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PACIFIC LAMPREY RESEARCH AND RESTORATION PROJECT

ANNUAL REPORT 1999

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EXECUTIVE SUMMARY

This report summarizes results of research activities conducted from 1996 through 1999. The findings in these chapters represent the efforts of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and collaborative efforts among other researchers working on Pacific lampreys (*Lampetra tridentata*) under this project. The findings in these chapters will help management and recovery of Pacific lampreys in the Columbia River Basin.

Traditional Ecological Knowledge (TEK) of Pacific lampreys from tribal members within the Confederated Tribes of the Umatilla Indian Reservation was useful in gaining baseline life history information. Tribal members described harvesting two types of lampreys from spring through fall, the short brown type and the long dark type. Lamprey spawning distribution was from the mouth to the headwaters in the Umatilla River. Larval lampreys were observed in the mud and sand areas of the river. Tribal members observed major declines in lampreys within the Columbia River basin.

Larval Pacific lampreys were distributed throughout the John Day River basin. Larval distribution in the other subbasins was patchy and limited to the lower reaches of the streams. Larval densities were highly variable in the Middle Fork John Day and North Fork John Day rivers, as opposed to the Main stem John Day River. Larval lengths varied little in the Middle Fork John Day and North Fork John Day rivers, but were highly variable in the Main stem John Day River. Larval abundance decreased as we moved upstream in the Columbia and Snake rivers. In addition, we found strong evidence for lack of larval recruitment as distance increased from the mouth of the Columbia River.

We identified clinical indicators of stress in adult Pacific lampreys. Plasma glucose became elevated soon after acute stress and remained elevated for one week. Plasma lactate also became elevated by 30 minutes; however, it decreased to resting levels by one hour after application of the stressor. Muscle lactate was shown to have an inverse relationship with glucose. Muscle lactate levels decreased by 4 hours and remained depressed for two days. Plasma chloride ions decreased by one hour, then returned to resting levels by 8 hours, decreased again at 24 hours, and then recovered by 48 hours. The steroid cortisol was not found in the plasma of Pacific lampreys. Our study suggests plasma glucose, lactate, chloride ions, and muscle lactate can be used as clinical indicators of stress in Pacific lampreys.

The swimming performance and physiological effects of surgical implantation of dummy radio transmitters into the peritoneal cavities of Pacific lampreys were assessed. Intraperitoneal implantation of 3.4 g transmitters had no significant effect on circulating levels of glucose (an indicator of stress) 4 months after surgery, while 10 gram transmitters caused a significant increase in plasma glucose. Lampreys implanted with 7.4-g transmitters recovered from surgery by day 4 based on levels of plasma glucose. Lampreys implanted intraperitoneally with 7.4-g dummy transmitters showed no significant difference in circulating glucose 30, 60, 90 and 180 days after surgery in comparison to sham-implanted controls. Ventilation rate decreased significantly by 30 minutes after surgery and was stable by 60 minutes; suggesting initial recovery from surgery is rapid. Swimming performance

was impaired immediately after surgery; however, swimming was not compromised at 1 and 7 days after surgery. Tagged fish showed a significant difference in oxygen consumption in fish tested immediately after surgery; however, oxygen consumption was at control levels at 1 and 7 days after surgery.

Genetic stock structure of Pacific lampreys in the Columbia River Basin was studied using 615 samples of juveniles and adults. Samples from 18 locations in the Pacific Northwest were analyzed. Pacific lampreys lack strong genetic stock structure, however, additional work could be useful to identify donor stocks for potential transfers and reintroduction.

Evaluations of culture techniques for Pacific lampreys were conducted. We found fecundity in Pacific lampreys ranging from 54,279 to 132,788. Average size of lamprey eggs was 1.7 mm (SD = 0.1, N = 61). Fertilization success from our manual spawning of lamprey ranged from 65 to 98%. In addition, hatching success of lamprey eggs was from 85 to 90%.

In-season homing was studied using displacement of radio-tagged Pacific lampreys in the lower Columbia River. We collected 25 migrating Pacific lampreys at Bonneville Dam on the Columbia River and an additional 25 at Willamette Falls on the Willamette River. Radio tags were surgically implanted in these 50 fish and then the lampreys were released throughout the migration season in the Columbia River approximately 25 km downstream of the confluence of the Willamette River. Radio tagged Pacific lampreys exhibited nonsignificant homing fidelity ($p=0.622$) based on the null expectation that one half of the total recoveries would home and the other half would stray. Final location classifications were 17 homed, 20 strayed, and 13 were undetermined. Final location classifications were not influenced by fish length ($p = 0.594$). Based on our telemetry observations, adult lampreys do not exhibit a photophobic response. The Pacific lamprey is capable of traveling at velocities near 2.5 km/hour and sustaining that activity for at least 24 hours. In addition, natal homing was investigated using mtDNA analysis of tissue samples from Pacific lampreys returning to the Willamette River compared to fish returning to the Columbia River. Tissue samples were collected from the same fish that were radio tagged along with additional individuals crossing Willamette Falls and Bonneville Dam. A total of 102 samples were analyzed. Polymorphism was observed in the Cytochrome b region and was designated Lt-A and Lt-B. Relative frequencies for Lt-A and Lt-B were 0.714 and 0.286 for Bonneville Dam samples and 0.766 and 0.234 for Willamette Falls samples.

Since the initiation of the CTUIR's lamprey research and restoration project, a Columbia Basin Pacific lamprey technical work group has been formed to discuss current issues and findings, coordinate ongoing project efforts, and define future project needs as requested by the NPPC. State, federal, university, and tribal entities have met to discuss all ongoing and proposed Pacific lamprey research and restoration efforts and identified what are believed to be priority needs.

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CHAPTER ONE

Traditional Ecological Knowledge of Pacific lampreys (*Lampetra tridentata*) in Northeastern Oregon and Southeastern Washington from Indigenous Peoples of the Confederated Tribes of the Umatilla Indian Reservation

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Introduction

The Pacific lamprey (Lampetra tridentata) is an anadromous fish, which is distributed in rivers from Baja California, Mexico along the Pacific Rim to Hokkaido, Japan (Ruiz-Campos and Gonzalez-Guzman 1996; Simpson and Wallace 1982). Native to the Columbia River basin, Pacific lampreys spawning migration extends hundreds of kilometers inland to rivers draining Oregon, Washington, and Idaho (Kan 1975; Hammond 1979; Simpson and Wallace 1982).

Pacific lampreys are important to Native Americans of the Pacific Northwest. Indigenous peoples from the coast to the interior Columbia and Snake rivers have harvested lampreys for subsistence, religious, and medicinal purposes for many generations (Close et al. 1995). Historically, tribal peoples harvested adult lampreys in the tributaries of the Columbia and Snake rivers. Traditional fishing areas of the Umatilla, Walla Walla, and Cayuse tribes included the John Day, Umatilla, Walla Walla, Tucannon, Grande Ronde, and Powder rivers. In the 1970s, tribal members began noticing declines in the numbers of lampreys migrating into the interior Columbia River basin and in 1995 the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) initiated a project for Pacific lampreys. The overall goal of the project is to restore natural production of Pacific lampreys in traditional fishing areas of the CTUIR. Restoration of Pacific lampreys in the Umatilla River may be challenging due to unknown aspects of their life history. A recovery plan for a species should include several strategies. Petersen et al. (2000) states, " An overall recovery strategy should include habitat restoration, monitoring of the population, research of the life history, and an understanding of the population dynamics of the species."

This report focuses on one of those strategies, understanding the life history. We were interested in using Traditional Ecological Knowledge (TEK) to assist in understanding Pacific lamprey life history and their historical status in the Umatilla River and surrounding subbasins. Understanding lamprey life history in the Umatilla River basin will help managers make decisions about the recovery processes. Due to the lack of literature concerning knowledge about lamprey in the Umatilla River, a preliminary study to gain TEK from tribal members is appropriate.

Resource managers may not appreciate TEK as a way of knowing, or an alternative means to gain knowledge (Berkes et al. 2000). However, there is increased interest in traditional knowledge as a legitimate and integral part in conservation biology and sustainable resource use in general. Agrawal (1995) questions whether a real difference exists between TEK and western science. Further, both TEK and western science contain virtually the same processes in gaining knowledge. Important components of each are 1) accumulation of observations, 2) development of hypotheses and 3) testing of hypotheses either by strict methods or by long term observations.

We presume that during fishing, tribal members may have developed hypotheses to explain what was observed in nature. Tribal members may know the historical timing of adult migration into tributaries, location of spawning areas, larval rearing areas, and limiting factors in the Umatilla River basin. Our objective was to gain TEK about Pacific lampreys from indigenous peoples of the CTUIR

Methods

We developed questions designed to help us understand the life history and historical status of Pacific lamprey in the Umatilla River. From these questions, we developed a standardized questionnaire to be used in interviews with tribal members from fishing families of the Umatilla Indian Reservation. To encourage tribal members to interview, a notice was advertised in the local newspaper (Confederated Umatilla Journal). Information sought was fishing site names, name of rivers fished, years of harvest, numbers harvested, indicating signs for start of lamprey harvest season, stream conditions, gear used for harvest, dietary importance, and cultural significance. Twelve tribal members (ages 48 to 90) from the Umatilla Indian Reservation were interviewed from 1996-1999. Interviews were conducted at their homes or in the CTUIR's Fisheries office. All interviews were recorded on videotape or cassette tape for review and analysis. Tapes were replayed and questionnaires were filled out according to the response for each question. Verbal consent from tribal members to publish information was acquired. Information collected from tribal members were summarized and given back to the families in report form.

Results

Interview # 1

For the record please state your name?

Percy Brigham, 90 years old.

How long have you lived in this area? and where were you born?

I was born in Salem, Oregon, and lived at Gibbon, Oregon since 1920.

How far back can you remember fishing?

I started commercial fishing in 1930 at Celilo.

Who are some of your family members?

I have a son who lives right down here (at Cayuse, Oregon), Oliver Brigham.

Where did most people fish?

Celilo--everybody fished at Celilo.

What species of fish did your family fish for?

Chinook and Steelhead both.

Did you/your family ever fish for eels?

> What they call Chief's Island there is a little creek running over there with rocks and the eels would run over there by the thousands. I caught enough eels for six different people there one night.

How many eels do you think that was?

> Probably two to three hundred.

Was there a popular area that people fished for eels?

> Yeah, Celilo, nighttime is when the eels would come. They would hit the channel; a few would come up the channel. They could catch a few there.

How many people would you say fished this area at once?

> It's hard to say they would be coming all night long in pickups and load up with eels and taking off. How many they got I don't know. A lot of people, we had more eels in one year than since (recently).

Did your family have a special fishing site besides Celilo that you fished for eels?

> Well the site everybody fished there (Celilo) but you wouldn't always fish there.

When did you know that the eels were going to run, and what time of year was that?

> The eels would start to run when the water went down in June, but there was no place that we could get them before that.

Any other signs indicating the run of the eels?

> No, eels ran only at nighttime. Years ago before my time there was an area near Boardman that tribal members used to go to get eels. Ninety percent of the eel go up the Snake River. We used to go up the John Day at the little falls and get a few eels but not many. We went right at the mouth to get eels.

Describe the eels that were harvested? (color, size, etc.)

> Most of the eels were called big blue eels, we didn't bother with them other ones. They just didn't have as much meat on them. They (big blues) were three feet long, pretty good size.

What forms of gear did you use to harvest eels?

We used gloves. If you hooked one eel the rest would be gone as soon as the blood came out. We would start at the bottom of the falls and work our way up. If you started at the top and get one eel the rest would take off.

What were the stream conditions like when the eel runs were good in the past?

The water was low, we didn't catch to many eels till September when they really come in.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

Different times I saw them pretty thick in the channel. We would go down with a gunny sack, and one guy would spit in the water and they (lamprey) would fall in the sack. Right now we could catch a few near Cascade Locks with a dipnet.

How long did the eel runs last?

Oh, probably two months.

Did you ever see or hear of areas where eels spawned?

They spawned mostly around Thornhollow (Umatilla River, Rk 118.4), they hardly ever come above Thornhollow. One place that you can see them is Multnomuth Falls in that little creek.

Was there more than one season or run of eels per year?

Just the one run.

What other types of animals/fish were abundant when the eels were running?

Suckers.

How were the eels prepared after they were caught?

Well, a lot of the Indians dried them, we took and skinned them then boiled them a little bit to get the oil out, then put them in the oven and roasted them.

When was the last time you/your family caught enough eels for a good mess?

The boys would go to Oregon City, and come back with a ton or so. You can still do it now.

Do you still fish for eels? If not, why did you stop fishing for eels? What year did you last fish for eels?

> I can't even fish. I haven't done much eel fishing after Celilo.

Did you fish the same sites for eels as you did salmon?

> No, we had to have areas where eels would come clear out of the water. There was a pipe at Celilo that was wet, and I seen them eels work their way right up there.

What types of gear did you/your family use when fishing for salmon?

> The season opened the 10 of September for years. Would do a little fishing before to get in shape, and give to our friends, family, and other tribes. When the season opened we fished till the run was over in November. We would be catching nothing but silvers once in a while a chum. The Chum salmon used to run up this river (Umatilla River) before the 1900's by the millions.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

> We would eat them everyday if we had them. Everybody ate eels them days. We would be down there fishing, and we would build a fire, cut them in links and hold them on sticks by the fire and roast them.

What items could you trade for with eels?

> When we fished at Celilo people told that they took there eels home and dried them. You have to have a warm dry air with a breeze to get them to dry right.

If eels were restored to this tribes fishing sites, would you fish for them again?

> No, we never really fished for them, we took a few off of Three Mile Dam...(Umatilla River, Rk 5.9) we couldn't get more than 10 or 12 there.

What was the eels abundance when you saw people catching them, as compared to today?

> I am not sure what they are now, but when the boys are down dipping shad, they seem to be hitting them quite regularly.

Did you ever observe other animals feeding on eels? (eagles, hawks, seals, bears) Did they take large numbers?

> The seagulls would catch them little ones sometimes. The mink must of. The otter probably too.

Do you know any other information about eels that we have not discussed today?

We used to sneak an eel or two out of the ladders at Bonneville and John Day area for Sturgeon bait. They never counted eels when they were accessing the income for Indians at Celilo, when they sold it. They (assessors) never came at night when the eels were running, so they were not counted as a fishery. Once we found eels in Beaver Creek when we were installing a bridge.

Is there anyone else that you know that we could talk to about eels?

My son Oliver he collects down by Bonneville.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

The Colville fished up here (Celilo), I don't see why they didn't get paid.

Interview # 2

For the record please state your name?

Elias Quaempts.

How long have you lived in this area? and where were you born?

I was born at Gibbon, Oregon in 1921.

How far back can you remember fishing?

started as a child.

Who are some of your family members?

Oh, my cousin Steve Hall, my cousin Dan, Pete Hall, Joe Shoeship

Where did most people fish?

Up Meacham Creek, Gibbon area, and up the Umatilla, Bingham Springs, Buck Creek, North Fork Meacham, and South Fork Umatilla, Celilo, Wallula, Blalock channel

You mentioned Meacham Creek, how far up did you catch them?

We used to go up to the falls near Duncan (Meacham Creek, Rk 19.3) and fish. We

used to go to the depot and pay a nickel and ride up to Duncan and fish back. We used to go up North Fork (Umatilla River, Rk 144) and fish. If we looked real pitiful, my cousin Steve and I would take our fish poles and ride up and fish back.

What species of fish did your family fish for?

Salmon, eels

Did you/your family ever fish for eels?

We used to fish for eels at Three Mile Falls (Umatilla River).

Were there a popular area people fished for eels?

Just down here at Three-Mile Falls Dam.

How many people would you say fished this area at once?

It all depends, my mother and my aunt would tell us to go get fish. If we needed it real bad there would be about 4 or 5 of us. Two would throw rocks and two would hook.

When did you know that the eels were going to run, and what time of year was that?

Oh..late summer.

Any other signs indicating the run of the eels?

No, someone would just say that the eels were running, and down we would go.

Describe the eels that were harvested? (color, size, etc.)

There were lampreys..lampreys. The blue eels or night eels.

What forms of gear did you use to harvest eels?

Hooks made from wire. When the eels would bump the hook, I would pull up and have an eel.

What years was this?

The (nineteen) thirties.

What were the stream conditions like when the eel runs were good in the past?

About medium. In the fall the water would get low and we would go fish up by Gibbon for trout by horseback.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

> Oh, it must of been about 1955. That's when they started the fish poisonings. "We want to get rid of the trash fish"..now the river is so bare that you can't do nothing with it. When they had chubs, shiners, bullheads, suckers the river was clean. They killed all them fish..the trout have nothing to eat.

How long did the eel runs last?

> We used to go down there a couple times..we'd get two sacks full, or whatever we wanted. We would camp down there a couple days. Someone was always getting eels, so they was around.

Did you ever see or hear of areas where eels spawned?

> Eels used to spawn right over here (Mission Falls, Umatilla River, Rk 95.9). You would see little eels with their heads sticking out of the sand, with their mouth upstream. Once in a while you would see an eel swim by.

Was there more than one season or run of eels per year?

> Gosh I never paid no attention. When we were young we never paid no attention, we just went. We was always out doing something.

How were the eels prepared after they were caught?

> Well my wife (Lucille) and I would go down to Three Mile and then take them up McKay Creek and clean them. We would make a fire and get a stick and put them on there and cook them and eat eels. Most everybody did. Some that were good smellers would smell the eels cooking and sit down and eat.

When was the last time you/your family caught enough eels for a good mess?

> Oh, last year we happen to get some that was caught at Oregon City. And we would get some at Fifteenmile Creek. Yeah my cousin used to go get them down there. Another area was where Tom Joe was born there is some falls near there, and that was a good area.

How many was this approximately?

> We would catch a half of a wash-tub. It wasn't how many you caught, it was how many sacks you caught.

Did you fish the same sites for eels as you did salmon?

> No...eels you had to find an area where they could climb up. If you hooked them, once the blood got in the water the eels would disappear.

What types of gear did you/your family use when fishing for salmon?

> Hooks, nets.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

> It wasn't everyday but it was quite a bit. They dried a lot of eels. In the winter time you would take those dried eels and there was nothing better. Eating eels is like eating popcorn...when one don't do, you have to eat another.

What items could you trade for with eels?

> My folks did...my mother used to go digging and get roots put them in a bag and go to Mox`ee out of Yakama and trade for dried clams..or she would go down river to our relation and trade for dried fish.

What do you think led to the decline of the eels?

> Well, around here (Umatilla River) when they poisoned the river. After the railroad got done with Meacham Creek.. There used to be good fishing in Meacham Creek...the river used to come winding down…there used to be a lot of meadows, a lot of beaver ponds and marshes and alot of grassy areas..and the river used to come meandering down and there was a lot of good fishing holes. Then the railroad came along and straightened it out because they didn't want their track near the water..and it all went to hell.

If eels were restored to this tribes fishing sites, would you fish for them again?

> Oh yeah...yeah.

Did you ever observe other animals feeding on eels? (eagles, hawks, seals, bears) Did they take large numbers?

> No...Oh dead eels yeah...we used to see dead eels down at Celilo. Eels down there..if you get hungry you catch and eels, make a fire, and cook it right there..Indian style...I miss all that.

Do you know any other information about eels that we have not discussed today?

> I have seen what you may never see in your life time..I've seen salmon..I've seen the

river blue-green...salmon bank to bank pushing themselves out of the river trying to get up. I go down there...and there was hundreds and thousands and thousands of salmon. Indians had laws when fishing for salmon, some of them were pretty tuff...when commercialized fishing came in everyone was a fisherman.

Interview # 3

For the record please state your name?

Armand Minthorn.

How long have you lived in this area? and where were you born?

I have lived here all of my life and I was born in Pendleton, Oregon.

How far back can you remember fishing?

I can remember back on the late 50's and 60's going out fishing at Catherine Creek, Fly Creek, McCoy Creek, Vey Meadows, Tucannon River and Imnaha River. Those are the places that I can remember fishing for salmon.

Who are some of your family members?

Charlie Wacotsie, Lucy Minthorn (grandmother), Phillip Minthorn (father), Wilbur Minthorn (grandfather).

Where did most people fish?

My family fished those areas I mentioned.

What species of fish did your family fish for?

Many of the times we fished there..at these area..one species we fished for is the whitefish, and the other was the salmon.

Was there a popular area people fished for eels?

North Fork John Day, Middle Fork John Day, confluence of John Day and Columbia, another place was Tup-ta across from Prosser, Washington now on the Yakama River. North and South Fork Walla Walla River, Looking Glass Creek, confluence of Looking Glass and Grande Ronde River, Wallowa River, Minam River.

Did your family have a special fishing site?

What I can remember there were specific areas that were used, specifically on the Tucannon River and on the Imnaha River, and too on Catherine Creek.

Where was this site located at?

Answered above.

When did you know that the eels were going to run, and what time of year was that?

What I've heard the old people say it was a time or times that they went to gather the eels..they knew it was getting close when the huckleberries and the choke cherries were getting ready. And also another indicator was the fish runs that would take place in September, they also would call it the fall run. But generally somewhere either end of July into August was the time they knew the eels would be coming.

Describe the eels that were harvested? (color, size, etc.)

That's one of my shortcomings, I never did harvest the eels. I had several opportunities but again I can go back on my oral histories...the eels that were harvested were harvested at night.

What forms of gear did you use to harvest eels?

They would use gloves and grab hooks

What were the stream conditions like when the eel runs were good in the past?

They only thing that they indicated was when the moss on the rocks was long...which indicated low flow.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

No.

How long did the eel runs last?

I understand from ones that caught eels before that the time to harvest them was not along time. They don't run to long.

Did you ever see or hear of areas where eels spawned?

Jasper Shippentower said that they used to spawn in Meacham Creek (confluence. with Umatilla River, Rk 126.9) as well as the mouth of Meacham Creek.. He said that's where they used to spawn….that's where he also remembers getting the short eels.

What other types of animals/fish were abundant when the eels were running?

> One of the indicators when the steelhead were running was the fishhawk...Jasper used to say that when the short eels were running here there used to be the cranes or herons near the river.

How were the eels prepared after they were caught?

> They were basically dried, that's the only way I have seen them.

When was the last time you/your family caught enough eels for a good mess?

> I think it was several years ago we had a root feast..the eels were got at Shears Bridge..Shears Bridge on the Deschutes River.

Did you fish the same sites for eels as you did salmon?

> Yes....exactly. One was at Three Mile Dam. Another was on the Columbia near The Dalles on the south (Fifteen Mile Creek).

What types of gear did you/your family use when fishing for salmon?

> Hooks and nets

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

> I understand what the white man says, the eel is high in protein but is also high in fat. I don't know if that is true or not. The eels was part of the July feast..because along with the salmon..this is what our older people tell us..that when time began the foods were created..the foods were here before us..and they said that the foods made a promise on how they would take care of us as Indians and the eels was one of those who made a promise to take care of us.

If eels were restored to this tribes fishing sites, would you fish for them again?

> If the eels were to become available again, I think tribal members would take advantage of it.

Do you know any other information about eels that we have not discussed today?

> Jasper Shippentower used to harvest the short eel at the mouth of Meacham Creek...he used to catch those at Cayuse (Umatilla River, Rk 107.8) also..they were part of our diet…those type.

What do you think led to the decline of the eels?

> The first is the dams..the dams killed everything. Second is when they treated the rivers, in particular when they treated the Umatilla River to kill what they call the trash fish..just wiped out everything..not only the trash fish but also the eels. But I think the dams are the major factor. If they would have some form of facility for them to do what they need to do.

Is there anyone else that you know that we could talk to about eels?

> Inez Spino, Elizabeth Jones, Jesse Jones, Raymond Burke, Lawrence Patrick, Velma Burke, Teresa Eagle, Les Minthorn, Marcus Luke, Percy Brigham, Jasper Shippentower, Eva Watchman..that's about all I can think of now.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

> The Wanapums, Nez Perce, Yakamas..at the mouth of the Walla Walla River....Wallowa River, Wallowa Lake, Imnaha, Minam those are jointly used with the Nez Perce...Mainstem and Middle Fork John Day was shared with the Warm Springs, Paiutes and Columbia River Tribes..and mainly the North Fork was shared with the Paiutes and the Sho-Bans. And then Yakama River..Andrew Barnhart had a fishing site right at the mouth of the Yakama River, we called the Yakama River "Koots-Koots A-nim-na"...that site was jointly used with the Yakamas and the Wanapums. Another up further called "Wina-wish" which is... what the white name for it?....I can't remember, anyway it's up further and it was jointly used by us, the Yakamas, and the Wanapums...at the corner of the Yakama and Benton City..Johnson Chapman used to have a fishing site there, it was used by the Yakamas and the Wanapums...I can go on and on..

Did you/your family ever make it up to the Malheur River on the Snake River?

> Yeah..not the Malheur but where the mouth of Camas Creek (conflu. with NF John Day River, Rk 91.5) comes into the (North Fork) John Day (River), I remember hearing a story from Lewis Spino..he worked with the highway department years ago..he said they were constructing a bridge across Camas Creek one time..he said there used to be eels right there and they used to go up Camas Creek by Ukiah..I don't know if he meant they went to spawn up there or what..I don't know. But I've never heard anything about Malheur. But again there used to be a big eel fishery on the Snake River..there was a big cave by the bank of the Snake..the eels would be there.

Have you heard of Asotin before?

> Yeah, that's right outside of Clarkston..they (eels) used to go up and spawn there.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

> I do remember somebody telling me that..and I forget who told me that..they said they missed eating Indian foods...I can't remember who said that..but yeah they used to go there.

Other than for food, what other uses was there for eels?

> It is was also used as a medicine..we could use the oils to heal our bodies and our illnesses. I used to hear stories on how they would use the oils to remedy ailments. But I think it would be a wonderful thing if we could get our eel back in the river.

Interview # 4

For the record please state your name?

> Alphonse F. Halfmoon

How long have you lived in this area? and where were you born?

> I have lived here since 1922, and I was born at the old homestead where I am living at now. Just north of the Umatilla River.

How far back can you remember fishing?

> Fishing like for any kind of fish?...we had a fish hatchery adjacent from our property. My father used to work there and he planted our creek in our property. So that we could fish every Friday...we usually had fish on Fridays. With friends we would hook Whitefish, we would use a small hook on our gaff.

Who are some of your family members?

> Mathias Webb, Gus Slickpoo..Charlie Wacotsie...there was quite a few of us.

Where did most people fish?

> There used to be, before they straighted the river all out, it used to meander all over..there were logs, trees or whatever and they created nice holes..about every mile or so there would be a good hole.

What species of fish did your family fish for?

> Just the boys we fished for whitefish and trout as our target fish...and suckers for the older people that enjoyed them.

Did you/your family ever fish for eels?

> My friend and I, after the war, would go to Celilo out at Chief Island and there was scaffold with a 9ft drop off...the eels would hang on the basalt breaks. We would get a gunny sack and put as many as we could handle in the gunny sack.

Was there a popular area people fished for eels?

> The Slide and Albert Island (Both Near Celilo)

How many people would you say fished this area at once?

> I'd say a couple hundred..there were many scaffolds and fishing sites..so it's hard to estimate..there were some on the Washington side too. But the main fishing was right there on both side of the main channel, just below what they call Papoose Island.

When did you know that the eels were going to run, and what time of year was that?

> Usually in the summer months they were always there...when the water came down because you had to go to Chief Island to get them, or find an area where there were rocks hanging...there were areas like this on the Washington side. The easiest place was Chief Island..you didn't have to walk so far.

Any other signs indicating the run of the eels?

> No.

Describe the eels that were harvested? (color, size, etc.)

> At nighttime when you seen them they looked kind of brownish..but they were large lamprey..bluish colored...(Alphonse confirmed that some would be 3 feet long).

What forms of gear did you use to harvest eels?

> Hooks, canvas gloves, or eel nets. Eel nets were 1/2 inch mesh, double-knotted so it wouldn't slip..you would get one about 8 feet long and take it (scrape) along the rocks...had to make sure everything was tight because they got out of there.

What were the stream conditions like when the eel runs were good in the past?

> Blue-green..some clear water.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

I think the average catch was about 4 or 5 sacks..whatever they could take care of to dry.

How long did the eel runs last?

As long as they were fishing for salmon the eels would be there also..there wasn't a real effort just to concentrate on eels.

Did you ever see or hear of areas where eels spawned?

No, well I know they used to spawn in the Umatilla...we used to go to Lostine (conflu. with Wallowa River, Rk 41.4) in the summer swimming, we did notice eels up there but never did both catching them.

Was there more than one season or run of eels per year?

It was just that one run that we were concerned with...everyone seem to know when the eels would come...there were no regulations, you went and got what you wanted and that was it.

What other types of animals/fish were abundant when the eels were running?

Before the rotenone there was mink, otter, skunk...there was a lot of mink on the river.

How were the eels prepared after they were caught?

They would clean them out..try to take the backbone out, stretch them out, use cedar to help keep them spread out and wind dry them.

When was the last time you/your family caught enough eels for a good mess?

We weren't that good of fisherman..we would have dried eels, but we didn't make it our main course.

Do you still fish for eels? If not, why did you stop fishing for eels? What year did you last fish for eels?

The last time we fished for eels was at Three Mile Dam just before they (ODFW) rotenoned the river..we went to collect trout..I remember seeing little eels floating in the mud.

Did you fish the same sites for eels as you did salmon?

I don't know.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

eels were not a everyday food for my family.

What items could you trade for with eels?

I don't know..they weren't that popular for trading.

If eels were restored to this tribes fishing sites, would you fish for them again?

Yes, I think there would be..for fresh eels for drying.

What was the eels abundance when you saw people catching them, as compared to today?

It's opposite extremes now...there is nothing, except for Willamette Falls...then on the Chehalis River there was also a good run, but you have to travel.

Did you ever observe other animals feeding on eels? (eagles, hawks, seals, bears) Did they take large numbers?

No, I never have.

Do you know any other information about eels that we have not discussed today?

No.

Is there anyone else that you know that we could talk to about eels?

Charlie McKay, Inez Reeves, Elizabeth Jones, Cecila Bearchum, Edith McCloud, Eli Quaempts, Lillian Spino, Lillian Hoptowit, Eva Watchman.

Prior to Three Mile Dam, where did people go to get eels? on the Umatilla? elsewhere?

Over on the Snake, and a place known as Asotin, Washington. "Hoastino" is the Nez Perce word for eel.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

Nez Perce, Yakamas.

Did you/your family ever make it up to the Malheur River on the Snake River?

No.

Did you ever fish at Wallowa Lake area?

Yes.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

No.

Other than for food, what other uses was there for eels?

They kept the oil and used it for earaches, and other medicinal purposes. The oil was almost pure black like coffee.

Interview # 5

For the record please state your name?

Michael Farrow, Cayuse-Walla Walla.

How long have you lived in this area? and where were you born?

I was born in Pendleton in 1948, I was gone 7 years in military service and I have been here ever since.

How far back can you remember fishing?

When I was about 8 or 9 years old. By age 12 I was gaffing.

Who are some of your people you fished with? family members?

Shippentower Clan, the Cranes.

Where did most people fish?

We hit the Grande Ronde, Vey Meadows, Catherine Creek, Tucannon, John Day..mostly for salmon, and hook and line for trout.

What species of fish did your family fish for?

Salmon and trout.

Did you/your family ever fish for eels?

Mostly locally..at Three Mile Dam, we would get fifteen or twenty and that would last us for a while.

Was there a popular area people fished for eels?

Three Mile because it was close..I fished at Preist Rapids dam..I would climb around on the dam and go eeling.

How many people would you say fished this area at once?

Hooking salmon…3 to 5 guys.

Did your family have a special fishing site?

Not really, like I say we were tributary fisherman. I didn't really fish the mainstem (Columbia). I was brought up down there, and my family used to get eels at Celilo before The Dalles dam went in. My uncle Joe Shoeships used to repair nets at Celilo, people would trade him fish for repairs.

Where was this site located at? other areas of harvest?

At Celilo there was a big island that people used to get there by pulley cars.

When did you know that the eels were going to run, and what time of year was that?

Word of mouth..End of June, July..sometimes August.

Describe the eels that were harvested? (color, size, etc.)

Color? They were dark colored in the Umatilla. We watched them in swimming holes...they were 1 1/2 to 2 feet...maybe grayish or black.

What forms of gear did you use to harvest eels?

Gloves and gunny sacks, sometimes small dipnets, hoopnets.

What were the stream conditions like when the eel runs were good in the past?

The water was fairly low in the Umatilla. The best place to go now is Oregon City, I would eel there with Yakamas, and Warm Springs people.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

No, I think I'm to young to witness the good days..before the dams went in.

How long did the eel runs last?

This time of year..summertime..you could find them. At Priest Rapids, it seemed like the last part of July, first of August they were up there pretty good. At Three Mile, probably early July.

Did you ever see or hear of areas where eels spawned?

Mouth of the Yakama, and Hanford Reach. I've seen them in the mainstem Umatilla.

Was there more than one season or run of eels per year?

I couldn't say. I think it was summertime because that's the only time I went after them.

What other types of animals/fish were abundant when the eels were running?

Mink, raccoons and skunks, crows, ravens, magpies

How were the eels prepared after they were caught?

We always baked them or roasted them over a fire. The ladies would clean and fillet them, they are hung in a garage and wind dried. Depending on how hot the wind was maybe a week to two week to dry them.

When was the last time you/your family caught enough eels for a good mess?

Probably about 4 or 5 years ago..they were from Oregon City. We rented a boat and got eels..some Norwegian people bought a couple from us.

Do you still fish for eels? If not, why did you stop fishing for eels? What year did you last fish for eels?

The early 1960's was the last time we went eeling at Three Mile Dam. Thirty-five or 40 eels. About the only choice for eeling anymore is Oregon City…that's all we have.

Did you fish the same sites for eels as you did salmon?

No, before the tribe regulated each other in ceded areas, I would dipnet with my in-laws at Parker Dam on the Yakama River..caught my first salmon at Parker Dam.

What types of gear did you/your family use when fishing for salmon?

Gaffs, nets, hooks, hook and line.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

I would say they were more seasonal..my family never dried them but we used to barter for them.

What items could you trade for with eels?

Usually the ladies did the trading..clothes, foods, huckleberries, sometimes people just give them to you. You didn't have to trade...part of being neighborly.

If eels were restored to this tribes fishing sites, would you fish for them again?

Yes..I crave them from time to time..barbecue them now.

What was the eels abundance when you saw people catching them, as compared to today?

There is nothing to eel for really without damaging the run.

Do you know any other information about eels that we have not discussed today?

Not really.

Is there anyone else that you know that we could talk to about eels?

Inez Reeves, and Lucy Minthorn.

Prior to Three Mile Dam, where did people go to get eels? on the Umatilla? elsewhere?

Seems to me..Walla Walla, Hanford Reach, NF John Day, and here on the Umatilla.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

When I was a young guy we would spend berry season at Tower Ridge. Then, the next summer at Potato Hill with the relatives and berry up there. (Then,) Howard Lake and Fish Lake…like a rotation.

Did you/your family ever make it up to the Malheur River on the Snake River?

I've never spent much time there, mostly just driving through. I understand there is a

good bull trout population up there.

Did you ever fish at Wallowa Lake area?

I fished up there..never caught to much..mostly swam.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

The last person that went to Chemowa, in our family, was my dad that was a long time ago.

Other than for food, what other uses was there for eels?

Some use the eelskin like a wrap, for a fiber. Possibly glue, I can't remember if that was eels or salmon.

Interview # 6

For the record please state your name?

Ceceila Charlie-Bearchum

How long have you lived in this area? and where were you born?

I was born up at Cayuse..I have lived here most of my life.

How far back can you remember fishing?

Since I was very young, my dad would only fish in the spring time...he fished until bluebacks came. The particular place he fished was his..it was unspoken law that no one ever bothered your site..that's when peoples word was good.

Who are some of your family members?

Thomas Charlie (father), Sophie Wilson Charlie (mother)

Where did most people fish?

In the spring, my dad fished at Spearfish. It's just upriver from the dam (The Dalles Dam)…it's all under water now. In the fall, the people that lived across from us fished at Celilo, but my father never did fish there. Across from Chenino there was another fishing site there.

What species of fish did your family fish for?

Spring Chinook, and Bluebacks eventually.

Did you/your family ever fish for eels?

Oh yeah, my mother dried them.

Was there a popular area people fished for eels?

Spearfish and Three Mile Falls Dam.

How many people would you say fished this area at once?

My father fished by himself.

Did your family have a special fishing site?

Spearfish

Where was this site located at?

Spearfish, just above The Dalles Dam.

When did you know that the eels were going to run, and what time of year was that?

It was just a known fact..everyone knew when they were running because you could see them in the water...springtime.

Any other signs indicating the run of the eels?

Not to my knowledge.

Describe the eels that were harvested? (color, size, etc.)

They are about the same as they are now. night eels.

What forms of gear did you use to harvest eels?

Dipnet and Cotton gloves.

What were the stream conditions like when the eel runs were good in the past?

There was a channel the old wheels used to set in, after they outlawed that, the eels used to come up in the channel and it was swift and low.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

No.

How long did the eel runs last?

I don't know.

Did you ever see or hear of areas where eels spawned?

There was a lake from where we stayed, and in the mud we would find the little eels.

Was there more than one season or run of eels per year?

That's the one I only ever knew.

What other types of animals/fish were abundant when the eels were running?

Carp, Sturgeon, the Silver sometimes.

How were the eels prepared after they were caught?

Dried them, just dried them.

When was the last time you/your family caught enough eels for a good mess?

Oh gosh...years ago, just before they dammed the river at The Dalles.

How many was this approximately?

Haven't the slightest idea.

Do you still fish for eels? If not, why did you stop fishing for eels? What year did you last fish for eels?

No, none of my family members fish. Because after we got the money from The Dalles Dam our site was flooded.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

It was like a variety of food, eels were just another form of seafood.

What items could you trade for with eels?

We never traded for eels...we gave.

If eels were restored to this tribes fishing sites, would you fish for them again?

Not at the rate of what people are eating now.

What was the eels abundance when you saw people catching them, as compared to today?

I don't no because I don't go down there.

Did you ever observe other animals feeding on eels? (eagles, hawks, seals, bears) Did they take large numbers?

I haven't the slightest idea because the fishing area was quite away from where I was staying...we weren't allowed to go down to the river.

Do you know any other information about eels that we have not discussed today?

My cousin said she had heard there were small eels going up the Umatilla.

Is there anyone else that you know that we could talk to about eels?

Elizabeth Jones..her sons still fish.

Prior to Three Mile Dam, where did people go to get eels? on the Umatilla? elsewhere?

Don’t Know.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

It was more a family thing..there were some others across the river.

Did you/your family ever make it up to the Malheur River on the Snake River?

No.

Did you ever fish at Wallowa Lake area?

I don't think so. My dad would go to Wenaha, but that was just for a couple of days.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

(Cecila confirmed that she attended school at Chemowa, but fish came from Celilo).

We canned (foods) at the school...it was part of our training.

Other than for food, what other uses was there for eels?

Some of them used the oil for something, but I couldn't tell you what.

Interview # 7

For the record please state your name?

Jay Minthorn, member of the Umatilla Tribe, I am 60 years old and I have witnessed the great, unique Celilo Falls.

How long have you lived in this area? and where were you born?

I was born here on the Umatilla Reservation on April 22, 1936.

How far back can you remember fishing?

I started fishing as a child, and we continued to fish there for the subsistence and the income. We fished sometimes into November.

Who are some of your family members?

We fished a lot with Charlie McKay, Bruce McKay, Henry Beavert, my Dad (Aaron Minthorn), Louie McFarland, Oswald Tias, and Bill James.

Where did most people fish?

Well we had different areas where we fished, some of the people had their own regular sites and alot of us fished with the different members who had sites. Then we fished with people from different tribes. It was kind of a mixture of all the tribes fishing with each other.

What species of fish did your family fish for?

I don’t think there was a definite species in them days. They always said the bluebacks were good for the oil, and everything, and the tules were good for drying, but it seemed like there wasn’t a definite species, they were all used for subsistence.

Did you/your family ever fish for eels?

We done a lot of that, and a lot of it had to do with people from here who would even pay the way to go down to pick them up such as Mrs. Craig. She used to hire us sometimes. We would be home yet, and she’d make it a point to pay our way down

and give us so much money if we'd go down and fill her up sacks of eels, and there was alot of people who came down that didn't fish. They had ways of trading for the eels.

Was there a popular area people fished for eels?

There was an abundance of that you didn't really have to look for a certain place. Alot of them talked of Albert Island where you had to cross along cable to get them, I fished out on what they called Standing Island (at Celilo) and there was three or four areas where you could go out and get an abundance needed.

How many people would you say fished this area at once?

Sometimes two or three, we had fishing partners, someone who you fished together with all the time and when the people came down, if there was a man among them, we had him come out and help.

Did your family have a special fishing site?

We didn't have a special fishing site. Everyone awaited the Celilo Feast.

Were the eels a part of the Celilo Feast?

The eels were a big part of the Celilo Feast, and you will hear a lot of our elders talk of getting the eels right here at Three Mile Falls Dam. The eels could be caught here at Three Mile for the Celilo Feast.

When did you know that the eels were going to run, and what time of year was that?

I think probably the latter part of the spring, and they run almost all summer.

Any other signs indicating the run of the eels?

From here now it seemed like when the Root Feast came it seemed like the eels were available at that time so you could look toward the end of April and the beginning of May when they came into Three Mile Falls Dam.

Describe the eels that were harvested? (color, size, etc.)

The ones we caught were kind of a blueish-gray color, they had a yellow mouth on them, I notice the eels today don't have the color to them and they are a lot smaller. You could catch some of those eels that were big, they were big long eels, they were big. The big blues or night eels were the ones we used to see when we where down there. We used to see tiny eels in the sand at Celilo.

What forms of gear did you use to harvest eels?

I depended on how close you were. If you were close enough, you put on a canvas glove and threw them out. If you were quite away off, you had an eel net with small mesh which the fisherman made, or you had the gaff hooks. Those are the ways that we caught them.

What were the stream conditions like when the eel runs were good in the past?

It seemed like they followed a muddy water and a high fast flow, it seemed like that is how they began to come up.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

It seemed like right until the of the flooding (The Dalles Dam flooding) that there was an abundance.

How long did the eel runs last?

It seems like they lasted most of the summer.

Did you ever see or hear of areas where eels spawned?

No, that's one thing. But certain times of the year when you'd catch them or when the women would cut them for drying, they'd find a lot of eggs.

Was there more than one season or run of eels per year?

At that time we never addressed different runs, it seemed like they were all in an abundance so we never addressed these species and there runs.

What other types of animals/fish were abundant when the eels were running? Did you see eel carcasses?

There wasn't that many around the falls except for the seagulls. But never did see animals at the falls. When the water would drop down you could see ponds where carcasses were.

How were the eels prepared after they were caught?

We cooked them on a stick, or dry them. They also began to can eels in the later years.

When was the last time you/your family caught enough eels for a good mess?

About three years ago. A family at Warm Springs catches them at Shears Bridge. But not this year, there has been a decline in abundances.

Did you fish the same sites for eels as you did salmon?

The eels were in the fast rapids like the salmon.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

They were one of the main ones, I would say that it was just a way of life at that time.

What items could you trade for with eels?

Just about anything now.

Is there anyone else that you know that we could talk to about eels?

Elenor Shippentower, Louis McFarland, Wes Tias, Jasper Shippentower, Shirley Speedius.

Did you ever fish at Wallowa Lake area?

Just for trout.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

No, not that I can remember

Other than for food, what other uses was there for eels?

I think every species were used, the different oils were as fuel for the fire.

Interview # 8

For the record please state your name?

Lillian Shocki-Spino, Yakama enrollee.

Who are some of your family members?

Alfalfa Jim

Where did most people fish?

Three Mile Dam for eels.

What species of fish did your family fish for?

Eels and salmon.

Did you/your family ever fish for eels?

Yes.

Was there a popular area people fished for eels?

Three Mile Dam, Shears Bridge, Celilo, and Priest Rapids. They used to stack up like logs against the ladder, and we would put our nets below them and spit the water and the eels would fall in. You could get all you needed at Three Mile Dam.

How many people would you say fished this area at once?

Many people would come and go all day and night long.

When did you know that the eels were going to run, and what time of year was that?

April.

Describe the eels that were harvested? (color, size, etc.)

Night eels. The long eels are the eels that I know.

What forms of gear did you use to harvest eels?

Our hands, treble hooks, eel nets, and gloves.

What were the stream conditions like when the eel runs were good in the past?

I can't remember the water color, the water used to be low. We would see steelhead and salmon at the fish ladder at Three Mile Dam at that time. Just about everybody from up here used to go down there.

How long did the eel runs last?

Most of the summer.

Did you ever see or hear of areas where eels spawned?

Lewis said that eels used to spawn below Three Mile Dam in a big pool, the same type of a area that a salmon spawns at. I'm not sure if they still spawn there or not, it's been a long time since I have been down there. I haven't been there since they fenced it off.

How were the eels prepared after they were caught?

We air dried them and froze them. I liked them dried better. We used to take them up to the mountains for lunch.

When was the last time you/your family caught enough eels for a good mess?

Last Friday, (Nov 29, 1996) the McKay family had a feast and their family brought some from Shears Bridge.

Were eels an important part of your everyday diet? When they were abundant how often did you eat eels?

Part of it yeah, now it's just a luxury to know that there are some at somebody's table. Because we can't get it around here anymore, I get mine from somewhere else.

If eels were restored to this tribes fishing sites, would you fish for them again?

Oh yeah, I believe so because there's still a lot (of people) that use them.

Is there anyone else that you know that we could talk to about eels?

Inez Reeves, or Louie Dick, Jr. and Jay Minthorn.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

There used to be some people that came from Yakama Valley.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

No, when I was there I spent most of my time in the hospital.

Other than for food, what other uses was there for eels?

The eel oil was too rich for me. We just let it all drip out. But they used to use (it). I remember, my aunt got as earwig in her ear and we were going berry picking and we camped. I remember waking up at night when I was real young and they put that eel oil into her ear and the earwig backed out.

Interview # 9

For the record please state your name?

Eva Watchman, Ka-ta-paut-kna (Indian name).

How long have you lived in this area? Where were you born?

Most of my life, but I've been off the reservation a few times. I've lived up in Nespelem (Washington), and then I went to school down at Chemawa (Government Boarding School in Salem, Oregon). Those are the times I've been gone but I've been here most of my life.

How far back can you remember fishing?

Well I was a very small girl, I don't know how old I was but , when school was let out at Saint Andrews, all the children went home and I was there alone. My Uncle, James Billy would come down from the mountains and he'd pick me up, and they'd be coming back from digging roots. And that would be in the spring, I don't know when school was out. May or June, it could have been the later part of May or early June, I can't remember that. I figure I must have been about seven, seven or eight, but I remember that when we'd get home they'd put their roots away. He use to have a great big wagon, the old people use to call it a Spring Wagon. We'd load that all up with camping gear and everything and we'd move down to the Columbia River right about Umatilla. I couldn't say exactly how many miles away from Umatilla it was, but it was above there. But of course the dams flooded that. It must have been below Hat Rock because, when we'd run out of anything, my uncle use to walk down the tracks and he wouldn't be gone very long. So it must have been near Umatilla (likely near present day Wanaket on Columbia River, Rk 476). But I know there were bluffs and there was a plateau. Well we use to put our camp, what you would say drying shack. And my uncle use to fish for eels there and what ever he caught that night then the next day my aunt Agnes and I use to cut them. I know how to cut eels and how to dry them. And, I don't know how long we'd stay there. But my, when we'd catch up with our cutting, then my uncle, he'd go fishing during the night and then what he caught, we'd cut it the next day. Well I'd guess we'd cut eels until we had enough to last the winter. While we waited for the eels to dry we use to go up to the marshes and get those reeds that you make those mats with. We'd make those there too, and there use to be wild curds, use to grow along the river. My aunt Agnes use to make jelly out of it. Well, when our eels would get dry then we'd move home, and after we'd move home, then that's when we'd move to Celilo. And the only other place that I we use to get eels is where that Three-Mile Falls Dam is, until they closed it to us. But we never did dry that because we had no drying shack but we froze most of that. That's all I know about eels.

Who are some of your family members?

No, there was just me, cause other people would already be at Celilo, my Grandfather, Grandmother.

Where did most people fish?

Celilo

What species of fish did your family fish for?

