

2011

Assessing Sources for Nutrient Enhancement



*Prepared for: Rock Island Habitat Conservation Plan
Tributary Committee (#2010-05 RI)*

Table of Contents

Table of Contents	i
Acronyms	ii
Introduction	1
Objective	2
Background/History	3
Methods	5
Results	6
Adult Salmon and Steelhead Collection	6
Pathogens Found in Adult Salmon and Steelhead	7
Treatment of Pathogens Found in Adult Salmon and Steelhead	8
Disposal of (Treated) Adult Salmon and Steelhead Carcasses	9
Disposal of (Untreated) Excess Adult Salmon and Steelhead Carcasses	9
Adult Management Plans	9
Federal Allocation of Excess Broodstock	10
Use and Distribution of Salmon and Steelhead Carcasses for Nutrient Enhancement	12
Storage and Transportation	12
Cost	13
Other Sources of Marine Derived Nutrients	13
Storage and Transportation	14
Cost	14
Local, State, and Federal Agency Roles and Responsibilities	14
Discussion	18
Acknowledgements	20
References	21
Other Sources of Literature	22
Appendices	23
Appendix A – Hatchery Interview Questions.....	23
Appendix B - Hatchery Facilities in Washington’s Upper Columbia River Basin.....	24
Appendix C – USFWS Risk Assessment.....Nutrient Enrichment.....	25
Appendix D – USFWS Carcass Selection Criteria.....	28
Appendix E – WDFW Protocols and Guidelines for Distributing Salmonid Carcasses.....	30

Acronyms

BIA	Bureau of Indian Affairs
CCFEG	Cascade Columbia Fisheries Enhancement Group
CCT	Colville Confederated Tribe
USACE	United States Army Corps of Engineers
MDN	Marine Derived Nutrients
HSRG	Hatchery Scientific Review Group
NFH	National Fish Hatchery
UCSRB	Upper Columbia Salmon Recovery Board
RTT	Regional Technical Team
WDOE	Washington Department of Ecology
WDFW	Washington Department of Fish and Wildlife
USFWS	United States Fish and Wildlife Service
YN	Yakama Nation
QAPP	Quality Assurance Project Plan
OFHC	Olympia Fish Health Center
ESA	Endangered Species Act
NMFS	National Marine Fisheries Service
ISRP	Independent Scientific Review Panel
PUD	Public Utility District

Introduction

Pacific salmon and steelhead once contributed large amounts of marine-derived carbon, nitrogen and phosphorus to freshwater ecosystems in the Pacific Northwest. These marine derived nutrients (MDN's) are no longer available in the historic quantities because fewer adult fish are returning to freshwater systems. MDN's have been detected throughout the food chain (flora and fauna) in and along anadromous streams and studies have shown direct and indirect uptake by juvenile salmon, as well as subsequent increases in growth and survival. In a recent meta-analysis, Roni et al. (2008) found *“all studies (18) on nutrient addition reported some positive response by fish or other biota”*. Recent research has indicated that MDN loading rates as low as 6 to 15% of historical levels currently exist in many salmon streams in the Pacific Northwest (Jorgenson 2010). To compensate for reduced nutrient load and resultant lowered stream productivity, recent mitigation efforts have focused on addition of nutrients to freshwater systems (HSRG 2009).

The Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007) calls for nutrient enhancement in specific watersheds within the Columbia Basin. With funding from the Rock Island Tributary Committee, Cascade Columbia Fisheries Enhancement Group (CCFEG) has compiled this assessment to support stakeholders with planning and conducting nutrient enhancement in the Upper Columbia salmon recovery region. The intent of this report is to investigate the feasibility of using excess salmon and steelhead carcasses for nutrient enhancement and to investigate other potential sources of nutrients for distribution.

Objective

The purpose of this assessment is to investigate logistical and technical aspects of collecting, storing, screening, transporting, and distributing excess hatchery-origin salmon carcasses throughout the Upper Columbia region, including the Wenatchee, Entiat, and Methow basins. Other sources of nutrients are also examined. The objective of this report is to provide information for stakeholders interested in implementing nutrient enhancement.

Background/History

Historically, hundreds of thousands of salmonids from the Upper Columbia Basin are believed to have migrated to and from the ocean; sockeye were most abundant, followed by coho, summer/fall, spring run Chinook salmon, and steelhead (Mullan et al. 1992). The run timing of these abundant stocks overlapped and likely provided a relatively steady stream of returning marine derived nutrients to the watersheds throughout the year. Factors, usually categorized under the “four H’s” - habitat, hydro, harvest, and hatcheries - are usually attributed to the continued depression of salmonids, not only in the Upper Columbia Basin, but throughout salmon’s range. Dams constructed on tributaries to the Columbia for early log transport, degradation of spawning habitat from logging and mining activities, and commercial fisheries were the causes for the initial declines, followed by modifications from dams, which continue to impact salmonid productivity.

Currently, populations of spring Chinook salmon, summer steelhead and bull trout are listed under the Endangered Species Act, while populations of sockeye and summer/fall Chinook salmon in the Upper Columbia Region are relatively stable. Coho, once abundant in the Upper Columbia were extirpated due the factors aforementioned. The Yakama Nation are reintroducing coho salmon throughout their native range in the Middle and Upper Columbia River tributaries; however, the number of returning coho adults today remains well below historic numbers.

As wild stocks of spring Chinook salmon and steelhead remain at risk for extinction in the Upper Columbia, many hatchery programs are being implemented to mitigate for the effects of hydropower construction and operation on anadromous salmon and steelhead populations. Mitigation programs, specifically those involving ESA listed and threatened species (spring Chinook and steelhead) are being operated to assist in recovery. These programs are implemented to meet each of the projects proportional inundation and/or No Net Impact obligations under their respective FERC license agreements. Some ancillary benefits of these programs are to increase natural origin fish abundance and harvest.

The Hatchery Scientific Review Group (HSRG) evaluated hatchery practices throughout the Columbia Basin and Puget Sound and developed several recommendations to reduce potential negative effects of hatchery programs on natural populations. The US Congress established the HSRG project in 2000 because it recognized that while hatcheries play a legitimate role in meeting harvest goals for Pacific Northwest salmon and steelhead, the hatchery programs were in need of comprehensive reform. One of the many recommendations from the HSRG included nutrient enhancement: *“use some of the surplus fish to provide ecological benefit through nutrient enhancement of streams and rivers”* (HSRG 2009).

The Upper Columbia Spring Chinook and Steelhead Recovery Plan (the Plan; UCSRB 2007) acknowledge the lack of marine derived nutrients as a potential limiting factor inhibiting recovery. According to the

Upper Columbia River Regional Technical Team's (RTT) Biological Strategy (RTT 2007), understanding the need and magnitude for nutrient enhancement is considered a high priority data gap. In addition, Mullan et al. (1992) demonstrated that the Methow, Entiat, and Wenatchee watersheds have some of the lowest nutrient loads of anadromous streams and may benefit from nutrient enhancement activities.

Recognizing the significant reduction of marine derived nutrients in oligotrophic (low nutrient) streams throughout the northwest, salmon recovery stakeholders have been experimenting with increasing nutrients using a variety of techniques, including planting hatchery carcasses, carcass analogs (fish meal based pellets), and organic fertilizers. Benefits from nutrient enhancement actions are generally short-lived and spatially limited, whether the nutrients are added as part of a restoration activity or a function of natural spawning (Honea and Gara 2009). The ultimate goal is to recover populations, which will sustain adequate levels of marine derived nutrients in the watershed thereby eventually rendering nutrient enhancement projects unnecessary.

Throughout the Upper Columbia region and the Pacific Northwest stakeholders are investing millions of dollars to rehabilitate stream habitats for depleted salmon stocks. While these efforts will most likely improve freshwater survival of salmon and steelhead over the long term (multiple life cycles), it is difficult to detect improvements to survival and growth of the target species and life stages. Nutrient enhancement is employed to boost primary production in oligotrophic streams and lakes, which increases food availability and subsequent survival of juvenile salmonids. While the effects of nutrient enhancement may be short lived, many published studies point to direct positive influences on growth of juvenile salmon. Nutrient enhancement cannot replace the role of process-based habitat restoration, but compliments these efforts as a means of stimulating the base of the food web in nutrient deficient systems.

Methods

Adult collection hatcheries in the Upper Columbia region were identified and hatchery staff were interviewed ([Appendix A](#)) to obtain the following:

- a qualitative summary of hatchery carcasses (including species, run timing, and average numbers),
- storage and transportation capacity (e.g., trucks, totes, freezers),
- prevalent disease, pathogens and treatment history, and
- other relevant information, such as existing practices for the disposal of salmon carcasses.

Interviews with hatchery staff indicated that many of the hatchery-origin salmon retained at hatchery facilities were treated with medications. State and federal fish pathologists were consulted to discern the presence of pathogens and current hatchery practices used to remedy disease transmission.

CCFEG ascertained water quality concerns related to nutrient enhancement, identified existing water quality data collection efforts and Total Maximum Daily Load (TMDL) “hot spots”, sought guidance/guidelines for implementing nutrient enhancement plans, and established personnel contacts from the Washington Department of Ecology (WDOE).

