, dissolved oxygen) associated with stranding or entrapment was recorded. Avian predator presence and activity was noted throughout the course of the field season.

Sampling of larval resident fish in the field was often complicated by incomplete development of meristic characteristics necessary for identification. Field determination of taxonomic classification to the species level of early life stages of resident fish was often not possible with standard taxonomic keys. In addition, classification of some species of resident larval fish was considered to be logistically impractical in the field due to the large numbers of fish often sampled as well as the lengthy procedure and magnification equipment required. Some samples of larval fish were taken to the BRD Columbia River Research Laboratory for taxonomic classification that in some cases, even under laboratory conditions, was only possible to the genus level. Therefore, species such as smallmouth and largemouth bass which were not distinguishable at the earliest life stages, were simply classified as "bass" *(Micropterus* spp.) unless large enough to allow species determination. A similar situation occurred for suckers (*Catostomus* spp.) and sculpins (*Cottus* spp.). A limited number of scale samples were taken from peamouth, redside shiners, northern pikeminnow, and suckers to determine the relationship between age and size. The scale samples were analyzed by the WDFW Scale/Otolith laboratory (Olympia, Washington) for age verification. The age/size relationship for other species of resident fish was determined through literature search.

PST/SMP Collaborative Work

An ongoing Pacific Salmon Treaty (PST) coded wire tagging (cwt) program has been conducted for the past 12 years during the first ten days of June on the Hanford Reach near White Bluffs. The objective of this work is to capture and tag 200,000 wild juvenile fall chinook for PST stock management. Fish are captured with stick and beach seines by WDFW personnel, Columbia River Intertribal Fish Commission (CRITFC) personnel, as well as by Yakima and Umatilla Indian Nation members. Capturing efforts are centered in the primary fall chinook rearing areas located upstream from the White Bluffs ferry landing boat launch. Detailed records of capturing success by location are maintained by the participating agencies. Juvenile resident fish are also captured incidentally during this program.

Length frequency information on juvenile fall chinook captured for this program are maintained by the WDFW. In conjunction with the PST program, McNary Smolt Monitoring Program (SMP) personnel also conduct Passive Integrated Transponder (PIT) tagging of wild juvenile fall chinook as well as GBT examinations.

Information from these two programs (PST and SMP), although collected independently of the Hanford Stranding Evaluation, was obtained and used to:

1) index size composition of the wild juvenile fall chinook population inhabiting the Hanford Reach during the first two weeks of June (cwt records);
2) index, a) wild juvenile fall chinook rearing area locations over multiple years, and b) year to year shifts in primary rearing locations which may result from annual changes in prevailing river flows (capturing records); and
3) augment information on juvenile resident fish population structure (incidental catch).

Wild juvenile fall chinook were examined for microscopic symptoms of Gas Bubble Trauma (GBT) on a limited number of occasions in the field in response to relatively high levels of total dissolved gas reported in tailwater of the Priest Rapids Dam. This work was conducted under the Smolt Monitoring Program (SMP) in conjunction with the Hanford Stranding Evaluation. The equipment used for these examinations was provided by the SMP GBT monitoring sites, as were the personnel who conducted the examinations. The results of this work are included in the 1997 annual report for the Smolt Monitoring Program (Hillson et al. 1998).

Controlled River Elevation Reduction Tests

During the 1997 pilot year, two controlled river elevation tests were identified as part of Objective 4. However, due to excessively high river flows during the juvenile fall chinook rearing period and the over-riding concern for flood control, implementation of these two controlled tests was determined to be impractical and therefore these tests were not completed during the pilot year.

Benthic Macroinvertebrate Evaluation

The University of Idaho Fish and Wildlife Department and Streamside Programs Consultation were subcontracted to determine the feasibility of evaluating the affect of diel water fluctuations on the benthic macroinvertebrate community inhabiting the Hanford Reach and, if feasible, to develop a workplan. Several meetings occurred in 1997 at the WDFW Kennewick office to determine the feasibility of conducting this assessment.

Modeling

Micro-Habitat Surveys

Micro-habitat mapping surveys were performed by BRD on the Hanford Reach in past years as part of an ongoing juvenile fall chinook habitat utilization study (Rondorf and Miller 1991, 1992, Rondorf and Tiffan 1993-95). Microhabitat mapping surveys were completed in 1997 by WDFW personnel in cooperation with BRD to: 1) augment the database begun by BRD, and 2) to quantify to a high level of precision habitat characteristics associated with stranding and entrapment. Microhabitat surveys were conducted in previously identified stranding/entrapment areas beginning September 4 and concluding October 23 after spring flows subsided and the survey areas were unwatered. Survey information was also collected in areas adjacent to stranding/entrapment zones for comparison. Detailed topography/bathymetry data was collected using a Nikon Top Gun Laser surveying unit and Husky datalogger. Other data collected included substrate and vegetation composition and embeddedness. Location coordinates were obtained through use of the military issued Rockwell GPS unit. The data collection protocol was identical to that used by BRD (Key et al. 1994) with one deviation. Low-lying vegetation (<8 cm above ground) was not recorded, as it was not considered to constitute a vegetation barrier to fish during inundated periods.

GIS Work

Two Geographic Information Systems (ERDAS IMAGINE, ARC/INFO) were used in 1997 to create base area maps for a variety of applications including habitat classification of the Hanford Reach. Redd count data were obtained from the PNNL Ecology Group in the form of GIS data layers and used to identify chinook production (spawning/incubation) areas. The general premise under which field-sampling activities were focused was that chinook fry emerge from production areas and are displaced by the river current downstream to rearing areas. Based upon this premise, most of the 1997 field survey work was conducted in locations downstream from known chinook production areas. The GIS work conducted in 1997 was the initial step in the development of the susceptibility model scheduled to be completed in 1999. This work is ongoing and will continue in collaboration with the PNNL Ecology Group.

USFWS Flow Modeling

The USFWS performed field flow modeling surveys on the Hanford Reach in 1997 as part of an ongoing white sturgeon habitat study (Anglin 1995 and 1996). Information derived from this work may be used in conjunction with the PNNL unsteady flow model and BRD microhabitat survey model to complete the susceptibility model for the Hanford Stranding Evaluation. Completion of the susceptibility model is scheduled for 1999. WDFW personnel assisted USFWS personnel for three days in 1997 collecting flow transect data near White Bluffs.

Historical Flow Review

Hourly discharge and tailwater elevation information for Priest Rapids Dam for the years 1987 through 1997 was obtained from GCPUD and the U.S. Army Corps of Engineers. This information was queried to determine the range of discharge and tailwater elevation changes which have occurred during the fall chinook emergence and rearing periods in past years. Water elevation history was used with the unsteady flow model to determine the flow changes that produced stranding/entrapment in 1997 at specific locations in the Hanford Reach. Real data as well as model simulations were used to determine a wide range of discharge scenarios as part of the development of the controlled river elevation reduction tests scheduled to begin in 1998. Other biological and operational considerations were identified and incorporated into the test development process. A proposed test schedule and protocol were developed and submitted to GCPUD for review.

RESULTS

Biological Data

Chinook

Population Structure

Chinook were found in entrapment areas located between river mile 348.5 and 375.0. A total of 1,130 stranded/entrapped juvenile fall chinook were sampled from stranding/entrapment areas between May 15 and July 7. Most (99.5%) of these were entrapped in newly created backwater areas. Very few (0.5%) could be classified as stranded. Of those found on unwatered substrate and classified as stranded, all were found in close proximity to potential entrapment areas and may have died as a result of being entrapped and then left on the beach as these areas drained. Of the 1,130 stranded/entrapped chinook, 135 (11.9%) were mortalities. Live entrapped fish ranged in size from 39 mm to 105 mm and averaged 60.9 mm in forklength. Entrapment mortalities ranged in size from 32 mm to 86 mm and averaged 49.2 mm.

For baseline population comparison, an additional 2,860 juvenile chinook were also randomly sampled from nearshore areas of the river via beach and stick seines. Average lengths of juvenile chinook were calculated for each of the twelve weeks of the rearing period. A comparison of entrapped fish versus randomly sampled fish was performed in an effort to reference susceptibility to entrapment as related to fish size. This comparison, illustrated in Figure 2, shows a general pattern of smaller fish from the population of chinook rearing nearshore tending to be more susceptible to entrapment.

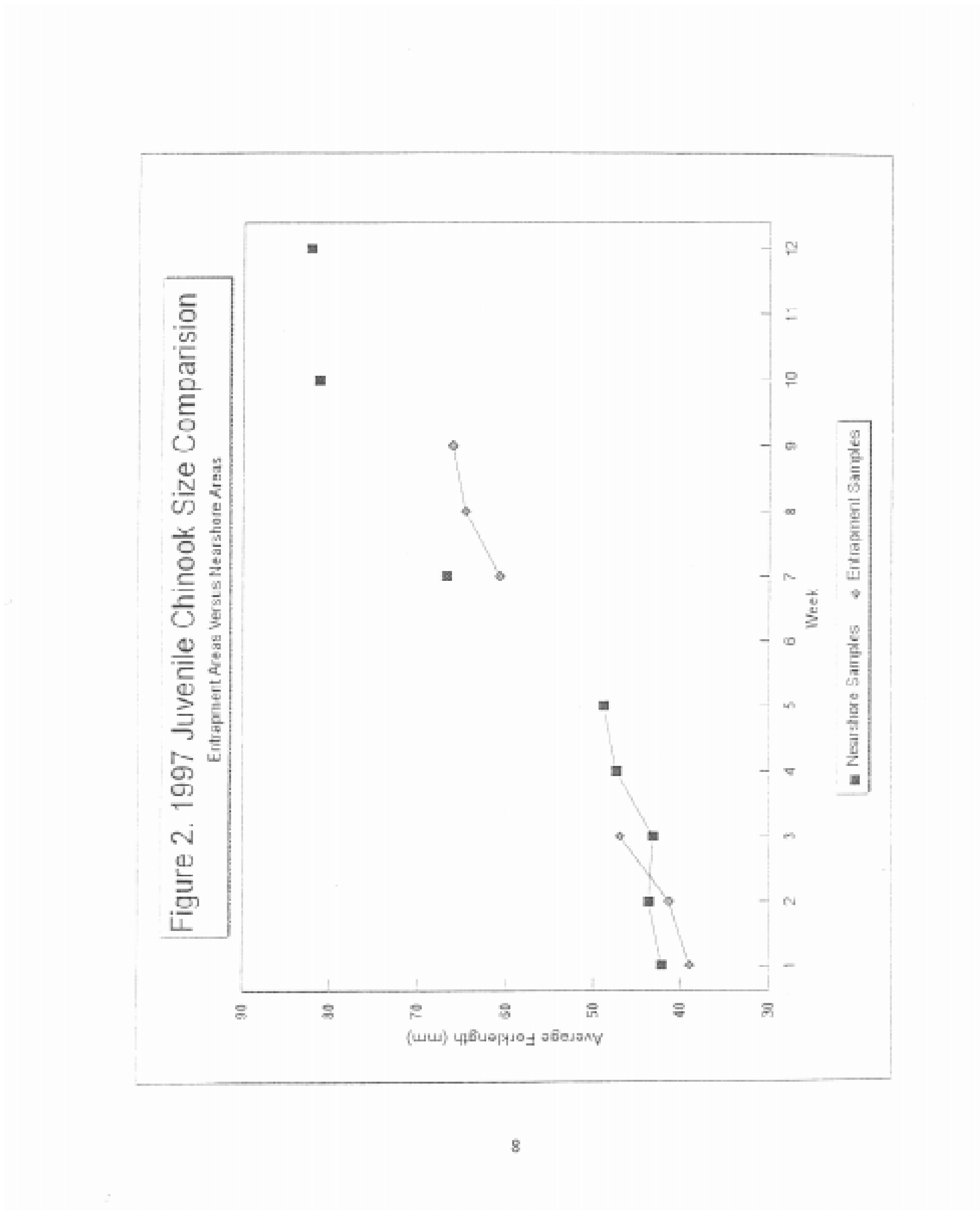

Figure 2. 1997 Juvenile Chinook Size Comparison

To further reference when juvenile chinook move away from the nearshore areas and are less susceptible to entrapment, length frequency data from fish coded wire and PIT tagged on the Hanford Reach for the PST and SMP marking programs during the years 1993-96 were compared to 1993-96 data collected for zero age chinook migrants passing McNary Dam. Figure 3 depicts the two data sets. The larger mode in the McNary data represents outmigrating zero age chinook smolts. Data collected in 1997 were not used due to unusually high spring river flows which flushed fall chinook fry out of the Hanford Reach and past McNary Dam in numbers well in excess of what has been observed in more typical flow years. The line of intersection between the Hanford CWT/PIT tag data and the McNary zero age chinook collection data presumably represents a size threshold upon which rearing parr begin to move away from the shoreline as they transition to downstream outmigrants. The intersection between the two data sets is approximately 81 mm.

Water Quality Data

Dissolved Oxygen

Dissolved oxygen concentrations in entrapment areas containing chinook ranged from 4.6 ppm to 13.0 ppm and averaged 9.1 ppm. The critical dissolved oxygen concentration for chinook is approximately 5.0 ppm (Bell 1973). On only two occasions were dissolved oxygen concentrations in chinook entrapment areas near or below the critical level (4.6 ppm on May 22 at rm 375.0 and 5.3 ppm on July 3 at rm 367.5). Chinook mortalities were sampled on both of these occasions. Oxygen saturation measurements in chinook entrapment areas ranged from 46.0% to 147.0% and averaged 107.9%. The highest measurements were most likely due to a combination of supersaturation resulting from high volumes of spill at Priest Rapids Dam (ambient river Total Dissolved Gas ranged from 120% to 130%) combined with off-gassing of aquatic or flooded terrestrial vegetation.

Water Temperature

Water temperatures ranged from 16.1^0 C to 33.2^0 C and averaged 24.1^0 C in entrapments where juvenile chinook were sampled. On the three occasions when water temperatures equaled or exceeded 29.0^0 C, 100% direct mortality was observed.

On the May 15 survey, chinook mortality which apparently resulted from thermal shock was observed in an entrapment area. On this date a shallow (average depth 42.2 cm), moderate sized entrapment area (approximately 187.2 square meters) was discovered on the western (channel) side of Savage Island (rm 357.5). This entrapment area was connected to the main channel by a small side channel approximately 3 meters in length containing relatively short but dense vegetation. This vegetation appeared to be a barrier at the time of the survey but would not have been at slightly higher water elevations. Observations made during the course of the survey as supported by the water elevation history (unsteady flow model) for this location (Figure 4) indicated that the water elevation was rising and that the entrapment area was being re-flooded. Dead chinook were observed at the start of the survey while live chinook were observed to lose equilibrium prior to dying during the course of the survey. Seventy-eight dead chinook were found in this area and no live chinook were observed by the end of the survey. Water temperatures in this entrapment area ranged from 20.5^0 C to 29.0^0 C. The 8.5^0 C temperature gradient was apparently the result of a combination of atmospheric warming during the isolated (low water) period followed by re-flooding of the entrapment area by mainstem river water at ambient river temperature (13.7^0 C).