Use to catch Steelheads and Chinook. There was an old Indian thing that we believe, eels and fish could not be dried together. They had to be dried separately. We never did dry eels down at Celilo, we just dried fish. Whatever eels we did catch down there, we ate it. I don't know what it was, ah, whether the eels spoiled the fish or what it was, but the Indians never did dry eels and fish together.

Was there a popular area on these rivers people fished for eels?

Celilo and Three-mile Falls Dam.

How many people would you say fished this area at once?

There weren't any body else, just James Billy's family (Eve Watchman confirms Umatilla site for fishing of eels). But I remember way back when I was really small, I know my grandfather and grandmother use to go down there but I don't know where, and to tell you for sure, I don't know why we weren't down there. But I can still picture the place, how it use to look.

Did your family have a special fishing site?

Celilo and the Umatilla River at Three Mile Falls Dam and Columbia River near Umatilla .

Where was this site located?

Above mouth of Umatilla River but below Hat Rock and Celilo Falls above present day The Dallas Dam.

When did you know that the eels were going to run, and what time of year was that?

My Uncle James Billy and his family would come down from the mountains and pick me up after school was out, late May or early June, after the roots were gathered and put away. Spring time I always thought was eel time.

Any other signs indicating the run of the eels?

Well it was usually after they had gathered their roots.

Did you/your family ever fish for eels on the John Day, Umatilla, Tucannon, Grande Ronde, and/or Walla Walla Rivers?

I don't nothing about that, all I know is the Columbia River.

Describe the eels that were harvested? (Color, size, etc.)

Well they kind of look black to me and they must of been about, I'd say about foot and half long. The big one's were in all the females because they had all the eggs inside. (Eva Watchman confirms female eels reached up to two feet in length). The small ones we never used them we threw them back.

What forms of gear did you use to harvest eels?

They use to have different nets for eels and different nets for salmon. They'd have small mesh for eels, its like they use to dip it.

How long did the eel runs last?

It was in the spring when we dried our eels. Then when we'd move to Celilo that was during the summer and fall that we dried our fish.

How long did the eel runs last?

I'd say May and June.

Was there more than one season or run of eels per year?

It was usually after they dug their roots and had that all put away, then it was time to go down to the Columbia River to catch the eels. I always thought of spring as eel time.

What other types of animals/fish were abundant when the eels were running?

Well I don't know, I know, the Indians use to move down there, (Eva Watchman confirms mouth of Umatilla). Oh along time ago the Indians would wait along the railroad track and when the train would come by, on flat beds they would load their gear in there and ride down on the train and they always use to camp down there on the mouth of the Umatilla River. And of course their use to be clams down there too. Cause I remember when we use to go around there we would see a lot of those shells. But I don't think theirs any there anymore.

How were the eels prepared after they were caught?

The way they use to roast, they wouldn't even gut it, they'd put it on a stick and make a circle out of it without gutting it and cook it like that. And when was done they'd cut it with a string, other times they'd just cut it in pieces and put it just like barbecuing, always roasted out side. I don't know why it just never did taste good in the oven. They'd always cook it out, I guess maybe the fire gave it better flavor.

Were eels and important part of your everyday diet? When they were abundant how often did you eat eels?

Oh yes it was. Just like now, we don't get any eels on this reservation. We have to go to the valley to eat eels, (Yakama Valley). I don't know were they get theirs. Ever since, the Indians use to get their eels down at Three-mile, then we use to freeze that for winter use. We gutted those and just put them in a can whole and put a little water in there to keep them moist. But we never did dry them on the reservation.

If the eels were restored to tribes' fishing sites, would you fish for them again?

Well I wish, ah, I don't know who would fish for It, I don't have anymore fishermen in my family.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

No.

Other than for food, what other uses was there for eels?

Just the oil, if you wanted to collect the oil. I don't know what they use to use it for. But the oil off of the salmon they use to save that cause it was right inside it. It was kind of, ah, I can't describe it, but they'd melt that and then when, then they'd make that real fine salmon you know, I mean, meal , they use to mix that oil in that.

Interview # 10

For the record please state your name?

Wes Tias.

How long have you lived in this area?

About sixty years.

How far back can you remember fishing?

Back about 1949 or 1950.

Who are some of your family members?

Sisters Veronica Tias and Eleanor Shippentower, my father was Oswald Tias and my mother was Mary Wildbill Tias.

Where did most people fish?

Mostly at Celilo.

What species of fish did your family fish for?

All kinds, chinook, steelhead, jack salmon.

Did you or your family ever fish for eels on the John Day, Umatilla, Tucannon, Grande Ronde, and/or Walla Walla rivers?

Yes.

Did you have areas on these rivers where it was more popular for people to fish for eels?

Not really.

How many people would you say fished this area at once?

About 3 or 4 at one time.

Did your family have a special fishing site?

Yes.

Where was this site located?

There were scaffolds out in the middle islands of Celilo Falls.

When did you know that the eels were going to run, and what time of year was that?

We knew in the early spring, between March and April.

Any other signs indicating the run of the eels?

After the season would change, a few eels would come out early.

Describe the eels that were harvested? (Color, size, etc.)

No, I don’t remember the size.

What forms of gear did you use to harvest eels?

Just my hands.

How long did the eel runs last?

About a month and half, something like that, yeah.

Did you ever see or hear of areas where eels spawned?

No.

Was there more than one season or run of eels per year?

No, just springtime.

How were the eels prepared after they were caught?

Cut and dried.

When was the last time you and/or your family caught enough eels for a good feast?

I can't remember that.

Do you still fish for eels?

No.

Why did you stop fishing for eels?

Because there's really no place to get them now. There're dams everyplace.

What year did you last fish for eels?

1952

Did you fish the same sites for eels as you did salmon?

Yeah, pretty close.

What types of gear did you and/or your family use when fishing for salmon?

Nets, dip nets and set nets.

When they were abundant how often did you eat eels?

Oh, about once a week, just for your taste you know. When you were sitting around you would chew on eels.

What items could you trade for with eels?

One time I traded, I can't remember what I traded but I traded this one guy, he was looking for eels to fish for sturgeon. Oh, two boxes of apples.

If eels were restored to tribes fishing sites, would you fish for them again?

Oh, if they'd come up you know I'd fish for them.

What was the eel's abundance when you saw people catching them, as compared to today?

There were a lot of eels then.

Did you ever observe other animals feeding on eels? (Eagles, hawks, seals, bears, herons)

Oh yes.

Did they take large numbers?

Oh, no, they'd just swoop down and get'em and take off.

Did tribal members from other tribes use the same fishing sites?

No.

Did tribal members go to get eels at Willamette Falls while going to school at Chemawa Indian School?

I don't know.

Do you remember going to Willamette Falls? Have you gone down and got eels down there?

Yes!

Other than for food, what other uses was there for eels?

Well ah, it was like I was telling you, people was coming along there, asking me how many eels I had, and I'd tell them. It was like: I'll give so much you, you know, I mean, for sturgeon bate.

Were they tribal members?

No.

White People?

Yes.

Do you know any other information about eels that we have not discussed today?

No.

Is there anyone else that you know that we could talk to about eels?

Ah, Jasper Shippentower, but he's in Salem now.

What do you think lead to demise of the lamprey on the Umatilla River and other known fishing sites?

Dams!

Interview # 11

For the record please state your name?

Ethel " Tessie " Williams

How long have you lived in this area? And where were you born?

About sixty years. Was born in Cayuse, Oregon in a long tent.

How far back can you remember fishing?

Well being raised by a grandmother most of our activities, dealing with all of the woman issues. But fishing as always been a part of are lives because it was kind of a family life. Everybody always went in the directions of whatever time it was, whatever season it was, we all went together. We'd go to the mountains and go fishing there and fish was always part of the meal.

Who are some of our family members?

My great great grandmother raised me and she was my teacher. We always ate traditional meals. Tuk-waa-sau (Tessie Williams, confirms, great great grandmother), she was the mother of the Johnlee's, and the Johnlee's of the Cayuse area, and their were four brother's. They were pretty well known for their horsemanship, there was a time that, this was kind of their life style.

Where did most people fish?

> I guess when we did anything it was up to the forks, (Tessie Williams confirms forks of the Umatilla River, Rk 144), and I guess at that time prior to are days they would tell stories of how thick the salmon run use to be up the Umatilla River. There was fish all the time and the river was high and they told us a lot of times that they use to not have to worry whether their was going to be fish or not, it was always there.

Did you/your family ever fish for eels on the John Day, Umatilla, Tucannon, Grande Ronde, and/or Walla Walla rivers?

> Well eels were mostly caught kind of coming up the river. We never new were they came from when we were small, because they had their own areas. But as we grew older they use to talk about Three-Mile Dam down in that location in Umatilla.

When did you know that the eels were going to run, and what time of your was that?

> This was mostly when I recall in the fall.

Describe the eels that were harvested? (Color, size, etc.)

> They were all sizes; some were short and very fat. Some were long and gray and some shiny and just a grayish color.

What forms of gear did you use to harvest eels?

> Most of the time they just about getting them by hand.

What were the stream conditions like when the eel runs were good in the past? (Clear high water, muddy, warm, cold, etc.)

> The water was definitely better then it is today. Because there weren't the traffic that there is along the rivers that there is today. And it was just a flow all the time, and it was clear.

How long did the eel runs last?

> Well at that time their was such and activity, we just knew when they brought in eels and whether it would be every other day or a week it was just always there.

Did you ever see or hear of areas where eels spawned?

> No.

Was there more than one season or run of eels per your?

Just the one certain time.

How were the eels prepared after they were caught?

Yes, that's the fun part, but that was a lot of work. At that time the elders, you know, didn't really complain. They were always just happy to have it because this was part of our life and it was part of their survival. So when ever anything came in, like the eels or the fish they were happy to get because they were either going to dry it or they were going to cook it for the family. But it was always saving some and cooking some now. So this was the time when they started thinking of how many eels they had and how long it was going to last. So then, they would either cut it or dry it or cut it and cook it on a stick like they use to a long time ago, out side. With a fire burning out side, just put the eels on a stick until they were done.

When was the last time you/your family caught enough eel for a good feast?

We were fortunate in our younger years that the men didn't mind doing these things, because they could run up and down the river along all the areas to chase the salmon, So whenever they went in a distance to where the were, they would get the eels too.

How many was this approximately?

Tessie Williams confirms about 100 eels to a gunnysack and some times they would work on 1 or 2 sacks at a time.

Were eels and important part of your everyday diet? When they were abundant how often did you eat them?

When they were dried, you could just take them and rap the up when you went digging or camping of any time of the meal, like lunch meal, like lunch meal, so dried eels were good all the time.

What items could you trade for with eels?

I don't know if my grandparents ever did, just know that if company came, they would share it with them because they were happy to see them.

What was the eel's abundance when you saw people catching them, as compared to today?

There are no eels, what ever happen to them?

Did you ever observe other animals feeding on eels? (Eagles, hawks, seals, bears, herons). Did they take large numbers?

No.

Do you know any other information about eels that we have not discussed today?

Oh, just that, the Indian People respected all of these foods. Took just what they needed and used just what they needed and tried not to waste it. So what ever they got, either in deer meat, or ah, elk, or fish, eels. It was always an amount they could use and not waste.

Did tribal members form other tribes use the same fishing sites? Where might such sites be located?

I think that they use to talk over about Richland (Washington) there. There was an area when the Yakamas use to come over, and they'd meet, ah, at that time there was no boundaries, you know. Where ever they want to be along the Columbia River or the Umatilla River there was food there that was plentiful for the Indian People.

Did tribal members go to get eels at Willamette Falls while going school at Chemawa Indian School?

I know that families use to go down there, because when they would come up, they use to come up with a lot of eels, and they'd bring some to our families, and it was down in that area there.

Other than for food, what other uses was there for eels?

Oh, they used a lot of things, oil would be use for earaches, and because of the oil, people needed it in their diet.

In your mind, what do you think led to the demise of the eels on the Umatilla River?

Oh, all of these changes in these last few years. The dams going up, the changes of the people that didn't believe how important all of this food was, and, all of the agriculture that came in. All the people that moved into the areas recognized these foods that we ate and they became familiar with it and enjoyed it and they started making use of it too. So it was people learning to eat these foods would also take it. So it was just the changes in everything through these years would have a tremendous affect on all of these traditional foods.

Interview # 12

For the record please state your name?

KUTS-KUTS-WAPTA, (Little Eagle Feather), Earl " Taz " Conner.

How long have you lived in this area? And where were you born?

Approximately thirty-five years and was born in Pendleton, Oregon in 1938.

How far back can you remember fishing?

Late forties and fifties.

Who are some of our family members?

My father and mother were the late Gilbert and Elise Conner.

Where did most people fish?

Francis Mcfarland and I would hunt mostly up and down the Umatilla River and fish and swim, always looking for a nice swimming hole. From about Maudey Antoine's place (Mission, Oregon) to Thornhollow, Oregon. About fifteen miles was our range.

What species of fish did your family fish for?

We would fish for trout and once in a while we would catch a steelhead.

Did you/your family ever fish for eels on the John Day, Umatilla, Tucannon, Grande Ronde, and/or Walla Walla rivers?

On the Umatilla, here and there we would see the eel.

Was there a popular area on these rivers people fished for eels?

Only here and there we would see the eel attach it self to the rocks around the areas where there would be small water falls.

Did your family have special fishing site?

No.

Where was this site located?

Maybe just Celilo.

What forms of gear did you use to harvest eels?

We would catch them by hand.

Is there a specific year you can remember many eels being caught? If so, do you remember where this was?

If there were any great runs, they were depleted before that my time.

Did you ever see or hear of areas where eels spawned?

No.

Was there more than one season or run of eels per year?

The fall run is when we would be down there.

How were the eels prepared after they were caught?

Our extended family had drying sheds and that's where the woman would say, you guys didn't get any eels, you better go get some eels.

When was the last time you/your family caught enough eel for a good feast?

We had quite an encampment down at Celilo. We would camp down by the channel. We had a bow tent we would put up down there. Twenty camps or twenty families any way, (Taz Conner 1940's).

How many was this approximately?

Usually a couple of gunny sacks.

If eels were restored to tribes' fishing sites, would you fish for them again?

Yes.

What was the eel's abundance when you saw people catching them, as compared to today?

At Celilo, there were great numbers.

Do you know any other information about eels that we have not discussed?

No.

Did tribal members from other tribes use the same fishing sites? Where might such sites be located?

I've heard of our relatives that are related to the Lyle, Washington area and those tributaries over there. They've got fishing places over there that they use, both eels and salmon.

Did tribal members go to get eels at Willamette Falls while going to school at Chemowa Indian School?

I've heard of people going down that way but not in organized family group.

The sites that you spoke of, what other tribes utilized these areas?

Our extended families would use these sites.

What do you believe lead to the demise of the eels?

I think the dams had a lot to do with it. Stopped the salmon run, stopped the eel run. To many dams on the river for them to get passed.

Conclusions

1. Two types of lampreys were harvested and observed by tribal members; short brown eels and dark long eels in the interior Columbia River basin.

2. Harvest of lampreys occurred from spring through fall.

3. Adult lampreys spawned from the mouth to the headwaters in the Umatilla River.

4. Juvenile lampreys live in the mud and sand areas of the rivers.

5. Tribal members have noticed major declines in lampreys within the Columbia River basin.

6. Pacific lampreys are culturally important to families of the Umatilla Indian Reservation.

7. Tribal members believe the decline of lampreys is related to declining habitat conditions, fish poisoning operations, and dams.

8. Tribal members harvested adult lampreys and observed production of larvae in the Umatilla River.

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CHAPTER TWO

Distribution of Larval Pacific Lampreys (*Lampetra tridentata*) in Northeastern Oregon and Southeastern Washington Streams

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Introduction

The Pacific lamprey (*Lampetra tridentata*) is an anadromous fish, which is distributed in rivers from Baja California, Mexico along the Pacific Rim to Hokkaido, Japan (Ruiz-Campos and Gonzalez-Guzman 1996; Simpson and Wallace 1982). Native to the Columbia River basin, Pacific lampreys spawning migration extends hundreds of kilometers inland to rivers draining Oregon, Washington, and Idaho (Kan 1975; Hammond 1979; Simpson and Wallace 1982). After Pacific lampreys spawn, eggs incubate and hatch in the gravel. Following hatching, larvae drift into soft sediment areas to burrow and begin filter feeding (Beamish 1980). During this stage, larvae may be subjected to habitat alterations such channelization, flow regulation (Kirchhofer 1995), and poor water quality (Myllynen et al. 1997). River channelization negatively impacts larval lamprey habitat by increasing velocity that reduces depositional areas. Flow regulation occurring throughout most of the arid West, impacts larvae by dewatering rearing habitat. Further, larvae are more susceptible to contaminants due to their sedentary life in the benthos. However, it is unknown if these types of habitat alterations have impacted larval lampreys in the Columbia River basin. In addition, no systematic surveys of larval abundance have been conducted for the purpose of measuring status and trends in the Columbia River basin.

Pacific lampreys are important to Native Americans of the Pacific Northwest. Indigenous peoples from the coast to the interior Columbia and Snake rivers have harvested lampreys for subsistence, religious, and medicinal purposes for many generations (Close et al. 1995). Historically, tribal peoples harvested adult lampreys in the tributaries of the Columbia and Snake rivers. Traditional fishing areas of the Umatilla, Walla Walla, and Cayuse tribes included the John Day, Umatilla, Walla Walla, Tucannon, Grande Ronde, and Powder rivers. In the 1970s, tribal members began noticing declines in the numbers of lampreys migrating into the interior Columbia River basin and in 1995 the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) initiated a project to restore natural production of Pacific lampreys in traditional fishing areas of the CTUIR. Thus, it is important to assess the status of larval lampreys in these basins. After assessing status, recovery efforts can be prioritized. The next important step is to monitor larval response to restoration efforts. Restoration efforts include science-based monitoring to determine whether restoration activities have been successful.

Our objectives were to 1) establish baseline data on the distribution and abundance of larval Pacific lampreys in the Columbia and Snake basins, and 2) select sites for future monitoring of trends in lamprey abundance. This work represents the first attempt in the Pacific Northwest to examine status and trends in larval lamprey populations. This study is unique, and an important step towards conservation of Pacific lampreys.

Study Area

Study areas included the main stem John Day (MSJD), Middle Fork John Day (MFJD), North Fork John Day (NFJD), South Fork John Day (SFJD), Umatilla (UM), Walla Walla (WW), South Fork Walla Walla (SFWW), Tucannon (TU), and Grande Ronde (GR) rivers (Figure 1). The John Day and Grande Ronde drainages were the largest among the study areas, while the Tucannon was the smallest (Table 1).

From the mouth of the Columbia River, adult Pacific lampreys ascend three hydroelectric dams to enter the John Day and Umatilla rivers. To enter the Walla Walla, Tucannon, and Grande Ronde rivers, adults must pass a total of four, 6, and 8 hydroelectric dams. In addition to main stem hydroelectric dams, adults ascend low head diversion dams in three of our tributaries. Lampreys entering the Umatilla, Walla Walla, and Tucannon rivers ascend five, four, and one low head diversion dams.

We sampled sites in the following river sections: MSJD, river kilometer (rkm) 64-446; MFJD, rkm 16-120; NFJD, rkm 4-163; SFJD, rkm 7-79; UM, rkm 0-124; WW, rkm 8-72; SFWW, rkm 3-11; TU, rkm 1-57; and GR, rkm 48-330.

Methods

Our approach was to assess the distribution of larval Pacific lampreys at two different scales; within and among subbasins in the mid-Columbia River basin. In addition, we assessed the amount of variability among sampling plots for larval densities and lengths. We expected the longitudinal distribution of larval density and lengths to increase as we moved downstream in subbasins. We also expected a decrease in larval abundance as distance increased from the Pacific Ocean.

Data collection

Larval Pacific lampreys were collected from 9 rivers in northeastern Oregon and southeastern Washington. The rivers were selected due to their importance as traditional fishing areas of the CTUIR. Larval Pacific lampreys were collected and measured during the summer between July 1999 and September 1999. Sampling of sites began near the mouth of each river and continued upstream to the headwaters. Sites in each subbasin were spaced at intervals of 10-16 km. An exception to the distance between sites was the Umatilla River, which was sampled about every 4 km. At each site sampling plots were visually selected based on silty substrate characteristics where larvae are typically most abundant (Young et al. 1990, Potter et al. 1986). Each 7.5-m^2 plot was measured and larvae were collected in two 11.25 minute passes with a backpack model Abp-2 electrofishing unit (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin). The electrofishing unit delivered 3 pulses per second (125 volts DC) at 25% duty cycle, with a 3:1 burst pulse train (three pulses on, one pulse off) to remove larvae from the substrate (Weisser and Klar 1990). Once larvae emerged from the substrate, 30 pulses per second was applied to stun and capture larvae. Voltage and pulse rates were selected based on electrofishing studies on

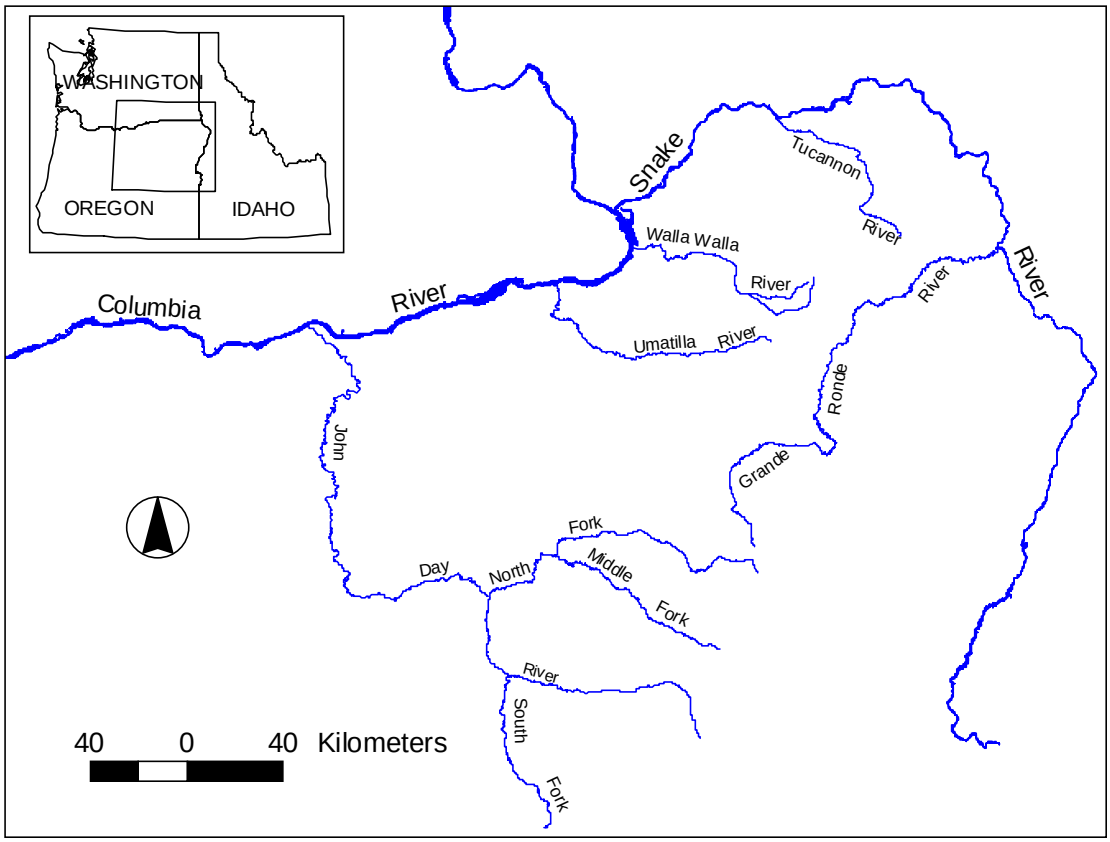

Figure 1. Study streams in the mid-Columbia River basin in northeastern Oregon and southeastern Washington.

Table 1. Characteristics of subbasins located in northeastern Oregon and southeastern Washington.

River basin	Distance from Pacific Ocean (rkm)	Elevation (m)	Drainage area (km^2)	Annual discharge (m^3/s)	Precipitation (cm/yr.)
John Day	350	61-2,743	20,979	59	<30-127
Umatilla	465	79-1,768	5,931	13	22-140
Walla Walla	505	81-1,800	4,553	16.1	25-100
Tucannon	623	165-1,951	1,303	4.7	25-102
Grande Ronde	793	305-2,438	10,360	86.8	25-152

sea lamprey larvae (Hintz 1993; Weisser 1994). Following collection, larvae were anaesthetized in MS-222 (50 mg/L tricane methanesulfonate), identified by tail pigmentation (Richards et al. 1982) and measured for total length (± 1mm). After recovery, larvae were returned to the river. Approximate location of each site was determined using 1:24,000-scale topographic maps. We used hand-held thermometers to collect water temperatures (°C) at each plot.

Data analysis

For estimating the larval population in each plot, we used the Serber and LeCren (1967) estimator to analyze the data. The population, *N*, and variance, var (*N*), are described as

$$N = \frac{(C_1)^2}{(C_1 - C_2)}$$

$$\text{var}\,(N) = \frac{(C_1)^2 (C_2)^2 (C_1 + C_2)}{(C_1 - C_2)^4}$$

where C_1 is the catch at first fishing and C_2 is the catch at second fishing. For the Serber and LeCren model we assumed that 1) larvae could not be lost from the sample plot, 2) all stunned fish were captured, and 3) equal effort was used on each pass. We calculated a population estimate for each 7.5-m^2 plot. Estimates for each plot were calculated using the Capture software program (White et al. 1982). In addition, we standardized the population estimate for each plot to density (no./m^2) and then a mean for all plots was calculated for each river. We also calculated average larval length and temperature for each plot and for each river. Densities and lengths for each plot were plotted versus river kilometer to visually assess longitudinal patterns. Length data for all samples in each river were pooled and then graphed as relative frequency to assess recent recruitment. Larval occurrence (presence/absence) was mapped using a geographic information system (GIS).

Results

Larval distribution

We examined spatial distribution of larval Pacific lampreys among and within basins. In general, the occurrence of larvae decreased as distance increased from the mouth of the Columbia River (Figure 2). Among the rivers surveyed, the highest average density 32.0 larvae/m^2 (range 0.0 to 87.1/m^2; SD = 27.1; N = 8), was in the MFJD, and the lowest average density, 0.2 larvae/m^2, was found in the GR (Table 2).

Larval lamprey was distributed throughout the entire John Day subbasin but was patchy in the other subbasins. In upriver subbasins, larval distribution was limited to the lower reaches of the rivers (Figure 2). The percentages of sites containing larvae in

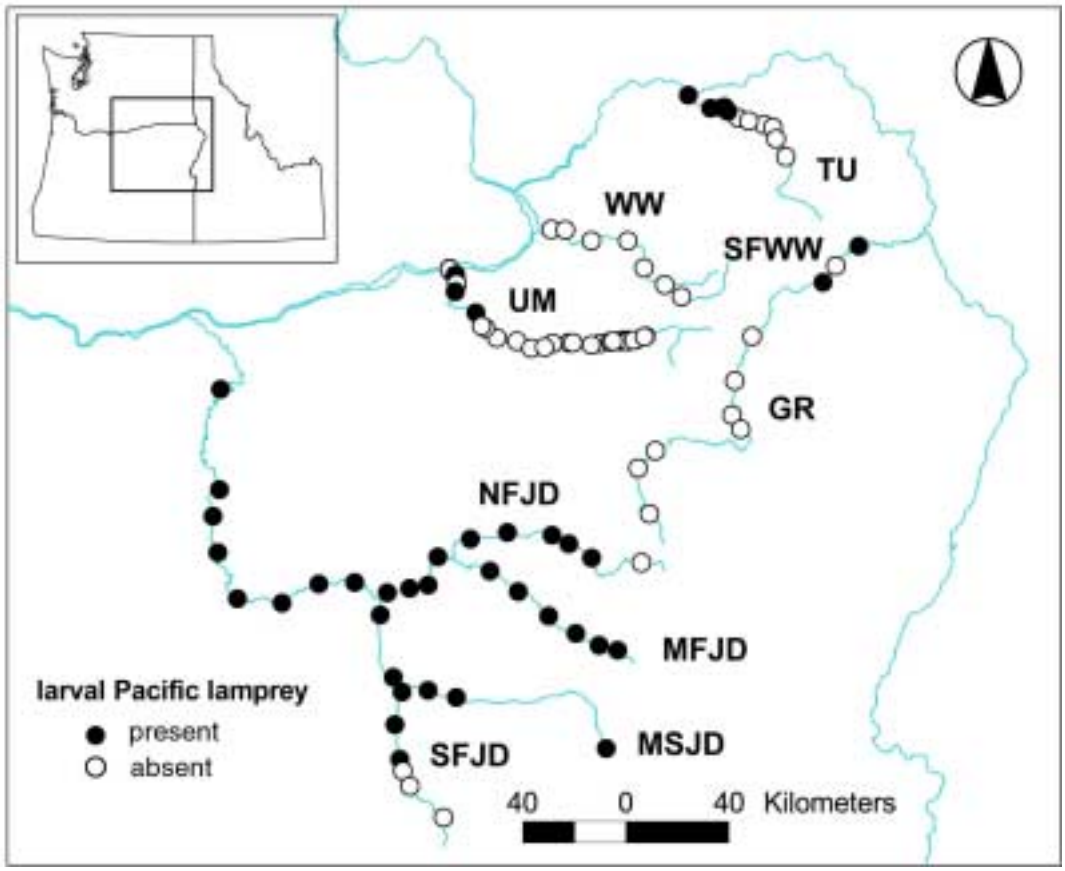

Figure 2. Distribution of larval Pacific lampreys in northeastern Oregon and southeastern Washington.

Table 2. Site means, standard deviations (SD), and ranges of larval densities, lengths and river temperatures.

River	No. of sites	Mean Density (no./m^2)	SD	Range	Mean Length (mm)	SD	Range	Mean Temp. (ºC)	SD	Range
MSJD	13	12.0	9.0	3.8-36.6	56.2	26.7	20-138	17.5	2.2	13.5-20.2
NFJD	9	26.7	13.7	0.0-43.3	69.6	20.7	12-165	21.8	3.2	17.0-26.0
MFJD	8	32.0	27.1	0.0-87.1	63.1	20.7	18-145	19.6	3.1	15.0-24.0
SFJD	6	14.2	17.6	0.0-42.4	90.5	23.6	13-166	16.0	3.5	12.0-22.0
UM	32	0.6	1.5	0.0-5.2	112.1	29.2	29-170	21.0	2.2	17.0-26.0
WW	5	0.0	0.0	0.0	0.0	0.0	0.0	23.8	3.3	19.0-27.0
SFWW	2	0.0	0.0	0.0	0.0	0.0	0.0	13.5	4.9	10.0-17.0
TU	11	5.3	9.5	0.0-29.8	77.8	28.3	24-131	13.7	2.2	9.2-16.8
GR	11	0.2	0.7	0.0-2.1	98.3	19.2	75-149	15.3	5.4	4.3-23.3

each river were: MSJD (100%), NFJD (89%), MFJD (87%), SFJD (50%), UM (12%), WW (0%), SFWW (0%), TU (45%), and GR (18%). We found no larval Pacific lampreys in the WW and SFWW rivers. However, we did find the non-anadromous larval western brook lampreys (*Lampetra richardsoni*) in two sites in the SFWW (4.8 and 36.7 larvae/m^2, respectively).

Because larvae were absent or uncommon in several of the rivers, we assessed the MSJD, MFJD, and NFJD rivers for longitudinal patterns of larval density. Each sample site was georeferenced by location, enabling us to examine spatial patterns in larval density and variability among sites within rivers. Larval densities were highly variable in the MFJD and NFJD compared to the MSJD (Figure 3). Densities in the MSJD were highest at rkm 300.

Larval lengths

Among the rivers surveyed, we found the highest average length 112 mm (range 29 to 170 mm; SD = 29.2; N=32) in the UM and the lowest average length 56 mm (range 20 to 138 mm; SD = 26.7; N = 13) was found in the MSJD. Over all, larval lengths ranged from 12 to 166 mm in the John Day River basin, 29 to 170 mm in the UM, 24 to 131 mm in the TU, and 75 to 149 mm in the GR (Table 2). We found a general trend of increased length as distance increased from the mouth of the Columbia River.

Average larval length in each sample plot was plotted versus river kilometer to visually assess patterns. Longitudinal patterns of average larval length varied little in an upstream direction in the MFJD and NFJD rivers. In contrast, average larval length was highly variable moving upstream in the MSJD River (Figure 3).

In order to assess recent recruitment, we pooled all lengths from all sites in each river and graphed length frequencies. We found strong evidence of recruitment in the John Day River basin and slight evidence of recruitment in the TU (Figure 4). However, recent recruitment was low to non-existent in the UM, WW, SFWW, and GR. Recent recruitment (< 60.0 mm) decreased with increasing distance from the mouth of the Columbia River.

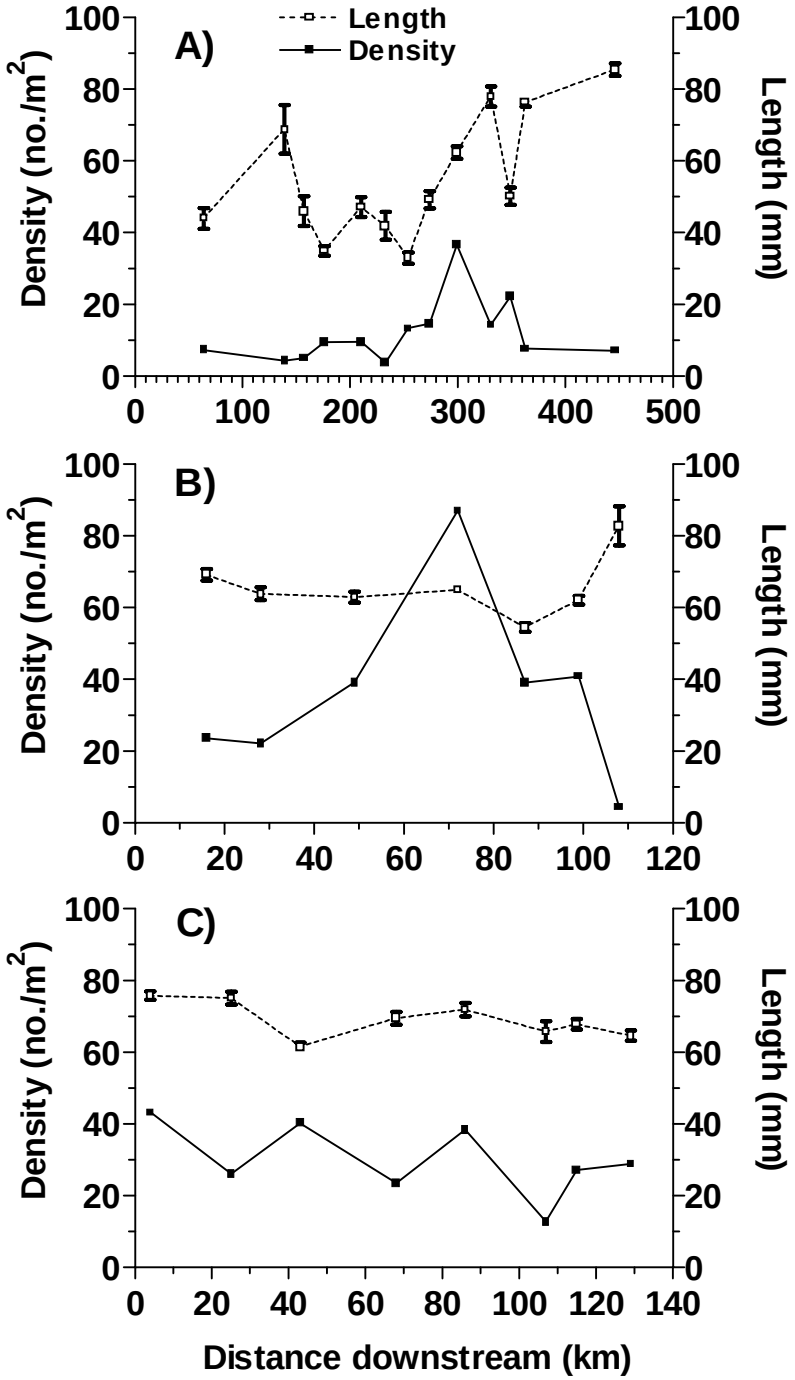

Figure 3. Longitudinal stream profiles of mean larval lamprey densities (solid lines) and mean lengths (dashed lines) ± SE in the (a) MSJD, (b) MFJD, and (c) NFJD study sections of the John Day River, Oregon.

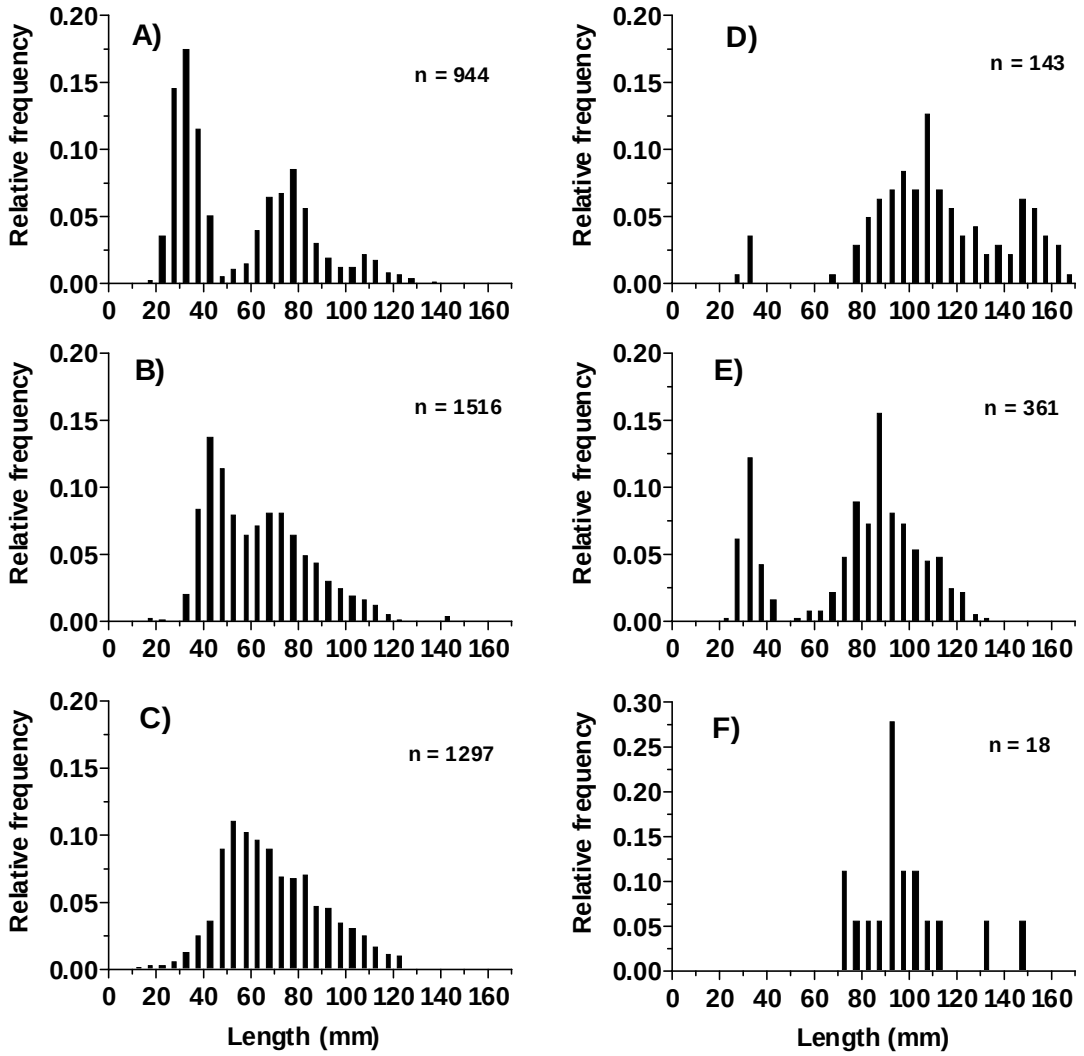

Figure 4. Distribution of larval lamprey lengths in sites in the (a) MSJD, (b) MFJD, (c) NFJD, (d) UM, (e) TU, and (f) GR rivers.

Discussion

Larval Pacific lampreys were distributed throughout the John Day River Basin indicating general reproductive and rearing success. In the other tributaries of the Columbia and Snake rivers, larval densities generally decreased as distance from the mouth of the Columbia River increased. There may be several hypotheses that explain the current distribution of larval lamprey in our study areas: 1) larval distribution may have always been distributed as we observed, 2) due to recent events, habitat conditions are more favorable for larvae in the John Day River compared to the other rivers, and 3) adult spawning or recruitment is limited due to passage problems at the dams.

Like salmon, adult lampreys migrate long distances to spawn. Gilbert and Evermann (1894) observed 40 dead adult lampreys in the Snake River at Lower Salmon Falls located approximately 1,445 river kilometers from the mouth of the Columbia River. They also reported that adult lampreys were found in the UM, the GR, and the Boise River. Even though observing adults in these rivers does not prove that they were good larval producers, sampling efforts in the 1950s suggest that larval production was significant in the Snake River basin. Bell (1960) reported that larval lampreys comprised 47% of the catch in downstream migrant barge traps fished below Brownlee Dam in 1959.

Hydroelectric dams in the Columbia River Basin impede the adult Pacific lampreys' upstream migrations. Recent studies found total passage efficiency ranging from 38 to 41% in 1997 through 1999 at Bonneville Dam in the Columbia River (Mary Moser, National Marine Fisheries Service, pers. comm.). This suggests a loss of 50% or more at each hydroelectric facility. Thus, it seems likely that a major reduction in lamprey spawning recruitment occurred with each subsequent dam. Finding non-anadromous western brook lampreys in the SFWW and no Pacific lampreys suggests another major problem in addition to dams. Water withdraws for irrigation typically cause dewatering of the WW and keeps adult Pacific lampreys from ascending the river during adult migration. Therefore, finding non-anadromous lampreys in the SFWW may indicate that the freshwater habitat is intact above the habitat alterations in the lower Walla Walla River Basin.

It is unclear why larval densities in the NFJD and MFJD were highly variable compared to the MSJD. One possibility is that detecting patterns depends upon the scale in which data are measured. For example, if we only sampled from rkm 65 to 110 in the MFJD, the pattern detected would be that densities increased moving downstream. However, by measuring densities over a broader scale we found larval densities peaking midway upstream with lows towards the mouth and in the headwaters. At the larger scale, peak densities found around rkm 300 in the MSJD may be explained by the confluence of the NFJD River.

The John Day River Basin appears to have recent recruitment, while sites in the interior Columbia and Snake rivers lacked smaller individuals, indicating poor recruitment. We emphasize the importance of collecting larval length data for assessment of recruitment patterns. In surveys for other benthic organisms such as freshwater mussels, it has been suggested that recruitment patterns may be the most useful and important information gained during surveys (Payne et al. 1991). Although the Pacific lamprey has a much shorter larval life than freshwater mussels, we suggest that larval recruitment data provide useful information. It may be important for managers to know if lampreys are recruiting to certain areas or reaches within streams.

Our coarse scale sampling approach was appropriate for establishing preliminary baseline abundance data within and among the CTUIR's traditional fishing areas. We recommend that sampling efforts be increased at the site level. For example, sampling many small 1-m^2 plots should be considered, as opposed to one large 7.5-m^2 plot. This may be more effective for separating local-scale variation in larval density from large-scale patterns of larval abundance. Continued monitoring and increased sampling efforts will allow us to properly evaluate whether recovery efforts are working at the basin scale.

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CHAPTER THREE

Effects of Acute Stress on the Physiology of
Pacific Lampreys (*Lampetra tridentata*)

by

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Introduction

The reasons for the decline of Pacific lamprey (*Lampetra tridentata*) populations throughout the Columbia River Basin are unknown. One possible contributor to this precipitous fall may be migratory failure resulting from the inability of lampreys to negotiate passage around the dams within the Columbia River Basin. In order to determine if migrations of adult lampreys are impaired by hydroelectric projects, methods for examining their behavior around dams must be developed. Currently, National Marine Fisheries Service (NMFS) biologists are using radio telemetry to follow the movement of adult lampreys around Columbia River dams (Vella et. al 1999). One of the assumptions of biotelemetry studies is that radio tagged animals behave like untagged animals; however, this assumption must be verified. Handling and tagging fish can cause stress in fish, which may lead to a decrease in performance and fish health (Pickering 1981). Acute stress in fish can be measured using both clinical indicators (Wedemeyer and Yasutake 1977) and behavioral tests (Sigismondi and Weber 1988). Our study objective was to identify clinical indicators of stress in adult Pacific lamprey. Experiments were designed to assess the utility of plasma cortisol, glucose, lactate, chloride, and muscle lactate as physiological indicators of stress for use in Pacific lampreys. Identification of clinical indicators of stress will be the first step toward evaluation of biotelemetry methods in lampreys.

Methods

Experimental Animals

Adult Pacific lampreys were collected from Willamette Falls, Oregon and transported to Oregon State University's Fish Performance and Genetics Laboratory, Corvallis, Oregon. Following their capture, the animals were treated with salt (50 g/37.8 L) during transport and subsequently with formalin (5.9 ml/37.8 L) to prevent fungal infection. After fish were anesthetized in tricaine methansulfonate (MS-222; 200 mg/L), they were weighed and injected with oxytetracycline (0.5 ml/kg) to combat bacterial infection. Before the experiments, fish were maintained in flow-through 0.9 m diameter tanks (336 L) supplied by underground water at a temperature of 12-13 °C at least 1 week under natural photoperiod.

Experimental Design

In experiment I, we examined the effects of acute stress on plasma glucose through time. Adult lampreys were distributed into 0.9 m diameter tanks (n=10/tank). Each tank was randomly assigned a sampling time (i.e. no individual fish was sampled more than once). Fish in all but one tank (control; time = 0) were exposed to a 5 minute dewatering stressor, then sampled 1, 2, 3, 4 and 24 hours after stress.

In experiment II, we examined the effects of acute stress on plasma glucose, lactate, chloride ion, and muscle lactate through time. Adult lampreys were distributed into 0.9 m diameter tanks (n=5/tank). Each tank was randomly assigned a sampling time. After two

weeks of acclimation, the fish were sampled before the stress (controls; time = 0) or stressed by dewatering their tanks for 5 minutes and then returning water into tank. At each sampling time (0, 0.5, 1, 4, 24, or 48 hours after the stress), one tank of lampreys were sampled. This sampling design was conducted on one group of fish on 10/24/96 and another group of fish on 12/3/96.

In experiment III, we examined the time required for plasma glucose to recover after acute stress. Adult lampreys were distributed among tanks (n = 10/tank; 2 tanks/sampling time), acclimated, and stressed as before; however, replicate tanks were sampled at 0 (controls), 1, 24, 72, and 168 hours (7 days) after the acute stress.

Experiment IV was designed to determine if plasma cortisol could be detected. Six adult lampreys were held in one tank filled with water. Three fish were immediately netted out and sampled for blood, while the other three fish were netted out and put into a dewatered 20 L bucket for 30 minutes, then returned to tank with water. After one hour the fish were sampled for blood.

Experiment V was designed to qualitatively assess corticosteroid production in Pacific lamprey. Two adult lampreys were transported to Oregon State University, held in garbage can filled with water. Fish were then anesthetized and injected with 5 μCi of radiolabeled pregnenolone. One fish was placed in bucket (20L) with water while the other was subjected to a 10 minute dewatering stress then transferred into a bucket (one fish per bucket) that contained water with air supply. Lampreys were then sampled for blood at 30, 60, and 180 minutes.

For experiments I and III, stress was imposed by netting the fish from the tank and placing them in a dewatered bucket for five minutes. After the stress, fish were placed back into their designated tanks. In experiment II, fish were dewatered in their tanks for five minutes. In experiment IV, 3 fish were placed in a dewatered bucket for 30 minutes. In experiment V, one fish was placed in a dewatered bucket for 10 minutes.