In June 2011, CCFEG held a nutrient enhancement workshop to collaborate with representatives from local Public Utility Districts, Washington Department of Fish and Wildlife (WDFW), United States Fish and Wildlife Service (USFWS), Yakama Nation, Chelan County, Trout Unlimited, Washington Department of Ecology (WDOE), Water Quality Engineers, and the Upper Columbia Salmon Recovery Board. Stakeholders discussed challenges, opportunities, and experiences conducting nutrient enhancement.

State and Federal agencies processes roles and responsibilities were documented as related to nutrient enhancement.

Other sources of nutrients such as analogs, pikeminnow, and shad were researched to determine the feasibility of distribution within a watershed.

Results

Adult Salmon and Steelhead Collection

Seven state and federal hatcheries in Washington's Upper Columbia region (Figure 1 and [Appendix B](#)) were selected as potential sources of carcasses for conducting nutrient enhancement. Upper Columbia hatcheries collect hatchery-origin adult salmon and steelhead on-site or at remote locations, hold them until "ripe" (gametes are mature), and spawn them. Some hatcheries collect the exact number of spawning adult fish to meet brood targets, while other hatcheries collect all returning adults (Table 1).

Figure 1. Hatchery collection and facility locations in the Upper Columbia.

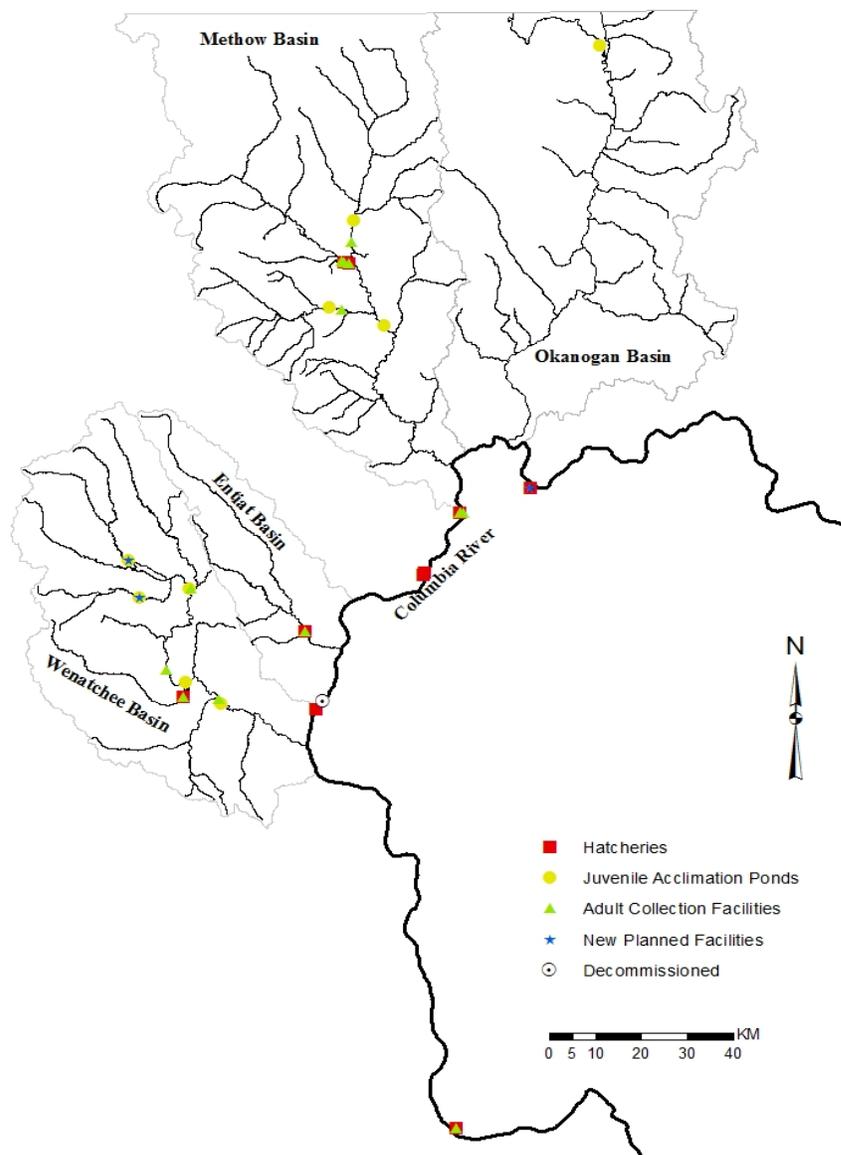


Table 1. Salmon and steelhead escapement and brood targets for Upper Columbia Hatcheries.

Hatchery	Species	Spawn Timing	Escapement (to Hatchery)	Brood Target
Leavenworth National Fish Hatchery	Spring Chinook	Aug/Sept	4,264	1,000
	Coho	Oct/Nov	<i>Collected remotely.</i>	1,000
Entiat National Fish Hatchery	Summer Chinook	October	<i>Adults from Wells Dam.</i>	200-240
Winthrop National Fish Hatchery	Spring Chinook	Aug/Sept	1,000	400
	Coho	Oct/Nov	500	500
	Steelhead	April/May	28	28
Priest Rapids	Fall Chinook	Sept/Oct	10,000-13,000	4,500
Eastbank Complex	Spring Chinook	Aug	<i>All adults collected at remote sites in Wenatchee.</i>	170
	Summer Chinook	Oct		1,048 ¹
	Sockeye	Sept/Oct		206
	Steelhead	Feb/March		208
Wells Complex	Summer Chinook	Oct	3,015	1,200
	Steelhead	Feb-April	1,040	327
Winthrop WDFW	Steelhead	Aug/Sept	40	40
	Spring Chinook	April/May	360	360

¹ Includes 556 summer Chinook adults collected at the east and west ladders of Wells Dam and transferred to Eastbank for the Methow and Okanogan programs.

Results show that escapement at three hatcheries exceeds brood targets and surplus fish may be available for nutrient enhancement. However, a majority of fish collected at hatcheries are either distributed for consumptive use or treated with antibiotics, hormones, or sedatives and are not viable for nutrient enhancement (Table 2). (All broodstock are injected with an antibiotic or sedative at Federal hatcheries.)

Pathogens Found in Adult Salmon and Steelhead

Hatchery and natural-origin salmon and steelhead in the Upper Columbia region carry certain pathogens (Table 2). Most diseases caused by bacteria, viruses, and parasites are transmitted from carcasses of infected fish to live fish via juvenile consumption of the infected carcasses or by the release of pathogens into the water (i.e., feeding and rearing habitat). Many pathogens

survive in the water, the sediment, invertebrates (e.g., leeches or small worms), and/or birds and animals and can later infect fish (USFWS 2006). To address these concerns, state and federal fish pathologists have developed treatments for broodstock at their respective hatchery facilities.

Treatment of Pathogens Found in Adult Salmon and Steelhead

After salmon and steelhead have been collected, and prior to spawning, broodstock are regularly inoculated with various antibiotics and drugs for handling and to prevent disease outbreaks. Some of these medications can be metabolized over the course of several weeks making the fish potential candidates for nutrient enhancement out-planting, while other treatments render hatchery-origin carcasses unusable for nutrient enhancement (Table 2). If treated fish are spawned or die prior to the specified withdraw times they are deemed unusable.

Table 2. Pathogens, treatments and persistence of medications in adult salmon and steelhead found in Upper Columbia hatcheries.

Hatchery	Species	Pathogen	Treatment	Persistence
Leavenworth National Fish Hatchery	Spring Chinook	BKD, IHNV, external parasites, fungus,	MS-222, Formalin, Hydrogen Peroxide, Erythromycin	21 days 0 days 0 days 90 days
	Coho	n/a	n/a	n/a
Entiat National Fish Hatchery	Summer Chinook	BKD, furunculosis, external parasites, fungus	Erythromycin Oxytetracycline Formalin	90 days 90 days 0 days
Winthrop National Fish Hatchery	Spring Chinook	BKD, IHNV, external parasites, fungus	Erythromycin Formalin	90 days 0 days
	Coho	Coho	n/a	n/a
	Steelhead	Coho	n/a	n/a
Priest Rapids	Fall Chinook	BKD, external parasites	Erythromycin Formalin	90 days 0 days
Eastbank Complex	Spring Chinook	BKD, columnaris	Erythromycin Oxytetracycline	90 days
	Summer Chinook	BKD, columnaris	Erythromycin Oxytetracycline	90 days
	Sockeye	BKD, columnaris	Erythromycin Oxytetracycline	90 days
	Steelhead	BKD, columnaris	Erythromycin Oxytetracycline	90 days

Wells Complex	Summer Chinook	BKD,IHNV, columnaris, ERM, furunculosis	Oxytetracycline Erythromycin Chloramine-T	90 days 90 days 0 days
	Steelhead	IPVN	Oxytetracycline Chloramine-T	90 days 0 days
Methow WDFW	Steelhead	n/a	n/a	n/a
	Spring Chinook	BKD , external parasites	Formalin Erythromycin	0 days 90 days

Disposal of (Treated) Adult Salmon and Steelhead Carcasses

Adult salmon and steelhead used for broodstock are treated with medications for handling and to limit exposure and amplification of pathogens while being held at the hatchery for maturation and spawning. Once broodstock targets have been met, hatcheries must dispose of spawned salmon and steelhead carcasses. Once spawned, these carcasses are deemed unusable for nutrient enhancement, (unless fish have been kept alive long enough to metabolize medications administered at the hatchery) and either buried on-site or hauled to a municipal landfill.