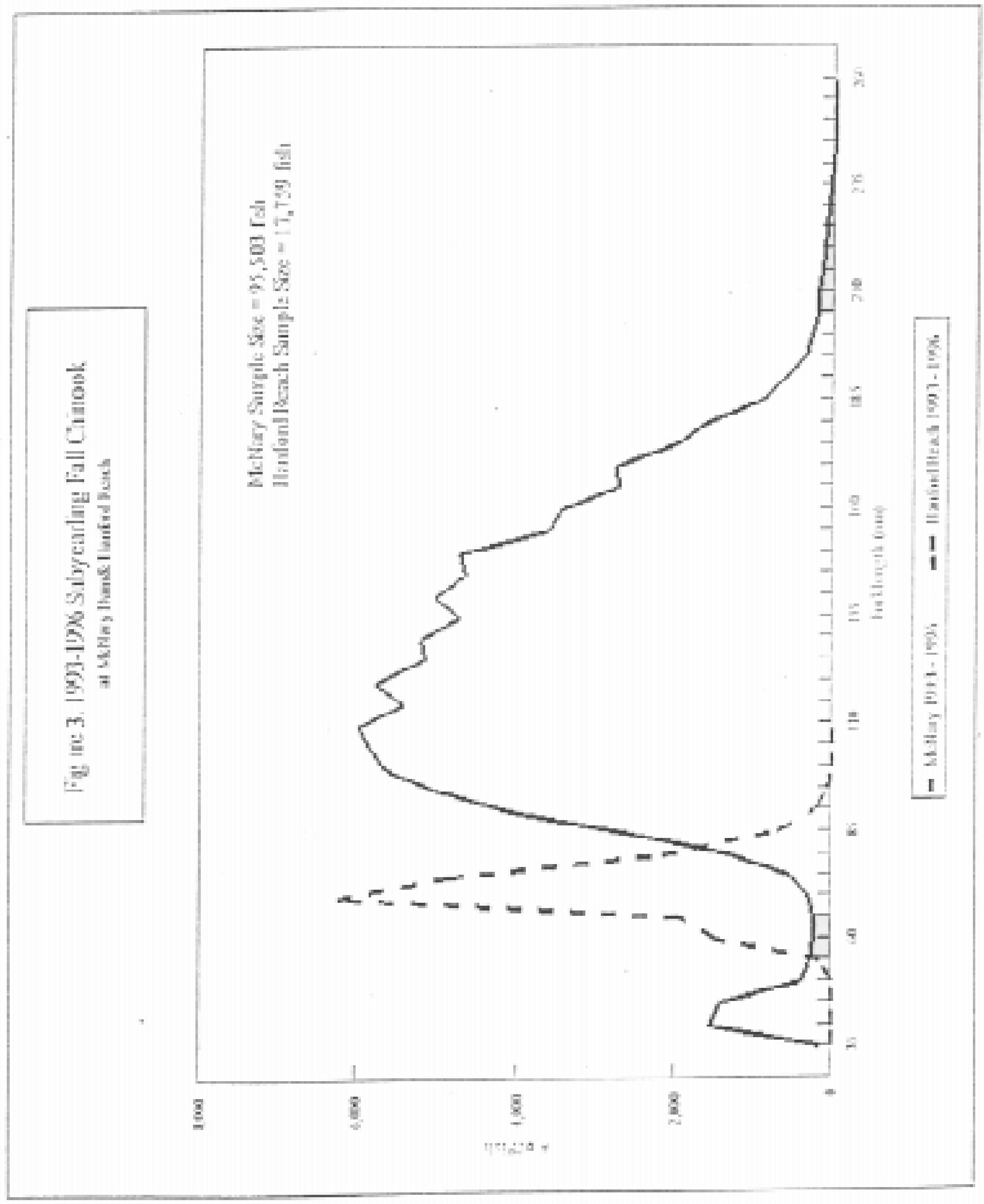

Figure 3. 1993-1996 Subyearling Fall Chinook at McNary Dam & Hanford Reach

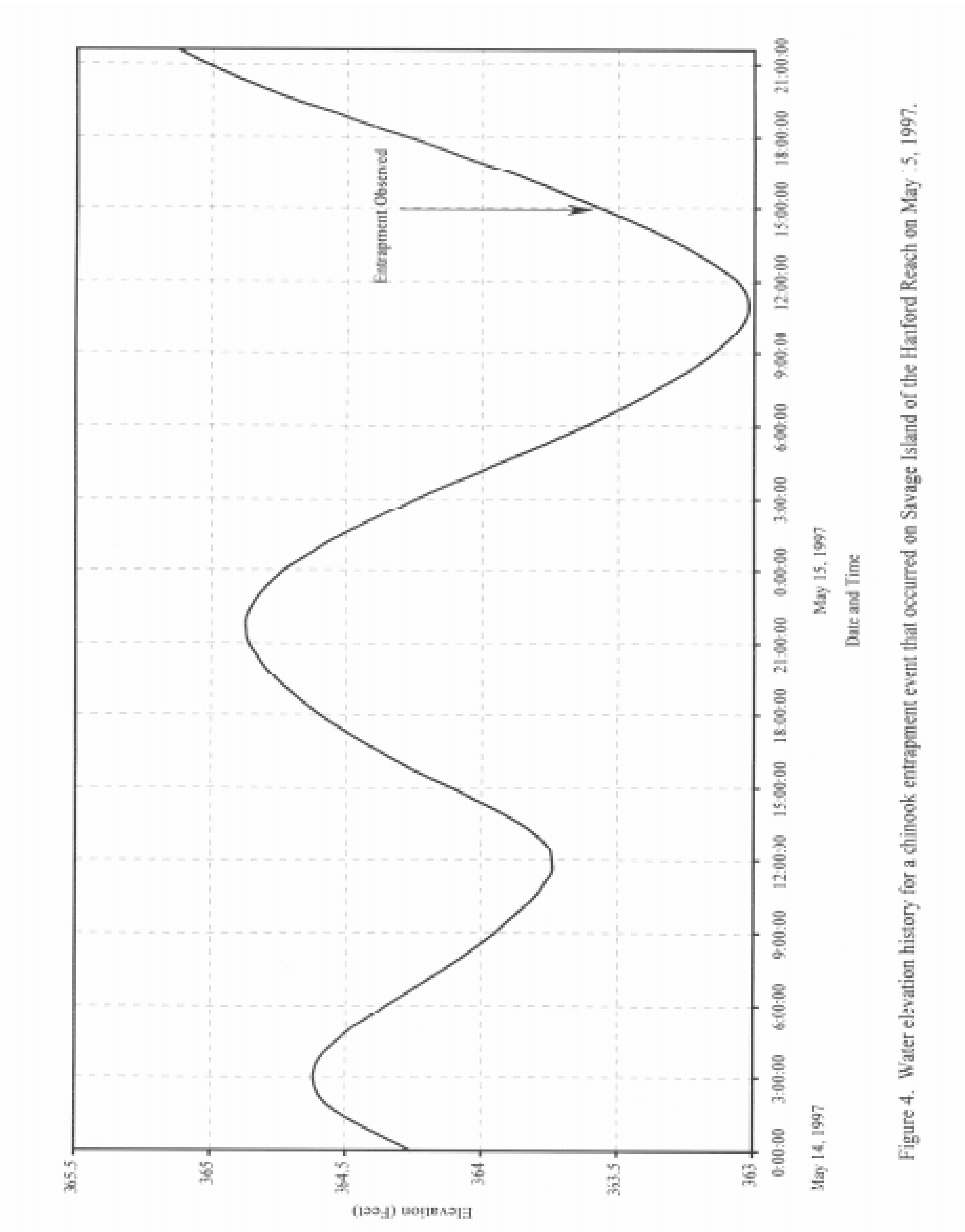

Figure 4. Water elevation history for a chinook entrapment event that occurred on Savage Island of the Hanford Reach on May 15, 1997.

Figure 4. Water elevation history for a chinook entrapment event on Savage Island, May 15, 1997.

Resident Fish

<u>Species Composition and Population Structure</u>

Resident fish captured from nearshore and entrapment areas included: largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), chiselmouth (*Acrocheilus alutaceus*), dace (*Rhinichthys* spp.), peamouth (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), sculpin (*Cottus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), sucker (*Catostomus* spp.), threespine stickleback (*Gasterosteus aculeatus*), walleye (*Stizostedion vitreum),* and yellow perch (*Perca flavescens*) (Table 1). Walleye, yellow perch, chiselmouth, and dace were present in limited abundance in the nearshore samples but were not found in entrapment areas. Redside shiners, northern pikeminnow, peamouth, and suckers were the dominant species in both nearshore and entrapment area catches. In all four cases, entrapped fish were on average smaller than those sampled nearshore. Most of the resident fish sampled from nearshore areas or entrapment areas were yearlings or young of the year.

Table 1. Resident fish abundance and size as sampled from nearshore and entrapment areas of the Hanford Reach, 1997.

Species	Nearshore (Number)	Percent of Total	Average Length (mm)	Entrapped (Number)	Percent of Total	Average Length(mm)
Redside Shiner	563	57.2	46.3	503	12.8	43.1*
Northern Pikeminnow	205	20.8	59.1	1,244	31.6	39.2*
Peamouth	90	9.1	55.7	286	7.3	53.9*
Sucker spp.	75	7.6	57.2	1,596	40.6	37.8*
3 Spine Stickleback	32	3.2	25.0	62	1.6	48.0
Juvenile Bass spp.	10	1.0	65.1	171	4.4	20.7*
Dace	3	0.3	47.0	0	0.0	NA
Chiselmouth	2	0.2	85.0	0	0.0	NA
Sculpin spp.	2	0.2	19.0	37	0.9	74.3
Walleye	2	0.2	66.0	0	0.0	NA
Yellow Perch	1	0.1	44.0	0	0.0	NA
Adult Smallmouth	0	0.0	NA	2	0.1	350.0
Carp	0	0.0	NA	30	0.8	28.8
Total	985	100.0		3,931	100.0	

* Species sampled in entrapment areas smaller on average than same species sampled inhabiting nearshore areas.

Fish composition for both nearshore and entrapment seine catches made by WDFW in 1997 was compared to seine and electrofishing (combined) catch composition from the BRD sampling efforts on the Hanford Reach for the years 1992-95 (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). This comparison is summarized in Table 2. Suckers, northern pikeminnow, redside shiners, and peamouth dominated the resident fish catches made by both agencies.

Table 2. USGS/BRD 1992-95 incidental catch and WDFW 1997 resident fish catch composition comparison.

Species	WDFW Total Sampled (Number)	WDFW Percent of Total	USGS/BRD Total Sampled (Number)	USGS/BRD Percent of Total
Sucker spp.	1,671	34.0	274	9.7
Pikeminnow	1,449	29.5	463	16.3
Redside Shiner	1,066	21.7	1,131	39.9
Peamouth	376	7.6	510	18.0
Bass spp.	183	3.7	69	2.4
3 Spine Stickleback	94	1.9	286	10.1
Sculpin spp.	39	0.8	22	0.8
Carp	30	0.6	44	1.6
Dace	3	0.1	0	0.0
Chiselmouth	2	0.0	0	0.0
Walleye	2	0.0	0	0.0
Sunfish	2	0.0	6	0.2
Yellow Perch	1	0.0	13	0.5
Mountain Whitefish	0	0.0	12	0.4
Crappie	0	0.0	4	0.1
Sandroller	0	0.0	0	0.0
Shad	0	0.0	0	0.0
Total	4,918	100.0	2,834	100.0

Other Resident Fish Observations

Carp and Suckers

Field observations of carp and sucker entrapment/stranding were made in addition to the data presented in Table 1. Beginning June 26, large numbers of newly hatched carp fry were found entrapped and stranded in various locations throughout the Hanford Reach. Similar observations of newly hatched sucker fry stranding and entrapment were also made later in July. Small samples were taken to verify identification but due to the large number of fish and extensive effort required no attempt was made to quantify the observations. Mortality rates for stranded and entrapped carp and sucker fry appeared quite high, ranging to 100% in many cases.

In addition to newly hatched carp and sucker fry, adults were also observed on a limited number of occasions in large entrapment areas. Most of these observations were made during the June 26 through July 8 time period. Observations of adults were noted but empirical data were not collected for a variety of reasons. For example, in entrapment areas where seining was possible, adult carp were often able to escape capture. In one case, roughly 100 adult carp were observed entrapped on Rosseau Island (rm 370.5) in an area too large to seine. These fish were first observed entrapped on June 26 and subsequent observations through July 2 suggested that all entrapped fish succumbed to a combination of desiccation and predator/scavenger activity as the entrapment area slowly drained. All adult suckers were identified as largescale and were observed less frequently than adult carp.

Smallmouth Bass

One 500 mm adult smallmouth bass was entrapped on Rosseau Island apparently on June 26 along with the adult carp previously described. This bass was found desiccated on July 2. On June 30, thirteen desiccated or partially desiccated fish nests (8 dry, 5 wet) with eggs present were found on Wooded Island (rm 348.5). These nests were found perched high on the island and were dewatered as a result of the seasonal flow reduction which occurred at the end of June. A drainage pond was located immediately downstream from the nests but the pond contained only larval suckers (which are not nest builders) and no adult fish to indicate the origin of the nests. However, the Wooded Island area supports a popular smallmouth bass recreational spring sport fishery and based upon the size (approximately 60 cm in diameter), the nests were believed to be the result of smallmouth bass spawning activities which occurred during the high water period earlier in June.

Miscellaneous

Larval bullheads (*Ictalurus* spp.) were observed in an entrapment area in late July but no samples were taken. Two pumpkinseed sunfish (*Lepomis gibbosus*) were observed in a nearshore seine haul catch at the lower end of Homestead Island but these fish escaped before measurements were taken.

Notably absent from both entrapment and baseline samples were white sturgeon (*Acipenser transmontanus*) and mountain whitefish (*Prosopium williamsoni*). Both species are important food/gamefish and support popular recreational fisheries immediately downstream from Priest Rapids Dam. Other fish known to inhabit the Columbia River between McNary and Priest Rapids Dams which were not sampled were bluegill sunfish (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), crappie (*Pomoxis* spp.), and sandrollers (*Percopsis transmontana).*

Other migratory fish which were not sampled included Pacific lamprey (*Entosphenus tridentatus*), American shad (*Alosa sapidissima*), and all species of juvenile yearling and adult migratory salmonids (*Oncorhynchus* spp.*)* with one exception. One adult steelhead was found entrapped in a pothole depression at Ringold Hatchery on June 30 immediately adjacent to the downstream most boat launch. However, Ringold Hatchery supports a substantial steelhead sport fishery in this location and surplus adults trapped at the hatchery are recycled at the boat ramp. Recycled fish are normally operculum marked. The entrapped steelhead which was adipose fin clipped but not operculum marked may have been released from the sport fishery. In terms of entrapment susceptibility, this fish did not likely represent typical migrating adult steelhead.

Two sizes of desiccated tadpoles were observed in drained entrapment areas. The larger ones were believed to be Great Basin spadefoot toads (*Spea intermontana*) while the smaller ones were believed to be Woodhouse's toads (*Bufo woodhousei*).

Predator/Scavenger Interactions with Stranded/Entrapped Fish

Predator activity associated with stranding/entrapment was observed to be minimal in 1997. Mammalian predator/scavenger activity at entrapment areas was not observed. Avian predator activity associated with chinook entrapment was surprisingly minimal in 1997. Although several species of piscivorus birds (Table 3) were observed on the Hanford Reach, observations of bird activity in chinook entrapment areas were infrequent. Single great blue herons were occasionally observed wading in areas with entrapped chinook but were not observed catching fish. Two chinook mortalities sampled from entrapment areas did exhibit injuries characteristic of bird attacks. Similarly, Becker (1981) observed minimal predation activity in entrapment areas of the Hanford Reach and classified most bird activity as scavenging.

Table 3. Piscivorus birds most frequently observed on the Hanford Reach in 1997.

Common Name	Genus/Species
Great Blue Heron	*Ardea herodias*
Great Egret	*Casmerodius albus*
Forster's Tern	*Sterna foresteri*
Caspian Tern	*Sterna caspia*
Double-Crested Cormorant	*Phalacrocorax auritus*
Ringbill Gull	*Larus delawarensis*
California Gull	*Larus californicus*
Western Grebe	*Aechmophorus occidentalis*
Common Loon	*Gavia immer*
Common Merganser	*Mergus merganser*
Black-Crowned Night-Heron	*Nycticorax nycticorax*
Osprey	*Pandion haliaetus*
American White Pelican	*Pelecanus erythrorhynchos*

On one occasion in 1997, considerable bird activity was observed in an entrapment area which contained resident fish. This was a large area which became isolated from the river during the seasonal flow reduction which began in the middle of June. Entrapped resident fish, primarily adult carp, were first observed in this area on June 26. By July 2, this entrapment area had virtually drained. Considerable great blue heron and ringbill gull scavenger activity was observed at this time. The entrapped fish which included approximately 100 adult carp, 2 adult largescale suckers, and one adult smallmouth bass were essentially stranded and partially exposed leaving them highly vulnerable to bird attack.

Early in the field season, large colonies of gulls were observed nesting on islands near Richland, but were not observed feeding on fish. The City of Richland waste disposal site is located approximately 10 miles from these islands and may attract gulls to this area. The CRITFC conducted dietary analysis of gulls from these islands in 1997 as part of on ongoing bird predation study and did not find salmonids present in the diets of either ringbill or California gulls (Ken Collis CRITFC, personal communication). On one occasion during the field season, Forster's terns were observed diving along the eastern face of Wooded Island in an area where juvenile chinook were present. Late in the field season, groups of both gulls and Forster's terns were observed roosting on islands near White Bluffs. However, feeding activity, when observed, appeared to be targeted on insects.

Large predatory fish were observed entrapped with chinook on only one occasion. One relatively large smallmouth bass was observed entrapped with chinook on July 2. This fish escaped from the seine and was therefore not measured but the length was estimated at approximately 200 mm. The largest northern pikeminnow sampled from an entrapment area was only 52 mm.

Micro-Habitat Selectivity

Entrapped fall chinook were not observed to be randomly distributed throughout the areas sampled. Chinook entrapment areas were on average within 30 meters from the main river channel and close to what had been current eddies at higher river elevations. Areas such as vast newly unwatered grassy flats were searched extensively in 1997 but stranded or entrapped chinook were not observed. Chinook were also generally not observed or sampled in flooded areas of more dense vegetation. Due to unusually high river flows which occurred during the fall chinook emergence and rearing period, the opportunity to evaluate stranding/entrapment in cobble type substrate did not present itself in 1997. This type of habitat generally occurs at the margins of the main river channel which was inundated throughout the spring of 1997. Juvenile fish appeared to have specific habitat preferences and juvenile resident fish, especially cyprinids and catostomids, appeared to be segregated from rearing chinook to a high degree. In general, chinook were found in entrapment areas that were relatively close to main river channel current and main channel current eddies. In contrast, resident fish, primarily cyprinids and catostomids, were found in calmer backwater areas more distant from main channel current. Observations of entrapment events that occurred on Island 8 (rm 367.5) this past spring are used here as an example of juvenile resident fish and chinook segregation. On May 27 and 28 three entrapment areas were sampled near the upstream end of Island 8 which separates the 100F slough area from the main river channel.

The three entrapment areas were in close proximity to each other but contained markedly different fishes (Table 4). Entrapment area 1 was most closely associated with the main channel, areas 2 and 3 were more distant from the main channel and main channel flow. In addition, areas 2 was located immediately adjacent to 100F slough; area 3 more distant. A summary of the physical description of each of these three entrapment areas as well as the fish composition is as follows:

Area 1
Physical Description: Relatively close to main river channel, primary access from main channel, average depth 94 cm, no vegetation barrier, dissolved oxygen 12.8 ppm.
Area 2
Physical Description: More distant from main river channel, primary access from 100F slough, average depth 43 cm, partial vegetation barrier, dissolved oxygen 11.3 ppm.
Area 3
Physical Description: Most distant from main river channel, primary access from 100F slough, average depth 28 cm, heavy vegetation barrier, dissolved oxygen 4.4 ppm.

Table 4. Fish composition in three entrapments located at Island 8 (100F Slough).

	Area 1		Area 2		Area 3	
	#	%	#	%	#	%
Redside Shiners	0	0.0	441	23.3	15	5.4
Peamouth	1	0.8	285	15.0	0	0.0
Pikeminnow	3	2.3	935	49.4	265	94.6
Suckers	2	1.6	217	11.5	0	0.0
Chinook	123	95.3	16	0.8	0	0.0
Total	129	100.0	1,894	100.0	280	100.0
Non-Salmonids	6	4.7	1,878	99.2	280	100.0
Salmonids (Chinook)	123	95.3	16	0.8	0	0.0
Avg. Chinook Length	47.4		43.1		NA	

Area 1 was sampled again one month later on June 26. A total of 205 fish were sampled of which 203 were chinook (average forklength 61 mm) and the remaining two were adult sculpins. Areas 2 and 3 had dried by this date.

As river flows continued to decrease in July, a fourth entrapment area was created immediately downstream from entrapment areas 2 and 3. This area was the most distant from the main river channel but immediately accessible from 100F Slough at higher water elevations. Access to area 4 from 100F Slough was not impeded by a vegetation barrier. Area 4 was sampled on July 28 and the composition of fish was as follows: 1,210 (86.1%) suckers, 6 (0.4%) sticklebacks, 169 (12.0%) bass, and 21(1.5%) carp. Five of the six sticklebacks were most likely young of the year with lengths ranging from 13 mm to 27 mm. The sixth stickleback (53 mm) was found dead and was probably a post-spawn adult. The other species were all within the size range of recently hatched fry (average lengths: bass 20.4 mm, carp 26.8 mm, suckers 17.0 mm). It is interesting to note that although suckers were abundant in the May 27 area 2 sample, these were within size range of yearlings (average length 53.2 mm), whereas suckers sampled from nearby area 4 two months later were all newly hatched fry.

Juvenile bullheads were also observed in area 4 in late August. This observation was incidental to initial micro-habitat survey work which was being conducted on Island 8 and the fish were therefore noted but not sampled.

Benthic Macroinvertebrates

Evaluation of the effects of diel water fluctuations on the benthic macroinvertebrate community inhabiting the Hanford Reach was determined to be feasible. Several draft workplans were developed by the University of Idaho Department of Fish and Wildlife and reviewed by WDFW and Streamside Programs Consultation. The final draft version is provided for review in Appendix A of this report.

Modeling

Habitat Classification on the Hanford Reach

Generally, based upon 1997 field observations of juvenile fall chinook presence, rearing appeared to occur primarily in the 36 mile river section located between Coyote Rapids and the downstream end of Wooded Island (Figures 5a-d). Chinook were also observed below Vernita Bar near Vernita Bridge but in relatively low abundance. Less effort was extended to determine chinook presence downstream of Wooded Island, as water fluctuations which might produce stranding/entrapment are far less severe downstream from this location near the McNary Pool. Limited survey work was conducted between the upstream end of Vernita Bar and Priest Rapids Dam. Based upon redd counts, this river section is not considered a primary natural fall chinook production area and juvenile fall chinook were generally not observed here in 1997. Although field sampling effort was concentrated in the 36 mile river section described above, boat or ground surveys were conducted on all shoreline areas of the Hanford Reach from Priest Rapids Dam downstream to Richland at least once in 1997.

