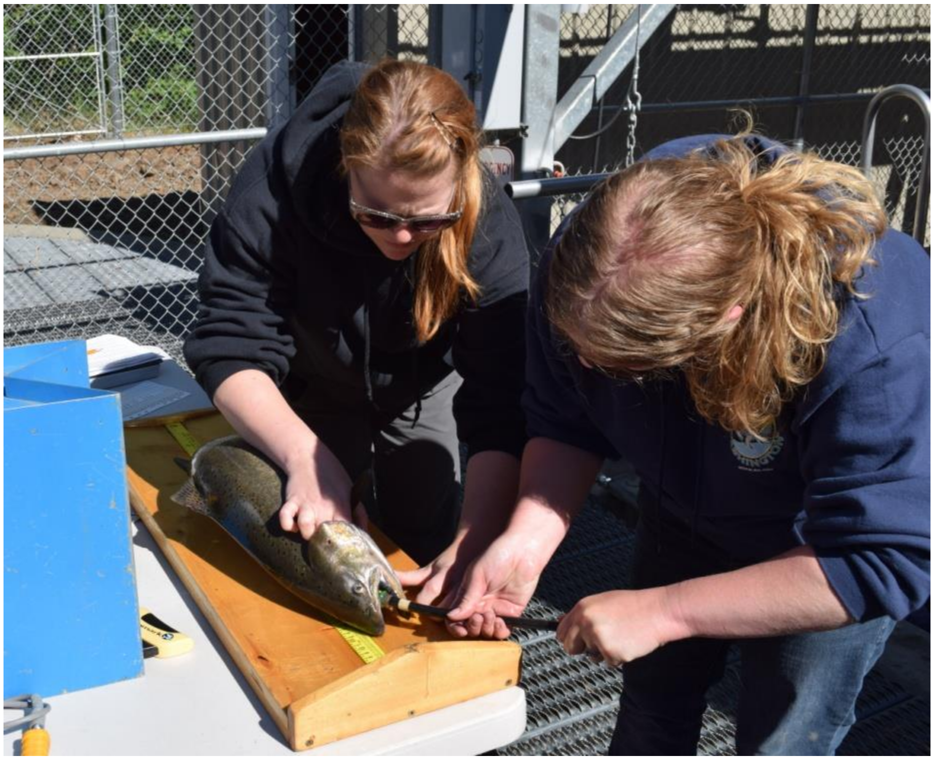
Tucannon River Spring Chinook Salmon
Pre-Spawn Mortality Investigations for 2014



by

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Abstract

High pre-spawn mortality of spring Chinook salmon (*Oncorhynchus tshawytscha*) was documented in the Tucannon River during 2013. The reason for this high pre-spawn loss was not readily understood, therefore, an investigation was conducted in 2014 in an attempt to look at factors that were potentially causing the loss. We utilized radio telemetry, conducted pre-spawn mortality surveys, installed hidden game cameras, and provide a cursory look at water quality and fish pathology in the attempt to determine the cause, or causes, for this high pre-spawn loss. Of the 47 fish gastrically implanted with radio tags, one tag was regurgitated, 18 died from perforated stomachs from tagging, 21 died from unknown causes, four were killed by predators, two spawned, and one tag stopped working or the fish left the river on its own or other means (possibly poached). Pre-spawn mortality surveys were conducted from 13 June to August 22 during 2014, after which regular weekly spawning ground surveys commenced. A total of 119 cumulative river kilometers were walked from Lady Bug Flat Campground (rkm 78) to Bridge 12 (rkm 47) and only three pre-spawn mortalities were recovered that were not related to the radio telemetry study. Disease was not noted in fish collected from the river for broodstock and river water temperatures were not thought to be at a level to cause undue stress based on temperature monitors. We were unable to determine the cause of the high pre-spawn mortality rate observed in the Tucannon River during 2013. This was primarily due to the fact that the high pre-spawn mortality rates observed in 2013 were not duplicated in 2014, and mortality associated with the radio telemetry project was high. During our investigation we found that high pre-spawn mortality rates were not that unusual for spring Chinook salmon populations. However, high pre-spawn mortality can significantly affect production for small populations such as Tucannon River spring Chinook salmon. Recommendations for future actions are provided to help increase survival rates of returning adult salmon.

Introduction

During 2013, Tucannon Fish Hatchery (TFH) staff passed 374 spring Chinook salmon (*Oncorhynchus tshawytscha*) above the TFH adult trap. Based on ultrasound scans, 118 of those passed fish were females. However, only 25 redds were counted above the trap, which resulted in a marked increase in the females/redd ratio compared to previous years (Figure 1). In addition, substantially fewer carcasses were observed and recovered both upstream and downstream of the adult trap and robust live fish that were observed actively spawning during surveys disappeared quickly. Some surveyors noted an unusually high number of small "test digs" that were not developed into complete redds. It was unknown whether these "missing" fish were preyed upon by predators, poached, or died of disease or stress.

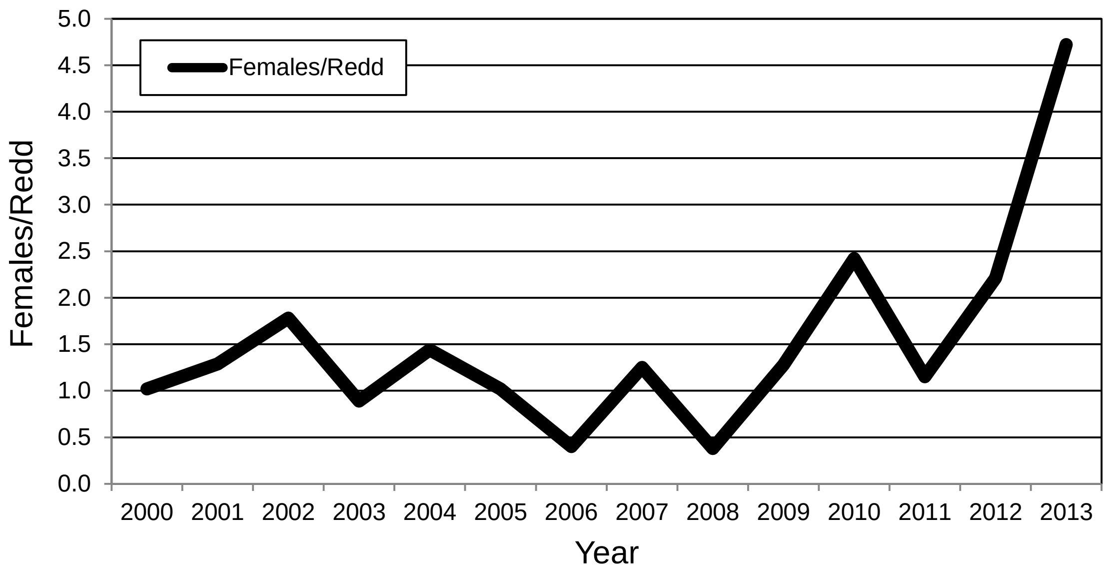

Figure 1. Females per redd ratio of Tucannon River spring Chinook salmon above the Tucannon Fish Hatchery adult trap, 2000-2013. The number of females is based on the number of captured females, and has not been adjusted for fish that bypass the adult trap via jumping the dam.

