Confederated Tribes *of the*
Umatilla Indian Reservation
Department of Natural Resources
Administration

46411 Timíne Way
Pendleton, OR 97801

www.ctuir.org ericquaempts@ctuir.org
Phone 541-276-3165 Fax: 541-276-3095

October 13, 2020

Shane Jeffries, Forest Supervisor,
Ochoco National Forest,
3160 NE Third Street,
Prineville, OR 97754

Delivered electronically to SM.FS.EScreens21@usda.gov and through https://cara.ecosystem-management.org/Public/CommentInput?project=58050

Re: Forest Management Direction for Large Diameter Trees in Eastern Oregon #58050

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Department of Natural Resources (DNR) provides the following comments on the proposed revision of the *Interim Management Direction Establishing Riparian, Ecosystem and Wildlife Standards for Timber Sales (Eastside Screens).* The Eastside Screens were developed in anticipation of a more comprehensive regulatory effort that unfortunately has not occurred in the intervening 25 years. Given the complexity of the issue and the relatively short period of time proposed for review of the Environmental Assessment, the CTUIR DNR requests that the Forest Service undertake this regulatory effort through an Environmental Impact Statement (EIS). The comments below are intended to inform the path the Forest Service takes in this effort.

CTUIR Treaty of 1855 & Federal Trust Responsibility Background

The CTUIR is a federally-recognized Indian tribe, with a reservation in Northeast Oregon and ceded, aboriginal, and usual and accustomed areas in Oregon, Washington, Idaho, and other Northwest states. In 1855, predecessors to the CTUIR—ancestors with the Cayuse, Umatilla, and Walla Walla Tribes—negotiated and signed the Treaty of 1855 with the United States. The Treaty is a contract between sovereigns and is "the supreme Law of the Land" under the United States Constitution. In the Treaty the CTUIR ceded millions of acres of land to the federal government, and in exchange received assurances that various pre-existing tribal rights would be protected, and our interests would be respected, in perpetuity. A paramount objective in the Treaty was protecting and maintaining our tribal First Foods—water, fish, big game, roots, berries, and other plants—and the habitats and environmental conditions that support and sustain them, then, now, and forever. This remains a paramount objective of the CTUIR. These habitats would be affected by your proposed rule.

The Forest Service, and all federal agencies, have a duty to honor and uphold the Treaty of 1855 and all Indian treaties and to act as stewards and trustees to ensure that the terms and commitments of such treaties can be fulfilled. In implementing federal laws and adopting rules pursuant to them, the Forest Service can and should always remain attentive to how such laws and rules impact treaty-based obligations; the laws, rules, and treaties must be read in tandem to ensure they are mutually supportive and reinforcing. Rules and regulations that diminish the United States' ability to honor and uphold Indian treaties and related Trust Responsibility to tribes should not be adopted.

The Treaty of 1855 explicitly guarantees to the CTUIR and its members the right of "taking fish" and of hunting and gathering. Associated with these rights is the implicit, concurrent assurance that there will be fish to take, game to hunt, and plants to gather—all will exist—and that the habitats and environmental conditions that support and sustain them will exist. Without those habitats, the Treaty becomes an empty promise. The lands and waters necessary for the existence of these Treaty resources must also be protected and maintained. Water is the first of the tribal First Foods. Implicit in the Treaty Right to fish is the right to water—clean, available water necessary to effectuate tribal fishing rights—and protection of the lands associated with providing that water.

Eastside Screens & Their Unintended Results

The Eastside Screens planning rule has been in place since the mid-1990s. Specifically the 21-inch rule was an attempt to move forests to maintain larger diameter-at-breast-height (DBH) trees and provide some semblance of old growth characteristics in Eastern Oregon forests. The relevant portion of the rule states:

> Outside of [late and old structural stages LOS], many types of timber sale activities are allowed. The intent is still to maintain and/or enhance LOS components in stands subject to timber harvest as much as possible, by adhering to the following standards:
>
> > a) Maintain all remnant late and old seral and/or structural live trees ≥ 21-inch dbh that currently exist within stands proposed for harvest activities.
>
> [From the Interim Management Direction Establishing Riparian, Ecosystem and Wildlife Standards for Timber Sales, Regional Forester's Forest Plan Amendment #2.]

The Eastside Screens were established as one of several temporary land management provisions designed to protect water resources and wildlife habitats. As noted above, this temporary effort was never amended in favor of a more appropriate, permanent solution which has resulted now in an effort to revise the 21-inch rule and provide forest managers more flexibility to address overcrowded stands of trees now deemed a wildfire hazard.

While the Eastside Screens and 21 inch rule has resulted in larger diameter trees within Eastside forests, the underlying canopy trees for the most part have not been proactively and sustainably managed due to three primary factors; a) litigation, b) poor market conditions resulting from an overabundance of cheap timber from other sources, making many local and regional timber sales uneconomic, and c) underfunded/understaffed Forest Service programs without the resources to implement the large, landscape scale projects needed to address forest-wide overstocking problems. These three factors, combined with a history of aggressive fire suppression, have resulted in grossly over-stocked forests exhibiting species mix and structure ripe for disease, insect outbreaks, and catastrophic fire, particularly in drought conditions. Amending the Eastside Screen rule in the short term could make timber sales economical, but it merely exacerbates the overall problem.

When forest management is constrained to maintain all trees over 21-inches DBH, stands should be managed by removing smaller trees to maintain consistency with its site potential. When foresters are required to maintain any trees 21-inches DBH and above all of the stocking potential is tied up in 21-inch DBH or larger trees which limits how much regeneration can be allowed take place if a healthy forest is the goal. When a stand reaches its potential trees begin to slow growth, show signs of stress, get infected with disease or insect and eventually die. This process coupled with over a century of fire suppression contributes to fuel loading and wildfire risk. There are thousands of examples in the arid west of forest stands that have been impacted from over stocking.

CTUIR Management Visions

The CTUIR DNR supports keeping large trees on the landscape. In the absence of normative fire regimes, stands must be managed to maintain health and vigor that provide healthy forests and provide many of the First Foods required to secure the Tribe's health and culture. We have developed our First Foods River and Upland Visions, attached, to explicitly identify a vision for properly functioning floodplain and upland landscapes and ensure healthy, resilient, and dynamic ecosystems capable of providing First Foods that sustain the continuity of the Tribe's culture.

Our Upland Vision is based on four fundamental touchstones, including:

1. Soil Stability (physical and chemical);
2. Hyrdologic Function – water capture, storage, and safe release;
3. Landscape Pattern; and
4. Biotic Integrity.

In the Upland Vision you will find sections on "Dry Conifer Forest" and "Moist Conifer Forest" as they relate to primarily biotic integrity, landscape pattern, and hydrologic function. It is our hope this information will assist in the development of appropriate standards to replace or enhance the Eastside Screens.

Conclusion

The current proposal will alter rules governing the management of approximately 10 million acres, but does not clearly identify and define what metrics will be used to evaluate whether or not to retain old-growth trees on the landscape. Consequently, protection of old growth devolves into a management option rather than an enforceable standard. Because of the scope and scale of this issue, and the current ambiguity of the proposal, the CTUIR recommends the Forest Service engage in an EIS process to correct perceived shortcomings of the existing rule with specific metrics that can be communicated, managed, and enforced. Providing funding for staff implementation of this rule change, appropriate coordination with the CTUIR, conservationists, and forest product industries, will be necessary to make implementation effective to our mutual benefit.

Finally, in the time of COVID 19 when many staff are working remotely and in-person meetings are practically impossible, 60 days is a very short turn around particularly during fire season to adequately review the complexities of this rule-change and the comment should be extended to 90 days.

The CTUIR DNR looks forward to working with the Forest Service in the development of this rules to best manage the forests in our aboriginal use lands and ensure that management guidance and decisions take into account impacts to the Forest Service's trust responsibility and treaty-protected resources. This proposed rule does not seem to have taken either of those into account. If you have any questions regarding these comments or wish to schedule meetings to discuss these comments, please contact Audie Huber, Intergovernmental Affairs Coordinator, at 541-429-7228 or AudieHuber@ctuir.org.

Respectfully,

Eric Quaempts, Director
Department of Natural Resources

Enclosure: CTUIR DNR First Foods Upland Vision,
CTUIR DNR Umatilla River Vision

First Foods Upland Vision

Confederated Tribes of the Umatilla Indian Reservation
Department of Natural Resources

Bryan A. Endress, Eric J. Quaempts, Shawn Steinmetz

April 2019

Vision
To ensure healthy, resilient and dynamic upland ecosystems capable of providing First Foods that sustain the continuity of the Tribe's culture.