Disposal of (Untreated) Excess Adult Salmon and Steelhead Carcasses

While a majority of broodstock carcasses are not suitable for use in a nutrient enhancement program, there are hatchery-origin adult salmon and steelhead that are not treated with medications. These fish are in excess of broodstock goals and pose a low/no risk of carrying infectious disease. These fish are collected and disseminated or disposed of according to state hatchery protocol, adult management plans, or other agreements. The Yakama Nation's adult hatchery-origin coho are not treated with sedatives or antibiotics and are therefore a potential source of carcasses for nutrient enhancement.

Adult Management Plans

Adult management plans are being initiated by the WDFW and other stakeholders within the Upper Columbia region. For example, the adult management plan for Wenatchee basin spring Chinook salmon allocates excess hatchery-origin fish for various environmental, social, and political functions. Depending on the abundance of fish returning to the Wenatchee River, excess hatchery-origin fish from the Wenatchee River are dispersed as follows (not in order of priority):

1. Distribution (out planting) to minor spawning areas (live fish).
2. Consumptive uses (Tribal ceremonial/subsistence, food banks, etc.).
3. Nutrient enhancement.

4. Conservation fisheries.
5. Non-human consumptive use (e.g., rendering plant).

At any given time one or more of these elements may be implemented to manage adult surpluses. The quantity, quality, and timing are factors considered for carcass allocation to the most appropriate venue.

While nutrient enhancement may not be the first priority of an adult management plan, in years of high abundance, there may be opportunities to distribute excess hatchery-origin fish in streams with low levels of marine derived nutrients.

Federal Allocation of Excess Broodstock

Adult salmon in excess to broodstock needs at the USFWS's Entiat, Winthrop, and Leavenworth National Fish Hatcheries are primarily allotted to local Native American Tribes for subsistence and ceremonial purposes. Some fish may, particularly later in the run, may be deteriorated and inappropriate for consumptive use and therefore available for nutrient enhancement. After spawning the carcasses are potentially available for nutrient enhancement; however, carcasses require pathogen screening to determine the potential of disease transmission prior to distributing throughout the watershed.

While it appears that there may be thousands of surplus hatchery fish available for nutrient enhancement, when disease control measures and hatchery requirements for allocation for consumptive uses are accounted for, the total number of fish available for nutrient enhancement throughout the Upper Columbia basin is relatively low (Table 3).

Table 3. Total number of hatchery-origin salmon and steelhead carcasses available for nutrient enhancement in the Upper Columbia River Basin. The numbers below do not account for subsistence and ceremonial allocation.

Basin	Hatchery	Species	Number of Untreated Hatchery-Origin Carcasses Potentially Available for Nutrient Enhancement (Average per Year)
Wenatchee	Leavenworth National Fish Hatchery	Spring Chinook	0 ¹
		Coho ²	1'000
Entiat	Entiat National Fish Hatchery ³	Summer Chinook	0
Methow	Winthrop National Fish Hatchery	Spring Chinook	1,000
		Steelhead	28 ¹
		Coho	500 ²
	Winthrop WDFW	Spring Chinook	0
		Steelhead	40
Columbia (Mainstem)	Priest Rapids ⁴	Fall Chinook	In excess of brood (Potentially ~5,000)
	Eastbank Complex	Summer Chinook	0
		Spring Chinook	0
		Sockeye	0
		Steelhead	0
	Wells Complex	Summer Chinook	1,815 ¹
		Steelhead	713 ¹

*No adult collection hatcheries are located in the Okanogan Basin.

¹ Typically Native American Tribes receive high quality surplus fish. Fish collected in excess of brood and Tribal needs may be available for nutrient enhancement.

² Coho (at the hatchery) are the property of the Yakama Nation, but may be available for nutrient enhancement.

³ In the near future the Entiat NFH may have adult summer Chinook available.

⁴ Some of the excess carcasses at Priest Rapids are obligated to other programs; however, this is the single largest opportunity to collect salmon carcasses for nutrient enhancement.

Use and Distribution of Salmon and Steelhead Carcasses for Nutrient Enhancement

Until recently, some hatchery programs would regularly distribute brood and surplus salmon carcasses throughout basins in which the fish returned. However, management practices have become more conservative and risk averse to avoid transmitting and amplifying pathogens to natural-origin fish. In order to use hatchery-origin salmon carcasses for nutrient enhancement, the USFWS Fish Health Center recommends assessing the risks associated with carcass planting for nutrient enrichment ([Appendix C](#)) and following the “Carcass Selection Criteria for Planting of Adult Salmonids to Benefit Stream Productivity” ([Appendix D](#)) to reduce the risk of amplifying and/or transmitting pathogens. WDFW also has protocols and guidelines for conducting nutrient enhancement ([Appendix E](#)).

Heat pasteurization can be employed to reduce disease transmission via carcass distribution; however, further refinement of this technique will need to be developed. Specifically, the pasteurization process must preserve target nutrients and ensure nutrients are not lost through the pasteurization process, while eliminating risks of pathogens. Heat pasteurization is likely not feasible for neutralizing medications as relatively high heat would be needed (i.e., temperatures must exceed 300°F). Further, it is likely not cost effective to expend the energy and resources pasteurizing hatchery fish provided other potential alternatives, such as analogs, are readily available.

In summary, certain criteria need to be met before hatchery-origin carcasses can be used for nutrient enhancement.

Storage and Transportation

Most hatchery staff indicated that totes and trucks are available for transporting carcasses; however, these resources are committed to essential functions of the individual hatcheries. Some hatcheries also had freezers available, but it was recommended that small chest freezers be purchased for freezing smaller quantities of carcasses, as it would not be cost effective to use the large walk-in freezers to store smaller quantities of carcasses.

Stakeholders interested in utilizing existing resources at State and Federal hatcheries will need to communicate and agree on individual needs and arrangements; however, to guarantee adequate storage and transport it is recommended that totes, trailers and transportation be provided by the proponent. (Plastic totes are readily available from suppliers in the Northwest and cost around \$300.00 per tote.) For small, volunteer based nutrient enhancement activities hatchery staff may be able to provide the infrastructure to store and transport carcasses. Nutrient enhancement is not the highest priority of the Upper Columbia hatcheries and individual arrangements will need to be made to ensure infrastructure support.

Cost

The cost of distributing carcasses throughout the watershed for nutrient enhancement is dependent on the size and scope of the treatment. Costs may include, but are not limited to: fish health examinations, eviscerating and beheading carcasses, pasteurization, storage, transportation, permitting, agency approval, and physical distribution (labor). State and Federal hatchery facilities in the Upper Columbia region are generally amenable to this activity and may provide limited infrastructure (e.g., freezer space, totes, and trucks) support. For relatively small volunteer-based nutrient enhancement projects, hatcheries may be able to provide infrastructure support; however, for larger sustained efforts stakeholders are encouraged not to rely solely on hatchery resources.

Other Sources of Marine Derived Nutrients Used for Nutrient Enhancement

The practice of releasing salmon carcasses from hatcheries is thought to be the preferred source of nutrients, but there are considerable logistical problems with deploying large numbers of salmon and steelhead carcasses throughout a stream network. Salmon carcasses are logistically unwieldy, may not be in steady supply, and carry disease transfer risks (Pearsons et al. 2007). The recent development of carcass "analogs" has been suggested as a much more tractable method, with the additional advantage of being able to deploy the material at the desired time and place, not just when fish are available from a hatchery (ISRP Project #200704099), and have a lower risk of pathogen transfer.

Analogs are essentially a larger version of fish food found at a fish hatchery. They come in a variety of sizes (6-10cm in diameter) and can be made up of fish meal from any number of fish species including, but not limited to: anchovy, Pacific hake, salmon, and salmon/hake blends of fish meal. These special order products are available from a number of manufacturers in the Pacific Northwest and Canada including Skretting (a subsidiary of [Bio-Oregon](#)) and [Aqua Dine](#) based out of California.

Other potential sources of fish meal, or nutrients, for the production of analogs could come from abundant shad runs in the lower Columbia or, despite not containing Marine Derived Nutrients, pikeminnow from the BPA-lead bounty program. In the Upper Columbia over 100,000 pikeminnow are removed annually via sport and commercial fisheries and at five-six fish per pound this opportunity could offer upwards of 20,000lbs of fish based nutrients. While pikeminnow do not offer traces of marine derived nutrients, they may be a viable and consistent source for fish meal for the production of carcass analogs. Currently, WDFW is operating an experimental commercial shad fishery in the Lower Columbia. This source may offer a similar nutrient signature (MDN) as they spend a portion of their lives at sea. Testing of the nutrient composition and viability (including pathogen testing) of creating an analog from these sources needs further investigation.