Numerous physiological and behavioral conditions can affect salmonid pre-spawn mortality rates. Water temperature, turbidity, and flow during migration and holding, ocean conditions, maturation timing, speed of migration, disease (including bacterial, parasitic, and fungal infections), and stress may all play a role (Lloyd 1987; Keefer et al. 2010).

For 2014, it was decided that by inserting radio tags into a representative group of fish, and intensively tracking those fish, we might be able to determine which factors were responsible for the high pre-spawn loss observed in 2013. At the same time, we understood that the conditions that caused the pre-spawn mortality during 2013 might not be duplicated in 2014.

The University of Idaho's Cooperative Fish and Wildlife Research Unit and the National Marine Fisheries Service have successfully radio-tagged thousands of adult spring/summer Chinook salmon (Matter and Sandford 2003; Keefer et al. 2004; Burke and Jepson 2006). Radio telemetry studies have been conducted on Tucannon River spring Chinook salmon over the years since 1989 (Bugert et al. 1990), with the most recent study occurring during 2002 (Gallinat and Varney 2003). The focus of the earlier studies was primarily on outplanting success and habitat utilization; however incidents of poaching, predation, and high pre-spawn mortality rates were noted in those studies (Bugert et al. 1991; Mendel et al. 1993).

In addition to radio telemetry, we also conducted weekly pre-spawn mortality surveys, installed hidden game cameras, provide a cursory look at water quality, and collected tissue samples for histological examination in an effort to determine the cause of the high pre-spawn mortality. This report provides the results of those investigations.

Radio Telemetry

Forty-nine radio tags were provided to the Washington Department of Fish and Wildlife (WDFW) by the U.S. Army Corps of Engineers for the radio telemetry study. The supplied tags were Lotek model MCFT2-3A radio transmitters with a rated life expectancy of 574 days. Individual tags weighed 16 g in air, 6.7 g in water, and have a diameter of 16 mm and a length of 46 mm. Each tag transmits a unique, digitally coded signal every 5 s on a set frequency that enabled us to track individual fish.

We chose gastric implantation as the attachment method to minimize handling and because this method has had success with high survival rates and tag retention in other studies of adult spring Chinook salmon (Hockersmith et al. 1994; Keefer et al. 2005). Gastric implantation is the commonly accepted method for inserting radio tags into semelparous adult salmonids that generally do not feed during the freshwater migration (Burger et al. 1985; Ruggerone et al. 1990; Matter and Sanford 2003). This method is also usually preferred over surgical or external attachment, as tags can be inserted quickly with minimal fish handling stress (Bridger and Booth 2003).

A common criticism of radio telemetry projects is that tagged fish do not represent the population at large. We hypothesized that pre-spawn mortality would differ between sexes for behavioral or physiological reasons. For example, jacks (Age 3 males) are smaller and may be easier prey, or carcasses may become lost in log jams more often than older, larger fish. Males are known to move a great deal as they search for females to spawn with and have higher rates of fall back. Females spend a large amount of time in open water while they construct redds and may be more prone to predators or poachers. In addition, hatchery and natural origin salmon may behave or reside in different parts of the river, where one group could be more vulnerable to loss.

Therefore, tagging goals for this project were selected based on sex and origin to provide a representative sample of the Tucannon River spring Chinook salmon population (Table 1). Fish were radio tagged at the TFH adult trap (rkm 59.2) from 17 May to 12 June of 2014 (Appendix A). All tagged fish were in pre-spawning condition (silver skin coloration and not emitting milt or eggs) at the time of capture. Fish were anesthetized in tricane methanesulfonate (MS-222) and their sex, origin (hatchery or natural), fork length (cm), and date of tagging recorded. Scale samples were collected for aging. A rubber castration band was placed over the radio tags to increase roughness along the tag surface to reduce the chance of regurgitation. Tags were coated in glycerin and implanted into the stomach just posterior of the esophageal sphincter via the esophagus using a hard rubber tube (12 mm diameter). The antenna (~ 45 cm long) extended out of the mouth, but was bent backwards at the maxilla so it would trail along the side of the fish. Implantations were performed by a single experienced tagger. Fish were given an operculum punch (left side) and a passive integrated transponder (PIT) tag was inserted into the dorsal sinus so that recovered carcasses could be checked for loss of radio tags. After tagging and data collection, fish were allowed to recover in a tank with freshwater and released into the adult trap outlet structure after recovery (~ 30 minutes).

Data on fish tagged by WDFW are provided in Appendix A. Sample size, mean age, and length information by origin and sex are summarized in Table 2.

Table 1. Target number, by sex and origin, of Tucannon River spring Chinook salmon to be gastrically implanted with radio tags, and actual numbers tagged during 2014.

		Target Numbers		
Radio Channel	**Sex**	**Hatchery Origin**	**Natural Origin**	**Total Tags**
22	Males	10	10	20
22	Jacks	3	2	5
18	Females	12	12	24
Tagging Goal		**25**	**24**	**49**

		Tagged Numbers		
Radio Channel	**Sex**	**Hatchery Origin**	**Natural Origin**	**Total Tagged**
22	Male	7	10	17
22	Jack	3	2	5
18	Female	11	13[a]	24
18	Male[b]	1	0	1
Total Tagged		**22**	**25**	**47**

[a] One natural origin female regurgitated the radio tag shortly after release so that tag was reinserted into another natural origin female.
[b] Sex was misidentified for this fish.

Table 2. Sample size, mean age, mean fork length (cm), standard deviation (SD), and length range by origin and sex for Tucannon River spring Chinook salmon radio tagged during 2014.