Specific identification of rearing areas is in process. Information collected from the PST capturing effort for the years 1987-1997 is being obtained from the Yakima and Umatilla Indian Nations, CRITFC, and from the WDFW Columbia River Laboratory. This information is being incorporated into a GIS to identify rearing locations as well as to assess shifts in location which may occur due to changes in annual river flow.

Based upon 1997 field observations of physical characteristics, the study area was classified into six gross nearshore habitat categories.

1) **Steep embankment** - located within the main river channel and main channel flow and characterized by steep slope, large substrate or clay (White Bluffs), minimal vegetation, and relatively high current velocity.

2) **Gravel bars** - characterized by gravel and cobble substrate, moderate to shallow slope, lacking vegetation, with moderate to high current velocity, and usually identifiable as main channel islands, island complexes, or other moderate to shallow sloping areas exposed to main channel flow.

3) **Willow flats** - characterized by a mix of cobble and boulder substrate intermixed with fines, moderate to shallow slope, larger terrestrial vegetation, moderate current velocities, and immediately adjacent to the main river channel and main channel flow.

4) **Grass flats** - characterized by gravel and sand substrate, shallow slope, small vegetation, moderate to slow current velocities, and more distantly located from the main river channel and main channel flow.

5) **Backwater sloughs** - characterized by fine substrate, shallow slope, moderate to dense terrestrial and aquatic vegetation, lacking current, and isolated from the main river channel and main channel flow.

In addition to the five general habitat categories listed above which essentially describe the transition from main channel to backwater areas, a sixth category is also identified. Category six is unique, complex, important to fish life on the Hanford Reach, and consists of some combination of categories 1 through 5 but in a relatively specific area.

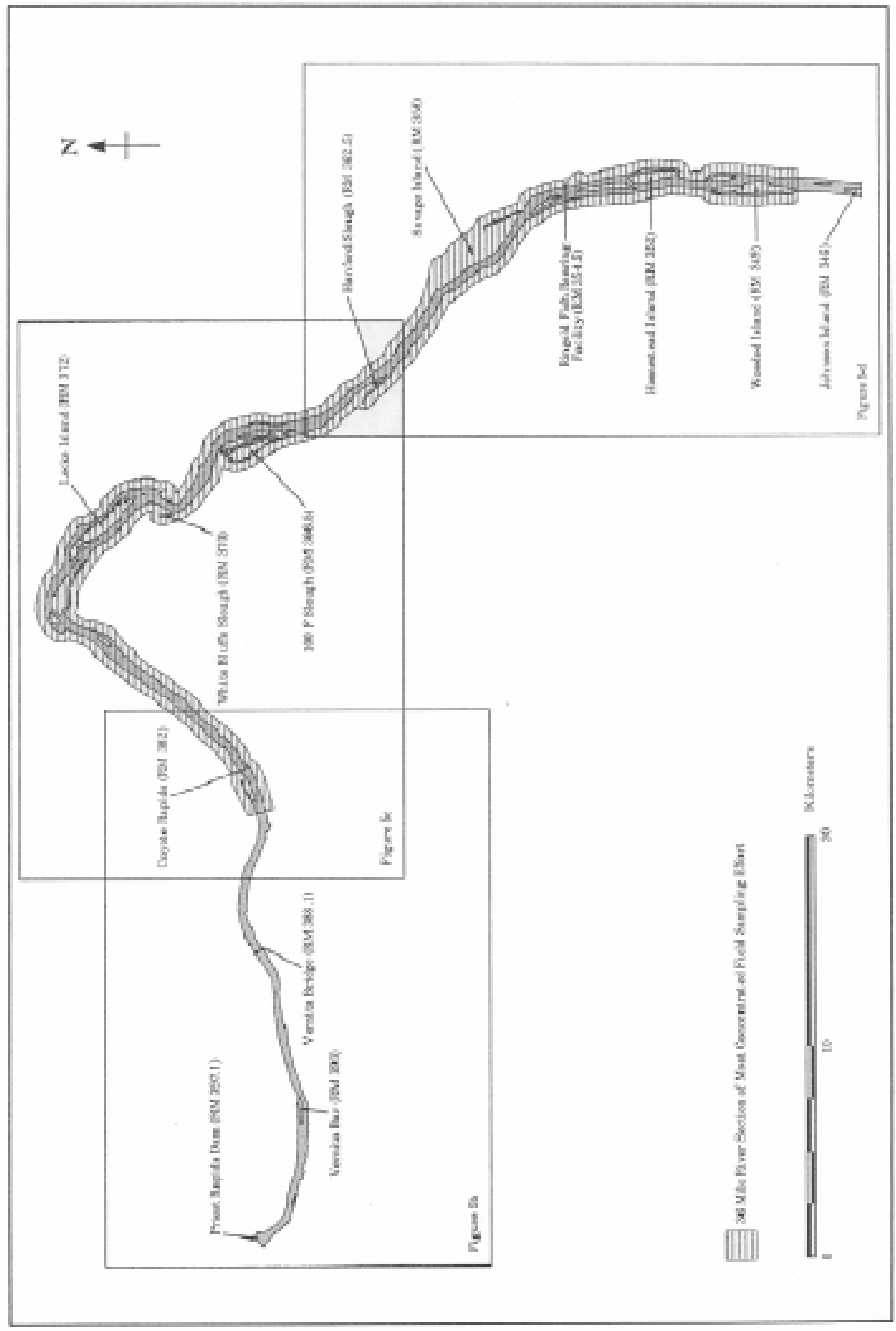

Figure 5a. Map of the Hanford Reach of the Columbia River showing 36 mile river section of most concentrated field sampling effort.

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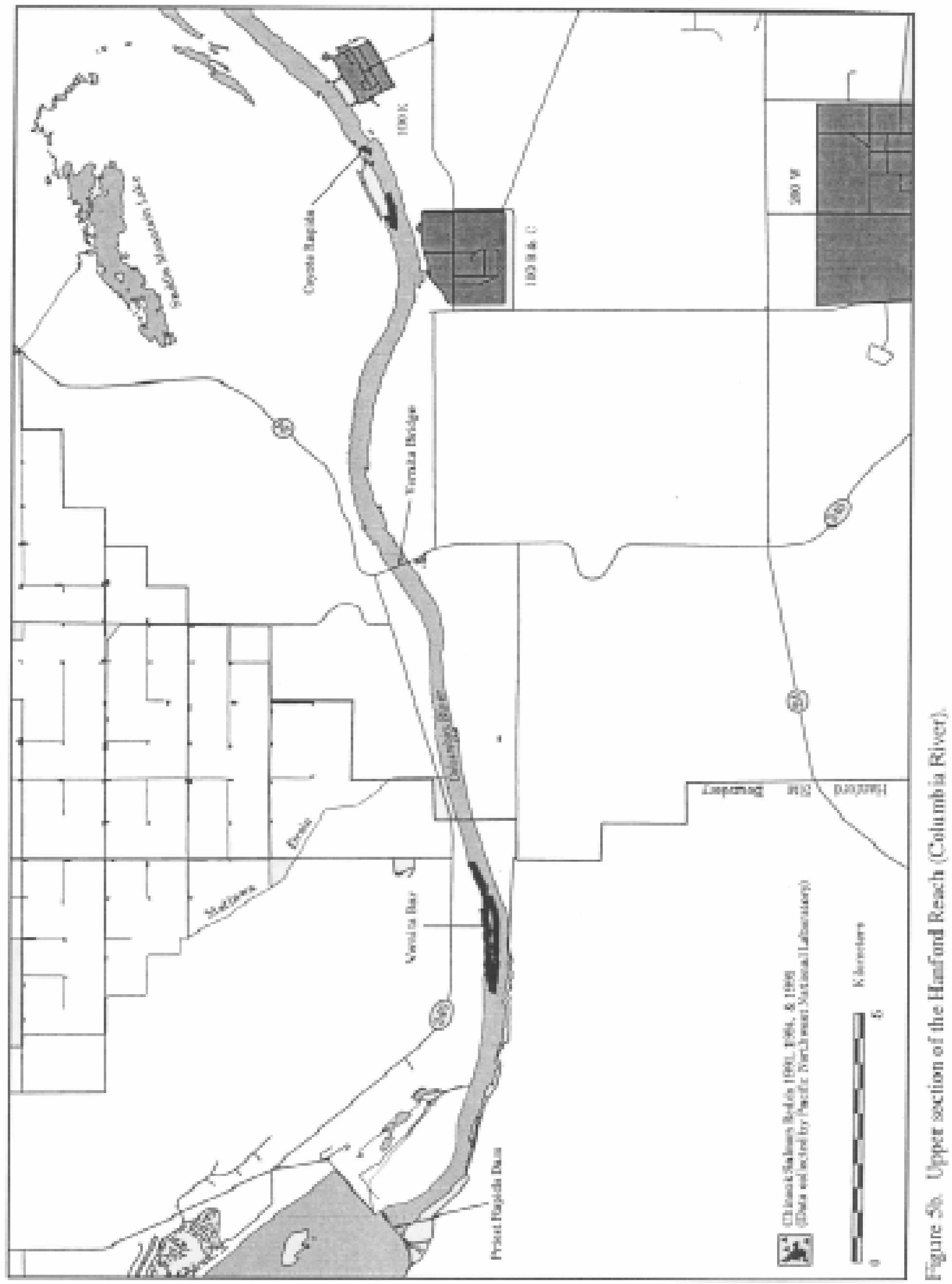

Figure 5b. Upper section of the Hanford Reach (Columbia River).

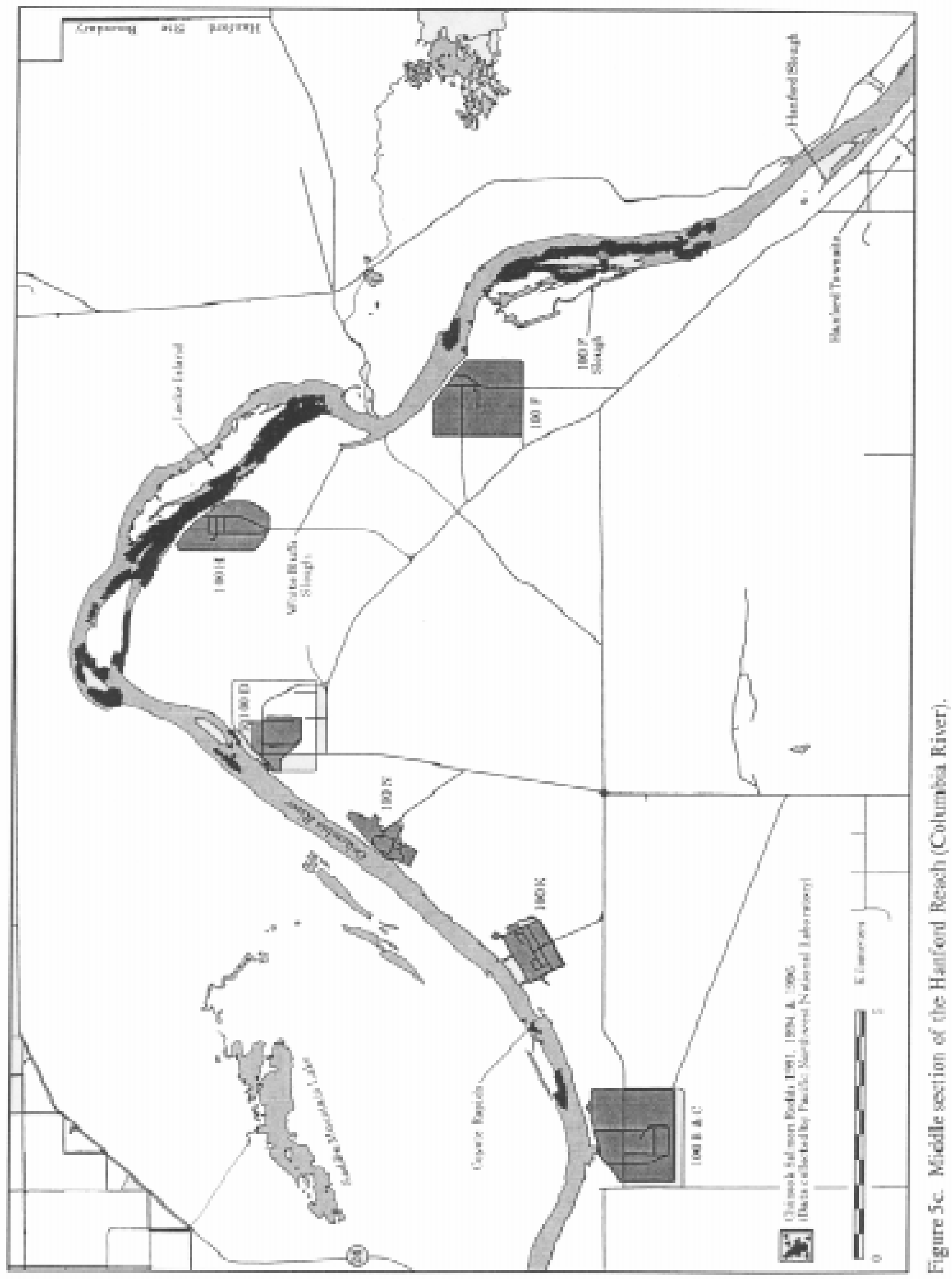

Figure 5c. Middle section of the Hanford Reach (Columbia River).

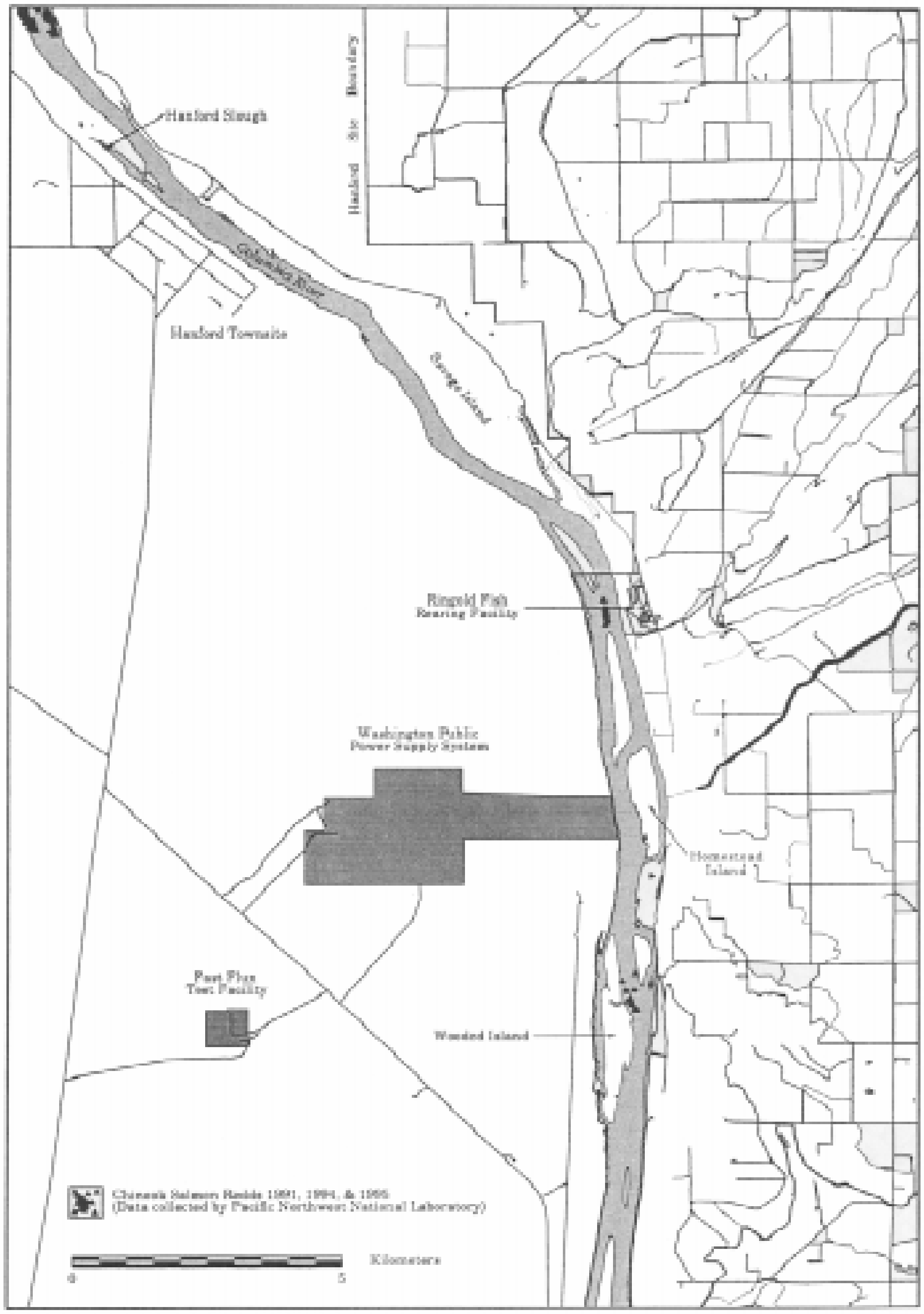

Figure 5d. Lower section of the Hanford Reach (Columbia River).

Figure 5d. Lower section of the Hanford Reach (Columbia River).

6) **Island complexes -** characterized by one or more side channels (often ephemeral) in areas where river braiding occurs.

The habitat categories listed above are coarse and constitute a working classification scheme for the purpose of identifying 1998 sampling sites. It is important to note that transition areas exist between categories where the characteristics of two categories may overlap. In addition, due to the dynamics of the river system, this classification scheme must be considered relative to river flow and water elevation. For example, what may be classified as an island complex (category 6) at high river elevation may be a backwater slough (category 5) at low water.

A general example of the habitat stratification scheme is illustrated in Figure 6. Selection of specific sampling sites within the six habitat categories is in progress and will be completed after analysis of PST capturing records and historical flow information prior to the spring of 1998. Additional ground truthing field surveys may also be conducted to further delineate habitat stratification prior to the spring of 1998. Determination of actual sampling site dimensions, as well as the statistical protocol used for subsampling activities (i.e., excavation of cobble substrate, defoliation of vegetation areas) will be completed after site selection.

Micro-Habitat Mapping

In past years, BRD completed 42 microhabitat surveys on the Hanford Reach as part of another research project to define juvenile fall chinook habitat preference (Figure 7). In 1997 (Task 4.3), WDFW personnel completed an additional 17 microhabitat surveys (Figure 8). The BRD sites were specifically selected to fill cells in a velocity/depth/substrate habitat matrix. WDFW surveys were specifically conducted at stranding/entrapment sites identified during earlier field surveys (May 7-July 28). Fourteen of the seventeen sites were selected based upon observed stranding/entrapment events and the remaining three sites were selected at random locations adjacent to entrapment areas to allow microhabitat comparisons. Additional sites which were identified in 1997 will be surveyed in 1998. An example of the topography/bathymetry detailed in microhabitat surveys is illustrated in Figure 9.

1998 Controlled River Elevation Reduction Tests

A proposed controlled river elevation reduction test protocol and schedule was developed. This proposal was reviewed by the Fish Passage Advisory Committee and approved contingent upon approval by the GCPUD. GCPUD review is in progress. This proposal is attached to this interim report (Appendix B) and will be submitted to the study coordination group as part of the draft review process.