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Authors

Bryan A. Endress—Bryan is an Assistant Professor for Oregon State University at the Eastern Oregon Agriculture Research Center in La Grande, Oregon. Bryan studies the ecology and management of economically and culturally important plant species, ecological restoration, vegetation dynamics, and community-based resource management.

Eric J. Quaempts—Eric possesses a Bachelor's in Wildlife Science from Oregon State University, 14 years of habitat and project management, and 14 years of experience as DNR Director. His personal experiences with First Foods and the CTUIR community informed the initial development of the DNR First Foods mission.

Shawn Steinmetz—Shawn is an archaeologist working for the Confederated Tribes of the Umatilla Indian Reservation. His work for the past ten years has focused on the confluence of archaeology, treaty rights, food sovereignty, and tribal traditional use. He started working as an archaeologist for the BLM in 1984, and obtained a Bachelor's in Anthropology from Oregon State University. He has worked for the CTUIR since 1998.

Introduction

First Foods have sustained tribal people since time immemorial and the relationship between First Foods and the Tribes is essential to the ongoing culture of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). The First Foods serve a fundamental role in the health, well-being and cultural identity of the Tribes. In 2007, to convey the important role of First Foods to the Tribes, the CTUIR's Department of Natural Resources (DNR) adopted a mission based on First Foods ritualistically served at tribal meals.

The CTUIR DNR considers First Foods to constitute the minimum ecological products necessary to sustain CTUIR subsistence and cultural needs. The mission was developed in response to long-standing and continuing community expressions of First Foods traditions and community member requests that all First Foods be restored for their respectful use, now and in the future.

CTUIR Department of Natural Recourses Mission
To protect, restore, and enhance the First Foods - water, salmon, deer, cous, and huckleberry - for the perpetual cultural, economic, and sovereign benefit of the CTUIR. We will accomplish this utilizing traditional ecological and cultural knowledge and science to inform: 1) population and habitat management goals and actions; and 2) natural resource policies and regulatory mechanisms.

In 2008, the CTUIR DNR published the Umatilla River Vision to assist Tribal and non-Tribal land managers in moving this mission statement from concept to application within the Umatilla River and adjacent basins (Jones et al. 2008). The overarching goal of the Umatilla River Vision is to support a healthy, dynamic river system that can sustain production of First Foods, with an emphasis on Water and Salmon. It presents the vision for desired ecological characteristics of river ecosystems and provides a framework for planning and restoration efforts with associated objectives for assessing the success of management activities.

In this document, we expand the First Foods conceptual framework to upland ecosystems that provide a wide range of First Foods, including Big Game, Roots and Berries. Our vision for upland landscapes is to: ***ensure healthy, resilient and dynamic upland ecosystems capable of providing First Foods that sustain the continuity of the Tribe's culture***.

The primary goals of this document are to:

1. Articulate the CTUIR's vision for upland resource management based on the First Foods mission.

2. Serve as the foundation for DNR staff to organize, plan, and manage land and natural resources.

3. Serve as a resource for non-Tribal land managers, policy makers and other stakeholders to enhance their understanding of the importance of First Foods to the CTUIR and to provide a framework to consider and incorporate First Foods concepts into their management activities within CTUIR's ceded territory where the Tribes retains hunting, fishing and gathering rights (among others).

This document outlines a vision for desired characteristics of upland ecosystems that will facilitate the production of First Foods and serve as a foundation for natural resource management and restoration activities to ensure healthy, resilient and dynamic upland ecosystems. These characteristics are founded on four fundamental "touchstones." These are:

1. Soil Stability
2. Hydrologic Function
3. Landscape Pattern
4. Biotic Integrity

These touchstones and the interconnections between them, are central to the proper functioning of upland ecosystems and their ability to provide a range of ecosystem services, including First Foods. Our framework adopts a broad definition of healthy ecosystems and incorporates environmental, biological, ecological and cultural dimensions. It is based on the premise that healthy upland ecosystems are dynamic and resilient and will continue to produce the full range of First Foods into the future. The term 'dynamic' recognizes the spatial and temporal change inherent in ecological systems as living and non-living ecosystem components interact. 'Resilient' refers to the capacity of an ecosystem to recover from disturbance or withstand chronic stresses. Our framework utilizes these four touchstones to help guide the assessment, management and restoration of upland landscapes to support functional ecosystems capable of sustained natural production of First Foods.

Scope

This document focuses on upland ecosystems and First Foods production within the ceded territory of the Cayuse, Umatilla and Walla Walla Tribes that constitute the CTUIR, with a focus on Big Game, Roots, and Berries (Figure 1). The First Food groups of "Water" and "Salmon" are the focus of the Umatilla River Vision (Jones et al. 2008) and thus will not be included directly in this document. However, when appropriate we will touch upon on relevant upland issues that also affect the health and function of river and riparian systems that provide these essential First Foods.

Geographically, this region covers a large portion of Southeast Washington and Northeast Oregon (Figure 2). In the Treaty of 1855, 6.4 million acres of Tribal land was ceded to the United States government, the majority of which

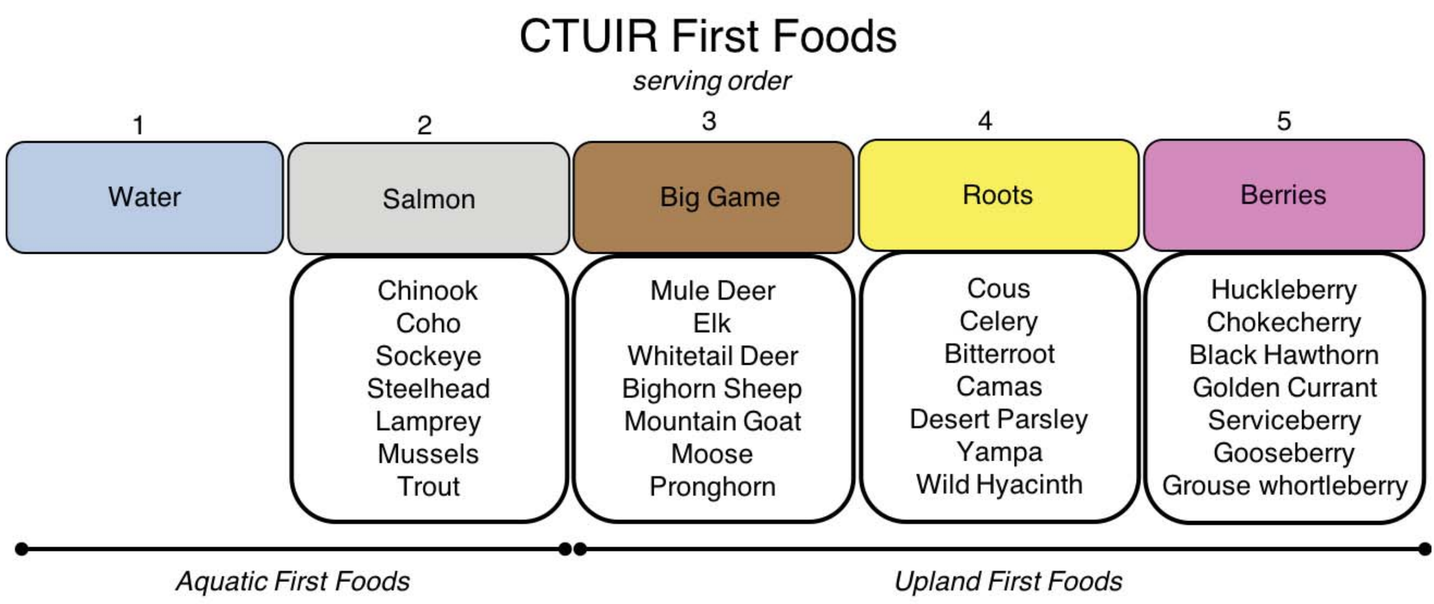

Figure 1. The First Foods serving order with a partial list of ecologically-related species for each serving group. The First Food groups of Big Game, Roots and Berries are associated with upland ecosystems and are the focus of this document. The First Food groups of Water and Salmon are discussed in detail in Jones et al. (2008).