Origin and Sex	Sample Size	Mean Age	Mean Fork Length (cm)	S.D.	Range (cm)
Hatchery Females	11	4.0	69.9	3.4	64.0-75.5
Hatchery Males	8	4.0	68.6	4.8	61.5-76.0
Hatchery Jacks	3	3.0	51.7	2.5	49.0-54.0
Natural Females	13	4.0	70.7	4.2	65.0-78.0
Natural Males	10	4.0	70.1	4.3	64.5-74.5
Natural Jacks	2	3.0	51.3	5.3	47.5-55.0

In addition to the fish tagged by WDFW, two natural origin adult males and one hatchery jack spring Chinook salmon tagged by the University of Idaho at Bonneville Dam in the lower Columbia River were also tracked in the Tucannon River during 2014 (Appendix B). The University of Idaho study adults were tagged with MCFT-7F Lotek radio transmitters. These tags weigh 29 g in air (13 g in water) and have a diameter of 16 mm and are 83 mm long. Life expectancy for this tag is 296 days. The jack was tagged with a Lotek MCFT2-3BM radio transmitter. This tag has a 184 day standard life expectancy and weighs 8 g in air (3.7 g in water) and was 11 mm in diameter and 43 mm in length.

Two fixed antennas (one above and one below the Tucannon Hatchery dam) and a receiver were placed at the TFH adult trap to monitor movement (e.g., fallback) at the adult trap dam. Mobile trackers (primarily by vehicle) followed the movement of radio tagged fish Monday through Friday of each week. Additional mobile monitoring occurred on foot, in combination with snorkeling, for pinpointing the exact location of tagged fish. When a radio tagged fish was located, the date, time, and location were noted. A note of "U" for upstream, "D" for downstream, or "---" for same location were used to denote the position of the fish from its previously detected position. When a fish had not moved from its previous detected location, or had steadily drifted downstream, the trackers attempted to pinpoint the location of the fish and determine if it was alive or dead. If a fish was dead, the trackers described the location of recovery, and if the carcass was still present, we attempted to determine the cause of death if possible. Necropsies were performed on all recovered carcasses and comprised an inspection of the body cavity and stomach for stomach rupture. Cause of death was classified as either; 1) tag mortality (stomach ruptured by tag), 2) predation (fish was recently observed alive, tag in stomach, carcass consumption started), 3) spawned (fish had spawned and died of natural causes), and 4) unknown (indeterminate cause of death). Recovered carcasses were sampled using routine sampling protocols (fork length (cm), sex, scale samples, opercle punch presence or absence noted, head removed for CWT extraction and DNA sample, and radio tag recovered). A GPS location of the recovered carcass or tag was taken.

It soon became apparent that many of the tagged fish were steadily falling downstream so additional tracking personnel were added in an effort to determine if these fish were alive. By the time this was done, many of the carcasses had either; 1) disappeared and only the tags were found, 2) the carcass was recovered and examination showed the radio tag had perforated the stomach, leading to death, or 3) the carcass was decomposed and it was impossible to determine the cause of death. Based on the observed high mortality associated with the gastrically implanted tags, tagging was discontinued after 47 fish were tagged (Table 1).

Of the 47 fish tagged by WDFW, one tag was regurgitated, 18 died from perforated stomachs from tagging, 21 died from unknown causes (radio tag only or decomposed carcass), four were killed by predators, two spawned, and one tag (22-57) either; 1) stopped working, or 2) the fish left the system on its own, or 3) the fish was removed from the system (possibly poached) (Table 3, Appendix A). The regurgitated tag (18-57) was retrieved and re-inserted into a different fish (Appendix A). The average time between tagging and recovery was 23 days for tagging related deaths, 35 days for death by predation, 100 days for fish that spawned, and 25 days for fish with an unknown cause of death (Table 3).

Table 3. Period of time (in days) between gastric insertion and recovery of radio tagged Tucannon River spring Chinook salmon based on the recovery classification during 2014.

	Regurgitated	**Tagging**	**Unknown**	**Predation**	**Spawned**
Sample Size	1	18	21	4	2
Mean Days	14.0	22.6	25.2	34.5	100.0
Range	14	14-37	16-44	24-61	96-104

Of the three University of Idaho radio tags recovered in the Tucannon River, two had spawned (12-370 and 4-403) and the cause of death could not be determined on the third (8-261). The average time span between insertion of the tag and recovery was 138 days for the two spawned fish (range 115-160 days) and 109 days for the fish with unknown cause of death (Appendix B). A map showing locations of the recovered radio tagged fish and their recovery classification is provided in Figure 2.

Death did not occur immediately after tagging, suggesting fish did not suffer immediate trauma from the tagging process itself. Damage likely occurred after tagging as the result of continued tissue atrophy. It is not known if the tag, or the band around the tag, caused stomach perforation. In a study on radio tagged spring Chinook salmon, Corbett et al. (2012) found survival of fish with gastrically implanted radio tags was low (10%), while 70% of controls and 90% of fish with externally mounted tags survived to the end of the experiment. However, Keefer et al. (2010) reported high loss of tags attached externally to spring Chinook salmon in the Willamette River basin, Oregon.

Corbett et al. 2012 cited problems with gastric implantation that included: stomach rupture; tag regurgitation, migrational delay; downstream fallback; and post-tagging mortality. During the spawning migration of salmon, tissues degenerate, particularly in the alimentary canal, and overall condition declines with advanced stages of sexual maturity (Corbett et al. 2012). However, in other studies, sockeye salmon (*O. nerka*) with ruptured stomachs after tagging lived and were observed to behave normally (Ramstad and Woody 2003).