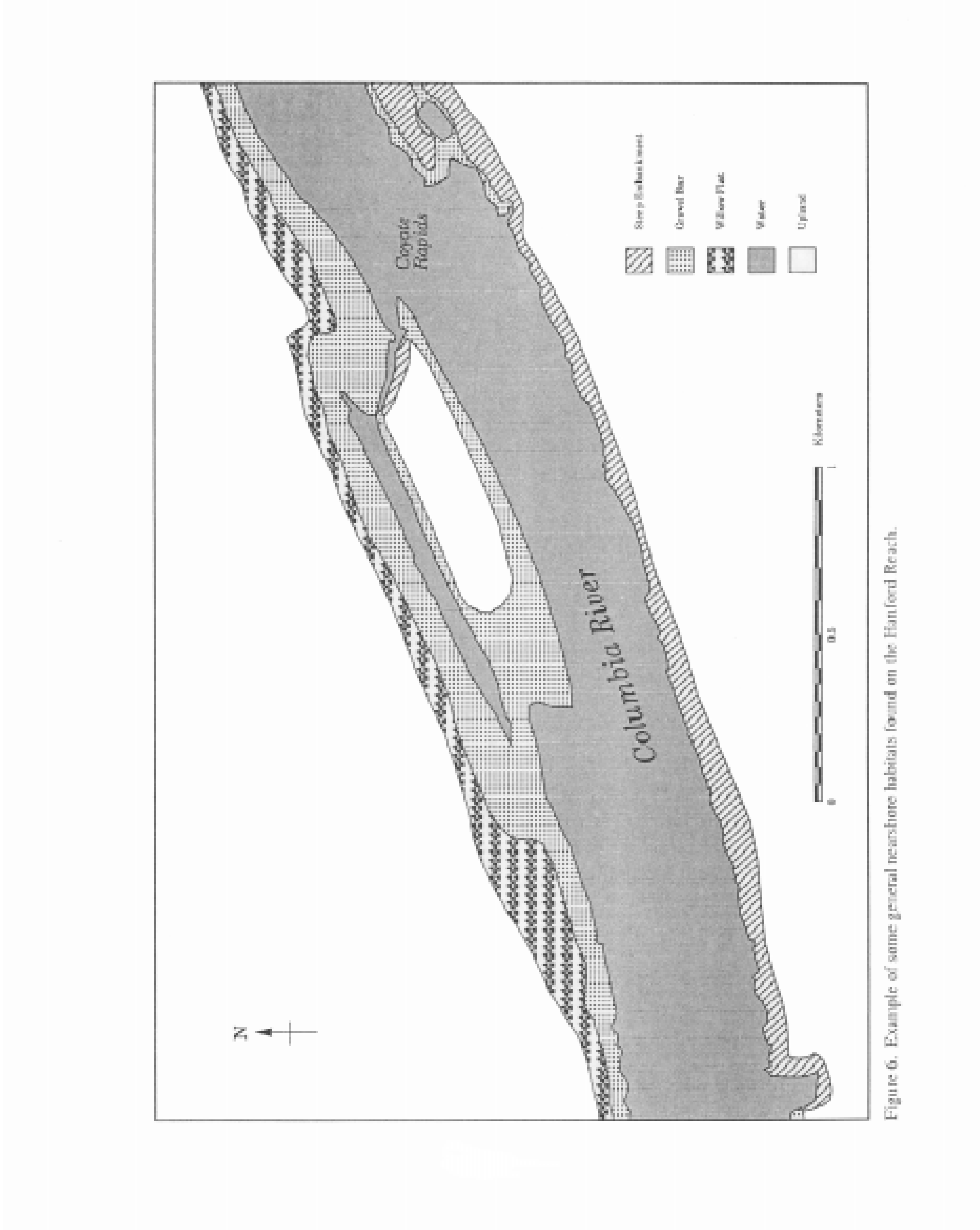

Figure 6. Example of some general nearshore habitats found on the Hanford Reach.

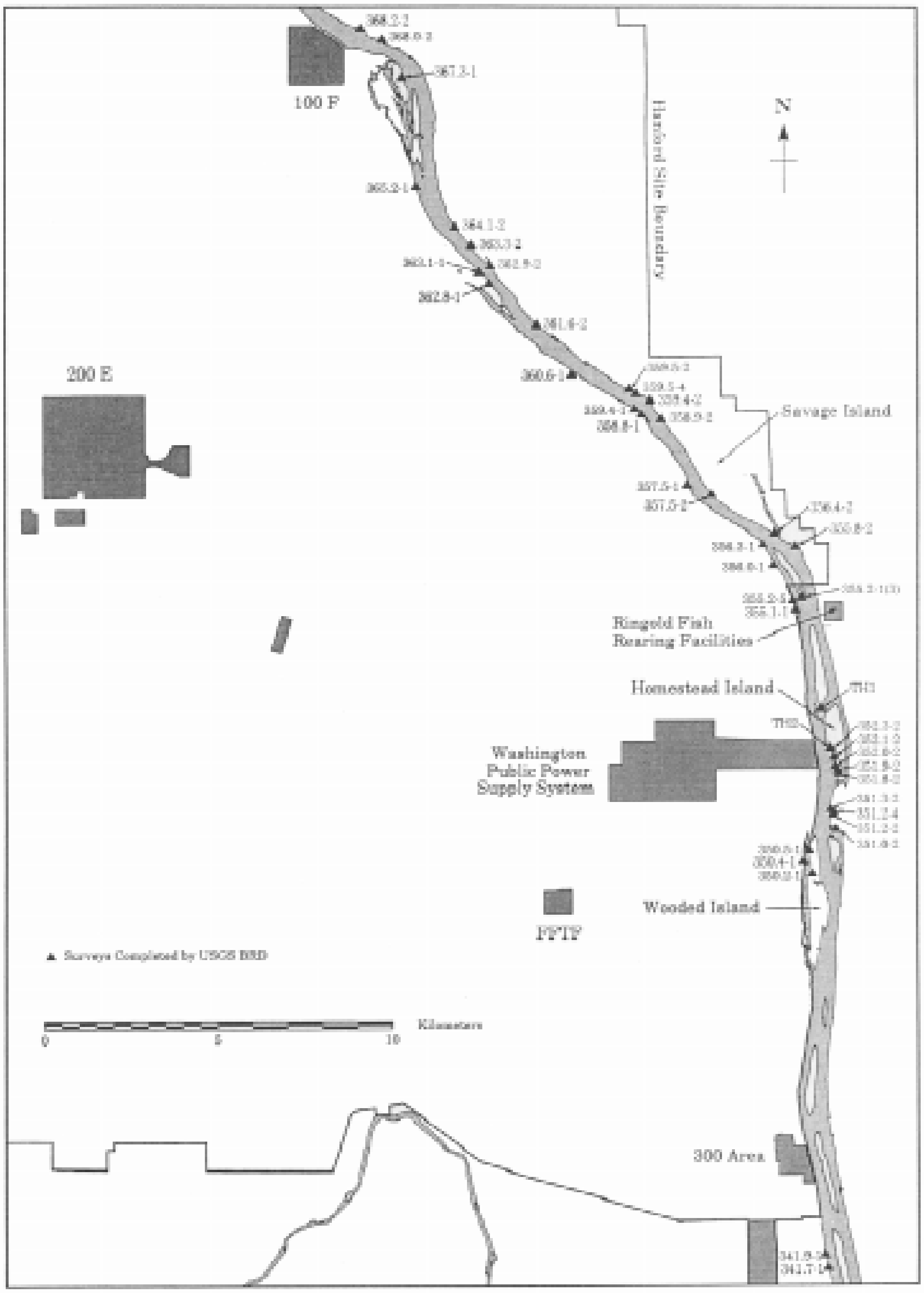

Figure 7. Juvenile fall chinook micro-habitat surveys completed by USGS BRD.

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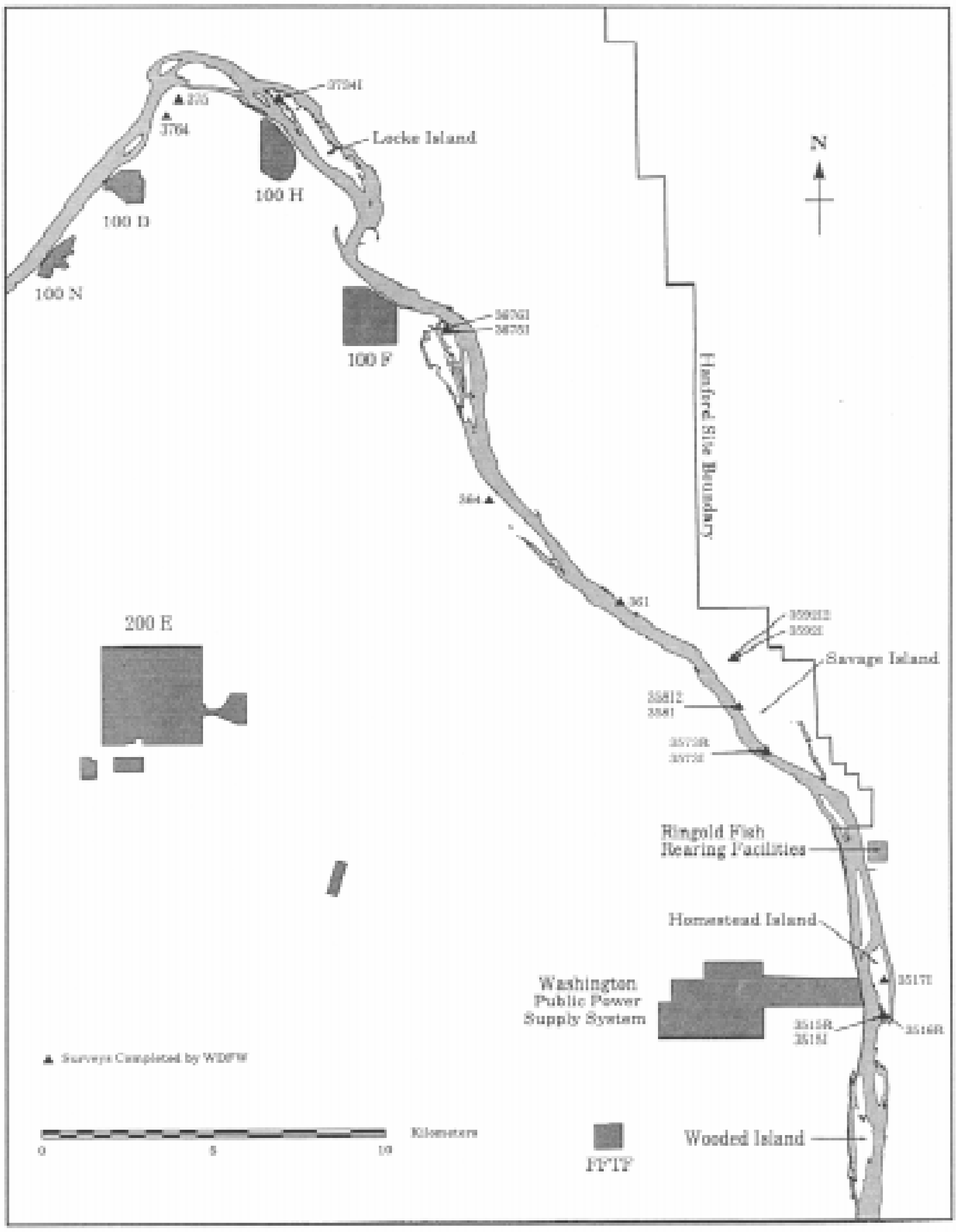

Figure 8. Juvenile fall chinook micro-habitat surveys completed by WDFW.

Figure 8. Juvenile fall chinook microhabitat surveys completed by WDFW.

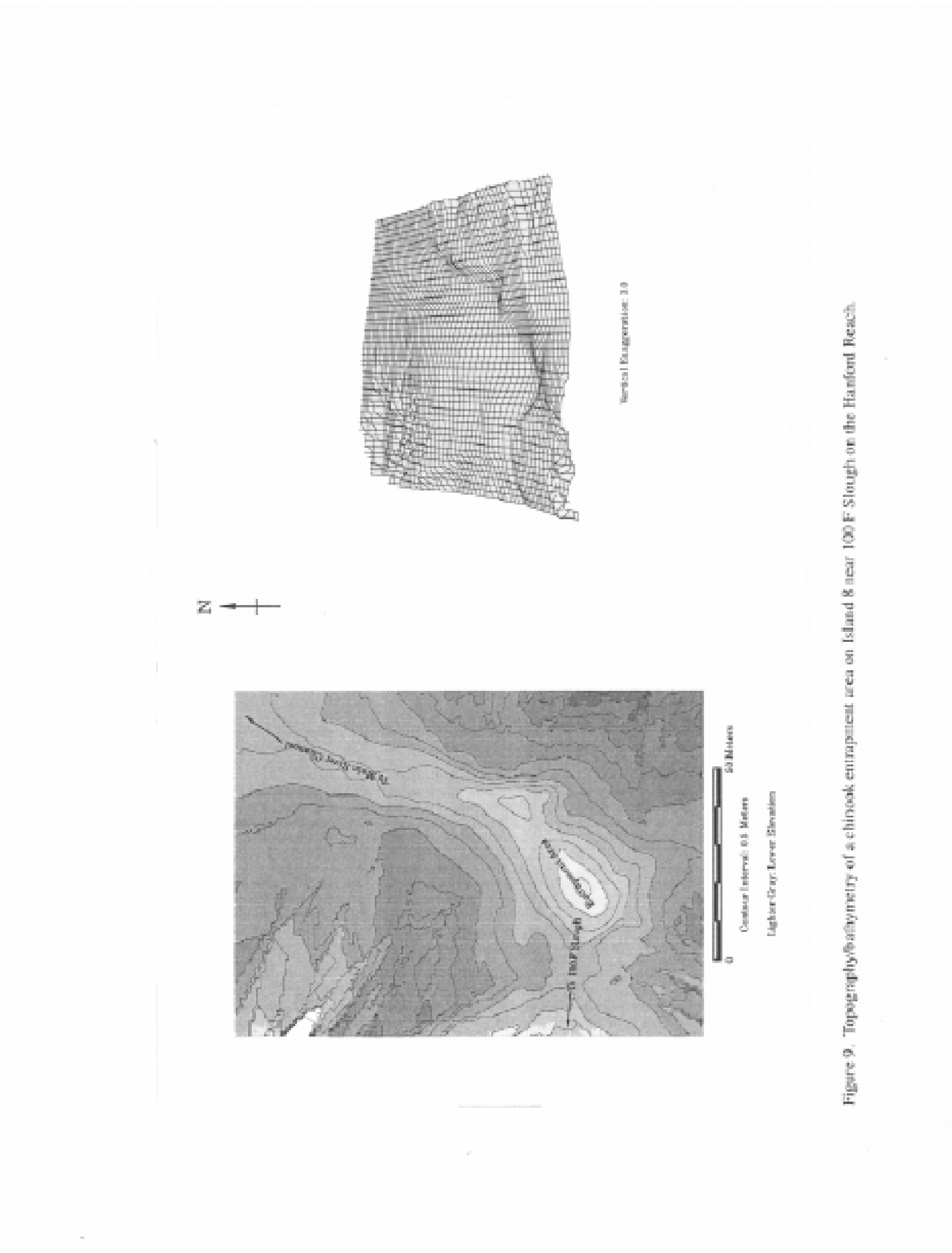

Figure 9. Topography/bathymetry of a chinook entrapment area on Island 8 near 100 F Slough on the Hanford Reach.

DISCUSSION

1997 River Conditions

Pilot work was conducted in 1997 under exceptionally high river flows. Chinook stranding/entrapment was observed during the 1997 pilot year but was not extensive. However, ancillary data suggest that much of the rearing chinook population may have been displaced downstream from the Hanford Reach during the normal rearing period. For example, due to low fish abundance, less than one half (94,656) of the Pacific Salmon Treaty Coded Wire Tagging program goal of 200,000 fish was reached in 1997. In addition, 1997 Smolt Monitoring Program records for McNary Dam indicate that the passage index for juvenile fall chinook fry (< 60 mm in forklength) was 949,278 in 1997 compared to 190,480 in 1996. These data suggest that far fewer fry and rearing parr remained in the Hanford Reach this past spring to be exposed to diel water fluctuations.

The exceptionally high spring flows of 1997 were followed by a substantial reduction in river elevation as flows subsided for the season (Figures 10 and 11). Priest Rapids tailwater elevation dropped 17 vertical feet from the middle through the end of June. This reduction provided a good opportunity to conduct pilot work under conditions similar to those which would occur under a controlled test because areas where entrapment occurred remained unwatered throughout each sampling day. Although diel water fluctuations occurred during this time, stranding and entrapment may have been related more to the seasonal change than to diel fluctuations. Separation of the two effects (diel versus seasonal changes) is difficult. Although the information collected in 1997 is useful and will become part of the overall database for this evaluation, the primary use of this information is for development of the 1998 full-scale evaluation effort. The information provided in this report will be used as a guide to establish sampling protocols and effort allocation during the 1998 field year. The data collected and included in this report pertaining to the effects of diel water fluctuations on fish life and the river ecology of the Hanford Reach are suggestive but not conclusive.

Fall Chinook

Pilot field studies in 1997 began under two working hypotheses: 1) the smallest rearing chinook utilize shallow nearshore habitat to a greater extent than do larger rearing parr and therefore would be more susceptible to stranding and entrapment and, 2) rearing parr reach a size threshold at which time they move away from the shoreline as they transition to outmigrating smolts and are no longer susceptible to entrapment.

The data collected in 1997 support both hypotheses. Work in 1998 should therefore focus on determining flow conditions that produce entrapment at various stages of the rearing cycle from most to least susceptible stages. Additional data should also be collected to better define the size threshold at which rearing parr are no longer susceptible to entrapment.