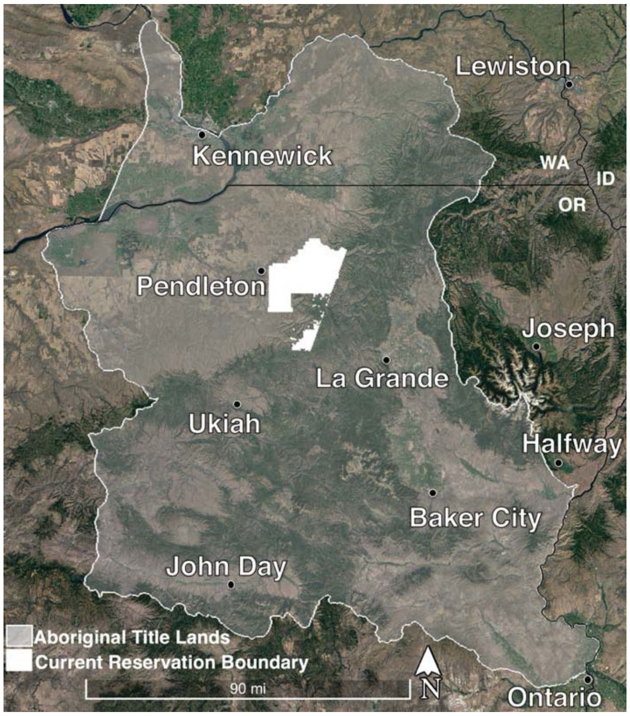

Figure 2. Lands owned and occupied by right of aboriginal possession immediately prior to treaty-making (Aboriginal Title Lands) and current CTUIR Reservation boundaries.

became private property of Euro-American settlers. Much of the remaining land not privatized continues to be owned and managed by United States government agencies such as the USDA Forest Service and Bureau of Land Management. Changes in land ownership and management have had profound impacts on the CTUIR's ability to access, harvest and manage First Foods.

The CTUIR traditionally harvest about 135 species of plants as sources of food (Hunn et al. 1998). Other plants and plant products are used for a variety of other purposes. For example, over 125 plants were used for dyes, cordage, containers, glues, weaving materials and other uses. Plateau cultures, including the tribes of the CTUIR also used over 125 plant species for medicinal and spiritual purposes (Hunn et al. 1998). While not First Foods, these culturally important resources are also a fundamental part of the health, cultural identity and sovereignty of the CTUIR. While not explicitly discussed within this document, utilitarian plant resources and medicines are likewise products of healthy upland ecosystems, and our conceptual framework and touchstones can be readily applied to these plant species.

This document is not intended to replace or substitute specific land management plans or other natural resource planning documents, but rather to provide a framework for managers to help ensure current and future management activities are aligned with and account for the protection and enhancement of the CTUIR's First Foods. This vision document can be used to guide management plans and help inform policy.

First Foods

Traditional foods of the CTUIR are referred to as the First Foods. Today, the First Foods are served at the Longhouse, the center of the CTUIR's community. The serving order is also practiced for feasts held out on the landscape and at people's homes. The First Foods include Water, Salmon, Big Game, Roots, and Berries. Each First Food represents a grouping of similar species (Figure 1, Table 1) – Salmon represent aquatic life forms (e.g. steelhead, lamprey, freshwater mussels, and various resident fish); Big Game represent large wildlife (e.g. mule deer, elk, bighorn sheep), Roots represents plant foods that are dug (e.g. biscuitroot, camas, bitterroot); Berries represents plant foods that are picked (e.g. huckleberry, chokecherry, golden currant). All meals begin and end with a drink of water, and the Foods are served in the same order at every meal. This order of presenting food in the Longhouse reflects the CTUIR's intimate connection to and ecologically informed view of the landscape (Quaempts 2008). The Cayuse, Umatilla and Walla Walla Tribes traditionally followed a seasonal round through their territory to obtain the food and resources essential to sustain life and for spiritual wellbeing (Hunn et al. 2015).

Table 1. A partial list of representative upland First Foods important to the Cayuse, Umatilla and Walla Walla tribes and the principal vegetation zones in which they are found.

Common Name	Scientific Name	Principal Vegetation Zone
Big Game		
Mule Deer	*Odocoileus hemionus*	All
Rocky Mountain Elk	*Cervis canadensis*	All
Bighorn Sheep	*Ovis canadensis*	Shrub-steppe
Whitetail Deer	*Odocoileus virginianus*	Riparian
Moose	*Alces alces*	Forest & Riparian
Pronghorn	*Antilocapra americana*	Shrub-steppe
Roots (and celery)		
Camas	*Camassia quamash*	Riparian & Shrub-steppe
Spring Beauty	*Claytonia lanceolata*	Dry Conifer Forest
Yellow Bell	*Fritillaria pudica*	Dry Conifer Forest
Bitterroot	*Lewisia rediviva*	Shrub-steppe
Desert Parsley	*Lomatium canbyi*	Shrub-steppe
Cous	*Lomatium cous*	Shrub-steppe
Spring Gold	*Lomatium grayi*	Shrub-steppe
Barestem Biscuitroot	*Lomatium nudicale*	Shrub-steppe
Yampa	*Perideridia gairdneri*	Shrub-steppe & Dry Conifer Forest
Wild Hyacinth	*Triteleia grandiflora*	Shrub-steppe & Dry Conifer Forest
Berries		
Serviceberry	*Amalanchier alnifolia*	Dry and Moist Conifer Forest
Black Hawthorn	*Crategous douglasii*	Dry and Moist Conifer Forest
Chokecherry	*Prunus virginiana*	Dry and Moist Conifer Forest
Golden Current	*Ribes aureaum*	Riparian
Bigleaf Huckleberry	*Vaccinium membranaceum*	Moist Conifer Forest
Grouse Whortleberry	*Vaccinium scoparium*	Moist Conifer Forest

Importance to CTUIR religion and culture

In Tribal creation belief, in the time before people, the Creator gathered all the plants and animals and explained that there were going to be people and that they would be like infants and would need to learn about their new world. The Creator asked the plants and animals 'who will take care of the Indian people?' Salmon was the first to promise his knowledge and body, then other fish lined up behind salmon. Next came Deer and the other game animals, then *Cous* and other roots, then Huckleberry and all the other berries. In return, Indian people promised to respectfully harvest and care for the First Foods. The First Food serving ritual in the Longhouse is based on the order of the First Food promised themselves and serves as a reminder of the promise and people's reciprocal responsibility to respectfully use and take care of the foods. Embedded within this promise is that people need to harvest First Foods in order to fulfill their responsibility to the First Foods.

Many in the CTUIR, therefore, regard plants, like animals and other natural objects, to have a spirit and morality. For instance, the roots that are dug are 'persons' and you must treat them as you would treat an influential person, with respect and consideration for their feelings and needs. If you disrespect the cous (*Lomatium cous*), it is offended, just as a person might feel if disrespected. The consequences of such mistreatment are likewise analogous, the withdrawal of friendly contact, and exclusion from the web of mutual support. One's wellbeing literally depends upon maintaining good relations with your food and the ecosystem as a whole (Hunn 1990). In this system, you cannot just take what you want, that would be disrespectful.

The longevity and constancy of the First Foods and serving rituals across generations, and their recognition through First Food ceremonies, demonstrate the cultural and nutritional value of First Foods to the CTUIR community. Though the means to locate, acquire, process and prepare First Foods have changed dramatically following Euro-American settlement, First Foods, their serving order, and ceremonies have remained constant. Moreover, First Foods have not been replaced in the serving ritual with new, readily-available introduced foods. For instance, introduced fish such as bass, or grains such as wheat, or fruit such as watermelon, have not replaced salmon, cous and huckleberry. When new foods are served at tribal meals, they are not recognized in the serving ritual; instead, they are served following the First Foods and with no formal order or sequence.

Distribution, Use and Management

The ceded land of the CTUIR is a vast, heterogeneous landscape spanning a wide range of temperature, precipitation and soil gradients. This results in a diverse array of upland ecosystems, ranging from low elevation sagebrush-steppe to subalpine forest and grasslands. First Foods and other culturally important resources are found throughout this complex landscape, and their abundance and distribution is determined by the individual species' ecology and life history strategy, as well as current and historic land use patterns, management and disturbance regimes. In the most general terms, the First Foods serving order follows an elevation gradient, from lower elevation river, wetland and riparian systems (Water, Salmon), to higher elevation grassland (Roots) and forest (Berries), highlighting the importance of the entire landscape to support and produce the full array of First Foods (Figure 3). 'Big Game' occupy the full elevational gradient, with several species like mule deer, and elk seasonally migrating across ecosystems.