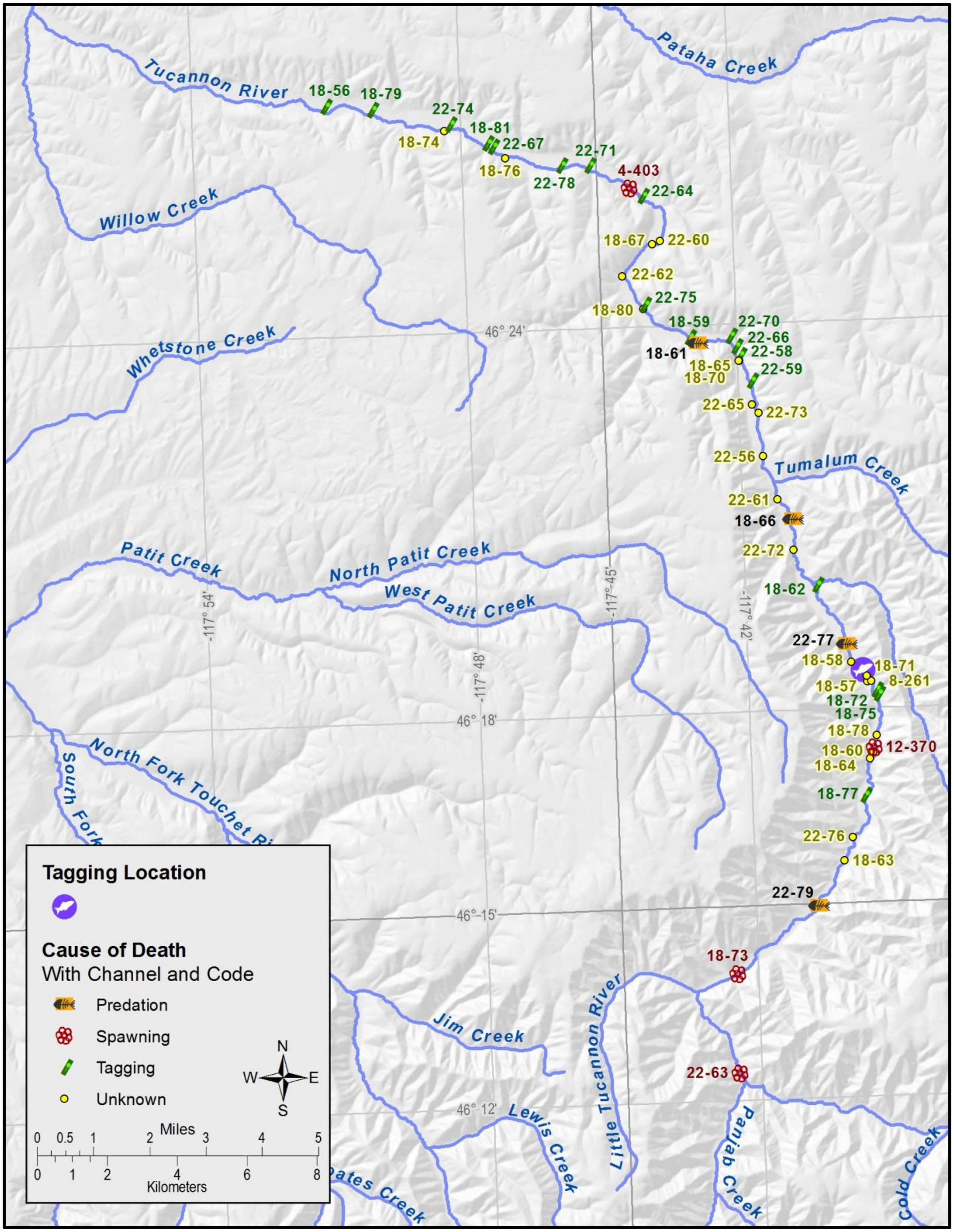

Figure 1. Final locations and recovery classification for spring Chinook salmon radio tagged at the Tucannon Fish Hatchery adult trap during 2014.

While our study did not provide much useful information, Keefer et al. (2010) found that radio tagged females had consistently higher pre-spawn mortality rates than males. They surmised that this may be related to both behavior (searching for redd sites) and physiology (larger investment in reproductive development than males). Naughton et al. (2013) and Keefer et al. (2010) also found that fish tagged later in the run, and fish that were thin had the highest rates of pre-spawn mortality.

Pre-spawn Mortality Surveys

We conducted pre-spawn mortality surveys from 13 June to 22 August during 2014, after which regular weekly spawning ground surveys commenced. Pre-spawn mortality surveys covered from Lady Bug Flat Campground (rkm 78) to Bridge 12 (rkm 47). The greatest number of surveys were conducted from Camp Wooten Bridge (rkm 68) to Cummings Creek Bridge (rkm 56) where the majority of fish historically hold prior to spawning. A total of 119 rkms were walked but only three pre-spawn mortalities were recovered that were not related to the radio telemetry study (Table 4). Pre-spawn mortality surveys have historically produced limited data as carcasses have a tendency to disappear quickly due to predators/scavengers. Cause of death could not be determined for any of the recovered pre-spawn mortalities, but all three had been partially to mostly consumed by predators/scavengers (Table 4).

Table 4. Recovery information for carcasses recovered from the Tucannon River during pre-spawn mortality surveys during 2014.

Recovery Date	Origin	Sex	Fork Length (cm)	Age	Recovery Location (rkm)	Comments
6/13/14	H	F	77	4	58.1	Fungus on head; scavenged.
6/26/14	H	J	47	3	59.3	Partially consumed.
8/08/14	H	M	---	4	61.6	Head only.

It has been suggested that the plastic jump barrier deployed along the top of the adult trap may be causing increased mortality of fish. Specifically, that fish were jumping and hitting the plastic curtain and it was de-sliming the fish and/or causing other injuries leading to mortalities. During the course of our investigations no documented evidence to support this theory was found through either pre-spawn mortality surveys or game cameras set up at the adult trap. Furthermore, the high pre-spawn mortality during 2013 was noted both above and below the trap. If the plastic jump barrier was the cause we would expect pre-spawn mortality to be higher below the adult trap. The hanging plastic curtain was installed during the winter of 2008 while the largest Tucannon River spring Chinook runs since the hatchery program began in 1985 occurred during 2009 and 2010 without the high pre-spawn loss observed during 2013 (Figure 1). Numerous other agencies also use similar jump barriers and scientific literature searches did not reveal any reports of high mortalities associated with these types of bypass barriers.

It has also been suggested that handling of fish at the TFH adult trap may also cause stress or injury, and has contributed to the pre-spawn loss. Fish are handled at the adult trap every year in order to collect broodstock for hatchery spawning and data for estimating run size and spawning escapement. Fish collected for broodstock are handled the most, however pre-spawn mortality rates of these fish have remained low (Gallinat and Ross 2014). Also, fisheries agencies in other watersheds handle a greater number of fish at their traps than those found on the Tucannon River without experiencing significant mortalities (Becky Johnson, Nez Perce Tribe, personal communication). In addition, the collection and handling process at the TFH adult trap has not been changed since the current adult trap was put in operation in 1998. Since the increase in pre-spawn loss has only been observed in the last few years (Figure 1), we do not believe that handling/sampling of fish at the TFH adult trap is responsible.

Fish with existing wounds or fungus on the head are observed every year at the TFH adult trap and during pre-spawn mortality and spawning ground surveys. These fish typically enter the Tucannon River in this condition (Figure 3). This is most likely the result of injuries sustained during the long migration through the hydrosystem from the ocean to their natal streams. During years with high flows in the migration corridor, numbers of fish with this condition may be high. Survival of these fish is thought to be low. However, flows through the migration corridor during 2013 were not considered to be unusually high, but other factors in the main stem Columbia and Snake rivers could also cause the injuries observed.