In terms of water quality, low dissolved oxygen levels were measured in entrapment areas where chinook mortality occurred. Therefore, low DO can not be ruled out as contributing to mortality. However, direct chinook mortality resulting from exposure to water temperatures in entrapment areas that exceeded the upper lethal limit was observed this past spring. Brett (1952) lists the upper lethal water temperature threshold for chinook at 25.0^0 C. On one occasion, chinook mortality was observed resulting from an apparent combination of exposure to warm water above the upper lethal threshold and thermal

Figure 10

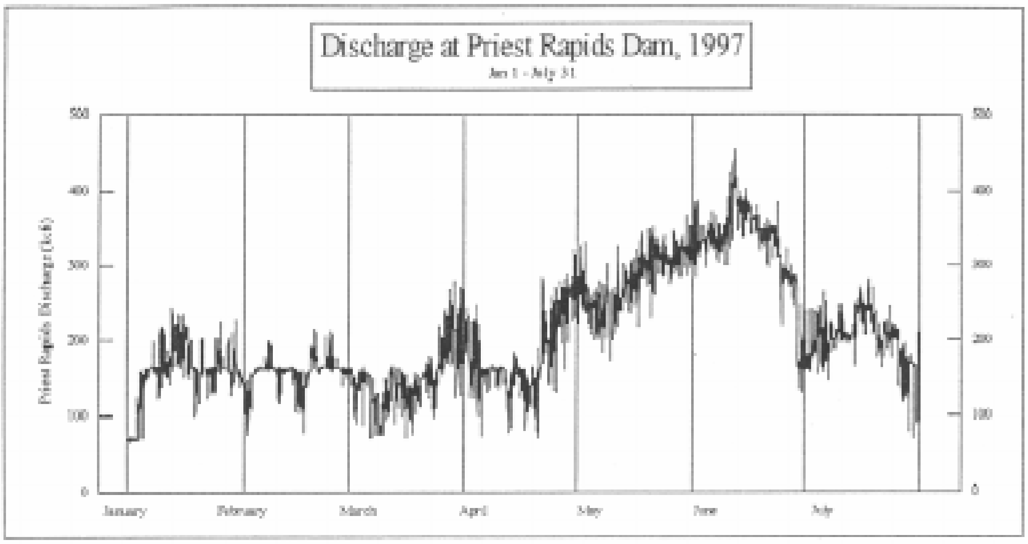

Figure 11

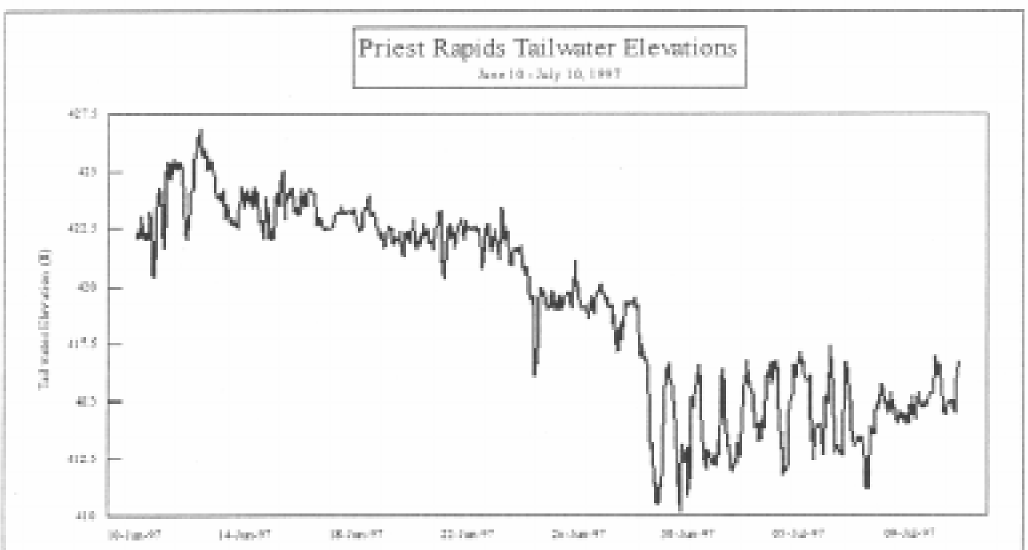

Figure 10. Discharge at Priest Rapids Dam, 1997

Figure 11. Priest Rapids Tailwater Elevations.

shock resulting from flooding of the warm entrapment area with cooler main channel river water at ambient river temperature. Although the occurrence of thermal shock induced mortality was only observed once in 1997, such occurrences are difficult to observe directly in the field as the observers must be present at a given entrapment area when: 1) atmospheric conditions are such as to cause elevation in water temperature approaching the upper lethal threshold, 2) during the flooding phase, but 3) prior to the full re-inundation phase during which mortalities could simply be swept and dispersed downstream by the newly invading river current.

In addition, similar to thermal shock, delayed juvenile chinook mortality resulting from thermal stress cannot be readily observed in the field but has been documented. An Environmental Protection Agency sponsored "Columbia/Snake River Mainstem Water Temperature Workshop" was held in 1997 during which Dr. Charles Coutant (Independent Scientific Advisory Board) presented information pertaining to N-reactor temperature tolerance testing conducted in past years with yearling spring chinook by PNNL. These data indicated that juvenile salmonid exposure to warm water resulted in three mortality components: A) direct mortality due to exposure to upper lethal limits, B) delayed mortality due to exposure to warm water below the upper lethal limit, and C) reduced performance ability as a result of exposure to warm water below the upper lethal limit. Work with other salmonids including juvenile fall chinook from the Hanford Reach showed similar results (Dean and Coutant 1968, Coutant 1969a and 1969b, Coutant 1970, Jaske et al. 1970, Templeton and Coutant 1971, Coutant et al. 1972). Direct mortality is readily observable in the field and was observed for fall chinook during the 1997 field season on the Hanford Reach. However, delayed mortality and mortality resulting from reduced performance cannot be observed directly in the field. Complete assessment of chinook mortality due to exposure to thermal conditions as would occur in entrapment areas will require additional laboratory analysis.

Water temperatures in entrapment areas are controlled by several variables including the surface area, depth, and volume of the entrapment area, duration of separation from the river, and atmospheric conditions. Although chinook entrapment and mortality was not observed to be extensive in 1997, fewer fish apparently reared in the Hanford Reach due to displacement by unusually high river flows. In addition, atmospheric conditions may be such in other years as to exacerbate thermal conditions in entrapment areas when larger numbers of fish are present. Some existing data further suggest that indirect mortality resulting from exposure to warm water also occurs and, unlike direct mortality, is not directly observable in the field. Thermal shock is another mortality component which is difficult to observe in the field.

Resident Fish

Evaluation of the effects of diel water fluctuations on resident fish involves multiple species with diverse life histories. A total of 43 species (including anadromous fish) representing 13 families are reported to inhabit the Hanford Reach (Gray and Dauble 1977). Some of these species are important game (smallmouth bass) or food fish (white sturgeon) while others, such as carp, have questionable public value. Still others have been deemed deleterious to juvenile salmonids (northern pikeminnow). All are a part of the aquatic ecosystem of the Hanford Reach and are therefore potentially affected by diel water elevation changes. In the case of sculpins, suckers, carp, and bass, young of the year appeared to be particularly susceptible to stranding and entrapment due to water fluctuations.

Suckers and other species such as peamouth, redside shiners, sculpins, threespine sticklebacks, and northern pikeminnow also demonstrated susceptibility to stranding/entrapment through the first year of life. This is an important consideration in that, unlike chinook, these species are present throughout the year and therefore are potentially exposed to water elevation fluctuations outside of the time frame sampled during this evaluation. Some species of resident fish such as smallmouth bass, sculpins, carp, largescale suckers, and threespine sticklebacks showed some susceptibility as mature adults. This appeared to be the result of movement into the shallow nearshore areas for spawning. For example, threespine sticklebacks were absent from both nearshore and entrapment samples until late June when yearling sized fish began to appear, first in entrapment areas and later in nearshore baseline samples. Freshwater forms of threespine sticklebacks reach sexual maturity during the second year of life and spawn by building nests in shallow water and then die after spawning (Wydoski and Whitney 1979). This species may inhabit deeper water and only migrate into the shallows to spawn.

Adult carp were found entrapped but were completely absent from baseline nearshore samples. The latter is misleading in that adult carp were commonly observed nearshore but were not captured. Carp can grow to 46 cm (18 inches) in total length by the second year of life (Whitney and Wydoski 1979) and are quite capable of eluding seining efforts. This was found to be true even in relatively small entrapment areas where adult carp were observed but not captured due to their ability to jump over the seine. General observations suggest that adult carp tend to "cruise" the shoreline and move quickly into newly flooded areas for feeding or spawning during the spring and early summer. The greatest susceptibility to entrapment appeared to be during spawning as the greatest number of entrapped adult carp were observed at approximately the same time that thousands of newly hatched carp fry were found similarly entrapped. This occurrence coincided with an overall seasonal reduction in project discharge and may have been more related to seasonal flow changes rather than diel fluctuations.

Adult largescale suckers were susceptible to entrapment and were found entrapped near the end of June in 1997. Similarly, Page (1976) observed approximately 500 adult suckers stranded during a single flow reduction event on the Hanford Reach in April. Dauble (1986) reported largescale sucker spawning to occur from April through July on the Hanford Reach in water temperatures ranging from 6 to 15^{0}C with upstream migration occurring primarily in June possibly in association with either spawning or feeding behavior. The sex of entrapped largescale suckers was not determined in 1997 but Nelson (1968) reported that ripe female suckers tend to inhabit shallow nearshore areas while males preferred swifter offshore habitat. Dauble (1986) reports “Larval sucker >8 mm total length were pelagic and common in nearshore areas of low current velocity by mid-June of most years at Hanford.” Similarly, newly hatched sucker fry were also observed in entrapment areas near the end of June through July in 1997.

Mature adult (60-130 mm) and young of the year (22-27 mm) sculpins were found entrapped at the end of June. These entrapment areas were unique in that they were located in scoured depressions at the base of shrubs and small trees (i.e., mulberry trees). Sculpins are demersal and cover oriented, and it appeared that the entrapped fish may have sought overhead cover as the water receded. The presence of larger mature adults suggests that susceptibility to entrapment may have been associated with spawning activity. Bond (1963) indicates that prickly sculpins (*Cottus asper*), a species commonly found in the Columbia River, migrate from areas of fine bottom material to stony areas prior to spawning and require rubble or boulders for spawning. Large individuals typically remain in deep water but migrate to spawn while the smallest individuals are known to utilize the shoreline and vegetation cover. Whitney and Wydoski (1979) indicate that prickly sculpins spawn in Conner Creek (Washington) in April and May and from Mid-February to June in British Columbia. Spawning adults construct nests under rocks and logs in areas with slow water velocities.

One adult (500 mm) smallmouth bass was entrapped at Rosseau Island on June 26. In addition, 13 desiccated fish nests, believed to be smallmouth bass nests, were discovered on Wooded Island on June 30. Virtually all other smallmouth bass taken from entrapment areas were young of the year sampled near the end of July. Once again, these data suggest that greatest susceptibility to entrapment for this resident species is associated with the use of nearshore shallow water by spawning adults and rearing of larval fish. Walleye are an important gamefish and support a popular recreational fishery especially in the Priest Rapids tailrace. The walleye fishery occurs primarily during the late winter and early spring. Two juvenile walleye (both 66 mm) were sampled from the nearshore area on July 29 at the downstream end of Homestead Island (rm 350.5). Walleye spawn in the late winter/early spring when water temperature ranges from 3.3^{0} C to 6.7^{0} C (Wydoski and Whitney 1979). Adults generally prefer main channel areas and typically spawn on gravel bottoms of riffles in rivers or rocky shorelines of lakes. Information pertaining to larval walleye habitat utilization in the Columbia River system is extremely limited. Larval walleye are approximately 8 to 9 mm in length at hatching and do not form paired fins until they reach approximately 13-14 mm in length and therefore require immediate access to calm rearing areas and a zoo plankton or larval fish food base for successful rearing (Bill Zook WDFW, Tom Poe BRD, John Pitlo Bellevue Research Station (Iowa), personal communications). Because of the general lack of this type rearing habitat in the Hanford Reach it is suspected that survival after hatching may be minimal (Bill Zook WDFW, personal communication). Survival of newly hatched walleye fry in the Hanford Reach may have been especially poor in 1997 due to the exceptionally high spring flows which essentially changed the slough areas into free flowing riverine habitat which would not be conducive to successful rearing during the critical early life stage. Walleye were also absent from BRD seine catches in past years in the Hanford Reach but were present in very small numbers in catches made from the McNary Reservoir (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). The absence of walleye in 1997 sample catches may have been the result of poor larval survival, utilization of habitat in the Hanford Reach other than that sampled, or downstream displacement to the reservoir. The 1997 pilot work suggests that walleye at all life stages are not highly susceptible to entrapment. However, spawning most likely occurred prior to the start of 1997 field operations.

Northern pikeminnow are a resident cyprinid considered to be a detrimental juvenile salmonid predator. Currently a BPA funded northern pikeminnow bounty program exists in the Columbia Basin. Northern pikeminnow are reported to spawn in gravel areas primarily in June in the John Day Pool of the Columbia River (Tom Poe BRD, personal communication) and in July in other Washington waters (Wydoski and Whitney 1979). Spawning is keyed to water temperature and would most likely occur in July as water temperatures are typically cooler in the Hanford Reach than the John Day Pool (Dennis Dauble PNNL, personal communication). No adult pikeminnow were sampled from entrapment areas although small yearlings were frequently found entrapped. Young of the year were not present in the samples, however, this may have been due to spawning and hatching occurring after end of the field season.

Nearly all peamouth sampled from nearshore areas and entrapment areas were yearlings. This is consistent with nearshore habitat use as reported by Wydoski and Whitney (1979); " In British Columbia and Lake Washington young peamouth inhabit very shallow water in spring, summer, and fall." Young of the year and mature fish were essentially absent from entrapment and nearshore catches. Spawning occurs on gravel and rubble substrate in the spring when water temperatures reach approximately 54^{0}F. Peamouth have been observed ascending lower Columbia River tributaries in large schools during spawning migrations (personal observation). Gray and Dauble (1976-79, Volumes 1,2,4,5,6) report spawning in the Hanford Reach to occur in June and early July. Data collected by the PNNL indicate that hatching on the Hanford Reach typically occurs in July (Dennis Dauble PNNL, personal communication). The general absence of mature adults and young of the year suggests that spawning may have occurred in areas other than those sampled such as riffle habitat and/or after the end of 1997 field sampling activities.

Redside shiners are another cyprinid which was frequently found in nearshore areas and less so in entrapment areas. The redside shiners sampled from entrapment areas were all yearling sized fish. Most of the shiners sampled from nearshore areas were also yearlings although a few may have been small two year old fish. Redside shiners school in shallow water and utilize vegetation cover during the spring (through July) in British Columbia lakes (Wydoski and Whitney 1979). These fish mature at age 2 to 3 and mature adults and young of the year were completely absent from entrapment areas and generally absent from nearshore areas of the Hanford Reach. These fish spawn in the spring over gravel bottoms in inlet or outlet streams or in vegetation along lake shorelines in British Columbia (Wydoski and Whitney 1979). Spawning timing on the Hanford Reach is reported to occur primarily in late June and July (Gray and Dauble 1976-1979 Volumes 1,2,4,5,6) and is similar to that of northern pikeminnow (Dennis Dauble PNNL, personal communication). It is therefore likely that the absence of mature and young of the year shiners from sample catches in the Hanford Reach may have resulted from sampling ending prior to spawning or that spawning occurred in areas other than those sampled.

Two chiselmouth and three dace were sampled from nearshore areas but not in entrapment areas. Dace are adapted to living in interstitial spaces within bottom substrate in swift current and therefore would not be expected to a high degree in nearshore seine samples. Dace were not reported to have been captured on the Hanford Reach by BRD in past years (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). Chiselmouth are reported to be abundant in the Columbia and Yakima Rivers (Wydoski and Whitney 1979). However, none were identified by BRD in past sample catches on the Hanford Reach (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). Adult chiselmouth prefer warmer areas of streams and moderately fast water and migrate into smaller tributaries in the spring and early summer to spawn (Wydoski and Whitney 1979). Spawning occurs at a time similar to that of northern pikeminnow (Gray and Dauble 1976-1979 Volumes 1,2,4,5,6) and it is therefore likely that 1997 field sampling ceased prior to chiselmouth spawning.

Young largemouth bass were distinguishable from smallmouth bass in some cases and were verified as present in entrapment areas although in very small numbers. Very small numbers of yellow perch and pumpkinseed sunfish were also sampled from nearshore areas. Other species of sunfish (*Lepomis* spp.) and black (*Pomoxis nigromaculatus*) and white (*Pomoxis annularis*) crappie, known to inhabit the Columbia River between McNary Dam and Priest Rapids Dam, were absent from all samples collected in 1997. This is consistent with seine catches made by BRD in past years on the Hanford Reach (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95) and is most likely the result of the lack of suitable habitat for these species on the Hanford Reach relative to the McNary Reservoir.

Juvenile bullheads (*Ictalurus* spp.) were observed on one occasion in an entrapment area on Island 8 (rm 367.5) at 100F Slough in late August. This was after the field sampling period and the observation was made in conjunction with microhabitat map survey training. Therefore these fish were observed but not sampled. Brown bullheads (*Ictalurus nebulosus*) are common in Washington waters and according to Wydoski and Whitney (1979) "this species inhabits warm-water ponds, lakes, sloughs, and sluggish areas in streams. Adults are usually in deeper water along the shoreline of lakes but move into shallow weedy areas to feed and spawn." Spawning begins when water temperatures reach 70^0 F and occurs in shallow fine sediment areas where nests can be constructed. After spawning, both sexes may guard the nest until the young are several weeks old. Bullheads were not collected in the seine samples during the 1997 field season. However, bullhead spawning and use of shallow water most likely occurred after the end of the sampling season. Bullhead habitat would be restricted primarily to slough areas and abundance of this species is probably low on the Hanford Reach. These fish may be highly susceptible both as juveniles and mature adults to entrapment during spawning and rearing periods.

Channel catfish inhabit the Columbia River between McNary and Priest Rapids Dams and were not sampled in 1997 or in BRD seining efforts during past years (Rondorf and Miller 1992, Rondorf and

Tiffan 1993-95) but are known to inhabit the Hanford Reach. Channel catfish are well established in the Snake, Walla Walla, and Yakima River systems and are present in the McNary Pool but do not appear to be well established on the Hanford Reach. Channel catfish spawn in sheltered areas when water temperatures are between 70^0 F and 80^0 F (Wydoski and Whitney 1979). The generally cooler water and lack of spawning habitat associated with the free flowing stretch of the Hanford Reach may simply limit their abundance in this area compared to other locations downstream.

Mountain whitefish are known to inhabit the Hanford Reach and support a popular recreational fishery near Vernita Bar during the fall months. However, whitefish were not sampled in 1997 by WDFW personnel and relatively few (12) were sampled by BRD personnel during seining/electrofishing efforts conducted in past years (Rondorf and Tiffan 1992-95). Mountain whitefish do not build nests or "redds" and typically spawn in gravel substrate in streams from October to December (Wydoski and Whitney 1979). Fry hatch within 30 days in 48^0 F water temperatures although a longer period is required for hatching at cooler temperatures (Wydoski and Whitney 1979). Scott and Crossman (1979) report "Newly hatched fry could be found in stream shallows for a few weeks but at lengths of 30-40 mm they moved off shore." Most likely juvenile mountain whitefish were not sampled on the Hanford Reach in 1997 because they were not near shore during the sampling period. Susceptibility to entrapment during early life history could therefore not be established.

Sandrollers are present in the Columbia River and have been collected in past studies from the Hanford Reach (Gray and Dauble 1976 and 1979) but were not sampled in 1997. Wydoski and Whitney (1979) report "This species inhabits quiet backwaters with cover such as undercut banks, submerged tree roots, and debris. Its secretive habits make it a difficult fish to capture." Sandrollers were also not collected by BRD during 1992-95 seining/electrofishing sampling efforts. These fish are apparently low in abundance on the Hanford Reach or not susceptible to the sampling gear used in 1997.