Since time immemorial, tribes of the CTUIR have managed this landscape to promote the production of First Foods and other important resources (Hunn et al. 2015, Lake et al. 2017). This is contrary to the modern-day concept of 'wilderness' and the long-held erroneous belief that pre-European landscapes were 'pristine' and 'untouched' landscapes (Anderson 2005, Diekmann et al. 2007). Moreover, traditional Native American wildland food and resource production systems have largely been described as 'hunter-gatherer' or 'forager' systems, which incorrectly implies a hand-to-mouth existence and a lack of long-term stewardship of the landscape or its resources. These beliefs have been shown to be wildly inaccurate (Johnson 1999, Anderson 2005, Deur 2009, Taylor et al. 2016, Lake et al. 2017), and Native American peoples, including the Tribes of the CTUIR actively managed landscapes for the sustained production of First Foods and other resources.

A wide range of management techniques were developed and utilized to manage natural resources across the landscape, including, but not limited to pruning, burning, sewing seeds following harvest, and coppicing. These management techniques were developed based on the collective knowledge of the natural world, acquired through hundreds of years of direct experience and contact with the environment. This is commonly referred to as Traditional Ecological Knowledge (TEK), and TEK- based stewardship has had a large and lasting impact on the structure, composition, diversity, and disturbance regimes of western landscapes, including the CTUIR ceded lands. This changed dramatically in the past 150-200 years, when Native American peoples were excluded from natural resource-decision making processes (Long and Lake 2018). Fire, in particular, was a key tool in natural resource stewardship utilized by the tribes of the CTUIR and across western North America (Lake et al. 2017); the exclusion of Native peoples and their extensive knowledge on the use of fire in natural resource stewardship of western landscapes and the strong push to suppress fire across the landscape resulted in major changes to the structure, composition and function of many ecosystems (Taylor et al. 2016).

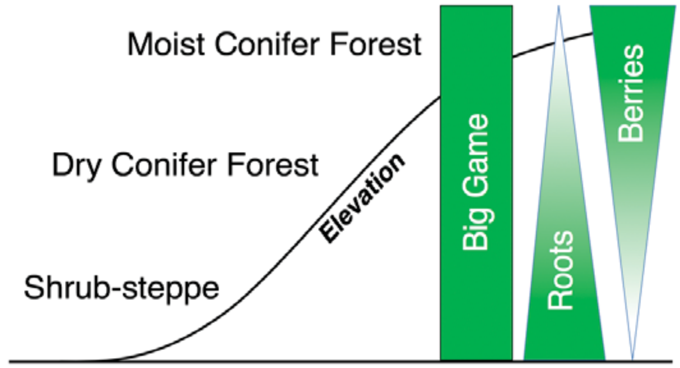

Figure 3. Generalized relationship between major vegetation zones and their relative importance for the production and harvest of upland First Foods.

Changes with Euro-American Settlement

Settlement of the CTUIR lands by European-Americans led to profound changes in First Food distribution, abundance and management. Large swaths of lower elevation areas dominated by Pacific Northwest bunchgrass and sagebrush steppe were settled by Euro-Americans and subsequently cultivated for agricultural production. This resulted in large reductions in the abundance of several First Foods, particularly for a number of roots (e.g. *Lomatium* spp.), while also reducing winter range habitat for elk and mule deer. Areas not converted to agricultural production have been exposed to decades of over-grazing by domestic livestock as well as the introduction of a non-native invasive plants such as annual bromes (*Bromus* spp.), North African bentgrass (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusae*). This has resulted in large alterations to grassland and shrubland composition, structure, and function (Johnson and Swanson 2005). At higher elevations dominated by ponderosa pine and mixed-conifer forests, large scale fire-suppression of both wildfires and Native American burning regimes across the landscape resulted in large changes in ecosystem structure, composition, and health. Historical forests were characterized by a diversity of successional stages, with a high proportion of relatively young stands (Odion et al. 2014, Taylor et al. 2016). This is much different than contemporary forests, which are characterized by reduced successional diversity, and the overabundance of dense, closed canopy mid- and late successional stands (Franklin et al. 2013).

The ability to harvest First Foods was further reduced by changes in land ownership which greatly impacted access to areas to dig, harvest and hunt. At the time of Treaty of 1855 signing, the CTUIR's ceded territory of 6.4 million acres, was

Figure 4. Roots are most abundant in lower elevation grassland and shrubland ecosystems (shrub-steppe vegetation zone). Roots are dug and celery (leaves and stems) are harvested spring through early summer. a) and b): harvest of bitterroot (*L. redivia*), c) digging bag and cupin, d) harvested cous (*L. cous)* and camas (*C. quamash*), e) cleaned bitterroot (*L. rediviva*) ready for boiling.

considered the core region for harvesting First Foods and other culturally important resources. This land base was *the minimum* amount of land need for the CTUIR's ceremonial and subsistence needs. The CTUIR reservation boundaries of about 172,000 acres constitutes less than about 3% of the CTUIR's 6.4 million acre of land that they had previously to the Treaty signing. The current land base is not large or ecologically diverse enough to provide the full array of First Foods resources. Privatization of land and agricultural development beyond reservation boundaries have also further reduced the CTUIR's ability to access its traditional foods. Today, just 24% of the ceded territory are public land where Tribal members can exercise their treaty rights. While the CTUIR's treaty guarantees the right of access, there is no guarantee that the Tribes' First Foods and other culturally important resources will be present for them to harvest. Moreover, because the goals of state and federal land management agencies do not explicitly include management or stewardship for First Foods, it is the responsibility of the CTUIR to speak on behalf of the First Foods and engage public lands managers. This responsibility is part of the reciprocal relationship that the CTUIR has with their traditional foods and an acknowledgment that the First Foods are not only important for health, but also for cultural identity. Gathering traditional plant foods is an activity that is inextricably linked with the ceremonial and ritual life of the CTUIR and is essential for continued cultural identity and sovereignty.

Figure 5. Huckleberry has been picked since time immemorial. The species dominates forest understories of many moist conifer forest stands and is also an important food source for wildlife.

Implications for First Foods Management, Tribal Health and Cultural Traditions

The myriad of changes that accompanied Euro-American settlement of CTUIR's ceded territory affects the access, harvest and management of First Food resources by the CTUIR in four important ways: (1) a significant reduction in the amount of land area where Tribal members can exercise treaty rights, (2) in many areas still accessible, ecological conditions are outside of their historic range of variability; at some sites, degradation has resulted in local loss of First Food resources, (3) although the CTUIR manages First Food resources inside of the reservation boundaries, the reservation is not large enough and does not contain the variety of ecosystems required to provide all First Food resources, and (4) outside of reservation boundaries, but within their ceded lands, the CTUIR DNR is not the primary land manager and there are limited mechanisms by which the CTUIR is able to inform the decision-making process regarding land management issues that affect First Foods, a central component of the CTUIR culture and wellbeing. These factors as well as several others stemming from Euro-American settlement have fostered 'socio-ecological traps' that inhibit Tribes from continuing traditional land stewardship activities, such as managing for First Foods, that support the well-being of Tribal members, tribal sovereignty, and ecosystem health (Long and Lake 2018).

Barriers to access and use of First Foods can impact the health of the tribal community in a number of ways. Restricted access to harvesting areas could eliminate First Foods from the Longhouse, particularly if habitats supporting a First Food are rare and found only on private land. This is most problematic in lower elevation ecosystems including riparian, grassland and shrublands ecosystems. Additionally, habitat degradation and deviation from historical conditions can result in lower abundances and even local extirpation of certain First Foods requiring additional time and effort to access and harvest sufficient amounts of First Foods. Herbicide and pesticide application in wildland settings and along the agricultural-wildland interface may also affect health, as residue from these chemicals may remain on plant-based First Foods. Loss of traditional food resources exacerbates tribal health issues including poor fitness, diabetes, and other health challenges. Research has shown that the loss of traditional food resources is associated with lifestyle changes (e.g., increasing sedentary lifestyle while decreasing cultural-specific activities and food diversity) and health problems (increased diabetes, obesity, heart disease, etc.; Kuhnlein and Receveur 1996). Thus, ensuring abundant First Foods across the landscape and restoring tribal food resources is likely to benefit the health and culture of the tribal community by providing traditional food choices and promoting activities (e.g. hunting, digging, gathering, and fishing) that draw on tribal knowledge and skills.

