ECONOMIC BENEFITS OF BEAVER-CREATED AND MAINTAINED HABITAT AND RESULTING ECOSYSTEM SERVICES[1]

by

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[1] This document was originally created for a "*Petition to Initiate Rulemaking to Amend OAR 635-050-0070 to Permanently Close Commercial and Recreational Beaver Trapping and Hunting on Federally-Managed Public Lands and the Waters that Flows Through These Lands*" which was brought before the Oregon Fish and Wildlife Commission on September 24, 2020. On November 13, 2020, the Commission denied the Petitioners request to initiate rule making despite economic and ecological benefits.

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EXECUTIVE SUMMARY

Beaver, through their dam-building activity, help retain water on the landscape in beaver ponds and on floodplains, leading to reduced flood risk for landowners immediately downstream, improved water quality and stream flows, and an expansion of fish and wildlife habitat. Public utilities which manage reservoirs benefit as improved floodplain connectivity and channel complexity evens out peak highs and lows in streamflows. Oregonians from across the state benefit as opportunities for outdoor recreation such as wildlife viewing, fishing, and hunting expand. Ranchers and farmers benefit as water stored in beaver-created wetlands and behind beaver ponds provides valuable water during droughts. Cities and towns benefits with improved water quality and more dependable flows. And in addition to all these benefits, there is also the creation of carbon capture and store areas as wetlands and wet meadows increase in size and abundance, a response strategy to climate change that has yet to be assigned a monetary value.

There are also the large economic benefits related to salmon as it moves through its life cycle. Beaver-created and maintained habitat provide key juvenile coho salmon winter rearing habitat, decrease stream temperatures, increase channel complexity and habitat connectivity, and expand riparian habitat all along migration corridors. These improvements along migration corridors not only enhance the potential for salmon to survive and expand within a changing climate but provide the same services to migratory birds. Increases in beaver-created habitat would therefore aid ODFW and to the state in their efforts to achieve conservation goals for affected species at little to no cost. In addition, there is the chance to prevent the extinction of salmon due to lack of habitat, something that abundant beavers and their habitat can help remedy. An extinction event would be a devastating cultural and ecological loss. Assigning a price tag to such an event should only be considered a point when considering salmon's economic, social and cultural importance and value.

These beaver-generated economic and ecological benefits are currently only future potential benefits because they require landscapes where there are abundant beaver who are creating and maintaining abundant beaver habitat. These conditions that do not currently exist in Oregon because continued beaver trapping and hunting on federally managed public lands under ODFW furbearer regulations has left abundant suitable beaver habitat unoccupied and thus abundant ecological and economic benefits unrealized.

Beaver trapping and hunting prevents Oregonians from receiving these benefits for two major reasons related to 1) family dynamics and 2) dam maintenance needs. First, the beaver furbearer season under ODFW furbearer regulations occurs in the winter when the fur quality is best and thus overlaps the beaver breeding and pregnancy season. Because kits can stay with their parents up to two years, an entire colony can be trapped/hunted out in a single seaon which eliminates dispersal potential. Even if some beaver remain, there is a lag between birth, adulthood, dispersal and finding a mate which limits creation and maintenance of habitat and its benefits and future dispersal. Those that remain are vulnerable to trapping and hunting pressures the following year in addition to all the other mortality causes. Second, removal of beaver leaves dams unmaintained. As a result, when the dams fail, they are not repaired. The ponds drain, water tables drop, water quality declines, wetlands and wet meadows begin converting to drier species and fish and wildlife habitat decreases. The ecological and economic benefits begin to unravel. Therefore, maintaining family units is key for expanding populations, successful dam building and maintenance, dispersal, and habitat creation and maintenance.

This document presents the ways that beaver-created and maintained habitat, though their influences on aquatic and terrestrial ecosystems, can generate large market and non-market benefits from the water and habitat-based changes. These potential future benefits are in the 100s of millions of dollars and would occur at little to no cost to Oregonians. Table 1 compares these future beaver-driven benefits versus the existing economic benefits gained by trappers and hunters under ODFW's furbearer regulations (Table 1). The remaining document provides information on how those numbers were arrived at and their supporting documentation.

Table 1. Comparison of economic value of continued beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands versus closing these lands and allowing beaver-driven restoration to begin.

Item	**Year**	**Action**	**Dollars**	**People and/or fish and wildlife served**
Continued Beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands				
Total Beaver/Castor sales	2015-2019	Money earned by Trappers/hunters	< $48,596 (maximum)	< 170 because not all trap/hunt on federally-managed public lands and the waters that flow through these lands
Closure of beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands				
Restored Salmon Runs	future	estimate of household willingness to pay (WTP) for increased salmon populations in the future	Tribal Ceremonial and Subsistence: Value is incalculable. WTP: $100 to $120 per household per year which results in an estimated value of $195 million in 2016 increasing to $241 million in 2035.	Countless salmon and communities who depend on or benefit from healthy salmon populations culturally and/or economically plus countless other species and individuals that benefit from improved fish and wildlife habitat
Improved Stream Temperatures on a Minimum of 23,413 Miles of 1st - 4th Order Streams (beaver dam building sized streams)	future	estimated cost of human driven restoration	$ 1.7 to 9.6 billion dollars	4.2 million people, unknown number of species and individuals

Item	Year	Action	Dollars	People and/or fish and wildlife served
EPA and NOAA Restoration Dollars	2015-2019	Dollars that have been lost due to failure to require water quality improvements. Voluntary compliance still only required.	$5.8 million	4.2 million people, unknown number of species and individuals
Oregon Watershed Enhancement Board (OWEB) Restoration Expenditures	2014-2019	Spent	$35.6 million	4.2 million people, unknown number of species and individuals
Recreational Spending on Wildlife Viewing, Fishing, Hunting, and Shellfishing	2008	Spent	$2.8 billion	2.8 million people
Aquatic Habitat Ecosystem Value for two Beaver Restoration Assessment Tool (BRAT) Area Examples	future	estimated cost of human driven restoration	$8.8 million	County residents in these areas plus unknown number of species and individuals
Aquatic Habitat Ecosystem Value for ODFW Aquatic Habitat Inventory Area Example of 17 one-mile reaches	future	estimated cost of human driven restoration	$348,800	Salmon and communities who depend on or benefit from healthy salmon populations (4.2 million people) plus countless other species and individuals
Delayed Flow Upstream of Reservoir Due to Water Storage via Beaver Ponds for NFBR Example	future	estimated value of water to downstream uses	$5,499 to $32,990 per year	Fisheries, downstream irrigators

BEAVERS AND THEIR ECOSYSTEMS SERVICES

Beaver create habitat that has multiple impacts on aquatic and terrestrial ecosystems. They provide both market and non-market economic benefits for human society . Market-defined economic benefits involve goods and services traded in markets and involve monetary transactions, which provide information useful for measuring the economic importance society places on the goods and services. The transactions may derive directly from the habitat that beavers create, e.g., when recreationists spend money to take advantage of recreational opportunities created by beaver habitat such as fishing or wildlife viewing. They also may occur indirectly, e.g., when landowners and public agencies can avoid spending money to restore a wetland or decrease stream temperatures because beavers have already created the habitat that brings about these outcomes.

Non-market economic benefits involve goods and services not traded in markets. These benefits can materialize as beavers have increased and improve habitat for at-risk species, thereby increasing the likelihood that these species will avoid extinction. Because these goods and services are not traded in markets, they do not involve monetary transactions. The absence of transactions does not mean the goods and services have no economic value. Indeed, these goods and services often are not traded in markets because society considers them too important to be bought and sold. Economists measure the economic importance of non-market goods and services using sophisticated survey techniques. These techniques estimate society's potential willingness to pay to acquire goods and services they do not already possess, or the amount of money they would require as compensation to give up those they already possess. This text illustrates the technique: [1]

> "We find that the average household WTP (willingness to pay) for the most ambitious recovery program is $179/year. This is the recovery program involves OC [Oregon Coast] Coho salmon reaching recovered status under the ESA. . Upon aggregating to the broader population of PNW residents, the WTP for this most ambitious recovery program ranges from a lower bound of $321 million/y to an upper bound of approximately $1.46 billion/y depending on aggregation assumptions. Given that the most ambitious recovery program in our experimental design is based on the OC Coho Conservation Plan for the State of Oregon [10], the population benefit estimates represent the non-market economic value associated with successfully implementing this state-level conservation plan. Importantly, we also find that the public has significant WTP for habitat restoration programs that generate much smaller changes in salmon abundance, even for programs that do not result in the stock becoming delisted from the ESA. For example, the average household WTP of approximately $60/y for the least ambitious scenario in our experimental design (100,000 more returning fish with no change in the threatened status under the ESA) still produces between $107 million/y (lower bound) to $518 million/y (upper bound) in non-market economic benefits (**Table 3** in referenced document). Given that no ESA-listed species of Pacific salmon have been delisted as of 2018, our results provide evidence that the public values ESA conservation activities that have yet to achieve a recovered status for their target species."

The key point of the above analysis is that recovery of salmon promises to yield economic benefits up to $500 million a year. However, we can only realize those benefits if we have abundant beavers creating and maintaining abundant beaver habitat across the landscape.

ASSIGNING VALUE TO ECOSYSTEM SERVICES

Table 2 presents the potential economic benefits of the ecosystem service Oregonians would realize by ending commercial and recreational beaver trapping/hunting on federally managed public lands. These can also be thought of as the ongoing economic losses Oregonians are experiencing from the past and continued removal of beavers and loss of beaver-created habitat.[2] The Commission and ODFW should anticipate that the per-unit values shown in Table 2 will only increase over time as climate change brings increased frequency of drought, declining snow pack, and a change in the timing of melt with their impacts to water quality and habitat conditions for fish, wildlife and human communities.[3]

Table 2. Ecosystem Services Potentially Provided by Beavers via habitat creation and per-unit Value. Shaded services will be discussed with case study examples provided in this document.[4]

Ecosystem Service Provided	Per unit value for service
Sediment retention	$2 per cubic yard
Riparian habitat	$1,000 per acre per year
Wetland habitat	$8,000 per acre per year
Aquatic habitat	$4,000 per acre per year
Sensitive-species habitat	$9–$256 per household per year
Pollutant Removal through Sediment Capture	$100,000 per year per percent improvement
Recreation	$75-$375 per recreation day
Delayed Water Flow upstream of reservoirs	$50 per acre-foot
Water temperature	$74,000 – $411,000 per river mile
Aesthetic Benefits	Qualitative Description
Existence Value	Qualitative Description
Flood Resilience	Qualitative Description

The assignment of value for the shaded ecosystem services is based on the following sources:

Increased Adult Salmon Returns: Assigning a value to salmon recovery is complicated and the reader is directed to the "*Economic Benefits of Improved Salmon Populations*" section below where market and non-market values are explained in depth and multiple examples are given.

Improved Stream Temperature: The value assigned ranges from $74,000-$411,000 per mile. These values are based on estimates of costs incurred in the Gifford Pinchot National Forest for restoration work aimed largely at reducing stream temperatures. [5]

Increased Aquatic Habitat: The value assigned is $4000 per acre per year. The value is based on a meta-analysis examining willingness to pay (WTP) estimates for various freshwater ecosystems. The meta-analysis suggests that freshwater ponds are about half as valuable as river-fed wetlands.[6]

> If aquatic habitat created by beaver activity has half the value of wetland habitat, we estimate that ponds upstream of beaver dams may be worth about $1,200–$6,200 per acre per year. For our analysis, we assume the value of aquatic habitat (ponds) generated from beaver activity is in the middle of the range, about $4,000 per acre per year. Throughout our analysis, we have assumed averages for the surface area of beaver ponds in the Escalante River Basin of 0.5 and 1.5 acres. Using the middle value of ecosystem service provided by ponds, $4,000, we estimate the value of each pond may be $2,000–$6,000 per year. Basin-wide, we estimate beaver activity could generate about 34,500–103,500 acres of pond habitat, and that these ponds could produce ecosystem services worth up to $138 million - $414 million per year.

Delayed water flow upstream of reservoirs: The value assigned is $50 per acre-foot. The value is based on the average value of water used downstream from national forests for irrigation or municipal /industrial uses. This value increases during droughts. Irrigators in California, for example, often pay more than $1,000 per acre-foot during drought periods.[7]

It is important to note that the above economic benefits would accrue to diverse segments of Oregon's society. Much of the economic benefits would accrue by restoring and enhancing habitat for a multitude of species, including species at risk of extinction and the 82/294 strategy species in the Oregon Conservation Strategy that require the habitat beavers create. Oregon's fish and wildlife would benefit from improved habitat quality, greater habitat connectivity and complexity, and expanded distribution and size of the habitat types thus increasing their survival under a changing climate. Increases in beaver-created habitat could therefore reduce costs to ODFW and to the state, aiding efforts to achieve conservation goals for affected species.

Many Oregonians would also realize the benefits that come from the retention of water behind beaver ponds and on floodplains in terms of both reduced flood risk for landowners immediately downstream and improved water quality and stream flows. Public utilities that manage reservoirs would also benefit from beaver-created habitat such as ponds, restored floodplain connectivity, and increased channel complexity because these features help attenuate peak highs and lows in streamflows. Oregonians from across the state would realize benefits as increased populations of beavers on federally managed public lands create habitat resulting in new and better opportunities for outdoor recreation. Finally, there would be a positive impact on climate as the wetlands and wet meadows increase in size and become carbon capture and store areas.

POTENTIAL ECONOMIC BENEFITS OF PROPOSED AMENDMENT, QUANTIFIED

As the above paragraph notes, there are many benefits that come with beavers and the habitat they create and maintain. For the petition, we have quantified the economic benefits using data from Oregon for four ecosystem services that would result from an expansion of beaver-created habitat. The data represent only a small portion of Oregon but even this limited scale captures the significance of beaver and the economic harm being done to Oregonians, and Oregon's fish and wildlife as a result of existing regulation:

1) Increased adult salmon returns
2) Improved water quality via decreases in stream temperatures
3) Increased aquatic habitat as a result of increased beaver ponds, and
4) Delayed water flow upstream of reservoirs due to pond storage.

Economic Benefits of Improved Salmon Populations

Determining the economic value of salmon is complex but economists have developed categories of value that provide a useful basis for describing the different ways in which salmon are important to Oregonians (Figure 1). "Use value" materializes through commercial and recreational fishing activities, as individuals directly interact with and extract fish from the environment. It also includes values generated indirectly by salmon/steelhead, as when healthy fish habitat helps reduce the severity of downstream flooding. "Non-use value"(sometimes called "passive-use value") materializes when people derive satisfaction not through interactions with fish but from knowing that they exist and through the interactions of others who enjoy fishing for recreational or commercial purposes.