The application of fertilizer to increase wild fish production has been conducted in the Pacific Northwest for years. Currently, there are two methodologies in use: (1) introducing liquid fertilizer into the water via large slug dosages or through low-level drip and (2) placing solid fertilizer pellets that dissolve at a

predetermined rate to release nutrients over a period of months. Both methods have been shown to cause substantial increases in fish growth, survival, condition factors, and the like. Water quality monitoring associated with the application of these fertilizers has shown that they are rapidly taken up into the food chain and are generally not detectable in the water column outside of the treatment area/reach (Michael, J.H., WDFW, 2002).

Storage and Transportation

If analogs are used in place of hatchery carcasses, freezer storage and totes will not be necessary, although walk-in freezers available at many of the hatcheries may provide convenient, secure, dry and cool places to store the analogs. Analogues are lighter in weight per nutrient unit than carcasses, come in 50lb bags, and can be transported in any vehicle.

Cost

Costs may include, but are not limited to: purchasing the product, storage, transportation, permitting, agency approval, and physical distribution (labor). Recently, the Lower Columbia Fisheries Enhancement Group developed a salmon based analog with AquaDine which sell for about \$2.00 per pound. Finding a more consistent and local source of fish meal in the Northwest may lead to reduced costs for production and sale of analog products.

Local, State, and Federal Agency Roles and Responsibilities

It became clear during the assembly of this assessment and the workshop held in June 2011, that there are many stakeholders throughout the Upper Columbia region who have an interest in nutrient enhancement. While several of the stakeholders have a direct interest in conducting nutrient enhancement, others will play a role through funding, regulation, and technical support based on their management responsibilities and mandates (Table 4).

Table 4. Roles and responsibilities of stakeholders.

STAKEHOLDER	ROLES & RESPONSIBILITIES
<p>Washington Department of Fish and Wildlife (WDFW)</p>	<ul style="list-style-type: none"> • Manages Public Utility District funded hatcheries in Washington’s Upper Columbia River Basin. As a fish and hatchery manager, follows HSRG recommendations (such as implementation of adult management actions to remove excess hatchery-origin fish on the spawning grounds) and implements a carcass disposal contract. • Develops protocols and guidelines for distributing salmon carcasses, analogs, and fertilizers to enhance stream productivity (Appendix E). These protocols and guidelines require final approval from the WDFW Regional Fish Program Manager prior to the supplementation of nutrients into streams. (Application and Approval Forms can be obtained from the Fish Health Center in Olympia, WA.) • Provides hatchery carcasses and infrastructure to store and transport carcasses, if resources allow. • Provides technical assistance, fish health screening, and Carcass Transfer Permits.
<p>US Fish and Wildlife Service (USFWS)</p>	<ul style="list-style-type: none"> • Manages Bureau of Reclamation funded hatcheries in the Upper Columbia. • Provides hatchery carcasses and some facilities and/or equipment in the form of trucks, totes, storage space and/or personnel store and transport carcasses, if resources allow. • Provides technical assistance and fish health screening through Olympia Fish Health Center. • Provides guidelines for selecting carcasses and streams for nutrient enhancement (Appendices C and D).
<p>Yakama Nation (YN)</p>	<ul style="list-style-type: none"> • Conducts nutrient enhancement activities in the Methow and Wenatchee watersheds at the present time. • Serves as one of the Upper Columbia co-managers. Project proponents of nutrient enhancement activities should coordinate with YN prior to implementation.
<p>Colville Confederated Tribe (CCT)</p>	<ul style="list-style-type: none"> • Serves as one of the Upper Columbia co-managers. Project proponents of nutrient enhancement activities should coordinate with CCT prior to implementation.

STAKEHOLDER	ROLES & RESPONSIBILITIES
Washington Department of Ecology (WDOE)	<ul style="list-style-type: none"> • Serves as the lead agency for implementing and ensuring compliance with the Federal Clean Water Act and State water quality standards. In watersheds such as the Wenatchee, their management and regulatory role is important given the degraded water quality and subsequent nutrient loading restrictions outlined in the Total Maximum Daily Load (TMDL) (WDOE 2009). • Issues Administrative Orders or other permit for implementing nutrient enhancement actives, if necessary. While WDOE is working to develop regulatory guidance for considering nutrient enhancement implementation, the avenue for receiving their approval is currently through an Administrative Order. • Requires a Quality Assurance Project Plan (QAPP) as a condition of their approval to conduct nutrient enhancement in certain watersheds, if applicable. A QAPP must follow WDOE protocols and provide specific information about each proposal. <p><i>WDOE should be consulted prior to the dispersal of carcasses or analogs for nutrient enhancement purposes in any of the Upper Columbia tributaries to ensure that state and federal water quality standards are not exceeded. Of particular concern are any nutrient additions to the Wenatchee watershed as WDOE has implemented a TMDL restriction on phosphorus and is the lead agency responsible for reducing existing, and authorizing any new nutrient sources. Within the Wenatchee, areas of particular interest are generally downstream of Lake Wenatchee.</i></p>
Upper Columbia Salmon Recovery Board (UCSRB)	<ul style="list-style-type: none"> • Implements and ensures compliance with the Upper Columbia Spring Chinook and Steelhead Recovery Plan. • Oversees the Regional Technical Team. • Coordinates funding the implementation of the “Plan”.
Upper Columbia Regional Technical Team (RTT)	<ul style="list-style-type: none"> • Provides oversight and technical assistance for projects supporting implementation of the Upper Columbia Spring Chinook and Steelhead Recovery Plan.
Public Municipalities (such as wastewater facilities, etc.)	<ul style="list-style-type: none"> • Regulates discharge and upholds water quality standards (where applicable). Project proponents of nutrient enhancement activities will need to inform public municipalities especially within the Wenatchee watershed prior to implementation.
National Marine Fisheries Service (NMFS)	<ul style="list-style-type: none"> • Serves as the regulatory agency for ESA-listed anadromous salmonids. As such, NMFS reviews all hatchery management programs, actions related to capturing ESA-listed fish, and adult carcass disposal processes to determine the possible effects to or existence of ESA-listed species.

STAKEHOLDER	ROLES & RESPONSIBILITIES
Local Public Utility Districts (Chelan, Douglas, and Grant County)	<ul style="list-style-type: none"> <li data-bbox="487 281 1396 514">• Funds the operation of Eastbank, Priest Rapids, Wells, and the Winthrop Hatcheries. Project proponents using PUD owned facilities for nutrient enhancement activities should coordinate with PUD's prior to implementation. PUD's may facilitate Hatchery/Habitat Committees and form facility use agreements (PUD's may also assist with carcass storage and handling).

Discussion

Large numbers of hatchery-origin salmon and steelhead return to hatcheries in the Upper Columbia region and therefore potentially available for nutrient enhancement. However, we found that very few hatchery carcasses are actually viable for nutrient enhancement due primarily to drug treatments administered at the various hatcheries and allocation to Native American Tribes for subsistence and ceremonial uses. While a majority of hatchery-origin fish are not encountered at trapping or hatchery facilities, the vast majority of hatchery fish retained at facilities in the Upper Columbia are either deemed unusable for human consumption and nutrient enhancement, or are allocated to consumptive use. In the future, availability of hatchery fish may actually be much higher than portrayed if elements such as operations, permitting, etc. were flexible to allow a higher interception rates. Unusable (treated) hatchery carcasses are typically buried on site, or hauled to a municipal landfill. However, recently agreed to (and not yet implemented) adult management plans may make hatchery-origin fish more available for nutrient enhancement in years where the number of returning fish are in excess of broodstock, out-planting, and consumption needs.

The overriding assumption during the development of this proposal was that there were tens of thousands of hatchery origin salmon available in the Upper Columbia to conduct nutrient enhancement, and that compiling information about when, where, and how to utilize this resource would be of great value to stakeholders interested in conducting nutrient enhancement. However, very early in the information gathering phase of this assessment this assumption proved to be much more complicated and it became apparent that hatchery carcasses from broodstock sources were likely not the most reliable or cost effective nutrient source for this kind of work. Unless current interception methods and/or fish health practices to provide viable (i.e., untreated adult salmon and steelhead) are altered, hatchery origin carcasses are not a viable option for large scale nutrient enhancement.

Because of the logistical constraints (e.g., testing, beheading and gutting, freezing or pasteurizing, transporting) of using hatchery-origin carcasses, finding a reliable alternative such as carcass analogs is likely the most viable option for conducting meaningful nutrient enhancement activities in the Upper Columbia. Analogs provide a consistent source of pathogen and drug-free nutrients which can be easily stored, transported and distributed. Further, due to the high moisture content of carcasses, analogs provide a greater nutrient density per unit. Currently there are two known sources for this product in the western United States. Analogs vary by price, size, availability and composition from the manufacturers.