Managing ecosystems and landscapes for First Foods is a cultural strategy of natural resource management. It incorporates spatial, temporal and phenological

Figure 6. Tiyá-po Farrow (white shirt) and Jace Ashley. Tiyá-po was hunting for the annual Children's Root Feast. Jace was brought along to learn from Tiyá-po and the other hunters. Tiyá-po was the lead hunter for the feast. The Children's Root Feast is a ceremonial event to recognize new food (root) gatherers. A traditional meal, with some of the roots gathered by the children, are eaten at the meal. Tiyá-po had his first kill ceremony when he was 9 years old. At that ceremony he was recognized as a provider of that First Food for his family and tribal community. Photo by T. Farrow Ferman.

considerations because resources are used throughout the landscape and year based on availability and seasonality. It also integrates natural resources management with tribal resource needs. The longevity and constancy of the First Foods ritual at tribal ceremonies underscores their importance to the tribal community and highlights the strong connections between cultural traditions and ecosystem health across the landscape. Additionally, First Foods may provide an appropriate context in which to evaluate habitat management and restoration progress to the tribal community. In fact, each First Food and its grouping could be considered a potential unit for reporting metrics such as abundance, distribution, restoration efforts, restoration achievements, and policy and regulatory mechanisms. Ultimately, the most direct and culturally appropriate indication of the CTUIR DNR's progress is measured by the CTUIR community's continued ability to access, harvest, process, preserve, and share First Foods at the Longhouse and in their homes.

Upland Ecosystems (Touchstones)

The availability and long-term production of First Foods in the uplands throughout ceded lands requires healthy, functional ecosystems. Healthy ecosystems maintain their full array of ecosystem services, which are the benefits supplied to society by natural ecosystems (Alcamo et al. 2003, Chapin et al. 2011). The Millennium Ecosystem Assessment (Alcamo et al. 2003) categorized ecosystem services into four groups: (1) Provisioning Services, which are goods or products that people can use directly, such as fresh water, fiber, wood, genetic resources, medicine and food, including First Foods; (2) Regulating Services, which includes processes such as climate regulation, disease and pest regulation, pollination, erosion control, flood regulation, and water filtration; (3) Cultural Services which encompass non-material benefits such as cultural identity and heritage, spiritual, inspirational and aesthetic benefits, recreation, and tourism; and (4) Supporting Services, which are necessary for the production of all the other services and include maintenance of soil resources, water cycling, carbon and nutrient cycling, maintenance of disturbance regimes and biological diversity. This section provides a general framework centered around four primary ecological components or touchstones, associated with healthy upland ecosystems that provide their full array of ecosystem services, including the continued natural production of First Foods for utilization by the CTUIR community. These touchstones are 1) *Soil Stability*, 2) *Hydrologic Function*, 3) *Landscape Pattern* and 4) *Biotic Integrity* (Table 2). These touchstones support the maintenance of ecosystems, species, and associated ecological processes and interactions within their natural ranges of variability (Poiani et al. 2000). Because the touchstones are interrelated, they must be considered in concert with respect to First Foods production, restoration and management.

Table 2. Ecological touchstones (Soil Stability, Hydrological Function, Landscape Pattern, Biotic Integrity) and key attributes that support the maintenance of ecosystems, species and associated ecological processes and interactions, including First Foods.

Soil Stability	Hydrological Function	Landscape Pattern	Biotic Integrity
• Physical • Chemical • Biological	• Water capture • Water storage • Water release • Water quality	• Patch size and extent • Heterogeneity • Arrangement • Connectivity	• Composition • Structure • Species interactions • First Foods

Soil Stability

Soil stability refers to the capacity of a site to stabilize and maintain soil structure and resources (soil, nutrients, organic matter, water) which are critical to support living communities (Pellant et. al, 2005). Stable soils promote and support soil health which is the continued capacity of soil to function as a vital living ecosystem sustaining plants, animals and humans (USDA NRCS 2018). The importance of physical (depth, texture, structure, organic matter, bulk density, porosity, water holding capacity, etc.), chemical (pH, cation exchange capacity, available nutrients, etc.), and biological properties (biotic crust, fungi, bacteria and other microfauna, etc.) to soil stability and health is well documented (Faist et al. 2017) and a range of indicators have been developed to assess and evaluate soil stability, health and function (Pellant et al. 2005). Many of these indicators are also utilized to evaluate hydrologic function (below).

Baseline soil properties of an area are greatly influenced by physical factors such as climate, hydrology, geology, substrate and physiographic features (slope, aspect, elevation, topographic position, etc.). Due to the wide range in physical conditions throughout the ceded land of the CTUIR, the physical, chemical and biological properties of soil, their capacity to support plant and animal productivity, including First Foods, varies substantially from site to site across the landscape. Biological factors (e.g. plant species occurrence, composition, production, species interactions), disturbances (e.g. fire regimes, timber harvest, invasive species, drought) and land management activities (e.g. livestock grazing, prescribed fire) also affects soil stability by altering physical, chemical and/or biological properties of the soil (Whisenant 1999, Wilcox et al. 2017).

Maintaining soil stability is an important management issue because of its role influencing numerous ecological patterns and processes necessary for the production of ecosystems services including First Foods. These include biodiversity, vegetation production, cover and composition, nutrient and water cycling (acquisition, storage, release) and more (Evans et al. 2017). Land use and management activities that negatively affect soil properties can create feedback loops that support continued degradation of the site and multiple ecological touchstones (Figure 7). For example, water infiltration rates into soil are directly linked to management practices and disturbances (grazing systems, fire, shrub management, invasive species) that alter soil structure and vegetation cover (e.g. compaction, loss of biological soil crusts, type of vegetation; Pierson et al. 2011, Belnap et al. 2013, Wilcox et al. 2017). Water that does not infiltrate into the soil leaves a site via overland flow, not only reducing the water available for vegetation uptake or groundwater recharge, but also contributing to soil erosion, further affecting soil stability, health, and productivity, and ultimately First Foods production.

Hydrologic Function

This refers to the capacity of an area to (1) capture, store, and safely release water from precipitation and run-on from adjacent areas, (2) to resist reductions in this capacity and recover following disturbance events (resistance and resilience), and (3) the ability of a site to process and filter nutrients, sediments, and pollutants as water moves through upland ecosystems into streams and rivers. Baseline hydrologic capacity and function of a site is a product of climatic, geological and physiographic attributes (slope, aspect, substrate type, soil depth, etc.). Additionally, hydrologic function is closely tied to soil stability and vegetation structure and cover (Biotic Integrity). These factors influence hydrologic function by affecting whether water infiltrates into the soil or becomes overland flow, and whether water entering the soil drains out of the root zone, is absorbed by plants, or is lost to evaporation from the soil surface (Wilcox et al. 2017). This has implications to First Foods production as hydrologic function greatly affects water availability for plants, and the capacity of site to support food webs and all trophic levels.

How upland ecosystems are managed, particularly with respect to their surface cover, greatly influences hydrologic function. In general, vegetative cover, biological soil crusts and soil organic matter promote infiltration of water into the soil (Whisenant 1999, Snyman and du Preez 2005). The rooting depth of plant species on a site also influences whether water drains out of the root zone, whether soil water evaporates, or is absorbed and used by plants. Land management and disturbance regimes can affect this by influencing the species composition, structure, and diversity of a site (biotic integrity). For example, degraded shrub-steppe ecosystems dominated by shallow-rooted non-native annual grass species have a much-reduced rooting profile than intact areas dominated by a mix of shrubs, perennial

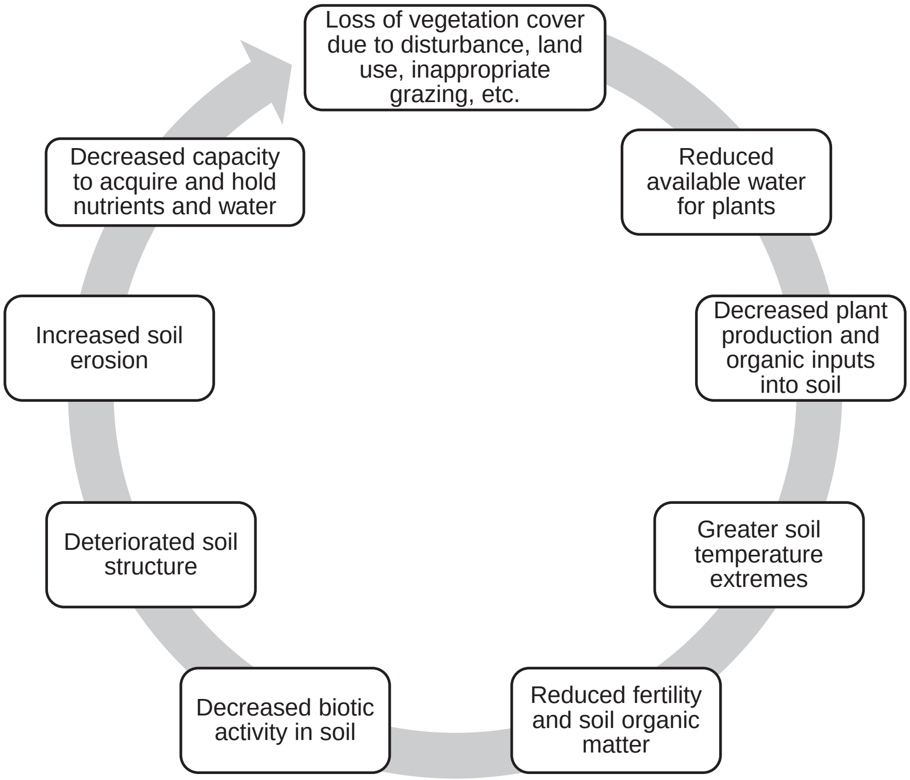

Figure 7. Cycle of soil degradation in response to disturbance, land use or management activities, affecting not only soil stability, but also hydrologic function and biotic integrity touchstones (modified from Whisenant 1999).