Other Anadromous Fish

White sturgeon are an important anadromous food fish that inhabit the Hanford Reach and is essentially land-locked. White sturgeon were not present in any of the samples collected in 1997. Adult white sturgeon are known to inhabit deep main channel areas. Spawning occurs in the spring in deep water with strong current such as tailrace areas and is completed by the time water temperatures reach 64.6^0 F (Mike Parsley BRD, personal communication). Larval sturgeon are displaced downstream by the current after hatching and then sound and remain within the substrate in relatively deep water throughout the rearing period and do not utilize nearshore habitat where they might become susceptible to entrapment (Parsley et al. 1993).

American shad were not sampled in 1997. These anadromous fish pass upstream through the Columbia River corridor as mature adults beginning in June. Due to the configuration of the adult passage facilities at Priest Rapids Dam, adult shad arrive at but do not pass this project. Wydoski and Whitney (1979) indicate that peak spawning above Bonneville Dam usually occurs between July 20 and August 5 and that spawning occurs in open water not associated with the shoreline. Larval shad first arrive at the McNary Juvenile Collection Facility in mid-August. The absence of adult American shad in the 1997 samples is most likely due to the lack of nearshore habitat use. Hatching is reported to occur 7 to 10 days after spawning (Wydoski and Whitney 1979) and therefore 1997 sampling activities may have ended prior to peak spawning and hatching. In addition, fertilized eggs may be displaced downstream to the McNary Pool prior to hatching and juvenile American shad may therefore rear in areas not affected by water elevation fluctuations.

Pacific lamprey were not sampled in 1997 but pass through the Columbia River upstream as spawning adults and downstream as outmigrants. Adult lamprey construct nests similar to salmon redds typically in gravel areas of small tributaries in the spring. Ammocoetes remain in fine sediment and filter feed until they transform into parasitic young adult outmigrants (Wydoski and Whitney 1979). Outmigrants utilize main channel habitat and current and are not near shore during downstream migration (Blaine Parker CRITFC, personal communication). Young outmigrants are collected at McNary Dam throughout the spring, summer, and fall, however, it is unknown where most of the spawning and rearing takes place. Much of the spawning and rearing may occur in smaller tributaries which are located downstream from the Hanford Reach. For example, adult and juvenile pacific lamprey have been recently sampled from the Yakima River system (Geoff McMichael WDFW, personal communication). It could not be confirmed that Pacific lamprey utilize nearshore habitat on the Hanford Reach to a great extent in 1997 or, if so, were not susceptible to capture with seines during the ammocoete phase. However, during a low flow test to determine river elevations at various points on the Hanford Reach, Page (1976) did observe 30-40 stranded larval lampreys at river mile 345.

Wild fall chinook in the Columbia basin out-migrate during the first year of life. Other anadromous salmonid species such as sockeye (*Oncorhynchus nerka*), steelhead (*Oncorhynchus mykiss*), coho (*Oncorhynchus kisutch*), and spring chinook *(Oncorhynchus tshawytscha*) outmigrate primarily as yearling smolts. Although hundreds of thousands of these fish pass through the Hanford Reach as they migrate downstream to the ocean, none were sampled in 1997. This was also the case in 1992 through 1995 during BRD seining activities in the spring (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). Yearling salmonid smolts do not appear to be susceptible to entrapment as a result of diel water fluctuations.

Adult steelhead and spring chinook also pass upstream through the Hanford Reach during the spring. Spring chinook are fall spawners but steelhead spawn in the spring and steelhead redds have been counted in the past on the Hanford Reach (Eldred 1970). Steelhead redds were looked for but not observed on the Hanford Reach during 1997 survey work and rearing steelhead fry or parr were not sampled. The latter was also true of BRD seining work during the 1992 through 1995 time period (Rondorf and Miller 1992, Rondorf and Tiffan 1993-95). Adult salmonids generally utilize main channel areas and are probably not susceptible to entrapment. One adult steelhead was found entrapped near Ringold Hatchery, however this was thought to be an anomaly associated with the terminal sport fishery which occurs at this location.

Habitat Utilization/Susceptibility Model

Determination of the relationship between chinook habitat preference/utilization and stranding/entrapment is a critical component in the development of the susceptibility model which is identified as an objective of this evaluation. Juvenile chinook habitat utilization data has been obtained by past and present BRD research efforts on the Hanford Reach (Rondorf and Miller 1991, 1992, Rondorf and Tiffan 1993-95). More work is needed to define the relationship between habitat use and susceptibility to entrapment. WDFW work to define this relationship began in 1997 in collaboration with BRD and PNNL and will continue in 1998. Juvenile chinook were not found randomly distributed in 1997 and stranding events appeared to be located in areas with specific habitat characteristics. In 1997, chinook production areas were identified based upon redd count information provided by PNNL. Data were also obtained from the PST coded wire tagging program which is currently being used to identify rearing areas and annual shifts in rearing locations that may occur as a result of changes in annual flow. This information is being incorporated into a GIS mapping system along with general habitat categorization data as part of the initial development of the susceptibility model. Detailed bathymetric information for the Hanford Reach does not currently exist but can be obtained in 1998 through Scanning Hydrographic Operational Airborne LIDAR (Light Detection and Ranging) Survey work. This technology is currently available through the U.S. Army

Corps of Engineers and the information which can potentially be derived is another essential component of the susceptibility model.

Preliminary information was collected during the 1997 pilot year that suggests that chinook are most susceptible to entrapment at the earliest stages of the rearing cycle and that a size threshold exists upon which susceptibility essentially ends. Work will continue in 1998 to better define each of these factors as both are necessary components of the susceptibility model. An unsteady flow model was created in 1997 that describes the stage/discharge relationship between Priest Rapids Dam and all points downstream on the Hanford Reach. This model was used in 1997 to determine water elevation histories for specific locations where chinook entrapment was observed. This information was used to develop the 1998 controlled water elevation reduction test protocol. The relationship between specific discharge changes at Priest Rapids Dam and chinook susceptibility to stranding/entrapment at each stage of the rearing cycle will be determined in 1998 through a combination of controlled river elevation reduction tests and field surveys conducted under normal operations.

Evaluation of the effects of diel water fluctuations on resident fishes is also an objective of this evaluation. Data collected in 1997 suggest that some segregation occurs between juvenile resident fish and rearing chinook due to differences in habitat preference. Generally, chinook appeared to favor current eddy areas adjacent to the main channel and main channel flow presumably to optimize pelagic feeding on drifting organisms. Juvenile resident fish, especially cyprinids, catostomids, and centrarchids, generally were found in backwater areas further displaced from the main river channel and often associated with vegetation. Observations made by WDFW in 1997 were similar to those made in past years by BRD personnel in that juvenile chinook generally did not pass through vegetation barriers (Dave Venditti BRD, personal communication). Chinook were found in entrapment areas surrounded by vegetation but this most likely resulted from the river rising above the vegetation effectively removing the barrier and allowing the fish to enter and then become entrapped when the water receded. Some mixing of juvenile resident fish with juvenile chinook in the earliest stages of rearing was also observed. These data suggest that newly emergent chinook fry may utilize shallow backwater areas until they become large enough to hold in current eddy areas. During this early stage chinook may be more susceptible to stranding and entrapment. Microhabitat data collected in past years by BRD and in 1997 by WDFW and BRD can be used in conjunction with detailed bathymetry information for the entire Hanford Reach to better define both resident fish and chinook habitat utilization.

CONCLUSIONS

This year (1997) was a pilot study. All conclusions reached in 1997 are general, are based upon field observations, limited field data, and analysis of data obtained from independent sources, and not upon controlled field tests. Such tests will be conducted during the full-scale formal evaluation scheduled for 1998 and 1999. Therefore, all conclusions listed below are to be used only as general guidelines in the development of the full-scale evaluation testing protocol. Final conclusions regarding the effect of diel water fluctuations on resident and anadromous fish as well as the river ecology of the Hanford Reach will be based upon the results of the work scheduled for 1998 and 1999 along with information collected in 1997.

1) Seining as opposed to electroshocking appeared to be the best method for sampling juvenile fish, with the possible exception of Pacific lamprey ammocoetes.

2) Although rearing juvenile chinook of all sizes (size range 32 mm-105 mm) were found in entrapment areas, smaller sized fish in the earliest stage of rearing appeared to be most susceptible to entrapment and direct mortality as a result of diel water fluctuations.

3) A size threshold exists at approximately 81 mm upon which rearing chinook parr presumably begin to move away from shoreline areas and are less susceptible to entrapment resulting from diel water fluctuations.

4) Migrating salmonids, both juvenile outmigrants and returning adults, did not appear to be susceptible to entrapment due to diel water fluctuations.

5) No evidence was collected in 1997 that suggests that natural reproduction of steelhead occurs in the Hanford Reach. However, verification of steelhead reproduction and rearing in the Hanford Reach was not a study objective and more work should be conducted.

6) A variety of factors may serve to reduce the survivability of entrapped rearing chinook. Based upon the 1997 field season, the most important of these appears to be exposure to elevated water temperatures.

7) Segregation between juvenile resident fish and salmonids based upon differences in habitat preference occurs to some extent. Chinook tend to be more closely associated with current eddy areas lacking vegetation barriers whereas juvenile resident fish tend to utilize quiet backwater areas more distant from the main river channel and often containing vegetation cover.

8) Several species of resident fish appear to be susceptible to stranding/entrapment, especially newly hatched fry and spawning adults.

9) Avian and mammalian predator activity associated with entrapment appeared minimal in 1997. Resident predatory fish were seldom entrapped with chinook and therefore predation of chinook by piscivorus resident fish in entrapment areas also appeared minimal.

10) Evaluation of the effect of diel flow fluctuations on the benthic macroinvertebrate community inhabiting the Hanford Reach was determined feasible.

RECOMMENDATIONS

1) Sampling should be conducted in 1998 under both controlled conditions (Appendix B) and normal operations throughout the fall chinook emergence and rearing period.

A) During controlled river elevation reduction test days, sampling locations should be selected to index each of the six habitat categories. All habitat types should be sampled with the greatest emphasis placed in anticipated high use chinook habitat types (i.e., willow flats), and less emphasis in low use chinook habitat types (i.e., steep embankment).

B) Sampling should also be conducted twice per week during normal operations throughout fall chinook emergence and rearing to augment the information collected during controlled tests. This sampling should be conducted primarily in high use chinook areas. Sampling through the end of August should be considered to allow collection of information regarding late spawning resident species such as northern pikeminnow (see recommendation 5).

C) For both A and B, the data collected will include:

i) date, location, and start and end time of the survey. This will allow calculation of water elevation history by location through use of the unsteady flow model. The high water mark will be identified at the start of each controlled test. The time of entrapment will be recorded during controlled tests to allow specific calculation of flow fluctuations that cause the entrapment.

ii) complete counts on all species present. Resident fish will be identified to genus unless species identification can be efficiently conducted in the field

iii) forklengths to the nearest millimeter of all fish sampled. One hundred fish subsamples of resident fish will be taken when large numbers are present.

iv) dissolved oxygen content and water temperature in entrapment areas and in the river adjacent to the sampling sites.

v) dimensions of entrapment areas and distance from the river.

vi) drainage rates of entrapment areas.

D) Chinook will also be sampled from the river adjacent to entrapment locations to allow comparison of entrapped fish to the baseline population.

E) Chinook were not observed entrapped in heavy vegetation or cobble substrate in 1997. It is not anticipated that chinook will be observed in heavy vegetation in 1998. However, due to high river flows, assessment of chinook stranding in cobble substrate was not possible in 1997. Some level of assessment will therefore be required. The general approach will be to conduct random excavation in cobble areas to determine the occurrence of stranding then, if needed, to implement a systematic block subsampling procedure after verification. Estimates of stranding will be based upon simple extrapolation. The number and area of subsamples will be based upon calculated subsample variance as well as logistical constraints.

2) Thermal profiling of entrapment areas should be conducted in 1998 using portable temperature probes.

3) Laboratory tests should be conducted in 1998 to assess both delayed mortality and reduced performance ability of juvenile fall chinook exposed to warm water and thermal shock in entrapment zones. Temperature data collected from entrapment areas should be used to establish temperature scenarios used in the laboratory tests. BRD personnel at the Columbia River Research Laboratory have extensive background and resources from similar type assessments of other salmonid stressors and were therefore requested to: 1) conduct a literature search, and 2) develop a workplan and budget to conduct a temperature assessment. Both 1) and 2) have been completed. The work statement and cost estimate are included in Appendix C. This proposed work will require the collection of wild juvenile fall chinook from the Hanford Reach to be used as test fish in 1998.

4) Microhabitat map surveys should continue in 1998 to augment the database begun by BRD. This information will be used in the development of the susceptibility model for this evaluation. The methods used will be the same as used in 1997 and by BRD in past years.

5) Several species of resident fish demonstrated susceptibility to entrapment. Large numbers of newly hatched carp fry were observed stranded and entrapped in 1997. Carp are a cyprinid species that have limited public value. However, northern pikeminnow are cyprinids that are the subject of a population control program in the Columbia Basin due to their predatory behavior on juvenile salmonids. Field sampling should continue in 1998 throughout the northern pikeminnow spawning and hatching period to determine nearshore use of newly hatched pikeminnow fry. This work can easily be accomplished in 1998, is consistent with the objectives of this evaluation, and may ultimately serve to identify potential

operational scenarios which could be used to minimize northern pikeminnow production in the Hanford Reach through a controlled river elevation approach.

6) PNNL should assume the lead role in the completion of the susceptibility model in coordination with other agencies such as the BRD and the USFWS. PNNL has the technical expertise and resources to conduct this work as well as a long history of ecological studies in the Hanford Reach. In addition, the PNNL Ecology Group office is located within the boundaries of the study area.

7) The University of Idaho Fish and Wildlife Department should continue with the benthic macroinvertebrate evaluation in 1998 in accordance with the workplan developed in 1997. Streamside Programs Consultation should continue to work with U of I staff throughout the course of this evaluation.

8) Field work in 1998 should be conducted in coordination with GCPUD staff, BRD predator sampling efforts and ongoing juvenile chinook research in the Hanford Reach, and WDFW predator work in the Yakima River Basin. This will allow cost efficient sharing of manpower and equipment during field activities and exchange of data.

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Appendix A

EFFECTS OF WATER LEVEL FLUCTUATIONS ON BENTHIC MACROINVERTEBRATES ON ARTIFICIAL SUBSTRATA IN THE HANFORD REACH OF THE COLUMBIA RIVER

Prepared For:

Bonneville Power Administration
The Public Utility District of Grant County

by

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August 1997/Revised January 1998

STATEMENT OF WORK

Title: EFFECTS OF WATER LEVEL FLUCTUATIONS ON BENTHIC MACROINVERTEBRATES ON ARTIFICIAL SUBSTRATA IN THE HANFORD REACH OF THE COLUMBIA RIVER.

Administration

Project Investigator:

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Project Leader: David H. Bennett

Administrative Contact: Dick Bottger
(208 885 6443)

Performance Period: January 1, 1998-December 31, 1999

Date of Submission: August, 1997

BACKGROUND

Benthic macroinvertebrates are an important food item to downstream migrating salmonids and to salmonids rearing in both lotic and lentic environments. Curet (1994) reported that subyearling chinook salmon in Lower Granite Reservoir in 1992 were opportunistic feeders, consuming mainly dipterans and ephemeropterans. Neitzel (1996) reported close association between organisms in the stomachs of nearly all juvenile and adult fishes and the benthic and drift invertebrate communities in the Hanford Reach of the Columbia River.

The purpose of this study is to evaluate effects of diel water level fluctuations on the benthic macroinvertebrate community downstream of Priest Rapids Dam in the Hanford Reach of the Columbia River (Figure 1). This section of the Columbia River is highly significant for the perpetuation of the fall chinook salmon, Oncorhynchus tshawytscha, stock in the Columbia River.

Currently, the largest wild stock of salmon in the Columbia River, the fall chinook salmon, spawns in the Hanford Reach. This reach is the last free-flowing section of the Columbia River and is known as the last "strong-hold" for wild chinook salmon, a stock that supports a large and diverse fishery. Although free flowing, the Hanford Reach is affected by water level fluctuations from hydroelectric operations from Priest Rapids Dam at the head of the reach. Water level fluctuations can strand rearing chinooks and their food items. As a result, concern has been expressed about the impacts of these water level fluctuations on macroinvertebrate food production and populations.

Historically, the Columbia River supported populations of six species of anadromous salmonids. A variety of life history strategies were found in these species that adapted them to the specific habitat conditions within the mainstem and its tributaries. Adults migrated upstream and spawned either in tributaries or the main-stem of the Columbia River. Juvenile salmon migrated downstream to the Pacific Ocean after rearing their first summer and fall or after rearing several years. Land and water development activities have largely altered the Columbia River and many tributaries into a series of impoundments. Dam construction and the resulting reservoirs have been identified as major sources of mortality and partly responsible for salmon population declines.

Limited information exists on the benthic macroinvertebrate fauna in the larger rivers of the Columbia River system. Brusven et al. (1974) examined effects of flow fluctuations downstream of Hells Canyon Dam on the Snake River, Idaho on the benthic macroinvertebrate community. They reported that a rich fauna largely abounded in regions of the river not experiencing daily water fluctuations. Chironomids displayed remarkable survival after exposure to desiccation for 120 hours while ephemeropterans were the least sensitive. Brusven and Trihey (1978) assessed the interacting effects of minimum flow and fluctuating shorelines on benthos in the Clearwater River, Idaho, one of the larger tributaries of the Snake River. They found that small to moderate shifts in seasonal densities of principal species were not related to hydropower releases from Dworshak Dam. Dorband (1980) reported that soft sediment benthic communities were similar in composition throughout the Lower Snake River reservoirs while Trichoptera, Ephemeroptera, and Diptera dominated hard substratum communities. Bennett et al. (1988,1990, 1991, 1993, 1995) and Bennett and Shrier (1986) examined the benthic macroinvertebrate fauna of Lower Granite Reservoir associated with in-water disposal of dredged material. Their findings indicated that the invertebrate fauna in Lower Granite Reservoir was largely composed of chironomids and oligochaetes. Cushing (1993a) reported the impacts of an early spring experimental drawdown in Little Goose Reservoir. More recently, Bennett and Nightengale (1997) reported on the benthic macroinvertebrate fauna on both soft and hard substrata in the Lower Snake River reservoirs. *Corophium* spp. was the most abundant invertebrate sampled from hard substrata and the faunal characteristics of soft substrata were similar to those previously reported by Dorband (1980).