Sampling

In all experiments, animals were netted from tanks and anesthetized in tricaine methansulfonate (MS-222; 800 mg/L for lethal sampling; 200 mg/L for non-lethal sampling) buffered with sodium bicarbonate. In experiment I, blood samples were collected by cardiac puncture using heparinized vacutainers. In the other experiments, blood was collected from the caudal vein (once the technique was perfected). Blood samples were kept on ice before plasma was separated by centrifugation at 1750 *g* for 5 min. Samples were kept frozen at -80°C until analysis. Muscle samples (~0.10 g) were collected with a scalpel after a lethal dose of MS-222. Muscle samples were taken just below the anterior dorsal fin, snap frozen in liquid nitrogen and stored at -80°C. Each muscle sample was homogenized in 1.0 ml of ice-cold 0.6N perchloric acid. Samples were centrifuged at 12,800 g for 10 minutes at 5°C. Lactate concentration of the supernatant was then measured by the spectrophotometric procedure of Passonneau (1974). Muscle lactate concentration was calculated by multiplying

the homogenate lactate concentration by the total homogenate volume, then dividing the result by the sample weight.

Extractions

Plasma samples (0.5 ml each) from experiment IV and V were extracted twice with 8 ml of diethyl ether. Tubes were vortexed vigorously for 30 seconds after the addition of ether. The organic phase was removed from the aqueous phase after snap freezing in liquid nitrogen. Combined extracts were dried in a Speed Vac centrifuge, resuspended in 1 ml of methanol, filtered through 0.45 um Acrodiscs and then redried. Dried extracts were resuspended in 0.1 ml of mobile phase and injected onto the HPLC.

HPLC System

The HPLC consisted of a Waters system with a 600 controller, 717 autosampler, 996 photodiode array detector (steroids were monitored at 254 and 280 nm), a Digital Venturis computer, Millenium PDA software and a reverse phase C18 (Hewlett Packard) column. Extracts were examined on HPLC as described by Huang et al. (1983) and modified by Feist et al. (1990). Briefly, we used an isocratic mobile phase (flow rate 0.4 ml/min) of water : methanol : acetonitrile : isopropanol (62:28:5:5), followed by a linear gradient (3.3%/min) of water : methanol : butanol (35:45:20) for 30 minutes. This system allowed for the separation of 16 steroid standards (Table 1) when monitored at 254 nm with detection limits of 5 ng for each steroid. Fractions from the HPLC were collected at 1 minute intervals and counted on a Packard 1600CA scintillation spectrophotometer.

Assay Methods

Plasma glucose, lactate, and muscle lactate levels were determined by colorometric assays (Wedemeyer and Yasutake 1977; Pasonneau 1974). Bill LaVoie at the Idaho Cooperative Fishery Research Unit determined plasma chloride levels by the use of a Corning 920 M chloridometer. In experiments II, IV, and V, cortisol levels in plasma were determined by radioimmunoassay (RIA) techniques described by Foster and Dunn (1974) and modified by Redding et al. (1984).

Statistical Analysis

In experiment I, individual fish were treated as the experimental unit. In the second experiment II, plasma glucose and plasma chloride data were pooled from each replicate treatment, and individual fish treated as the experimental unit because there was no evidence of tank effects within treatments (nested ANOVA) using SAS^{TM}, release 6.10 (SAS Institute Inc., Cary NC, USA). Replicate tanks were not pooled for plasma lactate or muscle lactate

Table 1. Steroid standards for HPLC

name	abbreviation	Nomenclature
aldosterone	ALDO	4-pregnene-11b,21-diol-3,18,20-trione
cortisone	E	4-pregnene-17a,21-diol-3,11,20-trione
cortisol	F	4-pregnene-11b,17a,21-triol-3,20-dione
11-ketotestosterone	KT	4-androstene-17b-ol-3,11-dione
11b-hydroxyandrostenedion	OHA	4-androstene-11b-ol-3,17-dione
11b-hydroxytestosterone	OHT	4-androstene-11b,17b-diol-3-one
corticosterone	B	4-pregnene-11b,21-diol-3,20-dione
11-deoxycortisol	DOF	4-pregnene-17a,21-diol-3,20-dione
11-ketoprogesterone	KP	4-pregnene-3,11,20-trione
androstenedione	A	4-androstene-3,17-dione
17b-estradiol*	E2	1,3,5(10)-estratrien-3,17b-diol
testosterone	T	4-androstene-17b-ol-3-one
17a-hydroxyprogesterone	17-OHP	4-pregnene-17a-ol-3,20-dione
dihydroxyprogesterone	DHP	4-pregnene-17a,20b-diol-3-one
progesterone	P4	4-pregnene-3,20-dione
20b-hydroxyprogesterone	20-OHP	4-pregnene-20b-ol-3-one

* detectable only at 280 nm.

data due to tank effects, and were analyzed as separate treatment groups. Glucose data from fish in replicate tanks were pooled in experiment III. Experiments IV and V were descriptive studies.

A one way analysis of variance (ANOVA) was performed to compare plasma glucose, lactate, chloride, and muscle lactate followed by multiple range testing using Duncan's LSD method for experiments I, II, and III. For all analysis, statistically significant differences were considered when the p-value (P) was less than 0.05.

Results

Lampreys used in these experiments had a mean weight of 387 ± 9 g (mean ± SE). In experiment I, mean resting glucose level (time 0) rose significantly from 38.8 mg dl^{-1} ± 1.6 (SE), to 53.0 mg dl^{-1} ± 1.3 (SE) at one hour after stressor (P = 0.001) and remained elevated for 24 hours (Fig 3.1). At 4 hours after the stressor, glucose levels were significantly lower than those at 1, 2, and 24 hours; however, these levels were still significantly higher than those at time 0 ($P \leq 0.05$). In experiment II, plasma levels of cortisol were undetectable in all fish (data not shown; detection limit of assay 5 ng/ml plasma). Mean resting glucose level was 47.8 mg dl^{-1} ± 2.4 at time 0, and within 30 minutes after stress, circulating glucose had increased significantly ($P < 0.05$) reaching maximum concentrations by 4 hours after stress (Figure 3.2). Glucose levels remained elevated for 48 hours. Mean resting plasma Cl^- level was 97.7 meq l^{-1} ± 1.1 at time 0; within 4 hours after stress, circulating Cl^- had decreased significantly (P = 0.002) to 93.0 meq l^{-1} ± 0.8 (Fig. 3.3). Cl^- returned to resting levels by 8 hours; however at 24 hours, levels again were significantly decreased (P = 0.0001) before returning to resting levels once again at 48 hours. The means for resting plasma lactate levels in the two control tanks were 16.0 mg dl^{-1} ± 4.4 (n = 5); and 19.0 mg dl^{-1} ± 3.7 (n = 5) respectively at time 0; within 30 minutes after stress, circulating lactate had increased significantly (P = 0.01 and P = 0.0001) reaching maximum concentrations (Fig. 3.4). Lactate levels then decreased to resting levels at one hour. Only one replicate treatment changed significantly through time for muscle lactate. In fish from this replicate, mean muscle lactate levels decreased significantly from 53.6 mg g^{-1} ± 10.1 at time 0 to 13.6 mg g^{-1} ± 7.6 by 4 hours after stress

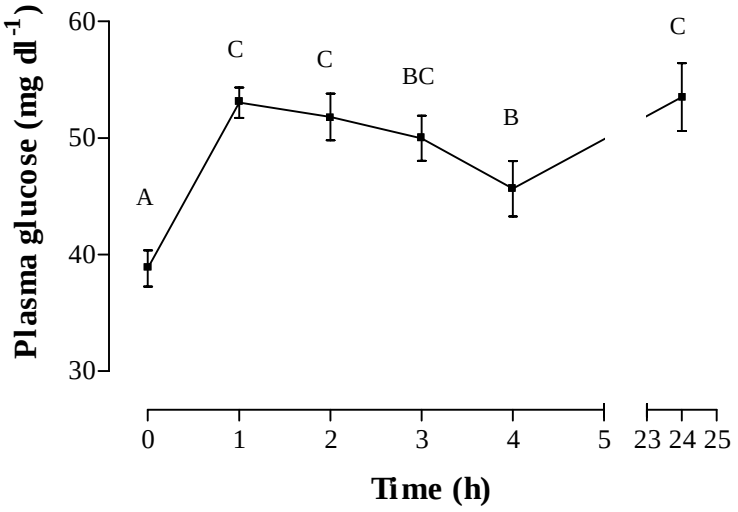

Figure 3.1. Mean plasma levels of glucose from Pacific lampreys at various times after acute stress in experiment I. Each point represents the mean (± SE) of 10 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$).

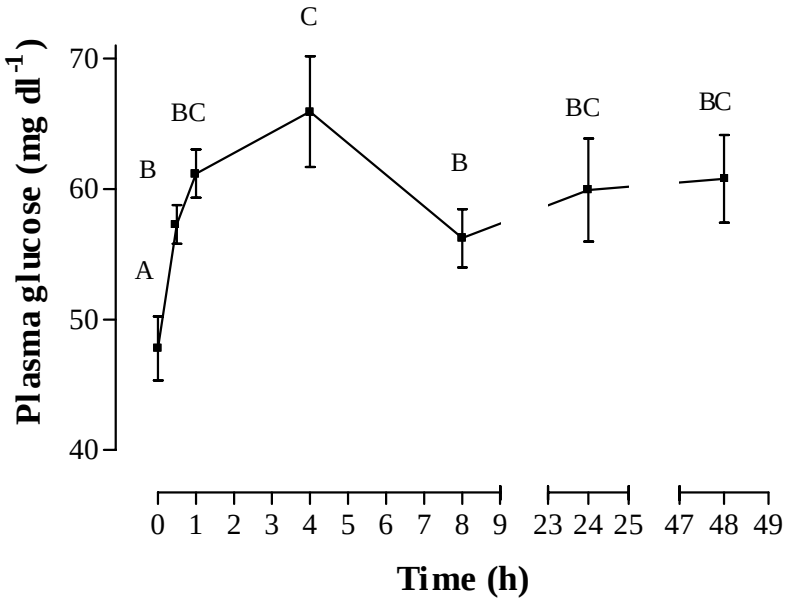

Figure 3.2. Mean plasma levels of glucose from Pacific lampreys at various times after acute stress in experiment II. Each point represents the mean (± SE) of 10 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$).

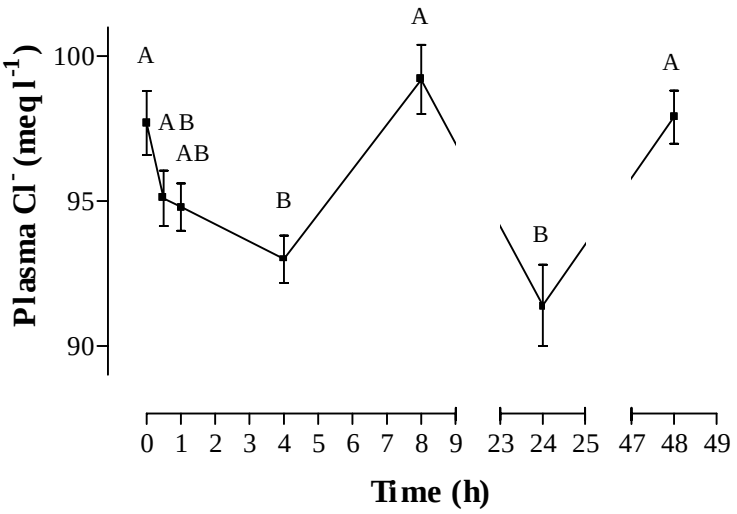

Figure 3.3 Mean plasma levels of chloride ion from Pacific lampreys at various times after acute stress in experiment II. Each point represents the mean (± SE) of 10 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$).

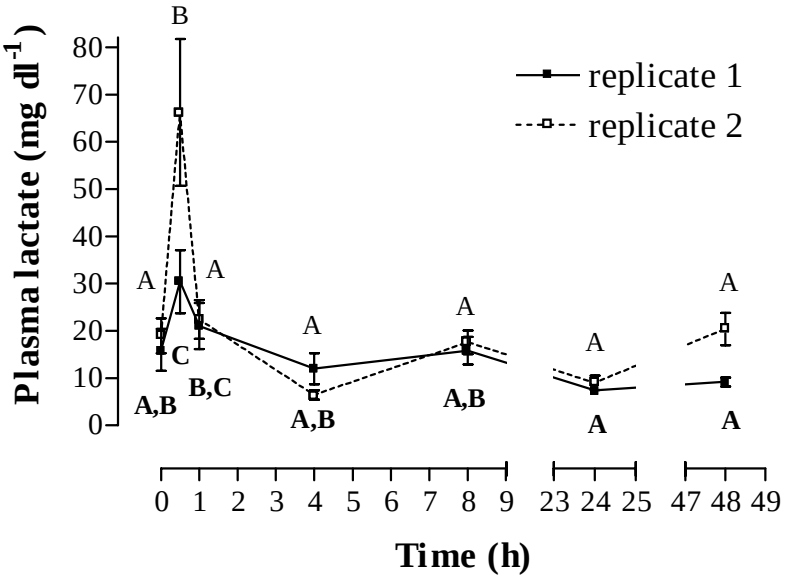

Figure 3.4 Mean plasma levels of lactate from Pacific lampreys at various times after acute stress in experiment II. Each point represents the mean (± SE) of 5 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$). Bold letters represent replicate 1, while regular letters represent replicate 2.

(P = 0.0004), and remained decreased by at 48 hours (Fig. 3.5). Muscle lactate levels in the second replicate were not significantly different (P=0.07) through time; however, the mean followed a similar pattern as the other replicate. In experiment III, mean resting glucose levels increased significantly from 45.4 mg dl^{-1} ± 1.7 to 59.0 mg dl^{-1} ± 1.7 within 1 hour of applying the stressor (Fig. 3.6). Mean circulating level of glucose at 24 hours (52.1 mg dl^{-1} ± 3.1) were not significantly different from the mean resting level (P = 0.07); however, mean glucose at 72 hours was significantly higher than the mean at time 0. At 168 hours (7 days), glucose levels were not significantly different than at time 0. In experiment IV, no cortisol was found in fractions collected from HPLC (data not shown; detection limit of assay 5 pg/ml plasma). In experiment V, radiolabeled pregnenolone injections into two lampreys, produced compounds with similar retention times as some of the steroids in the standards. Corticosterone, 11-ketoprogesterone, testosterone, progesterone, pregnenolone and two unknown peaks were identified in plasma of lampreys at 30, 60, and 180 minutes after injections (Fig. 3.7). Validation of steroids was done by comparing retention times of known standards listed in Table 3.1.

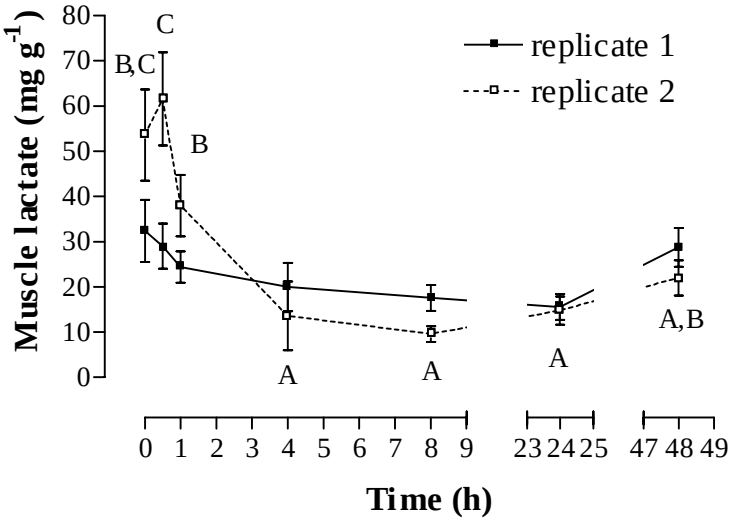

Figure 3.5 Mean muscle lactate levels from Pacific lampreys at various times after acute stress in experiment II. Each point represents the mean (± SE) of 5 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$). Letters represent replicate 2.

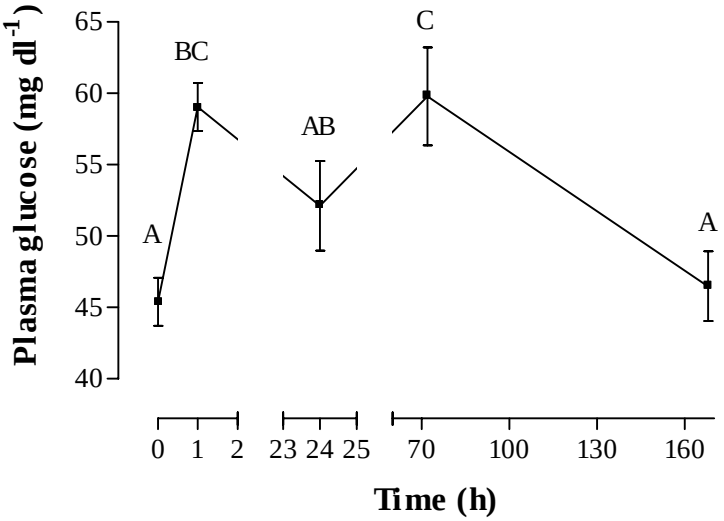

Figure 3.6 Mean plasma levels of glucose from Pacific lampreys at various times after acute stress in experiment III. Each point represents the mean (± SE) of 20 animals. Means without letters in common are significantly different by analysis of variance ($P < 0.05$).

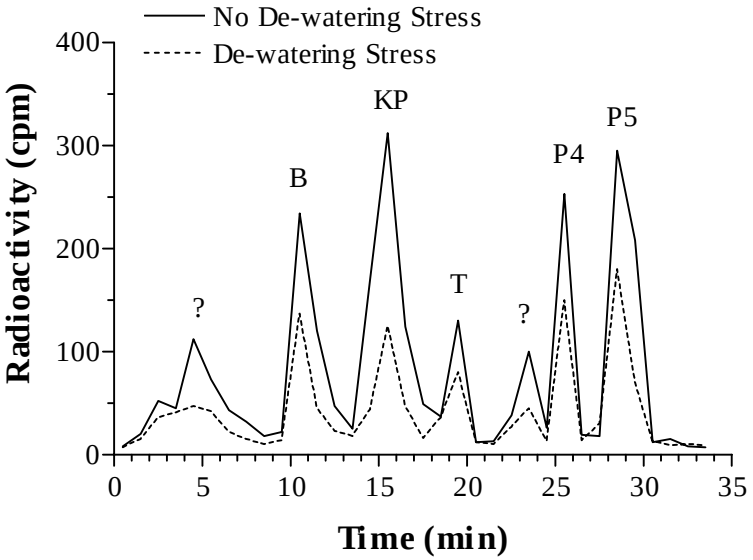

Figure 3.7 High Performance Liquid Chromatogram of radioactivity in plasma 180 minutes after ^{3}H-pregnenolone injection in experiment V. Each line represents one lamprey. Each letter represents the following steroids: B=corticosterone, KP=11-ketoprogesterone, T=testosterone, P4=progesterone, P5=pregnenolone, ?=unknown.

Discussion

The results obtained in this study show that the effects of acute stress on Pacific lampreys could be measured using clinical indicators. Pacific lampreys became hyperglycemic after stress in our studies. Resting levels of plasma glucose became elevated soon after the stressor was applied, then remained elevated for a week. Similarly, Larsen (1976) found hyperglycemia after stress in river lampreys (*Lampetra fluviatillis*) with glucose returning to resting levels after one week. Different mean resting levels of glucose were found in the current experiments conducted in the spring and the fall. The differences may be explained by a natural increase in glucose metabolism during maturation. Larsen (1976) found glucose levels increased as *Lampetra fluviatillis* approached sexual maturity in the spring. Different types of stressors such as dewatering and exercise (Stabrowsky 1967), anesthesia (Larsen 1976), handling (Morris and Islam 1969), and transportation (Leibson and Plisetskaya 1969) can induce hyperglycemia in lampreys. Stress can increase glucose levels for fish such as Atlantic salmon (Wendt and Saunders 1973) and has become a common indicator of stress in fish (Wedemeyer and Yasutake 1977; Wedemeyer et al. 1990). The elevation of glucose for such long periods raises the question of whether glucose is hormonally regulated in these fish. Insulin levels did not increase in *L. fluviatillis* after injecting a glucose load (Plisetskaya and Leibush 1972), nor did *L. fluviatillis* become hyperglycemic from increasing glucagon levels (Leibson and Plisetskaya 1969). It is thought that increased levels of circulating catecholamines stimulate glucogenolysis in fish (Mazeaud and Mazeaud 1981). Plasma levels of epinephrine and norepinephrine were shown to increase in sea lampreys (Mazeaud 1969), and in rainbow trout (*Oncorhynchus mykiss*) (Gingerich and Drottar 1989; Barton and Iwama 1991) after various stressors. However, Dashow and Epple (1983) found that injections of epinephrine only had an effect on glycemia at superphysiological doses.

Plasma lactate and possibly muscle lactate were shown to have utility as clinical indicators of stress in Pacific lampreys. While plasma lactate levels increased rapidly (by 30 min) and decreased rapidly (by 1 hour), muscle lactate levels decreased slowly through time after acute stress. This may suggest plasma lactate is metabolized quickly, and muscle lactate remains depressed because gluconeogenesis is very efficient at metabolizing lactate from muscle tissue into circulating levels of glucose. However, Wood (1991) argues that lactate is metabolized in white mussel and not released into the blood stream. Lactate levels in fish generally increase rapidly after exercise or stress (Wedemeyer et al. 1984).

Circulating plasma Cl^- was shown to decrease through time after stress in lampreys. A similar response was shown by rainbow trout after exercise; however, recovery was stable after 12 hours (Postlethwaite and McDonald 1995). In our study, Cl^- levels where shown to recover by 8 hours; however at 24 hours, levels had decreased again before returning to resting by 48 hours. The reason for the second decrease at 24 hours is unknown. We are unsure how stress disrupts ion regulation in lampreys. Although, the loss of ions through the gills (chloride cells) or loss during filtration in the kidneys may be possible (Beamish 1980; Morris 1980). Postlethwaite and McDonald (1995) speculated that increased net influx of water at the gills above the level of urine production might increase extracellular fluid volume and dilute ions. Regardless, our study has shown that stress alters ion regulation in

Pacific lampreys. Disruption of osmoregulatory function by stress is common among other fish (Mazeaud et al. 1977; McDonald and Robinson 1993).

The steroid hormone cortisol becomes elevated after stress in many species of fish (Barton and Iwama 1991) such as salmon (Strange et al. 1978); however, experiments II and IV indicated that stressed Pacific lampreys do not have detectable levels of cortisol. Our results concur with Buus and Larsen (1975), in which they found no detectable levels of cortisol in river lampreys *L. fluviatillis*. However, lamprey injected with radiolabeled pregnenolone appeared to produce a compound with a similar retention time as corticosterone, a stress-related corticosteroid found in other animals. It may be possible that in response to stress lampreys: 1) produces a compound similar to cortisol with no cross-reactivity to the antibody in the assay, 2) have cortisol levels below detection of assay, or 3) corticosteroids are not stress-related steroids in lamprey. Katz et al. (1982) postulates that the role of sex steroids in agnathans may differ from other fish and that androstenedione may be a stress-related hormone in sea lamprey.

Our experiments have shown that Pacific lampreys exhibit a classical stress response similar to other fishes and that clinical indicators such as plasma glucose, lactate, Cl^-, and possibly muscle lactate can be measured to assess stress in Pacific lampreys. However, plasma cortisol was not detected in Pacific lampreys.

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CHAPTER FOUR

The Effects of Intraperitoneally Implanted Radio Transmitters on the Swimming Performance and Physiology of Pacific Lampreys (*Lampetra tridentata*)

by

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Introduction

Pacific lampreys (*Lampetra tridentata*) have declined throughout the Columbia River Basin and along the Oregon Coast. Many factors may have contributed to the decline of Pacific lamprey, including development of hydroelectric projects. Following construction of hydroelectric dams in Finland, European river lamprey (*L. fluviatilis*) populations declined (Tuunainen et al. 1980; Eklund et al. 1983; Ojutkangas et al. 1995). Further, in the 1800's, the decline of the sea lampreys (*Petromyzon marinus*), on the East Coast of the U.S. was blamed on dams (Goode 1884).

Columbia River hydroelectric projects may be causing migration delays and impeding passage of lampreys to spawning areas in the interior basin. In 1996, the National Marine Fisheries Service (NMFS) started using radio telemetry to follow movement of lampreys around the Columbia River dams. These studies from 1996 to 1999 found that 59 to 79% of radio tagged lampreys did not pass Bonneville Dam (pers. comm. M. Moser, 2000, National Marine Fisheries Service).

One of the assumptions of a radio telemetry study is that the tagged individuals are representative of the entire population. Specifically, the method should not affect the physiology, behavior, or survival of the fish. While surgically-implanted transmitters have been evaluated and found to be successful in juvenile Atlantic salmon, *Salmo salar* L. (Moore et al. 1990) and juvenile chinook salmon *Oncorhynchus tshawytscha* (Martinelli et al. 1998), other studies have shown problems with transmitter expulsion in channel catfish *Ictalurus punctatus* (Marty and Summerfelt 1986) and rainbow trout *O. mykiss* (Lucas 1989). In addition, externally attached transmitters on juvenile white sturgeons *Acipenser transmontanus* decreased swimming performance (Counihan and Frost 1999). However, we are unaware of any published literature testing the effects of radio transmitters on lampreys. Our objective was to determine the effects of surgically implanted radio transmitters on the physiology, swimming performance, and survival of Pacific lampreys.

Methods

Adult Pacific lampreys were obtained from Willamette Falls, Willamette River, Oregon and transported to Oregon State University's Fish Performance and Genetics Laboratory, Corvallis, Oregon. Upon arrival, fish were anesthetized, weighed, measured and marked with passive integrated transponder (PIT) tags for identification. Before the experiments, fish were maintained in flow-through 0.9 m diameter tanks (336 L) supplied by underground water at a temperature of 12-13 °C at least 1 week under natural photoperiod. Dummy transmitters were made by dipping tags into rubber cast, then filling casts with resin (courtesy of Advanced Telemetry Systems, Isanti, Minnesota) used for actual transmitters. Steel split shot was attached to antennae and placed into wet resin within the molds. After drying, the transmitters weighed the same in air as functional tags (3.4 g and 7.4 g). Transmitters were then surgically implanted into the body cavities of lamprey. The procedure was carried out on 131 adult lampreys.

Experimental design

In experiment I, adult lampreys (n = 5 fish/treatment/time) were anesthetized and then implanted with a 3.4 g dummy transmitters. Control fish were treated the same as tagged fish, but no incision or sutures were used. At 1, 6, and 24 hours after completion of surgery, the fish were anesthetized and sampled for blood. In experiment II, adult lampreys (n = 4 fish/tank; 3 tanks/replicate treatment) were either implanted with a 3.4 g tag (tagged), put through implantation surgery but without tag implantation (sham), or anesthetized but otherwise left intact (control). In addition, other lampreys (n = 6 fish/treatment) were implanted with either a 10 gram tag or left intact (control) by John Vella at the National Marine Fisheries Service in Pasco Washington, and then transported back to Oregon State University four weeks after surgery. Fish were sampled for blood at 4 months after completion of surgery. In experiment III, fish were anesthetized in MS-222 buffered with sodium bicarbonate and implanted with pit tags (passive integrated transponder). Lampreys were distributed to holding tanks to acclimate for 2 weeks (n=10/tank; 2 tanks/sampling time). Each tank was randomly assigned a treatment: control or tagged and no individual fish was sampled more than once. Each lamprey was anesthetized and implanted with a 7.4-g tag into the body cavity. Control fish were handled the same as tagged fish except no surgery or tag implantation was performed. At 3, 24, and 96 hours after completion of surgery, the fish were anesthetized and sampled for blood. Lampreys were then maintained in tanks and sampled for blood at 30, 60, 90 and 180 days after surgery. In experiment IV, swimming performance of radio-tagged individuals (n=47, mean length 60.1 cm with a 95% confidence interval from 59.8 cm to 60.3 cm) were tested at 1, 24, and 168 hours after surgery. Eight control and eight tagged lampreys (except for seven tagged during 168 hour test) at each time were tested individually. Adult lampreys were anesthetized in MS-222 buffered with sodium bicarbonate and then surgically implanted with the 7.4-g tag. Fish were acclimated in the flume one-hour before starting the flow of water.

Surgical procedure

Fish were netted from tanks and anesthetized by immersion in tricaine Methansulfonate (200 mg/L buffered with sodium bicarbonate). Fish were placed in a PVC pipe with a sealed T end. A portion of the pipe was cut away to allow room for surgery. A peristaltic pump added anesthetic solution to the pipe sufficient to submerge the head and gill pouches during surgery. Fish were laid ventral side up with towel underneath the fish to prevent slippage. An incision was made ventrally along the center of the body. The dummy transmitters, previously sterilized in ethanol, were inserted through the incision. The antenna was guided through a catheter starting at the incision through the muscle tissue and exiting through the skin 15 mm below the incision. The incision was treated with oxytetracycline and closed with four single stitches using cat gut sutures. The time of the surgical procedure was ~5 minutes (3.4 g tags) and ~10 minutes (7.4 g tags). The fish were transferred to recovery tanks until sampling or placed into flume for the swimming assessment. In addition to the tagged (3.4 g) group, twelve fish underwent surgery as previously described but did not receive implants (shams). All other fish in the experiments that had no operation were held as controls.

Swimming performance

Ventilation rate was counted (beats/min) at 5, 30, and 60 minutes after placement in the flume. The flume was lined with a high-density polyethylene aqua-net grid. The lining in the flume prevented the lampreys from attaching on the walls of the flume. After an hour, the flow was turned on and the lampreys were acclimated to swimming for 10 minutes (5 minutes each at both 20 and 30 cm/sec). After swimming acclimation, the flow was increased to 40 cm/sec and swimming time measured. An electrical current (12 volts) was applied to keep the lampreys off the back screen. Lampreys were considered exhausted when the animals could not avoid the back screen. After one hour of swimming or at exhaustion, the test was ended. The lampreys were then taken out of the flume and placed into a respirometer. The dissolved oxygen levels were recorded at 5 and 30 minutes after swimming exhaustion for all fish.

Sampling

Each lamprey was anesthetized in tricane methansulfonate (MS-222) at 80 mg/L buffered with sodium bicarbonate and then a blood sample was collected from the caudal vein with a vacutainer needle. The plasma was separated by centrifugation and stored for analysis at -80°C. Plasma samples were analyzed for glucose by colorometric assay (Wedemeyer and Yasutake 1977). Observations of ventilation rate (beats/min) were recorded during the acclimation in flume. Time to swimming exhaustion was recorded by use of a stopwatch. Time spent on the back screen was subtracted from total swimming time. Oxygen consumption after swimming performance was determined by containing fish in a respirometer. Dissolved oxygen was measured with a YSI Dissolved Oxygen meter (Cech 1990).

Statistical analysis

In experiments I and II, plasma levels of glucose were compared by a one way analysis of variance (ANOVA) followed by multiple range testing using Newman-Keuls method. In experiment III, plasma levels of glucose were compared by two way ANOVA followed by one way ANOVA with multiple range testing using Newman-Keuls method. In experiment IV, plasma levels of glucose were compared by repeated measures ANOVA followed by multiple range testing using Newman-Keuls method. In experiment V.a, ventilation rates were compared by repeated measures ANOVA followed by multiple range testing using Newman-Keuls method. In experiment V.b, swimming time was compared by the nonparametric tool Mann-Whitney U test. In experiment V.c, oxygen consumption levels were compared using a two-tailed unpaired t-test. The significance levels were set at $p \leq 0.05$ for all statistical tests.

Results

In experiment I, plasma glucose levels at 1, 6, and 24 hours after surgery did not differ significantly between control and 3.4 g tagged adult lampreys (Fig. 4.1). In experiment II, plasma glucose levels at 4 months post-surgery were not significantly different between control, 3.4 g tagged, and sham fish; however, lampreys implanted with 10 g tags had significantly higher glucose levels ($p=0.01$) than controls (Fig 4.2).

In experiment III, mean plasma glucose levels between control and tagged fish were significantly different ($p=0.0001$). In addition, a sex effect was shown to be significant ($p=0.0001$). Therefore, we analyzed males and females separately. Mean plasma glucose levels in male control fish (55.7 mg dl-1 ± 3.7) (n=11) at 3 hours, were significantly lower ($p=0.001$) than those in male tagged fish (79.6 mg dl-1 ± 5.4) (n=9). By 24 hours, mean glucose levels in control males (52.5 mg dl-1 ± 2.0) (n=11), were still significantly different ($p=0.01$) than male tagged fish (70.4 mg dl-1 ± 3.9) (n=10). However, by 96 hours there was no difference in plasma glucose between control and tagged males.

Mean plasma glucose levels in female control fish (44.6 mg dl-1 ± 1.5) (n=9) at 3 hours were significantly lower ($p=0.001$) than those in female tagged fish (72.1 mg dl-1 ± 5.6) (n=10). By 24 hours, mean glucose levels in control females (44.9 mg dl-1 ± 2.1) (n=8), were still significantly different ($p=0.05$) from female tagged fish (61.2 mg dl-1 ± 4.9) (n=10). After 96 hours, there was no difference in glucose levels between control and tagged females (Fig. 4.3).

In experiment IV, plasma glucose levels at 30, 60, 90 and 180 days were not significantly different ($p>0.05$) between control and tagged fish. However, there was a significant sex effect ($p=0.005$) and overall time effect ($p=0.0001$). Plasma glucose levels increased significantly ($p=0.0001$) from 30 days to 60 days and from 90 days to 180 days ($p=0.0058$) after surgeries. There was no significant increase or decrease from 60 to 90 days after surgeries ($p=0.82$) (Fig. 4.4). Control and tagged lampreys appeared to sexually mature, developing secondary sexual characteristics (21.6 % of control (n=13) and tagged (n=13) lampreys became fully mature with loose eggs or flowing milt by 3/21/98).

In experiment V.a, ventilation rates decreased significantly ($p<0.05$) from 5 to 30 minutes in both control and tagged fish at 1, 24, and 168 hours after tagging. In addition, ventilation rate did not differ significantly ($p>0.05$) from 30 to 60 minutes between control and tagged fish at 1 and 24 hours; however, tagged fish at 168 hours did show a significant decrease ($P=0.04$) from 30 to 60 minutes. Ventilation rates compared between control and tagged fish at 5, 30, and 60 minutes did not differ significantly at 1, 24, and 168 hours after surgeries (Fig. 4.5).

In experiment V.b, swimming performance measured in terms of duration was significantly lower ($p=0.04$) in tagged lampreys at 1 hour after surgery in comparison to control fish. Swim time was not significantly different between control and tagged lampreys at 24 and 168 hours after surgeries (Fig. 4.6).

In experiment V.c, oxygen consumption was significantly lower ($p=0.04$) in tagged lampreys 1 hour after surgery in comparison to control fish; however, there was no difference between control and tagged lampreys 24 and 168 hours after surgery (Fig. 4.7).

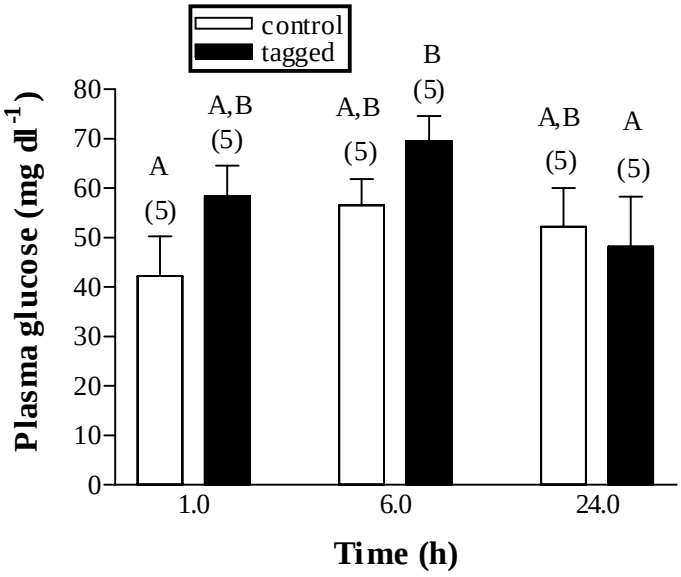

Figure 4.1. Mean plasma glucose levels for control and surgically implanted adult Pacific lampreys with 3.4 gram dummy transmitters. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by analysis of variance ($p < 0.05$).

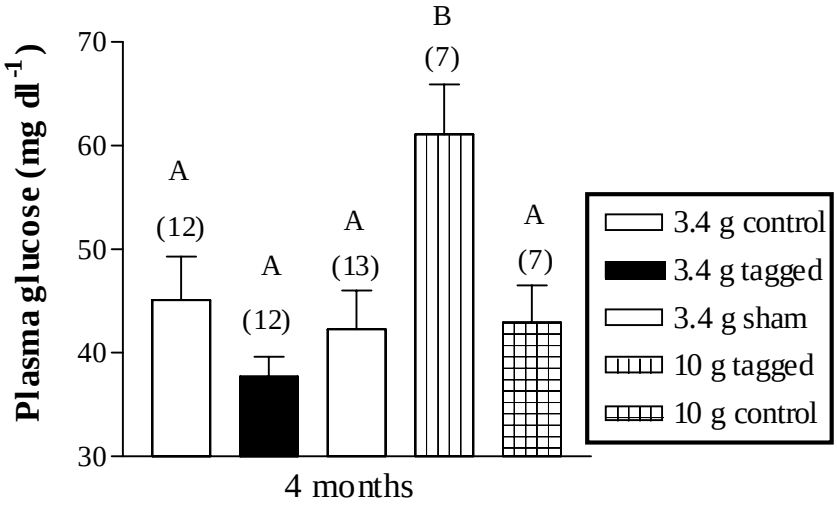

Figure 4.2. Mean plasma glucose levels for control, sham, and surgically implanted adult Pacific lampreys with 3.4 and 10.0 gram dummy transmitters 4 months after implantation. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by analysis of variance and unpaired t-test ($p < 0.05$).

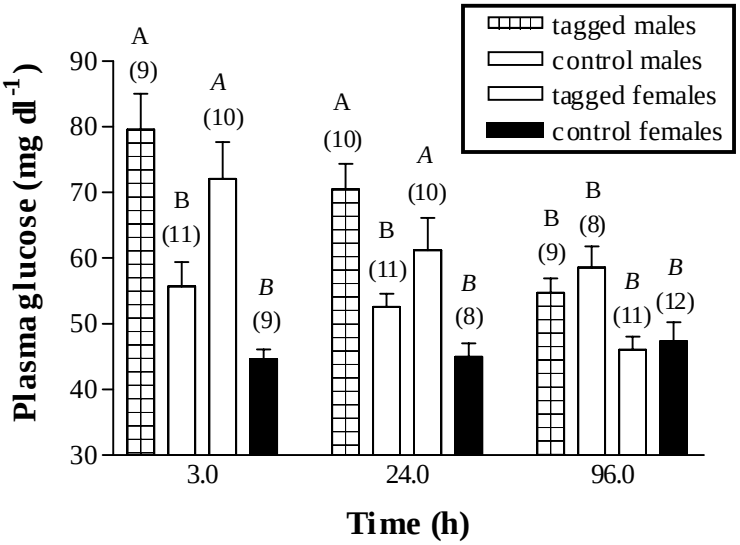

Figure 4.3. Mean plasma glucose levels for control and surgically implanted adult Pacific lampreys with 7.4 gram dummy transmitters 3, 24, and 96 hours after implantation. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by analysis of variance ($p < 0.05$).

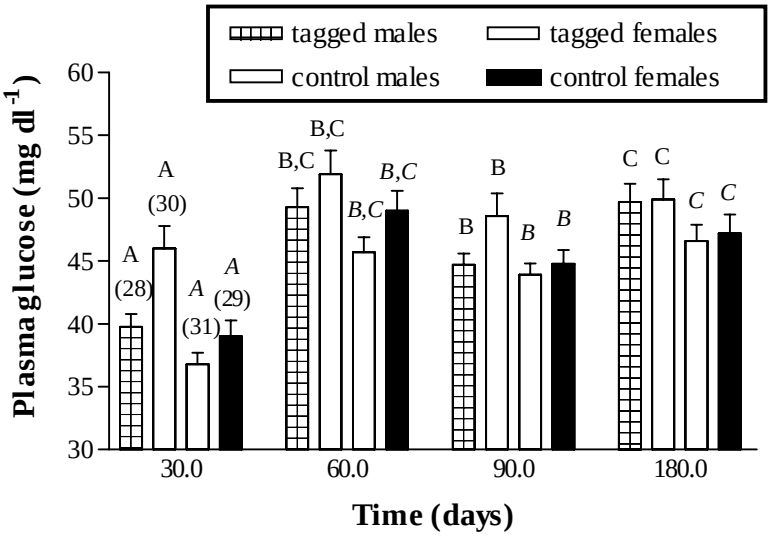

Figure 4.4. Mean plasma glucose levels for control and surgically implanted adult male and female Pacific lampreys with 7.4 gram dummy transmitters 30, 60, 90, and 180 days after implantation. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by repeated measure analysis of variance ($p < 0.05$).

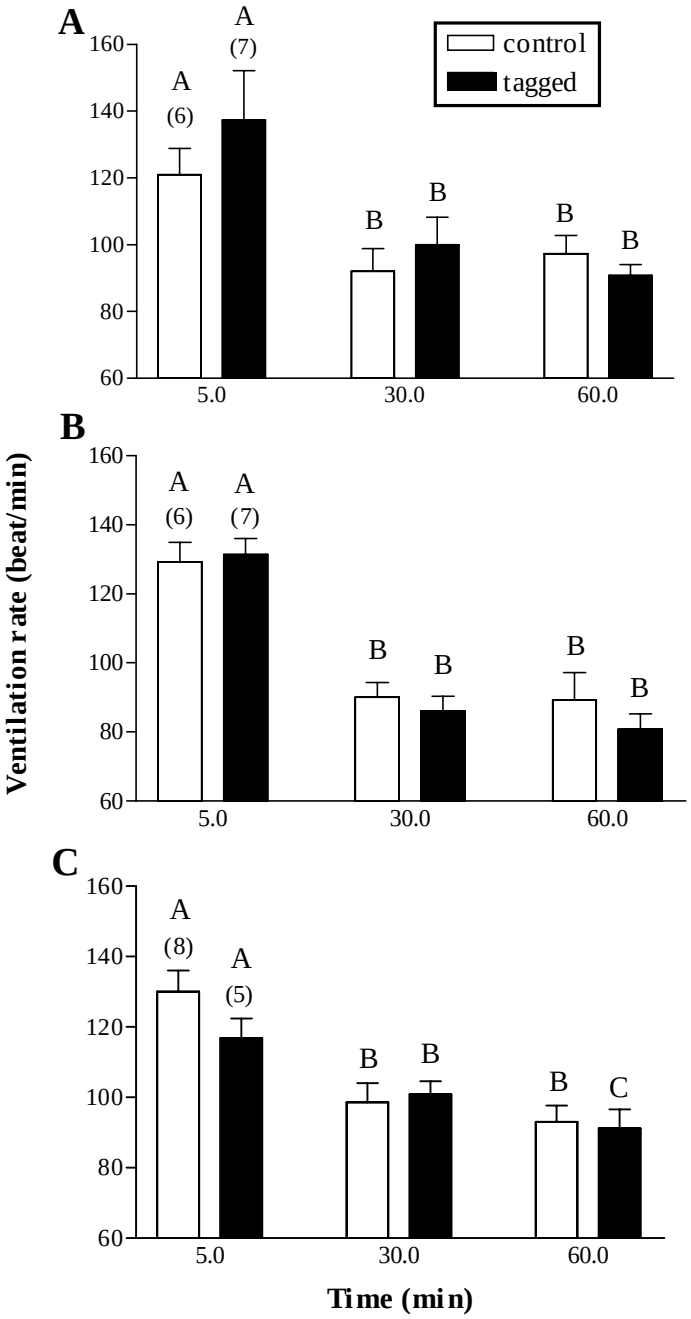

Figure 4.5. Mean ventilation rate of control and surgically implanted adult Pacific lampreys with 7.4 gram dummy transmitters after recovery from surgical anesthesia. **A**, **B**, and **C** represent groups of fish tested at 1, 24, and 168 hours after surgery. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by repeated measure analysis of variance ($p < 0.05$).

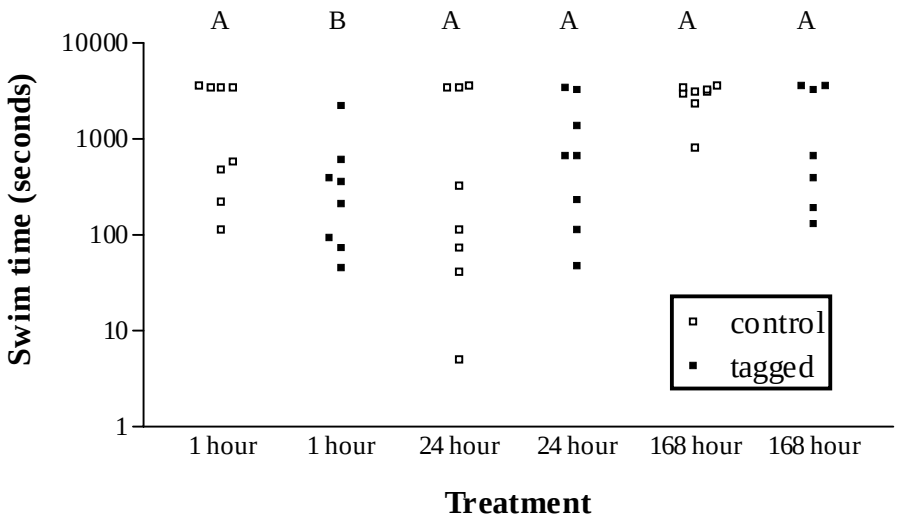

Figure 4.6. Individual swim times of control and surgically implanted adult Pacific lampreys with 7.4 gram dummy transmitters. Each point represents an individual fish swim time for 1, 24, and 168 hours after surgery. Treatments without letters in common are significantly different by Mann-Whitney U tests ($p < 0.05$) within treatments.

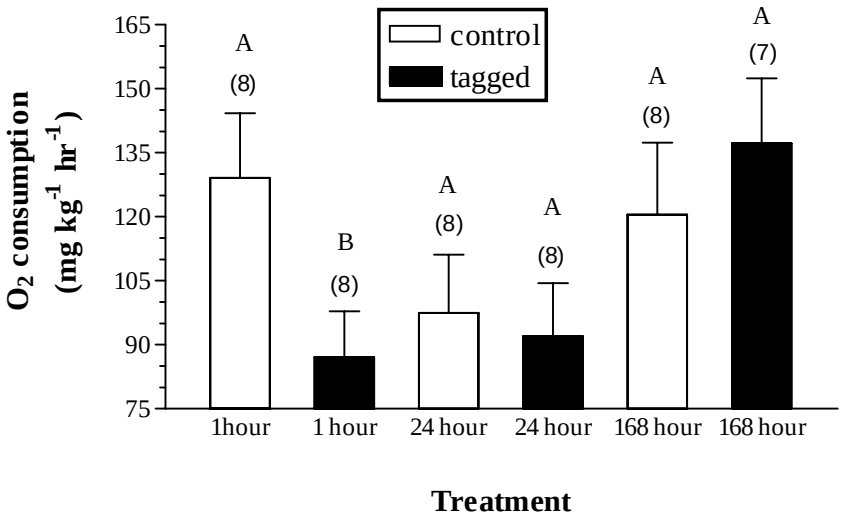

Figure 4.7. Mean O_2 consumption of control and surgically implanted adult Pacific lampreys with 7.4 gram dummy transmitters after recovery of swim performance test. Bars represent the mean, error bars are the standard error of the mean, and sample size is noted in parentheses above the bar. Bars without letters in common are significantly different by unpaired t-tests ($p < 0.05$) within treatments.

Discussion

Although there was 100% survival of surgically implanted adult lampreys during our study, 10.0 gram tags stressed (as indicated by glucose levels) our study animals 4 months after surgeries. We found no difference between 3.4 g tagged and control lampreys in glucose levels during recovery and no chronic effect measured by plasma glucose at 4 months after surgeries. The 7.4 gram tagged fish did not recover from the stress of surgery and implantation until day 4. In addition, we found no evidence indicating chronic stress in lampreys implanted with 7.4 gram tags during the 6 months of monitoring plasma glucose levels. We found no tag expulsions in any of the study animals; however, necropsies did show clear tissue encapsulating the transmitters at 4 and 6 months. A similar response has been shown in surgically implanted Atlantic salmon (Moore et al. 1990).