bunchgrass and forb species, whose rooting profile is deeper and multi-layered which allows for greater water capture by plants. Increased shading of the soil surface by vegetation as well as the presence of biological soil crusts, litter and soil organic matter may also reduce soil evaporation rates from the soil surface. Damage to soil due to inappropriate management can also affect water quality. As water infiltration into the soil is reduced from loss of vegetation, roots, overland flow increases, reducing water quality, by increasing sedimentation rates into nearby stream and riparian ecosystems.

Landscape Pattern

This refers to spatial arrangement, or pattern, of ecosystems across the landscape. Spatial heterogeneity within and among ecosystems across the landscape affects the functioning of individual ecosystems, their component parts, and the ecological services they provide. Landscapes can be described as a mosaic of ‘patches’ that differ in their ecological properties, including their structure, composition and function (e.g. Ponderosa pine stand, camas meadow; Chapin et al. 2011). The size, shape and spatial arrangement of patches influences the ecological functioning of each individual patch, as well as interactions among patches, and the behavior and functioning of the entire landscape (Turner 1989, Chapin et al. 2011). Landscape pattern is principally driven by spatial variation in (1) abiotic and environmental factors (e.g. topography, substrate/soil characteristics, slope, aspect, temperature, precipitation), (2) interactions between dominant plant species and disturbance events (fire, insect outbreak, etc.), and (3) land use and management activities.

Landscape factors that affect ecological patterns and processes include patch size, patch shape, and the spatial configuration and connectivity of patches. Patch size influences habitat heterogeneity and biotic integrity. For example, larger patches have greater internal heterogeneity than smaller patches, and as a result contain greater species richness and diversity. Together, patch size and shape determines the ratio of edge to interior habitat, which can affect the habitat suitability of different species. Patches with a large proportion of edge habitat (e.g. small, narrow patches) are heavily influenced by the adjacent patches, while large patches, with more interior habitat are less influenced by their neighbors. This can have important implications for ecosystem structure, composition and function. For example, small remnants of shrub-steppe surrounded by dryland farms, support fewer species and are much more susceptible to invasion by non-native invasive plants, as compared to large intact habitats.

The configuration, or spatial arrangement of patches across a landscape is also important because it determines the degree to which patches interact. Spatial configuration, in concert with the size and shape of patches, influences the connectivity among patches. This dictates the movement and exchange of organisms across the landscape (e.g. migration, geneflow, dispersal, colonization) and can greatly affect species population dynamics (Mittelbach 2012, Primack 2012). Patch size, shape, configuration and connectivity can also influence the movement and spread of disturbances across the landscape including fire, insect outbreaks, and disease. Land use activities and management, both past and present greatly influence landscape pattern, and subsequent ecological functioning. Within ceded lands of the CTUIR, habitat reduction and fragmentation, the creation of barriers (e.g. roads) across important wildlife migratory routes, increased forest stand homogeneity due to fire suppression, and loss of winter range for wildlife are some of major changes to landscape pattern since Euro-American settlement.

Biotic Integrity

Biotic integrity Is the ability of the biotic community to support ecological processes and interactions within the historic range of variability; this supports ecosystem resistance and resilience following disturbance events and promotes the long-term production of ecosystem services, including First Foods. In general, healthy functioning ecosystems rely on biota to control primary processes (capture, storage and release of water, nutrients and energy) and are able to 'self-repair' or recover following disturbance events (Whisenant 1999, McDonald et al. 2016). Therefore, biotic integrity is a critical touchstone that affects, and is affected by, the other touchstones (soil stability, hydrologic function and landscape pattern). Key components of biotic integrity include species composition, richness, diversity and structure. These are necessary to support critical ecological processes and interactions including seed dispersal, pollination, mutualisms, food webs, and trophic cascades, in addition to being important for the sustained production of ecological services, including First Foods.

Figure 8. Key components of biotic integrity include species composition (richness, diversity), structural complexity and species interactions (food webs, pollination, etc.). This supports the ability of ecosystems to maintain their full array of ecosystems services, including the production of First Foods. Photo by E.J. Quaempts.

Loss of First Food species can occur directly as a result of particular disturbances or land use activities (e.g. cultivation, over-hunting, improper management or use). Changes in ecosystem structure, or disruption of species interactions can also result in major reductions in First Food availability indirectly by altering ecosystem structure and dynamics in ways that reduce their abundance and population dynamics. For example, fire suppression in huckleberry-dominated moist conifer forests increases the density of overstory conifers and reduces canopy openness. This change in forest structure reduces light availability in the understory which in turn can reduce the abundance and fruit production (Holloway and Endress 2018). Upland food webs and species interactions are critical to the sustained production of ecosystem services because of their role in "supporting services" such as primary productivity, carbon storage, and the cycling of nutrients and water.

Upland Vision

Our vision for upland landscapes is to ensure healthy, resilient and dynamic upland ecosystems capable of providing First Foods that sustain the continuity of the Tribe's culture. The four touchstones described above support the maintenance of ecosystems, species and associated ecological processes and interactions necessary to achieve this vision. Because the production of First Foods is tied to soil stability, hydrologic function, landscape pattern and biotic integrity, the Upland Vision must address attributes of each of these touchstones. The uplands of CTUIR ceded lands are incredibly diverse, spanning multiple ecoregions, and hundreds of vegetation communities and plant associations have been defined (Johnson and Simon 1987, Johnson 2004, Powell 2017). Biophysical characteristics, disturbance regimes, historic and contemporary land use and management activities, alterations since Euro-American settlement and the presence, abundance and distribution of First Foods vary widely across this heterogenous landscape. This makes it difficult to generalize and identify key touchstone attributes, ecological processes and critical management issues that are uniformly relevant across all upland environments. Here, we focus on three broadly-defined, widely-distributed vegetation zones that cover the majority of the CTUIR ceded lands: Shrub-Steppe, Dry Conifer Forest, Moist Conifer Forest. For each, we will highlight alterations to touchstones since Euro-American settlement and discuss and identify key attributes, and issues relevant to the harvest, management and restoration of First Foods within this upland vision framework. It is important to recognize that within each of the broad vegetation zones discussed below, there exists a wide range of ecological and biophysical conditions, and numerous other ecosystems and plant community types exist within the CTUIR ceded lands (aspen stands, alpine/subalpine grasslands, etc.). While it is not within the scope of this document to specifically address each in depth, the upland vision framework and focus on touchstone attributes remains applicable to these systems.

Figure 9. Photograph from 1915 depicting extensive soil disturbance and degradation in the North Fork John Day Ranger District, Umatilla National Forest (Kellogg, 1915).