Figure 3. Photograph of a spring Chinook salmon with fungus on the head entering the Tucannon River near rkm 3.0.

Hidden Cameras

We used hidden game cameras to look for possible evidence of poaching and predation. Game cameras were deployed at river kilometers 77.7, 77.2, 67.5, 67.3, 64.3, and 59.0 at various times over the spawning period (end of August – September). Sport anglers were captured on the cameras when the river was closed to fishing. They were observed carrying lightweight gear (small spinning rods and flies) designed for trout fishing and were not suspected to be snagging salmon. However, salmon poaching likely occurs to some degree and has been documented since the very first radio telemetry surveys were conducted on the Tucannon River (Bugert et al. 1991). Evidence of poaching in the past has included transmitters recovered on the stream bank near popular fishing holes, transmitters found under rocks, snagging gear found along the stream bank, recovery of a salmon head cut off with a knife, and filleted salmon carcasses (Bugert et al. 1991; Bumgarner et al. 1994).

The cameras also captured predators scavenging on salmon carcasses. Predators/scavengers detected during this investigation included great blue heron (*Ardea herodias*), river otter (*Lontra canadensis*), mink (*Neovison vison*), and raccoon (*Procyon lotor*).

Hatchery personnel have noted an increase in the number of observations of river otters in recent years while working at the hatchery adult trap and Curl Lake Acclimation Pond (Doug Maxey, WDFW, personal communication). We did not photograph predators actively catching and consuming live fish on the game cameras; however, with only two cameras deployed at one time, the odds of doing so were likely small. On 28 August 2014, a female otter and her kit were chased off a freshly killed adult bull trout (*Salvelinus confluentus*) by a surveyor conducting spring Chinook spawning ground surveys at rkm 83.8. The head portion had already been consumed and all that remained of the fish was from the dorsal fin back to the tail (approximately 25 cm). Populations of these types of predators may be increasing in the Tucannon River watershed due to low harvest/trapping rates and larger run sizes of salmonids in recent years.

Water Quality

Temperature

Snake River Lab staff annually deploy continuous recording thermographs throughout the Tucannon River to monitor daily minimum and maximum water temperatures (temperatures are recorded every hour) from May through October. Data from each of these water temperature recorders are stored as electronic files in our Dayton office. We compared water temperatures at selected locations (rkms 22, 51.5, 61.3, 68.1, 77.8) for 2012, 2013, and 2014 (Figure 4). This allowed us to examine water temperatures for one year before and one year after 2013, the year with the high pre-spawn mortality rates.

Maximum water temperatures were slightly higher in 2013 than for 2012 and 2014 (Figure 4). Although average maximum and average mean water temperatures for 2013 and 2014 were nearly identical (Figure 4).

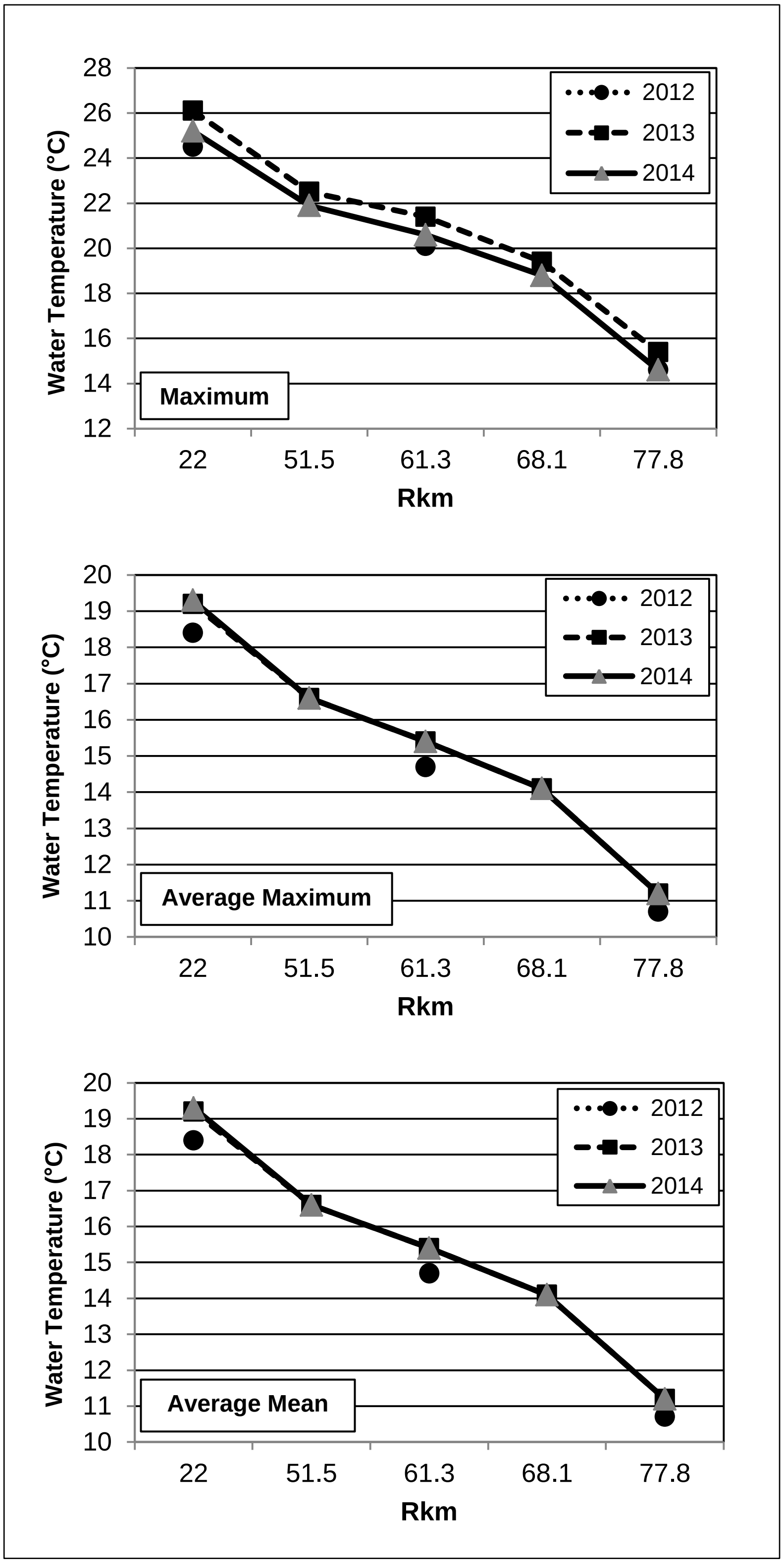

Figure 4. Maximum temperature, average maximum temperature, and average mean temperature recorded by thermographs at five selected sites along the Tucannon River for 2 June through 28 October for 2012, 2013, and 2014.