There may be opportunities to use hatchery carcasses for nutrient enhancement, for example, Priest Rapids hatchery, which has the single largest annual escapement to the facility (10,000-13,000) of fall Chinook salmon may be one of the most viable sources of relatively consistent surplus salmon carcasses in the Upper Columbia. Grant PUD and the Army Corps of Engineers (USACE) funds the operation of this facility, but WDFW oversees operations, and contracts with American Canadian to dispose of all surplus carcasses. (American Canadian holds the statewide contract for carcass disposal for WDFW and must meet several objectives including: removing carcasses from WDFW operated facilities in a timely

manner, donating food quality fish to NW Harvest (or other food banks), selling processed fillets to Washington's Department of Corrections facilities at a discounted rate, generating revenue for the Regional Fisheries Enhancement Groups, and providing carcasses for nutrient enhancement.)

The use of salmon and steelhead carcasses for nutrient enhancement may be a feasible option for relatively small scale efforts. However, recognizing the limited and inconsistent availability of surplus salmon carcasses, alternative sources need to be considered if there is to be a robust nutrient enhancement program in the Upper Columbia. While costs for analogs may seem high, having a consistent and reliable, pathogen and drug free product that is easy to store, transport and distribute may be desirable. This assessment did not do a quantitative cost comparison between using hatchery carcasses and analogs; however, given the costs associated with the pre-disposition activities, i.e., fish removal at weirs, transport to facilities, storage, carcass processing including disease testing and evisceration, it is likely comparable in cost to use analogs, and potentially more costly to utilize hatchery carcasses for nutrient enhancement. While not a substitute for healthy and sustainable salmon runs, analogs have been used successfully (detectable increases in juvenile growth rates) in other watersheds throughout the Pacific Northwest and may provide the short-term benefits expected from conducting nutrient enhancement.

Based on the current status of hatchery origin salmon and steelhead, and existing literature analogs may provide the most consistent and viable option for conducting sustained and meaningful nutrient enhancement in the Upper Columbia region. While exploring alternatives to analogs was not within the scope of this assessment, we believe there may be opportunities to use Upper Columbia hatchery origin salmon and steelhead carcasses, pikeminnow or shad from the Columbia mainstem fisheries to support the development of analogs. These sources are readily available, local, and may offer cost efficiencies not currently realized with existing commercially produced analogs. Feasibility of using local nutrient sources needs to be explored further with existing manufacturers, or a new business model could be developed to produce these products within Washington State.

Prior to conducting any nutrient enrichment activity, it is recommended that assessing the baseline conditions and gaining an understanding of the need must occur prior to implementation. It is therefore recommended that clear goals and objectives are set and a corresponding monitoring plan be developed prior to conducting nutrient enhancement.

Acknowledgements

Cascade Columbia Fisheries Enhancement Group (CCFEG) would like to thank Rock Island HCP Tributary Committee for funding this feasibility study and Becky Gallaher (Chelan PUD) for her administrative support. In addition, CCFEG would also like to thank the following contributors: Ken Bevis, WDFW Watershed Steward, for shamelessly and tirelessly promoting nutrient enhancement as an important component of salmon recovery in the Upper Columbia region; Casey Baldwin, WDFW Research Scientist, Mike Tonseth, WDFW ESA/HCP Biologist, and John Jorgenson, Yakama Nation Biologist, for their ongoing technical support; WDFW and USFWS Hatchery Managers and staff for all of their help assembling this information and willingness to help toss fish when we're ready; USFWS personnel: Steven Croci (Complex Manager), Chris Pasley, Craig Chisam, Dave Carie, Al Jensen, Travis Collier, and Matt Cooper, Joy Evered, and Sharon Lutz; WDFW staff: John Penny, Pat Phillips, Jeffery Korth, John Kerwin, Jayson Wahls, Guy Weist, Jeffery Benjamin, Glen Pearons; Jim Yates with WDOE; Cory Kamphaus, Yakama Nation; Lance Keller and Steven Hayes, Chelan PUD; David Duval and Russell Langshaw, Grant PUD; Jason Hatch, Trout Unlimited; Peter Burgoon, Water Quality Engineering; Mary Jo Sanborn, Chelan County Natural Resources; Tony Meyer, Lower Columbia Fisheries Enhancement Group; and Chuck Peven. Thanks to the Cascade Columbia Fisheries Enhancement Group Board for their support and guidance; Chuck Brushwood, John Arterburn, Greg Knott, Don Bolstad, Aaron Penvose, Dick Evans, Gilbert Biles and Phil Archibald.

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<p>Mark S. Wipfli and John P. Hudson, John P. Caouette. Restoring Productivity of Salmon-Based Food Webs: Contrasting Effects of Salmon Carcass and Salmon Carcass Analog Additions on Stream-Resident Salmonids,. 2004. Transactions of the American Fisheries Society 133:1440–1454</p>	<p><i>Abstract.</i>—We tested the hypotheses that salmon carcasses and salmon carcass analogs (dried, processed hatchery salmon) increase the condition factor, production, and whole-body lipid content of stream-resident salmonids and that stream shading affects responses to enrichment.</p>
<p>Mesa, Mathew G.,U. S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, The efficacy of salmon carcass analogs for enhancing stream and fish production in the Wind River watershed</p>	<p>Summary: We placed carcass analogs made from Chinook salmon into 500-m reaches of two streams in the Wind River watershed, Washington, to evaluate the effects of nutrient enhancement on measures of stream and fish production.</p>
<p>Columbia River Hatchery Reform Project Final Systemwide Report – Appendix A White Paper No. 6, Nutrient Enhancement of Freshwater Streams to Increase Production of Pacific Salmon</p>	<p>Summary: The purpose of this paper is to inform resource managers about the use of stream nutrient enhancement as a tool for increasing survival of juvenile salmonids. Nutrient enhancement is widely recognized as a benefit to natural salmonid stocks.</p>
<p>Pearson T.N, Roley D.D., Johnson C.L., Development of a Carcass Analog for Nutrient Restoration in Streams. Fisheries Vol. 32, No 3, March 2007.</p>	<p><i>Abstract.</i>—Resource managers are becoming more interested in restoring nutrients to food-limited salmonid bearing streams, but all of the current approaches have some shortcomings. The objective of our work was to develop a nutrient restoration product that reduced these shortcomings.</p>
<p>Jorgenson, John, BPA 200847100</p>	<p>Summary: This project will assess and characterize nutrient availability, and if needed will perform controlled experimental addition of limiting nutrients to enhance natural production of anadromous salmonids and their supporting ecological functions and limnological conditions in rivers in the Methow Subbasin.</p>
<p>Edmonson, Mike, Idaho Nutrient Enhancement Project, Idaho Office of Species Conservation. 2011. Columbia Basin Fish Accords; 2008-607-00 ISRP FAN1 Nutrient Enhancement Project.</p>	<p>Summary: This habitat improvement project will involve the addition of nutrient sources to Idaho streams with the goal of providing benefits to Idaho steelhead populations.</p>

Appendix A

Hatchery Interview Questions

1. Hatchery Name
2. Funding Source
3. Contact Information
4. Where do you collect adult salmonids for spawning (i.e., name of facility)?
5. What species of adult salmonids are collected at the hatchery?
6. When are the fish spawned at the hatchery?
7. What is the average escapement to hatchery by species?
8. What is the brood target?
9. What is the average number of pre-spawn mortality?
10. What is the average number of salmonids passed upstream of hatchery?
11. How does the hatchery dispose of salmonid carcasses?
12. On average, how many carcasses are available for nutrient enhancement?
13. What diseases or pathogens are found in salmonids returning to the hatchery?
14. How are these diseases or pathogens treated?
15. If carcasses are available for nutrient enhancement, what type (e.g., type, size) of storage facilities are available?
16. If carcasses are available for nutrient enhancement, is transportation available? Type?
17. Is fish pellet processing equipment available (for analog production)?
18. Other comments?

Appendix B

Hatchery Facilities in Washington's Upper Columbia River Basin

Hatchery	Facilities (River, Collection Facility, Location)	Funding Agency	Managing Agency
Leavenworth National Fish Hatchery (NFH)	River: <i>Icicle Creek</i> Collection Facility: <i>Leavenworth NFH</i> Location: <i>12790 Fish Hatchery Road Leavenworth, WA 98826</i>	US Bureau of Reclamation	USFWS
Entiat National Fish Hatchery	River: <i>Entiat</i> Collection Facility: <i>Wells Hatchery</i> Location: <i>6970 Fish Hatchery Drive Entiat, WA 98822</i>	US Bureau of Reclamation	USFWS
Winthrop National Fish Hatchery	River: <i>Methow</i> Collection Facility: <i>Winthrop NFH, Methow Hatchery</i> Location: <i>PO Box 429 Winthrop, WA 98862</i>	US Bureau of Reclamation	USFWS
Priest Rapids	River: <i>Columbia River (mainstem)</i> Collection Facility: <i>Priest Rapids Dam</i> Location: <i>PO Box 937 Mattawa, WA 99349</i>	Grant PUD	WDFW
Eastbank Complex	River: <i>Columbia River (mainstem)</i> Collection Facility: <i>Spring Chinook - Tumwater Dam, Chiwawa River weir, Steelhead - Dryden Dam, Tumwater Dam, Summer Chinook - Dryden Dam, Tumwater Dam (if necessary), Fall Chinook - Wells Dam, Sockeye - Tumwater Dam</i> Location: <i>13246 Lincoln Road East Wenatchee, WA 98802</i>	Chelan PUD	WDFW
Wells Complex	River: <i>Columbia River (mainstem), Twisp River</i> Collection Facility: <i>Wells Dam</i> Location: <i>24621 US Highway 97 Pateros, WA 98846</i>	Douglas PUD (with some funding from CPUD and GPUD)	WDFW
Winthrop WDFW	River: <i>Methow River</i> Collection Facility: <i>Wells Dam - transitioning to local broodstock program (capture in Methow River)</i> Location: <i>44C Wolf Creek Road Winthrop, WA 98862</i>	Douglas PUD	WDFW

Appendix C



United States Department of the Interior

FISH AND WILDLIFE SERVICE

Olympia Fish Health Center

3859 Martin Way, Suite 101

Olympia, WA 98506

Phone: 360-753-9046 Fax: 360-753-9403

Website: www.fws.gov/olympiafishhealth/

RISK ASSESSMENT TO THE ECOSYSTEM FOR PATHOGEN AND CONTAMINANT INTRODUCTION AND/OR AMPLIFICATION DUE TO CARCASS PLANTING FOR NUTRIENT ENRICHMENT

Appropriate permits and authorizations need to be obtained from the Federal, Tribal, and State Agencies, and all private landowners whose property or water supplies might be affected by this activity.