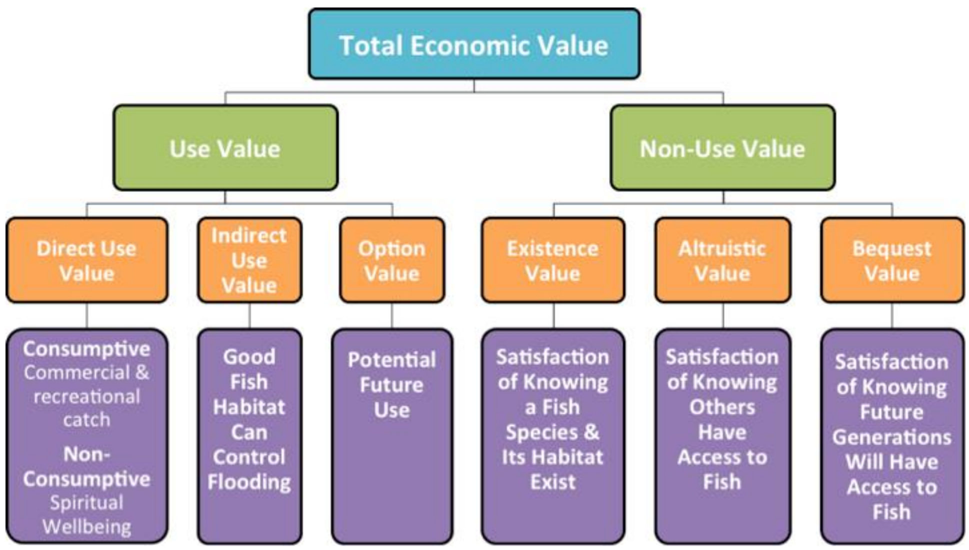

Figure 1. Components of the value Oregonians place on the state's salmon, trout, and other cold-water fish.[8]

These use and non-use values reflect the multiple ways in which these Oregonians and others realize a benefit from their interactions with these fish. A summary by Weber (2015)[9] described these interactions this way:

> "Valuing societal impacts from changes in salmon proceeds from recognizing various pathways of human benefit. Some benefits are relatively obvious, such as resource use and extraction in the market economy, e.g., commercial fish harvest, and revenue from fishing-related expenditures. A less recognized but important dimension are nonmarket benefits, such as the recreational enjoyment of a fishing experience. An angler may contribute only minimally to a local economy through the act of fishing—yet the opportunity to engage in this pastime may be of extraordinarily high value to that individual. Yet human appreciation of natural resources such as salmon goes deeper still. For decades environmental economists have recognized an important category of benefits known as non-use values. Essentially, resources may be valued without the necessity of direct experience. Notions of value predicated on resource extraction, harvest, and even nonconsumptive recreational

use are overly limiting. Categorically neglecting non-use values can lead to significant underestimates of public welfare. … Salmon recovery within a relatively small watershed has been found to be valuable to households across the nation. … [S]tudies consistently indicate that households in the Pacific Northwest and beyond have a high WTP [willingness to pay] for increased salmon." [citations omitted]

The studies mentioned in the last sentence, reaching back more than 30 years, have consistently found that households place a high value on actions that result in increases to salmon/steelhead populations. The economic benefits from increases in salmon populations is high in part because those populations have declined significantly and the outlook is bleak given climate change predictions and the degraded condition of many stream systems.

Valuing salmon for its use value ($ spent)

- **Commercial use values** represent the estimated profits associated with harvest. The literature suggests that profitability in the relevant industries ranges from 43 percent to 99 percent. This analysis assumes a profitability percentage of 80 percent. It uses weighted 5-year averages to estimate harvest value and catch in each fishery. It assumes the Integrated Plan's impact on fish populations would not affect prices in the relevant fishery markets.

- **Sport use values** represent both expenditures ($ spent) and consumer surplus[10] associated with sport fishing in the relevant geographies. The literature describes these values per fishing day. This analysis uses sport-fishing data to estimate the number of days spent fishing per fish harvested in the different geographies. It applies the days spent fishing, per fish harvested, to the increase in fish populations, and then multiplies by the daily use value associated with sport fishing. Furthermore, it assumes that use values associated with sport fisheries are directly related to the number of fish harvested. The literature supports the assumption that sport fishermen fish more often as their harvest rate (fish caught per day spent fishing) increases, with their consumer surplus directly proportional to their harvest rate.[11]

Table 3 summarizes the use values (per fish in 2012 dollars). This analysis applies to the increase in fish harvests attributable to the Yakima River Basin Integrated Plan for managing water resources. The per-fish values represent updated data but remain similar to those used by the Bureau of Reclamation in similar analyses for this area.[12] Use values range from about $10 to about $750 per fish, with the variation representing factors such as species, size of fish, location of the fishing site, catch rate, time of year, and fishing regulations. The use values associated with sport fishing are higher than those associated with commercial fishing, which is consistent with the literature.[13]

Table 3. Economic use value per fish by species and fishery (2012 dollars)

Harvest Category	Coho	Spring Chinook	Fall Chinook	Steelhead	Sockeye
Ocean Commercial	$10	$50	$50	-	-
Ocean Sport	$160	$120	$120	-	-
Lower Columbia Commercial	$10	$60	$30	-	$10
Lower Columbia Sport	$330	$330	$330	-	$330
Columbia Tribal Commercial	$10	$50	$20	$10	$10
Columbia Tribal Ceremonial and Subsistence	Value is incalculable				

Recreational fishing-related expenditures provide insights into the use value of Oregon's cold-water fish. The most recent estimates exist for 2008[14]. That year, 631,000 anglers spent about $780 million on gear, boats, guides, travel, and other items associated with recreational fishing in Oregon. Trip-related travel expenditures associated with freshwater fishing occurred throughout the state and totaled about $270 million. In addition, anglers spent more than $70 million on trip-related travel associated with saltwater fishing, and $441 million on equipment and other items (Table 4). Almost all of this spending focused on cold-water fish.

Oregon's commercial fishery demonstrates another category of use value for salmon. Over the five-year period of 2010-2014, commercial boats delivered to fish processors 3.4 million pounds of salmon worth more than $11 million per year, on average. [15]

Table 4. Recreational fishing expenditures in Oregon, 2008

Type of spending	Amount (million)
Total	$780
Equipment, etc.	$441
Travel expenditures	
Saltwater fishing	$70
Freshwater fishing	$269
Willamette Valley	$43.3
North Coast	$21.0
Central Coast	$24.0
South Coast	$11.6
Portland Metro/Columbia	$34.7
Southern	$39.6
Central	42.7
Eastern	$33.7
Mt. Hood/Gorge	$18.3

Source: Dean Runyan Associates (2009)

Valuing salmon for its non-use value

Economists have made several attempts to estimate the total value Oregonians place on salmon. To do this, they've had to look beyond the spending that indicates the use value to also capture the non-use values, which typically do not involve spending. The best studies to date have focused on the value people place on increasing salmon populations to insulate them from going extinct. These studies generally indicate that, on average, households are willing to spend about $100–$120 per year for a program that promises to increase salmon populations (Table 5). Some of these studies have focused on Washington, but evidence indicates that Washingtonians and Oregonians place similar values of salmon (ECONorthwest 2012).

Table 5. Estimates of household willingness to pay (WTP) for increased salmon populations in the future (2012 dollars)[16]

Location	Columbia River[a]	Elwha River, WA[b]	Coastal OR and WA[c]	Columbia River[d]
Increase in salmon population	2,500,000	300,000	165,000	300,000
Average WTP/year	$100	$100	$120	$110

[a] Olsen et al. (1991). [b] Loomis (1996). [c] Bell et al. (2003). [d] ECONorthwest and ESA (2012).

Olsen et al (1991), Loomis (1996) and Bell et al (2003) were published in peer-reviewed academic journals. The analysis in ECONorthwest and ESA (2012) was peer-reviewed and approved by economists at the Bureau of Reclamation. Bell et al. (2003) estimated the WTP for increases in coho populations of residents living within 30 miles of five Pacific Northwest estuaries: Grays Harbor and Willapa Bay in Washington and Tillamook Bay, Yaquina Bay, and Coos Bay in Oregon.

An important finding from the research on the total value Oregonians place on salmon is that they are willing to pay now for the enjoyment they receive from increases in salmon population that will materialize in the future. The same research showing that Oregonians are willing to pay about $100–$120 per household per year to support a program that promises to increase salmon populations also indicates that the prospect of climate and habitat-related reductions in salmon populations imposes an economic harm of at least the same dollar amount. However, it is also reasonable to expect that Oregonians will place a greater value on a population loss than the value they place on a comparably sized gain because the potential for loss of salmon will generate a greater sense of urgency and thus a greater willingness to pay to reverse conditions. Therefore, this analysis uses the upper bound of the range of values in Table 5 above, $120/household, to indicate the annual economic harm to Oregon's households from the prospect of widespread extinctions.

Oregon is expected to have about 1.6–2.0 million households over the next two decades[17]. These numbers suggest that the annual economic harm from the prospect of population declines will range from about $195 million in 2016 to about $241 million in 2035, and the overall economic harm for 2016–2035 (20 years) will total $4,400 million, or $4.4 billion (Table 6).

Table 6: Economic harm to Oregonians from projected widespread extinctions of salmon. Using $120/household and adjusting to reflect increased population over time. Sum includes use and non-use values.

	2016	**2017**	**2018**	**2019**	**2020**	**2025**	**2035**	**Sum 2016-2035**
Total economic harm (million)	$195	$198	$200	$202	$204	$218	$241	$4,400

The annual economic harm may vary from the indicated amounts. In the near term, the economic harm may be less than indicated insofar as most Oregonians do not yet perceive the full extent of the extinction threat to salmon. Over time, though, the annual economic harm likely will exceed the estimates as climate change and continued loss of salmon habitat brings about declines in salmon populations and the threat of widespread extinction becomes more apparent. Oregonians will experience additional economic harm from population declines for steelhead, trout, and other cold-water species. If, over the two decades, declines in salmon and trout populations materialize and Oregonians perceive the imminent threat of widespread extinctions, the total economic harm from the effects of climate change and habitat loss on salmon and trout could far exceed $4.4 billion.

Total Economic Value: the LBP Study and the Yakima River Basin

[Note: This section contains text and data excerpted from ECONorthwest and ESA (2012)][18]

This section summarizes research conducted in the Yakima River Basin to provide a foundation for understanding recent estimates of the economic benefits that would result from potential increases in Oregon's salmon populations. It draws on research completed in 1999, when the Washington Department of Ecology commissioned the development and application of a model (*LBP Study)* for estimating the total economic value of benefits derived from potential programs to increase fish populations in waterways across the state (Layton et al., 1999).[19] Though never published in an academic journal, the *LBP Study* has received considerable peer review through other channels.[20] One review "recommend[s] that any reliable economic estimates of impacts on salmon and steelhead [in the Columbia River Basin] should be assigned values based upon the methodology developed in [the *LPB Study*]".[21] This conclusion is reinforced insofar as the values developed in the LBP study are similar to those found in other comparable peer reviewed studies, as discussed below. This section applies the *LBP Study* model to data specific to the Yakima River Basin (YRB) Integrated Plan for managing water resources to estimate the economic benefits associated with increases in fish populations resulting from it. Specifically, this section (1) describes the *LBP Study*'s methodology and findings, (2) summarizes the parameters for applying its model to the YRB Integrated Plan, and (3) summarizes the total economic value of the YRB economic benefits from anticipated increases in salmon populations. This description provides the foundation for understanding the potential economic benefits from beaver-related increases in salmon populations in Oregon.

The researchers used survey responses to develop a model of households' willingness to pay (WTP) for increases in fish populations. Figure 2 shows a graph with their corresponding curves. The blue curve describes households' average annual WTP for increases in salmon populations when the baseline fish population remains stable over the next 20 years. The red curve describes households' average annual WTP for increases in salmon populations when the baseline fish population declines over the next 20 years.

Figure 2 shows that, as the potential for decreases in salmon populations and possible extinction go up, so do the urgency to reverse the trends and households' willingness to pay more. However, thresholds can be crossed that no amount of money can fix and the public, regardless of how much they value salmon, have limited extra dollars to spend. This is why beaver-driven restoration is so critical and cost-effective. Beaver-driven restoration can restore key winter rearing habitat, decrease stream temperatures, increase channel complexity and alter riparian habitat for salmon along their migration corridors, thereby enhancing their potential for survival and expansion. All of this can be done at little to no monetary cost.

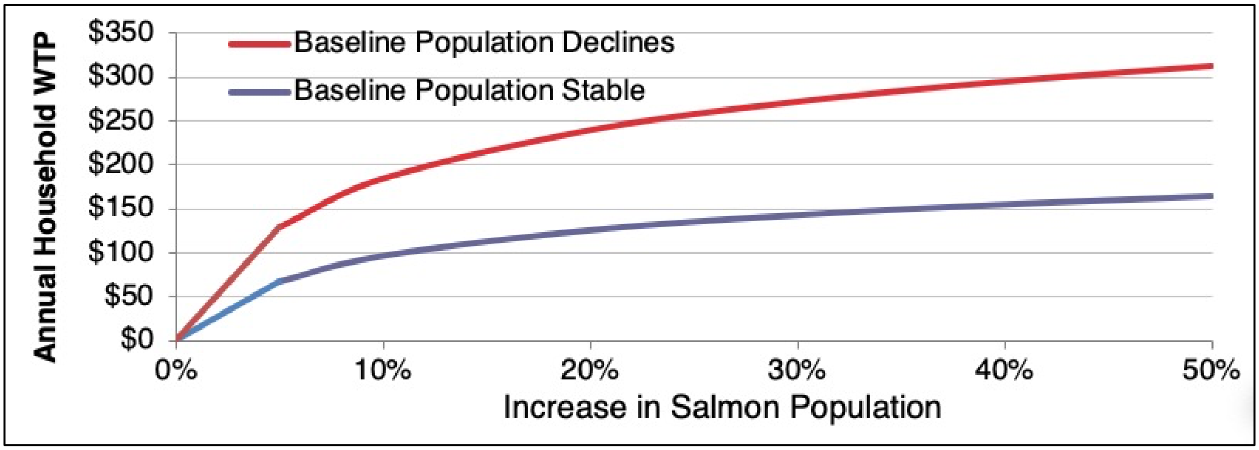

Figure 2. Annual household willingness to pay for an increase in the Columbia River and Eastern Washington salmon/steelhead population

Use Values: *LBP Study*[22]

[Note: This section contains text and data excerpted from ECONorthwest and ESA (2012)

This section isolates the portion of the total value ($4.4 billion) noted in Table 6 above that would be captured by activities that entail direct use of the potential increase in fish populations.

> Note: Direct use values are components of total economic value as shown in Figure 1. They should not be added to the estimate of total value presented in Table 7 below. The harvesting might occur in several ways: commercial, sport, subsistence, and Tribal ceremonial.

- **Commercial use values** represent the estimated profits associated with harvest. The literature suggests that profitability in the relevant industries ranges from 43 percent to 99 percent. This analysis assumes a profitability percentage of 80 percent. It uses weighted 5-year averages to estimate harvest value and catch in each fishery. It assumes the Integrated Plan's impact on fish populations would not affect prices in the relevant fishery markets.

- **Sport use values** represent both expenditures ($ spent) and consumer surplus[23] associated with sport fishing in the relevant geographies. The literature describes these values per fishing day. This analysis uses sport-fishing data to estimate the number of days spent fishing per fish harvested in the different geographies. It applies the days spent fishing, per fish harvested, to the increase in fish populations, and then multiplies by the daily use value associated with sport fishing. Furthermore, it assumes that use values associated with sport fisheries are directly related to the number of fish harvested. The literature supports the assumption that sport fishermen fish more often as their harvest rate (fish caught per day spent fishing) increases, with their consumer surplus directly proportional to their harvest rate.[24]

Table 7 summarizes the use values (per fish in 2012 dollars) this analysis applies to the increase in fish harvests attributable to the Yakima River Basin Integrated Plan for managing water resources. The per-fish values represent updated data but remain similar to those used by the Bureau of Reclamation in similar analyses for this area.[25] Use values range from about $10 to about $750 per fish, with the variation representing factors such as species, size of fish, location of the fishing site, catch rate, time of year, and fishing regulations. The use values associated with sport fishing are higher than those associated with commercial fishing, which is consistent with the literature.[26]

Table 7. Economic use value per fish by species and fishery (2012 dollars)

Harvest Category	Coho	Spring Chinook	Fall Chinook	Steelhead	Sockeye
Ocean Commercial	$10	$50	$50	-	-
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Columbia Tribal Commercial	$10	$50	$20	$10	$10
Columbia Tribal Ceremonial and Subsistence	Value is incalculable				

Pacific Ocean Commercial

The method used to calculate the average use value per fish caught in the commercial ocean fishery has two components: (1) the average profit per fish caught by commercial ocean fisheries in Alaska, Washington, Oregon, and California, and (2) the distribution across the fisheries of fish originating from the Yakima River Basin. The average profit per Chinook ranged from about $50 per fish in Alaska to about $60 in Oregon, and average profit per Coho ranged from about $8 per fish in Alaska to about $10 per fish in Oregon. The distribution of fish originating in the Yakima River Basin in Washington that were harvested by these fisheries was calculated using historical tracking records.[27] For example, from 1984–2011, Alaska accounted for about 90 percent of the take of Chinook that originated in the Yakima River Basin and were harvested in the commercial ocean fishery. The economic use value, per fish, in the commercial ocean fishery is about $10 for Coho and $50 for Spring and Fall Chinook. Steelhead and Sockeye are not harvested in the Pacific Ocean commercial fishery.