Water temperatures during 2013 peaked on 1 July at each recording location with the highest recorded temperature of 26.1°C at rkm 22. However, the majority of spring Chinook salmon had already entered the river by this time and were staging in the cooler water in the upper watershed. Mendel et al. (2007) provide a literature review table of seven day maximum temperature limits for various life stages for Chinook salmon. They report that to fully protect adult Chinook during migration that the 7-day average maximum temperatures should not exceed 17.0-19.0°C and that a barrier to migration appears when 7-day average maximum temperatures reach 20.1-24.6°C. The upper lethal temperature for adults was 21.0-26.0°C (Mendel et al. 2007). The average maximum temperatures where the majority of spring Chinook salmon hold in the Tucannon River were below these thresholds in all three years.

An improved understanding of the relationship between adult mortality and temperature is important given current climate predictions and uncertainty about the underlying mechanisms of pre-spawn mortality (Naughton et al. 2012). Chinook salmon are obligatory migrants and may have less flexibility in their migration timing response to environmental change (Keefer et al. 2004). Some stocks from the Columbia River are likely exposed to higher temperatures than those under which they evolved, and temperature-related stress and elevated metabolic demands may lead to higher incidence of pre-spawn mortality (Keefer et al. 2004). Even sub-lethal warm water temperatures during migration can be costly, resulting in elevated metabolic processes and increased stress which can increase the occurrence and virulence of several salmonid diseases (Keefer et al. 2010).

Habitat Alteration

One recent change that has occurred in the Tucannon River over the last couple of years is the reach scale size of the habitat improvement projects that are being carried out during the summer months. Prior habitat improvement projects were small and localized (100-200 meters in length), but recent projects have been 1-2 kilometers in length or greater. We would be remiss if we didn't also account for the possible effects this could have on the spring Chinook population. Tucannon spring Chinook salmon begin entering the Columbia River from the Pacific Ocean in February-March and start migrating into the Tucannon River in April/May; however they typically do not spawn until September. Bugert et al. (1992) found that Tucannon River spring Chinook salmon generally reduced their movements and began to "stage" or "hold" in mid-May to mid-June. These fish limited their movements until mid-August or early September (Bugert et al. 1992). Because spring-run Chinook salmon hold in freshwater for up to several months prior to spawning they may be particularly vulnerable to activities in the river that may depress the immune response and increase stress/mortality.

Migrating adult salmon rely on finite energy reserves and do not feed during their freshwater migration. These adults die within days to weeks of spawning, indicating their energy stores are likely fine-tuned by past selection to maximize reproductive output while also providing adequate energy to fuel upstream migration (Naughton et al. 2012). Activity in the river near holding/staging areas may cause fish to expend more energy than typical and prematurely deplete those energy stores.

Suspended sediment and turbid conditions over a wide range of levels and duration of exposure are known to adversely affect physiological, biochemical, histological, and behavioral responses of aquatic organisms (Newcombe and Jensen 1996). There is evidence that high suspended sediment concentration (SSC) is lethal to fish, and that somewhat lower levels of SSC and turbidity cause chronic sublethal effects such as stress and interference with environmental cues necessary for migratory orientation (Lloyd 1987). Lloyd (1987) emphasized that the spawning grounds of salmon and trout require special consideration and should be kept as free as possible from finely divided sediments. Salmonids are generally more susceptible to acute and chronic effects of sediment than are many species of warmwater fish; however, even among salmonids some species may be more sensitive than others (Lloyd 1987). Salmon may even stray into and spawn in non-natal rivers if their home river is altered sufficiently by suspended solids (Whitman et al. 1982). Turbidity level measurements were not known to have been taken during recent habitat improvement projects and potential effects are unknown.

Chemical Contaminants

Many western river systems receive substantial inputs from toxic chemicals (insecticides, herbicides, and other biocidal compounds), and the impacts of these compounds on salmon survival and reproductive health are poorly understood (Scholz et al. 2000). Toxic inputs were not sampled during this investigation due to lack of sufficient funding for this type of study, but we recognize the fact that they have the potential to play a significant role in salmon pre-spawn mortality. However, these compounds are typically used on an annual basis and the majority of Tucannon River spring Chinook salmon spawn above agricultural areas. Therefore, this factor may not apply to what was observed in 2013.

Disease/Histology Sampling

Pre-spawn mortalities of broodstock collected from the 2013 run year were low and within the historical range for fish collected and held at Lyons Ferry Hatchery since 1992 (Figure 5). There have been no fish health issues from the 2013 and 2014 run years (Steve Roberts, WDFW Fish Health Specialist, personal communication).

Two pre-spawn mortality carcasses recovered from the Tucannon River (radio tags 22-75 and 18-81) were histologically sampled during 2014. Tissue samples were collected from the gills, heart, liver, gastro-intestinal tract, ovaries, kidney, and spleen. Kidney and spleen samples were frozen. All other tissue samples were preserved in Davidson's Solution provided by WDFW Fish Health staff.

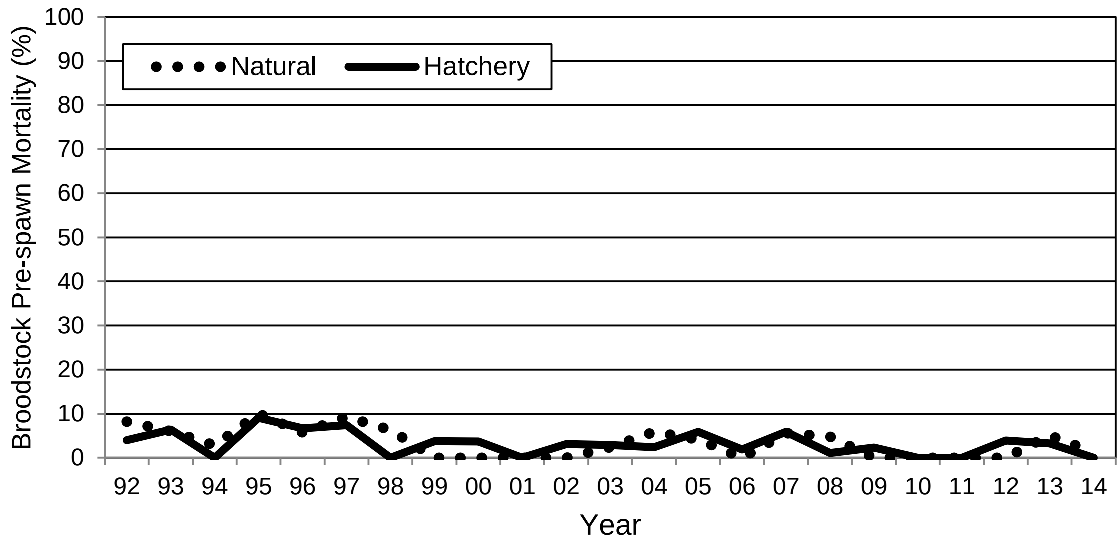

Figure 5. Pre-spawn mortality (%) of Tucannon River spring Chinook salmon collected for broodstock at Tucannon Fish Hatchery and held at Lyons Ferry Hatchery (1992-2014).