The risk assessment for carcass distribution should include information about the watershed, available spawning and rearing habitat for fish, pathogens present in wild fish in the area, pathogens present in carcasses to be introduced, and the potential for environmental contaminants or other toxins to be introduced into the stream by the carcasses.

EVALUATION OF THE STREAM TO BE ENRICHED

It should be documented by water quality testing and zooplankton and diatom assessments that the area to be planted is in need of Nitrogen and Phosphorus. Too much of these nutrients may actually putrefy the stream causing a less suitable environment for fish and invertebrates.

If the watershed is in need of additional nutrients, carcasses should be placed in appropriate locations and water conditions to ensure that they will remain in that area and will not be immediately washed away. The numbers of carcasses needed for each location should also be assessed and guidelines followed.

Appendix C

Water quality testing should continue after the carcasses are placed in the stream to monitor the benefit of the enhancement and ensure that an excess of nutrients have not been introduced.

Precautions should be taken in planting carcasses to avoid introducing or amplifying disease agents, toxins, and other contaminants into the system. Most diseases caused by bacteria, viruses, and parasites can be transmitted from the carcasses of infected fish to live fish, either by cannibalism or by the release of disease agents into the water. Many disease agents survive in the water, the sediment, invertebrates (such as leeches or small worms) and/or birds and animals and can later infect fish. Carcasses of fish should be evaluated by fish health specialists before planting – a river and its inhabitants cannot be cleaned or disinfected if a new pathogen is introduced!

PATHOGENS OF CONCERN IN ANADROUMOUS FISH CARCASSES

Whirling Disease (*Myxobolus cerebralis*) is a parasite with a very complex life cycle that affects the cartilage and bone formation of susceptible fish species. Rainbow trout and Chinook salmon are very susceptible to this parasite and it can decimate populations of wild fish. Once the parasite is established, it is impossible to remove; its spores survive in mud for up to 30 years, it is not killed by freezing or even by some forms of cooking.

IHN (*Infectious Hematopoietic Necrosis Virus*) is commonly detected in some stocks of returning adult salmon. Some species of fish are very susceptible to the disease caused by this virus which has also been found in some invertebrates. Unprocessed infected carcasses could release high levels of this virus into the environment. The virus can survive in the sediment or even inside leeches. Fry emerging from redds or young fish face the risk of dying from the virus which can cause 80% or greater mortality. There is no treatment for infected fish and survivors can carry the virus and infect other fish and invertebrates. Sockeye salmon, Steelhead and some other trout species are particularly susceptible to this disease.

Bacterial Kidney Disease or BKD (*Renibacterium salmoninarum*) may be found in high levels in returning spring Chinook salmon. The disease is extremely difficult to control because the causative bacterium hides inside the fish cells, protected from antibiotics, and can be passed directly from the mother to her offspring as well as between fish (vertical and horizontal transmission). The bacteria survive about 10-20 days in water and are also transmitted by cannibalism. Recent reports indicate that the northern pikeminnow may be a carrier of this pathogen. While this pathogen is most likely already present in river systems containing spring Chinook salmon, the planting of carcasses with overt BKD would unnecessarily amplify this bacterium.

Coldwater Disease (*Flavobacter psychrophilum*) can be found in the brain and spinal column where very few antibiotics are effective in treating it. Like *Renibacterium salmoninarum* (BKD), it may be transmitted vertically and horizontally which makes it difficult to control. Coho salmon and Steelhead trout are highly susceptible to the disease which can cause high mortality and bone deformities in these species.

Furunculosis (*Aeromonas salmonicida*) is a highly contagious bacterial disease associated with a bacterial toxin. The bacteria and toxin can be found in nearly all tissues of the body including pustules

Appendix C

under the skin. The main route of transmission of this bacterium is ingestion of it in the water column or food sources.

Enteric Redmouth (*Yersinia ruckeri*) is a contagious bacterial disease that is mainly transmitted through ingestion in the water column and food sources.

Ceratomyxosis (*Ceratomyxa shasta*) is a parasite found in the intestines. Like *Myxobolus cerebralis*, this parasite has a complex life cycle and the spores found in the adult fish are very resistant to degradation by heating, freezing, or chemical contact.

Nucleospora (*Nucleospora salmonis*) is a parasite found in internal organs, especially the digestive tract. Little is known about its life cycle but mortalities have been attributed to this parasite in Steelhead and Cutthroat trout.

ICH or White Spot Disease (*Ichthyophtherius multifiliis*) is an external parasite found on skin, gills, and fins. The encysted form is highly resistant to chemical treatment and drying but its numbers are probably reduced with freezing and heating above 100°F (38°C).

IPNV (*Infectious Pancreatic Necrosis Virus*) has been found in several species of marine and freshwater fish and shellfish and can cause severe enteritis in young rapidly growing salmonids. Fish that survive the disease may become carriers and shed the virus through the feces. This virus can also be vertically transmitted through the milt and eggs. It is very stable under a wide range of environmental conditions and survives for several days in water. It is resistant to a wide range of chemical disinfectants but is deactivated by 70% ethanol.

Non-endemic pathogens, unidentified replicating agents, or any replicating agent not known to occur in that water shed are of great concern and should not be spread to new areas.

If there is a detection of a known pathogen or unidentified replicating agent found during the Inspection that might be detrimental to the fish and other aquatic life in the area to be enhanced, carcass planting must be stopped until a full assessment of the risk of such an activity can be determined and a plan developed to eliminate or minimize any detrimental impact is agreed to by all Agencies and Groups involved.

10/27/06

Appendix D



United States Department of the Interior

FISH AND WILDLIFE SERVICE

Olympia Fish Health Center

3859 Martin Way, Suite 101

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Phone: 360-753-9046 Fax: 360-753-9403

Website: www.fws.gov/olympiafishhealth/

CARCASS SELECTION CRITERIA FOR PLANTING OF ADULT SALMONIDS TO BENEFIT STREAM PRODUCTIVITY

Plant only fish that:

1. Do not have internal or external lesions (look healthy) and did not die in the pond
2. Have been beheaded and gutted. Removing the skull and brain will reduce the levels of *Myxobolus cerebralis* and *Flavobacter psychrophilum* and removing the internal organs, including the kidney and intestinal tract will reduce the levels of many of the bacterial, viral, and parasite pathogens
3. Have been frozen or heated to reduce the levels of many of pathogens contained in the muscle, bone, skin, nervous tissue and blood. Although heating and freezing will not completely eliminate all pathogens, it will reduce the numbers of most of them and also provides an extended storage time that allows for the completion of the laboratory tests
4. Are from the local river or have returned to the local area
5. Have been examined by fish health personnel at spawning
6. Have the completed results of a Fish Health Inspection showing that no pathogens of concern were detected and no pathogens were found in high levels

Do not plant:

1. Broodstock that die prior to spawning (may have died of infectious disease or toxin)
2. Broodstock that have been injected with antibiotics or exposed to anesthetics or other chemicals until after the legal withdrawal period has elapsed
3. Fish from outside the watershed
4. A stock of fish that has not been evaluated by fish health personnel
5. Carcasses that are infected with high levels of any pathogen or contaminant

Appendix D

6. Carcasses that are suspected or shown to be infected with a pathogen or contaminant not previously detected in the planting area or an unknown replicating agent.
7. Carcasses near a hatchery, municipal, or irrigation intake
8. Anadromous fish carcasses above a fish passage barrier

Dispose of all diseased carcasses, heads and “guts” away from other animals (burial, landfill, rendering plant). These precautions reduce the risk of amplifying and/or transmitting disease agents to the enhancement location.