Pacific Ocean Sport

The method used to calculate the average use value per fish caught in the ocean sport fishery has three components: (1) the average value per fishing day (which includes expenditures and consumer surplus),[28] (2) the number of sport fishing days off the California, Oregon, and

Washington coasts, and (3) the number of fish caught by recreational anglers off the California, Oregon, and Washington coasts. A literature review of studies estimating the total use value associated with ocean sport fishing in the region concluded that each fishing day is worth about $128 (Reclamation, 2008). This value includes expenditures (e.g., fishing gear, fuel, transportation, fishing guides) and consumer surplus. The average number of days it took for anglers to catch a Coho or Chinook ranged from 0.7 days in Washington to 3.2 days in California. Each state's catch rate (days per fish harvested) was weighted by the percentage of fish harvested in the ocean sport fishery off each state's coast, then multiplied by the average value per fishing day to calculate the average value per fish. The economic use value, per fish, in the ocean sport fishery is about $160 for Coho and $120 for Spring and Fall Chinook. Steelhead and Sockeye are not harvested in the Pacific Ocean sport fishery.

Lower Columbia River Commercial (zones 1–5)

The method used to calculate the average use value per fish caught in the Lower Columbia River's commercial fishery has two components: (1) the average profit per pound of Chinook and Coho harvested in the Lower Columbia River commercial fishery, and (2) the average weight per fish. From 2007–2011, the average Coho harvested in the Lower Columbia commercial fishery weighed about 10 pounds, the average Fall Chinook weighed about 18 pounds, and the average Winter/Spring/Summer Chinook weighed about 14 pounds. The economic use value, per fish, in the Lower Columbia River commercial fishery is about $10 for Coho, $60 for Spring Chinook, and $30 for Fall Chinook. Steelhead and Sockeye are not targeted in the Lower Columbia River commercial fishery. Some Sockeye will be caught as incidental catch; however, the analysis assumes those Sockeye have a use value of about $10 per fish.

Lower Columbia River Sport (zones 1–5)

The method used to calculate the average use value per fish caught in the Lower Columbia River sport fishery has three components: (1) the average value per fishing day (which includes expenditures and consumer surplus), (2) the number of sport fishing days on the Lower Columbia River, and (3) the number of fish caught by recreational anglers in this area. A literature review of studies estimating the total use value associated with sport fishing in the region concluded that each fishing day is worth about $76.[29] This value includes expenditures (e.g., fishing gear, fuel, transportation, fishing guides) and consumer surplus. From 2007–2011, anglers spent about 351,500 days per year fishing on the Lower Columbia River. Each year, they caught an average of 81,500 fish. In other words, they caught one fish every 4.3 days. These numbers indicate the economic use value, per fish, is about $330 for each fish species in the analysis.

Columbia River Tribal Commercial (zone 6)

The method used to calculate the average use value per fish caught in the Columbia River's Tribal commercial fishery has two components: (1) the average profit per pound of Chinook and Coho harvested in the Columbia River (zone 6), and (2) the average weight per fish. The average

Coho harvested in the Lower Columbia commercial fishery (zone 6) weighed about 10 pounds, the average Fall Chinook weighed about 17 pounds, and the average Winter/Spring/Summer Chinook weighed about 14 pounds. The economic use value, per fish, is about $10 for Coho, $50 for Spring Chinook, and $20 for Fall Chinook. Sockeye and steelhead have not been harvested in this fishery for several years. With no data from which to derive Sockeye- and steelhead-specific values, this analysis assumes they have the same value as the Coho harvest, $10 per fish.

Summary

Fish-population modeling determined that it is reasonable to assume implementation of the Integrated Plan would cause annual populations of catchable adult salmon/steelhead produced by the Columbia River Basin to increase beginning in 2013, with the increase leveling off at 181,650–472,450 additional fish in 2042.[30] Table 8 provides an estimate of the monetary value of salmon based on the categories in Figure 1. Table 8 shows an estimate of the present value of households' willingness to pay for the expected increases in salmon/steelhead populations: $5.0–$7.4 billion accounting for households in Washington and Oregon. Because these estimates do not consider the benefits accruing to residents of other regions, both estimates underestimate the full value, from a national perspective, of the increase in salmon/steelhead populations.

Table 8. Summary of fish-related benefits from anticipated increases in salmon populations originating in the Yakima River Basin. (See Figure 1)

Value Category	Sub Category	Washington and Oregon
Total Economic Value		$5.0–$7.4 billion
Use Value	Direct use value, Indirect use value, Option value	$0.1–$0.3 billion
Passive-Use (Non-Use) Value	Existence value, Altruistic Value, Bequest Value	$4.9–$7.1 billion

Increases in future salmon/steelhead populations would potentially support increases in fish harvests and the associated use values. Under expected fish-harvest regimes, annual fish harvests would increase to 37,997–102,603 fish by 2042. Table 8 shows the use values associated with the additional annual harvests have a present value of $0.1–$0.3 billion. This estimate was developed independent of the estimate of total economic value. The estimate of use value is a component of, not an addition to the estimate of total value. The difference between total value and use value represents the passive-use (nonuse) value of the increases in salmon/steelhead populations expected to result from the Yakima River Basin Integrated Plan. The passive use value is estimated to be $4.9–$7.1 billion, when total value reflects Washington and Oregon households combined.

Rogue River Salmon Example

[Note: the text and data in this section are excerpted from Helvoigt and Charlton (2009).[31]]

We conclude with one final example from the Rogue River to help make clear the economic benefits that would result from abundant beaver-created and maintained habitat and the variety of widely distributed improvements in salmon habitat it brings.

In 2008, the *Save the Wild Rogue Campaign* engaged ECONorthwest to analyze the economic value of salmon and steelhead in the Wild & Scenic Rogue River. In this report, we summarize the results of our analysis, which is based on peer- reviewed, published research, results from the Oregon Population survey, and fish-count data published by the Oregon Department Fish and Wildlife.

In this analysis, we develop estimates for only three of the economic values associate with Rogue River salmon: commercial fishing, sport fishing, and non- use value. Non-use values represent the vast majority of the economic value of Rogue River salmon.

- − $1.4 million annually associated with commercial fishing
- − $16 million annually associated with sport fishing
- − $1.5 billion annually associated with non-use values

For more than a decade, Oregonians have consistently stated that improving salmon habitat is important and have expressed a willingness to pay more than $70 million dollars per year to enhance salmon habitat in Oregon. By protecting salmon and steelhead populations in the Rogue River, Oregon is protecting an asset important to residents of the Pacific Northwest. For example, studies indicate that households in Washington and Oregon are willing to pay $30-$130 per year to finance salmon recovery efforts. [citation omitted] Salmon populations also help sustain jobs in the Pacific Northwest. If salmon populations were restored sufficiently to allow increases in commercial harvest, fishers and those in related industries would enjoy new business and job opportunities in Oregon, Washington, and elsewhere along the salmon's migration routes. Further benefits accrue to recreational anglers and all residents of the Pacific Northwest who benefit from the clean water, flood control and open spaces associated with salmon habitat. Since the values of many of these benefits accruing from salmon habitat are not captured by market prices, economists must employ different methods to measure the aggregate benefits that salmon and steelhead provide to the Northwest. Hence, the household surveys provide a means to estimate the extent to which Northwest residents value salmon and enhancements to salmon habitat – enhancements that can be gained at little to no cost if beavers are allowed to expand their numbers and build and maintain their water-rich and complex habitats.

Economic Benefits of Improved Stream Temperatures

Stream temperature is an important water quality parameter because of its impacts on aquatic species and municipal drinking water. Currently, Oregon has at least 11,057 stream miles, 5th order or greater, that are 303d listed as water quality impaired for stream temperatures. In the case of first through fourth order streams, the size of streams where beavers tend to build dams, the number exceeds 23,413 miles (see SI-1). The stream miles exceeding the state standard is expected to rise even further in the next decades in response to climate change. Under current global greenhouse gas (GHG) mitigation strategies, salmon and other cold-water fish species are projected to be replaced in many areas of Oregon by less economically valuable fisheries over the course of the 21st century (Figure 3). While preserving existing coldwater habitats in Oregon through GHG mitigation will require long-term global cooperation, ODFW can act independently to preserve coldwater habitats in Oregon by immediately closing all federally managed public lands to commercial and recreational beaver trapping and hunting. A decision to do so would allow beaver populations to increase and begin building and expanding the habitat conditions that lead to improvements in stream temperatures (i.e. wetlands, wet meadows, increased floodplain connectivity, high water tables, ponds).

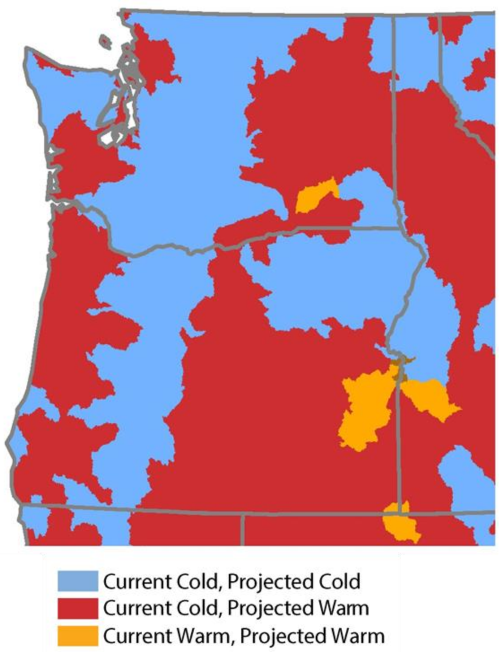

Figure 3. Projected impact of climate change on potential cold-water fish habitat in the year 2100 if global emissions continue at their current rate. BLUE areas are locations where there will be streams still cold enough to support salmon and other cold-water fish in 2100. RED areas are locations that currently have streams that can support cold-water fish but will have warmed enough by 2100 to compromise fish survival.[32]

Eliminating Costly Stream Temperature Restoration

Reductions in stream temperatures are valued at $74,000-$411,000 per mile (Table 2).[33] Given the miles of streams currently exceeding the state standard, the human-powered restoration activities needed to bring about these reductions would cost between $818 million to $9.6 billion (Table 9). A portion of these costs could be avoided if beavers were allowed to build and maintain dams that create the habitat conditions that lead to reduced stream temperatures. The beaver-driven restoration might occur solo or in partnership with human-powered restoration (e.g. debris jams, BDAs) when historic channel changes have altered stream hydraulics to the point that beaver dams are unable to persist through the spring high flows. This partnership is important given the scales and magnitudes of the climate changes expected and current improvement needs.

Table 9. Estimated costs to decrease stream temperatures on 303d listed streams.

Category	5th order or greater streams	1st - 4th order streams
Stream miles	11,057	23,413
Restoration cost @ $74,000/mile	$818,218,000	$1,732,562,000
Restoration cost @ $411,000/mile	$4,544,427,000	$9,622,743,000

Stream Temperature Reductions in Beaver-dominated Systems

The ability of beaver-created habitat to decrease Oregon's stream temperatures at little to no cost was documented in two recent studies in Oregon. The Morgan-Hayes (2018)[34] study looked at long-term temperature data at multiple sites in the North Fork Burnt River (NFBR) watershed on national forest in eastern Oregon. Data span years 1995 to 2017. This watershed currently has Redband trout but once was home to salmon prior to the building of the Hells Canyon dams. Weber et al (2017)[35] examined temperature changes on Bridge Creek in central Oregon from 2007 to 2014. Juvenile steelhead use Bridge Creek as summer rearing habitat. Both studies found temperatures positively influenced by the beaver-created habitat.

One example of reductions in temperature due to beavers is presented using data collected in the NFBR watershed in 2019. Two temperature loggers were deployed on a section of Trout Creek, tributary to the NFBR, with data collected every half hour. Trout.83D.5 recorded stream temperatures as it exited a long section of private land with little shade onto national forest. The stream then flowed through the beaver dam-controlled reach for about 747 feet before reaching the Trout.83D.1 site. The tributary then flowed another 208 feet to its confluence with the NFBR. A comparison of the daily maximum stream temperatures at these two sites found temperatures at Trout.83D.1 cooler than Trout.83.D.5 (Figure 4) during the summer months with temperatures up to 6°F lower (Figure 5).

The economic benefit of this temperature improvement, pro-rated to account for the shorter stream length, was $9,620 - $53,430. This economic value is in addition to the aquatic habitat and water storage economic values already assigned to other benefits of beaver-created habitat.

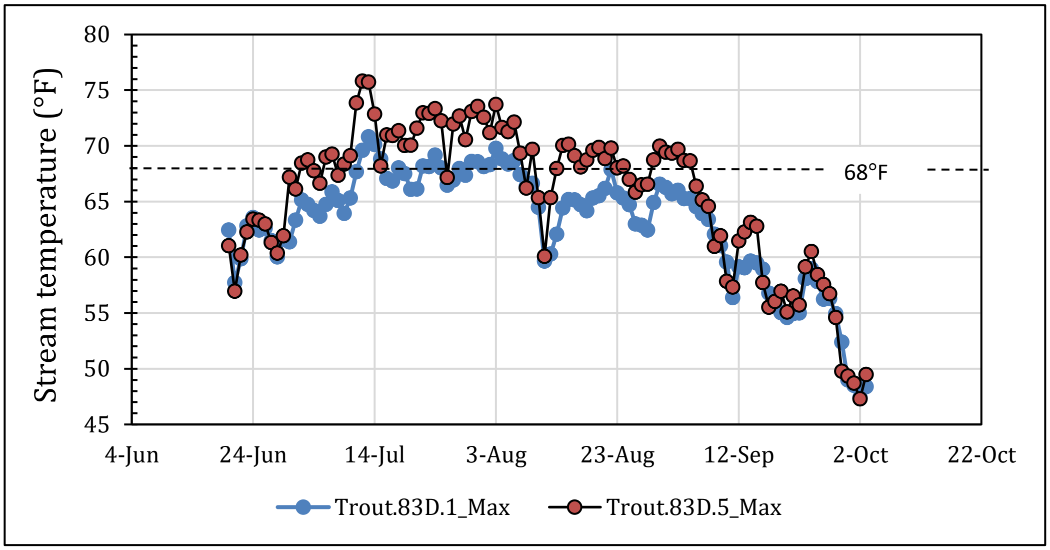

Figure 4. Comparison of the daily maximum stream temperatures of Trout.83D.5 and Trout.83D.1 in 2019.