Ventilation rate appeared stable by one hour, indicating some recovery before swimming performance assay. This one hour acclimation period is comparable to what NMFS uses on lampreys implanted with transmitters at Columbia River dams. Other research has shown ventilation rate decreases rapidly after handling and surgery. Moore et al. (1990) found tagged and sham juvenile Atlantic salmon increased opercular rate after surgeries; however, both groups returned to basal levels by 60 minutes.

The swimming performance tests of radio tagged lampreys with 7.4-g tags suggest that there is an immediate effect on Pacific lampreys, but the effects are reduced by 24 hours. Unfortunately due to time constraints, we did not conduct swimming performance tests on fish beyond one week.

Oxygen consumption after swimming performance suggested recovery was faster in control compared to tagged lampreys. There was no difference in oxygen consumption between control and tagged lampreys at 24 and 168 hours after surgery suggesting recovery in tagged fish.

Even though swimming performance was shown to recover by 24 hours, glucose did not recover to control levels until day 4; therefore, based on glucose levels, we suggest holding tagged lampreys a minimum of 4 days. It should be noted that in all tagged groups of fish during our experiments, glucose levels decreased slightly below control levels. However, the levels were not significantly different ($p=0.054$) in 7.4 gram tagged fish at 30, 60, 90, and 180 days after surgery. We also found a sex- and time-effect in glucose levels. Glucose levels increased in tagged and control lampreys through time as fish matured. These finding also agree with previous studies with river lampreys in Europe (Larsen 1976). Our study suggests 3.4 and 7.4 gram tagged lampreys perform equally to controls. Therefore, inferences can be made to the larger free swimming lampreys in the Columbia River.

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CHAPTER FIVE

Genetic Survey of Pacific Lamprey (*Lampetra tridentata*)
in the Columbia River Basin

by

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Introduction

Pacific lamprey (*Lampetra tridentata*) populations in the Columbia River Basin are in decline (Close et al., 1995 Jackson et al., 1996). The goals of the cooperative Pacific Lamprey Research and Restoration Project are to ultimately increase abundance of Pacific Lamprey above Bonneville Dam and ameliorate the problems responsible for their decline. Current objectives of the project involve an assessment of past and current abundance of Pacific Lamprey and identification of factors depressing population abundance.

Complimentary to the goals stated above, this investigation was designed to provide baseline information on genetic variation within and among populations of Pacific lamprey in the Columbia River Basin. Two approaches were evaluated for their utility in describing interspecific variation and population structure. First, starch gel electrophoresis was used to survey protein coding loci on juvenile and adult lamprey tissue collected from several locations. Additionally, restriction fragment length polymorphism (RFLP) analysis of polymerase chain reaction (PCR) fragments was used to examine DNA variation in two mitochondrial gene regions.

Preliminary life history information lends evidence to support a hypothesis of lower geographic resolution and structuring among populations of Pacific lamprey in the Columbia River Basin. By comparison, the degree of local adaptation and stock structure observed among anadromous salmonids is most likely higher. For this project, the following predictive statement will be tested: The genetic structure of sampled Pacific lamprey populations within the Columbia River Basin is not significantly different. The information provided by these analyses are essential for the prudent implementation of any management or restoration strategies considering stock transfers or the artificial culture of Pacific lamprey to restore and manage depressed stocks.

Methods

Collections

Table 1 lists the sample locations, life stage and tissues collected from 615 samples examined thus far. Figure 1 diagrams the locations of sample collection sites. Sample collection was primarily carried out in 1998 with two sample locations, #4 Deschutes River and #18 Willamette River, collected in 1996. There are three separate collections for the Willamette River listed and involve different sample strategies and dates. These collections have been treated as separate sample sets.

Allozyme Analysis

Whole, juvenile pacific lamprey (ammocoetes) or specific tissues collected from adults were frozen in the field on dry ice or with liquid nitrogen. Sampled tissues from adults included heart, liver, muscle and retinal tissue. Samples remained frozen until they were

Table 1. Collections of Lampetra tridentata samples from 18 locations. Fin clips were placed in "lysis buffer" and stored until DNA was extracted. All other tissues were frozen at -80oC, E=eye, H=heart, L=liver, M=muscle.

Location Number	Location	n	Life Stage	Collection Date	Tissue
1	Bonneville Dam	42	adult	1998	fin clip
2	Cedar Creek (Lewis River), WA	32	adult	1998	fin clip
3	Chehalis River, WA	50	ammocoetes	1998	E, H, L, M
4	Deschutes River, OR	38	adult	1996	E, L, M[1]
5	Fifteen Mile Creek, OR	56	ammocoetes	1998	E, H, L, M
6	John Day Dam	19	adult	1998	fin clip
7	John Day River, OR (Camas Cr.)	20	ammocoetes	1998	E, H, L, M
8	John Day River, OR	15	adult	1998	E, H, L, M
9	John Day River, OR RM 35.9	20	ammocoetes	1998	E, H, L, M
10	John Day River, OR RM 59.2	30	ammocoetes	1998	E, H, L, M
11	Lower Granite Dam	56	ammocoetes	1998	E, H, L, M
12	Milton Creek, OR	54	ammocoetes	1998	E, H, L, M
13	Red River, ID	22	ammocoetes	1998	E, H, L, M
14	Sherars Falls, OR	37	adult	1998	E, H, L, M
15	Shitake Creek, OR	25	ammocoetes	1998	E, H, L, M
16	Willamette Falls, OR	55	adult	1998	E, H, L, M
17	Willamette Falls, OR	5	adult	1998	fin clip
18	Willamette River, OR	39	adult	1996	E, L, M[1]

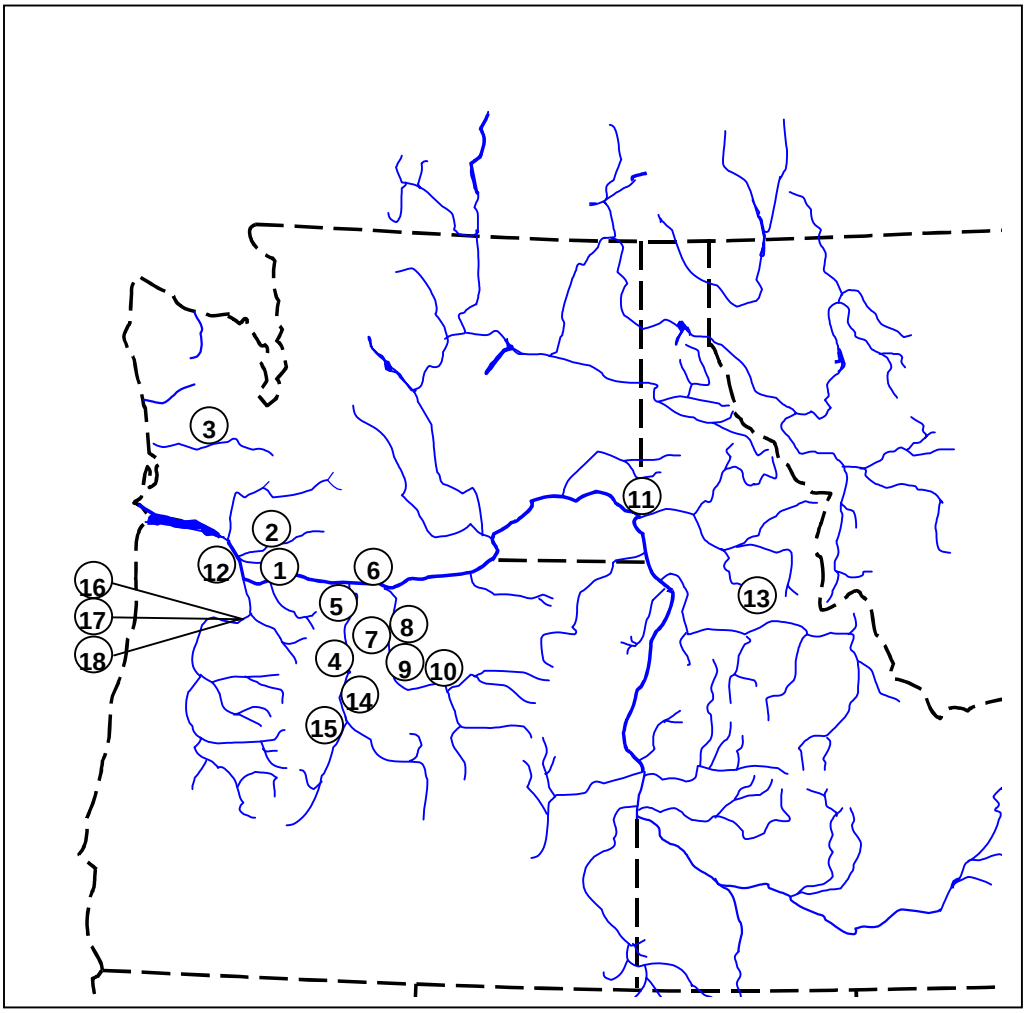

Figure 1. Sampling locations for Pacific lamprey collected in Washington, Oregon, and Idaho. Numbers correspond to sample locations listed in Table 1.

homogenized in buffer solution and loaded on to starch gels using methods indicated in Abersold et al. (1987) and Waples et al. (1991). Four separate buffer systems were used in combination with the four different tissues to screen enzymes and resolve particular loci. Enzymes and loci surveyed have been listed in Table 2. Allozyme data is in Appendix A. Alternate staining methods from Manchenko (1994) were also used when the resolution of banding patterns was problematic at some loci. Enzymes were denoted by their Enzyme Commission number as referenced by Manchenko (1994) which allows for comparison with enzyme nomenclature suggested for fishes by Shaklee et al. (1990).

Mitochondrial DNA Analysis

Fin tissue from juvenile or adult lamprey were stored in 95% ethanol or lysis buffer (50 mM Tris-HCl, pH 8.0; 200 mM NaCl; 50mM EDTA; 1% sodium dodecyl sulfate and; 0.2% dithiothreitol) until total genomic DNA was isolated using methods summarized in Paragamian, Powell and Faler (1999). Mitochondrial DNA was amplified using the polymerase chain reaction (PCR) and nucleotide primers specific for the NADH dehydrogenase subunit III region (ND 3) and the cytochrome b (Cyt b) gene region as referenced in Docker et al. (1999). Amplified fragments were then digested with three restriction endonucleases (*Eco*R I, *Hind* III and *Taq* I). Resulting fragments were electrophoresed on 3% agarose gels and stained with ethidium bromide. Banding patterns were visualized under UV light and compared to a pUC-19 size standard (Biosynthesis).

Data analysis

Utter et al. (1987) and references therein were used to interpret and assign genotypes to observed phenotypes (zymograms). The MONTE program in REAP ver 4.0 (McElroy et al. 1991) was used to test for significant geographic heterogeneity among frequency distributions of mitochondrial haplotypes.

Results

Allozyme analysis

Genetic variation was surveyed at 34 protein coding loci listed in Table 2. Polymorphic banding patterns were observed at 3 loci, IDHP-1, LDH, and MDH. However, variation at these loci was extremely low. The LDH locus showed the most variation with 4 lamprey samples from 3 locations having detectable variation (1 sample each from #13, Red River, #7 Camas Creek, and 2 samples from #8 John Day River). The IDHP-1 locus was polymorphic in two samples from Shitake Creek (#15). One sample from Sherars Falls (#14) was observed with a variant allele for MDH. The remaining 31 loci were scored as monomorphic among the samples surveyed.

Table 2. Enzymes for 34 loci screened for Lampetra tridentata (by Enzyme Commission Number) ar observed variation at each locus.

E.C. Number	Enzyme	Locus	Banding Pattern
1.1.1.2	Alcohol dehydrogenase	ADH	monomorphic
1.1.1.14	Sorbitol dehydrogenase	SORDH	monomorphic
1.1.1.27	Lactate dehydrogenase	LDH	polymorphic
1.1.1.37	Malate dehydrogenase	MDH-1	polymorphic
		MDH-2	reported but not observed
1.1.1.40	Malic enzyme	ME-1	monomorphic
		ME-2	monomorphic
1.1.1.41	Isocitrate dehydrogenase	IDHP-1	polymorphic
		IDHP-2	monomorphic
1.1.1.44	Phosphogluconate dehydrogenase	PGD	monomorphic
1.2.1.12	Glyceraldehyde-3-phosphate dehydrogenase	GAPDH-1	monomorphic
		GAPDH-2	reported but not observed
1.15.1.1	Superoxide dismutase	SOD-1	monomorphic
		SOD-2	reported but not observed
2.4.2.1	Purine-nucleoside phosphorylase	PNP	monomorphic
2.6.1.1	Aspartate aminotransferase	AAT-1	monomorphic
		AAT-2	monomorphic
2.7.1.40	Pyruvate kinase	PK	monomorphic
2.7.2.3	Phosphoglycerate kinase	PGK	monomorphic
2.7.3.2	Creatine kinase	CK	monomorphic
2.7.43	Adenylate kinase	AK-1	monomorphic
		AK-2	reported but not observed
3.1.1.1	Esterase-D	EST-D	monomorphic
3.4.1.1	Peptidase	PEP-1	monomorphic
		PEP-2	monomorphic
3.5.4.4	Adenosine deaminase	ADA-1	monomorphic
		ADA-2	monomorphic
4.1.2.13	Aldolase	ALD	monomorphic
4.2.1.3	Aconite hydratase	ACO	monomorphic
5.3.1.8	Mannose-6-phosphate isomerase	MPI	monomorphic
5.3.1.9	Glucose-6-phosphate isomerase	GPI-1	monomorphic
		GPI-2	monomorphic
5.4.2.2	Phosphoglucomutase	PGM-1	monomorphic
		PGM-2	monomorphic

Mitochondrial DNA Analysis

Amplification of the 351 bp ND 3 region did not show any detectable length variation among samples using 3% agarose gels. The amplified region also exhibited monomorphic banding patterns when digested with the three restriction endonucleases listed above.

The PCR amplified cytochrome b gene region exhibited one polymorphism when digested with *Taq* I. Restriction digests for both regions were combined into composite haplotypes and listed as *Lt*-A and *Lt*-B. Table 3 lists the frequency of *Lt*-A and *Lt*-B from each sample location. The *Lt*-A haplotype was most common and found in samples from every location at a frequency ranging from 54.5% to 100%. Three locations were fixed for *Lt*-A, Cedar Creek (#2), Camas Creek (#7) and samples from Lower Granite Dam (#11). The *Lt*-B haplotype ranged in frequency from 0% in samples from the three locations previously listed, to a high of 45.5% in samples from the Red River, Idaho (#13). An adjusted chi square analysis using bootstrapping (MONTE program in REAP) indicated a non-significant difference among the geographic distribution of haplotype frequencies (average χ^2=16.93, df=17, P=0.543).

Discussion

The protein electrophoretic methods used in this study failed to falsify the predictive statement that Pacific lamprey populations are genetically similar and those differences are non-significant. Further analysis of allele frequencies, and "F" statistics were not calculated for the allozyme data. The protein electrophoretic methods used in the survey did not provide sufficient variability among populations to address the question of adult homing in Pacific lamprey. Overall, scoring of zymograms was problematic. Banding patterns were poorly resolved or weak, generally suggesting either non-optimized enzymatic reactions, a loss of enzyme activity through poor handling (over preparation, or poor storage), a lack of sufficient tissue (ammocoetes were difficult to prepare), or some combination thereof. See Mitton (1997) for a review of factors effecting the performance of protein electrophoresis and the analysis of allozyme/isozyme banding patterns. The enzyme systems and buffers used were optimized for Pacific salmonids, which in most cases has resulted in sufficient resolution for many other freshwater fishes. Other studies of Pacific lamprey have used these particular enzyme systems with mixed results (D. Close pers. comm.). Alternatively, studies on European lamprey and Canadian lamprey populations have used slightly modified enzyme systems and have resolved several loci, which were unresolved in our systems (Krueger and Spangler 1981; Beamish and Withler 1986; Schreiber and Englehorn 1998). These loci are listed in Table 2 as "reported but not observed." Genetic variation was observed in the mitochondrial cytochrome b gene region, which was an amplified fragment, approximately 3x the length of the monomorphic ND 3 gene fragment. Unfortunately the distribution of haplotype frequencies were non-significant.

Table 3. Distribution of haplotype frequencies for Pacific lamprey collected from 18 locations. Polymorphisms observed in the Cytochrome b region were designated Lt-A and Lt-B. Relative frequencies for Lt-A and Lt-B are diagramed in Figure 2.

Location		ND 3	Cytochrome b	
Number	Location	A	Lt-A	Lt-B
1	Bonneville Dam	1.000	0.714	0.286
2	Cedar Creek (Lewis River), WA	1.000	1.000	0.000
3	Chehalis River, WA	1.000	0.740	0.260
4	Deschutes River, OR	1.000	0.684	0.316
5	Fifteen Mile Creek, OR	1.000	0.768	0.232
6	John Day Dam	1.000	0.895	0.105
7	John Day River, OR (Camas Cr.)	1.000	1.000	0.000
8	John Day River, OR	1.000	0.800	0.200
9	John Day River, OR RM 35.9	1.000	0.850	0.150
10	John Day River, OR RM 59.2	1.000	0.867	0.133
11	Lower Granite Dam	1.000	1.000	0.000
12	Milton Creek, OR	1.000	0.741	0.259
13	Red River, ID	1.000	0.545	0.455
14	Sherars Falls, OR	1.000	0.703	0.297
15	Shitake Creek, OR	1.000	0.760	0.240
16	Willamette Falls, OR	1.000	0.764	0.236
17	Willamette Falls, OR	1.000	0.800	0.200
18	Willamette River, OR	1.000	0.769	0.231

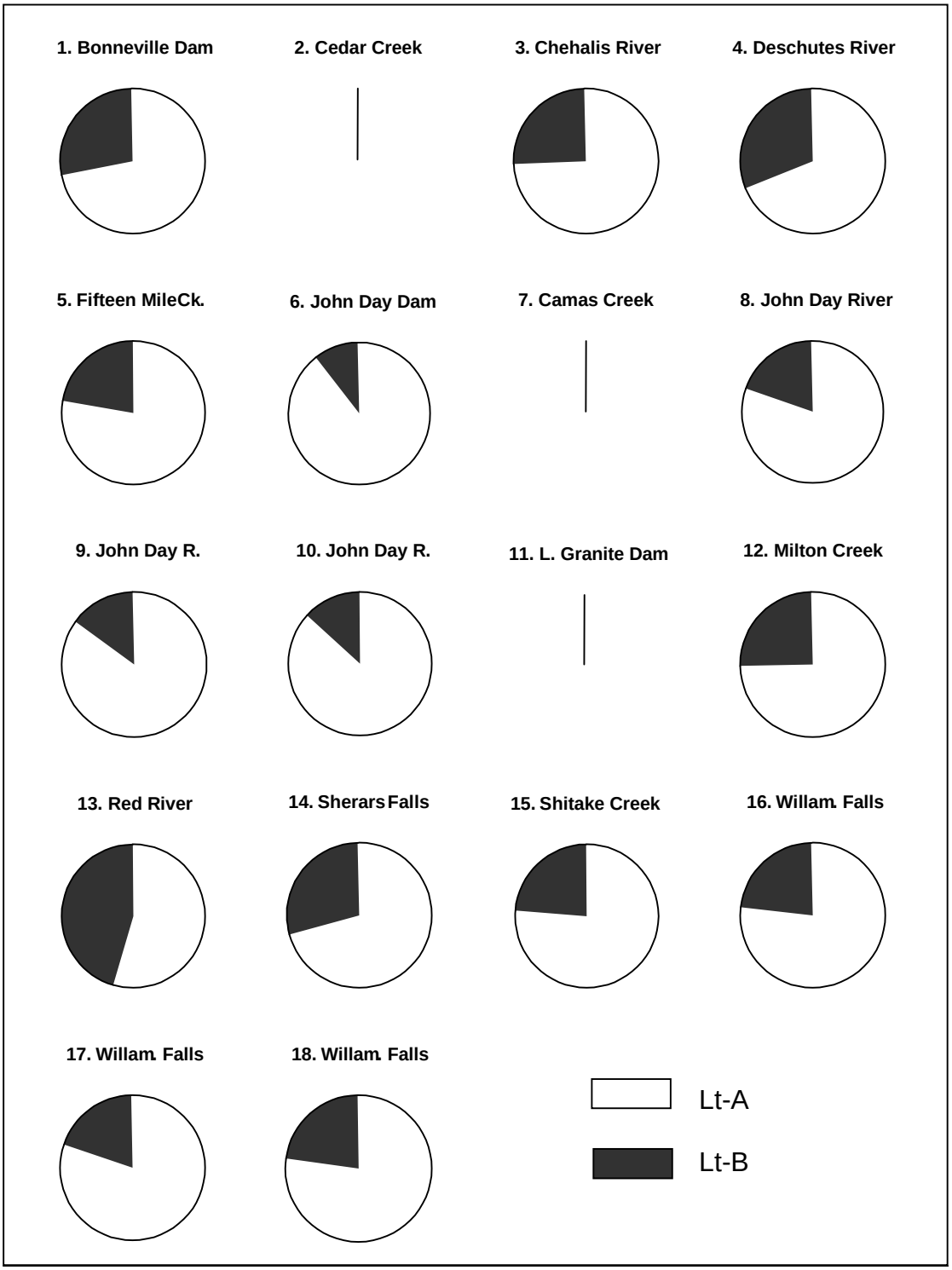

Figure 2. Relative frequency and distribution of Cytochrome b RFLPs among 18 Pacific lamprey populations. Frequencies for each haplotype are reported in Table 3.

Restriction enzymes for RFLP analysis were originally chosen on the likelihood that they would produce species specific fragments. There was some question during sampling that conspecific western brook lamprey (*Lampetra richardsoni*) ammocoetes may have been erroneously identified and mixed in with Pacific lamprey samples. A species-specific marker for *Lampetra* would be beneficial for juvenile identification since morphological identification can be difficult. As it turned out, mitochondrial variation observed with the three enzymes used was insufficient to address questions concerning adult homing. Further analysis of these amplified fragments with additional enzymes that have 4 and 5 base recognition sequences is likely to yield further intraspecific variation and perhaps shed more light on whether or not Pacific lamprey are philopatric.

Recommendations

Homing studies

Protein electrophoresis will not likely provide sufficient observable genetic variation among Pacific lamprey populations with the methods used in this study. However, as stated above, protein electrophoresis has been shown to be sufficient to delineate populations of lamprey in several other studies (Krueger and Spangler 1981; Beamish and Withler 1986; Schreiber and Englehorn 1998). Thus, the potential for optimizing allozyme/isozyme methodologies and obtaining sufficient observable variation probably still exists for Pacific lamprey genetic investigations. Future investigations will probably have to contend with a greater concern for lethal sampling of lampreys required for protein electrophoresis and attention to samples containing ammocoetes. For a review of problems associated with ammocoete sampling see Jacobsen, Torblaa and Morman (1984).

Mitochondrial DNA may also exhibit more variation if RFLP analysis is carried out on the amplified gene regions surveyed here using additional restriction enzymes. Additional nucleotide primer sets, which amplify other mitochondrial gene regions, may also yield greater variation using RFLP analyses. The extent mitochondrial DNA may be sufficiently variable to detect any natal homing behavior in Pacific lampreys remains speculative at this point.

Population structure

Protein electrophoresis methods, as previously stated, may be more valuable as a tool to describe population structure than the survey results reported here. However, with the numerous molecular methods currently being developed, it is likely that DNA analyses using highly variable loci such as microsatellites would be more informative especially for small amounts of tissue and non-lethal sampling that may be required in the future. Microsatellites would also be recommended for studies where parentage and kinship may need to be ascertained. Ammocoetes or macrophathalmia collected from a single location could be progeny from a single cross or from multiple parents. In either case this information would be valuable to managers. Likewise, if as indicated by the preliminary mitochondrial DNA results, Pacific lamprey populations do not possess a great deal of intrapopulation genetic

variation, then highly variable loci like microsatellites may be more appropriate to describe population level differences.

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CHAPTER SIX

Technical Assistance for Pacific Lamprey Studies: Report of Research

by

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Introduction

Pacific lampreys (Lampetra tridentata) in the Columbia River Basin are believed to have declined to only a remnant of their population prior to human development in the region. The Northwest Power Planning Councils Fish and Wildlife Program (1994) noted the apparent decline of Pacific lampreys and requested a status report to identify research needs. The resulting report (Close et al. 1995) called for studies on lamprey abundance, evaluation of their current distribution, and determination of habitat limiting factors. Rehabilitation is now being considered in some areas where lampreys have been extirpated and a pilot restoration project is planned for the Umatilla River.

The objective of this project was to provide products and technical guidance to assist the Confederated Tribes of the Umatilla Indian Reservation accomplish their goals of research and restoration of Pacific lampreys in the Columbia River Basin. Specifically, we have provided technical assistance for population assessment of upstream-migrating Pacific lampreys and developed preliminary culture techniques for Pacific lampreys.

Culture techniques for Pacific lampreys.

1. Evaluation of holding conditions for adult Pacific lampreys.

Thirty-three adult Pacific lampreys were collected from the John Day River by CTUIR personnel in July 1998 and transported to the CRRL. Lampreys were held in 1400 l circular tanks with a continuous inflow of well water at ambient Columbia River temperatures (10 - 16°C) and exposed to a simulated natural photoperiod produced by incandescent lights and timers.

The bottom of each tank was covered with river rocks ranging in size from gravel to cobble (~three cm^2 to ~15 cm^2). Within weeks of arriving at CRRL, lampreys showed external signs of disease, including patches of fungus, petechial hemorrhaging and open lesions. We solicited the help of the USFWS Lower Columbia River Fish Health Center (LCRFHC) to determine the nature and cause of the disease outbreak. On the recommendation of the LCRFHC, we administered antibiotics and salt and formalin baths. Unfortunately, we were unable to definitively answer this question.

In September, the surviving lampreys were supplied with unheated (6 °C) surface water from the Little White Salmon River. Soon after the transfer, the condition of the lampreys improved and we saw no additional mortality after this time. We believe the problem is somehow related to the source of the holding water (a 15 meter deep well), but extensive water quality testing revealed nothing suggesting a cause. As a precautionary measure, well water is no longer used to supply any lamprey holding tanks.

Although it was our intention to use only lampreys from the John Day River Basin for this work, the mortality during the holding period reduced our population to seventeen individuals. In order to increase the number of lampreys available for this work, adult Pacific lampreys were collected from the Willamette River at Willamette Falls in March

1999. These lampreys were subjected to the same holding conditions as the lampreys collected from the John Day River.

Water temperatures were adjusted to mimic the John Day River (based on data provided by Dave Close, personal communication). Temperatures during winter months (November – March) ranged from 4 – 6 °C. In mid-April, we began to heat the water, gradually increasing roughly 1° C a week to 15.5 °C by July.

We examined the lampreys periodically through the winter and spring. Starting in early April 1999, we began to see external morphometric changes consistent with published descriptions (Hardisty and Potter 1971) of secondary sexual characteristics of other species of lampreys. By 22 April (at 5.5°C), eight of 17 lampreys displayed the beginnings of the post cloaca swollen lobe (initially visible as a ridge starting immediately posterior to the cloaca) (Figures 1a and 1b). Around this time, we began to witness nest-construction behavior by these lampreys; rocks and gravel were regularly moved about the tank, often completely removed in oval areas approximately 40-50 cm long and 20-30 cm wide (Figure 2).

By mid-May 1999, several females had external characteristics very similar to a female lamprey that matured in captivity at the CRRL in 1998 (Figure 3b). At this time, we were also able to detect the male urogenital papillae. The lampreys became very active, including moving rocks by sucking on with their oral discs, attacking each other, pairing side by side, and attaching to the bottom of the tank and flagellating their entire body with sufficient force to throw gravel against the side of the tank. Volitional spawning in the holding tanks commenced 8 June 1999, coinciding with water temperatures of 12.5°C. We began manually spawning on 11 June. Of the lampreys collected from the John Day River, the males matured slightly faster than the females, requiring us to use male lampreys collected from Willamette Falls to fertilize the eggs. Of the lampreys from the John Day River, the last three females were manually spawned on 16 June 1999. Of the lampreys collected from Willamette Falls, the last female was spawned on 30 June. For female lampreys, the defining characteristic for complete maturity seemed to be when the swelling around the cloaca filled with blood and appeared red.

2. Spawning techniques

Mature lampreys were removed from the holding tanks, anesthetized for four minutes in 5 l of 60 mg/l concentration of tricaine methanesulfonate (MS-222) buffered with an equal concentration of sodium bicarbonate. Each lamprey was then rinsed in fresh water before spawning to remove traces of anesthetic.

Gametes were stripped from the female lampreys first. Each female lamprey was positioned over a glass bowl filled with about 2 l of fresh water. Eggs were forced out the cloaca by squeezing the abdomen in a downward motion (Figure 4a). This was repeated until blood appeared with the gametes. Male lampreys were stripped of gametes in a similar fashion (Figure 4b). Both sperm and eggs were released more readily when the urogenital

opening was submerged in the water. Eggs were slightly adhesive when exposed to air, but less so when mixed with water.

Gametes were mixed with a gentle flow of water from a laboratory wash bottle or a large pipette and allowed to rest undisturbed at room temperature for 1 – 3 h. Eggs were sampled from the bowl before and immediately following fertilization. Eggs were placed into incubators and provided continuous flow of water.

Figure 1a. Upstream migrating Pacific lamprey captured July 1998 from the John Day River (RM 10). Example of pre-spawning female; this individual was manually stripped of gametes on June 11, 1999 (photograph taken May 20, 1999).

Figure 1b. Upstream migrating Pacific lamprey captured July 1998 from the John Day River (RM 10). Example of pre-spawning male; this individual spawned on June 9, 1999 (photograph taken May 20, 1999).

Figure 2. Pacific lampreys excavated redds in holding tanks prior to spawning (photograph taken May 18, 1999).

Figure 3a. Upstream migrating Pacific lamprey captured July 1998 from the John Day River (RM 10). Example of spawning female; this individual was manually stripped of gametes on June 11, 1999 (photograph taken day of spawning).

Figure 3b. Magnified view of oedema around the cloaca of a mature female Pacific lamprey.

Figure 4a. Gametes were manually stripped from mature female Pacific lampreys first.

Figure 4b. Eggs were fertilized by manually stripping sperm from mature male Pacific lampreys.

3. Evaluation of egg incubation systems.

We evaluated two types of incubators: prefabricated "MacDonald" type jars and custom fabricated jars as in Holland and Libbey (1980). Both types of incubators function on the principle of water flow forced against a rounded bottom of the jar, resulting in an upwelling current. This upwelling moves water past the eggs and uniformly rotates them. This provides the eggs with a continuous flow of oxygen and flushing of wastes.
The custom fabricated hatching jars were made from 2 l plastic beverage containers fitted with PVC components for the inflow tube and outflow spout. The primary appeal of these incubators was their low cost (materials were around $5), although this savings was diminished by the considerable time required to construct them. The primary flaw of these units was that the eggs tended to float out the outflow spout. We tried to screen this opening, but the screen clogged and the incubator overflowed out the top. Therefore, we recommend the use of commercially available incubators.

The prefabricated incubators were 42 cm tall, 11.5 cm in diameter with a volume of 6 liters (Figure 4c). We estimate each incubator could hold roughly 600,000 – 700, 000 eggs (6-7 female Pacific lampreys). These incubators require a minimum inflow of 1 liter/minute to keep good flow moving past the eggs and an inflow of 2-3 liters/minute to keep the eggs suspended and circulating. Although they are considerably more expensive (around $125), there was no assembly required, water upwelling was consistent, and eggs did not float out. Additionally, they were considerably larger, which would be necessary for a large-scale hatchery operation.

4. Determination of fecundity, egg size, growth of larvae over time, fertilization (percentage success), hatch (percentage success), and survival to various developmental stages.

To calculate fecundity for individual females, first the total volume of eggs was measured in a large graduated cylinder. Three subsamples were taken from the total volume. Each subsample was measured in a small graduated cylinder and fixed in four percent buffered formalin to allow the eggs to be counted at a later time. The total fecundity was calculated by determining the average number of eggs per volume (using the average of the three subsamples) and extrapolating to the total volume of eggs. We calculated fecundity for four individuals. We used simple linear regression to determine the relationship between length and fecundity. The following equation describes this relationship:

Fecundity = 1564 (total length in mm) – 608,760 ($r^2 = 0.78$; $P = 0.12$).

While this provides a way to estimate fecundity, it is important to remember this regression equation is based on data from only four individuals.

Table 1. Total length, mean (SD) eggs/ml of subsamples, and total estimated fecundity for four Pacific lampreys.

Collection source	Total length (mm)	Eggs/ml	Estimated fecundity
John Day River	453	446 (11)	129,301
John Day River	435	426 (22)	58,605
Willamette Falls	427	329 (31)	54,279
Willamette Falls	482	408 (13)	132,788

Figure 4c. Pacific lamprey eggs and larvae in commercially available incubator.

A time series of progeny was examined under a dissecting microscope equipped with a polarizing filter and a calibrated ocular micrometer. Measurements were made to the nearest 0.1 mm. Eggs and larvae were measured following fixation in four percent borax-buffered formalin. Larvae were measured at hatch and at irregular intervals during development.

Eggs were maintained in the hatching jar until the majority of them had hatched. Larvae hatched 12 – 17 d after fertilization at a mean temperature of 16 °C. When the majority of eggs in an incubator had hatched, they were transferred to a 77 l aquarium. Each aquarium had substrate (river sand approximately 10 cm deep) and was provided a continuous flow of water at 16 °C. Larvae began burrowing into the substrate within a week and most were burrowed within two weeks.

Eggs were pale yellow-green in color, had a large perivitelline space, were slightly adhesive, and seemed quite durable (Figures 5a and 5b). Mean diameter (and standard deviation) of eggs was 1.7 (0.1) mm (N= 61). Recently hatched larvae had essentially no pigmentation. Internal organs, the circulatory system, and a large yolk mass that extended from the posterior tip of the heart to the vent were readily visible (Figure 5c). Larvae began feeding at approximately 4 weeks old and the yolk sac was fully absorbed shortly after feeding commenced. At three months, larvae appeared to be fully formed ammocoetes. Mean notochord length (and standard deviation) of larvae was as follows: at hatch = 6.7 (0.6); at 12 d =; 8.0 (0.5) at 27 d = 8.7 (0.9); at 58 d = 13.1 (1.1); at 92 d = 19.6 (2.5).

We were not able to rigorously sample eggs and larvae to determine accurate estimates of fertilization, hatch rate, and survival to specific developmental stages. Based on our limited sampling (eggs from five spawning events), we saw fertilization rates ranging from 65% – 98%. Hatching rate was determined by estimating the proportion of dead eggs remaining after hatch. We estimate our hatching rate was roughly 85% – 90 %. We cannot provide estimates on survival to specific life stages, however we do still have live larvae in the laboratory.

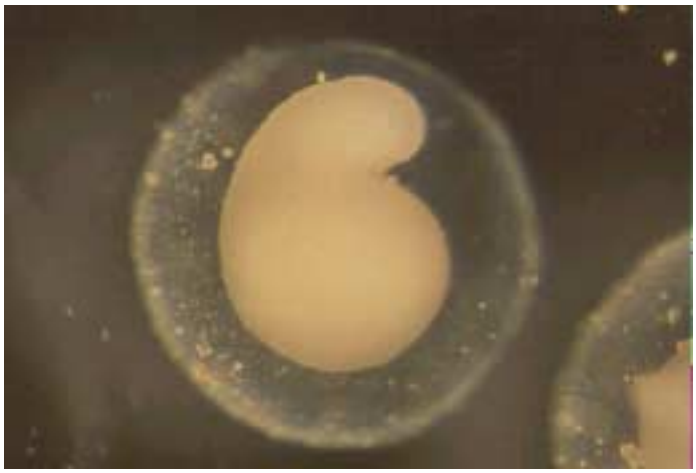

Figure 5a. Pacific lamprey egg after 10 days of incubation (photograph taken June 24, 1999).

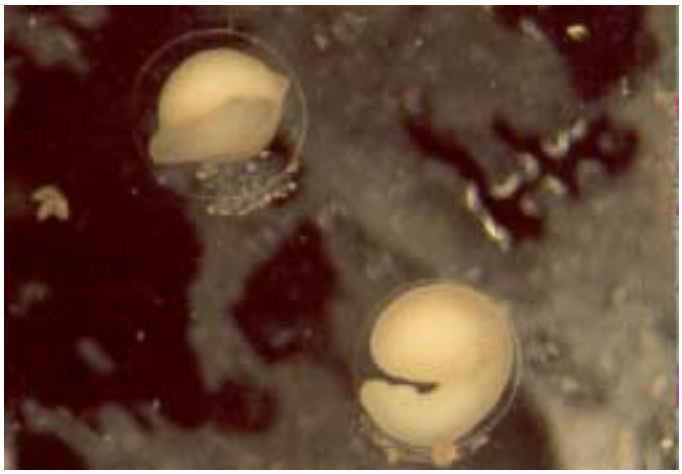

Figure 5b. Pacific lamprey egg after 12 days of incubation (photograph taken June 26, 1999).

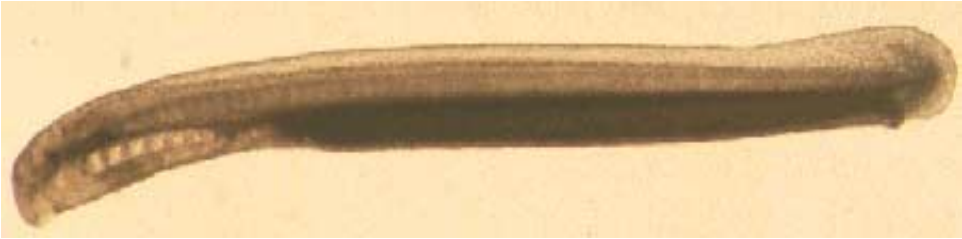

Figure 5c. Twelve day old Pacific lamprey larva (photograph taken July 12, 1999).

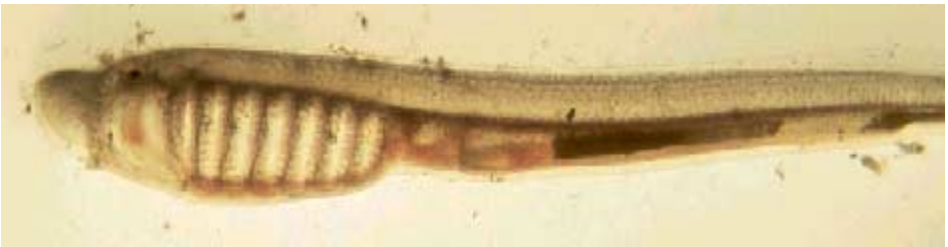

Figure 5d. Three month old Pacific lamprey larva (photograph taken September 22, 1999).

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CHAPTER SEVEN

In-Season Homing of Pacific lamprey (Lampetra tridentata) in the Columbia River Basin.

by

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Introduction

Homing and migration behavior of adult Pacific lamprey *Lampetra tridentata* after displacement from return locations was studied in the lower Columbia and Willamette rivers in 1998 and 1999. The objectives were: 1) to determine in-season homing performance of radio-tagged displaced Pacific lamprey, 2) to investigate evidence for natal homing using mtDNA analysis (see chapter 5); and, 3) to investigate the potential for genetic stock structure in Pacific lamprey from the Columbia River Basin (see chapter 5). An additional objective was to report the abundance of Pacific lamprey as indexed by counts at hydroelectric dams on the Columbia and Snake rivers. This chapter details the results of the in-season homing study and the fish ladder counts while the next chapter addresses the genetic analysis.

Gerking (1959) used the term homing in a general sense to mean the return of fish, after migratory, accidental, or experimental displacement, "to a place formerly occupied instead of going to other equally probable places." McCleave (1967) described equally probable places as areas "occupied by other individuals of the same species". In spawning migrations of fishes, three types of homing are recognized (McCleave 1967): (1) the return of adults to spawn in the same location in which they were hatched, termed "reproductive, parent stream, or natal homing" by Lindsey et al. (1959); (2) the return of adults to spawn in subsequent breeding seasons at the location of initial spawning, repeat homing; and, (3) the return of adults within the same breeding season to the location of initial choice after displacement, in-season homing.

Our displacement study offers little support for the hypothesis that Pacific lamprey exhibit in-season homing. This surprising result conflicts with similar studies that have been performed using a variety of fish species ranging from Gulf of Mexico sturgeon Acipenser oxyrinchus desotoi to black-and-yellow rockfish Sebastes chrysomelas. However, Bergstedt and Seelye (1995) reported a lack of natal homing by sea lamprey (Petromyzon marinus) in Lake Huron.

Besides the highly studied homing fidelity of anadromous salmonids (Oncorhynchus spp.), we located 22 studies that demonstrated homing in 15 additional species. Natal homing was demonstrated in Gulf of Mexico sturgeon (Stabile et al. 1996), American shad (Alosa sapidissima) (Carscadden and Leggett 1975), and rainbow trout (O. mykiss) (Lindsey et al. 1959). Repeat homing was demonstrated in American shad (Melvin et al. 1986), charr (Salvelinus willughbii Günther) (Frost 1963), brook trout (Salvelinus fontinalis) (O'Connor and Power 1973), and brown trout (Salmo trutta) (Tilzey 1977). In-season homing was demonstrated in Colorado squawfish (Ptychocheilus lucius) (Tyus 1985), lake trout (Salvelinus namaycush) (Martin 1960) flathead catfish (Pylodictis olivaris) (Hart 1971; Hart and Summerfelt 1974), muskellunge (Esox masquinongy) (Margenau 1994), black-and-yellow rockfish (Hallacher 1984), mosshead sculpin (Clinocottus globiceps) (Green 1973), charr (Frost 1963), Florida largemouth bass (Micropterus salmoides flordanus) (Mesing and Wicker 1986), cutthroat trout (O. clarki) (Platts 1959; McCleave 1967; McCleave and Horrall 1970), rainbow trout (Lindsey et al. 1959), brook trout (O'Connor and Power 1973), brown trout (Harcup et al. 1984; Halvorsen and Stabell 1990), largemouth bass (Micropterus

salmoides) (Quinn et al. 1978), and American shad (Dodson and Leggett 1973). Prior to this work, homing has not been studied in Pacific lamprey; however, Beamish (1980) speculated that at least some Pacific lamprey homed as evidenced by differences in adult length compositions among rivers that he investigated.

Bergstedt and Seelye (1995) used coded wire tag (CWT) and recovery methods to reject the hypothesis that Lake Huron sea lamprey home to natal streams. However, Wright et al. (1985) used allozyme data to identify statistically significant differences among five sample sites within Lake Huron, which they interpreted to indicate stock structure. For stock structure to exist, Lake Huron sea lamprey must exhibit natal homing. We offer the following explanations for the conflicting results from these two approaches to studying sea lamprey homing. Bergstedt and Seelye study may have captured adult sea lamprey explorers that had not yet reached their natal stream. After adult sea lampreys were trapped they were killed and the CWT was removed. The trapped fish were not spawning when they were captured, they may not have made a final spawning stream selection and could have been merely exploring a tributary as has been demonstrated in salmon (Hasler and Scholz 1983). However, because no coded wire tagged sea lampreys were detected in the stream of origin, there is strong evidence that they do not home. Possible explanations for false conclusions by Wright et al. (1985) could include nonrandom sampling, small effective population sizes, and mixing of year-classes in samples (Jacobson et al. 1984). Jacobson et al. (1984) provide a full critique of the Wright et al. (1985) study.

Pacific lamprey homing fidelity, or lack thereof, has many implications for restoration and management. The Pacific lamprey plays an important role in the ecosystem, and are used by native American Indians of the Pacific Northwest. The Pacific lamprey is native to the Pacific Northwest and sympatric with oncorhyncoids. Pacific lampreys provide a vehicle for recruitment of marine nutrients to the streams, as well as a buffer for avian (Merrell, T.R. 1959), marine mammal (Jameson and Kenyon 1977; Roffe and Mate 1984), and piscverous (Beamish 1980; Poe et al. 1991) predation. Counts of Pacific lamprey at fishway counting stations in the Columbia River Basin are currently about 3 to 5% of what they were 50 to 60 years ago, indicating a dramatic decline in lamprey abundance. Restoration efforts are being considered for specific Columbia Basin tributaries. If Pacific lamprey demonstrate poor homing fidelity, restoration efforts may need to be focused on subbasin or basin scale. The objective of this study was to investigate in-season homing of Pacific lamprey using radiotelemetry.

Methods

Study area

The study area (Figure 1) ranged from Columbia City, Oregon (RKM 137) upstream to Bonneville Dam (RKM 238) in the Columbia River and up to Willamette Falls (RKM 45) in the Willamette River.

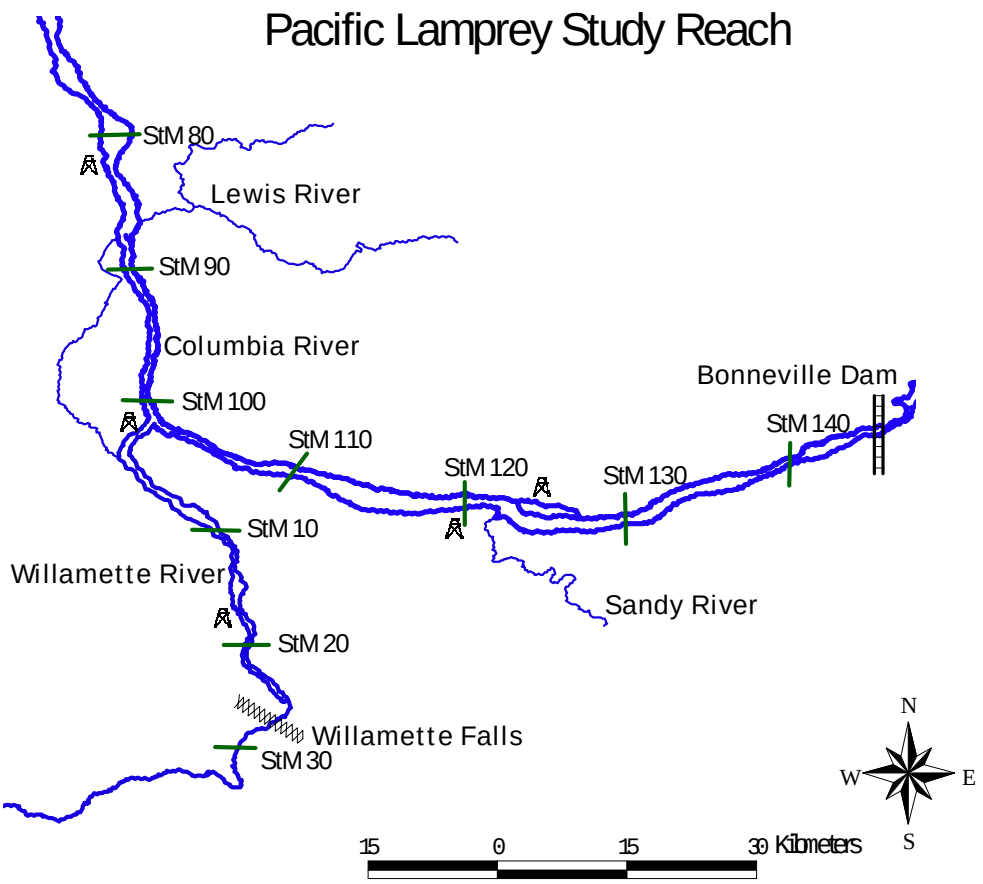

Figure 1. Telemetry study area, with locations of fixed receivers denoted by tower icons.

The confluence of the Willamette River is located at RKM 163 of the Columbia River. Fixed receiver locations were sited based on the following criteria: usefulness to the study, security from vandals, ambient noise levels, and elevation. Each fixed receiver site consisted of a Lotek SRX-400 radiotelemetry receiver, a nine-element Yagi antenna, and a deep cycle battery. The SRX-400 receivers ran the Code-Log software that allows data to be stored in permanent memory (Lotek Engineering 1994) and were set to scan only channel 16 (149.960 MHz). All of our tags were on a single channel, so scanning was continuous. We set the gain levels at each site as high as possible while trying to minimize the number of false codes received.