Kidney samples were examined for Bacterial Kidney Disease (BKD), which is caused by the bacterium *Renibacterium salmonirum*. Samples were tested for BKD by using the Enzyme Linked Immunosorbent Assay (ELISA) technique. Samples are categorized as "Below Low" (<0.10 Optical Density or O.D.), "Low" (0.11-0.19 O.D.), "Moderate" (0.20-0.45 O.D.), and "High" (> 0.45 O.D.). A fish with clinical signs (gray white lesions on the kidneys or other internal organs) would have an ELISA O.D. values in excess of 0.5 (Steve Roberts, WDFW Fish Health Specialist, personal communication). The results from both samples were "Below Low" (Table 6).

Table 6. Enzyme Linked Immunosorbent Assay (ELISA) results from kidney samples collected from Tucannon River Spring Chinook salmon pre-spawn mortalities during 2014.

Radio Tag ID	Origin & Sex	Histology Sample ID	ELISA Optical Density	ELISA Value
22-75	Hatchery Male	TU-CHS-01	0.058	Below Low
18-81	Hatchery Male	TU-CHS-02	0.082	Below Low

Both of the sampled carcasses had parasitic myxosporidian pansporoblasts and spores present. (Bethany Balmer, Washington Animal Disease Diagnostic Laboratory, personal communication). These parasites have been associated with high pre-spawn mortality in sockeye salmon (*O. nerka*) from the Fraser River in British Columbia, Canada (Bartholomew et al. 2007). Severity of infection in those fish was affected by water temperature, with early migrating fish having a higher vulnerability to infection as a result of longer holding time in the river before spawning (Bartholomew et al. 2007). Future collection of fresh pre-spawn mortality carcasses for histological examination is warranted (Steve Roberts, WDFW Fish Health Specialist, personal communication).

Discussion

We were unable to determine the cause of the high pre-spawn mortality rates observed in the Tucannon River during 2013. This was primarily due to the fact that the high pre-spawn mortality rates observed in 2013 were not duplicated in 2014 (Figure 6), and mortality associated with the radio telemetry project was very high. Results from on-going Willamette River spring Chinook salmon studies suggest that pre-spawn mortality is caused by an interaction of environmental factors (particularly water temperature), disease, fish condition, and energetic status (Naughton et al. 2012).

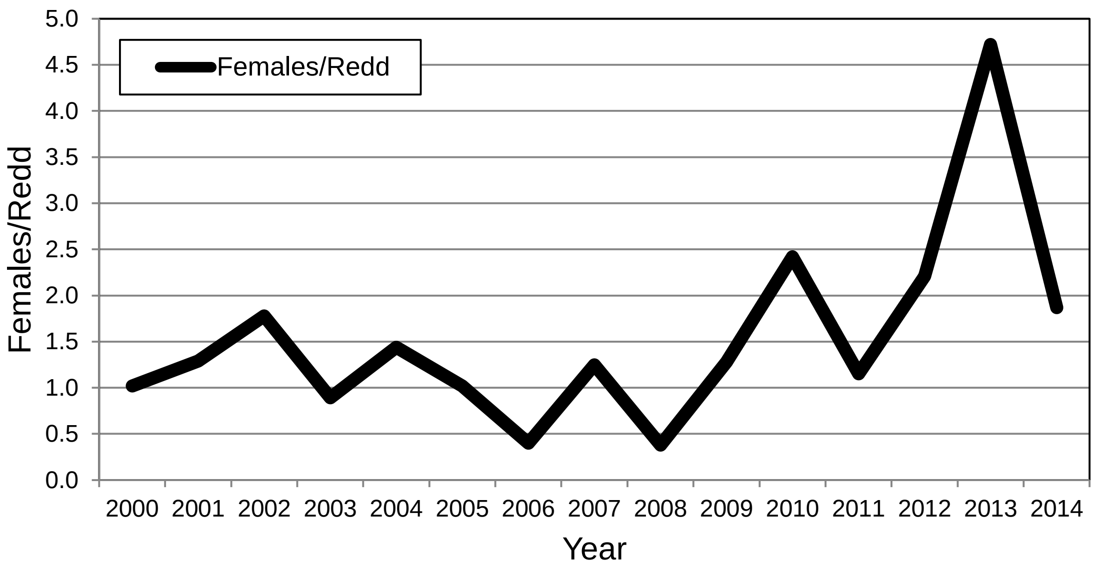

Figure 6. Females per redd ratio of Tucannon River spring Chinook salmon above the Tucannon Fish Hatchery adult trap, 2000-2014. The number of females is based on the number of captured females, and has not been adjusted for fish that bypass the adult trap via jumping the dam.

Some pre-spawn mortality is expected in any salmon population. In Oregon's Willamette River basin, adult salmon are routinely outplanted above dams to supplement natural production, but many die before spawning despite extensive suitable habitat (Keefer et al. 2010). High pre-spawn mortality levels have been observed in a number of Chinook salmon populations (Keefer et al. 2010; Naughton et al. 2012). At some sites, including some with relatively limited dam effects, mean annual pre-spawn mortality rates have been greater than 50%, and individual pre-spawn mortality estimates have frequently exceeded 90% (Keefer et al. 2010). In a study by Schreck et al. (1994), it was estimated that non-harvest mortality during migration and holding downstream from spawning areas ranged from 20-40%. High adult pre-spawn mortality can significantly affect production, particularly in small populations (Keefer et al. 2010).

We may never know what caused the high pre-spawn mortality rates observed in the Tucannon River during 2013, but it was likely caused by a combination of factors. It has been suggested by some that fish captured at the trap be held in hatchery tanks and released close to spawn time to lower pre-spawn mortality rates. However, there are inherent risks with such a plan, including but not limited to: transmission of disease, maturation effects, and catastrophic loss at the holding facility.