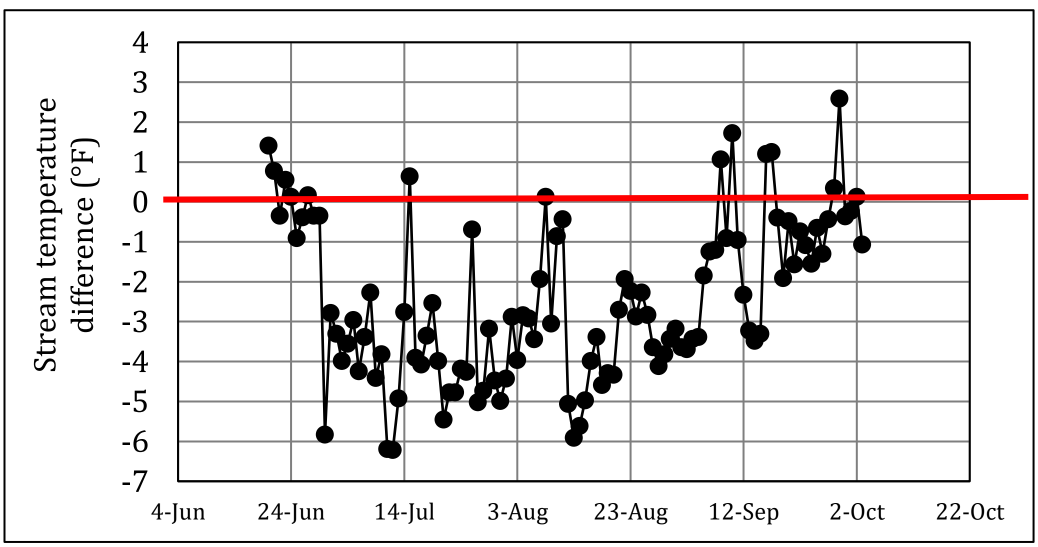

Figure 5. Difference between the daily maximum stream temperatures of Trout.83D.5 and Trout.83D.1 sites in 2019. Values were calculated as Trout.83D.1 – Trout.83D.5.

The significance of this improvement in temperature on Trout Creek due to habitat conditions created by beavers is underscored by data collected at the NFBR.83E.2 site in 2019. This site is about 1320 feet upstream of its confluence with Trout Creek and about 230 stream feet downstream of a long section of unshaded, private land. A comparison of the three sites found that the logger in the beaver dam-dominated reach (Trout.83D.1) was cooler than the other two sites, had fewer days where it exceeded the state standard, and the maximum it exceeded the standard was only 2.8°F. In contrast, Trout.83D.5 exceeded the standard by up to 7.8°F and the NFBR.83E.2 site by as much as 13.8°F (Table 10). Temperatures exceeded the state standard for 51 and 84 days respectively.

Table 10: Comparison of daily maximum stream temperatures and days exceeding the state standard.

Creek	Site number	Dates deployed	State standard (°F)	Max Daily stream temperature (°F)	Max date	# Days exceeding state standard	Total days measured	Elevation (ft)
Trout	Trout.83D.1*	6/20/19 - 10/3/19	68	70.8	13-Jul	15	106	4111
Trout	Trout.83D.5	6/20/19 - 10/3/19	68	75.8	12-Jul	51	106	4113
NFBR	NFBR.83E.2	6/5/19 - 9/26/19	68	81.8	12-Jul	84	114	4112

*in the beaver dam dominated reach

The value of temperature reductions generated by beaver-created habitat will extend beyond individual streams by contributing these cooler waters to larger streams at multiple points. Reductions in stream temperatures in vast miles of first through fourth order streams, the size that beavers build dams on and create habitat, would improve water quality conditions for salmon and humans along the length of the system.

Economic Benefits of Increased Aquatic Habitat

The potential economic value of beaver-created aquatic habitat resulting from the banning of trapping/hunting on federally managed public lands was assessed for: 1) Five areas where beaver dam capacity had been quantified for existing watershed conditions using the Beaver Restoration Assessment Tool (BRAT) developed out of Utah State University and 2) 17 one-mile reaches in the Coast Range using ODFW Aquatic Habitat Inventory (AHI) data. Each acre of beaver-created aquatic habitat represents money that would not need to be spent on human-driven restoration efforts. Increased aquatic habitat created by beavers is valued at $4000 per acre per year (Table 2).

Contributions based on BRAT

The existing watershed beaver dam capacity was modeled for the North Fork Burnt River watershed and the John Day Basin using BRAT under existing conditions (see SI-2). The dam numbers generated were used to estimate potential acres of ponds and aquatic habitat created by beavers (Table 11). The acres presented are a conservative number because only 50% of dams modeled by the BRAT were assumed to be present and maintained (see SI-2) and pond sizes used in calculations were only 20 feet wide by 75 feet long (Table 11). These numbers are only intended to give a sense of potential because they do not include ponds that are larger or extend onto the historic floodplain or other elements of aquatic habitat that come with increased stream system complexity. However, even these simplistic calculations for a small portion of Oregon capture the economic benefit of this beaver-created and maintained habitat, done at little to no additional taxpayer cost. For the North Fork Burnt River watershed and the John Day Basin, the combined value of these small beaver ponds in terms of aquatic habitat created is close to $9 million.

Table 11. Potential beaver-created aquatic habitat (i.e. ponds) based on potential beaver dam numbers and different ponds sizes for areas modeled using the BRAT and existing conditions. Value at $4000 per acre per year.

						50% of total existing capacity		
Name	**% public lands**	**HUC #**	**Drainage area**	**Perennial streams (km)**	**Total existing watershed dam capacity**	**# of dams**	**Aquatic Habitat (acres)**	**Value per year ($)**
North Fork Burnt River watershed	83	1705020201	124,084	495	7019	3510	121	$483,402
Lower John Day subbasin	0	17070204	2,000,000	2,905	19,781	9891	341	$1,362,328
Middle Fork John Day subbasin	60	17070203	508,000	1,474	16, 929	8465	291	$1,165,909
North Fork John Day subbasin	66	17070202	1,200,000	3,535	51,241	25621	882	$3,528,994
Upper John Day subbasin	51	17070201	1,300,000	3,317	32,994	16497	568	$2,272,314
TOTAL				**11,726**	**111,035**	**63, 984**	**2203**	**$8,812,947**

Contributions based on ODFW Aquatic Habitat Inventory

The second example of beaver-created aquatic habitat and its economic value used data from ODFW's AHI database that extends back to 1998. Seventeen stream reaches were selected from eight different subbasins, each reach a mile in length (see SI-3). These reaches have multiple interannual replicates and represent a broad cross-section of the coastal coho Evolutionary Significant Units (ESU). The analysis compared the maximum beaver ponded surface area within each reach to its most recent beaver ponded surface area. The analysis found dramatic declines in beaver ponds, an aquatic habitat that has been touted by many research publications as the most beneficial for coho production. The maximum beaver pond area for the 17 reaches of streams dropped from 424,326 sq. meters to 34,818 sq. meters resulting in a massive decline in juvenile coho production potential (Table 12). This drop in critical winter rearing habitat directly impacts fresh water production resulting in lower adult escapement from the ocean.

Table 12. Changes in beaver dam pond surface area based on ODFW AHI data.

			YEAR		Number of dams		Pond surface area (sq. m)	
HUC 8	**Coho Pop**	**Creek**	**MAX pond surface area**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**
17080006	Big Creek	Gnat Ck trib	2009	2018	4	0	10,795	0
17100202	Nehalem	Alder Ck	2007	2019	10	0	26,842	0
17100202	Nehalem	Buster Ck trib b	1999	2010	11	2	91,139	20,194
17100202	Nehalem	Cedar Ck	2001	2019	9	2	5,975	335
17100202	Nehalem	Little Rackheap	2001	2010	13	0	6,905	0
17100202	Nehalem	Sager Ck	2000	2018	9	0	20,883	0
17100202	Nehalem	Selder Ck, trib B	2013	2016	14	0	15,620	0
17100203	Tillamook Bay	Joe Ck	2002	2017	7	0	19,279	0
17100204	Salmon	Curl Ck	2015	2018	10	0	8,111	0
17100204	Siletz	Miller Ck	2005	2017			89,407	0
17100204	Yaquina	Montgomery Ck	2005	2019	6	0	23,750	0
17100205	Alsea	Walker Ck	2001	2019	11	0	4,210	0
17100206	Siuslaw	Russel Ck	2011	2019	9	3	26,853	4,859
17100206	Siuslaw	Russel Ck, sec 2	2007	2016	7	0	15,530	0
17100303	Middle Umpqua	Heddin	2001	2018	11	4	37,619	2,204
17100304	Coos	Lillian Ck	2003	2006	10	4	14,384	7,226
17100306	Floras	Boulder Ck	1999	2019	3	0	7,024	0
					155	**19**	**424,326**	**34,818**

Considering only the lost aquatic habitat, these 17 stream reaches represent an economic loss of $384,800 per year (Table 13). Implementation of the proposal to ban trapping/hunting of beavers on federally managed public lands could reverse this loss.

Table 13. Comparison of acres and value of beaver-created aquatic habitat (i.e. ponds) based on subset of ODFW's AHI surveys. Valued at $4000 per acre per year

17 AHI stream reaches	Total # dams recorded	Aquatic Habitat (sq. meters)	Aquatic Habitat (acres)	Value per Year ($)
MAX year	155	**424,326**	104.8	$419,200
Most recent surveyed year	19	**34,818**	8.6	$34,400
Difference	**- 136**	**- 389,508**	**- 96.2**	**- $348,800**

Economic Benefits of Increased Water Storage

In addition to the increased amount of aquatic habitat described above as a result of abundant beaver ponds, there is the added benefit of increased surface and groundwater storage on these federally managed public lands. Water flowing from national forests has an average economic value exceeding $50 per acre-foot (Table 2).[36] Some of this value comes from the ecosystem services, such as fish habitat, recreational opportunities, etc. that result from improvements of instream flows. Other values materialize as downstream users remove the water from the stream and use it to irrigate crops and for industrial-municipal purposes.

The value of water in Oregon's streams rises during late summers and drought years, when water is scarce. We can expect scarcity and, hence, values will increase sharply in the foreseeable future as changes in climate increase the risk of low streamflows during late summer, and during both short-term and prolonged droughts.[37] Irrigators in California, for example, often pay more than $1,000 per acre-foot during drought periods.[38]

Using data from the BRAT analysis for the North Fork Burnt River (see SI-2), Table 14 provides some idea of the monetary value that could be gained by increased temporary beaver pond storage and delayed water flow upstream of Unity Reservoir in Baker County. Volume stored varies as a function of pond dimensions and beaver dam numbers (see SI-4).

Table 14. Economic benefit of stored water behind beaver dams upstream of Unity Reservoir, Baker County as a function of number and size of beaver ponds. Valued at $50/acre-foot.

Ecosystem Service Provided	Water stored (gallons)	Water stored (acre-feet)	Households served for a year	Economic Benefit
Delayed water flow upstream of reservoirs if the watershed is at maximum modeled dam capacity (7019 dams)	4.2 to 12.7 million	725 -2,175	220 -660	$10,997 - $32,990
Delayed water flow upstream of reservoirs if the watershed is at half modeled dam capacity (3510 dams)	2.1 to 6.3 million	363 -1,088	110 - 330	$5,499 - $16,497

The benefits of the water stored behind beaver ponds can also be considered in terms of the number of household of four who could be served by this water. Assuming each household uses on average about 19,200 gallons of water per year, the example above shows that 363 to 660 households would benefit. Other studies support the significance of beaver ponds with actual pond measurements. In the Methow Valley area, a biologist measured the amount of water stored in 62 ponds created by beavers which had been released under the Methow Valley Project. She found they stored 5 million gallons of water, enough for an average Twisp household for 5 years.[39] And research by Walker et al (2010) examining water storage potential behind existing beaver dams in a number of counties in Washington State found that the potential was high to meet eastern Washington's water needs with increased beaver ponds storage. Their study examined both surface water and groundwater storage potential.[40]

Economic Benefits of Improved Recreational Opportunities

Oregon statute ORS 496.012 states "It is the policy of the State of Oregon that wildlife shall be managed to prevent serious depletion of any indigenous species and to provide the optimum recreational and aesthetic benefits for present and future generations of citizens of this state. In furtherance of this policy, the State Fish and Wildlife Commission shall represent the public interest of the State Oregon and implement the following coequal goals of wildlife management:

(7) To make decision that affect wildlife resources of the state for the benefit of the wildlife resources and to make decision that allow for the best social, economic and recreational utilization of wildlife resources by all user groups. "

The Runyan report (2009), commissioned by ODFW and Travel Oregon, found that the economic returns of fishing, hunting, wildlife viewing, and shellfishing were $2.8 billion.[41] Of this, wildlife viewers spent just over $1 billion and people who fish $783 million. These numbers matter because beavers directly influence the abundance, distribution and quality of many of the habitat types needed by fish and wildlife, 82 of which are listed as strategy species in the Oregon Conservation Strategy.

> ...nearly 2.8 million Oregon residents and nonresidents participated in fishing, hunting, wildlife viewing, and shellfish harvesting in Oregon. Of the total number of participants, 631 thousand fished, 282 thousand hunted, 175 thousand harvested shellfish, and 1.7 million participated in outdoor recreation where wildlife viewing was a planned activity.
>
> When all three categories [travel generated, local recreation, equipment purchases] are combined, fish and wildlife recreation resulted in expenditures of $2.5 billion in 2008. Oregon residents and nonresidents who traveled overnight and on day trips of 50 or more miles (one-way) from homemade travel-generated expenditures of $862 million. Local recreation expenditures of $147 million were made by Oregon residents while participating in these activities less than 50 miles from home. State residents and nonresidents also spent an additional $1.5 billion on specialty equipment and other activity-related purchases from retail establishments and suppliers based in Oregon. (p. 1)

The Responsive Management report (2016)[42], commissioned by the Oregon State Legislature, found the following set of values and concerns by Oregonians:

> An open-ended question asked about the most important fish, wildlife, or habitat issue in Oregon (there was no answer set; residents could say anything that came to mind). The top issues are habitat loss, lack of water, low/declining fish populations, urban sprawl, and conservation/management of resources in general.

> The survey asked respondents about the importance of eight fish/wildlife values. For each item, residents rated the importance they placed on it, using a 0 to 10 scale where 0 is not at all important and 10 is extremely important.
>
> "That healthy fish and wildlife populations exist in Oregon" was the top-ranked value, closely followed by "that Oregon's water resources are safe and well protected." Note that these top two values are purely ecological rather than utilitarian. The values that are more utilitarian are lower (but still rated quite high in absolute terms), such as the provision of opportunities for viewing wildlife, for hunting, or for fishing. (p. ii)"

These findings reinforce the findings of earlier research: Oregonians place high economic value on the non-market goods and services they derive from fish, wildlife, and habitat. This high value has important implications: improvements in fish, wildlife, and habitat will yield large economic benefits for Oregonians. Beaver-created habitat can assist in creating these benefits at a state-wide scale with little to no monetary cost. Conversely, failure to expand beaver populations and their habitat on federally managed public lands likely will be accompanied by deteriorations in fish, wildlife, and habitat and, hence, large economic losses.

Conservation Investments

Ending commercial and recreational beaver trapping/hunting on federally managed public lands would increase the productivity of the state's investments in conservation. These increases would occur through 1) restoration of conservation funding currently being withheld from the state and 2) improved effectiveness of conservation expenditures.