Five receivers were set up in the study area. One was located below the release site, near RKM 137, to monitor for fish moving downstream out of the study area. One receiver was set up on Sauvie's Island about a mile below the confluence of the Columbia and Willamette rivers. We deployed two upstream receiver sites in the Columbia and one in the Willamette. One Columbia River site was at the Port of Camas-Washougal Marina (RKM 193) on the North shore of the Columbia River, and one was at Chinook Landing on the South shore of the Columbia River (RKM 190). Having receiver sites on both sides of the river was necessary to increase the probability of detecting passing fish. The upstream receiver site on the Willamette River was located at the Staff-Jennings Marina (RKM 27) just below the Sellwood Bridge.

Capture sites

We collected adult Pacific lamprey at Bonneville Dam and Willamette Falls at approximately 10-day intervals from 11 June through 24 September 1998. Fish at Bonneville Dam were collected with an adult lamprey trap at the Washington Shore Adult Fish Facility. We collected Willamette River fish by dip-net at the Willamette Falls fish ladder while the ladder was in operation and by hand from Willamette Falls after the ladder was de-watered. We immediately transported captured fish to the Abernathy Technology Center near Longview, WA and held them for 1 to 4 days until tagging.

Tagging procedure

We surgically implanted 50 Pacific lamprey (25 from each collection site) with Lotek MCFT-3BM radio tags with 3 s pulse rates and a guaranteed battery life of 163 days. The tags had an air weight of 7.7g and a water weight of 3.7g. The water weight of the tag was less than 1% of the weight of the fish as recommended by Winter et al. (1978). Fish weights were estimated from the length-weight relationship ($W = aL^b$) calculated from 1997 data. The minimum length of fish tagged was set at 620mm.

An effort was made to maintain clean, but not necessarily aseptic conditions. All utensils and transmitters were washed in a betadine solution and surgical gloves were worn during surgeries. To ensure the quality of sutures and speed of tagging all surgeries were conducted by a licensed veterinarian and assisted by a fisheries technician. The adult lampreys were anesthetized in a 150 mg/l solution of MS222 (Methane-tricaine sulfonate). Anesthetized fish were measured and placed on the surgery table where we removed a small piece of fin tissue for analysis in the natal homing experiment described in the next chapter.

Throughout the tagging process, the gills were irrigated with a continuous flow of 75 mg/l solution of MS222, however, a 150 mg/l solution and freshwater were used to maintain a suitable level of anesthesia as needed. A 3-4 cm ventral incision was made just anterior to the second dorsal fin and slightly lateral. Approximately 3 cm posterior to the incision a 16-gauge hypodermic needle was inserted and fed through to the incised area. The whip antenna of the transmitter was inserted through the needle and the needle was removed. The transmitter was then placed into the coelom through the incision, and the incision was sutured with 3/0 non-absorbable nylon suture. No topical antiseptic was applied because of risk of damage to epithelial cells (Klontz and Smith 1968, Herwig 1979). The Pacific lamprey were placed in fresh water for recovery immediately after suturing. We held the tagged lamprey for 3-5 days before release to monitor the surgeries for healing and to allow stress levels of the fish to return to pre-tagging levels (Close et al. 1996).

Release and relocation

All radio tagged Pacific lampreys from the study were released near St. Helens, OR (Figure 1) on the downstream end of Sand Island (Rkm 137). Boat tracking was accomplished in an 18' jet sled fitted with two five-element yagi antennas mounted on ten-foot masts. The antennae were pointed forward and 45° to the side on both sides of the boat. This orientation allowed reception of signals as the boat approached tagged lamprey while allowing fish on either side to be picked up on a single pass. Aerial tracking was done in a Cessna aircraft with a two-element yagi mounted on each wing pointing down and to the side of the aircraft. Boat tracking was primarily limited to the study area; aerial tracking was conducted within the study area, upstream and downstream of the study area, and in tributaries flowing into the Columbia or Willamette rivers within the study area. Our mobile tracking receiver had the W-5 firmware that does not allow data records to be stored (Lotek Engineering Inc.) in permanent memory. The Scan-Log program, which displays the code of a detected fish for the operator to record, was run while searching for tagged fish.

When tracking by boat, we made 2 to 4 passes through river reaches depending on width and the number of islands and side channels present. Both antennae were active when cruising to maximize coverage. When a fish was detected, we disconnected one antenna to determine the direction of the signal and moved closer until we could record the transmitter code and determine the fish's location. Each transmitter detection recorded was coded a minimum of three times. The transmitter code, date, latitude and longitude (determined with a handheld GPS unit), and the nearest landmark or channel marker were recorded for each tag logged.

When aerial tracking on the Willamette and Columbia rivers, upstream and downstream passes were made. When aerial tracking on smaller tributaries, a single pass was sufficient to cover the entire river. When a signal was heard, the technician attempted to code out the signal immediately, but normally the pilot would need to circle a few times to determine the direction of the signal and to allow the technician to record the transmitter code. When tracking in flight-restricted zones (i.e., Portland International Airport,

downtown Portland) only a single pass was allowed. If the technician heard a signal but was unable to record the transmitter code, the location was noted for follow-up tracking using the boat.

The SRX-400 receivers at each fixed receiver station were downloaded multiple times per week during the lamprey run and every two to three weeks in the later stages of the study. Downloading was accomplished by connecting the receiver to a notebook computer with a serial link. The HOST software (Lotek Engineering) program was used to facilitate transfer of data from the receivers to the computer and the subsequent conversion of the data to a text file.

Due to the close proximity of the study area to the Portland Metropolitan area and shipping channels of Columbia and Willamette rivers, we encountered variable radio noise patterns. We wanted to keep our receiver functioning at a high enough gain to detect fish as they passed, so false codes and collision codes were included in our downloaded data. Most false codes that are received by the SRX-400 receiver are coded as 255 or 0; neither of these numbers represent an actual tag code and are easily filtered out. False codes are also recorded that represent actual tag numbers from passing boats, automobiles, or other noise; the same false codes tend to appear often in the data. We filtered for actual codes using the data filter function in Excel and examined the data for a reasonable pattern. Records for an individual fish consisted of a series of codes received every three seconds. Since it is possible for the receiver to not code every signal, we looked for a minimum of three codes every 15 seconds for several minutes. False codes tended to appear as a single reception and at irregular intervals.

Pacific lamprey were classified as homed, strayed, and undetermined (Figure 2). The last known detection had to be in the river of capture, upstream of the confluence of the Willamette River for fish to be classified as “homed”. A “strayed” classification was assigned to an individual that did not return to its river of capture and the final detection was not in the Columbia River between the confluence of the Willamette River and the release point (Sand Island RKM 137). If an individual was last detected in the Columbia River between the confluence of the Willamette River and the release point, or in the lower 2 km of the Multnomah Channel, then it was classified as ”undetermined”.

We calculated relative frequencies for each classification for Pacific lamprey captured in the Willamette River, Columbia River, and combined. The relative frequency of fish that homed, strayed, and were undetermined was calculated as:

% Homed = number homed / (number homed + number strayed) * 100
% Strayed = number strayed / (number homed + number strayed) * 100
% Undetermined = number undetermined / number released * 100.

Pacific Lamprey Abundance Estimates

Study area

Data on adult Pacific lamprey fish ladder passage were obtained from all mainstem Columbia and Snake river hydroprojects that are equipped with fish counting stations. These include Bonneville (RKM 232), The Dalles (RKM 305), John Day (RKM 343), McNary (RKM 463), Rock Island (RKM 719), Rocky Reach (RKM 752), Wells (RKM 817), Ice Harbor (RKM 16), Lower Monumental (RKM 67), Little Goose (RKM 113), and Lower Granite (RKM 173) dams (Figure 3). These hydroelectric projects were chosen because fish passage is recorded on videotape and/or on-site lamprey counts are made.

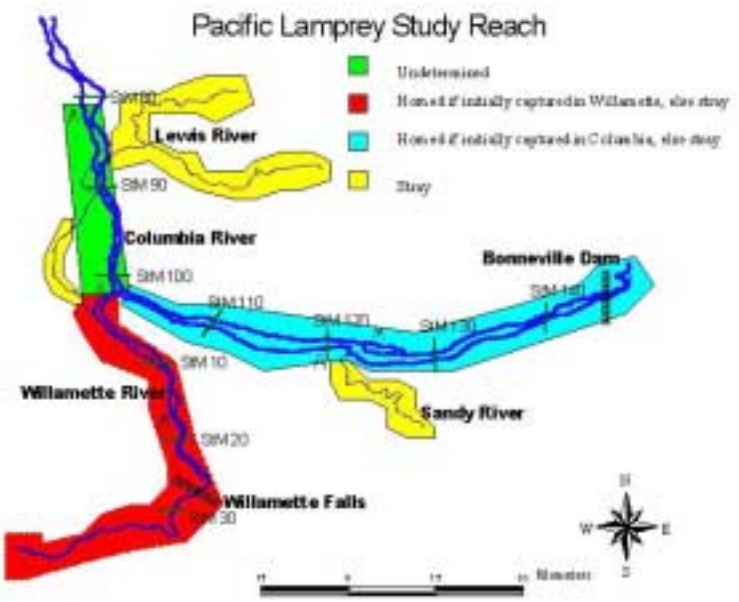

Figure 2. Classification scheme used for the In-Season homing experiment.

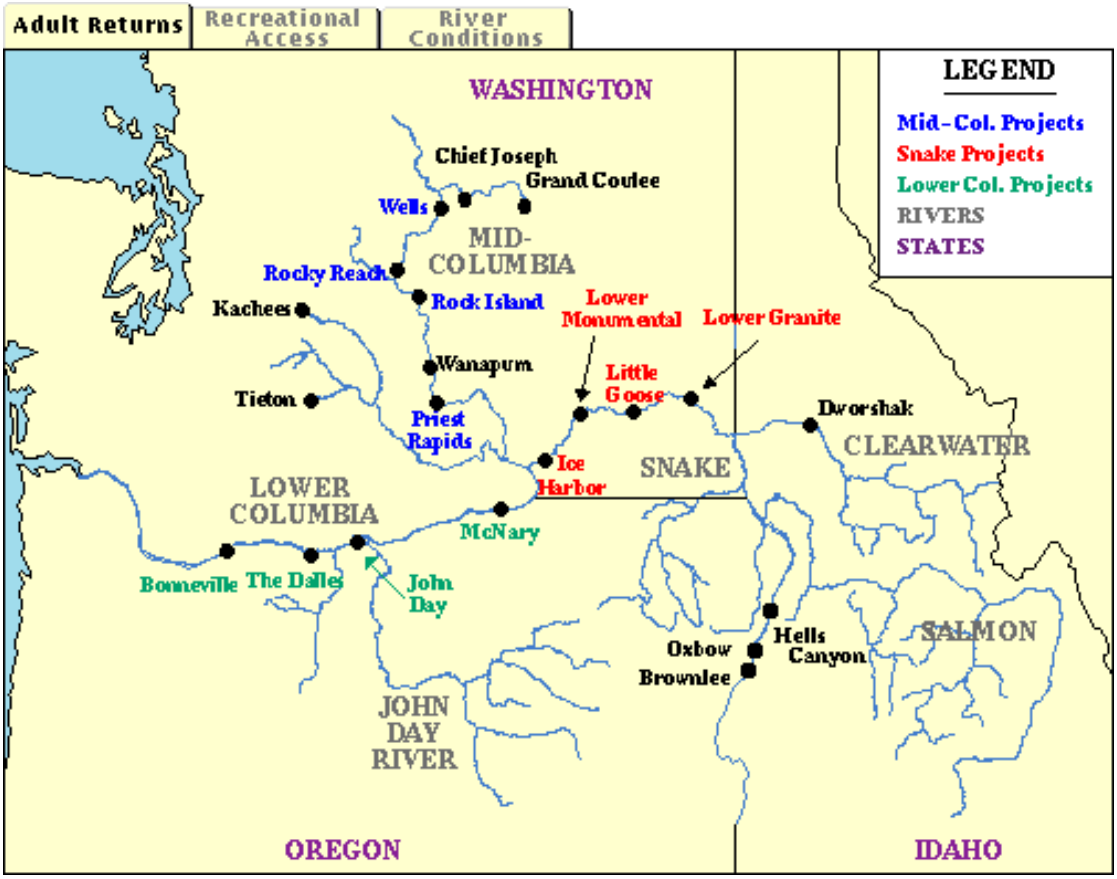

Figure 3. Map of the Columbia River Basin. The dams that are labeled in green, blue, or red are locations where adult Pacific lamprey fish ladder counts are made.

Abundance and Passage Trends

Abundance Estimates

Fish ladder counts of adult Pacific lamprey were used as an index of abundance. Fish ladder counts were obtained by reviewing time-lapse recorded videotape, or on-site counts. On-site Pacific lamprey counts were available for the four lower Snake River dams as well as McNary, John Day, The Dalles, and Bonneville dams. The on-site Pacific lamprey counting was conducted from 0400 to 2000 hrs. Lamprey counts from video records were available from Wells, Rocky Reach, and Rock Island dams and represent 24 h counts.

Results

In-Season homing

Pacific lampreys that were displaced demonstrated low fidelity for to capture sites. Of the 50 tagged individuals 46% homed, 54% strayed, and 26% were undetermined (Table 1). Seventy-four percent of the tagged fish were determined to have either homed or strayed. Pacific lamprey captured in the Columbia had a higher recovery rate and homing rate than the Willamette sample; however, both groups exhibited nonsignificant homing (p=0.622) based on the null expectation that one half of the total recoveries would home and the other half would stray. Had all of the individuals that were undetermined (5 Columbia, and 8 Willamette origin) strayed, then the tagged Pacific lamprey would have shown a significant

Table 1. Final location classifications for radio tagged Pacific lamprey. Combined groups in bold, Columbia origin in italics, and Willamette origin underlined.

Number Released	Homed		Strayed		Undetermined		Total	
	#	%	#	%	#	%	#	%
50	17	46	20	54	13	26	37	74
25	14	70	6	30	5	20	20	80
25	3	18	14	82	8	32	17	68

(p=0.024) tendency to stray. On the other hand, if all of the individuals that were undetermined were found to ultimately home, then the tagged Pacific lamprey would have still exhibited nonsignificant homing (p=0.157). We suspect that river discharge was an important factor influencing whether an individual ultimately homed or strayed. The Columbia River has much higher discharge than the Willamette River. Consequently, a higher frequency of Columbia origin Pacific lamprey returned to the Columbia River, than those captured in the Willamette River. However, the Pearson correlation (0.315) between the fraction of a release group returning to the Columbia River with the fraction of total discharge at the release area that was derived from the Columbia River upstream of the

Willamette River confluence was weak. This indicates that migration route selection must involve a suite of variables that we are currently unaware of.

Pacific lamprey collected at Bonneville Dam (mean 686 mm) were significantly ($p<0.001$ $t=4.428$, d.f.=48) longer than those collected from Willamette Falls (mean 647 mm). However, we compared the lengths of fish that chose the Willamette River with those that chose the Columbia River following displacement and discovered no significant ($p=0.701$) difference in mean length (672 mm, and 689 mm, respectively). This test should be viewed with some caution, as a result of small sample sizes ($n=22$ and $n=6$, for the Columbia and Willamette). Also, ANOVA results showed that final classifications (Figure 4) were not influenced by length ($p=0.594$). At one level the length difference at collection sites could be taken as evidence supporting a homing

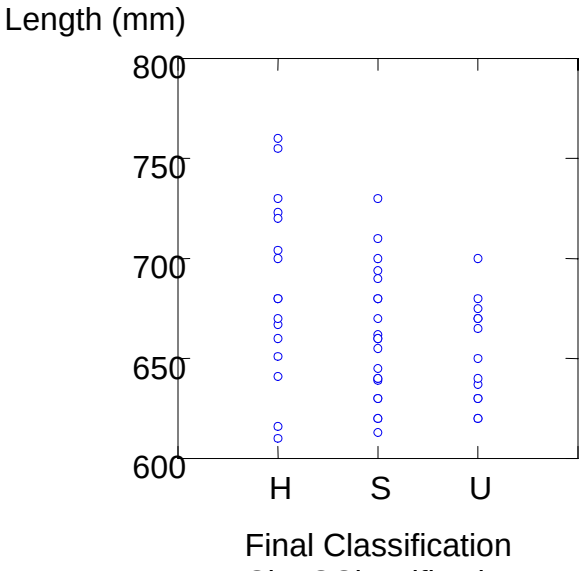

Figure 4. Lengths of radio tagged Pacific lamprey as a function of final classification. H=Homed, S=Strayed, and U=Undetermined.

hypothesis (Beamish 1980), but more likely was a result of sampling bias since the length composition of fish returning after displacement showed no differences between the Columbia and Willamette rivers. The location of the trap at Bonneville Dam required individuals to traverse the lower ¼ of the ladder prior to entering the trap. Vella et al. (1999) demonstrated that Pacific lamprey have difficulty negotiating the Bonneville Dam fish ladders. This phenomenon may be related to size, thus skewing the length composition of Pacific lamprey that were collected in the trap. Alternatively, the Pacific lamprey collected at Willamette Falls may be biased toward smaller fish as a result of collecting fish by hand or because collections were generally made 1 to 2 hours prior to sunrise, which may not coincide with movements of larger fish.

There appears to be some temporal variation the degree of homing. Less Pacific lamprey were classified as undetermined from early releases than from later releases (Figure 5). Perhaps there is a greater urge to migrate earlier in the year or increasing water temperatures may effect migration (M. Moser, NMFS Personal Communication). Beamish (1980), stated that "the lamprey apparently remain in the uppermost region of the stream or in a small lake until they spawn in mid-June". Columbia River origin Pacific lamprey demonstrated better homing from early releases and Willamette origin fish were more prone to stray throughout the releases.

The duration of time that we were able to track radio tagged individuals averaged 108 days (standard error = 13.0, range 0 to 254 days, median 143 days). There was no significant difference ($p=0.620$) in tracking duration between collections made in the Columbia River and those from the Willamette River. Fish length was not well correlated with tracking duration (Pearson product moment coefficient of correlation = 0.191) suggesting that the tags did not affect fish's final classification location.

Using ANOVA, we found that the final location determination did significantly ($p<0.001$) effected by the duration of radio tag detection. This effect was entirely due to the undetermined classification having significantly ($p<0.001$) lower duration than the fish that strayed or homed. It should be noted though that some of the tagged fish that were classified as undetermined were detected for over 130 days (Figure 6). In addition, a few instrumented fish that homed and strayed did so in a very short (2 - 5 days) period of time.

We tracked four individuals continuously for approximately 24 h. All four Pacific lamprey were released near Sand Island at 2115 hours on 22 June 1998: two fish with codes 52 and 54 were collected at Bonneville Dam, and the other two fish with codes 53 and 55 were initially collected at Willamette Falls.

The two Columbia origin fish (52 and 54) moved upstream along the North side of Sand Island and within 15 min from the time of release had traveled approximately 300 m. Number 54 was next located very near, probably attached to, a navigation dolphin close to the Washington shore approximately 400 m from the release point. We continued to detect that Pacific lamprey near the navigation dolphin until 0630 hours on

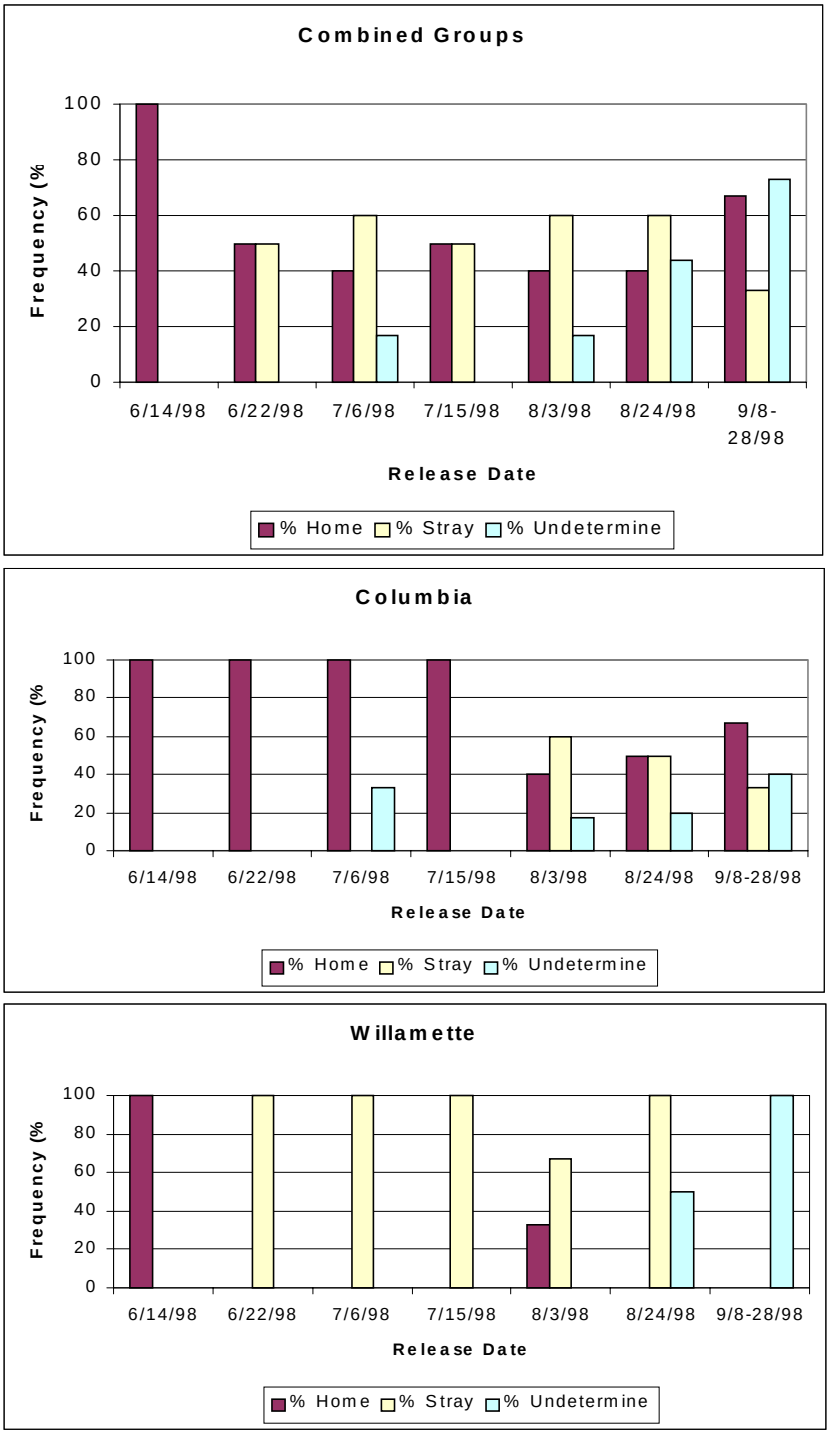

Figure 5. Frequency of final classifications by release date.

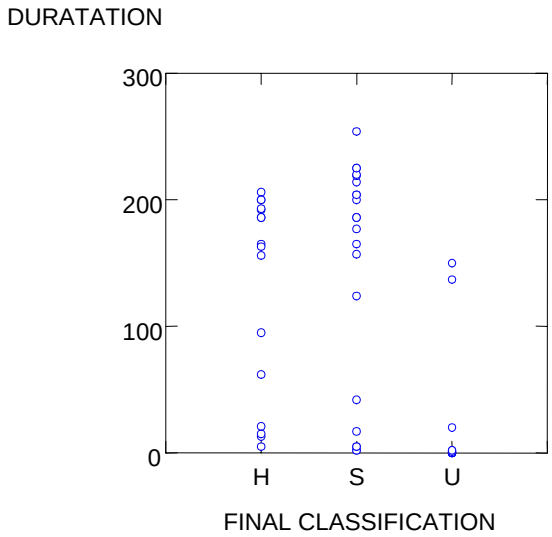

Figure 6. The duration (days) that radio tagged Pacific lamprey were detected as a function of final location. H = Homed, S = Strayed, and U = Undetermined.

23 June 1998. Number 54 was next detected about two weeks later on 7 July 1998 at 1030 hours near the Corbett Boat Ramp at RKM 204 on the Columbia River, approximately 41 km upstream of the confluence of the Willamette River. This was the final relocation for number 54, which was classified as having homed.

Number 52 moved rapidly up the Columbia River. We detected number 52 approximately a dozen times within the first 18 hours of tracking. It traveled directly up the Columbia River at a rate of 2.4 km/h for the first 4 hours and then 3.1 km/h over the next 13 hours. This fish swam at these very fast rates during both nighttime and daytime periods. At the end of our 24 hour continuous tracking period, number 52 was last detected at RKM 185 near Government Island on the Columbia River at 1625 hours on 23 June 1998. It had navigated 48 km in approximately 19 hours (2.5 km/h). In comparison, Bjornn et al. (1995) reported median travel rates for adult summer chinook salmon (Oncorhynchus tshawytscha) in river reaches between 0.42 and 1.24 km/h. Number 52 was next detected near the Corbett Boat Ramp (RKM 204) on 7 July 1998 and then near Beacon Rock (RKM 227) on 19 August 1998. This fish remained near Beacon Rock from 19 August 1998 until it was last detected on 1 January 1999.

The two Willamette origin Pacific lamprey (53 and 55) moved rapidly upstream following their release at 2115 hours on 22 June, 1998. Two hours after release, Number 53 was located approximately 4 km from the release point and Number 55 was located approximately 5 km from the release point. At 1305 hours on 23 June 1998, approximately 18 hours after release, Number 53 was located near the Portland International Airport (RKM 177), and its travel rate was 2.5 km/h. In later tracking efforts, Number 53 was detected at RKM 208 on 9 July 1998 and then at RKM 212 on 20 July 1998. Number 53 remained at RKM 212 near Cape Horn on the Columbia until 28 January 1999 and was classified as having strayed.

Number 55 moved up the Columbia River very rapidly, and was detected at RKM 181 near the I 205 bridge at 1335 hours on 23 June 1998. The travel rate for Number 55 in the first 18 hours following release was 2.4 km/h. Number 55 was classified as having strayed.

All of the Pacific lamprey that we continuously tracked were shoreline orientated. They stayed approximately 100 to 150 meters from the bank and generally were in water less than 10 meters deep. During continuous tracking, Number 55 left the Oregon bank, crossed the mid-channel and then continued upstream, approximately 150 meters off the Washington shore. This fish apparently was traveling near the bottom when it crossed the river, since we lost it's signal for a few minutes and then reacquired the signal as the water depth decreased close to the Washington shore. A photophobic response has been observed in upstream migrants of several lamprey species (Hardisty and Potter 1971). Kan (1975) speculated that this response might be true for Pacific lamprey based on observations in fishways where prespawning fish were seen attaching to the shaded side of fishway walls. Based on our telemetry observations, we would conclude that during upstream migrations in the lower Columbia River, adults readily moved during daytime and nighttime periods and didn't seem to exhibit any photophobic response. However, this may be more related to water quality

conditions in the lower Columbia River than to phototaxis. Kan (1975) estimated migration time as 4.5 km/day for Pacific lamprey in Clear Creek, a tributary to the John Day River. Our telemetry observations illustrate that although considered weak swimmers (Beamish 1974), Pacific lamprey are capable of traveling at velocities near 2.5 km/hour and sustaining that activity for at least 24 hours.

We observed that some radio tagged Pacific lamprey progressed directly to an upstream location while others would move upstream and then backtrack. Some fish that backtrack would once again continue upstream and others held their position or continued downstream. Directionality of movements was not associated with capture location or final classification (Figure 7).

Besides the movements of instrumented Pacific lamprey that were tracked continuously for 24 h, other fish exhibited some very interesting movements that were captured in traces based on relocations. We will discuss a few of the most interesting or unusual examples, but traces from all radio tagged individuals are presented in Appendix (A).

Pacific lamprey number 77 was captured at Willamette Falls and was released near St. Helens, OR on 3 August 1998. At 0400 hours on 5 August 1998, number 77 was detected via mobile tracking in the Willamette River approximately 400 meters from the confluence. At 1344 hours on the same day this fish was detected in the Willamette River approximately 2.5 km from the confluence. The next relocation was on 11 August 1998, in the Columbia River near the Portland International Airport (RKM 177) approximately 17 km from the last relocation. This fish was detected five more times in the general area of the airport, with the last relocation occurring on 14 September 1998. This is the only fish that was observed to first progress upstream in the river that it was first captured in and then backtrack and stray into the other river.

Pacific lamprey number 79 was captured at Willamette Falls and released near St. Helens, OR (RKM 137) on 3 August 1998. On 5 August 1998, number 79 was detected in the Columbia River approximately 1 km downstream of the confluence of the Willamette (RKM 161). Twenty days later on 25 August this fish was detected slightly downstream of the release site (RKM 136). This fish was detected four more times in the vicinity of the release site, the last relocation occurred on 14 October 1998. Number 79 was not heard again until 19 February 1999, when it was detected in the East Fork of the Lewis River (RKM 20).

Pacific lamprey number 64 was captured at Bonneville Dam and released near St. Helens, OR (RKM 137) on 15 July 1998. On 18 July 1998, this fish was detected by the University of Idaho receivers entering the fish ladder at Bonneville Dam (RKM 233) and then was recorded during our mobile tracking on 20 July 1998 near Multnomah Falls (RKM 219).

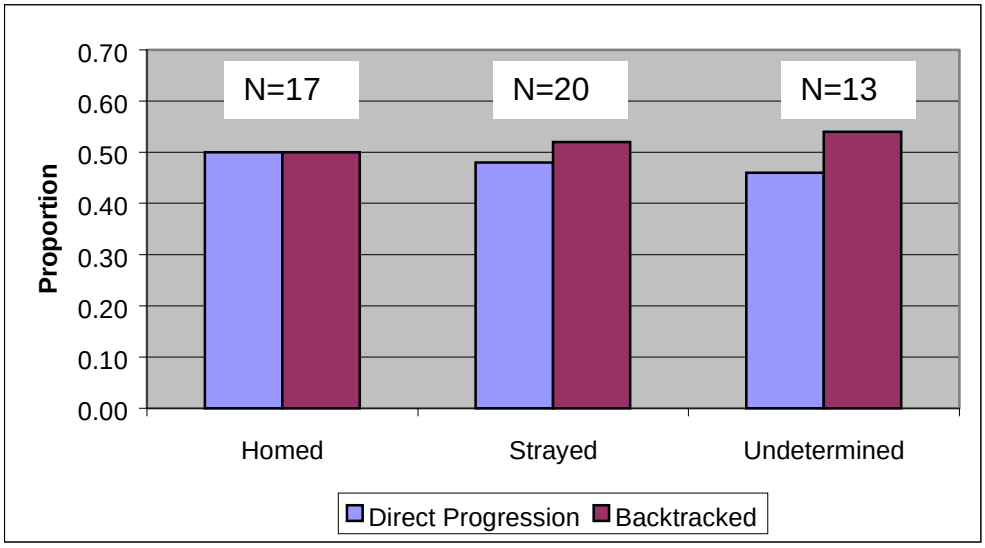

Figure 7. The proportion of radio tagged Pacific lamprey that were observed to progress directly upstream and those that backtracked by final classification.

Abundance and Passage Trends

Monthly fish ladder passage counts at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, Rock Island, Rocky Reach and Wells dams for 1999 are presented in Table (2). Counts from the lower Columbia River projects, Bonneville through McNary dams, were based on 16 h counts. Counts from all other projects were based on 24 h enumeration.

In general Pacific lamprey counts were lower in 1999 compared to 1998 (Table 3) at the mainstem dams, particularly at the upper-most projects in the Snake and Columbia rivers. Fish ladder counts were lower in 1999 compared to 1998 at 7 dams, higher at 2 dams, and unchanged at Bonneville Dam. The Dalles Dam showed the only marked increase from 1998 (26%).

To investigate passage trends at Bonneville, Ice Harbor, Rock Island, Rocky Reach, and Wells dams, we used least squares linear regression analysis. All trends were weakly negative however, the relationships were all also very weak as evidenced by low coefficient of correlation ($R^{2)}$ values (Table 3).

Based on USACOE fish ladder passage estimates in 1999 there appears to be a 72% drop in Pacific lamprey abundance between Bonneville and The Dalles dams. This compares to an 80% drop in 1998 and is compatible with radiotelemetry studies that reported a 66% drop in abundance (Vella and Stuehrenberg 1997).

Data generated from fish ladder counts of Pacific lamprey have many inherent shortcomings due to the physical conditions at the ladders and the behavior of lamprey (Jackson et al. 1997). Given these limitations, the data support the contention that the upstream migration of Pacific lamprey is severely impacted by hydroelectric projects. Preliminary investigations correlating Pacific lamprey swimming ability and water velocity in fish ladder weir orifices revealed that lamprey had extreme difficulty negotiating the orifices (T. Bjornn Personal Communication). Additionally, these data indicated that Pacific lamprey preferred to migrate through the orifices instead of over the weir crests. Research needs to be directed toward further assessing these impacts.

Table 2. Estimated total adult Pacific lamprey passage by month at Columbia and Snake river dams in 1999. Counts for Lower Granite and Ice Harbor are based on 24 h observation, all other counts are based in general on 16 h observation periods.

	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Rock Island	Rocky Reach	Wells
January											
February											
March											
April	65	0	0	0	0	0	0	0	0	0	0
May	4780	23	0	2	3	0	0	0	0	0	1
June	8801	651	130	4	2	2	2	0	0	0	1
July	12047	3819	1277	145	39	10	5	0	8	4	4
August	7584	4301	4668	552	183	49	64	43	211	123	12
September	3717	1473	3173	309	123	14	9	11	300	166	50
October	302	148	525	62	15	1	1	-1	40	15	5
November	0	0	0						0	0	
December											
Total	37296	10415	9773	1074	365	76	81	53	559	308	73

Table 3. Estimated total adult Pacific lamprey passage by year (1995 – 1999) at Columbia and Snake river dams. Counts for Lower Granite and Ice Harbor are based on 24 h observation, all other counts are based in general on 16 h observation periods.

	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Rock Island	Rocky Reach	Wells
1995	85736				680			264	111		362
1996	-37127				1154			639	2121	593	979
1997	22830	14835	14845	4213	1454	217	245	1274	2321	1405	773
1998	37478	7665	12579	3393	763	69	90	110	1410	819	
1999	37296	10415	9773	1074	365	76	81	53	559	308	73
R^2	0.0064				0.1441			0.0886	0.0009	0.0736	0.2349

Summary

1. An in-season homing experiment using radiotelemetry was conducted on 50 Pacific lamprey in the lower Columbia River in 1998-99.

2. Radiotelemetry results indicated that Pacific lamprey may have low in-season homing fidelity.

3. Using fish ladder passage counts as an index of Pacific lamprey abundance, we documented a large reduction in population size from 1995 to 1999 for the Columbia River Basin. Counts have declined from 100's of thousands forty years ago to a few tens of thousands of fish currently.

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CHAPTER EIGHT

Planning of Columbia Basin Pacific Lamprey Projects and Needs

By

Columbia Basin Pacific Lamprey Technical Work Group

Background

Severely declining Pacific lamprey populations throughout the Columbia River Basin has recently elevated the interest and concern of various entities. The tribes have expressed the most concern due to the cultural significance and lost traditional fishing opportunities.

In 1994, the Northwest Power Planning Council approved the first lamprey project in the Fish and Wildlife Program. The project proposed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), called for research and restoration of Pacific lamprey throughout tribal ceded lands. In 1995, an initial product (Status Report of the Pacific Lamprey in the Columbia River Basin) was completed. Since that time, the CTUIR has continued the lamprey project with efforts directed at mainstem abundance monitoring, NE Oregon tributary population abundance documentation (past and present), development of genetic baseline information, basic migratory behavior, and artificial propagation techniques (capture, transport, holding, spawning). This information has been essential for development of a pilot pacific lamprey restoration plan in the Umatilla Basin. CTUIR hopes the plan, to be completed in 1999, will lead to lamprey restoration in the Umatilla and ultimately other subbasins.

Additional lamprey studies have been proposed for which has created uncertainties regarding what are priority lamprey needs and projects. The NPPC approved FY 99 funding for the ongoing CTUIR project but not others that were proposed, due to these uncertainties and also due to potential project duplication. This document is intended to help clarify the various lamprey project purposes and needs and assist the NPPC in making FY 2000 funding decisions.

Since the initiation of the CTUIR lamprey research and restoration project, a Columbia Basin Pacific lamprey technical work group (Appendix A) has been formed to discuss current issues and findings, coordinate ongoing project efforts, and define future project needs as requested by the NPPC. Numerous state, federal, university, and tribal entities have met approximately twice a year for the last three years. The most recent meeting (entitled “Columbia Basin Pacific Lamprey Workshop”) took place in Mission, Oregon on October 22 and 23, 1998. This report will utilize information resulting from the work groups meetings and information from FY 2000 proposals to discuss all ongoing and proposed Pacific lamprey research and restoration efforts and will identify what are believed to be priority needs.

Brief historical facts

- The Pacific lamprey are native to the Pacific Northwest and are believed to have inhabited most tributaries throughout the Columbia River Basin.
- The overall distribution of Pacific lamprey is from southern California to the Gulf of Alaska and inland to central Idaho.
- Former distribution was likely broader than anadromous salmonids due to the ability of lamprey to cling to rocks and pass around slides or falls.
- Pacific lamprey were and still are highly regarded culturally and religiously by Native American tribes. Former lamprey abundance provided tribal fishing opportunities throughout Columbia River Basin tributaries.

- Significant non-Indian lamprey collection at Willamette Falls for fish food processing in 1913 was documented at 27 tons. Commercial fishermen in the 1940's harvested 40 to 185 tons annually (100,000 to 500,000 adults) at Willamette Falls for use as vitamin oil, protein food for livestock, poultry, and fish meal.

Current status of populations and fisheries

- The current potential distribution of Pacific lamprey in the Columbia River and tributaries extends to Chief Joseph Dam and to Hells Canyon Dam on the Snake River.
- Although adult lamprey counting at mainstem Columbia and Snake River dams is not standardized and was sometimes restricted to certain hours, population trends indicate precipitous declines.

Pacific lamprey counts at Columbia and Snake River dams

Dam	Former counts	1997 counts
Bonneville	350,000 in early 60's	22,830
The Dalles	300,000 in early 60's	14,835
John Day	----	14,845
McNary	25,000 in early 60's	4,213
Ice Harbor	50,000 in early 60's	1,454
Lower Monumental	----	217
Little Goose	----	245
Lower Granite	----	1,274
Rock Island	----	2,321
Rocky Reach	17,500 twice in 60's	1,405
Wells	----	773

- Based on 1997 COE fish ladder passage estimates, there appears to be a 65% drop in Pacific lamprey abundance between Bonneville and The Dalles Dams which suggests a substantial portion of the lamprey run spawn in the following tributaries - Wind, Little White Salmon, White Salmon, Klickitat, and Hood rivers.
- Based on 1997 COE fish ladder passage estimates, there appears to be another large drop (72%) between John Day and McNary Dam counts which suggests that the John Day River may support a run of approximately 10,000 Pacific lamprey. Sampling of juvenile lamprey by CTUIR in NE Oregon streams has shown that the John Day basin has the highest juvenile densities relative to other subbasins.
- In the mid-Columbia, there is approximately a 40% drop in counts between Rock Island and Rocky Reach Dams indicating that a sizable Pacific lamprey population may persist in the Wenatchee River. However, fish counting at Tumwater Dam on the Wenatchee River during most of the last 10 years between May and September have not recorded lamprey movement. The fish could over-winter in the lower river and go upstream prior to salmon counting.

- Passage over the last dams in the Snake and Columbia rivers in 1997 appears to be seriously low. Only 3% of the Pacific lamprey that crossed Bonneville Dam were counted at Lower Granite Dam and approximately 6% crossed Wells Dam.
- Pacific lamprey population declines have reduced, eliminated, or relocated the once widespread tribal fisheries to Willamette Falls on the Willamette River. A small tribal fishery also sometimes occurs at Shears Falls on the Deschutes River, Fifteen Mile Creek and on the Klickitat River.
- ODFW currently issues permits for Indian and non-Indian subsistence and commercial fisheries at Willamette Falls
  - fishing occurs by hand-type methods only on east side of the horseshoe falls area
  - of 55 permits issued in 1997, 17 of those people (about one-half Indian and one-half non-Indian) sold fish for commercial purposes
  - a calculation of catch through buyers records indicated about 28,000 pounds of lamprey were harvested commercially at Willamette Falls in 1997
  - the average, annual commercial harvest since 1990 is 22,000 pounds
  - since recent catch is remaining stable and the fishery is closed over one-half of the falls area, ODFW has determined that current harvest is not a biological problem.

Principle problems impacting populations

Mainstem passage at dams - Similar to anadromous salmonids, hydroelectric dams along the Columbia and Snake rivers also create passage impediments for Pacific lamprey. Recent NMFS studies (funded by COE) utilizing radio telemetry in the lower Columbia River indicates that 40% of adult Pacific lamprey migrating to Bonneville Dam do not move upstream past the fishways. This problem multiplied by several dams is likely the main reason for the severe declines or possibly extirpation of Pacific lamprey in most mid to upper Columbia and Snake river tributaries. Juvenile lamprey outmigrants are also subjected to high mortality rates at hydroelectric projects. Although mortality percentages are not known, it is believed to be higher than salmonids due to lesser swimming ability of lamprey and resultant poor avoidance and increased impingement on bypass screens.

Poor habitat conditions in tributaries - Reduced instream flows in many tributaries has greatly impacted the natural production potential of Pacific lamprey. Dewatering or low flows in late spring and summer impacts adult upstream migration into tributaries. Low flows, poor riparian conditions and resultant high water temperatures have also reduced the quality and quantity of adult spawning and juvenile rearing areas.

Goals

Other than the Tribes, no entity has stated any specific lamprey restoration goals in fisheries management plans. The Wy-Kan-Ush-Mi-Wa-Kish-Wit states the goal: within 25 years, increase lamprey populations to naturally sustainable levels that also support tribal harvest opportunities. The CTUIR is utilizing the Umatilla Basin as a pilot project to test lamprey restoration techniques with the ultimate goal of reestablishing self sustaining natural producing populations which also provide for tribal fishing opportunities at traditional locations within the subbasin.

Ongoing projects

The Columbia Basin Pacific Lamprey Workshop identified the ongoing lamprey projects, sponsors, general tasks, and funding sources (see Table 1).

Proposed projects

The Columbia Basin Pacific Lamprey Workshop also identified information relevant to proposed lamprey projects. This information in addition to that provided in the FY 2000 BPA lamprey proposals is presented in Table 2.

Critical uncertainties/lamprey project needs

Attendees at the Columbia Basin Lamprey Workshop identified the following regarding Columbia Basin Pacific lamprey (all are priorities, no order identified):

1) Estimate upstream migrant abundance at mainstem dams
2) Upstream migration - mainstem passage success
3) Downstream juvenile migration - mainstem passage success
4) Genetic database for population structure
5) Species identification techniques
6) Juvenile and adult life histories - habitat requirements
7) Artificial propagation success - hatchery practices
8) Pilot restoration actions in a tributary with associated M & E

To help assess the need for ongoing and proposed Pacific lamprey projects, a column was added in Tables 1 and 2 indicating which critical uncertainty or need listed above is addressed by each project.

Discussion of proposed project needs and priorities

If we assume that our long-range goal is to rehabilitate the population of Pacific lampreys in the Columbia River basin to self sustaining natural producing populations which also provide for fishing opportunities at traditional locations, the following general actions will need to be implemented:

1. We must identify the numbers and distributions of what we have currently.
2. We must identify the relative importance of factors limiting reproduction, primarily passage through dams (upstream and downstream) and habitat requirements of all life stages.
3. We must develop rehabilitation plans that include methods for collecting, transporting, and culturing Pacific lampreys
4. We must demonstrate rehabilitation is feasible by conducting controlled, designed studies in one stream.
5. We must initiate a long term monitoring program on the numbers of Pacific lampreys entering the Columbia River to assess our success or failure to increase the population.

The project critical uncertainties, I through VIII above, identified at the workshop are the subject of several ongoing and proposed projects. The workshop attendees agreed that all projects have a high priority considering the current status of lamprey populations.

Table 3 was developed to help the NPPC and project reviewers understand Columbia River Pacific lamprey project critical needs and ties to ongoing and proposed projects. There are more critical needs than there are approved projects. Also, one ongoing project listed does not mean it entirely meets the general objective need.
Restoration of Pacific lampreys and fisheries in the Columbia River basin will require a substantial effort in terms of dollars and time. Total restoration of Pacific lampreys is probably closely linked with restoration of salmon populations and all of the complexities of habitat changes both in the rivers and in the ocean. However, if we make a few assumptions about Pacific lamprey populations based on what we know of other species, we can develop plans and implement demonstration projects where individual tributaries to the Columbia River could have rehabilitated populations of Pacific Lampreys. At the workshop, there seemed to be a consensus that priorities of future work should be based on both the information needs for large scale rehabilitation and for rehabilitation of lampreys in the Umatilla River. Conducting studies that will benefit both objectives should be given highest priority. A systematic, logical progression of studies needs to be continued to make the best use of limited research dollars leading to the most complete rehabilitation of Pacific lampreys that we can achieve.

Changes in aquatic habitats in the Columbia River Basin have resulted in declines in populations of several desirable fishes including Pacific lampreys. Because the wellbeing of Pacific lampreys is closely tied to the wellbeing of salmonids in other systems, it follows that if we improve conditions for salmonids in the Columbia River Basin, we will see an increase in the Pacific lamprey populations.

Passage of upstream migrating Pacific lampreys through fishways designed to pass salmonids is one issue that needs to be examined early in our plans. Problems encountered by downstream migrating Pacific lampreys might be similar to problems juvenile salmonids encounter.

This report represents an initial assessment at what needs to be done concerning Pacific lampreys to facilitate their rehabilitation. As we conduct studies and learn more about lampreys in the Columbia River, we will likely need to modify our approach. Having a workshop periodically should allow that to happen. Having a meeting of researchers and others working on Pacific lampreys on an every other year schedule would keep the planning and evaluation process in an efficient mode. Producing list such as those in Tables 1, 2 and 3 on an annual basis will provide an index of how much progress we are making. An additional table should be included that lists reports and publications that have been produced since the Pacific lamprey rehabilitation effort was begun. Eventually this information could be set up in a WEB site that would allow frequent updating of lists.