10/27/06

Appendix E

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PROTOCOLS AND GUIDELINES FOR DISTRIBUTING SALMONID CARCASSES, SALMON CARCASS ANALOGS, AND DELAYED RELEASE FERTILIZERS TO ENHANCE STREAM PRODUCTIVITY IN WASHINGTON STATE

The declining abundance in many wild salmonid populations in Washington can be attributed to a combination of factors including harvest and hatchery issues, hydroelectric operations, habitat degradation and loss, alterations to stream flow, altered basin hydrology, and reduced stream productivity. Restoration of salmon populations to levels capable of sustaining fully functional ecosystems and consumptive fisheries will require addressing all these issues; nutrient restoration addresses only a part of the overall problem.

There are currently four options being considered to increase the level of nutrients in freshwater ecosystems in order to restore ecosystem productivity to “historic levels”. These are the application of fertilizers, the application of carcass analogs (processed fish cakes), the distribution of salmonid carcasses from fish hatcheries, and the allowance of increased levels of natural spawning by anadromous fish. These protocols and guidelines deal with nutrient recovery utilizing the first three methods; provision for increased spawner escapements will be dealt with in other forums.

The application of fertilizer to increase wild fish production has been conducted in the Pacific Northwest for years. Currently, there are two methodologies in use. One involves the introduction of liquid fertilizer into the water, either through large Aslug \cong dosages or through low-level drip. The second involves the placement of solid fertilizer pellets that dissolve at a predetermined rate, releasing nutrients over a period of months. Both methods have been shown to cause substantial increases in fish growth, survival, condition factors, and the like. Water quality monitoring associated with the application of these fertilizers has shown that they are rapidly taken up into the food chain and are generally not detectable in the water column outside of the treatment area/reach.

The use of carcass analogs is an emerging technology. The concept is that fish carcasses and other fish processing waste material is converted into a solid cake. The cake would be treated to kill associated fish pathogens. The advantage of the analog is that they are lighter in weight per unit of nutrient (when compared to carcasses) and they would present a much lower risk of pathogen transfer. The technology is currently in development and testing.

Appendix E

The predominant method currently used to increase nutrients in freshwater and terrestrial ecosystems has been through the distribution of carcasses of salmonids that have returned to hatcheries.

In order to determine whether or not a system is in a state of nutrient deprivation/starvation, the natural spawning escapement levels discussed in Bilby et al. (2001) will serve as minimums. Escapements below these levels will be assumed not to meet the minimal nutrient needs of the ecosystem. Other direct measures, such as smolts becoming older and/or smaller, analysis of benthic sediments, analysis of sequestration of marine derived nutrients in trees, etc. will also meet the assumption of lack of nutrients. For the application of fertilizer to streams the target concentration over the course of application will be 3-5 ppb of phosphorus based on Ashley and Slaney (1997). Preliminary sampling of the waterbody will be used to determine if or how much material needs to be added.

GOAL OF NUTRIENT RESTORATION ACTIVITIES:

Increase the biological productivity of Washington's streams, riparian areas, upland areas, and estuaries by returning the nutrients originally supplied by anadromous fish carcasses back to the anadromous zone of spawning streams. Ultimately, the goal is the functional restoration of ecosystems supported by naturally spawning salmonids. Restoration of this functionality will require the restoration of the terrestrial and aquatic communities in addition to simple anadromous fish restoration. It will also require the restoration of hydrologic cycles, restoration of the relationship between rainfall and streamflow, and restoration of aquatic habitat. Finally, restoration occurs when the nutrients are delivered to the ecosystem by naturally spawning fish and not through artificial methods.

OBJECTIVE # 1:

Enrich the nutrient supply to aquatic ecosystems (primary producers, scavengers, browsers, predators), enabling their population increases to be used for the trophic benefit of all interdependent species. This will result in increases in individual size and survival of juvenile salmonids living in the streams.

OBJECTIVE # 2:

Increase productivity in riparian zones and associated upland areas that will benefit the animals and plants that depend upon them.

OBJECTIVE # 3

Provide analogs or carcasses for direct consumption by juvenile fishes and aquatic macroinvertebrates.

OBJECTIVE # 4

Appendix E

Provide alternatives to the use of anadromous salmonid carcasses where carcasses are not available.

OBJECTIVE # 5

Where appropriate, conduct water quality monitoring to document the uptake of nutrients while maintaining water quality for non fish-producing purposes. This monitoring should be structured to document not only the cultural oligotrophication of watersheds but demonstrate the uptake of the nutrients and the ecosystem benefits therefrom. Monitoring will be structured, where possible, to result in peer reviewed publication in appropriate scientific journals.

PREMISES:

** Actions taken to restore a stream's productivity through restoration of nutrients shall not be viewed as supplanting or supplementing natural spawning by wild salmonids. The ultimate goal is to provide the nutrients necessary to drive the ecosystem only through natural spawning by anadromous fish.

** Streams identified for nutrient enhancement with carcasses must be within a designated Fish Health Management Zone (FHMZ), or smaller, that contains the source hatchery facilities.

** No nutrients will be distributed in stream reaches formally identified as being impaired because of excess nutrients without the express approval of the Department of Ecology. The Department of Ecology will provide WDFW with a current list of impaired waterbody segments and, if appropriate, the specific timing (within the year) of that impairment.

** All projects which exceed the identified biomass densities or those that introduce fertilizer will be monitored as follows: One sample immediately upstream of the uppermost input point to serve as a control, one sample at the downstream end of the calculated Atreatment zone≅ and one sample half a kiolmetre downstream from the lower end of the “treatment zone”. Samples will be collected monthly during the period of nutrient introduction and will continue for two months after the calculated date of pellet disintegration, after last application of liquid fertilizer, or after final degradation of carcasses or analogs. Measurements will be for parameters identified in the Memorandum of Agreement (MOA) supporting the Programmatic National Pollutant Discharge Elimination System (NPDES) discharge permit.

** All projects will be covered by formal approval of the Department of Fish and Wildlife (WDFW) and Department of Ecology (DOE) through individual project MOAs. The MOA will accompany transport and depositing of materials. The NPDES permit issued to WDFW will cover each project.

CRITERIA FOR TREATMENT STREAM IDENTIFICATION:

Appendix E

- 1) Treatment reaches shall be within the current anadromous zone of a watershed or within areas historically accessible to anadromous fish; exceptions will be based on research study needs.
- 2) Streams that have historic data sets and/or ongoing assessment projects that can be complemented by nutrient restoration will be given high priority in project planning. Conversely, streams with ongoing ecosystem assessment studies that would be adversely affected by nutrient enhancement will be avoided.
- 3) Streams or stream reaches where treatment ends less than two km upstream from municipal water supplies will be considered only with the expressed written concurrence of the water purveyor. Similarly, private domestic water diversions recognized by DOE will receive the same consideration.
- 4) Streams or stream reaches with identified water quality constraints for nutrients will be avoided; exceptions will be made only with written concurrence of the regulatory authority.
- 5) Treatment streams should have access points to the treatment reaches, (bridges, wet crossings, culvert crossings, etc.) to accommodate nutrient deposition, distribution, and monitoring.
- 6) Spawner index streams and smolt evaluation streams will not be selected for nutrient restoration unless potential impacts are resolved with the research or evaluation agency or organization.
- 7) Landowner approval for access to deposit materials will be obtained.

CRITERIA FOR ADULT CARCASS DEPOSITION:

- 1) Temporal and spatial distribution should reflect historic anadromous spawn timing and abundance for a particular stream, for each species. For purposes of this program, all carcasses are considered equal from a nutrient per weight basis. Consequently, the actual distribution goal may be calculated as biomass and then converted to fish numbers. In practice, chinook carcasses may be used as a substitute for coho, and vice versa, depending upon availability. Further, testing for pathogens, availability of access due to snow, etc. shall be considered when setting up distribution schedules.
- 2.) The maximum number of carcasses distributed within a stream segment will be based on Bilby et al. (2001). For coho, the target level is 0.15 kg/square metre of stream surface area based on bankfull channel width. Summer low flow area can be substituted as a conservative density. For mass spawning species of salmon (pink, sockeye, chum), 0.78-kg/square metre will be used. For chinook, which is a mass spawning species but also uses the freshwater environment for rearing up to a year, a value of 0.39 kg per/square metre will be used. Because of similarity in life history patterns the coho value of 0.15-kg/square metre of stream surface area will be used for steelhead. In streams where estimates of the natural spawning escapement are routinely made, carcass numbers can be reduced by the recent 5-year moving average for natural escapement to the treatment reach. For determining total carcass deposition maximums, the area historically

Appendix E

available to each species will be used to calculate the loading rates. This results in a separate calculation for each species/timing segment. Spawn timing will need to be factored into distribution schedules.