Restoration of Conservation Funding

Between 2015 and 2019 Oregon lost about $6 million of federal funds from Clean Water Act Section 319 and Coastal Zone Management Act Section 306 as a result of the state's refusal to adopt measures to achieve and maintain water quality standards under the Clean Water Act (Table 15). Instead, the funds were allocated to other states and will continue to be until measures are implemented that address the water quality concerns (see SI-5). In the meantime, the state budget continues to decline while the salmon recovery needs increase.

Improvements sought in coho habitat included improved stream temperatures, more wood in medium, small and non-fish-bearing streams and improved stream hydrology. These are improvements that can be accomplished by abundant, widely distributed and stable colonies of beavers actively building and maintaining habitat at little to no cost to the taxpayer.

Table 15. Dollars withheld from DEQ and State Lands as a result of Oregon's refusal to comply with the Coastal Zone Act Reauthorization Amendments of 1990.

Year	Withheld from DEQ	Withheld from State Lands	Total
2015	$631,500	$598,800	$1,230,300
2016	$435,540	$637,500	$1,073,040
2017	$516,000	$637,500	$1,153,500
2018	$509,100	$696,900	$1,206,000
2019	$523,035	$642,675	$1,165,710
TOTAL	**$2,615,175**	**$3,213,375**	**$5,828,550**

Improved Effectiveness of Conservation Expenditures

Beavers can build and maintain habitat and thus accomplish conservation objectives faster and more cheaply than engineered activities and infrastructure. They can also improve human-driven restoration efforts by adding additional complexity, stability and resilience into the project area without additional dollars spent.

The significance of their contribution is indicated in Table 16 which shows different restoration expenditures by OWEB (Oregon Watershed Enhancement Board) for coastal wetlands, streams, and riparian areas. Many of these restoration efforts could have been accomplished or enhanced by beavers through their habitat modification without expending any additional dollars. Examples include beaver ponds leading to higher water tables which leads to wetland creation or human wood placement supplemented by beaver dams leading to increased habitat complexity and stability.

Table 16. OWEB Expenditures on Stream, Riparian, and Wetland Restoration Efforts (2014-2019)

Category	Dollars invested
Coastal Wetlands	$3,638,006
Other Wetland Enhancement/restoration	$1,456,212
Large Wood Placement	$1,196,208
Riparian Restoration/Enhancement	$3,620,742
Floodplain Reconnection, Enhancement, Restoration	$3,560,756
Other stream-related restoration	$22,151,656
TOTAL	**$35,623,581**

An example of conservation expenditures that either beavers could have done better or would enhance is the construction of beaver dam analogues (BDAs). These are often necessitated because of the absence of real beavers to construct real beaver dams or by the need to improve stream hydraulics post channel incision so that beavers can build dams that persist through the high spring flows.[43] The Upper Nehalem Watershed Council recently estimated that it would cost more than $225,000 to construct 27 BDAs, or more than $8,300 each. It is important to note that these BDAs are intended to be a short-term solution. They are designed to help improve stream conditions in a way that can only be enhanced or maintained by the presence of stable and abundant beaver populations. They are not a substitute for healthy, abundant, stable and widely distributed beavers which will maintain and repair their dams for free. In contrast, it is unlikely that were the BDAs to fail that funds would be available for their repair.

POTENTIAL ECONOMIC BENEFITS OF PROPOSED AMENDMENT, UNQUANTIFIED

The economic benefits described above are just a small subset of the numerous benefits that would result from ending commercial and recreational trapping and hunting on federally-managed public lands. However, there are other benefits that cannot be quantified at this time. This does mean the value of these benefits is zero. Instead, they merely reflect the absence of suitable information for developing a credible quantitative estimate. Potentially significant, but unquantifiable economic benefits include, but are not limited to:

- Increases in earnings, jobs, and wages by agricultural producers, farm workers, and urban commercial water users in response to increased summer streamflows.
- Increases in the disposable incomes of households that consume municipal water, resulting from higher stream flows and, hence, lower water costs, during droughts.
- Increases in the value of the benefits enjoyed by outdoor recreationists, resulting from the positive impacts of beavers on stream flows, habitats, and the species dependent on them.
- Increases in the earnings, jobs, and wages of firms and workers related to outdoor recreation.
- Increases in the amounts of carbon sequestered and stored in wetlands and other ecosystems impacted by beavers.
- Reductions in wildfire risks and costs, resulting from beaver-related expansion of wetlands and riparian areas.
- Increases in earnings, jobs, and wages associated with commercial fishing, resulting from beavers' positive impacts on salmon populations.

ECONOMICS OF EXISTING RULE

Commercial and recreational beaver hunting and trapping under Oregon's Furbearer Trapping and Hunting Regulations occurs on both public and private land. However, locations are reported to ODFW only by county and therefore the number of beavers taken from the various types of public lands (federal, state, county, city) versus private lands is unknown. Several tables and figures are provided to give an idea of the value of commercial and recreational beaver trapping and hunting state-wide and used to compare against the economic values of not trapping and hunting beavers and acquiring the various ecosystems services generated by beaver-created and maintained habitat.

Table 17 estimates the maximum dollar return on beaver pelts if all beaver take reported to ODFW were sold. Table 18 indicates that the values found in the last column of Table 17 overstate the economic return of beaver trapping and hunting because beaver take was much greater than beaver pelts sold. Table 19 shows beaver sales (pelts and castor) at the Oregon Territorial Council on Furs sales. Economic return between 2015 to 2019 ranged from $ 6,899 to $11,669. During these same years, OWEB spent from $35.6 million dollars on coastal wetland and stream and riparian restoration. The information presented above indicates that much of this spending could have been avoided, or made more effective, if beavers had not been removed from the landscape.

It is important to note that the dollars listed in Tables 17, 18, and 19 reflect the economic return of beaver trapping and hunting on a statewide basis (includes both private and public lands). The petition to amend OAR 635-050-0070 only applies to federally managed public lands. Therefore, the economic losses from the approving the amendment is much less than presented in these tables.

Table 17: Data related to commercial and recreational trapping, beaver take, pelt prices, and statewide economic return if all pelts sold.

Year	Oregon's population	Furtaker Licenses sold (all) [1]	Furtakers reporting a beaver take[1]	Beaver take reported to ODFW [1]	Pelt price[1]	Maximum $ state-wide if all sold at pelt price
2000		1,580	250	3,385	$13	$44,005
2001	3,470,000	1,615	256	3,900	$10	$39,000
2002		1,815	256	3,178	$11	$34,958
2003		2,102	236	2,581	$14	$36,134
2004		2,238	257	2,771	$17	$47,107
2005	3,617,000	2,254	211	2,880	$21	$60,480
2006		2,556	276	3,251	$18	$58,518
2007		2,616	239	2,497	$20	$49,940
2008		2,782	284	2,501	$17	$42,517
2009		2,491	281	2,814	$19	$53,466
2010	3,856,000	2,353	268	3,246	$17	$55,182
2011		2,477	251	2,731	$21	$57,351
2012		2,491	278	2,869	$17	$48,773
2013		2,635	310	3,293	$20	$65,860
2014		2,339	214	1,945	$14	$27,230
2015	4,017,000	2,073	171	1,326	$11	$14,586
2016		1,851	161	1,231	$12	$14,772

[1]Oregon Furtaker License and Harvest Data: Appendices are from the Staff Summary at the ODFW Commission Meeting; June 7 2018, Baker City, OR. Appendix 1, p. 3 (licenses sold); Appendix 10, p. 12 (take and furtakers); Appendix 5, p. 7 (pelt prices). NOTE: Take numbers in the Staff Summary vary slightly between appendices in the document. The Staff Summary data differ from data obtained from ODFW and so differ slightly from those found in Table 17.

Table 18: Comparison of beaver take reported to ODFW compared to the number of beaver pelts offered for sale at the annual OTC auctions corresponding to the beaver trapping and hunting season. The number of pelts, if any, sold outside of OTC auctions is unknown.

Season	ODFW Reported Take[1]	Pelts Offered at OTC[2]	Pelts Sold at OTC[2]	ODFW Reported Take Sold (%)
2013-2014	3320	570	557	17%
2014-2015	1981	355	334	18%
2015-2016	1312	381	334	29%
2016-2017	1290	501	499	39%
2017-2018	1022	274	267	26%
TOTAL	**8925**	**2081**	**1991**	**22%**

[1]ODFW electronic harvest data provided by ODFW.
[2]Oregon Territorial Council on Furs, Inc. (http://www.otcfursales.com/sale-prices.html)

Table 19: Published sales figures of the Oregon Territorial Council on Furs, Inc. from the annual fur auctions from 2015 to present and the portion of those sales related to beavers (pelts and castor). The total fur sales do not include antler sales. Data for earlier years is not publicly available. Pelt values are taken from actual OTC sales.

Year	Total Fur Sales[1]	Beaver Sales[1] Including Castor	% of Total Fur Sales	Beaver Pelt Value[1]	Castor Value[1]
2015	$341,684	$11,669	3.4%	$14	$41/oz
2016	$206,021	$ 8,871	4.3%	$11	$39/oz
2017	$549,501	$ 9,880	1.8%	$12	$44/oz
2018	$459,538	$ 6,899	1.5%	$14	$52/oz
2019	$532,153	$ 7,489	1.4%	$13	$63/oz
2020[2]	$157,024	$ 3,788	2.4%	$ 8	$83/oz
TOTAL	**$2,245,921**	**$48,596**	**2.1%**		

[1]Oregon Territorial Council on Furs, Inc. (http://www.otcfursales.com/sale-prices.html),
[2] In 2020, 1 of 2 sales canceled due to the coronavirus

In summary, income generated over the last six years based on available data show that only $48,596 worth of beaver pelts and castor were sold (Table 19). In the five years with data, the total beaver pelts sold were 1991 or only 22% of the total number reported to ODFW (8925) (Table 18). This means that 6934 pelts were not sold suggesting that many were discarded. If one assumes that the beavers trapped were likely family units and use the estimate of 6 beavers/family, then the total number reported trapped could represent up to 1487 colonies. Of the 1487 colonies, it would appear based on the lack of sales to match the amount of take that as many as 1155 colonies were simply killed and discarded. This represents hundreds of millions to billions of dollars of lost ecosystem services. These lost ecosystem services could have been helping Oregonians weather climate change, create systems more resilient to wildfire and drought, restore salmon runs, make conservation investments more effective, and offset pandemic-related declines in the state budget.

ECONOMIC COMPARISON: PROPOSED AMENDMENT vs EXISTING RULE

The information presented in this document and the comparison between adopting the proposed amendment versus maintaining the existing rule reveals a stark economic, social and cultural tradeoff (Table 20). If the Commission rejects the petition, a few (< 170) will continue to enjoy the small benefits from largely recreational trapping/hunting on federally managed public lands to the detriment of the many that depend on beaver-created and maintained habitat. However, if the proposed amendment is approved, all Oregonians—4.2 million of us—and countless fish and wildlife, including threatened and endangered salmon and 82 strategy species, would realize benefits that total in the hundreds of millions to billions of dollars per year. These benefits come from the improvements in ecosystem services that arise from abundant and widely distributed beaver-created and maintained habitat.

Implementing the proposed closure on commercial and recreational trapping/hunting on federally-managed public lands and the waters that flow through them is required in order to receive these benefits because without beavers there is no beaver-created and maintained habitat. Taking these steps now is essential in order to set in motion the processes that will improve fish and wildlife habitat and other ecosystem services. These improvements will help insulate the state from the effects of changes in climate. Taking these steps now is also essential because there will be a lag between the cessation of trapping and hunting and the expansion and dispersal of beavers on federally managed public lands and the creation of habitat. Taking these steps now, thus, is the only way the Commission can help reverse the serious and ongoing decline in salmon populations and other indigenous species and provide optimum economic, ecological, social and cultural benefits to present and future generations of citizens of this state.

Table 20. Comparison of value of continued beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands versus closing these lands and allowing beaver-driven restoration to begin. (*NOTE: Table 20 is also Table 1 in the Executive Summary)*

Item	Year	Action	Dollars	People and/or fish and wildlife served
Continued Beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands				
Total Beaver/Castor sales	2015-2019	Money earned by Trappers/hunters	< $48,596 (maximum)	< 170 because not all trap/hunt on federally-managed public lands and the waters that flow through these lands
Closure of beaver trapping/hunting on federally-managed public lands and the waters that flow through these lands				
Restored Salmon Runs	future	estimate of household willingness to pay (WTP) for increased salmon populations in the future	Tribal Ceremonial and Subsistence: Value is incalculable. WTP: $100 to $120 per household per year which results in an estimated value of $195 million in 2016 increasing to $241 million in 2035.	Countless salmon and communities who depend on or benefit from healthy salmon populations culturally and/or economically plus countless other species and individuals that benefit from improved fish and wildlife habitat
Improved Stream Temperatures on a Minimum of 23,413 Miles of 1st - 4th Order Streams (beaver dam building sized streams)	future	estimated cost of human driven restoration	$ 1.7 to 9.6 billion dollars	4.2 million people, unknown number of species and individuals
EPA and NOAA Restoration Dollars	2015-2019	Dollars that have been lost due to failure to require water quality improvements. Voluntary compliance still only required.	$5.8 million	4.2 million people, unknown number of species and individuals
Oregon Watershed Enhancement Board (OWEB) Restoration Expenditures	2014-2019	Spent	$35.6 million	4.2 million people, unknown number of species and individuals

Item	Year	Action	Dollars	People and/or fish and wildlife served
Recreational Spending on Wildlife Viewing, Fishing, Hunting, and Shellfishing	2008	Spent	$2.8 billion	2.8 million people
Aquatic Habitat Ecosystem Value for two Beaver Restoration Assessment Tool (BRAT) Area Examples	future	estimated cost of human driven restoration	$8.8 million	County residents in these areas plus unknown number of species and individuals
Aquatic Habitat Ecosystem Value for ODFW Aquatic Habitat Inventory Area Example of 17 one-mile reaches	future	estimated cost of human driven restoration	$348,800	Salmon and communities who depend on or benefit from healthy salmon populations (4.2 million people) plus countless other species and individuals
Delayed Flow Upstream of Reservoir Due to Water Storage via Beaver Ponds for NFBR Example	future	estimated value of water to downstream uses	$5,499 to $32,990 per year	Fisheries, downstream irrigators

SUPPLEMENTAL INFORMATION (SI)

SI-1: STREAM TEMPERATURE

A request was made to ODEQ by Dr. Suzanne Fouty for the number of streams that are listed in Oregon as water quality impaired for stream temperatures. The results are shown in Table S1.1. The explanation of the data is the result of multiple conversations with Becky Anthony, DEQ Water Quality Assessment, in June 2020.

Table S1.1: Summary of ODEQ stream temperature data. Source: ODEQ

Category	River Miles	Miles assessed for one or more parameters	Miles listed for Temp
5th order or greater streams (Total miles)	17,608	13,193	11057
4th order or less (Total stream miles in watershed assessment units)	292,856	128,400*	78,044**
Total in the state	310,464		

* Not all streams within a watershed assessment unit (WAU) measured but at least one stream for at least one parameter was.
** Not all streams within the WAU were measured and above impaired for temperature, but at least one was. Therefore, all included in the number.

Seventy-five percent (13,193 miles) of Oregon's total miles of stream 5th order or larger have been measured for one or more water quality parameter. Of these miles, 11,057 miles are above the state temperature standard. These miles represent a minimum because 25% of the streams in this size category have no water quality data.

Interpreting the 78,044 miles within the watershed assessment units (WAU) shown as temperature impaired is less direct because of the method used. In the case of the WAUs, if at least one stream was above the standard in a WAU than all streams in that WAU are categorized as above. Therefore, this number overstates miles within these WAUs that are actually above the state standard. However only 26% of the WAUs were surveyed (810/3076) for temperature leaving a lot of WAUs without any temperature data. If only 30% of the streams in the WAUs listed for temperature were above the state standard, then at least 23,413 miles are above the standard. However, there are miles of streams without any data and the 23,413 miles is considered is a very conservative number because only 26% of the WAU were surveyed for stream temperatures.