Table 1. Ongoing Columbia Basin Pacific Lamprey projects

Sponsor	Funding	Project title	General project actions	Critical uncertainties and needs addressed
CTUIR/ CRITFC	BPA	Pacific Lamprey Research & Restoration (project #9402600)	· Monitor abundance & passage trends of adult lamprey at Columbia & Snake River dams · Develop a genetic database for determination of lamprey population structure in the Columbia Basin · Investigate adult lamprey homing fidelity back to initial capture sites · Document presence/absence and distribution of lamprey in NE Oregon & SE Washington subbasins · Develop pilot lamprey restoration plan for Umatilla subbasin · Begin initial restoration plan actions: 1) trap adults from John Day river; 2) evaluate lamprey hatchery practices while holding adults at USGS Cook, WA lab; 3) spawn adults, incubate eggs, rear & outplant prolarvea in Umatilla River; 4) monitor Umatilla River for juvenile survival and growth; 5) monitor lamprey migratory pheromone in water samples from the Umatilla & John Day rivers to better understand adult lamprey attraction into tributaries.	· Adult abundance monitoring · Adult homing behavior · Genetic database · Life histories & habitat req. · Hatchery practices · Pilot restoration actions - · M & E
NMFS/ U of Idaho	COE	Radio Telemetry of Adult Pacific Lamprey in the Lower Columbia River	· Evaluate passage of radio tagged adults below and at Bonneville Dam · Conduct laboratory evaluations of upstream movement through various augmented adult fishway structures	Adult upstream migration success
USGS CRRL	COE	Characteristics of Upstream Migration of Pacific Lamprey in the Columbia River	Evaluate adult maturation & physiology of adult lamprey collected at Bonneville Dam	Adult upstream migration success Life histories
USGS CRRL	COE	Effects of Swimming & Exhaustive Stress in Pacific Lamprey: Implications for	Evaluate swimming performance, metabolic condition, and exhaustive stress to assess efficacy of current upstream fish passage facilities at	Adult upstream migration success

Sponsor	Funding	Project title	General project actions	Critical uncertainties and needs addressed
		Upstream Migration Past Dams	Bonneville Dam.	
USGS CRRL	USFWS	Evaluation of Tagging Techniques for Pacific Lamprey Ammocoetes & Macropthalmia	Evaluate effectiveness (tag retention & animal survival) of visible implant (V1) & PIT tags in juvenile lamprey.	Juvenile downstream migration success
USGS CRRL	USFWS	Validation of Statolith - based aging Techniques for Pacific Lamprey Ammocoetes & Macropthalmia	Validate statolith-based aging techniques in laboratory & compare results to wild lamprey samples.	Life histories
U of Idaho	Misc	Genetic Analysis Pacific Lamprey	Receive tissue samples and conduct genetic analysis (generally a subcontractor under other studies)	Genetic database

Table 2. Proposed Columbia Basin Pacific Lamprey projects

Sponsor	Funding	Project title	General project actions	Critical uncertainties and needs addressed
IDFG	BPA	Evaluate Status of Lamprey in Clearwater River (#20019)	· Determine life history characteristics · Determine habitat requirements · Determine juv. & adult distribution · Develop & implement strategies to minimize impacts to habitat	Life histories & habitat req.
USFWS	BPA	Evaluate Habitat Use and Population Dynamics of Lamprey in Cedar Creek (#20121)	· Estimate adult abundance & determine migration timing · Determine larval lamprey distribution & habitat use · Determine outmigrant timing & abundance · Eval. homing fidelity, surv. rates & ocean residence with CWT's · Rear ammocoetes to verify species identifications · Evaluate effects of PIT tagging juveniles in lab · Evaluate adult spawning habitat requirements · Sample & cap redds to determine egg & larvae survival & developmental timing	· Life histories & habitat req. · Adult homing behavior · Species indentification · Juv. tagging/migration success
USGS CRRL	BPA	Identification of larval Pacific lampreys, river lampreys, and western brook lampreys and thermal requirements of early life history stages of lampreys. (#20065)	· Spawn three species in captivity & determine diagnostic characteristics of each · Collect ammocoetes and hold through metamorphosis to verify identification techniques · Evaluate temperature effects on the survival and early development of three species	· Species identification · Life histories & habitat req.
USGS CRRL	BPA	Upstream migration of Pacific lampreys in the John Day River: behavior, timing, and habitat preferences (#20064)	· Trap adults and use radio telemetry to determine lamprey movement to spawning · Describe overwintering & spawning habitat of radio tagged fish	· Adult upstream migration success · Life histories & habitat req.
Battelle PNNL	COE	Evaluate juvenile lamprey passage at John	Assess juvenile lamprey impingement and injury during screening/bypass and turbine passage	Juvenile downstream migration success

		Day Dam		

Table 3. Critical uncertainties, goals and objectives for Columbia Basin Pacific Lamprey projects

Critical questions/uncertainties	Goal statement	General objectives	Applicable projects[1/]
I. Current abundance	A. Annually determine numbers & distribution of current populations	1. Coordinate with entities conducting salmonid counts at mainstem dams to expand counts for adult lamprey abundance 2. Estimate upstream migrant abundance in major tributaries 3. Survey ammocoete populations in major tributaries and mainstem 4. Analyze population trends and distribution and develop a long term monitoring program to assess restoration success	O: 9402600 much more needed O:9402600 P: 20121 O: 94002600 P: 20019 P: 20121 Needed
II. Upstream migration - passage success.	A. Provide for safe adult passage at mainstem dams	1. Evaluate passage of radio tagged adults in mainstem 2. Conduct laboratory evaluations of upstream movement through various augmented adult fishway structures 3. Evaluate swimming performance, metabolic condition, and exhaustive stress to assess efficacy of current upstream fish passage facilities 4. Identify upstream passage impediments at mainstem dams 5. Determine what devices or operational procedures will allow adult migration through dams without excessive mortality 6. Implement appropriate passage improvements at mainstem dams	O: U of I - COE O: U of I - COE O: USGS - COE O: U of I - COE more needed O: U of I - COE more needed Needed
	B. Provide for safe adult passage in major tributaries	1. Identify upstream passage impediments in major tributaries 2. Determine solutions for passage impediments 3. Implement passage improvements in major tributaries	O: 9402600 (Umatilla) Needed

Critical questions/uncertainties	Goal statement	General objectives	Applicable projects[1/]
III. Downstream migration - passage success	A. Provide for safe juvenile passage at mainstem dams	1. Evaluate effectiveness of various tag types in juvenile lamprey 2. Identify downstream passage impediments at ainstem dams 3. Determine what devices or operational procedures will allow juvenile migration through dams without excessive mortality 4. Implement appropriate passage improvements at mainstem dams	P: 20121 O: USGS - USFWS P: Battelle - COE (John Day Dam) Needed Needed
	B. Provide for safe juvenile passage in major tributaries.	1. Identify downstream passage impediments in major tributaries 2. Determine solutions for passage impediments 3. Implement passage improvements in major tributaries	Needed Needed Needed
IV. Genetic population structure	A. Develop understanding of Columbia Basin Pacific lamprey population structure.	1. Develop a genetic database for determination of lamprey population structure	O: 9402600
V. Lamprey species identification techniques.	A. Develop species identification techniques for larval lamprey (Pacific, river and western brook).	1. Spawn and hold each lamprey species in captivity through metamorphosis to verify identification techniques	P: 20065
VI. Life history, behavior and habitat requirements	A. Gain understanding of adult migration/homing behavior.	1. Determine general migration behavior through radio tagging and genetic assessment techniques 2. Investigate adult migration attractant potential of pheromones emitted by larvae 3. Conduct large scale CWT or PIT tag homing/ocean survival study.	O: 9402600 O: 9402600 Needed?
	B. Gain understanding of life history and habitat requirements for adult lamprey.	1. Evaluate adult migration and holding & spawning habitat requirements 2. Sample and cap redds to determine egg & larvae survival & developmental timing	P: 20064 P: 20121 P: 20121

Critical questions/uncertainties	Goal statement	General objectives	Applicable projects[1/]
	C. Gain understanding of life history and habitat requirements for larval lampreys.	1. Validate statolith-based aging techniques 2. Evaluate effectiveness of various tag types in juveniles 3. Sample various tributaries to determine larvae distribution, life history characteristics, and habitat requirements 4. Sample juvenile outmigration in tributaries to determine timing and abundance	O: USGS - USFWS O: 9402600
			P: 20121 O: USGS - USFWS
			O: 9402600 P: 20121 P: 20019
			O: 9402600
VII. Artificial propagation and transplantation techniques & success	A. Develop transplantation and artificial propagation techniques for lamprey restoration in tributaries	1. Evaluate capture and transport techniques of adults from donor site to hatchery or recipient stream 2. Evaluate hatchery practices for adult holding, spawning, and early rearing of pro larvae	O: 9402600
			O: 9402600 P: 20065
VIII. Success of tributary restoration actions	A. Develop successful lamprey reintroduction/ restoration techniques for tributary application	1. Develop pilot restoration plan for Umatilla subbasin 2. Implement and monitor pilot restoration actions in Umatilla subbasin	O: 9402600
			O: 9402600

1/ P = proposed; O = ongoing; for BPA funded projects, the project number is given; for non BPA funded projects, the sponsor precedes the funding source.

LIST OF APPENDICES

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Appendix 1. Observed variation at 34 protein coding loci among samples of Pacific Lamprey.

Chapter 7:
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Appendix 4. Draft Guidelines for Pacific Lamprey Transplantation and/or Artificial Propagation Actions funded under the Columbia Basin Fish and Wildlife Program.

Appendix 1. Observed variation at 34 protein coding loci among samples of Pacific Lamprey.

Location Number	Location	n	ADH	SORDH	LDH	MDH-1	MDH-2	ME-1
3	Chehalis River, WA	50	M	M	M	M	n.o.	M
4	Deschutes River, OR	38	M	M	M	M	n.o.	M
5	Fifteen Mile Creek, OR	56	M	M	M	M	n.o.	M
7	John Day River, OR (Camas Cr.)	20	M	M	1/20	M	n.o.	M
8	John Day River, OR	15	M	M	2/15	M	n.o.	M
9	John Day River, OR RM 35.9	20	M	M	M	M	n.o.	M
10	John Day River, OR RM 59.2	30	M	M	M	M	n.o.	M
11	Lower Granite Dam	56	M	M	M	M	n.o.	M
12	Milton Creek, OR	54	M	M	M	M	n.o.	M
13	Red River, ID	22	M	M	1/22	M	n.o.	M
14	Sherars Falls, OR	37	M	M	M	1/37	n.o.	M
15	Shitake Creek, OR	25	M	M	M	M	n.o.	M
16	Willamette Falls, OR	55	M	M	M	M	n.o.	M
18	Willamette River, OR	39	M	M	M	M	n.o.	M

Location Number	Location	n	ME-2	IDHP-1	IDHP-2	PGD	GAPDH-1	GAPDH-2
3	Chehalis River, WA	50	M	M	M	M	M	n.o.
4	Deschutes River, OR	38	M	M	M	M	M	n.o.
5	Fifteen Mile Creek, OR	56	M	M	M	M	M	n.o.
7	John Day River, OR (Camas Cr.)	20	M	M	M	M	M	n.o.
8	John Day River, OR	15	M	M	M	M	M	n.o.
9	John Day River, OR RM 35.9	20	M	M	M	M	M	n.o.
10	John Day River, OR RM 59.2	30	M	M	M	M	M	n.o.
11	Lower Granite Dam	56	M	M	M	M	M	n.o.
12	Milton Creek, OR	54	M	M	M	M	M	n.o.
13	Red River, ID	22	M	M	M	M	M	n.o.
14	Sherars Falls, OR	37	M	M	M	M	M	n.o.
15	Shitake Creek, OR	25	M	2/25	M	M	M	n.o.
16	Willamette Falls, OR	55	M	M	M	M	M	n.o.
18	Willamette River, OR	39	M	M	M	M	M	n.o.

Location Number	Location	n	SOD-1	SOD-2	PNP	AAT-1	AAT-2	PK
3	Chehalis River, WA	50	M	n.o.	M	M	M	M
4	Deschutes River, OR	38	M	n.o.	M	M	M	M
5	Fifteen Mile Creek, OR	56	M	n.o.	M	M	M	M
7	John Day River, OR (Camas Cr.)	20	M	n.o.	M	M	M	M
8	John Day River, OR	15	M	n.o.	M	M	M	M
9	John Day River, OR RM 35.9	20	M	n.o.	M	M	M	M
10	John Day River, OR RM 59.2	30	M	n.o.	M	M	M	M
11	Lower Granite Dam	56	M	n.o.	M	M	M	M
12	Milton Creek, OR	54	M	n.o.	M	M	M	M
13	Red River, ID	22	M	n.o.	M	M	M	M
14	Sherars Falls, OR	37	M	n.o.	M	M	M	M
15	Shitake Creek, OR	25	M	n.o.	M	M	M	M
16	Willamette Falls, OR	55	M	n.o.	M	M	M	M

18	Willamette River, OR	39	M	n.o.	M	M	M	M

Location Number	Location	n	PGK	CK	AK-1	AK-2	EST-D	PEP-1
3	Chehalis River, WA	50	M	M	M	n.o.	M	M
4	Deschutes River, OR	38	M	M	M	n.o.	M	M
5	Fifteen Mile Creek, OR	56	M	M	M	n.o.	M	M
7	John Day River, OR (Camas Cr.)	20	M	M	M	n.o.	M	M
8	John Day River, OR	15	M	M	M	n.o.	M	M
9	John Day River, OR RM 35.9	20	M	M	M	n.o.	M	M
10	John Day River, OR RM 59.2	30	M	M	M	n.o.	M	M
11	Lower Granite Dam	56	M	M	M	n.o.	M	M
12	Milton Creek, OR	54	M	M	M	n.o.	M	M
13	Red River, ID	22	M	M	M	n.o.	M	M
14	Sherars Falls, OR	37	M	M	M	n.o.	M	M
15	Shitake Creek, OR	25	M	M	M	n.o.	M	M
16	Willamette Falls, OR	55	M	M	M	n.o.	M	M
18	Willamette River, OR	39	M	M	M	n.o.	M	M

Location Number	Location	n	PEP-2	ADA-1	ADA-2	ALD	ACO	MPI
3	Chehalis River, WA	50	M	M	M	M	M	M
4	Deschutes River, OR	38	M	M	M	M	M	M
5	Fifteen Mile Creek, OR	56	M	M	M	M	M	M
7	John Day River, OR (Camas Cr.)	20	M	M	M	M	M	M
8	John Day River, OR	15	M	M	M	M	M	M
9	John Day River, OR RM 35.9	20	M	M	M	M	M	M
10	John Day River, OR RM 59.2	30	M	M	M	M	M	M
11	Lower Granite Dam	56	M	M	M	M	M	M
12	Milton Creek, OR	54	M	M	M	M	M	M
13	Red River, ID	22	M	M	M	M	M	M
14	Sherars Falls, OR	37	M	M	M	M	M	M
15	Shitake Creek, OR	25	M	M	M	M	M	M
16	Willamette Falls, OR	55	M	M	M	M	M	M
18	Willamette River, OR	39	M	M	M	M	M	M

Location Number	Location	n	GPI-1	GPI-2	PGM-1	PGM-2
3	Chehalis River, WA	50	M	M	M	M
4	Deschutes River, OR	38	M	M	M	M
5	Fifteen Mile Creek, OR	56	M	M	M	M
7	John Day River, OR (Camas Cr.)	20	M	M	M	M
8	John Day River, OR	15	M	M	M	M
9	John Day River, OR RM 35.9	20	M	M	M	M
10	John Day River, OR RM 59.2	30	M	M	M	M
11	Lower Granite Dam	56	M	M	M	M
12	Milton Creek, OR	54	M	M	M	M
13	Red River, ID	22	M	M	M	M
14	Sherars Falls, OR	37	M	M	M	M

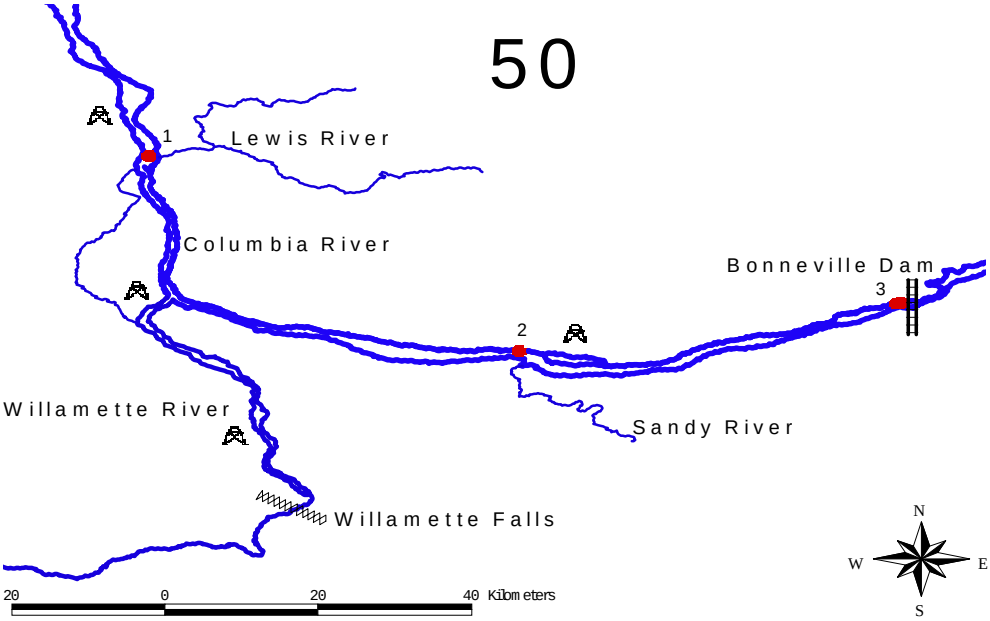
15	Shitake Creek, OR	25	M	M	M	M
16	Willamette Falls, OR	55	M	M	M	M
18	Willamette River, OR	39	M	M	M	M

Appendix 2. Traces of lamprey movement.

Code #	Released	Source	Last known location	Date	Tracking duration (days)	Classified	Results/Comments of individual behavior
50	6/14/98	C	Bonn. - under power lines	11/17/98	156	H	Began climbing Bonneville Ladder 6/14; then was detected below the dam from 7/20 until 11/17.
51	6/14/98	W	broadway bridge	11/24/98	163	H	Moderately convincing data from Staff Jennings suggests that this fish went past SJ on 6/17; and then was detected going back downstream on 6/20-21. This fish was detected near the Broadway bridge between 8/4 and 11/24.
52	6/22/98	C	beacon Rock area mkr. 85	1/1/99	193	H	Upstream migration for approx. one week +; then was detected in Beacon R. area from 7/8 to 1/1/99.
53	6/22/98	W	near marker 69 (Cape Horn)	1/28/99	220	S	Upstream migration for approx. one week +; then was detected at Cape Horn area from 7/8 to 1/28/99.
54	6/22/98	C	fishery boat ramp	7/7/98	15	H	
55	6/22/98	W	Bonneville Ladder	6/24/98	2	S	Rapid upstream migration within first 6 hours to I-205 bridge; then, detected ascending bonneville ladder on 6/24 @
56	7/15/98	C	Mt. Herman Creek	7/28/98	13	H	At Bonneville within 2 days of release; then took at least 2.5 hours climbing ladder. Detected at mouth of Herman creek two weeks after release.
57	7/6/98	W	Lewis River (I-5 Br.)	12/10/98	157	S	Detected in Lewis almost two months after release.
58	7/6/98	C	Marker 15 WA side	7/7/98	1	U	Detected at mkr. 15 about 24 hrs. after release
59	7/6/98	W	1/2 mile up from Chinook Landing, WA side mid-channel	2/5/99	214	S	Passed Sauvies receiver about 4 hrs. after release; then detected near Sandy R. area from 7/15 to 2/5
60	7/6/98	C	Bonneville Dam PH1 tailrace	7/27/98	21	H	Passed Sauvies receiver about 27.5 hrs. after release; detected at mkr. About 51 hrs. later. Reached Bonneville tailrace area on 7/27.
61	7/6/98	W	Bradford Island top of ladder	7/11/98	5	S	Tracked for 24 hrs. to area upstream of Reed Is.. At top of Bonn ladder less five days after release.
62	7/6/98	C	300 yds upstream of marker 91	1/28/99	206	H	Passed Sauvies rec. less than 12 hrs. after release. Detected in mkr. 91 area from 7/9 to 1/28.
63	7/15/98	W	1/4 mile up Sandy River from confluence (AT)	2/19/99	219	S	Passed Chinook Landing rec. about 36 hrs. after release. Detected inside mouth of Sandy R. from 8/5 to 2/19.
64	7/15/98	C	Bonneville Ladder	7/20/98	5	H	Tracked to area near Multnomah Falls within 5 days after release.
65	7/15/98	W	Scappoose Bay	1/8/99	177	S	Stayed at release site for at least 4 hours. Was located two weeks later inside Scappoose Bay.
66	9/28/98	C	Release site	9/28/98	0	U	Was detected near release site one hour after release….never detected again.
67	7/15/98	W	1/4 mile downstream from marker (north side, west end of government island)	7/20/98	5	S	Stayed at release site for at least 4 hours. Was located five days later in area of Gov't Is.
68	7/15/98	C	in Sandy R.	11/16/98	124	S	Passed Chinook Landing rec. about 8 days after release; then detected up Sandy R. on 11/16.
69	8/3/98	W	Lewis River	3/16/99	225	S	Not tracked at all; and then discovered in Lewis R. from 8/29 to 3/16.
70	8/3/98	C	small trib to Lewis	3/16/99	225	S	Tracked for 2 hours to 1/4 m. below release site; then detected 1 month later in small trib/creek of Lewis watershed.
71	8/3/98	W	airport, OR side	2/5/99	186	S	Tracked to confluence in about 28 hours. Passed Chinook Landing rec. on 8/14. Detected around PDX from 8/21 to 2/5.

72	8/3/98	C	Chinook Landing	2/19/99	200	H	Tracked to I-5 Bridge about 26 hours after release. Detected in area of chinook landing from 8/12 to 2/19.
73	8/3/98	W	Dolphin Club on Willamette	2/5/99	186	H	About 82 hours from release site to Staff Jennings rec. site. Detected near Lake Oswego from 8/28 to 2/5.
74	8/3/98	C	across fr/ Mult falls WA side	2/19/99	200	H	Detected in Multnomah Falls area from 8/19 to 2/19/99.
75	8/3/98	W	Morrison Bridge, Will.	2/5/99	186	H	Detected near Morrison Bridge in downtown Portland from 8/20 to 11/17. Then, detected at Willamette falls from 11/24 to 2/5/99.
76	8/3/98	C	Columbia City rec. site	8/5/98	2	U	Was logged going past the downstream Col. City receiver about two days after release.
77	8/3/98	W	OR side gov't Is.	9/14/98	42	S	Was tracked into Willamette (about 1 mile upstream fr/ confluence) within two days of release; then showed up six days later all the way up to Gov't Island in the Columbia.
78	8/3/98	C	Staff Jennings rec. site	8/5/98	2	S	Passed Staff Jennings receiver approximately 60 hours after release
79	8/3/98	W	1/4 m. west of release site	2/19/99	200	S	Sauvies receiver indicates it passed about 36 hours after release; then this fish was detected in the Col. City area downstream of release site between 8/25 and 10/14. THEN; aerial tracking picked up this fish up the Lewis on 2/19/99.
80	8/3/98	C	Willamette, Fremont Bridge	2/5/99	186	S	Detected in downtown Portland (near freemont Br.) from 8/25 until 2/5/99.
81	8/24/98	W	Port of Portland	2/5/99	165	S	Tracked to port of pdx docks (just upstream of confluence) inside of Hayden Island channel about one week after release. Detected at this spot until 2/5/99.
82	8/24/98	C	mkr. 35 - Chinook Lnding	2/5/99	165	H	Detected near Chinook Landing from 8/24 to 2/5/99.
83	8/24/98	W	Multnomah Channel	1/8/99	137	U	Tracked into Mult. Channel within first few hours after release. Detected at this same spot until 1/8/99.
84	8/24/98	C	~70 yds.up fr/ release site - WA side	8/24/98	0	U	Tracked for first few hours after release to WA side; then lost it.
85	8/24/98	W	released	8/24/98	0	U	Detected at release site - once.
86	8/24/98	C	Mt. Of Lewis	3/16/99	204	S	Picked up in mouth of Lewis about 10 days after release. Detected in this area until 3/16/99.
87	8/24/98	W	Mult. Channel	3/16/99	204	S	Detected in area around confluence of Scappoose Bay/Multnomah channel from 8/25 to 3/16. Best estimate of exact location is 1/4 m. up into the bay.
88	8/24/98	C	Lewis River	5/5/99	254	S	Detected in are of L. merwin/ water plant of Lewis River from 8/29 to 5/5/99.
89	9/8/98	W	one mile below confluence	2/5/99	150	U	Sauvies receiver logged it on 9/10. Tracked its location to about 1 m. below confluence on 9/16. Detected in this spot until 2/5/99.
90	9/28/98	C	between CW marina and buoy 50	4/8/99	192	H	Detected mid-channel near Camas Washougal about 10 days after release. Detected at this location until 4/8/99.
91	9/8/98	W	1/2 mi below release sitet	9/28/98	20	U	Tracked upstream movement for first 21 hours to Willow Pt. Then, was picked up on 9/11 and 9/28 below release site in Col. City area.
92	8/24/98	C	Bonneville Ladder	10/25/98	62	H	Tracked relatively slow upstream movement for first 48 hours after release to area(s) between warrior rock and willow pt. Then it was in Bonn. Ladder system on 10/22 (@CBO) and again on 10/25 (@7BO#'s).
93	9/8/98	W	1/2 mile up from Warrior Rock	9/8/98	0	U	Tracked near release site for about an hour; then lost it.
94	9/8/98	***W***	Columbia ciy rec.site	9/8/98	0	U	Logged at Col. City receiver about 10 hours after release.
95	9/8/98	W	1/2 mi. down from Willow Point WA side	9/9/98	1	U	Picked up about 24 hours after release at Willow Point. Never got it back.
96	9/28/98	C	Willamette, Fremont Bridge	10/15/98	17	S	Logged at Col. City receiver about 7 hours after release. Then picked up in Willamette near OMSI on 10/7, then slightly downstream at freemont bridge on 10/15.
97	9/28/98	***C***	nw side of sand is.	9/28/98	0	U	Lost it very soon after release.

98	9/8/98	***W***	Columbia City rec. site	9/10/98	2	U	Tracked upstream movement for first 24 hours to Willow Pt. Then, was logged on 9/10 at Col. City receiver.
99	9/28/98	***C***	Mouth of Sandy R.	1/1/99	95	H	Picked up across the river from the Sandy (on WA side) about 10 days after release. Detected in this area until 1/1/99.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Lewis River
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Sandy River
Willamette Falls
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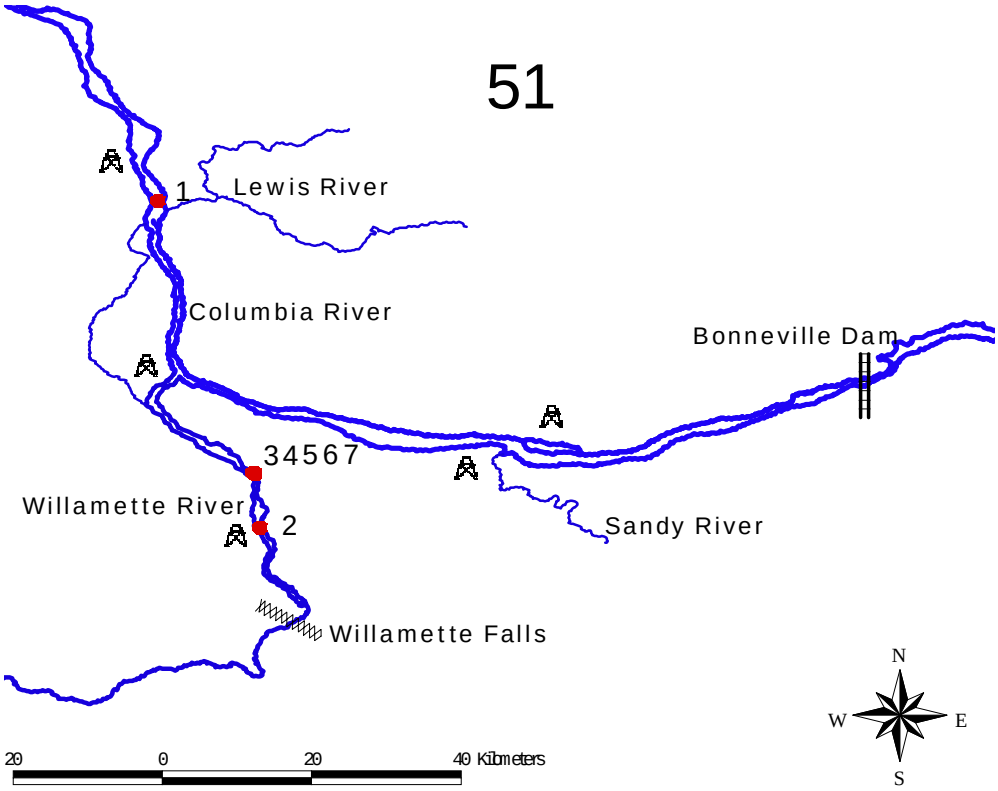
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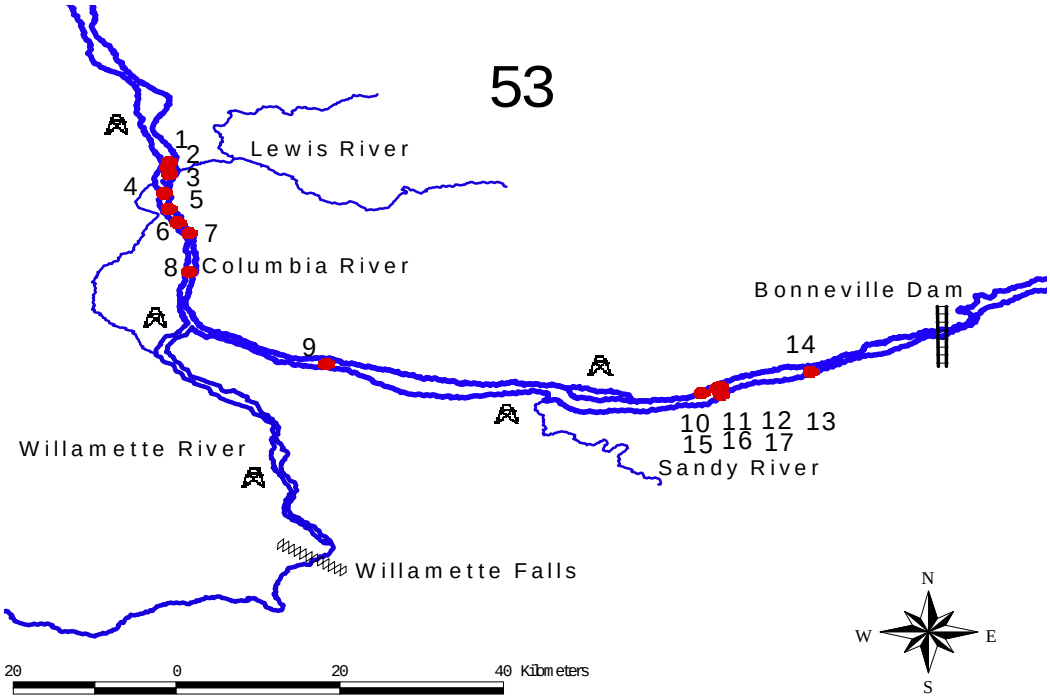
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Lewis River
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Bonneville Dam
Willamette River
Sandy River
Willamette Falls
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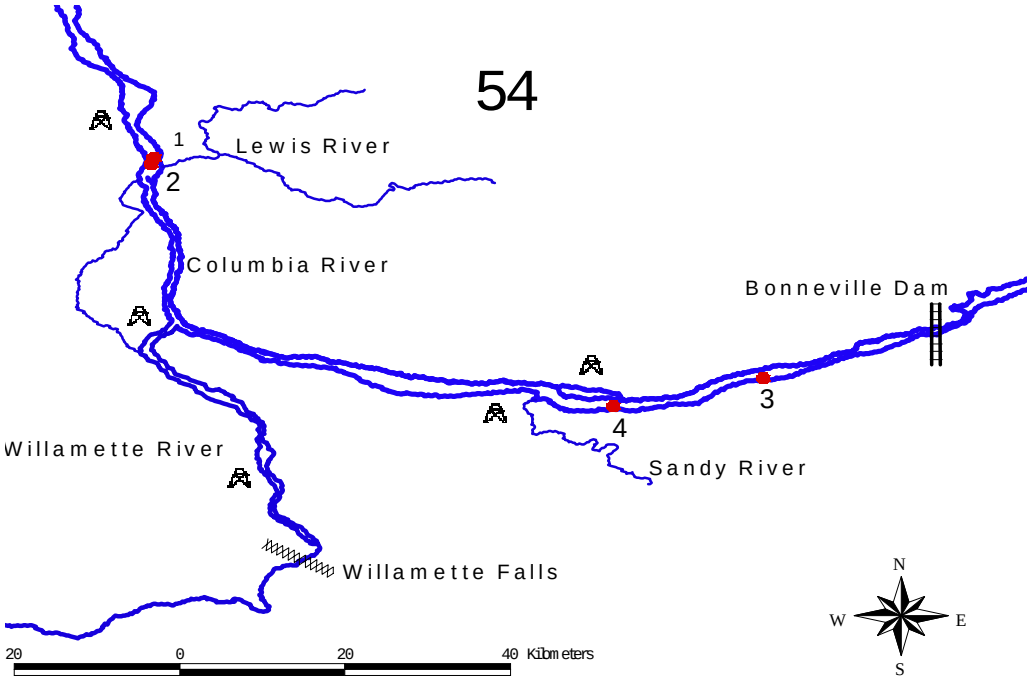
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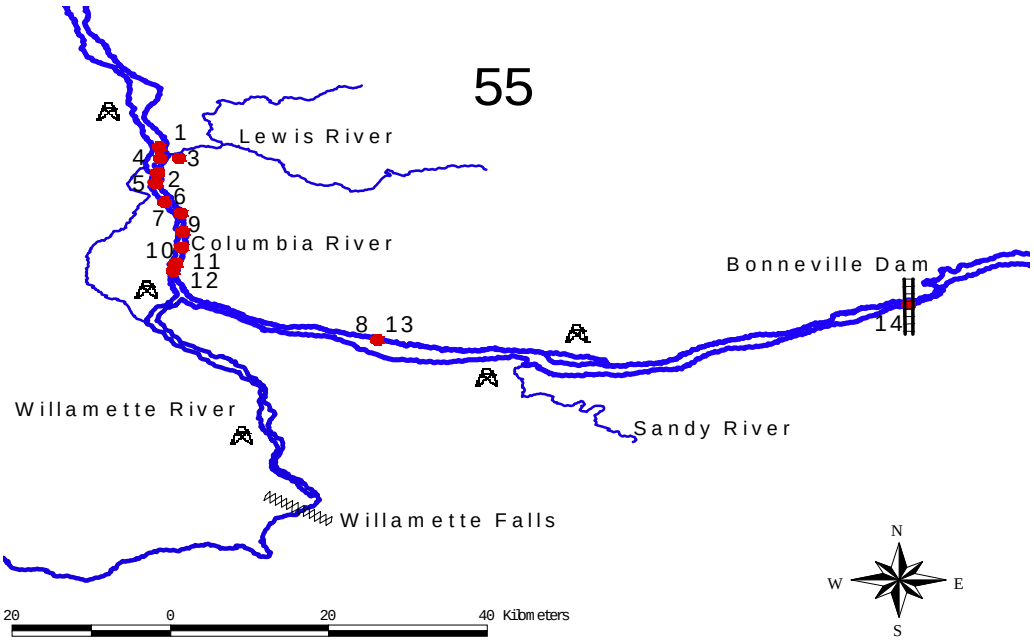
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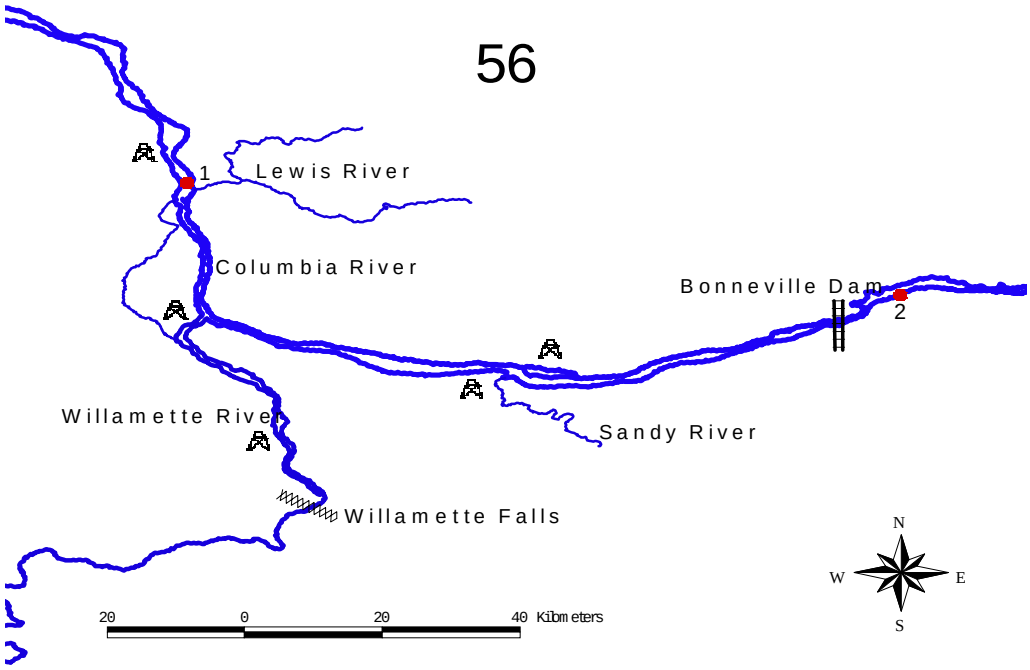
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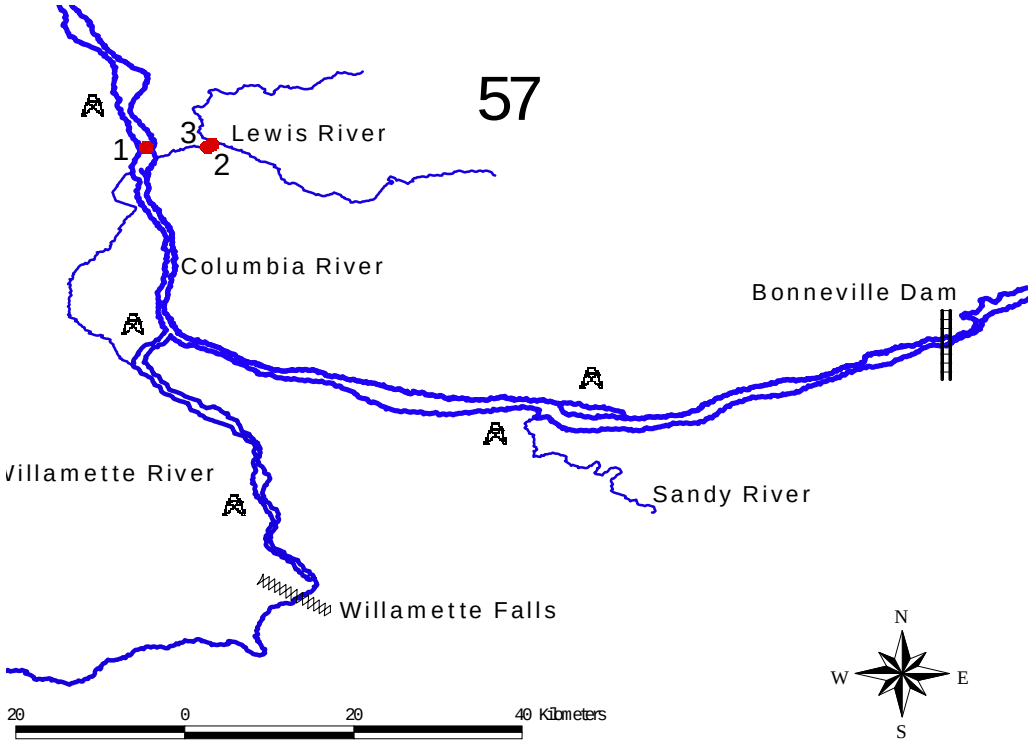
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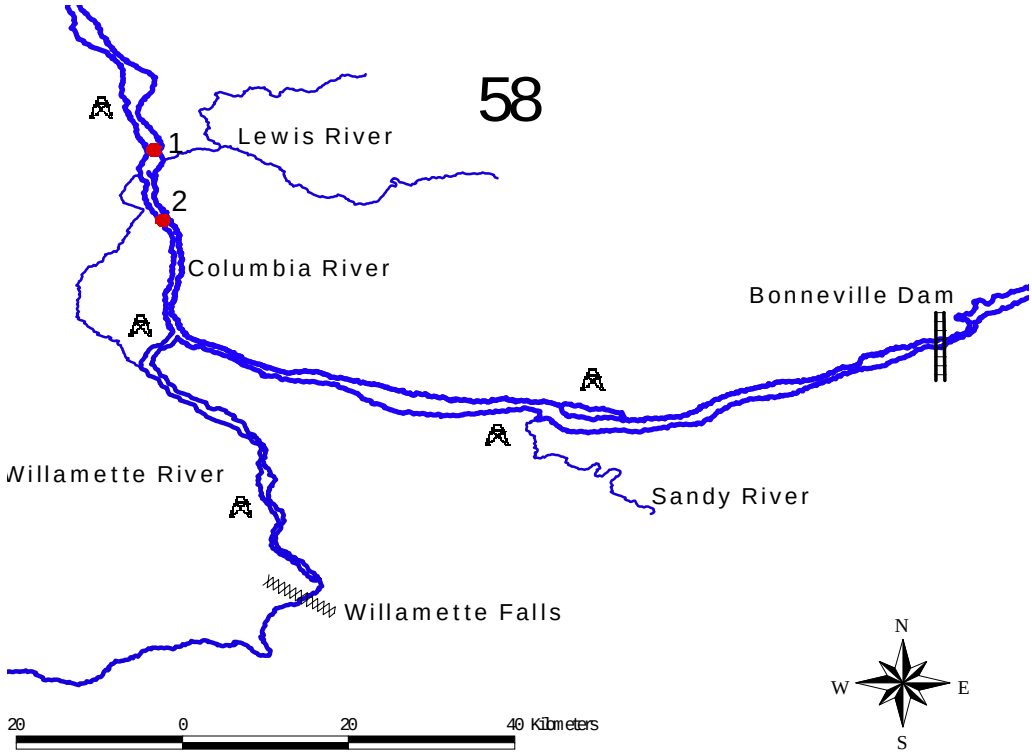
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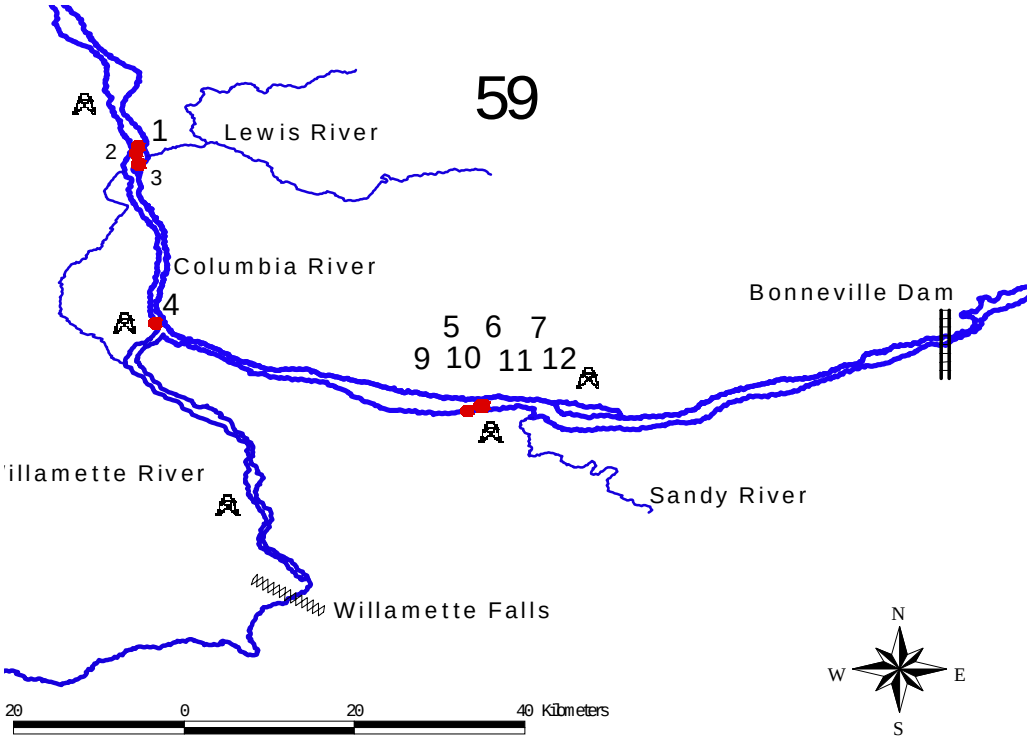
59
Lewis River
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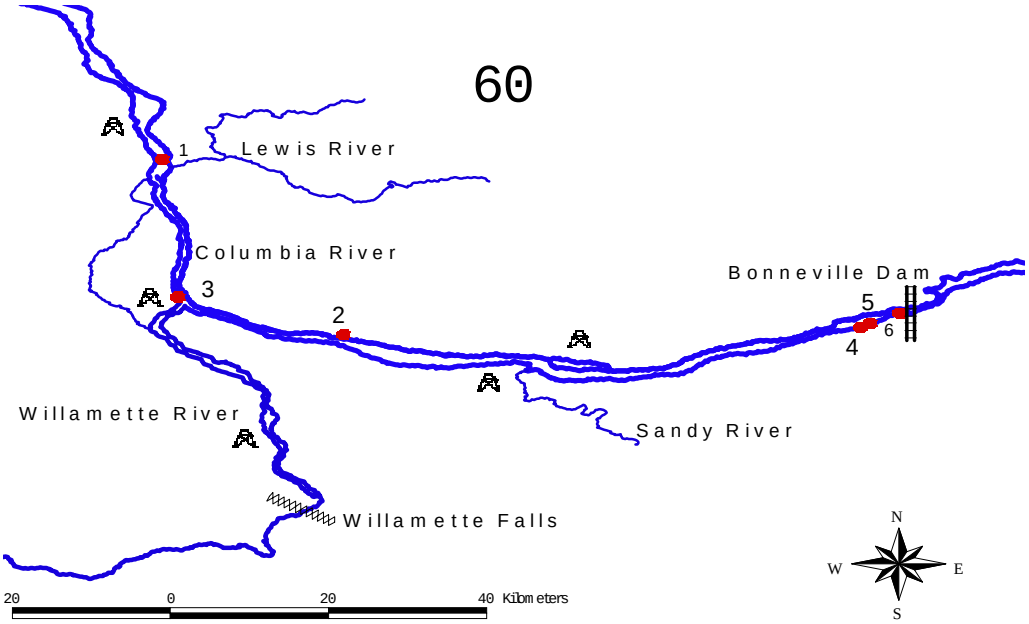
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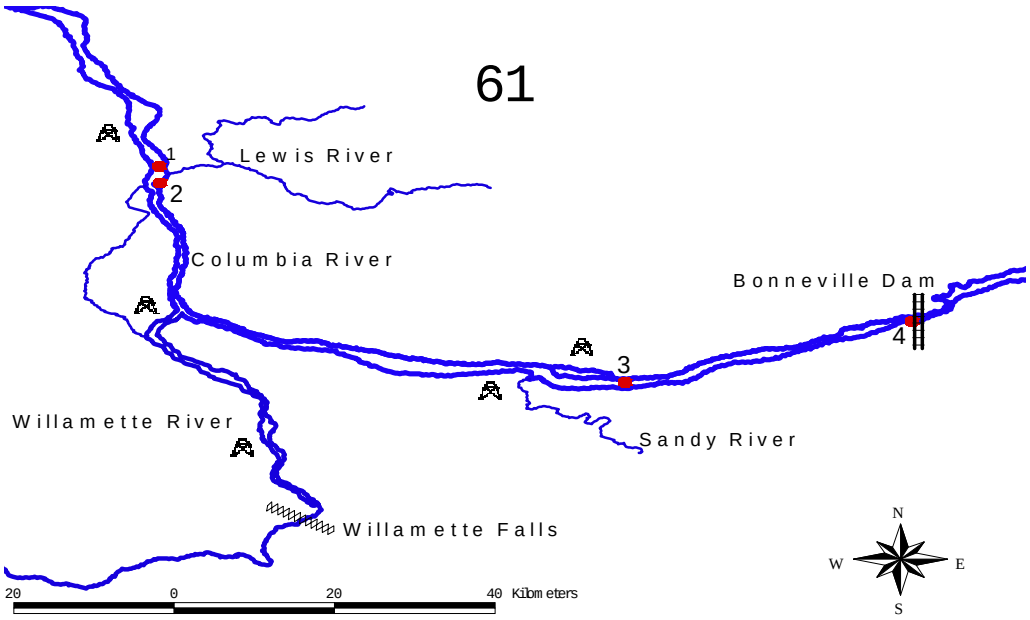
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Willamette Falls
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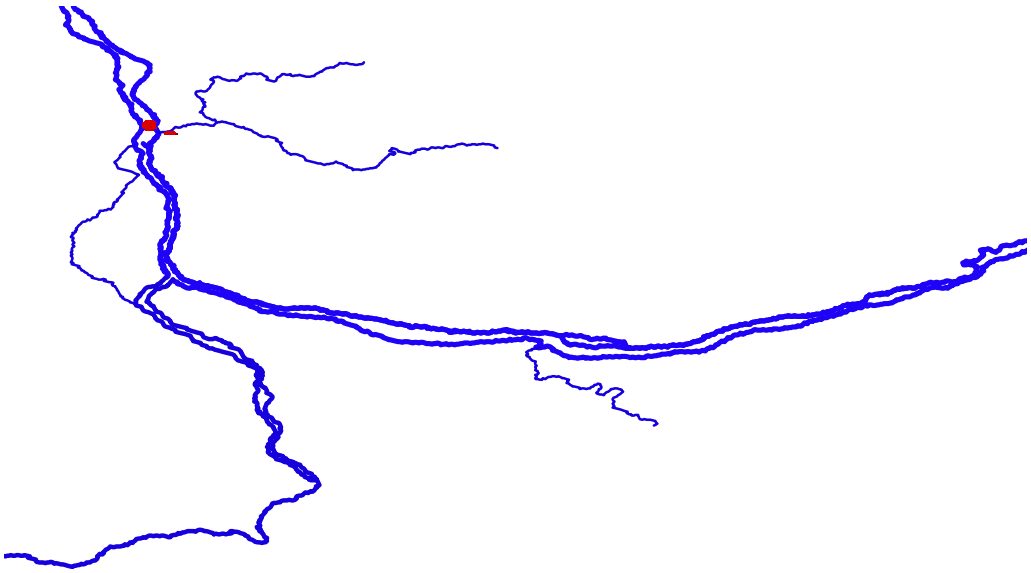