Shrub-Steppe

Shrub-steppe covers a large portion of the CTUIR-ceded lands across the Columbia Plateau, Blue Mountains, and Snake River Plain ecoregions. Climatically, shrub-steppe occupies arid to semi-arid areas, with hot, dry summers, and cold winters (Franklin and Dyrness 1988). Shrub-steppe communities span a large elevation range and vary from shrub-dominated (e.g. sagebrush species, rabbitbrush) to bunchgrass-dominated (e.g. Idaho fescue, bluebunch wheatgrass, Sandberg's bluegrass) with a diverse native forb component (e.g. biscuitroot, bitterroot, mule's ears). For purposes on this document, vegetation classified as Pacific Northwest Bunchgrass (Johnson and Simon 1987, Johnson and Swanson 2005) are included within the shrub-steppe vegetation zone. Variation and species composition is strongly influenced by abiotic factors (temperature, precipitation, elevation, slope, aspect, soil properties, water availability, etc.), in addition to land use, management and disturbance regimes that have changed dramatically since Euro-American settlement (Johnson and Swanson 2005). Of the broad upland ecosystem types within the CTUIR-ceded lands, shrub-steppe is the most heavily altered since Euro-American settlement. This has affected the production of a wide range of ecosystem services, including First Food abundance, by altering touchstone attributes in significant ways. It is important to stress the interconnectedness of the touchstones, and alterations to one have implications for the others. The primary drivers of altered touchstones in shrub-steppe include: (1) the introduction of livestock and decades of overgrazing, (2) invasion by non-native plant species, (3) changes in fire regimes, and (4) the conversion of large areas of shrub-steppe to cropland.

Alterations to Soil Stability— As Euro-Americans settled the region, they brought herds of livestock, first with large numbers of cattle in the 1860's and 1870's whose numbers peaked at the turn of the nineteenth century, followed by sheep, whose numbers peaked in the 1930s and 1940s (Galbraith and Anderson 1971, Reid et al. 1991, Johnson 2004). High stocking rates and decades of overgrazing by domestic livestock (sheep, horses, cattle) led to degradation of soil across the region, including soil loss, degradation of biological soil crusts, reduced water infiltration into the soil, soil compaction, declines in soil organic matter, and nutrient depletion. Some sites in eastern Oregon lost as much as 6-10 inches of topsoil (Reid et al. 1991; Figure 9). Damage to soil structure and health resulted in long-term loss of productivity. Changes to grazing systems and lower stocking densities of livestock since the 1950s have improved the situation, with many areas in a state of recovery, though it is unclear if or when some areas will ever recover to pre-settlement productivity (Johnson and Swanson 2005). The introduction and spread of non-native plant species, particularly annual grass species exacerbated the effects of overgrazing by quickly colonizing disturbed areas. Invasion of shrub-steppe by non-native annual grasses such as annual bromes (*Bromus tectorum*, *B. arvensis*, *B. hordeaceus*, etc.), ventenata (*Ventenata dubia*), and medusa-head (*Taeniatherum caput-medusae*) altered fire frequency and intensity, particularly in low-elevation areas. This resulted in larger, more intense and frequent wildfires that eliminate fire-intolerant shrubs and further increasing bare ground, susceptibility to erosion, and loss of biological soil crust. Inappropriate grazing, increasing fire frequency and intensity and other disturbances facilitate feedback loops that support continued degradation of not only soil stability and health but also hydrological function and biotic integrity touchstones (Figure 7).

Alterations to Hydrologic Function— Alterations to hydrological function accompanied the loss of vegetative cover and reduced soil stability caused by improper grazing, changing fire regimes, and increased dominance of non-native annual grasses. The magnitude, scope and scale of changes to hydrologic function depend on the degree to which vegetation, soil stability and disturbance regimes were altered. Areas heavily overgrazed and/or with frequent fire return intervals show reduced capacity to absorb and hold water which lowers water availability to plants and reduced biotic activity in the soil which in turn facilitates further alterations to soil stability and biotic integrity touchstones (Norris 1990, McNabb and Swanson 1990). Indicators of reduced hydrologic function include the presence of pedestals, terracettes, gullies and bareground (Pellant et al. 2005) and declines in function tend to be exacerbated on steep slopes. At higher elevations within the shrub-steppe ecosystem, fire suppression efforts that began in the early twentieth century changed hydrologic function in other ways. In the absence of fire, western juniper has increased over tenfold and shrub-steppe ecosystems have been transitioning into juniper woodlands. Juniper encroachment into high elevation shrub-steppe results in reduced understory vegetation and the creation of extensive bareground in the intercanopy (Pierson et al. 2013). Change in vegetation and cover reduce infiltration of rainfall and promote overland flow during precipitation events, reducing water availability and increasing soil erosion rates (Pierson and Williams 2016).

Alterations to Biotic Integrity— Change in land use and management have altered species abundance, structure, composition, and species interactions, resulting in profound changes to biotic integrity including the availability and abundance of First Foods. Across much of the shrub-steppe, the abundance of native perennial grass, forb, and shrub species have declined as a result of the combination of improper grazing, non-native species introductions, and changing fire regimes that facilitated the dominance of non-native plant species and/or the establishment of juniper. Changes in vegetation structure, composition, and diversity in addition to loss of habitat due and landscape fragmentation also affected a wide range of wildlife by altering habitat, food resources, and migratory routes, resulting in declining numbers of many species.

Alterations to Landscape Pattern—Vast areas of shrub-steppe, particularly in areas with deeper soils have been converted into cropland. Large areas of shrub-steppe within the CTUIR-ceded lands, particularly in the Columbia Plateau and Snake River Plain ecoregions was plowed and shrub-steppe is now fragmented with small patches of native vegetation isolated and embedded within a landscape dominated by irrigated and dryland fields with few corridors that connect isolated patches (Figure 10). These remnant patches are highly susceptible to invasion by non-native species and tend to have low species richness and diversity affecting their biotic integrity. Fewer changes in landscape pattern are evident in areas not as heavily impacted by cultivation. However, roads bisect the region, which affect migration routes of wildlife, particularly species who use lower elevation shrub-steppe as winter range (e.g. elk, deer). In recent years, wind energy developments have expanded, and the turbines and associated infrastructure (pads, roads, etc.) have increased landscape fragmentation and reduced connectivity. Additionally, changes in fire regimes have altered landscape pattern of remaining shrub-steppe

Figure 10. Large portions of shrub-steppe have been converted to cropland reducing the extent of shrub-steppe vegetation and altering landscape pattern.

ecosystems. Prior to Euro-American settlement, it is though the historic fire regime primarily consisted of small, high intensity fires at an interval of 30-80 years which created a heterogeneous landscape with patches of shrub-steppe dominated by different species and in various stages of recovery (Brown and Smith 2000). As fire return intervals have shortened and the size of fires increased, structural and species complexity of shrub-steppe has been simplified and large areas are dominated by non-native invasive grass and forb species affecting biotic integrity of the system.

Shrub-Steppe: Implications for First Foods

Water and Salmon—The two First Food groups of "Water" and "Salmon" are the primary focus of the Umatilla River Vision (Jones et al. 2008) and are discussed in depth within that document. However, it is important to consider how management of shrub-steppe affects both of these First Foods groups. Of primary concern is increased surface runoff and sedimentation caused by damage to the four touchstones, particularly soil stability and hydrologic function. Improper grazing, changes in fire regimes, loss or removal of woody species, and conversion of large areas to non-native annual grasses can increase surface runoff and sedimentation into rivers and streams (Brooks et al. 2013) affecting water quality and fish habitat (Megahan et al. 1992, Waters 1995, Wood and Armitage 1997). In particular, fire can affect soil stability, hydrologic function, and biotic integrity resulting in amplified overland flow (runoff) and erosion which can enter and impact streams and rivers. Effects are greatest in situations where fire increased bareground cover over 50-60% on slopes >15% (Pierson et al. 2008, 2011, 2013). Therefore, within shrub-steppe ecosystems, supporting ecological attributes and processes that maintain soil stability and hydrologic function will help support the sustained production of Water and Salmon. Management and restoration actions that support functional shrub-steppe communities with respect to Water and Salmon include the maintenance and establishment of native plant assemblages and biological soil crusts, which stabilizes soil, protects the soil surface, and supports the capture, storage and release of water at rates within a sites natural range of variability.

Big Game—Numerous species including, mule deer, rocky mountain elk, whitetail deer, bighorn sheep and more inhabit the shrub-steppe vegetation zone. Since Euro-American settlement, changes to biotic integrity and landscape pattern have affected these First Foods in two principle ways. First, reductions in native perennial plants and the conversion of large areas of native vegetation to non-native annual grasslands have reduced forage quantity and quality in many areas (Johnson and Swanson 2005). This in turn, may affect the health and functioning of adjacent riparian ecosystems (and associated First Foods) by increasing browse pressure on riparian vegetation, particularly woody shrubs and trees that are important for Salmon. Second, habitat loss due to the conversion of shrub-steppe to cropland and subsequent fragmentation of the landscape not only reduced the amount of available habitat, but also has impeded and altered the movement and migratory routes. Healthy, functional ecosystems will support sufficient quantity and quality of forage, habitat elements that provide cover, and corridors and connections across the landscape to allow for the movement of species across the landscape to ensure healthy populations of species now and into the future.