11,057 + 23,143 = 34,470 minimum miles impaired for temperature and most of those miles are in the upper watersheds and many of these are on these federally managed public lands. These streams are of the size where beavers build dams and create ponds and habitat.

SI-2: Aquatic Habitat Availability (BRAT)[44]

This appendix was generated by Dr. Suzanne Fouty, retired Forest Service hydrologist/soils specialist.

The BRAT model was developed out of Utah State University. It is a capacity model developed to assess the upper limits of riverscapes to support beaver dam-building activities. It outputs an estimated density of dams (i.e. dams per length of stream) and a rough count of an upper limit (i.e. capacity) of how many dams the conditions in and surrounding a reach could support. Both existing and historic capacity were estimated using readily available spatial datasets to evaluate seven lines of evidence:

(1) a reliable water source;
(2) stream bank vegetation conducive to foraging and dam building;
(3) vegetation within 100 m of edge of stream to support expansion of dam complexes and maintain large beaver colonies;
(4) likelihood that dams could be built across the channel during low flows;
(5) the likelihood that a beaver dam on a river or stream is capable of withstanding typical floods;
(6) evidence of suitable stream gradient; and
(7) evidence that river is too large to allow dams to be built and to persist.

Fuzzy inference systems were used to combine these lines of evidence while accounting for categorical ambiguity and uncertainty in the continuous inputs driving the models. The existing model estimate of capacity was driven with LANDFIRE vegetation data from 2014, whereas the 'historic' estimate represents a pre-European settlement model of vegetation, also from LANDFIRE.

BRATs were done for two areas in Oregon: North Fork Burnt River watershed and John Day Basin. The North Fork Burnt River watershed is 124, 084 acres and the GIS layer used noted about 307.8 miles of perennial streams. The BRAT estimated the existing NFBR watershed capacity for beaver dams at 7,019 dams with dam densities varying throughout the watershed (Figure S2.1, Table S2.1). In contrast only 53 dams were found either by virtual reconnaissance in Google Earth or ground based field work identified. The John Day basin is about 5.19 million acres. The estimated existing John Day basin (HUC 6) capacity is 120,945 dams. The Basin was analyzed based on its four subbasins: Lower John Day (2 million acres), Middle Fork John Day (508,000 acres), North Fork John Day (1.2 million acres) and Upper John Day (1.3 million acres). As is the case with the NFBR watershed results, dam densities varied throughout the subbasins as shown in Tables S2.2 to S2.5.

The same model was used to determine historic dam numbers based on estimates of historic vegetation types. The historic estimates for the NFBR watershed-wide capacity were 11,036 dams reflecting a 36% loss compared to historic capacity. Values for the John Day Basin watershed-wide with estimates of historic vegetation types were 169,781 dams reflecting a 29% loss compared to historic capacity. In both areas, the capacity losses can be explained in terms of vegetation loss and degradation associated with land use including 1) conversion of valley bottoms to agricultural land uses, 2) overgrazing, and 3) conifer encroachment of wet meadow areas. However, despite these losses, both areas are still capable of supporting and sustaining a substantial amount of beaver dam-building activity. Even if only 50% of existing potential was achieved, there would be 3510 dams (NFBR) and 60,407 dams (John Day Basin), numbers much greater than current conditions.

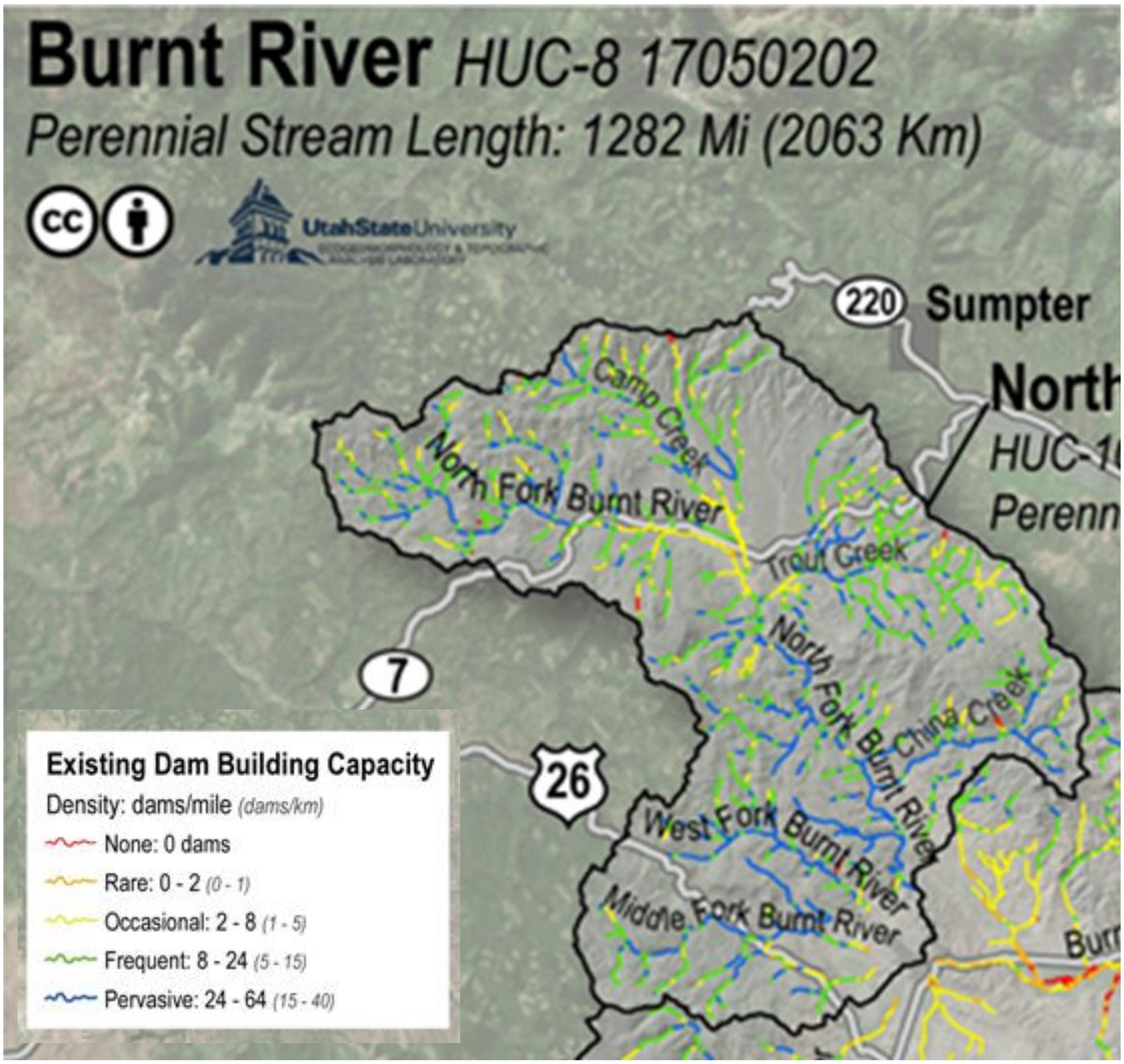

Figure S2.1: Close up of modeled beaver dam capacity for existing condition for the North Fork Burnt River watershed (MacFarlane et al 2019).

Table S2.1. Distribution of existing dam building capacity by category for the North Fork Burnt River Watershed (HUC 10: 1705020201). Drainage area = 124,084 acres

Category	Perennial Streams (miles)	# Beaver Dams	Dam density (dams/mile)
Pervasive	101.99	3,911	38
Frequent	151.9	2,702	18
Occasional	50.468	393	8
Rare	0.93	13	14
None	1.86	0	0

Table S2.2. Distribution of existing dam building capacity by category for the Lower John Day subbasin (HUC 8: 17070204). Drainage area = 2,000,000 acres

Category	Perennial Streams (mile)	# Beaver Dams	Dam density (dams/mile)
Pervasive	133.4	4,873	37
Frequent	300.3	5,345	18
Occasional	903.8	7,606	8
Rare	218.1	1,957	9
None	0.0	0	0
TOTAL	**1555.6**	**19,781**	

Table S2.3. Distribution of existing dam building capacity by category for the Middle Fork John Day subbasin (HUC 8: 17070203). Drainage area = 508,000 acres

Category	Perennial Streams (miles)	# Beaver Dams	Dam density (dams/mile)
Pervasive	231	8,618	37
Frequent	352	6,266	18
Occasional	257	1,947	8
Rare	11	98	9
None	0	0	n/a
TOTAL	**849.6**	**16,929**	

Table S2.4. Distribution of existing dam building capacity by category for the North Fork John Day subbasin (HUC 8: 17070202). Drainage area = 1,200,000 acres

Category	Perennial Streams (miles)	# Beaver Dams	Dam density (dams/mile)
Pervasive	836	32,850	39
Frequent	876	15,803	18
Occasional	310	2,388	8
Rare	23	200	9
None	146	0	0
TOTAL	**2192**	**51,241**	

Table S2.5. Distribution of existing dam building capacity by category for the Upper John Day subbasin (HUC 8: 17070201). Drainage area = 1,300,000 acres

Category	Perennial Streams (miles)	# Beaver Dams	Dam density (dams/mile)
Pervasive	344.7	12,761	37
Frequent	789.9	13,965	18
Occasional	703.1	5,481	8
Rare	93.6	787	8
None	124.6	0	0
TOTAL	2055.9	32,994	

SI-3: Aquatic Habitat Availability (ODFW AHIs) and Potential for Salmon Recovery

This appendix authored by Steve Trask, Senior Fish Biologist, Bio-Surveys, LLC and Trask Consulting, Inc.

Table S3.1 presents the quantified loss of beaver dams and resulting ponded surface area documented in ODFW's own Aquatic Habitat Inventory (AHI) database that extends back to 1998. Seventeen reaches were selected from this database that have multiple interannual replicates and represents a broad cross-section of the coastal coho Evolutionary Significant Units (ESU). The data set compared the maximum ponded surface area within the same reach over multiple years (1998 – 2019) to the most recent survey's measurement of ponded surface area. The analysis found dramatic declines in the beaver-created aquatic habitats that have been touted by many research publications as the most beneficial for coho production. The maximum pond area for the 17 reaches of streams surveyed dropped from 424,326 sq. meters to 34,818 sq. meters resulting in a massive decline in juvenile coho production potential. This drop in critical winter rearing habitat directly impacts fresh water production resulting in lower adult escapement from the ocean.

A comparison calculation was done assuming all other things remained the same except for beaver pond area. Based on this simplified scenario, the very recent loss of ponded surface area in the form of beaver ponds leads to an estimated decline in adult escapement of 38,637 adult coho if fresh water habitats were fully seeded post winter in both cases (1.6 smolts / sq. meter of beaver pond surface area). The dramatic decline in beaver pond area documented by ODFW indicates an ESU wide systemic crisis is in play for our most important aquatic keystone species. Because the observed decline is very recent, it is likely that the habitat that recently supported vast beaver pond surface areas still exhibits functional beaver habitat and that some combination of other factors are contributing to the decline of beavers. Therefore, if beavers were able to expand their numbers and build and maintain beaver dams to even contemporary levels of abundance (post 1998), then there is the potential for a large recovery of listed OCN coho to follow.

The key to this recovery is providing the remaining beaver (a fraction of their historical abundance) the ability to build, maintain, and expand their beaver dam complexes. While a number of factors contribute to beaver mortality, most are outside the ability of ODFW to affect. However, commercial and recreational beaver trapping is under their jurisdiction and one area where mortality can be decreased. The potential benefits to coho salmon of retaining more beaver on the landscape that could employ a dam building life history are great. ODFW's assumption that the lack of viable habitat (early seral vegetative resources) is the primary limiting factor controlling the proliferation of beaver on the landscape is poorly vetted and contradicted by its own readily available AHI data as well as field verified models such as the BRAT.

Table S3.1. Changes in Beaver dam pond surface area, smolt potential and adult returns.

			YEAR		Number of dams		Pond surface area (sq. m)		Smolt Potential at full seeding*		Adult Returns**	
HUC 8	Coho Pop	Creek	MAX pond surface area	Most Recent Survey	MAX year	Most Recent Survey	MAX year	Most Recent Survey	MAX year	Most Recent Survey	MAX year	Most Recent Survey
17080006	Big Creek	Gnat Ck trib	2009	2018	4	0	10,795	0	17,272	0	1,071	0
17100202	Nehalem	Alder Ck	2007	2019	10	0	26,842	0	42,947	0	2,663	0
17100202	Nehalem	Buster Ck trib b	1999	2010	11	2	91,139	20,194	145,822	32,310	9,041	2,003
17100202	Nehalem	Cedar Ck	2001	2019	9	2	5,975	335	9,560	536	593	33
17100202	Nehalem	Little Rackheap	2001	2010	13	0	6,905	0	11,048	0	685	0
17100202	Nehalem	Sager Ck	2000	2018	9	0	20,883	0	33,333	0	2,067	0
17100202	Nehalem	Selder Ck, trib B	2013	2016	14	0	15,620	0	24,992	0	1,550	0
17100203	Tillamook Bay	Joe Ck	2002	2017	7	0	19,279	0	30,846	0	1,912	0
17100204	Salmon	Curl Ck	2015	2018	10	0	8,111	0	12,978	0	805	0
17100204	Siletz	Miller Ck	2005	2017			89,407	0	143,051	0	8,869	0
17100204	Yaquina	Montgomery Ck	2005	2019	6	0	23,750	0	38,000	0	2,356	0
17100205	Alsea	Walker Ck	2001	2019	11	0	4,210	0	6,736	0	418	0
17100206	Siuslaw	Russel Ck	2011	2019	9	3	26,853	4,859	42,965	7,774	2,664	482
17100206	Siuslaw	Russel Ck, sec 2	2007	2016	7	0	15,530	0	24,848	0	1,541	0

			YEAR		Number of dams		Pond surface area (sq. m)		Smolt Potential at full seeding*		Adult Returns**	
HUC 8	**Coho Pop**	**Creek**	**MAX pond surface area**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**	**MAX year**	**Most Recent Survey**
17100303	Middle Umpqua	Heddin	2001	2018	11	4	37,619	2,204	60,190	3,526	3,732	219
17100304	Coos	Lillian Ck	2003	2006	10	4	14,384	7,226	23,014	11,562	1,427	717
17100306	Floras	Boulder Ck	1999	2019	3	0	7,024	0	11,238	0	697	0
					155	**19**	**424,326**	**34,818**	**678,840**	**55,708**	**42,091**	**3,454**

* Full seeding expansion utilizes 1.6 coho / sqm of BD surface area from Nickelson, 2012

**Smolt to Adult ocean survival utilizes 6.2%, the 10-year average from Life Cycle monitoring sites between 2001-2010 from Nickelson, 2012

SI-4: WATER STORAGE

This section was generated by Dr. Suzanne Fouty, retired Forest Service hydrologist. Source of beaver dam numbers is the BRAT done by Utah State University of the North Fork Burnt River watershed. See SI-2.

Table S4.1: Potential inchannel surface water stored behind the beaver dams estimated for the entire NFBR watershed using 7019 dams. This number was presented in BRAT as existing watershed capacity.