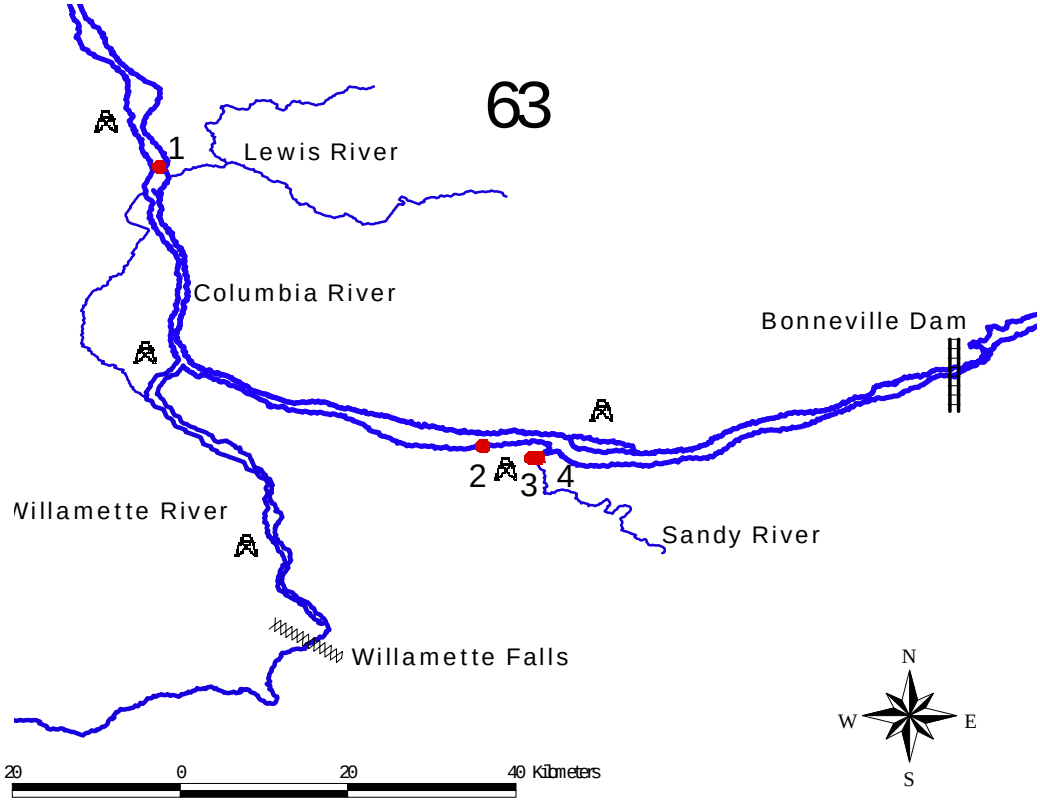
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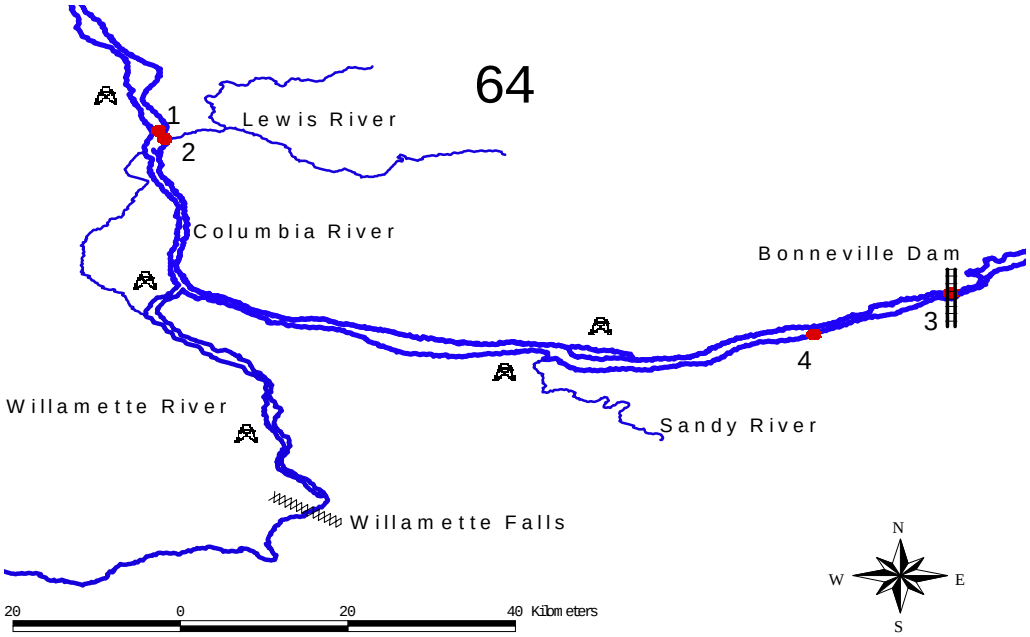
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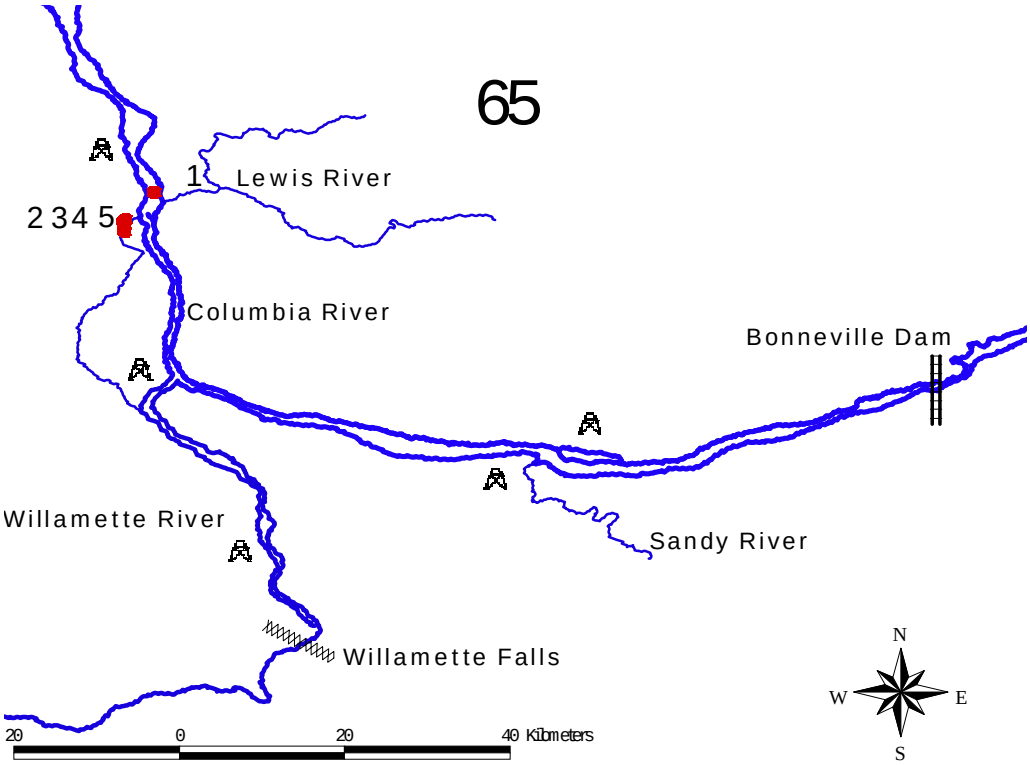
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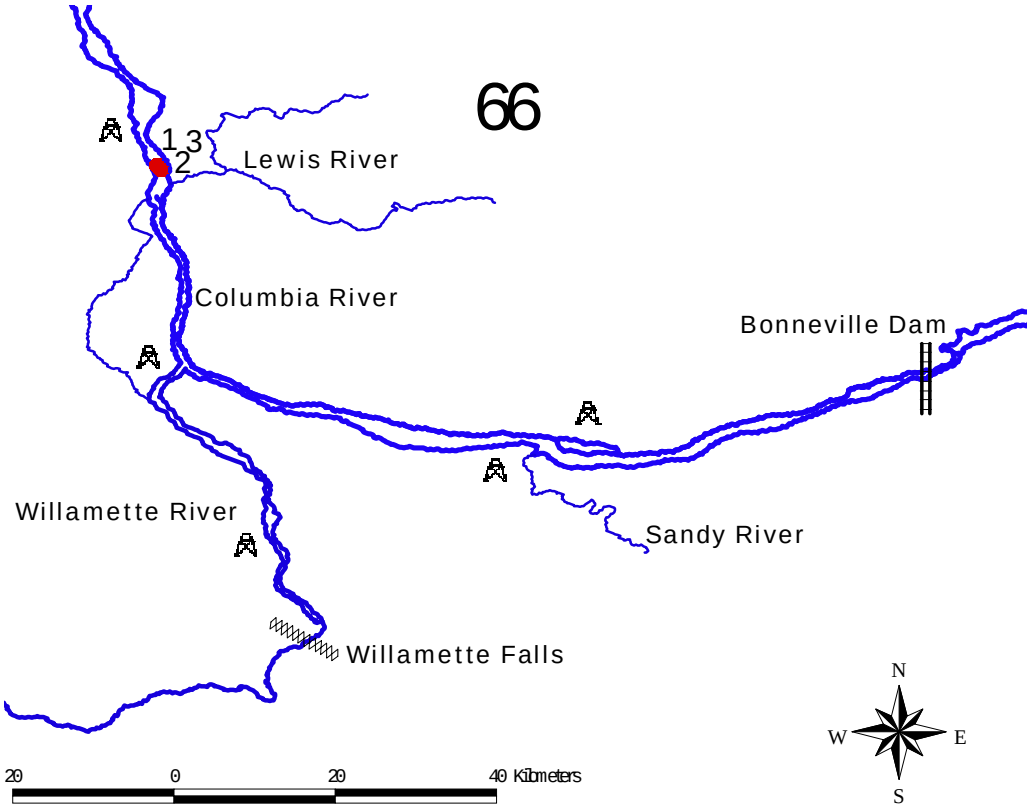
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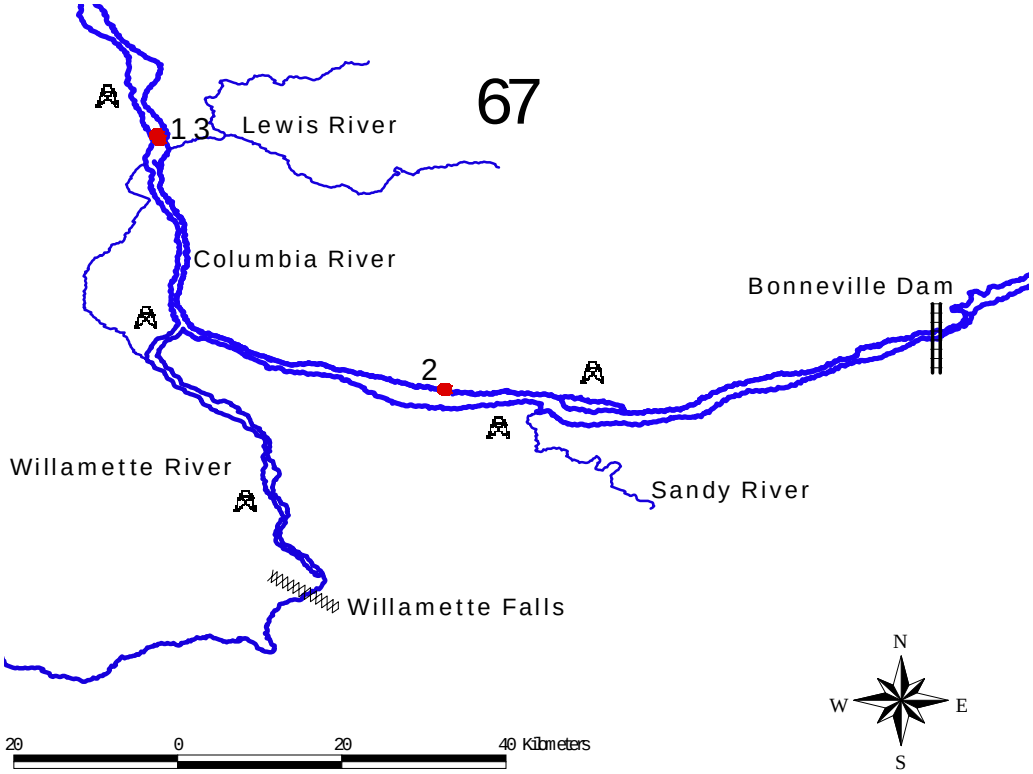
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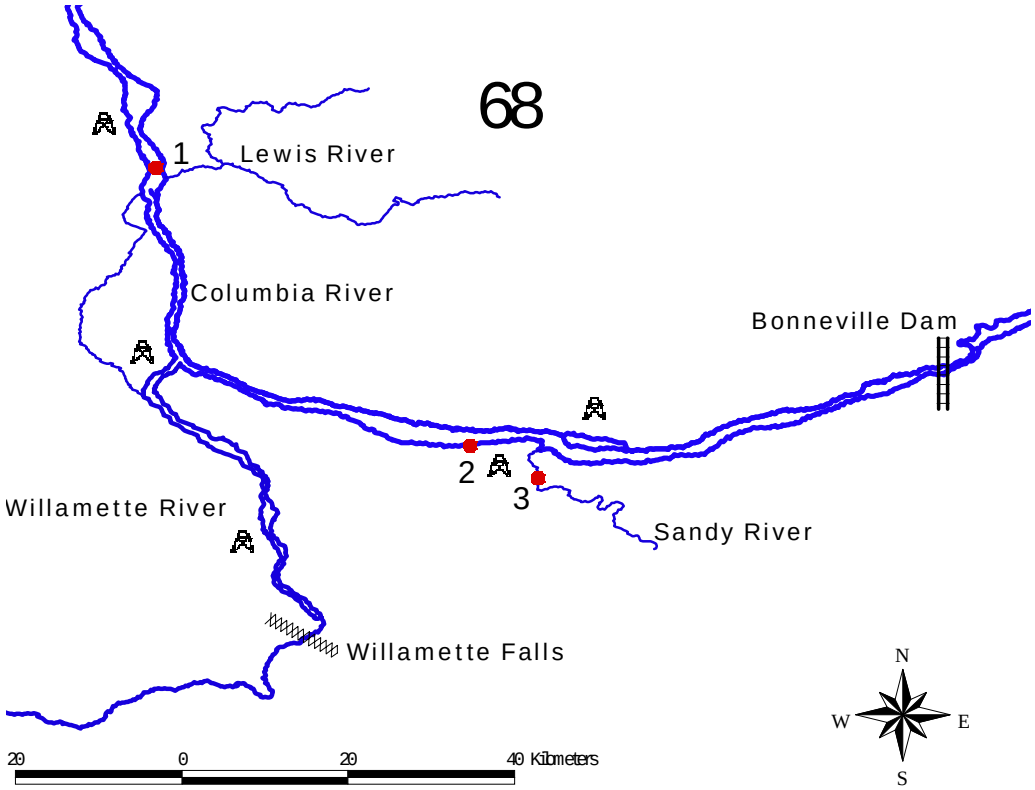
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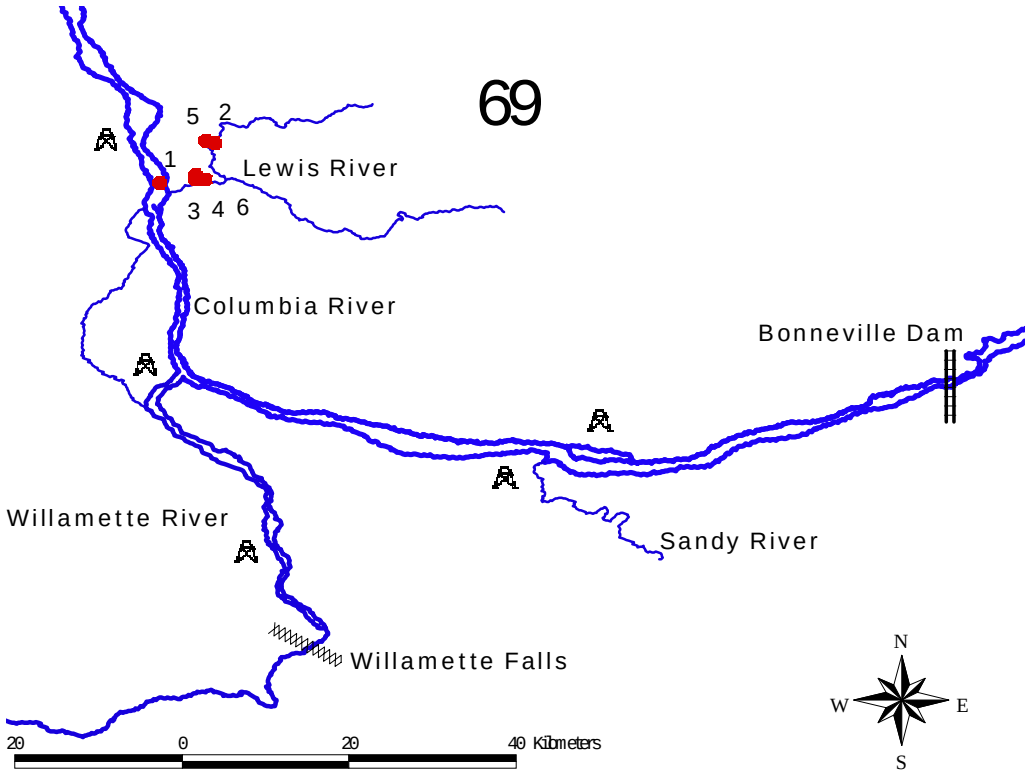
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Sandy River
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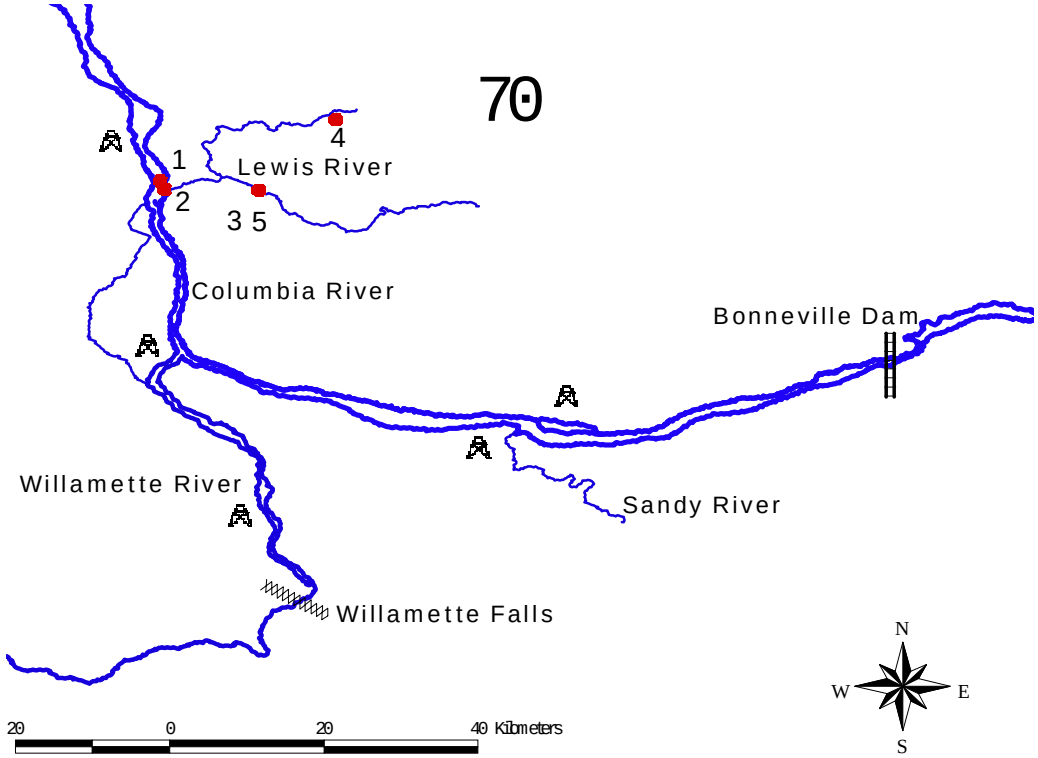
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Sandy River
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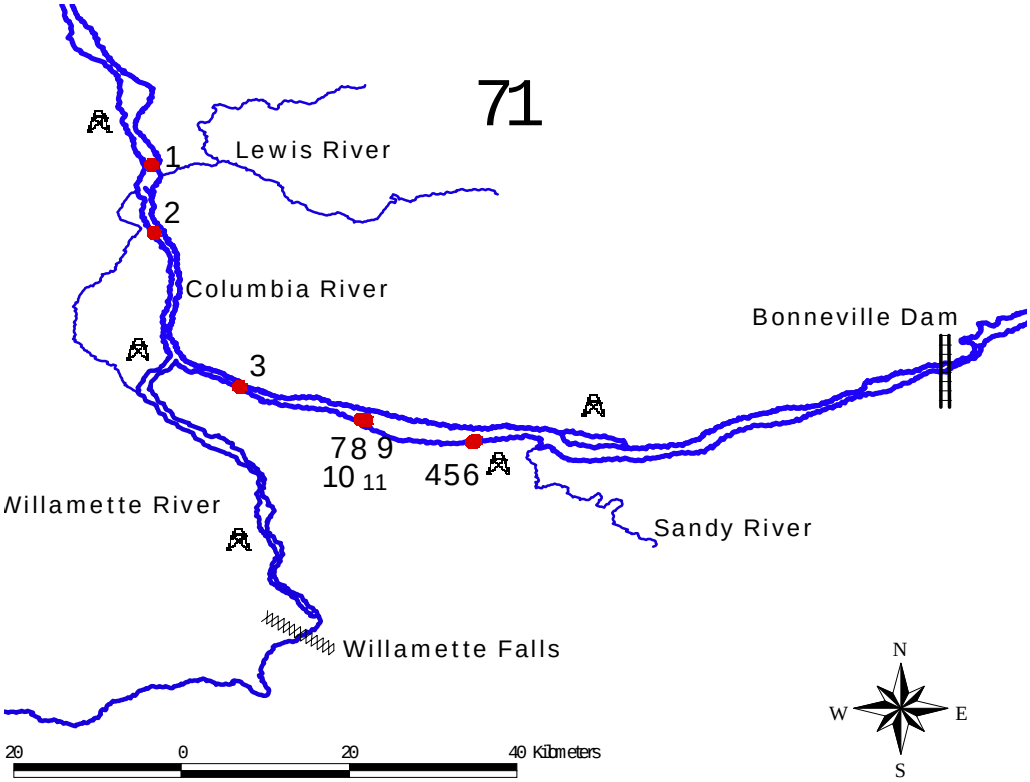
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Willamette Falls
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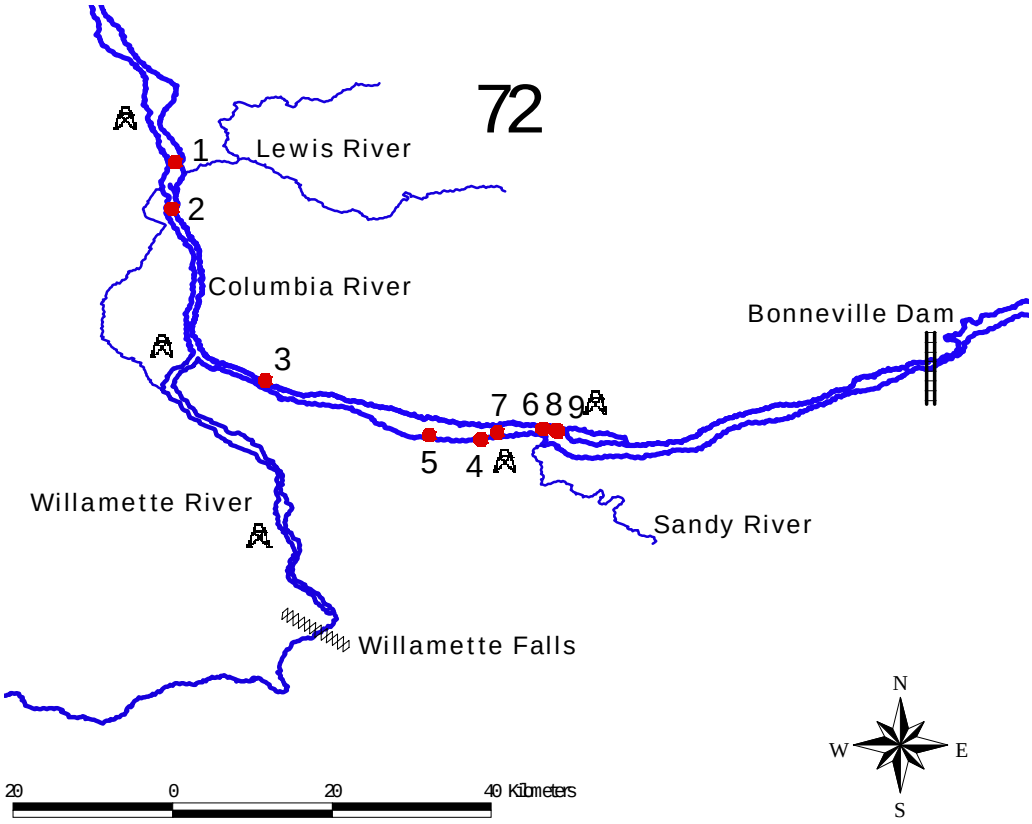
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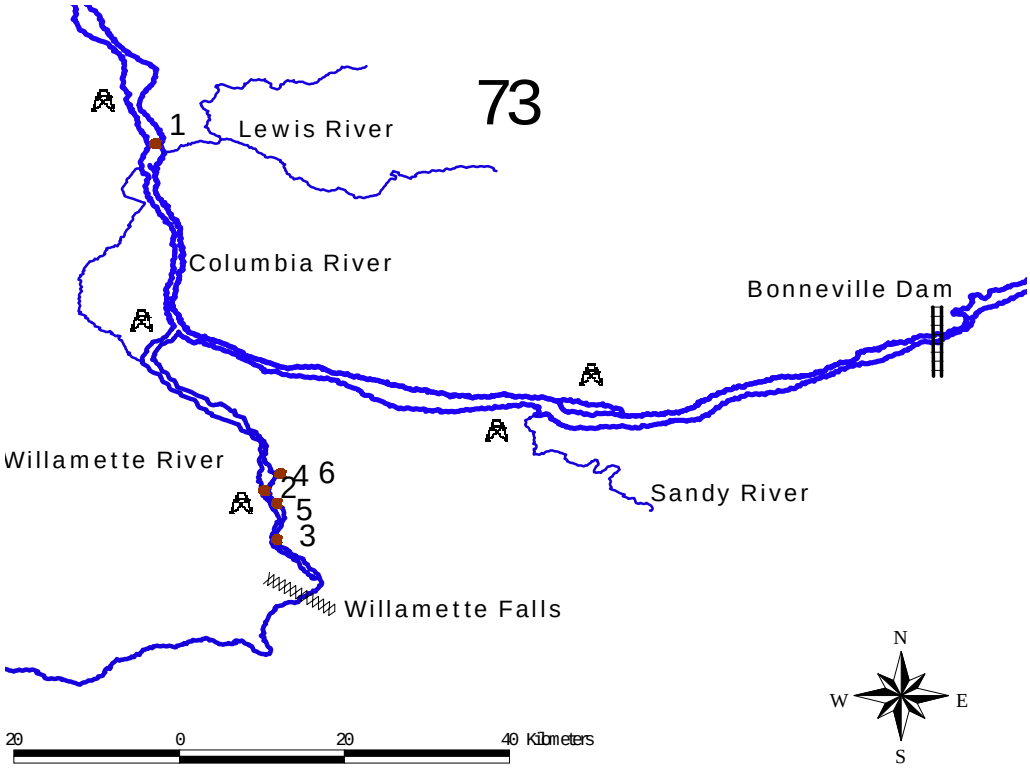
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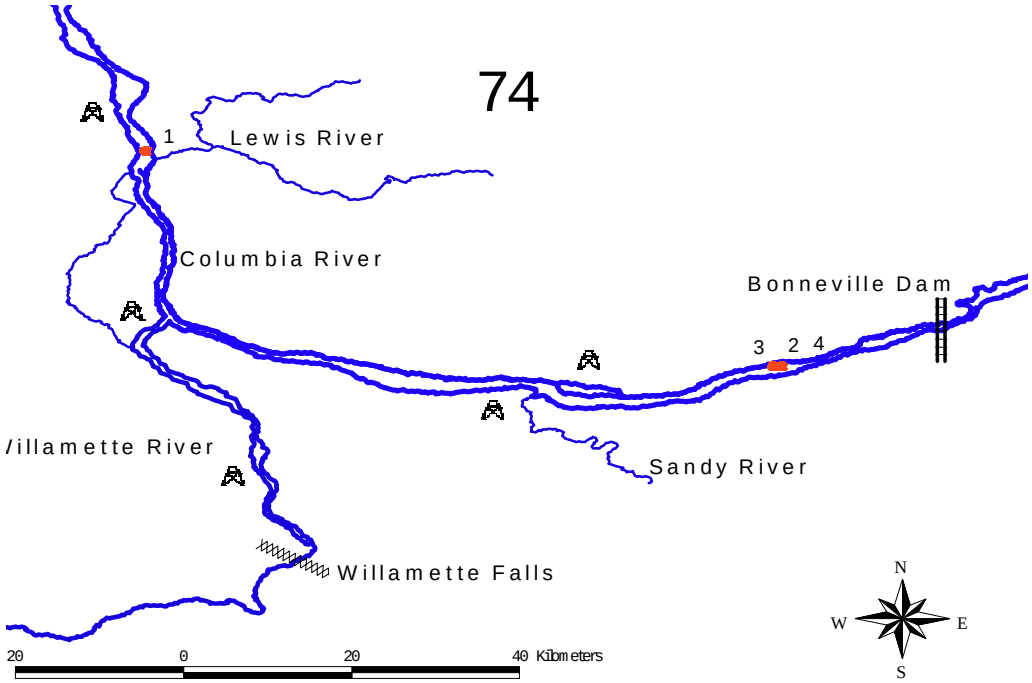
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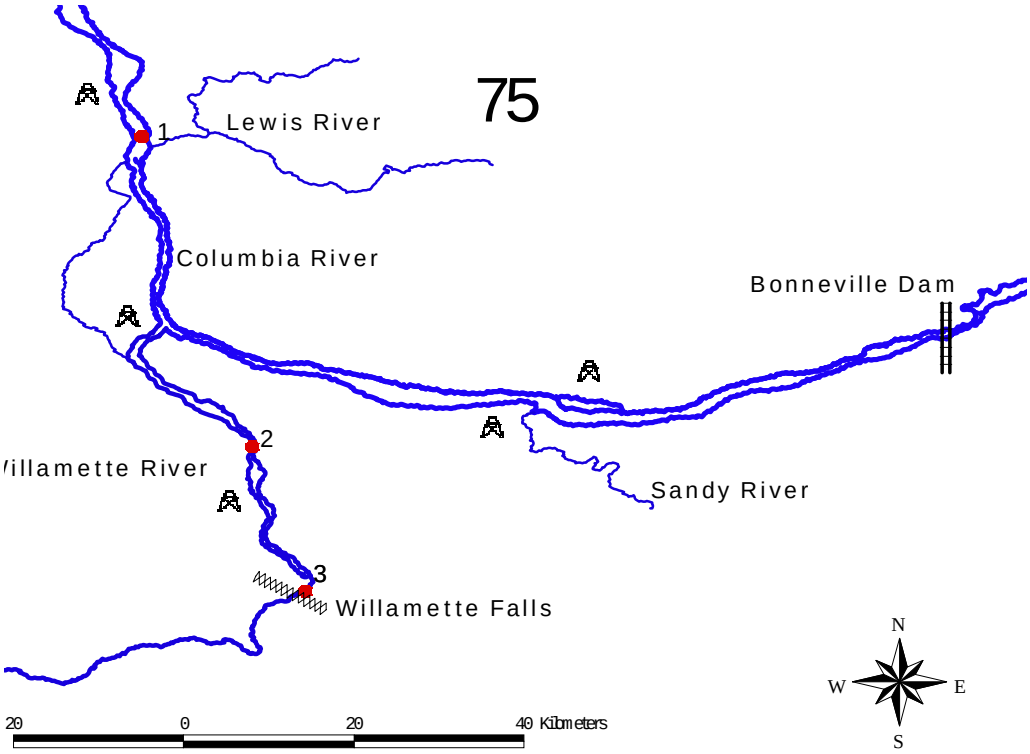
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Sandy River
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Willamette Falls
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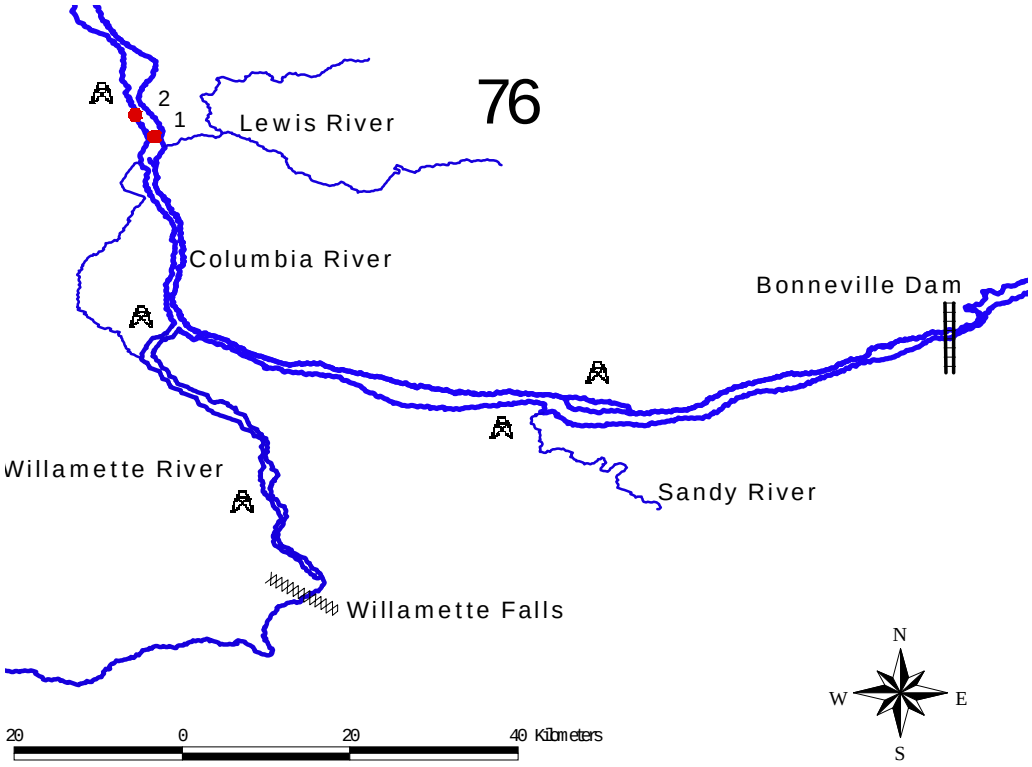
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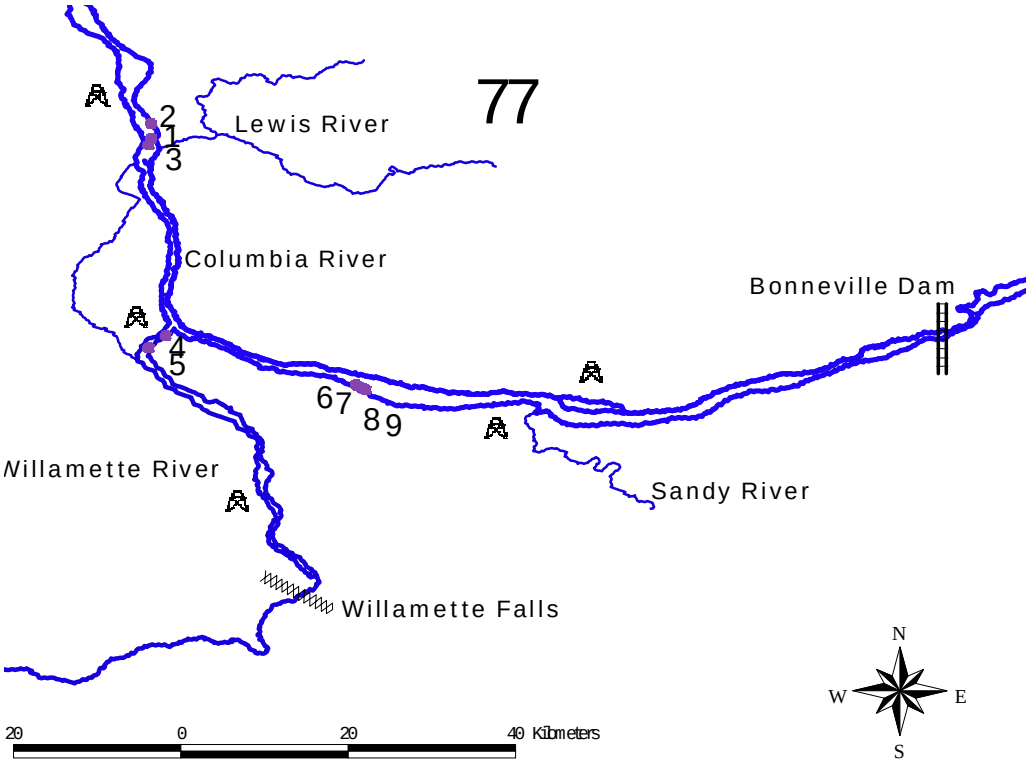
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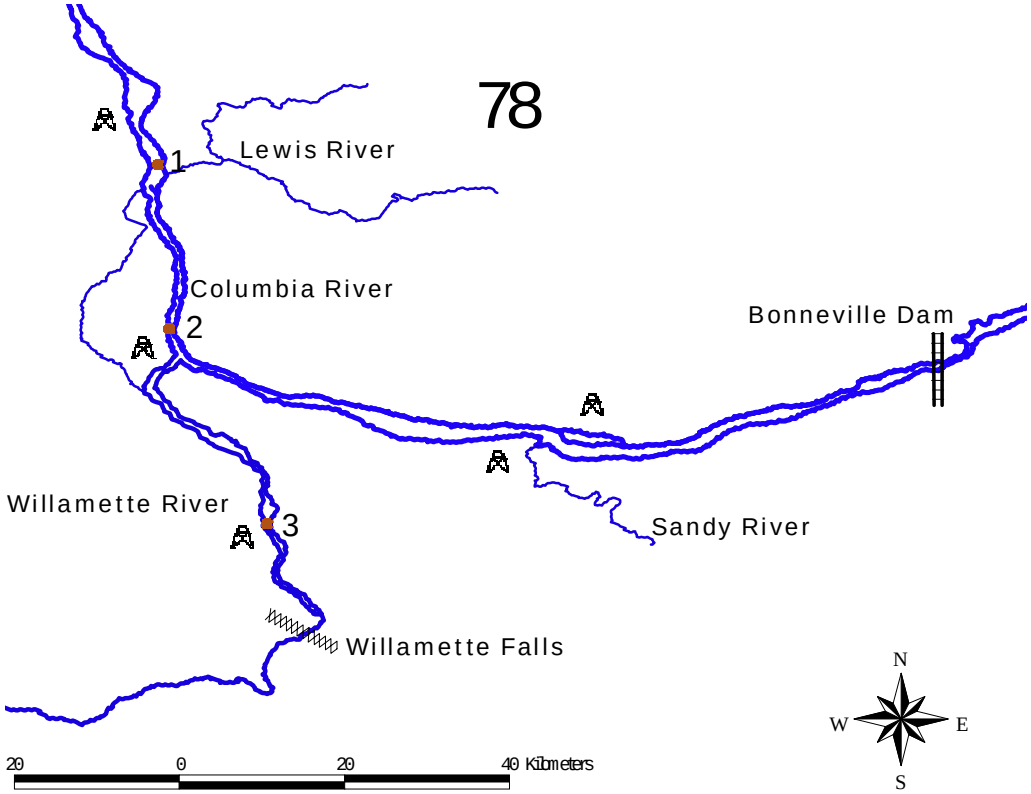
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Lewis River
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Sandy River
Willamette Falls
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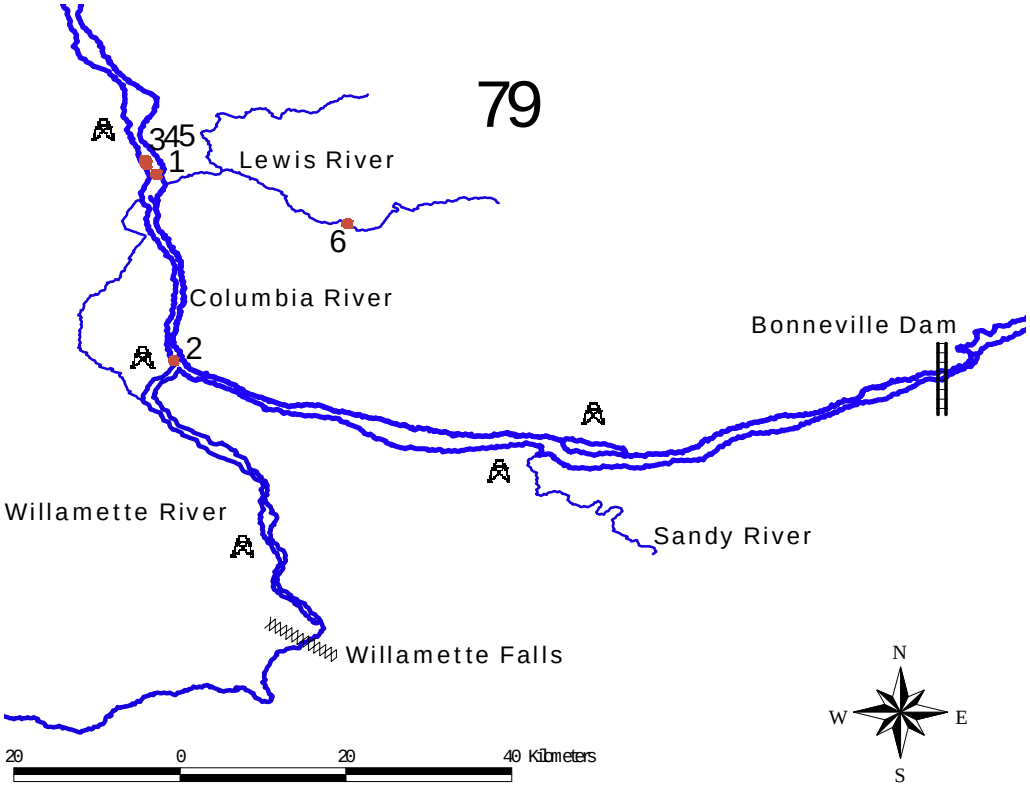
40 Kilometers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Lewis River
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Willamette River
Sandy River
Willamette Falls
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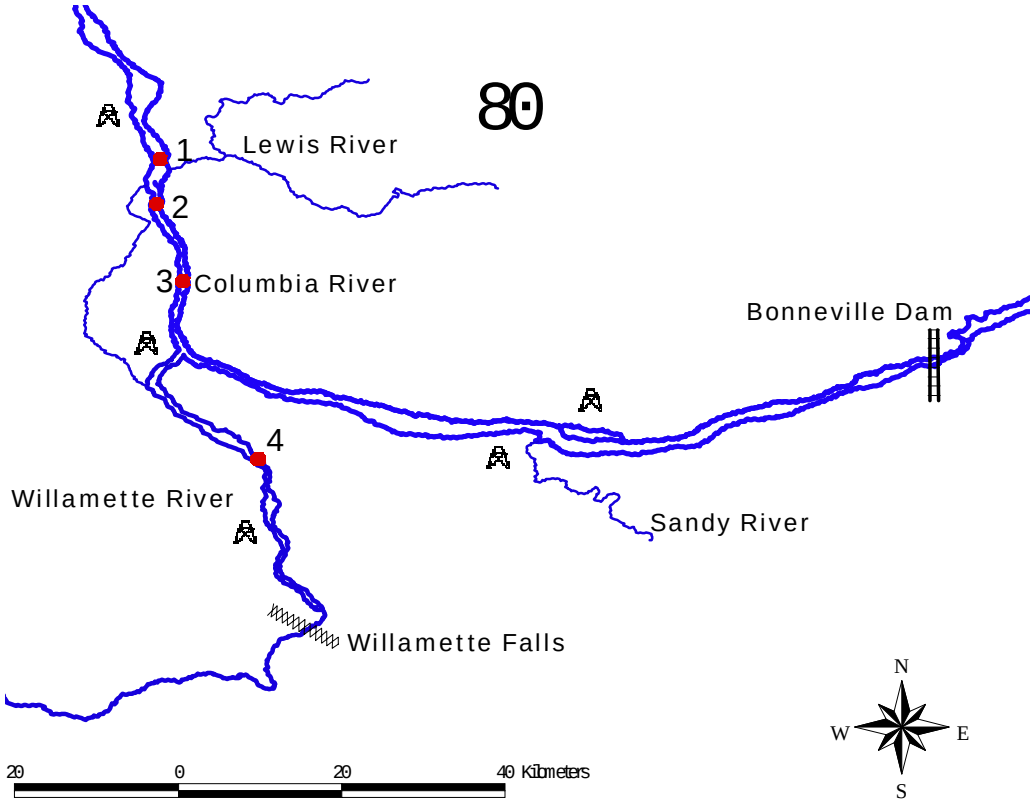
80
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Willamette Falls
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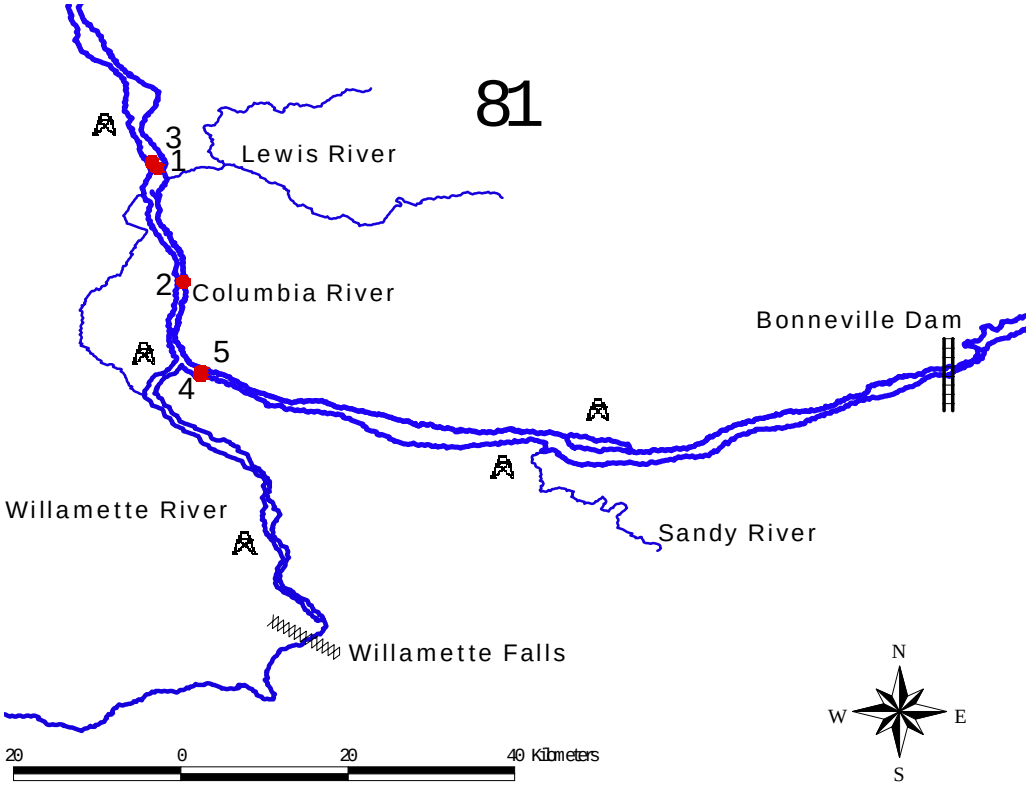
81
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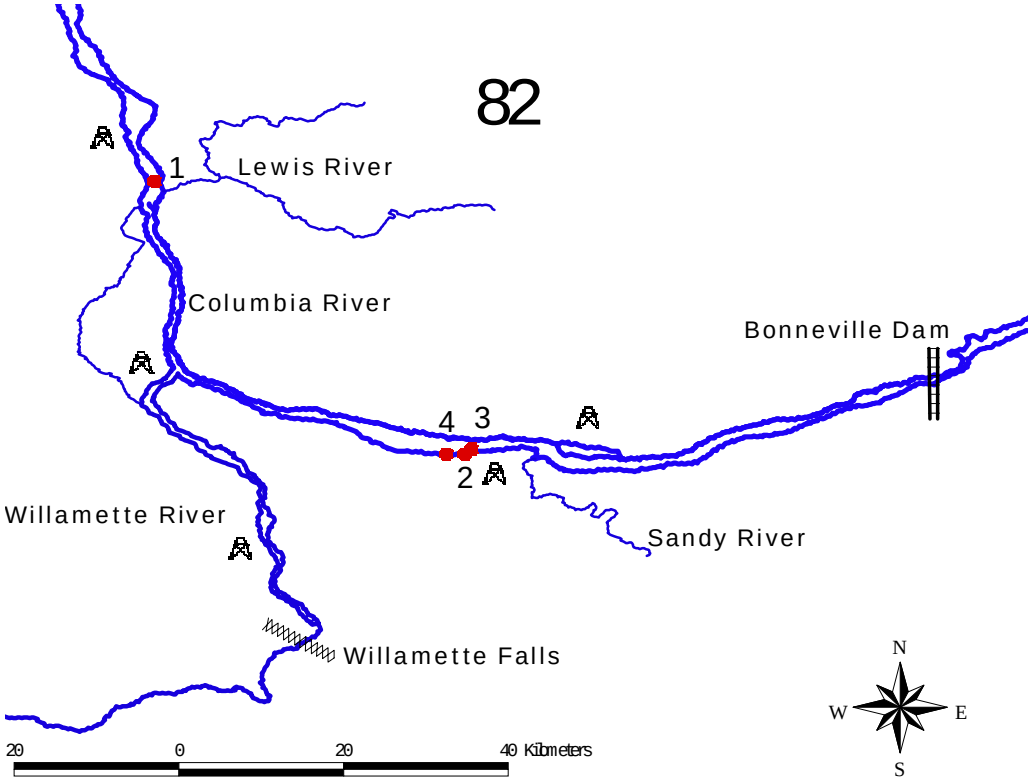
82
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Willamette River
Sandy River
Willamette Falls
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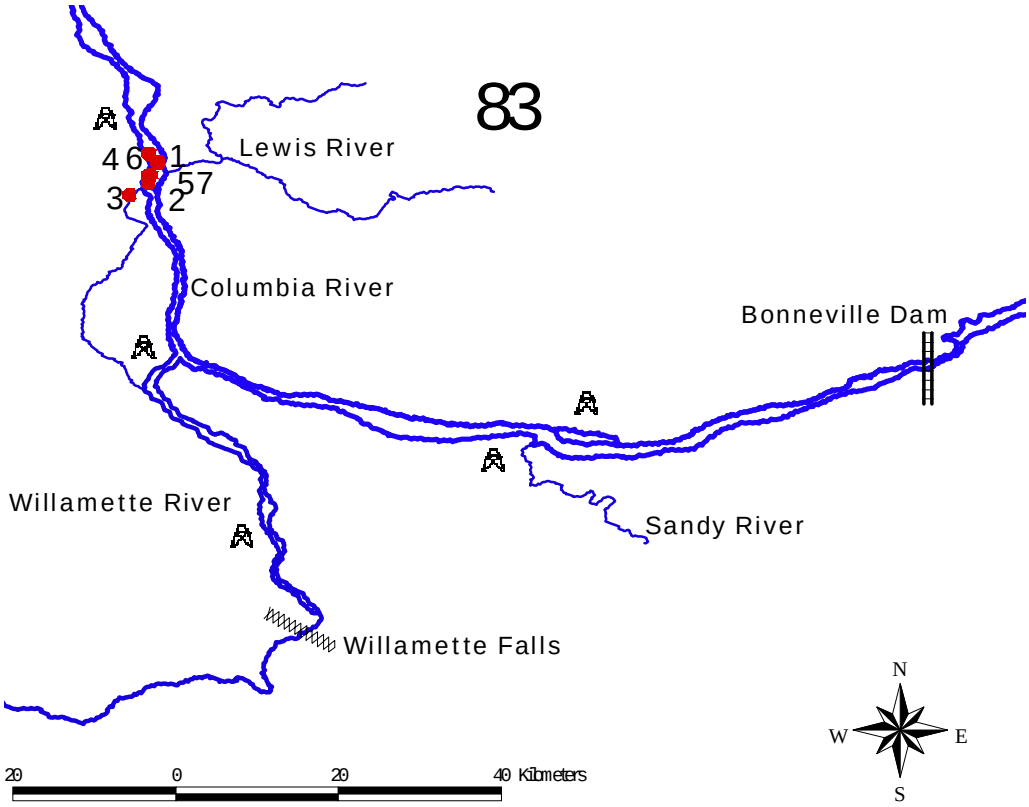
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Lewis River
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Columbia River
Bonneville Dam
Willamette River
Sandy River
Willamette Falls
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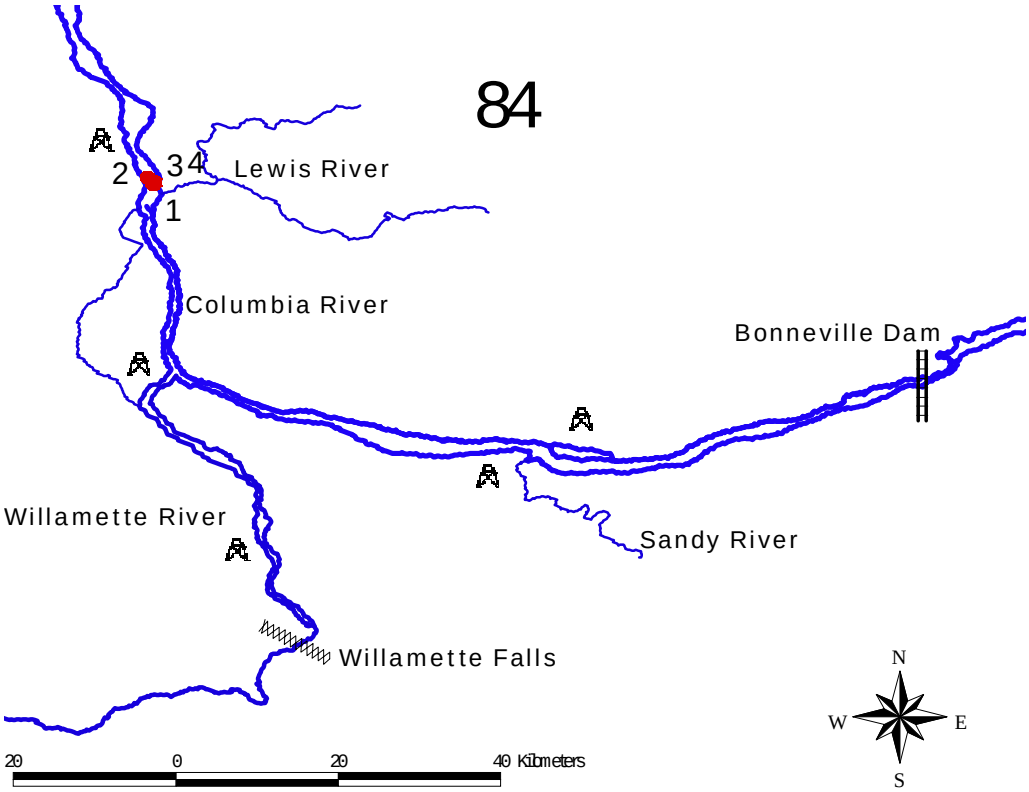
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Willamette River
Sandy River
Willamette Falls
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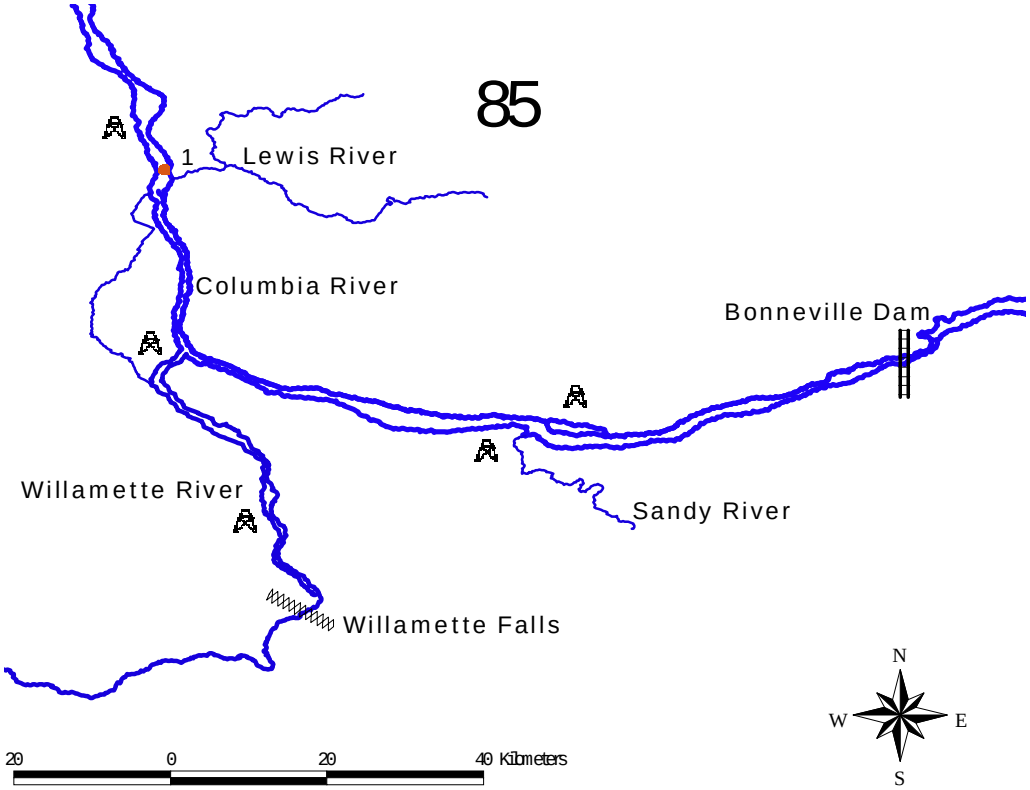
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Sandy River
Willamette Falls
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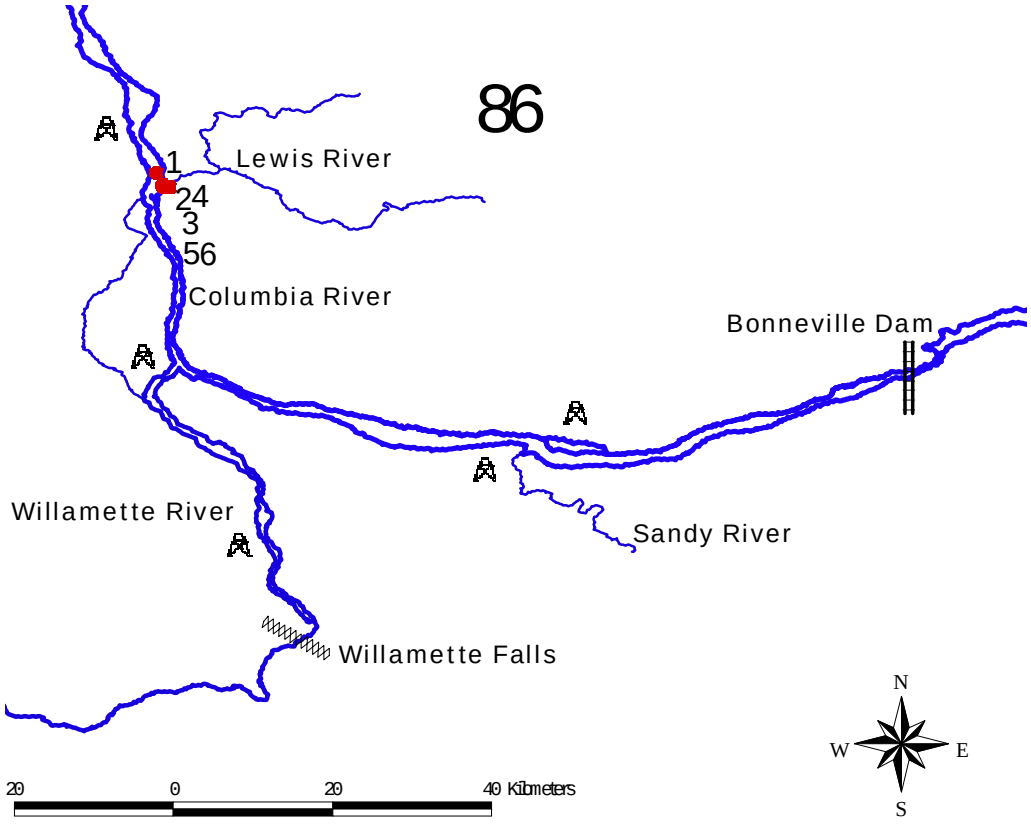
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56
Lewis River
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Bonneville Dam
Willamette River
Sandy River
Willamette Falls
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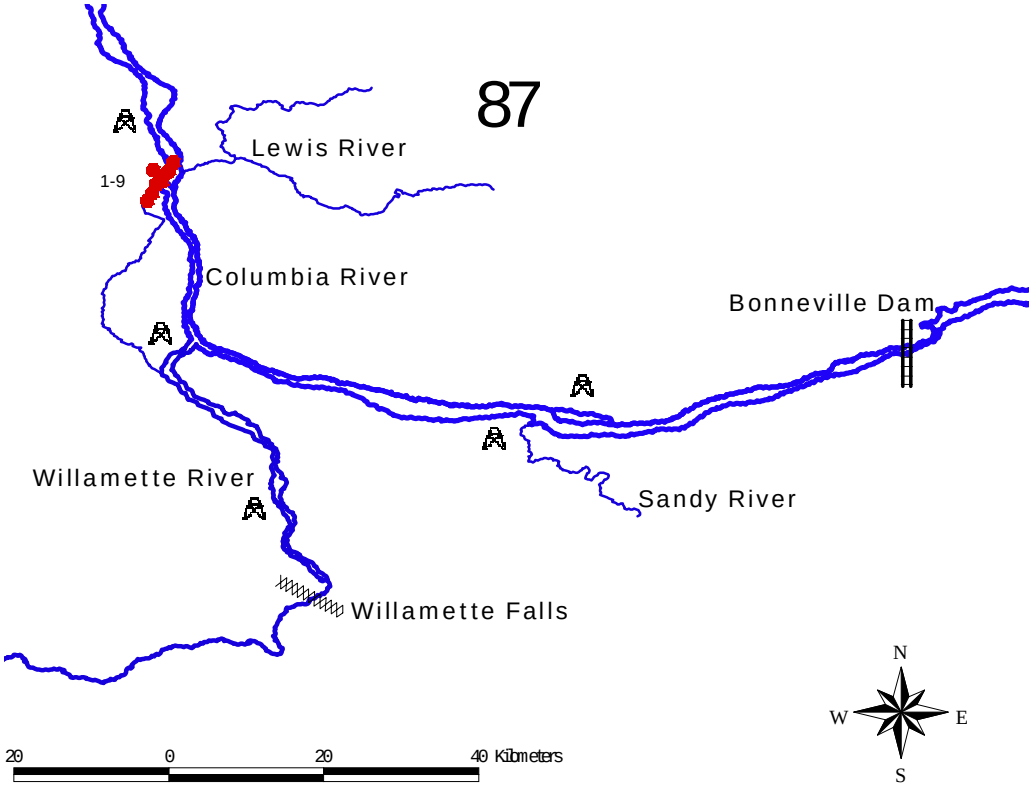
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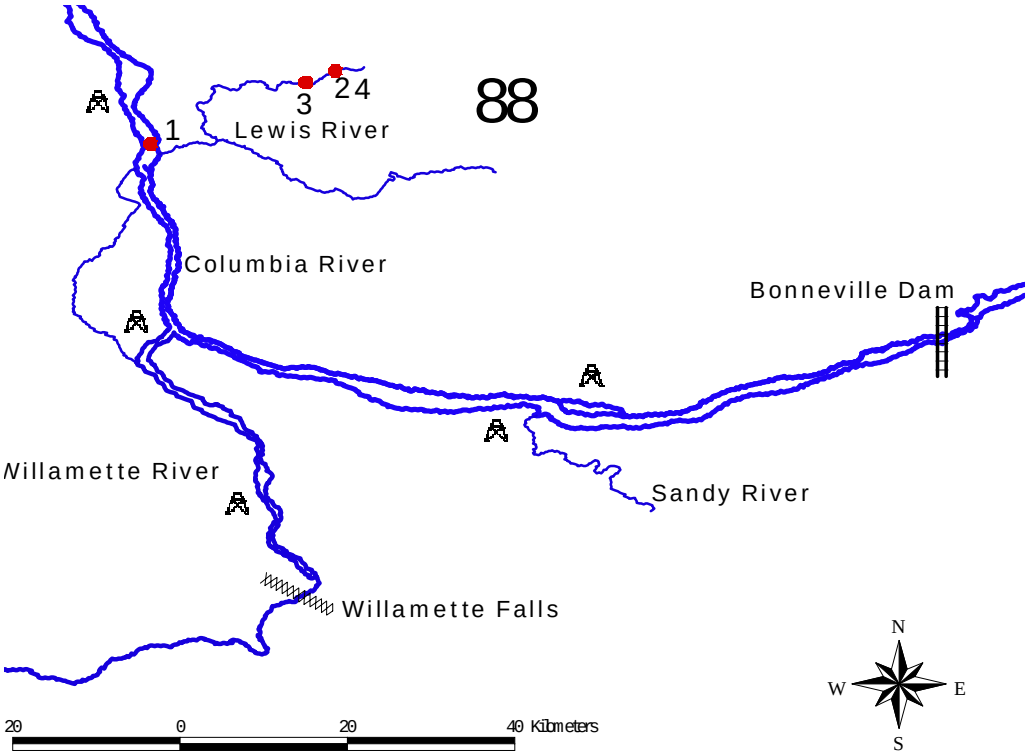
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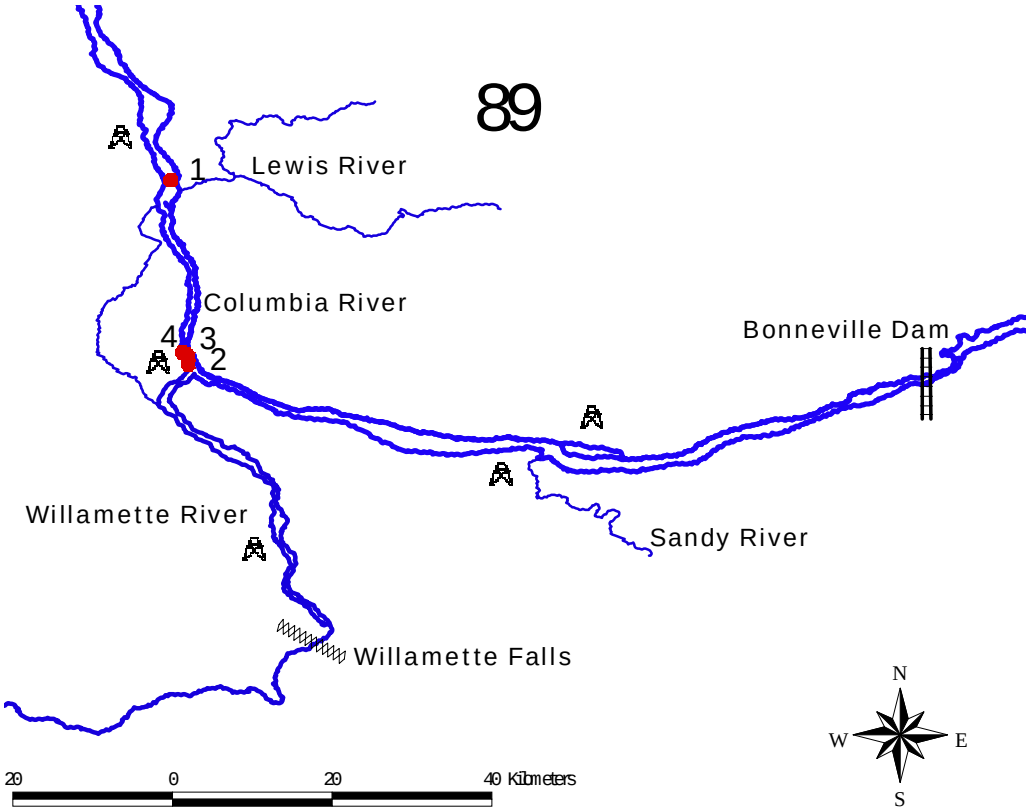
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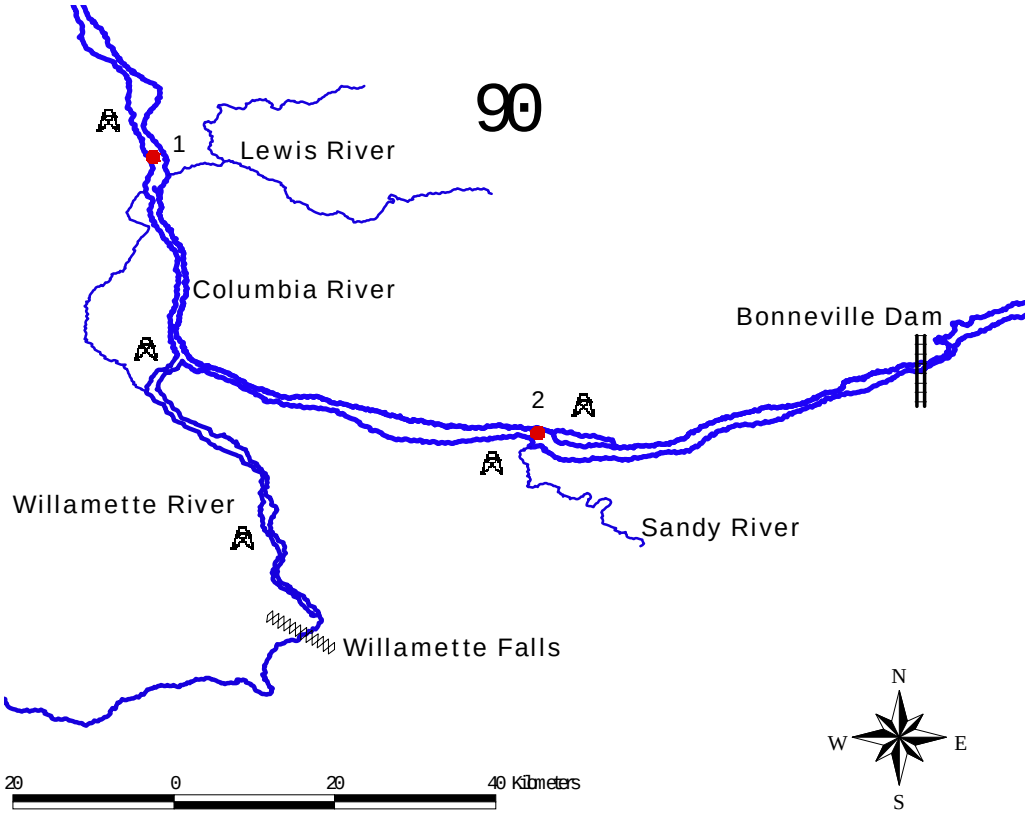
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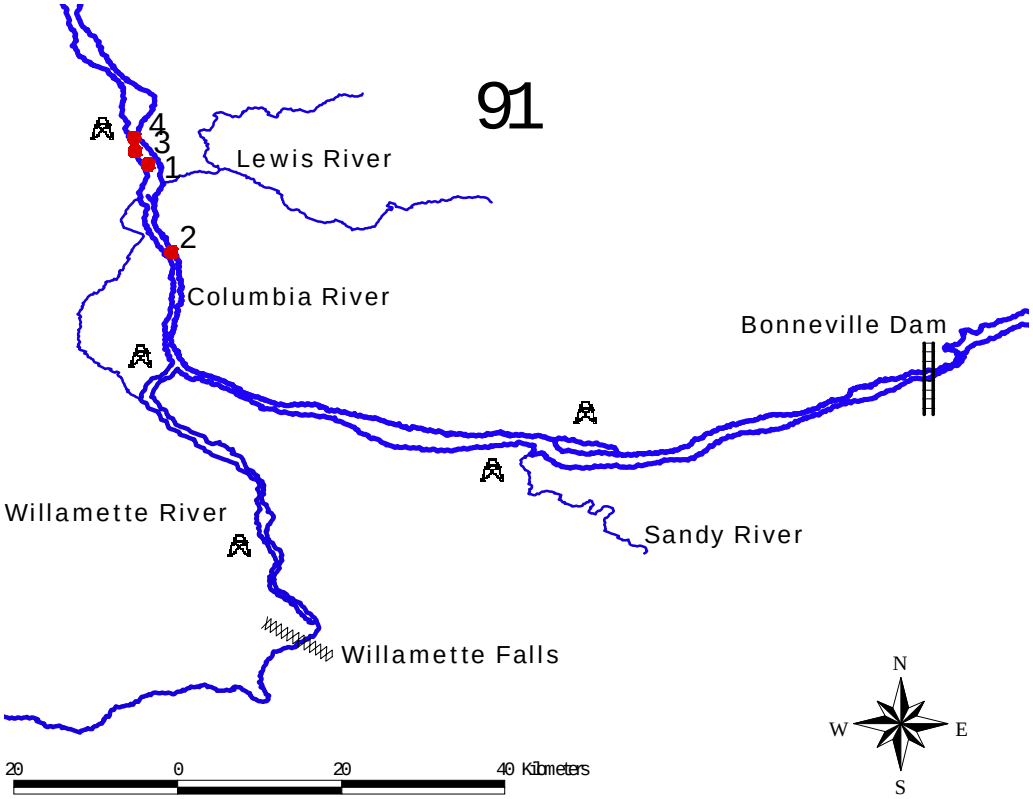
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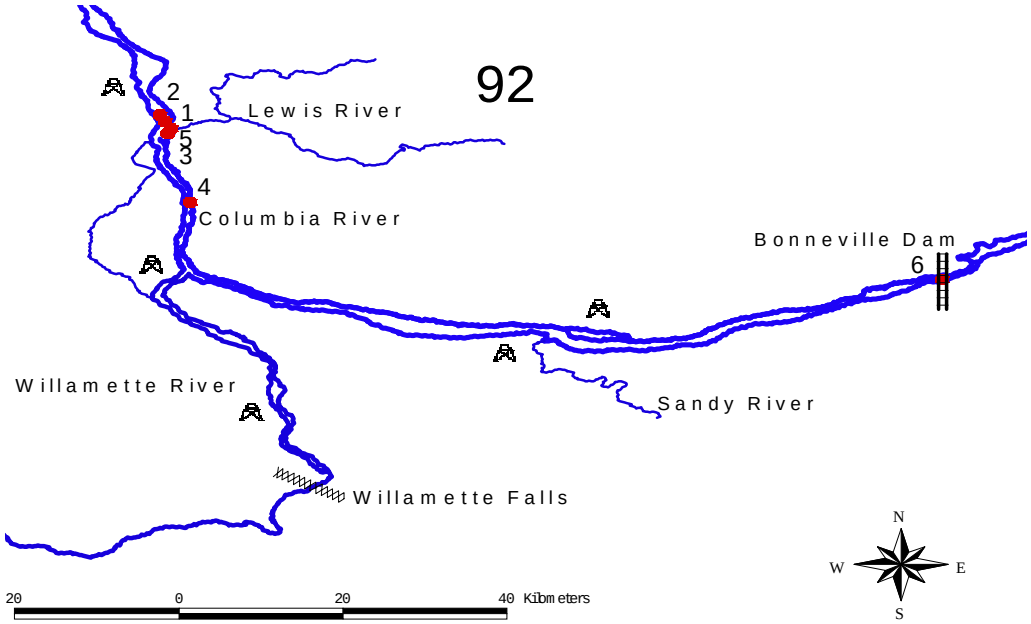
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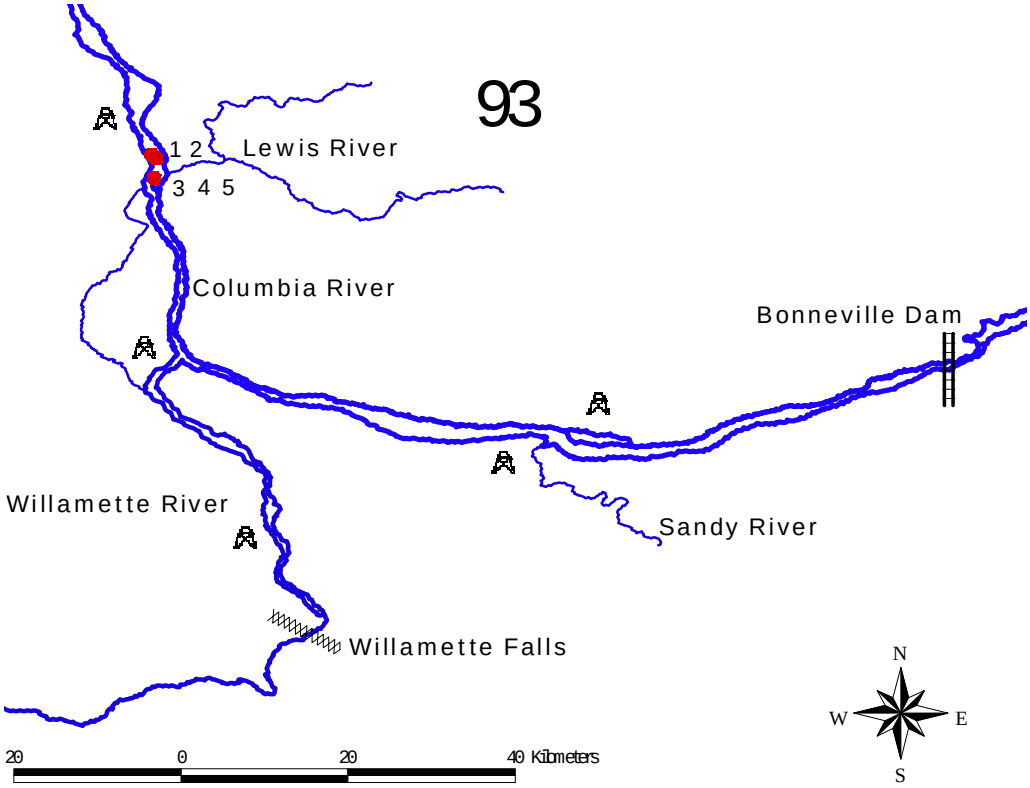
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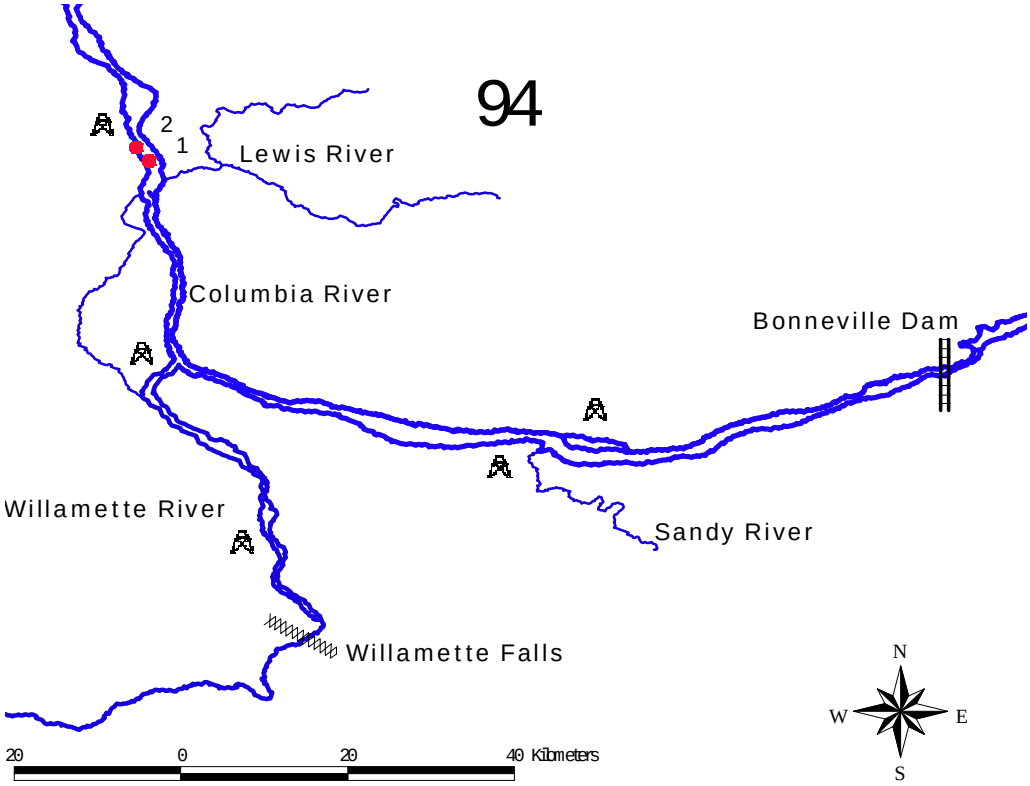
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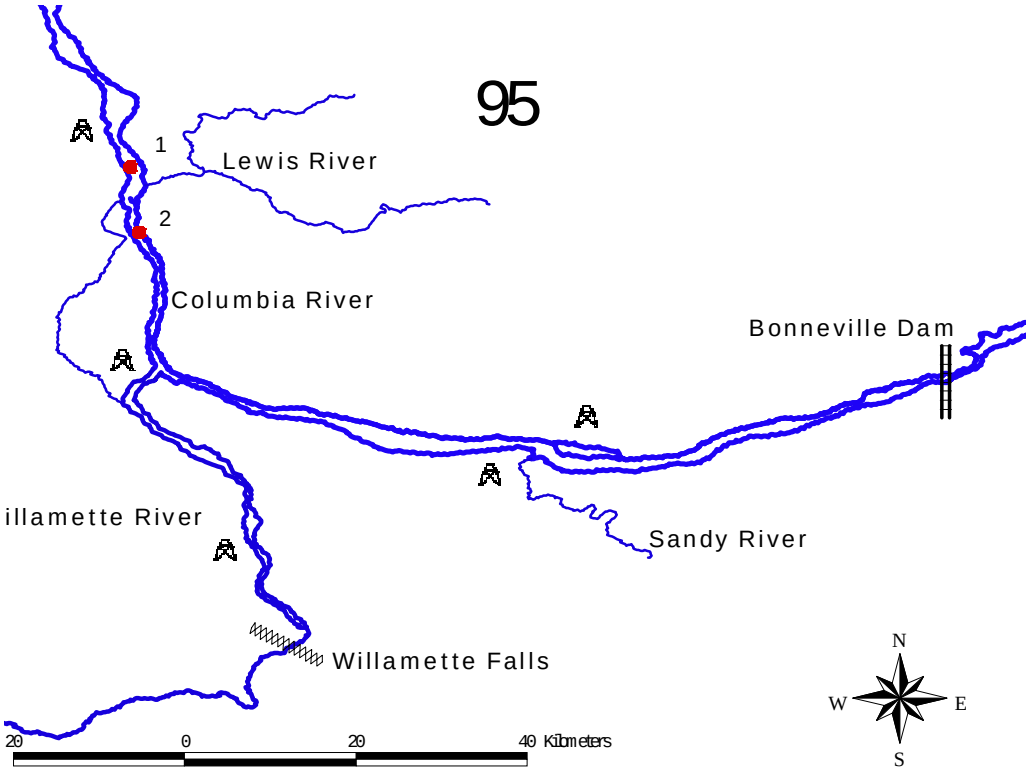
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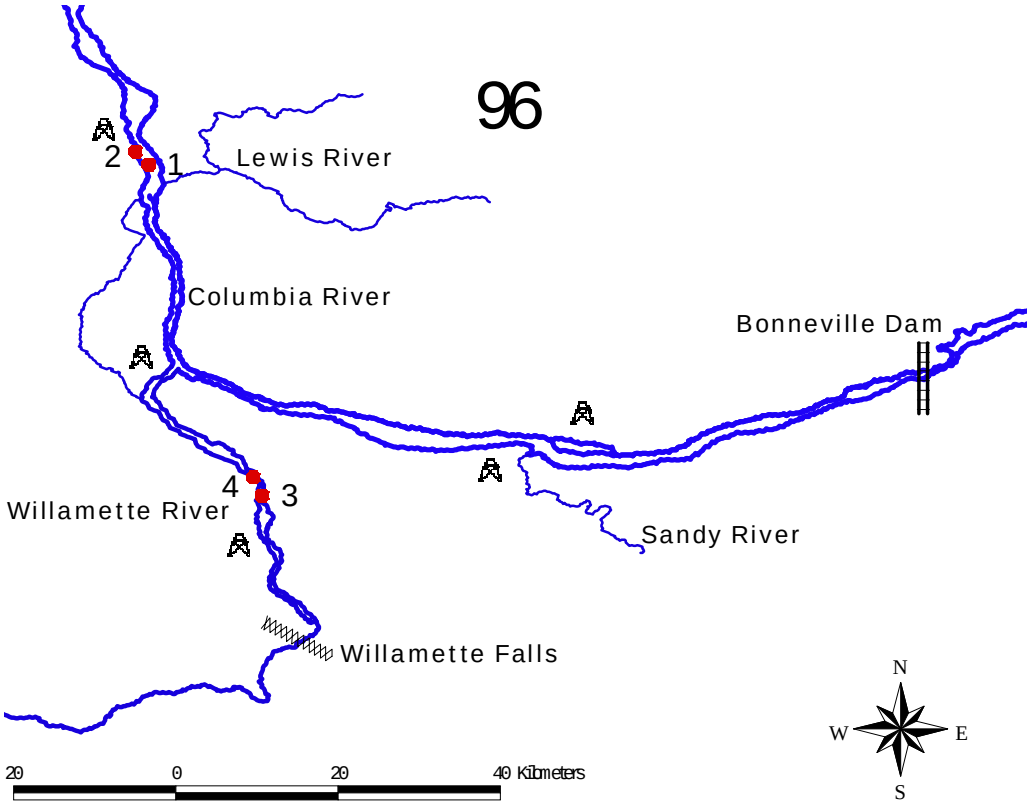
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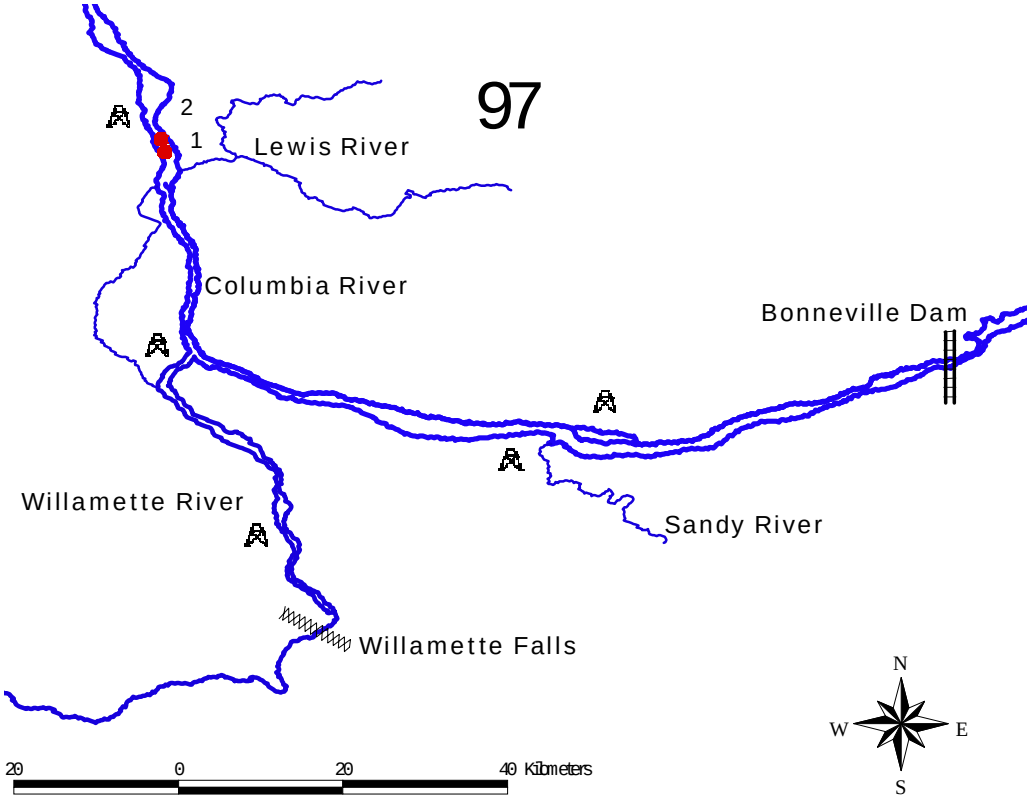
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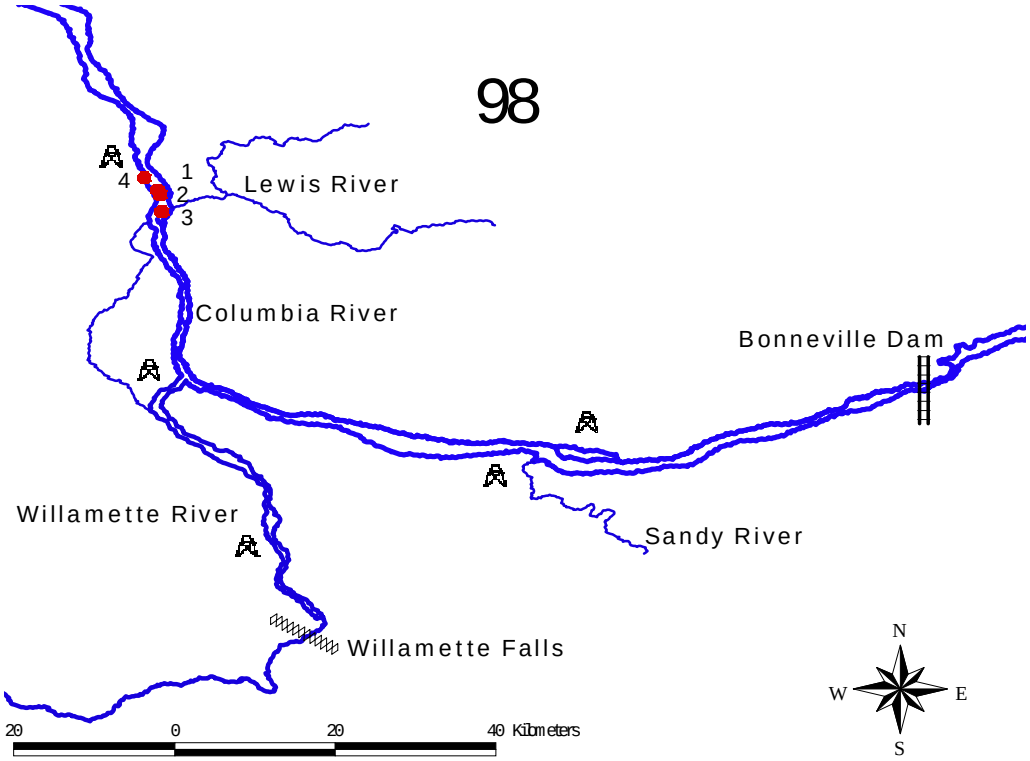
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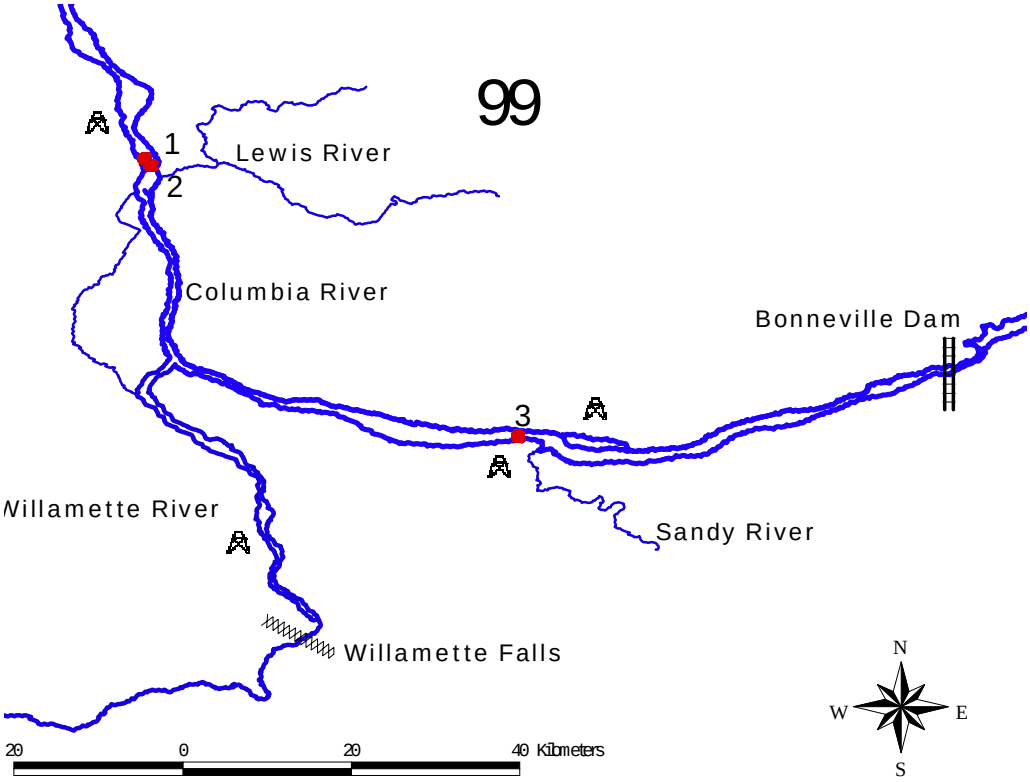
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Columbia River
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Willamette River
Sandy River
Willamette Falls
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40 Kilometers