Less information has been collected on the benthic macroinvertebrate fauna in the Columbia River, especially the Hanford Reach. Robeck et al. (1954) studied the Columbia River and its tributaries from spring 1951 to spring 1953. One of their findings suggested that the Columbia River has "clean water" forms of macroinvertebrates such as mayflies, midges, caddisflies, and mollusks. Areas at depths of 10-15 ft contained about 50% of the organisms that shallow riffles areas contained. Anonymous (1976) reported that caddisflies, sponges, and midges comprised more than 90% of the benthic community near the Washington Public Power Supply System's Hanford Generating Project, Columbia River. Nearshore benthos stations contained higher abundances than mid-river stations. Page and Neitzel (1977a) indicated that their benthic grab samples were co-dominated by midges and caddisfly larvae. Only on one occasion did any organisms other than midges and caddisfly larvae dominate their grab and artificial substratum samples. Page and Neitzel (1977b) reported that populations of insect larvae were higher in the areas sampled in the Columbia River in October and December than in June and July. Page and Neitzel (1978) used artificial substrata and found similar results to the earlier studies in the Columbia River; the fauna was low in diversity and dominated primarily by midges and caddisfly larvae. Page and Neitzel (1979) reported sampling 14 taxa near WNP 1, 2 and 4, Columbia River although caddisfly larvae dominated during September and December whereas midges dominated March through June 1977 samples. Together, they accounted for more than 90% of the macroinvertebrate fauna. Page et al. (1979) found similar results between January through August 1978. In addition, no station differences in the abundance of invertebrates were observed. Cushing (1993b) established background levels of chromium and radionucleides in caddisfly at the 100-NR-1 site, Columbia River, but did not collect population data.

This body of literature suggests that three categories of benthic macroinvertebrates-midges, caddisfly larvae, and others (mollusks, sponges other benthic invertebrates) would be the appropriate organisms for testing effects of water level fluctuations in the Hanford Reach of the Columbia River.

PURPOSE AND SCOPE OF STUDY:

Diel water level fluctuations downstream of electrical power generation facilities can adversely affect shallow water organisms by exposing the shoreline to desiccation. Macroinvertebrates can be affected directly by loss of habitat and desiccation and indirectly by loss of periphyton that is used for food. Numerous authors have reported that the littoral zone of aquatic ecosystems are highly productive for macroinvertebrates and important foraging areas for fishes. However, fluctuating water levels can expose these areas to desiccation and create conditions only inhabitable by more drought tolerant communities. Such water level fluctuations occur downstream of Priest Rapids Dam in the Hanford Reach of the Columbia River. Because of the importance of this area to rearing chinook salmon, this study is proposed with the following objectives:

OBJECTIVES

Objective 1. (Year-1/1998)-To determine the best location and the best of two artificial substrata to produce adequate numbers of benthic macroinvertebrates on artificial substrata for Year-2 manipulative studies in the Hanford Reach of the Columbia River.

I propose to examine colonization of benthic macroinvertebrates on two artificial substrata at three locations in the Hanford Reach. To effectively evaluate effects of diel water level fluctuations, sufficient numbers of benthic macroinvertebrates are needed. Satisfactory completion of this objective will provide the best location for colonization by midges, caddisfly larvae, and others (mollusks, sponges other benthic invertebrates) and the best substratum.

Objective 2. (Year-2/1999)-To evaluate effects of diel fluctuations of water levels on the benthic macroinvertebrate community in the Hanford Reach of the Columbia River.

Artificial substrata colonized by macroinvertebrates will be placed in selected locations to evaluate effects of diel water level fluctuations. Information obtained from Objective 1 will be used to identify appropriate locations for colonization and the best artificial substrate to use.

STUDY AREA

The Hanford Reach of the Columbia River is a 81.6 km (51 mile) free-flowing section extending from RM (river mile) 334 to RM 396. Sampling locations will be as follows:

Year-1

I have tentatively selected three locations in the Hanford Reach of the Columbia River for examination of the variability in macroinvertebrate colonization. The first location is approximately at RM 368 while the second and third sites are at RM 370.5 and 379 (Figure 1). The third location (RM 379) is considered the reference as this site has been used successfully (C. Cushing, Retired, Battelle Northwest Laboratory, Personal Communication) for colonization of artificial substrata by my target organisms. Although these three sites have been tentatively identified, use of alternative sites may be required to provide adequate numbers of macroinvertebrates on artificial substrata.

Year-2

The proposed locations for assessing effects of diel water level fluctuations on benthic macroinvertebrates is approximately at RM 368 while the second site is at RM 370.5 (Figure 1). These sites are preferred because they are important rearing areas for fall chinook salmon (Paul Wagner, Washington Department of Fish and Wildlife, Kennewick, Personal Communication), and are representative of habitats in the Hanford Reach that can have a high potential to be exposed by water level fluctuations.

METHODS and MATERIALS

Year-1 (1998).

The purpose of Year-1 sampling is to identify the best duration and location for colonization of benthic macroinvertebrates and the best artificial substratum. Attached organisms would be sampled by deploying two types of artificial substrata. Artificial substrata are an accepted method of sampling difficult habitats (Rosenberg and Resh 1982) and provide a useful means of comparing population trends of certain macroinvertebrates among locations (Brusven and Trihey 1978). One method would employ the use of 10 concrete cones, each with a surface area of 171.8 cm^2, that would be placed in a wire barbecue basket measuring 25.4 cm long X 16.5 cm in diameter. I would place 30 baskets at each of three locations. The second method would use 10 construction bricks that would also be used at the same locations and times as the barbecue baskets. Baskets and bricks would be collectively attached to ropes and deployed at sufficient depths to avoid exposure to air. Barbecue baskets and bricks would be positioned at each location for 3 and 5 weeks to assess the necessary time for colonization.

After each period of colonization, the bricks and the baskets would be retrieved and organisms from each substrata would be washed into a bucket by means of a high pressure water line or brush. Contents of the buckets would be poured through a 0.595 mm sieve bucket (#30), preserved in 10% formalin solution with rose bengal dye, and transported to the laboratory for identification, enumeration, and weighing. Organisms would be sorted from detritus and placed into the three major taxonomic groups of interest (midges, caddisfly larvae, and others), enumerated, and weighed collectively by taxonomic group. Dry weights would be measured after a 36 hour exposure to 60° C and weighed at two time intervals to assure complete dryness. This will produce data on the number and dry weight of each group of interest per basket or brick.

Statistical Analysis

Based on the variability in colonization of barbecue baskets and bricks, I would calculate the number of samples necessary to obtain statistical significance for Year-2 studies. The desired substratum and duration to assure adequate colonization would be based on the lowest variance of the samples. I would also compare locations of colonization by analysis of variance ($P < 0.05$) and test for differences among sites. Site selection would be based on proximity to the proposed Objective 2 test sites and adequacy of colonization by the three categories of macroinvertebrates.

Year-2 (1999).

The purpose of Year-2 sampling is to examine effects of diel water level fluctuations in the Hanford Reach of the Columbia River on the benthic macroinvertebrate fauna on artificial substrata. The success of this project is incumbent on quantifying the water level fluctuations that occur at the test sites. To do this, I would use two pressure sensors to detect the frequency and duration of water level fluctuations. I would place the artificial substrata along a transect at 1 foot vertical intervals from above water levels, assuring that the substrata were exposed to the air, down along the profile of the bottom to a depth of continuous inundation. Also, I would examine the frequency of water level fluctuations that occurred during the test period and compare those with water level fluctuations that have occurred in the past 5-10 year period. Comparison of years would assess how representative water level fluctuations were during the test to those in the past several years.

The design of the sampling program for Year-2 would be based on the findings from Year-1. The selected artificial substratum would be deployed for the selected duration of exposure for colonization, retrieved, placed in wash tubs to remain wet, and transported to the two selected test sites (Year-1 results). Number of replicates needed to show statistical significance ($P = 0.05$) will be determined from Year-1 sampling. As indicated above, samples would be deployed from highest water level to continuous inundation at 1 foot (0.3m) vertical increments (Figure 2). Following an additional 3-5 weeks exposure at the desired depths at the test sites, samples would be retrieved, and processed similarly to those during the initial Year-1 colonization study.

Handling loss from collection and redeployment of the artificial substrata would be quantified by retrieving three substrata and quantifying the number of macroinvertebrates present. I would assume that macroinvertebrates remaining on the substrata after a 2 day exposure are representative of those that will be exposed to the periodic water level fluctuations. Following the 3-5 weeks of exposure to "normal" water level fluctuations, the substrata would be retrieved, organisms removed from the substrata (same as Year-1), and preserved. In the laboratory, samples would be separated into midges, caddisfly, and other categories, enumerated, and weighed to dry weight as in Year-1. These data will show the differential effects of varying water depths over the test substrata.

Statistical Analysis

I would statistically determine the significance of the periodic water level fluctuations on macroinvertebrate fauna on artificial substrata using two methods. First, mean density and standing crops on the substrata would be calculated by different depth categories: wet-dry categories based on duration of exposure (e.g., 0-25 hours exposure, 25-50 hours, > 50 hours, and continuously inundated). Tests of normality and heteroscedacticity would be conducted and appropriate transformations made to "normalize" the data. Following transformation, analysis of variance would be used with exposure category as treatments using the Statistical Analysis System (SAS 1996). The second method would be to use density and standing crop as the dependent variables and duration of exposure to air as the independent variable and conduct regression analysis. The model would test the density (or standing crop) as a function of the duration of exposure to air.

EXPECTED RESULTS

This project will address two null hypotheses:

1. Colonization of artificial substrata is similar between construction bricks and barbecue baskets and that macroinvertebrate colonization is not different between 3 and 5 weeks; and

2. Macroinvertebrate survival on artificial substrata is similar among various depths in the Columbia River.

This study will examine colonization on two different substrata at three locations and assess survival of macroinvertebrates exposed to air by water level fluctuations. I will not make production estimates or quantify effects of diel water level fluctuations on overall population abundance in the Hanford Reach of the Columbia River.

I believe use of artificial substrata will provide the most representative results of the faunal dynamics experiencing the diel water level fluctuations. Advantages of using pre-colonized substrata are numerous as periodic water level fluctuations tests commence with a known faunal abundance and composition. This approach minimizes the variation associated with previous seasonal and diel water level fluctuations and focuses on effects of ongoing water level changes during the test. By use of this method, I will be able to quantify effects of diel water level fluctuations on the benthic macroinvertebrate fauna downstream from Priest Rapids Dam in the Hanford Reach of the Columbia River.

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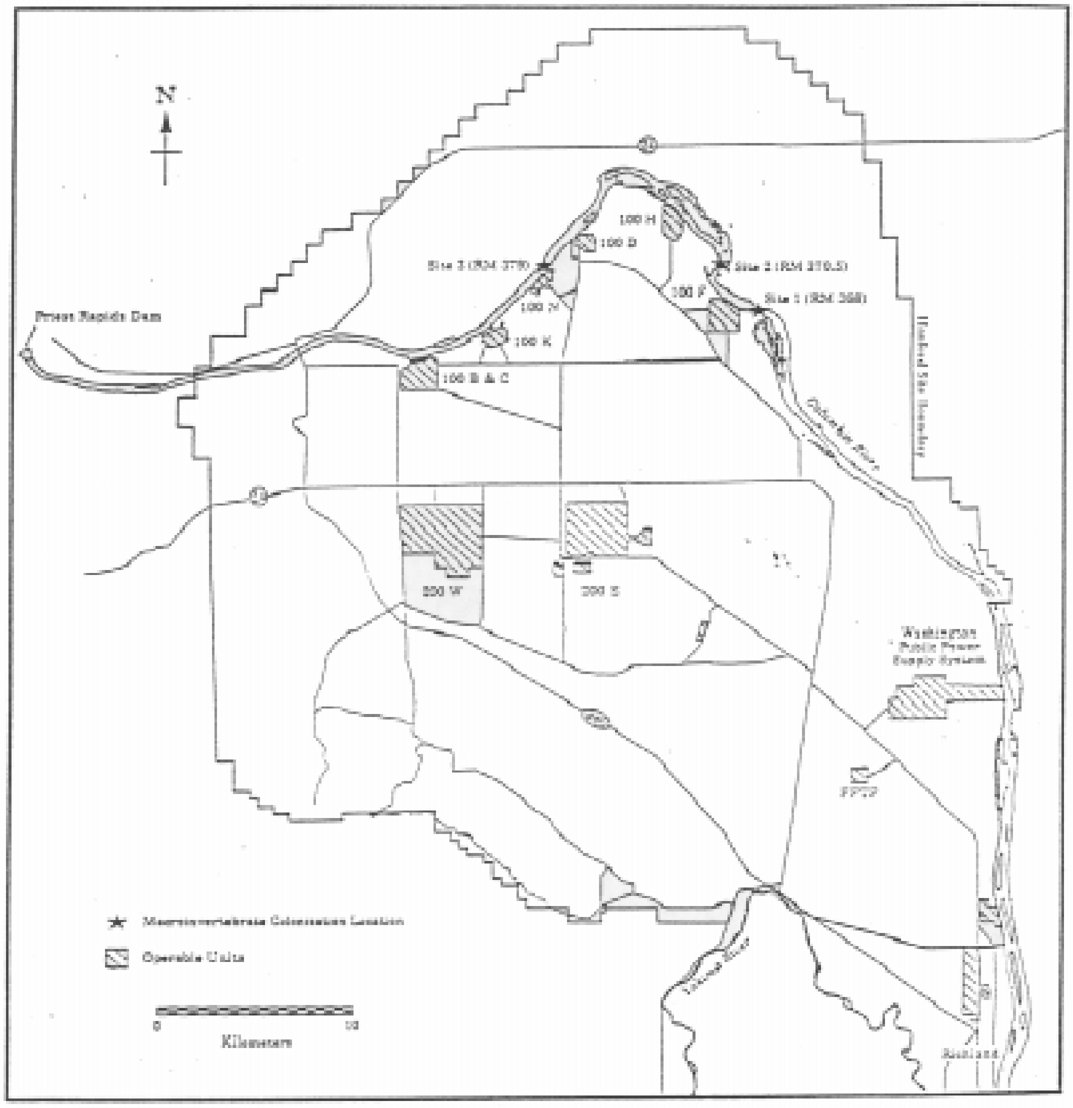

Figure 1. Map of the Hanford Reach of the Columbia River.

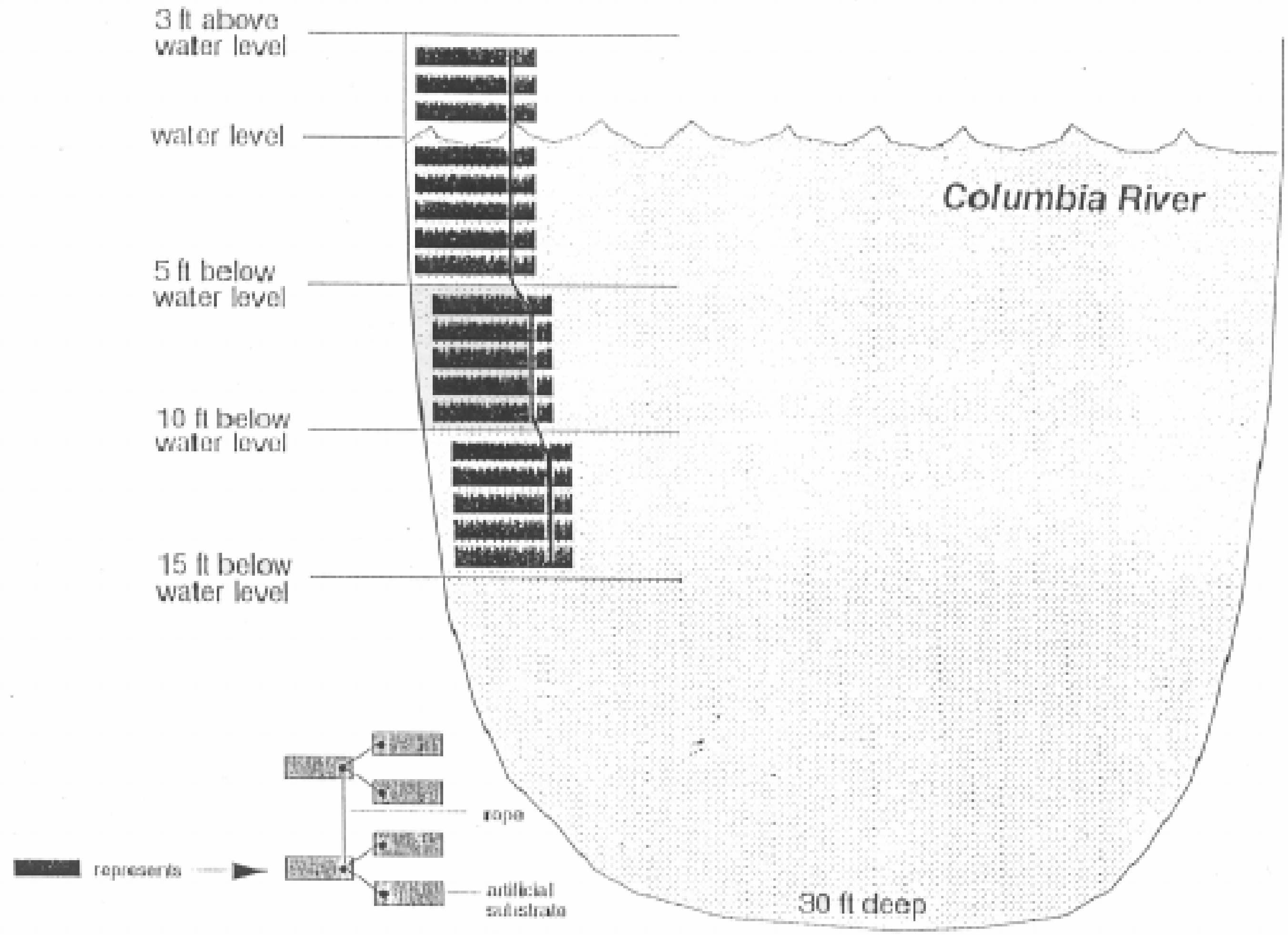

Figure 2. Diagram of depth distribution of artificial substrates.

Appendix B

State of Washington
Department of Fish and Wildlife
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Kennewick, WA 99336
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March 25, 1998

TO: Public Utility District of Grant County

FROM: Paul Wagner, WDFW

SUBJECT: 1998 Controlled River Elevation Reduction Test Schedule and Protocol.

The Evaluation of Juvenile Fall Chinook Stranding on the Hanford Reach is an ongoing study co-funded by the Public Utility District of Grant County and the Bonneville Power Administration. Pilot work began in 1997 with the full-scale evaluation scheduled for 1998.

The 1998 work is scheduled to include a series of controlled river elevation reduction tests encompassing the juvenile fall chinook emergence and rearing period. The objective of these tests is to mimic normal power peaking operations but in a controlled format to allow data collection at sampling sites located on the Hanford Reach downstream from Priest Rapids Dam. In establishing this test protocol, we have sought to minimize the impact on the population of fish inhabiting the Hanford Reach as well as Priest Rapids project operations to the extent possible while still obtaining meaningful test results. In addition, we believe that the test protocol outlined below will allow the work to be conducted within operational guidelines pertaining to other fisheries needs.

We formally request that one controlled river elevation reduction test per week be conducted each Friday night/Saturday morning beginning April 10, 1998 and concluding approximately June 27, 1998. The ending date for these tests is somewhat flexible in that chinook rearing in the Hanford Reach may conclude prior to June 27. These tests are to begin at 2200 hours on Friday night and continue through 0700 hours Saturday morning. It is further requested that discharge be maintained in a stable or increasing mode between the hours of 2200 and midnight Friday night followed by a total discharge reduction of 50 kcfs between the hours of 0000 and 0300 Saturday morning. The 50 kcfs flow reduction must begin at 0000 hours but the shape of this reduction during the three hour block can be variable, at the discretion of the Priest Rapids Dam operators. The final phase of each test will be to stabilize Priest Rapids discharge at the 50 kcfs reduction level until 0700 hours Saturday morning. Normal operations can resume at 0700 Saturday morning, Summary

Day	Time	Discharge
Friday	2200-Midnight	Stable or increasing
Friday	Midnight	Begin discharge reduction
Saturday	0000-0300	Reduce by 50 kcfs
Saturday	0300-0700	Stabilize
Saturday	0700	Resume normal operations,

The specific test schedule is included in Table 1.