NFBR watershed dams	water depth (ft)	Channel widths (ft)	pond lengths (ft)	Water stored (cubic feet)	water stored (gallons)	water stored (acre-feet)	Households served for a year (4 per family)	Economic value @ $50/acre-foot
7019	3	20	75	31,585,500	4,222,660	725	220	$10,997
7019	3	20	150	63,171,000	8,445,321	1450	440	$21,993
7019	3	30	75	47,378,250	6,333,991	1088	330	$16,495
7019	3	30	150	94,756,500	12,667,981	2175	660	$32,990

Table S4.2: Potential inchannel surface water stored behind the beaver dams estimated for entire NFBR watershed if use 3510 dams. This number represents 50% of the BRAT estimate of 7019 dams.

NFBR watershed dams	water depth (ft)	Channel widths (ft)	pond lengths (ft)	Water stored (cubic feet)	water stored (gallons)	water stored (acre-feet)	Households served for a year (4 per family)	Economic value @ $50/acre-foot
3510	3	20	75	15,795,000	2,111,631	363	110	$5,499
3510	3	20	150	31,590,000	4,223,262	725	220	$10,998
3510	3	30	75	23,692,500	3,167,447	544	165	$8,249
3510	3	30	150	47,385,000	6,334,893	1088	330	$16,497

Table S4.3: Potential inchannel surface water stored behind the beaver dams estimated for entire NFBR watershed if assume only 25% of the 7019 dams persists post-high spring flows.

NFBR watershed dams	water depth (ft)	Channel widths (ft)	pond lengths (ft)	Water stored (cubic feet)	water stored (gallons)	water stored (acre-feet)	Households served for a year (4 per family)	Economic value @ $50/acre-foot
1755	3	20	75	7,897,500	1,055,816	181	55	$2,750
1755	3	20	150	15,795,000	2,111,631	363	110	$5,499
1755	3	30	75	11,846,250	1,583,723	272	82	$4,124
1755	3	30	150	23,692,500	3,167,447	544	165	$8,249

CONVERSIONS: 1 cubic foot = 7.48 gallons; 43560 cubic feet = 1 acre-foot; Average water use for household of 4 = 19,200 gallons/yr

SI-5: Restoration of EPA and NOAA Funding

Source: This appendix was authored by Paul Koberstein using material from an unpublished book manuscript "Canopy of Titans" by Paul Koberstein and Jessica Applegate. Paul Koberstein is also the editor of Cascadia Times out of Portland, OR.

Past Funding Withheld Due to Failure To Improve Water Quality

A search of more than 1,000 documents obtained through the Oregon Public Records Law by Cascadia Times has revealed that the state of Oregon has failed to comply with federal Clean Water and Coastal Zone Management statutes protecting water quality and salmon habitat in Coast Range streams, resulting in multi-million-dollar fines levied by two federal agencies. Cascadia Times also found that the state's failure to comply these laws and its failure to protect beaver in coastal streams have combined to negatively impact wild coho salmon populations in the Coast Range. Cascadia Times plans to publish its findings in a forthcoming book on the coastal forest, Canopy of Titans.

1. In 1998, the federal government determined that the state of Oregon has failed to protect coastal streams as required by the Clean Water Act Section 319 and the Coastal Zone Management Act Section 306. Pursuant to 16 U.S.C. § 1455b(c)(3) and (4), the US Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) are withholding grant funds from Oregon until it submits a fully approved Coastal Nonpoint Pollution Control Program as required by section 6217(a) of the Coastal Zone Act Reauthorization Amendments of 1990. EPA and NOAA agencies have withheld approximately $1 million yearly from the Oregon Department of Environmental Quality and the Oregon Division of State Land since withholding began in 2015. As shown in Table S5.1., the total amount is approaching $7 million.[45]

Table S5.1. Funding withheld from Oregon as a result of its refusal to take restoration actions required by the Coastal Zone Act Reauthorization Amendments of 1990.

Year	Withheld from DEQ	Withheld from State Lands	Totals
2015	$631,500.00	$598,800.00	$1,230,300.00
2016	$435,540.00	$637,500.00	$1,073,040.00
2017	$516,000.00	$637,500.00	$1,153,500.00
2018	$509,100.00	$696,900.00	$1,206,000.00
2019	$523,035.00	$642,675.00	$1,165,710.00
2020 (Projected)	$523,035.00	$642,675.00	$1,165,710.00
TOTALS	$3,138,210.00	$3,856,050.00	$6,994,260.00

2. The federal court order to withhold grant funds was signed July 1, 2015 by US Magistrate Judge Paul Papak.[46]

3. The Section 6217 coastal non-point program includes all Oregon Coast streams excluding the Columbia River basin and the Umpqua and Rogue.[47]

4. Since withholding began in 2015, NOAA and EPA have been working with the State to address the conditions laid out in the Papak order. The State has made incremental modifications to its program and has since met most, but not all, of those conditions. The federal agencies objected to portions of the state program allowing actions that are voluntary but not mandatory.[48]

5. Specifically, EPA/NOAA required Oregon to apply certain mandatory management measures where water quality impairments and degradation of beneficial uses attributable to forestry exist and where voluntary efforts were unsuccessful.[49]

6. EPA/NOAA identified specific areas where Oregon's Forest Practices Act must be strengthened to attain water quality standards and fully support beneficial uses. These areas include protection of medium, small, and non-fish bearing streams, including intermittent streams. Under existing State forest practices, these streams may be subject to loss of sediment retention capacity, increases in delivery of fine sediments, and increases in temperature due to loss of riparian vegetation. The agencies determined that the Oregon's Forest Practices Act does not adequately address stream temperature increases stemming from forestry practices.[50]

7. EPA/NOAA are also concerned about the lack of adequate long-term supplies of large woody debris in medium, small, and non-fish bearing streams, a shortage of which can result in decreased sediment storage in upstream tributaries, increased transport and deposition downstream, and overall adverse impacts to beneficial uses.[51]

8. A 2011 report by the National Marine Fisheries Service points out that beaver ponds and side channels are "principal habitat features for coho salmon." The report notes that notes juvenile coho salmon may be dependent upon beaver dams "within the landscape."[52]

9. In 1997, the Oregon Department of Fish and Wildlife observed, "[t]he quality of freshwater habitat was one factor that was identified as potentially influencing the decline of coho in the ESU. Pools formed by the dam building of beavers (Castor canadensis) may be an important component of high-quality habitat for coho." It concludes that "[a]lthough the harvest of beaver in the ESU appears to have declined, habitat surveys conducted in the Oregon Coast Coho ESU from 1997-2003 show high annual variability but no significant trend in the occurrence of beaver pools." *Id*. at 9." Despite the importance of beavers to OC coho habitat protection and restoration, Oregon continues to enforce only voluntary, compliance with regulations.[53]

10. NMFS, in its 2016 5-Year Review: Summary & Evaluation of Oregon Coast Coho Salmon said for mid-coast streams, the recovery strategy is to protect current high quality summer and winter rearing habitat (including estuarine habitat) and strategically restore habitat quality in adjacent habitat for rearing and spawning, including the restoration of beaver populations.[54]

    The same document said the primary limiting factors are stream complexity in the Salmon, Siletz, Yaquina, Alsea and Siuslaw rivers and spawning gravel, including the lack of beaver. The secondary limiting factors are stream complexity, lack of beavers, and water quality. The continuing loss of beavers whose damming activities improve coho salmon rearing habitat, primary productivity, nutrient retention/cycling, floodplain connectivity, and stream flow moderation remains an ongoing habitat concern, as does fish passage and access in the Yaquina, Alsea, and Siuslaw rivers and Beaver Creek estuaries. (Reeves et al. 1989; Stout et al. 2012 as cited in NMFS 2016)[55]
    Among NMFS recommendations under the ESA:

    a. Implement the primary recovery strategy for the populations in this stratum to protect current high-quality summer and winter rearing habitat (including estuarine habitat) and strategically restore habitat quality in adjacent habitat for rearing and spawning including restoring beaver populations.

    b. Restore ecological processes to improve water quality (temperature and dissolved oxygen), instream habitat/channel complexity, and spawning gravel conditions. including restoring beaver populations.

    c. By protecting from adverse timber management and agricultural practices, urbanization, and beaver control.

NMFS' Recommended Future Actions

• Implement the primary recovery strategy for this stratum to protect current high-quality summer and winter rearing habitat and strategically restore habitat quality in adjacent habitat by improving instream flow, water temperature, and channel complexity by protecting the stratum from adverse timber management and agricultural practices, and lethal beaver control.

• Develop and implement a beaver conservation plan that includes reducing lethal control, improving public education and acceptance of beavers, and developing non-lethal beaver management practices to address winter and summer rearing habitat for this stratum.

State Regulatory Mechanisms Affecting Beaver Management

Beavers were once widespread across Oregon. There is general agreement that beavers are a natural component of the aquatic ecosystem and beaver dams provide ideal habitat for overwintering coho salmon juveniles. Some scientists argue that restoring beavers and beaver ponds would be the single most effective habitat action that we could take to rebuild OC coho salmon populations.

Implement the Strategic Action Plans to protect and restore ecosystem processes and functions and coho salmon habitats. Activities should include restoring habitat capacity for rearing juvenile coho salmon by increasing large wood loading, beaver habitat, and wetland/off-channel connectivity, and by increasing native riparian vegetation to provide bank stability and shade stream reaches during warm summer months.

Improve floodplain connectivity by increasing beaver abundance and reducing or limiting development of channel confining structures, including roads and infrastructure.

REFERENCES

Anderson, D. and M. Scott (1993). *Valuing the Salmon Resource: Columbia River Stocks Under Climate Change and Fishery Enhancement.* April. Northwest Regional Economic Conference.

Bair, B. (2004). *Stream Restoration Cost Estimates*. US Department of Agriculture, Forest Service. Gifford-Pinchot National Forest.

Bell, K., D. Huppert, and R. Johnson (2003). "Willingness to Pay for Local Coho Salmon Enhancement in Coastal Communities." *Marine Resource Economics*. 18: 15-31. http://www.journals.uchicago.edu/doi/pdfplus/10.1086/mre.18.1.42629381

Brouwer, R., I. Langford, I. Bateman, and R. Turner (1999). "A Meta-analysis of Wetland Contingent Valuation Studies." *Regional Environmental Change*. 1(1):47-57.

Buckley, M.T., T. Soulhas, E. Niemi, E. Warren, and S. Reich (2011). The economic value of beaver ecosystem services.

Bureau of Reclamation (Reclamation) (2008). *Economics Technical Report for the Yakima River Basin: A Component of Yakima River Basin Water Storage Feasibility Study, Washington.* Technical Series No. TS-YSS-23.

Dean Runyan Associates (2009). Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon: 2008 State and County Expenditures Estimates. Prepared for the Oregon Department of Fish and Wildlife and Travel Oregon. 72p.

ECONorthwest and ESA (2012). Yakima River Basin Integrated Water Resource Management Plan: Four Accounts Analysis of the Integrated Plan

EPA (2015). *Climate Change in the United States: Benefits of Global Action*. United States Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-15-001

Goodstein, E. and L. Matson (2007). "Climate Change in the Pacific Northwest: Valuing Snowpack Loss for Agriculture and Salmon Frontiers." *Environmental Valuation and Policy.* Edward Elgar New York

Helvoigt, T.L. and D. Charlton (2009). The economic value of Rogue River salmon. ECONorthwest, Eugene, OR

Hubble, J. (2012). *Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement, Fish Benefits Analysis Technical Memorandum. U.S. Bureau of Reclamation.*

[NOTE: incorrectly cited as Hubble, J. 2012 in document because incorrectly cited in the *Yakima River Basin Integrated Water Resource Management Plan: Framework for Implementation (October 2012*) as: *Hubble, J. 2012. Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement, Fish Benefits Analysis Technical Memorandum. U.S. Bureau of Reclamation. June 2012*. However, the Fish Benefits Analysis Tech. Memorandum was completed in May 2011 via a joint effort of U.S. Bureau of Reclamation, HDR Engineering, and Anchor QEA under contract to Bureau of Reclamation. Hubble was the principle author of the publication and a BOR employee.

The correct citation would have been: *Bureau of Reclamation (BOR). (2011). Yakima River Basin Study: Fish Benefits Analysis Technical Memorandum. Prepared by U.S. Bureau of Reclamation, HDR Engineering, Anchor QEA. Contract No. 08CA10677A ID/IQ, Plan of Study Task 7. May 2011.* However, document identified as Hubble_2012_BOR_2011 for ease a locating.]

Huppert, D., G. Green, W. Beyers et al. (2004). *Economics of Columbia River Initiative*. Washington Department of Ecology and Columbia River Initiative Economics Advisory Committee.

Jay W. Nicholas, Oregon Coastal Salmon Restoration Initiative, state of Oregon, (1997).

Layton, D., G. Brown, and M. Plummer (1999). *Valuing Multiple Programs to Improve Fish Populations*. Washington State Department of Ecology. April.

Lewis, D.J, Dundas, S. J., Kling, D. M., Lew, D. K., and S. D. (2019) The non-market benefits of early and partial gains in managing threatened salmon. PLoS ONE 14(8): e0220260. https://doi.org/ 10.1371/journal.pone.0220260

Loomis, J, P. Kent, L. Strange, and others (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent value survey.

Loomis, J. (1996). "Measuring the Economic Benefits of Removing Dams and Restoring the Elwha River: Results of a Contingent Valuation Survey." *Water Resources Research*. 32(2):441-447. http://onlinelibrary.wiley.com/doi/10.1029/95WR03243/pdf

Loomis, J. (2006). “Use of Survey Data to Estimate Economic Value and Regional Economic Effects of Fishery Improvements.” *North American Journal of Fisheries Management*.

Macfarlane W.W., Meier M.D., Hafen C, Albonico, M.T. and J. M. Wheaton (2019). North Fork Burnt River Beaver Restoration Assessment Tool: Building Realistic expectations for partnering with Beaver in Restoration and Conservation. Prepared for the Powder Basin Watershed Council. Logan, UT. 80 Pages.

Marshall, A. (2019). Climate change will mean more multiyear snow droughts in the West; The Conversation. https://theconversation.com/climate-change-will-mean-more-multiyear-snow-droughts-in-the-west-121406.

McCreay, A. (2020). Beavers may be part of answer to climate change: Local relocation project returns animals to natural habitat. 4p. https://methowvalleynews.com/2016/01/23/beavers-may-be-part-of-answer-to-climate-change/

Morgan-Hayes, A. (2018). Laws, regulations, and management plans to improve streamflow and stream temperature: a case study in the North Fork Burnt River Watershed. *MS Thesis, Oregon State University, Department of Natural Resources*. https://ir.library.oregonstate.edu/concern/graduate_projects/rj430962j

National Marine Fisheries Service, 2016 5-Year Review: Summary & Evaluation of Oregon Coast Coho Salmon, (2016).

Niemi, E. (2009). *An Overview of Potential Economic Costs to Washington of a Business-As-Usual Approach to Climate Change*. University of Oregon, Climate Leadership Initiative.

Niemi. E. (2020). Bigger than Expected: Climate-Change Costs and Emission-Reduction Benefits. Working Paper 20-01. www.nreconomics.com

NOAA and EPA letter to Richard Benner, director Oregon Department of Land Conservation (now Division of State Lands) and Landon Marsh, director of Oregon Department of Environmental Quality, (Jan. 20, 1998).

NOAA and EPA letter to Jim Rue, director Oregon Department of Land Conservation (now Division of State Lands) and Dick Pederson, director of Oregon Department of Environmental Quality, (July 28, 2015).

Olsen, D., J. Richards, and R. Scott (1991). "Existence and Sport Values for Doubling the Size of Columbia River Basin Salmon and Steelhead Runs." Rivers. 2(1):44-56;

Oregon Office of Economic Analysis (2015). *Oregon Economic and Revenue Forecast*. September http://www.oregon.gov/DAS/OEA/docs/economic/forecast0915.pdf.