Appendix 3. Columbia Basin Pacific Lamprey Technical Workgroup

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John Sanchez	USFS	Jasanchez@fs.fed.us	541-278-3819
Bill Maslen for Docherty	BPA	wcmaslen@bpa.gov	503-230-5549

Appendix 4. Draft Guidelines for Pacific Lamprey Transplantation and/or Artificial Propagation Actions funded under the Columbia Basin Fish and Wildlife Program

1) The target or recipient subbasin formerly (or currently) sustained a Pacific lamprey population.

2) The problems which lead to the reduction or demise of Pacific lamprey in a recipient subbasin have been addressed (dewatering, passage barriers, chemical treatments, etc.)

3) The existing recipient subbasin Pacific lamprey population has been determined to be below a level which could recover to self-sustainability with harvest.

4) Pacific lamprey removal (defined location, life history state, and number) from a subbasin donor population is determined to have insignificant impact on that population.

5) Disease clearance or screening has been conducted on the donor population and results have been approved by fish pathologist (similar to salmonid transfers).

6) The donor population was selected based on the following: 1) results of a Columbia Basin Pacific lamprey genetic database/stock structure study (being conducted under CTUIR project 9402600); 2) geographic locations of donor vs. recipient subbasins (may not be a critical factor depending on outcome of genetic database/stock structure study); and 3) availability of stocks.

7) NEPA requirements have been addressed – if applicable

8) ESA concerns/requirements have been addressed – if applicable

9) Proposed action includes monitoring and evaluation plan to determine effectiveness of action.