Critical Flow Criterion

This testing protocol is not intended to be in conflict with the 65 kcfs critical flow criterion for the protection of pre-emergent fall chinook. Prior to the end of chinook emergence, if inflow is less than 115 kcfs on Friday night, discharge should be reduced to the critical flow (65 kcfs) and not below (i.e., if inflow is 100 kcfs Friday midnight, reduce discharge from 100 kcfs to 65 kcfs between 0000 and 0300 Saturday morning and maintain 65 kcfs discharge from 0300 to 0700).

Collaboration

This project is intended to be a collaborative effort between WDFW, GCPUD, and others. Actual sampling during the controlled river elevation reduction tests will be conducted at three specific sampling sites. Each site will require three person crews (9 persons total). In addition, a roving two person boat crew will conduct other sampling activities throughout the Hanford Reach. Participation of two GCPUD staff members during the Saturday tests is requested. Participation of these individuals in other weekday sampling activities is also desirable. In addition, the use of a GCPUD jetboat and tow vehicle to facilitate moving of personnel and equipment between sampling locations is also requested.

Table 1. 1998 Controlled River Elevation Reduction Test Schedule

Day	Date	Begin Time	Stop Time	Discharge
Friday	4/10/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	4/11/98	0000	0300	Drop Discharge 50 KCFS
Saturday	4/11/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	4/17/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	4/18/98	0000	0300	Drop Discharge 50 KCFS
Saturday	4/18/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	4/24/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	4/25/98	0000	0300	Drop Discharge 50 KCFS
Saturday	4/25/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	5/l/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	5/2/98	0000	0300	Drop Discharge 50 KCFS
Saturday	5/2/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	5/8/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	5/9/98	0000	0300	Drop Discharge 50 KCFS
Saturday	5/9/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	5/15/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	5/16/98	0000	0300	Drop Discharge 50 KCFS
Saturday	5/16/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	5/22/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	5/23/98	0000	0300	Drop Discharge 50 KCFS
Saturday	5/23/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	5/29/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	5/30/98	0000	0300	Drop Discharge 50 KCFS
Saturday	5/30/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	6/5/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	6/6/98	0000	0300	Drop Discharge 50 KCFS
Saturday	6/6/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	6/12/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	6/13/98	0000	0300	Drop Discharge 50 KCFS
Saturday	6/13/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	6/19/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	6/20/98	0000	0300	Drop Discharge 50 KCFS
Saturday	6/20/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level
Friday	6/26/98	2200	2400	Maintain Constant or Increasing Discharge
Saturday	6/27/98	0000	0300	Drop Discharge 50 KCFS
Saturday	6/27/98	0300	0700	Maintain Discharge at 50KCFS Reduction Level

Appendix C

Statement of Work

Title: **Effects of heat stress on the survival, predator avoidance ability, and physiology of juvenile fall chinook salmon**

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Background and Justification

The Hanford Reach is the last free flowing section of the Columbia River and supports a large and important population of wild fall chinook salmon (*Oncorhynchus tshawytscha*). Recently, substantial concerns have been raised about potential losses of these fish due to river level fluctuations resulting from power peaking operations at hydroelectric facilities. Rapid fluctuations in river level can cause stranding (i.e., the trapping of fish on or beneath the unwatered substrate as a result of receding river level) of juvenile fall chinook salmon and lead to direct, rapid mortality. Indeed, such stranding has been observed in the Hanford Reach and has also been documented on other rivers during controlled drawdown experiments (Thompson 1970; Phinney 1974; Tipping et al. 1979; Woodin 1984).

Besides stranding, fish can also become entrapped in isolated potholes and backwaters that form when water rapidly recedes. Although entrapment (defined as separation of fish from the main river channel in enclosed backwater areas as a result of receding river level) may not cause direct, rapid mortality, it can lead to delayed mortality from two indirect sources--namely predation and alterations in performance caused by sublethal heat stress. Predation by birds and fish on juvenile salmon entrapped in pools has been observed on several occasions in the Hanford Reach. Such predation could be substantial in these shallow, isolated backwaters since prey have few options with which to counter the intense predation pressure. To date, however, there have been no quantitative studies addressing the magnitude of avian and piscine predation on juvenile salmon in these temporary backwaters.

Alterations in performance of fish caused by sublethal heat stress is a more insidious, yet potentially devastating, effect of entrapment. Juvenile fall chinook salmon entrapped in isolated backwaters can be subjected to rapid (e.g., during the course of daylight hours) and extreme (e.g.,

>10 C above ambient temperatures) increases in temperature and then experience a relatively abrupt decrease in temperature as they are liberated back into the main river when water levels subsequently rise. The behavioral and physiological effects and potential for delayed, but direct mortality of this type of stressor on fall chinook salmon are unknown. Sublethal heat stress is known to increase the vulnerability of fish to predation (Sylvester 1972; Coutant 1973; Yocom and Edsall 1974; Deacutis 1978), but these results are likely not applicable to the situation experienced by fall chinook salmon because of species, age, and procedural differences. Sublethal heat stress also causes a variety of physiological disturbances in fish, including general stress responses (Wedemeyer 1973; Strange et al. 1978), and altered acid-base balance, enzyme activities, ionic and osmotic relations, nervous system function, and metabolic rate (Crawshaw 1977; Crawshaw 1979; Bailey et al. 1991; Soncini and Glass 1997). In addition, elevated temperatures can also elicit the rapid synthesis of a suite of proteins called stress proteins that play a role in repair and protection from environmentally induced cellular damage and may be useful as biomarkers of natural and anthropogenic environmental stress (Sanders 1993). Clearly, the heat stress experienced by juvenile fall chinook salmon during entrapment has the potential to alter behavioral and physiological mechanisms that could lead to delayed, direct or indirect mortality. An understanding of the effects of heat stress on juvenile fall chinook salmon--at several levels of organization--is necessary to fully assess the impacts of entrapment on populations of these fish in the Hanford Reach.

In this statement of work, we propose to assess the effects of heat stress on selected aspects of juvenile fall chinook salmon performance. Although most of this research will be conducted in the laboratory, we will focus on behavioral, physiological, and cellular effects of heat stress and couple such information with data from the wild to produce a multi-disciplinary, holistic approach. Our results should prove useful to fishery managers and others trying to assess the relative importance of entrapment as a mortality factor of juvenile fall chinook salmon in the Hanford Reach.

Objectives

Specifically, our objectives are as follows:

1. Assess the extent of direct mortality attributable to various heat stress scenarios on juvenile fall chinook salmon.

Task 1.1. Set up wet laboratory for fish holding and testing. This would include fish tanks, water temperature control, photoperiod control, fish food, etc.

Task 1.2. Collect fall chinook from the Hanford Reach and transport back to our laboratory. Maintain fish under ambient conditions.

Task 1.3. Expose groups of fish (i.e., replicates) to a variety of heat stress scenarios, with and without predators, derived from actual heat stress exposures in the field. Maintain other groups of fish under similar holding conditions but do not expose them to heat stress.

Task 1.4. Monitor mortality in groups of control and treatment fish daily for a period of 4 weeks. Compare cumulative and total mortality among groups using slope comparisons and tests of independence.

2. Assess the vulnerability to predation by smallmouth bass (*Micropterus dolomieui*) and northern squawfish (*Ptychocheilus oregonensis*) of juvenile fall chinook salmon subjected to a sublethal heat stress.

Task 2.1. Construct laboratory predation tanks and set up wet laboratory for fish holding and testing.

Task 2.2. Collect smallmouth bass, northern squawfish, and juvenile salmon; acclimate in the laboratory.

Task 2.3. Conduct laboratory predation tests using groups of heat-stressed and unstressed prey. Uniquely mark prey, expose them simultaneously to predation, collect survivors, and analyze the data.

3. Assess some physiological effects of sublethal heat stress on juvenile fall chinook salmon, including the metabolic cost in terms of oxygen consumption, general stress responses, acid-base balance, osmoregulatory function, and accumulation of stress proteins.

Task 3.1. Obtain or construct swimming respirometers and all equipment necessary for estimating oxygen consumption and metabolism.

Task 3.2. Set up wet laboratory holding and testing facilities. Obtain juvenile fall chinook salmon and acclimate them to the laboratory.

Task 3.3. Estimate swimming metabolic rate of heat-stressed and unstressed juvenile salmon using swimming respirometry.

Task 3.4. After estimating swimming metabolic rates, rapidly remove fish from respirometers and sample blood and tissues for physiological analysis.

Task 3.5. Assess the difference in oxygen consumption between stressed and unstressed fish to derive estimates of the metabolic cost of the sublethal heat stress.

Task 3.6. Subject groups of fish to various modifications of a sublethal heat stress.

Task 3.7. Sample blood and other tissues, as necessary, before and at selected times after the stress for physiological analysis.

Task 3.8. Analyze physiological data to assess severity of stress and time-frame for recovery.

Expected Results and Applicability

The results of this work can be used to assess some indirect effects of power peaking operations on juvenile fall chinook salmon. These results should prove useful to managers in developing a plan to modify power peaking operations on the Columbia River to minimize impacts in the Hanford Reach. Our data should also increase our understanding of the effects of temperature (in general, as opposed specifically to heat stress) on juvenile fall chinook salmon and may prove useful in assessing temperature problems that occur in other areas. Finally, our results should prove useful to persons involved with development of a bioenergetics model for fall chinook salmon by providing baseline data necessary for the construction of such a model.

Detailed Methods

Direct mortality experiments

Juvenile fall chinook salmon will be either collected by seine from the Hanford Reach or obtained from a hatchery and transported back to our laboratory using a truck with a large aluminum tank and aerated water of ambient temperature. Upon arrival at our laboratory, fish will be placed in appropriately sized tanks that will receive water of the same temperature as that in the Hanford Reach. Fish will be held under ambient photoperiod and fed either blood worms (wild fish) or a moist pellet diet (hatchery fish).

To start an experiment, fish will be divided into groups of treatment and control fish and placed in replicate test tanks (two replicates for each treatment tested). Heat stress treatments will consist of temperature increases over time followed by a relatively abrubt decrease in temperature back to ambient and will be based on scenarios experienced by fish in the wild. To assess the stressful effects of the presence of predators, some groups will have predators in their tanks, other groups will not. Control fish will be maintained at ambient temperature throughout the experiment. After exposure to the stressor, fish will be held under ambient conditions for 2-4 weeks and mortality will be monitored in all tanks. We will assess differences in mortality by plotting cumulative mortality and comparing the slopes of the lines for each treatment. Chi-squared tests of independence will be used to determine whether total mortality was independent of treatment. These experiments will likely be conducted simultaneously with those described in objective 3.

Predation vulnerability experiments

Juvenile fall chinook salmon will be obtained and maintained as described above. At our laboratory, fish will be divided into groups of treatment and control fish; several weeks prior to the start of predation tests, fish in one group will be marked by removing their adipose fin, whereas the other group will be sham marked. Piscivorous-sized predators, comprised of smallmouth bass and northern squawfish, will be collected from the Hanford Reach or other areas of the Columbia River by electrofishing and transported to our laboratory. Smallmouth bass will be placed in each of two 3.75-m-diameter, 1-m-deep circular tanks (N = 6 fish per tank) which will be lined with gravel and cobble substrates and have several pieces of 0.25-m-long, 15-cm-diameter PVC pipe randomly scattered along the bottom to serve as cover for the predators. Northern squawfish (N = 12) will be held in a 7.6-m-long, 1.2-m-wide, 1.2-m-deep flowing water raceway. All predator tanks will receive water of a temperature similar to that in the Hanford Reach. All tanks will be surrounded with curtains to minimize outside disturbance and fish will be held under a simulated ambient photoperiod. Predators will be fed a maintenance diet of juvenile salmon and predation tests, which will occur in the same tanks, will not commence until predators are consistently feeding.

To begin a predation test, groups of treatment and control fish will be transferred to smaller circular tanks. These tanks will receive water of the same temperature as their larger holding tanks. Fish will be held in these tanks for at least one day to allow some recovery from the stress associated with netting and transfer. Early in the morning on the day of a predation test, fish designated as treatments will be subjected to a sublethal heat stress designed to mimic that experienced by fish in the wild. Basically, the heat stress will consist of gradually heating, over the course of several hours, the water flowing into the tank to some predetermined maximum temperature and then rapidly decreasing the temperature back to ambient holding temperature. The rate of warming (i.e., change in temperature/time), maximum temperature, and rate of temperature decrease will be estimated from data collected at the Hanford Reach. Control fish will remain at ambient holding temperature throughout the stressor period. After application of the stressor, equal numbers of treatment and control fish will be rapidly transferred into 19-L buckets filled with water and poured into a predation tank. Predation will be allowed to continue until 50% of the prey are eaten or for 3-6 h, whichever comes first. The limited time period is necessary to account for recovery from the heat stress. At the end of each trial, all survivors will be netted, identified as treatment or control fish, and measured. We will be able to observe the tests to count prey and make general behavioral observations, while concealed, from overhead. We will attempt to conduct at least 10 trials for each variation of the heat stress that we use.

Predation data will be analyzed in a manner identical to that of Mesa (1994). We first will subject all data to a heterogeneity chi-square analysis to determine if the individual tests were homogenous (Sokal and Rohlf 1981). Chi-square goodness-of-fit tests will then used on pooled data to determine if predation was random (i.e., 50:50) on treated versus control fish. Because the chi-square test has low statistical power (i.e., low probability of correctly rejecting the null hypothesis) when relatively small sample sizes are used, we will set at 0.10, the detectable difference in predation rates (i.e., the effect size) at 20%, and target sample sizes at about 200 to increase power and reduce the probability of the more serious type II error (Fairbairn and Roff 1980; Peterman 1990).

Physiological effects of heat stress

The purpose of these experiments is to document the magnitude and dynamics of selected physiological responses in juvenile fall chinook salmon subjected to a sublethal heat stress. Fish will be obtained as previously described and held in circular tanks receiving water of ambient temperature. They will be held under an ambient photoperiod and fed, depending on origin, either blood worms or a moist pellet at 1-3% body weight/day. Fish will be acclimated to the laboratory for at least 1-2 weeks prior to the start of experiments.

Metabolic cost experiments. Procedures used to assess the metabolic cost of a sublethal heat stress on juvenile fall chinook salmon will be modified after those described by Barton and Schreck (1987). We will use either Blazka (Blazka et al. 1960) or Brett (Brett 1964) type swimming respirometers to estimate oxygen consumption in stressed and unstressed fish. Our hope is to borrow, rather than construct, at least two respirometers with a total water volume small enough (ca. 10 L) for use with 40-60 mm fish. For details on the operation of these respirometers, see Cech (1990). To start a respirometry trial, either a single or a small (2-3) group of fish will be netted from their tank, anaesthetized with 50 mg/L buffered tricaine (MS-222), weighed and measured, and then placed in the respirometer. Fish will be allowed to acclimate in the respirometer for 2-4 d without food at a flow rate similar to that in their holding tanks to ensure a postabsorbtive state. After acclimation, water velocity in the respirometer will be increased slightly to elicit mild swimming in the fish at about 0.2-0.3 BL/s. During this easy swimming phase, we will subject treatment fish to a heat stress. The stressor will be as described above and will consist of increasing the water temperature in the respirometer to a predetermined maximum and then rapidly dropping the temperature back to ambient. Control fish will not receive this heat stressor but will swim for a similar length of time as treatment fish. Immediately after application of the stressor, fish will be subjected to a swimming challenge of about 0.5 BL/s for 1 h. This swimming challenge will help to reduce variance in metabolic rate caused by spontaneous activity. Flow through water will be shut off during the swimming challenge and we will measure dissolved oxygen in the respirometer immediately before and immediately after the trial. Dissolved oxygen will be determined electrometrically or titrimetrically. We will standardize the time of day for application of the stressor and the swimming challenge to minimize diurnal variations in activity. Trials with stressed and unstressed fish will be conducted simultaneously in the two respirometers.

After a respirometry trial, fish will be rapidly removed from the respirometer, placed in a lethal dose of tricaine (200 mg/L), and bled into a ammonia-heparinized capillary tube after severance of the caudal peduncle. If fish are too small to bleed effectively, we will place whole fish in liquid nitrogen for future analysis. Metabolites to be assayed from these fish include, but may not be limited to, cortisol, glucose and lactate as indicators of general physiological stress, sodium, chloride, or osmolality as an indicator of osmoregulatory dysfunction, and stress protein synthesis as an indicator of possible cellular damage.

Oxygen consumption of individuals or small groups will be averaged and compared between stressed and unstressed fish using two sample *t*-tests after confirming homogeneity of variance and similarity of mean weights of the two groups of fish. Differences in oxygen consumption between stressed and unstressed fish will be compared to estimates of scope for activity for salmonids from the literature to estimate the percentage of the energy budget required to compensate for the stress. Metabolite data will be compared between stressed and unstressed fish in a manner similar to that described for oxygen consumption.

Physiological stress experiments. We will assess physiological changes in fish subjected to three treatments. Fish designated as controls will be maintained at ambient conditions throughout the experiment. A second group of fish will be designated as heat stressed (HS) and will receive a sublethal heat stress as previously described. A third group of fish will be designated as heat stressed plus predators (HS+P) and will receive the heat stress and have predators present in their tanks. It is possible that different variations of the heat stress could be assessed, thereby adding treatments to this design or perhaps make it necessary to conduct additional experiments (this is true for all our proposed experiments). Blood and tissue samples will be collected from subsamples of fish in all groups just prior to the start of the stressor. Samples will be taken from HS and HS+P fish at frequent intervals during application of the stressor, which we surmise will take several hours, and also at several intervals after completion of the stressor (e.g., 1, 3, 6, 12, 24, 72 h post-stress). Control fish will be sampled at less frequent, but regular, intervals throughout the experiment. Fish in two tanks will serve as replicates for each treatment and we will sample N = 10 fish per time period.

As indicators of acid-base balance, a small sample of blood collected from fish will be immediately analyzed for pH using a pH meter; the remaining blood will be placed temporarily on ice, centrifuged to obtain the plasma fraction, and stored at -80 C for future analysis. We will remove small fin and muscle samples from fish and place them immediately in liquid nitrogen for stress protein analysis. As an indicator of physiological stress, we will assay plasma cortisol using an enzyme immunoassay modified from procedures described by Munro and Stabenfeldt

(1983) and Barry et al. (1993). To assess carbohydrate metabolism, plasma glucose will be measured using a Sigma diagnostic kit, and osmoregulatory function will be assessed by measuring plasma sodium and chloride using flame photometry and a cholridimeter. Tissue samples will be sent to the laboratory of Dr. Lee Weber at the University of Nevada-Reno for stress protein analysis.

For all data, we will calculate mean concentrations, subject them to tests for homogenous variances, and compare among treatments using analysis of variance followed by multiple comparison procedures.

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