- 3) Carcasses will be used within designated watersheds or FHMZ as identified by WDFW Fish Health Specialists.
- 4) Carcasses will be used from stocks that have been screened for pathogens as prescribed in the Co-managers Disease Control Policy.
- 5) If necessary to avoid duplicate counting, interference with spawner enumeration, or other studies, carcasses used for nutrient enhancement will receive a distinctive external mark or tag. As noted in (1), species may be substituted in order to avoid the potential for enumerating a distributed carcass as natural escapement.
- 6) If necessary to avoid confusion with specific genetic sampling studies, carcasses will have an identifiable external mark or non-target species will be utilized.
- 7) All use of carcasses for nutrient restoration will follow the specific plan submitted by the applicant and approved in the formal project review process.
- 8) A copy of the final project approval will accompany transport and deposition of carcasses.
- 9) Deposition of carcasses should be avoided at flow levels (e.g. high flows/freshets) that would compromise the carcass placement objectives.
- 10) Artificial deposition of salmonid carcasses must not create a direct human health hazard.
- 11) Frozen carcasses can be used to approximate historic run (mortality) timing and to improve distribution to inaccessible stream reaches.
- 12) Distribution of carcasses should include shoreline and shallow water reaches of the stream.
- 13) Final Project approval or denial will occur at the WDFW Regional Fish Program Manager level after appropriate internal review. The Regional Fish Program manager will ensure that Co-managers, the Department of Ecology, and other affected fish management entities have been consulted during project approval. Distribution of final approval/disapproval will be by the WDFW Science Division.

CRITERIA FOR CARCASS ANALOG DEPOSITION:

- 1) Temporal and spatial distribution should reflect historic anadromous spawn timing and abundance for a particular stream, for all species. For purposes of this program, the amount of analogs to be distributed will be converted to carcass biomass by correcting for the moisture/nutrient content of the analog. The actual distribution goal will be calculated as biomass and then converted to analogs.

Appendix E

- 2.) The maximum number of analogs distributed within a stream segment will be based on Bilby et al. (2001). For coho, the target level is 0.15 kg/square metre of stream surface area based on bankfull channel width. Summer low flow area can be substituted as a conservative density. For mass spawning species of salmon (pink, sockeye, chum), 0.78-kg/square metre will be used. For chinook, which is a mass spawning species but also uses the freshwater environment for rearing up to a year, a value of 0.39 kg per/square metre will be used. Because of similarity in life history patterns the coho value of 0.15-kg/square metre of stream surface area will be used for steelhead. In streams where estimates of the natural spawning escapement are routinely made, analog biomass can be reduced by the recent 5-year moving average for natural escapement to the treatment reach. For determining analog deposition maximums, the area historically available to each species will be used to calculate the loading rates. This results in a separate calculation for each species. Spawn timing will need to be factored into distribution schedules.
- 3) Analogs will be processed so that fish pathogens present in the raw material are destroyed during processing.
- 4) Use of analogs for nutrient restoration will follow the specific plan submitted by the applicant and approved in the formal project review process.
- 5) A copy of the final project approval will accompany transport and deposition of analogs.
- 6) Deposition of analogs should be avoided at flow levels (e.g. high flows/freshets) that would compromise the analog placement objectives.
- 7) Deposition of analogs must not create a direct human health hazard.
- 8) Final Project approval or denial will occur at the WDFW Regional Fish Program Manager level after appropriate internal review. The Regional Fish Program Manager will ensure that Co-managers, the Department of Ecology, and other affected fish management entities have been consulted during project approval. Distribution of final approval/disapproval will be by the WDFW Science Division.

CRITERIA FOR FERTILIZER DEPOSITION:

- 1) Temporal and spatial distribution should reflect historic anadromous spawn timing for a particular stream, for all species. Since the application of fertilizer targets only the dissolved nutrient fraction contained in a salmonid carcass, if data show that the release of dissolved nutrients by decomposing carcasses occurs at a time different from the time of carcass deposition, then fertilizer application can duplicate the release timing. Further, applications to lakes can be timed to promote maximum uptake by the phytoplankton community.
- 2) The maximum amount of fertilizer to be deposited will be based on the recommendations of Ashley and Slaney (1997) which is to achieve an instantaneous Soluble Reactive Phosphorus level over the 120-day treatment of 3-5 micrograms per litre at average streamflow during

Appendix E

application/release. Treatment reach will be defined based on the Ashley/Slaney calculations or other methodologies as information is developed.

3) Determination of the need to apply fertilizer will be based on specific water quality sampling undertaken at least a year prior to the intended time of treatment. For lakes, sediment core studies showing historic phosphorus deposition and/or zooplankton communities will be used as justification for programs and for determining natural levels of nutrient input to the system.

4) The fertilizer formulation will be reviewed to ensure that the entire formulation, including inert and other constituents, is Food Grade.

5) Use of fertilizer for nutrient restoration will follow a specific plan agreed to among water quality and fish management agencies. This plan will serve as a pre-deposition template for evaluating and directing carcass distribution requests or applications.

6) Transport and deposition of fertilizers will be accompanied by the appropriate approvals.

7) Placement of fertilizer should avoid flow levels that would compromise the placement objectives.

8) Each fertilizer application project will include a water quality monitoring component. At the minimum, the proponents will be required to collect Soluble Reactive Phosphorus samples from a point 50 m upstream of the uppermost fertilizing site, the midpoint of the treatment reach, the calculated bottom of the treatment reach, and 500 m downstream of the bottom of the treatment reach. Samples will be collected monthly from one month before fertilizer deposition to two months after the calculated release of the last of the fertilizer. For example, if 120-day release formulation is used, samples would be collected on day number -30, 0, 30, 60, 90, 120, 150, and 180.

9) Final Project approval or denial will occur at the WDFW Regional Fish Program Manager level after appropriate internal review. The Regional Fish Program Manager will ensure that Co-managers, the Department of Ecology, and other affected fish management entities have been consulted during project approval. Distribution of final approval/disapproval will be by the WDFW Science Division.

CRITERIA FOR TERRESTRIAL DEPOSITION OF CARCASSES

Deposition of carcasses or analogs in terrestrial areas within twenty (20) m of flowing water will be treated as if they were placed in the stream and will comply with the conditions listed above with regard to Fish Health Management Zones. It is desirable that, under normal deposition plans, some of the carcasses or analogs be applied terrestrially or in shallow water.

CRITERIA FOR ALL PROJECTS:

Appendix E

- 1) Approval is continuous as long as all operational requirements of a specific project are met.
- 2) Proponent must annually report to WDFW per the MOA. Proponent will indicate plans for the next year's activities and any changes proposed. This will be reported to the WDFW Science Division and will serve as the application for renewal for the subsequent year's program. In order to be automatically approved for the next year, the report must be received by June 30 following deposition. WDFW will ensure that interested agencies receive data summaries and results of monitoring. WDFW will annually issue an MOA, based on receipt of the annual report, which will be supplementary to the original approval document and must be present when carcasses, analogs, or fertilizers are transported and applied.
- 3) These criteria apply only to projects reviewed by the WDFW procedure. For carcass distribution projects, these protocols apply only WDFW operated facilities or to WDFW associated Coops. Carcasses from Federal or Tribal hatcheries can be covered by these protocols if the agency supplying the carcasses has met the necessary environmental review required by the appropriate governmental entity.
- 4) Applications will be reviewed and approved on a year-round basis. In order to have approval by September 1 it will be necessary to apply by July 1.

APPLICATION AND REVIEW PROCEDURE FOR ALL PROJECTS:

- 1) Contact WDFW Fish Program Science Division for copies of the protocols and an application form. Specific technical assistance will be available from the Technical Assistance List accompanying the application package.
- 2) Completed application forms are forwarded to the WDFW Fish Program Science Division who will initiate the review process. The address is:

WDFW Fish Program Science Division
Nutrient Enhancement Section
600 Capitol Way N
Olympia, WA 98501-1091

For applications for carcass distribution ONLY:

- A) *The completed application will be reviewed by the WDFW Aquaculture Coordinator who will approve/deny use of carcasses.*
- B) *WDFW Fish Health Manager will forward a copy of the application to the Northwest Indian Fisheries Commission for Co-Manager review. Following review by the Fish Health Manager the application will be forwarded to the Hatcheries Complex Manager for the source facility for review and approval. The application will then be returned to the Science Division.*

Appendix E

C) Applications that are recommended as Denied will be returned to the applicant with explanation. If the Hatcheries Division recommends changes in the application prior to approval, the Science Division will contact the applicant to address the necessary modifications.

3) All completed applications (fertilizer, analog) and Hatcheries Division approved (carcass) will be forwarded to the Regional Fish Program Manager for local review. Regional review will include signed approval by WDFW Regional Programs, Treaty Indian Tribes within whose Usual and Accustomed Area the application is proposed for, landowners controlling access to application sites, and the Department of Ecology Regional Office.

4.) Following regional review the Regional Fish Program Manager will approve or deny the application.

5.) The approved application and review forms will be returned to the Science Division for distribution. An MOA will be developed for each project based on the approved application and will be append to the WDFW approval.

LITERATURE CITED

Ashley, K. I., and P. A. Slaney. 1997. Accelerating recovery of stream, river, and pond productivity by low-level nutrient replacement, Chapter 13 *In* Slaney and Zaldokas, *eds.* Fish habitat rehabilitation procedures. Watershed Restoration program, MOELP, Vancouver BC.

Bilby, R.E., B. R. Fransen, J. K. Walter, C. J. Cederholm, and W. J. Scarlett. 2001. Preliminary evaluation of the use of stable isotope ratios to establish escapement levels for Pacific salmon. *Fisheries* 26:6-14.

Revised 22 March 2002