Recommendations

Progress is being made in rebuilding the Tucannon River spring Chinook salmon population with recruits per spawner for both hatchery and natural origin fish at or above replacement since 2004. However, adult returns have, for the most part, been well below management goals. Hatchery monitoring and evaluation personnel continue to explore new actions to improve overall returns of spring Chinook salmon to the basin, however if in-river survival is poor then these actions will be meaningless.

The following actions (in no particular order) are recommended for the future to maximize survival rates of returning adult salmon to the Tucannon River:

- Sport fishing regulations should be clarified and the closure of the Tucannon River above Marengo Bridge should be enforced, particularly during the month of September when spawning salmon are most vulnerable to poaching, harassment, and redd destruction by wading fishermen.

- Explore options to re-stock recreational fishing lakes with rainbow trout in the upper Tucannon River in early September to provide fishing opportunities to the public during that time of year.

- A depredation control plan, approved through the WDFW Enforcement and Wildlife programs, is recommended for the Tucannon River to help keep furbearer populations in check.

- Project leads of habitat improvement projects should be in communication with area fisheries biologists during the initial planning process to incorporate the protection of documented high use salmon holding and spawning areas in the river.

- Improvements to the holding areas of the TFH adult trap should continue (shading, etc.) and trap check frequency should be increased when large numbers of fish are moving upstream.

- The TFH adult trap/dam has been recognized as a barrier to fish passage since it was installed in 1998. Numerous options to improve attraction into the ladder/trap have been discussed, with some recently implemented. These enhancements should be monitored to see if they improve passage at the trap for all species of fish. If improvements are not made, than the TFH adult trap will need to be modified/redesigned.

- When and where possible, increase pre-spawn and spawning ground surveys for greater precision in our estimates. Recovered carcasses are critical to run size and spawning estimations, and may lead to more answers on pre-spawn mortality factors.

- Collect fresh pre-spawn carcasses for further histological examination.

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Appendices

Appendix A

Appendix A. Tag and recovery information for spring Chinook salmon tagged by Washington Department of Fish and Wildlife at the Tucannon Fish Hatchery adult trap during 2014.

Channel	Code	Tag Date	Origin	Sex	Fork Length (cm)	Recovery Date	Recovery Rkm	Cause of Death
18	56	5/17/14	N	F	67.5	6/08/14	31.7	Tagging
18	57	5/17/14	N	F	72.0	5/31/14	N/A	N/A - Regurgitated
18	58	5/18/14	N	F	69.0	6/08/14	58.5	Unknown
22	56	5/18/14	N	M	74.0	6/18/14	51.5	Unknown
22	57	5/18/14	N	M	65.5	N/A	N/A	Tag quit or left river
18	59	5/24/14	H	F	70.5	6/27/14	47.1	Tagging
18	60	5/24/14	N	F	70.0	6/25/14	61.5	Unknown
18	61	5/24/14	N	F	67.0	6/17/14	47.4	Predation
18	62	5/24/14	N	F	68.0	6/27/14	56.6	Tagging
22	58	5/24/14	N	M	74.0	6/18/14	48.9	Tagging
22	59	5/24/14	N	M	70.5	6/17/14	50.6	Tagging
22	60	5/24/14	N	M	74.5	6/12/14	43.0	Unknown
18	63	5/25/14	N	F	77.0	6/24/14	64.8	Unknown
18	64	5/25/14	H	F	70.0	7/02/14	61.8	Unknown
18	65	5/25/14	H	F	74.5	6/23/14	50.1	Unknown
18	66	5/25/14	N	F	65.0	6/19/14	53.4	Predation
22	61	5/25/14	N	J	47.5	6/19/14	53.2	Unknown
18	67	5/29/14	H	F	75.5	6/16/14	43.4	Unknown
18	70	5/29/14	N	F	76.5	6/18/14	48.8	Unknown
22	62	5/29/14	N	M	73.5	6/18/14	43.9	Unknown
18	71	5/30/14	N	F	78.0	6/25/14	59.6	Unknown
22	63	5/30/14	N	M	65.5	9/03/14	74.4	Spawned
22	64	5/30/14	N	M	64.5	6/18/14	42.2	Tagging
22	65	5/30/14	N	M	65.5	6/24/14	51.3	Unknown
22	66	5/30/14	N	M	73.0	6/19/14	47.2	Tagging
22	67	5/30/14	H	J	54.0	6/18/14	36.5	Tagging
18	72	5/31/14	N	F	68.0	6/25/14	61.2	Tagging
18	73	5/31/14	N	F	68.0	9/12/14	69.3	Spawned
18	74	5/31/14	H	F	69.5	6/18/14	36.0	Unknown
18	75	5/31/14	H	F	70.0	7/01/14	60.0	Tagging
18	76	5/31/14	H	F	69.5	6/26/14	37.0	Unknown
22	70	5/31/14	H	J	49.0	7/07/14	47.5	Tagging
22	71	5/31/14	H	M	69.5	6/18/14	39.8	Tagging
22	72	5/31/14	H	M	71.5	6/23/14	54.9	Unknown
18	77	6/01/14	H	F	64.0	6/24/14	61.9	Tagging
18	78	6/01/14	H	F	72.0	6/25/14	61.6	Unknown
18	79	6/01/14	H	F	67.0	6/18/14	31.9	Tagging
22	73	6/01/14	H	M	61.5	6/23/14	50.2	Unknown
18	57 #2	6/02/14	N	F	72.5	6/25/14	59.9	Unknown
18	80	6/02/14	H	F	66.5	6/18/14	46.3	Unknown
18	81	6/02/14	H	M	64.0	6/17/14	36.5	Tagging
22	74	6/02/14	H	M	65.0	6/18/14	34.9	Tagging
22	75	6/02/14	H	M	69.5	6/16/14	46.3	Tagging
22	76	6/09/14	H	J	52.0	7/23/14	64.6	Unknown
22	77	6/09/14	N	J	55.0	7/07/14	58.1	Predation
22	78	6/12/14	H	M	76.0	6/26/14	37.0	Tagging
22	79	6/12/14	H	M	72.0	8/12/14	62.5	Predation

Appendix B

Appendix B. Tag and recovery information for spring Chinook salmon tagged by the University of Idaho at Bonneville Dam that entered the Tucannon River during 2014.

Channel	Code	Tag Date	Origin	Sex	Fork Length (cm)	Recovery Date	Recovery Rkm	Cause of Death
12	370	4/08/14	N	M	64.0	9/15/14	61.5	Spawned
8	261	5/30/14	N	M	88.0	9/16/14	59.3	Unknown
4	403	5/30/14	H	J	49.5	9/22/14	40.0	Spawned