Responsive Management (2016). Oregon Residents' opinions on and values related to Oregon Department of Fish and Wildlife. *Conducted for the Orgon Legislative Task Force on Funding for fish, wildlife and related outdoor recreation and education*. 200p.

Richardson, L., and J. Loomis (2009). "The Total Economic Value of Threatened, Endangered and Rare Species: An Updated Meta-Analysis." *Ecological Economics*. 68: 1535-1548

Stout, H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G.Pess, G. Reeves, M. Scheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams and T. Williams (2012). Scientific conclusions of the status review for Oregon Coast coho salmon (Oncorhynchus kisutch). Draft revised report of the Oregon Coast Coho Salmon Biological Review Team. NOAA/NMFS/NWFSC, Seattle, WA.

The Research Group (2016). Oregon commercial fishing industry in 2015: Briefing report. With assistance from the Coastal Oregon Marine Experiment Station. http://www.dfw.state.or.us/agency/docs/OR%20Comm%20Fish%20Ec%20Impacts%20Brief%202015.pdf

University of California, Davis (2014). California: drought and jobs

US Magistrate Paul Papak, Stipulated and proposed schedule, (July 1, 2015)

USDA Forest Service (2002). Water & the Forest Service. FS-660. Washington, DC.

USDA Forest Service, Office of Sustainability and Climate. 2018. Potential drought impacts in the Pacific Northwest.

Walker, B., A. Parrish, M. Petersen, A. Martin, O. Moringstar, and K. Hall (2010). The beaver solution: An innovative solution for water storage and increased late summer flows in the Columbia River Basin. The Lands Council, Grant #G0900156. 67pp.

Webb, D. (2012). Personal Communication. Pacific States Marine Fisheries Commission.

Weber, M.A. (2015). Navigating benefit transfer for salmon improvements in the Western US

Weber, N., Bouwes, N., Pollock, M.M., Volk, C., Wheaton, J.M., and G. Wathen (2017). Alteration of stream temperature by natural and artificial beaver dams. *PLoS ONE* 12(5): e0176313. https://doi.org/ 10.1371/journal.pone.0176313

---

[1]David J. Lewis, D.J. S.J. Dundas, D.M. Kling, D.K. Lew, and S. Hacker. The non-market benefits of early and partial gains in managing threatened salmon

[2] The research underlying the figures in Table 2 focused on southern Utah, which has ecological and economic characteristics similar to those of eastern Oregon and, hence, it is reasonable to anticipate that restoring healthy beaver populations across this region would yield similar benefits. Many of the benefits would be even greater in western Oregon, in part because this region has a higher density of humans who would enjoy the benefits.

[3] Niemi, E., 2020. Bigger than Expected: Climate-Change Costs & Emission-Reduction Benefits. Working Paper 20-01. January 2020. Natural Resource Economics.

[4] Buckley, M.T., T. Soulhas, E. Niemi, E. Warren, and S. Reich. 2011. The economic value of beaver ecosystem services.

[5] Bair, B. 2004. *Stream Restoration Cost Estimates*. US Department of Agriculture, Forest Service. Gifford-Pinchot National Forest

[6] Brouwer, R., I. Langford, I. Bateman, R. Turner. 1999. "A Meta-analysis of Wetland Contingent Valuation Studies." *Regional Environmental Change*. 1(1):47-57.

[7] University of California, Davis. 2014. California: drought and jobs.

[8] Adapted from Loomis, J, P. Kent, L. Strange, and others. 2000. Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent value survey.

[9] Weber, M.A. 2015. Navigating benefit transfer for salmon improvements in the Western US

[10] Consumer surplus is the difference between what one is willing to pay for something and the amount one actually pays. If the amounts that one is willing to pay and actually pays are the same, there is no consumer surplus. If the amount that one is willing to pay for something is greater than what one actually pays, then there is a consumer surplus. Consumer surplus varies from person to person for the same item and, hence, economists measure it using carefully designed surveys. Consumer surplus is especially important because it represents an increase in economic well-being. Consider a person who has $100 cash and is willing to pay $70 for a recreational fishing trip. If they pay $70 for the trip, they have no consumer surplus—they've traded $70 of the cash for a fishing trip worth $70. They still have $30 of cash, plus $70 worth of pleasure from the fishing trip, so their total well-being remains $100. But, if they can take the fishing trip paying only $20, then they get $70 worth of fishing pleasure by spending only $20 and enjoy a consumer surplus of $50. After the trip, they have $80 of cash plus $70 of fishing pleasure, and their total economic well-being is $150.

[11]Loomis, J. 2006. "Use of Survey Data to Estimate Economic Value and Regional Economic Effects of Fishery Improvements." *North American Journal of Fisheries Management*.

[12]Bureau of Reclamation (Reclamation). 2008. *Economics Technical Report for the Yakima River Basin: A Component of Yakima River Basin Water Storage Feasibility Study, Washington.* Technical Series No. TS-YSS-23.

[13] Anderson, D. and M. Scott. 1993. *Valuing the Salmon Resource: Columbia River Stocks Under Climate Change and Fishery Enhancement.* April. Northwest Regional Economic Conference.

[14] Dean Runyan Associates. 2009. Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon: 2008 State and County Expenditures Estimates. Prepared for the Oregon Department of Fish and Wildlife and Travel Oregon. 72p.

[15]The Research Group. 2016. Oregon commercial fishing industry in 2015: Briefing report. With assistance from the Coastal Oregon Marine Experiment Station. http://www.dfw.state.or.us/agency/docs/OR%20Comm%20Fish%20Ec%20Impacts%20Brief%202015.pdf.

[16]Olsen, D., J. Richards, and R. Scott. 1991. "Existence and Sport Values for Doubling the Size of Columbia River Basin Salmon and Steelhead Runs." Rivers. 2(1):44-56; Loomis, J. 1996. "Measuring the Economic Benefits of Removing Dams and Restoring the Elwha River: Results of a Contingent Valuation Survey." *Water Resources Research*. 32(2):441-447. http://onlinelibrary.wiley.com/doi/10.1029/95WR03243/pdf; Bell, K., D. Huppert, and R. Johnson. 2003. "Willingness to Pay for Local Coho Salmon Enhancement in Coastal Communities." *Marine Resource Economics*. 18: 15-31. http://www.journals.uchicago.edu/doi/pdfplus/10.1086/mre.18.1.42629381; and ECONorthwest and ESA. 2012. Yakima River Basin Integrated Water Resource Management Plan: Four Accounts Analysis of the Integrated Plan.

[17]Oregon Office of Economic Analysis. 2015. *Oregon Economic and Revenue Forecast*. September http://www.oregon.gov/DAS/OEA/docs/economic/forecast0915.pdf.

[18]ECONorthwest and ESA. 2012. Yakima River Basin Integrated Water Resource Management Plan: Four Accounts Analysis of the Integrated Plan

[19] Layton, D., G. Brown, and M. Plummer. 1999. *Valuing Multiple Programs to Improve Fish Populations*. Washington State Department of Ecology. April.

[20] Examples of peer review include Richardson, L., and J. Loomis. 2009. "The Total Economic Value of Threatened, Endangered and Rare Species: An Updated Meta-Analysis." *Ecological Economics*. 68: 1535-1548; Goodstein, E. and L. Matson. 2007. "Climate Change in the Pacific Northwest: Valuing Snowpack Loss for Agriculture and Salmon Frontiers." *Environmental Valuation and Policy.* Edward Elgar New York; and Niemi, E. 2009. *An Overview of Potential Economic Costs to Washington of a Business-As-Usual Approach to Climate Change*. University of Oregon, Climate Leadership Initiative. The last report included review by these members of an Economics' Steering Committee: Katie Baird, *U. of Washington, Tacoma,* William Barnes, *U. of Portland,* Randall A. Bluffstone, *Portland State U.,* Gardner Brown, *U. of Washington,* Trudy Ann Cameron, *U. of Oregon,* Janie Chermak, *U. of New Mexico,* Bonnie G. Colby, *U. of Arizona,* Paul N. Courant, *U. of Michigan,* Peter Dorman, *Evergreen State College,* Kristine M. Grimsrud, *U. of New Mexico,* David Ervin, *Portland State U.,* Joel Hamilton, *U. of Idaho,* Hart Hodges, *Western Washington, U.* Daniel Huppert, *U. of Washington,* Don Negri, *Willamette U.,* Andrew Plantinga, *Oregon State U.,* Michael J. Scott, *PNW National Laboratory, and* W. Douglass Shaw, *Texas A&M U.*

[21]Huppert, D., G. Green, W. Beyers et al. 2004. *Economics of Columbia River Initiative*. Washington Department of Ecology and Columbia River Initiative Economics Advisory Committee.

[22]ECONorthwest and ESA. 2012. Yakima River Basin Integrated Water Resource Management Plan: Four Accounts Analysis of the Integrated Plan

[23] **Consumer surplus** is the difference between what one is willing to pay for something and the amount one actually pays. If the amounts that one is willing to pay and actually pays are the same, there is no consumer surplus. If the amount that one is willing to pay for something is greater than what one actually pays, then there is a consumer surplus. Consumer surplus varies from person to person for the same item and, hence, economists measure it using carefully designed surveys. Consumer surplus is especially important because it represents an increase in economic well-being. Consider a person who has $100 cash and is willing to pay $70 for a recreational fishing trip. If they pay $70 for the trip, they have no consumer surplus—they've traded $70 of the cash for a fishing trip worth $70. They still have $30 of cash, plus $70 worth of pleasure from the fishing trip, so their total well-being remains $100. But, if they can take the fishing trip paying only $20, then they get $70 worth of fishing pleasure by spending only $20 and enjoy a consumer surplus of $50. After the trip, they have $80 of cash plus $70 of fishing pleasure, and their total economic well-being is $150.

[24]Loomis, J. 2006. "Use of Survey Data to Estimate Economic Value and Regional Economic Effects of Fishery Improvements." *North American Journal of Fisheries Management*.

[25]Bureau of Reclamation (Reclamation). 2008. *Economics Technical Report for the Yakima River Basin: A Component of Yakima River Basin Water Storage Feasibility Study, Washington.* Technical Series No. TS-YSS-23.

[26] Anderson, D. and M. Scott. 1993. *Valuing the Salmon Resource: Columbia River Stocks Under Climate Change and Fishery Enhancement.* April. Northwest Regional Economic Conference.

[27] Webb, D. 2012. Personal Communication. Pacific States Marine Fisheries Commission.

[28] Consumer Surplus. See Footnote 22.

[29] Bureau of Reclamation (Reclamation). 2008. *Economics Technical Report for the Yakima River Basin: A Component of Yakima River Basin Water Storage Feasibility Study, Washington.* Technical Series No. TS-YSS-23.

[30] Hubble, J. 2012. *Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement, Fish Benefits Analysis Technical Memorandum. U.S. Bureau of Reclamation.*

[31] Helvoigt, T.L. and D. Charlton. (2009) The economic value of Rogue River salmon. ECONorthwest, Eugene, OR

[32] EPA. 2015. *Climate Change in the United States: Benefits of Global Action*. United States Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-15-001

[33] Bair, B. 2004. *Stream Restoration Cost Estimates*. US Department of Agriculture, Forest Service. Gifford-Pinchot National Forest

[34] Morgan-Hayes, A. (2018). Laws, regulations, and management plans to improve streamflow and stream temperature: a case study in the North Fork Burnt River Watershed. *MS Thesis, Oregon State University, Department of Natural Resources*. https://ir.library.oregonstate.edu/concern/graduate_projects/rj430962j

[35] Weber, N., Bouwes, N., Pollock, M.M., Volk, C., Wheaton, J.M., and Wathen, G. 2017. Alteration of stream temperature by natural and artificial beaver dams. *PLoS ONE* 12(5): e0176313. https://doi.org/ 10.1371/journal.pone.0176313
[36] USDA Forest Service (2002). Water & the Forest Service. FS-660. Washington, DC.
[37] *See,* for example, Marshall, A. 2019. Climate change will mean more multiyear snow droughts in the West; Institute of Industrial Science, The University of Tokyo. 2020. Half a degree more warming may cause dramatic differences on drought-flood compound risks; and USDA Forest Service, Office of Sustainability and Climate. 2018. Potential drought impacts in the Pacific Northwest.
[38] University of California, Davis. 2014. California: drought and jobs.
[39]McCreay, A. 2020. Beavers may be part of answer to climate change: Local relocation project returns animals to natural habitat. 4p. https://methowvalleynews.com/2016/01/23/beavers-may-be-part-of-answer-to-climate-change/
[40] Walker, B., A. Parrish, M. Petersen, A. Martin, O. Moringstar, and K. Hall. (2010). The beaver solution: An innovative solution for water storage and increased late summer flows in the Columbia River Basin. The Lands Council, Grant #G0900156. 67pp.
[41] Dean Runyan Associates. 2009.
[42] Responsive Management. 2016. Oregon Residents' opinions on and values related to Oregon Department of Fish and Wildlife. *Conducted for the Orgon Legislative Task Force on Funding for fish, wildlife and related outdoor recreation and education*. 200p.
[43] Weber, N., Bouwes, N., Pollock, M.M., Volk, C., Wheaton, J.M., and Wathen, G. 2017. Alteration of stream temperature by natural and artificial beaver dams. *PLoS ONE* 12(5): e0176313. https://doi.org/ 10.1371/journal.pone.0176313
[44] Macfarlane W.W., Meier M.D., Hafen C, Albonico, M.T. and Wheaton J.M. (2019). North Fork Burnt River Beaver Restoration Assessment Tool: Building Realistic expectations for partnering with Beaver in Restoration and Conservation. Prepared for the Powder Basin Watershed Council. Logan, UT. 80 Pages.
[45] NOAA and EPA letter to Richard Benner, director Oregon Department of Land Conservation (now Division of State Lands) and Landon Marsh, director of Oregon Department of Environmental Quality, Jan. 20, 1998.
[46] US Magistrate Paul Papak, Stipulated and proposed schedule, July 1, 2015
[47] NOAA and EPA letter to Richard Benner, director Oregon Department of Land Conservation (now Division of State Lands) and Landon Marsh, director of Oregon Department of Environmental Quality, Jan. 20, 1998
[48] NOAA and EPA letter to Jim Rue, director Oregon Department of Land Conservation (now Division of State Lands) and Dick Pederson, director of Oregon Department of Environmental Quality, July 28, 2015
[49] Ibid
[50] NOAA and EPA letter to Jim Rue, director Oregon Department of Land Conservation (now Division of State Lands) and Dick Pederson, director of Oregon Department of Environmental Quality, July 28, 2015
[51] NOAA and EPA letter to Richard Benner, director Oregon Department of Land Conservation (now Division of State Lands) and Landon Marsh, director of Oregon Department of Environmental Quality, Jan. 20, 1998

[52] , H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G.Pess, G. Reeves, M. Scheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams and T. Williams. (2011). Scientific conclusions of the status review for Oregon Coast coho salmon (Oncorhynchus kisutch). Draft revised report of the Oregon Coast Coho Salmon Biological Review Team. NOAA/NMFS/NWFSC, Seattle, WA.

[53]Jay W. Nicholas, Oregon Coastal Salmon Restoration Initiative, state of Oregon, 1997.

[54] National Marine Fisheries Service, 2016 5-Year Review: Summary & Evaluation of Oregon Coast Coho Salmon, 2016.

[55] Reeves et al. 1989; Stout et al. 2012 as cited National Marine Fisheries Service, 2016 5-Year Review: Summary & Evaluation of Oregon Coast Coho Salmon, 2016.