Figure 11. Recovery of upland native vegetation at the Southern Cross property, near Union, Oregon. Decades of over-grazing by livestock and subsequent non-native species invasions have altered touchstones in shrub-steppe ecosystems throughout the region, reducing First Foods resources. However, with proper management, many of these areas can recover. Photo by B.A. Endress.

Roots— Shrub-steppe is the most important vegetation zone for the production of Roots across the landscape. Cous (*L. cous*), bitterroot (*L. rediviva*), wild onions (*Allium* spp.), wild hyacinth (*T. grandiflora*), camas (*C. quamash*), celery (*Lomatium* spp.) and many other First Foods are found throughout this zone. The natural history and ecology of most of these species is poorly documented, making it difficult unequivocally state how alterations to the four touchstones directly affect these First Foods or to develop evidence-based

Figure 12. Bighorn Sheep and other big game (mule deer, elk, etc.) rely on healthy shrub-steppe vegetation to provide high quality forage. Shrub-steppe is particularly important for big game in the winter when many species migrate to these lower elevation areas in search of forage. Photo by E.J. Quaempts.

management and restoration plans to support their productivity. For example, little is known about how fire, invasive species, or herbivory by domestic livestock or wild ungulates affects abundance, distribution or population dynamics of many of these species. Prior to Euro-American settlement, members of the CTUIR frequently burned shrub-steppe as part of their management of First Foods (Oral History Interview #224), indicating that many of these species are likely fire tolerant of low severity fires. As non-native species have invaded many shrub-steppe areas, fires are thought to have increased in severity, and responses of roots to these altered fire regimes is unknown. Non-native plants species such as venenata, annual bromes and medusahead are thought to displace and outcompete native species, though no research has shown this to be the case with respect to these species. Herbivory by livestock and wild ungulates may also impact root production. Elk, deer, and cattle have been observed to browse many of these species (e.g. camas) in late spring and early summer, and future research should explore the potential impacts of domestic and wild ungulates in affecting the abundance and population dynamics of Root species. Alterations to landscape pattern (loss and fragmentation of habitat) and biotic integrity (reduction in perennial bunchgrasses and other forage species) may increase browse pressure on roots with potential consequences on Root abundance and production. Livestock grazing also likely increases pressure on these species in late spring to early summer. Research on the natural history, distribution, ecology, and management of these species is critically important in order to more fully inform management and restoration activities.

Another challenge to the management of Roots is that inventory and abundance data related to many of these species is not widely available and can be difficult to acquire as most of these species are spring ephemerals. That is, they grow, flower, and then senesce in the spring and early summer. By mid-summer all above-ground evidence of their presence may be gone, making it difficult at times to properly determine their presence and abundance. Therefore, assessments and surveys for these roots must be conducted early in the growing season (~March to mid-June). Despite uncertainties with respect to the ecology and management of Roots, land managers and decision makers can support continued production and availability of these First Foods by supporting and enhancing the key attributes of the four touchstones within their natural ranges of variability.

Berries— Shrub-steppe ecosystems do not contain large abundances or types of Berries. However, a number of species occur here, often at the ecotone between shrub-steppe and other vegetation zones (e.g. riparian areas). Some of the more common berry-producing species include serviceberry (*Amalanchier alnifolia*), black hawthorn (*Crataegus douglasii*) and chokecherry (*Prunus virginiana*). Species are most abundant ravines, draws and gullies where sufficient soil moisture and water availability supports their occurrence. It is important to note that many of these First Food species are also important forage for livestock and big game, and fruit from these species are consumed by a wide range of wildlife (e.g. birds, small mammals). In some areas with high densities of domestic livestock (horses, cattle) and/or wild ungulates (elk and deer) and a limited forage base (caused by dominance of non-native plants and habitat fragmentation), heavy browse pressure, particularly in late fall and winter, may reduce fruit production and availability as well as seedling recruitment. Functional shrub-steppe ecosystems then, are dependent on sufficient fruit production, seed dispersal and seedling establishment to ensure stable populations of these species.

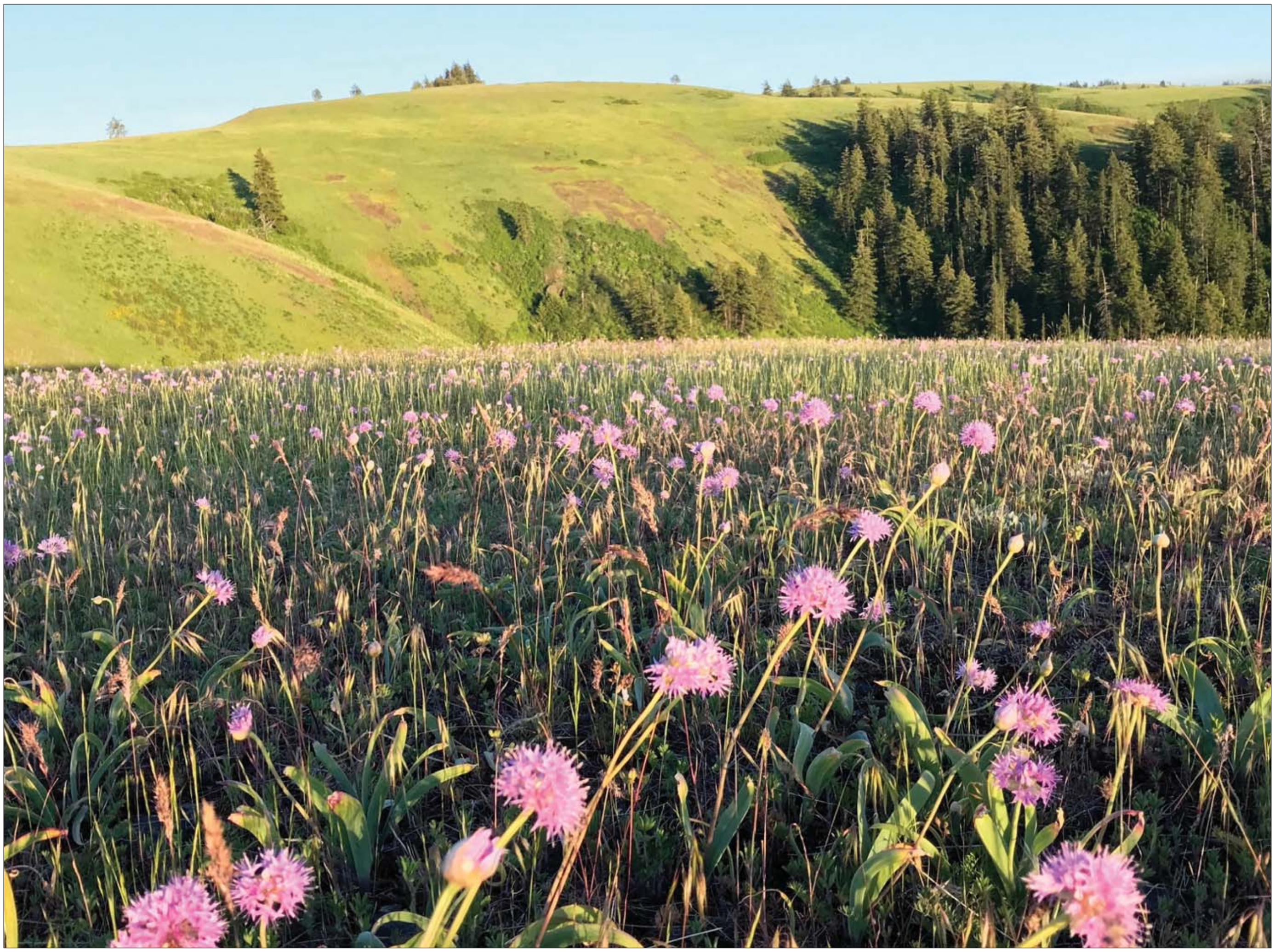

Figure 13. A meadow of wild onions (*Allium* spp.) and other Roots near Mission, Oregon. Photo by E.J. Quaempts.

Dry Conifer Forests

Dry conifer forest ecosystems are dominated by ponderosa pine and associated conifer species (Table 3), and generally occupy low to mid-elevations that are moisture limited with frequent fire events (Franklin and Dyrness 1988, Franklin et al. 2013). A number of different forest classification systems exist for dry forests that encompass CTUIR-ceded lands (Powell 2007, Franklin and Johnson 2012, Franklin et al. 2013, Powell 2017). For purposes of this document, dry forests refer to ponderosa pine and dry mixed-conifer forest stands as described by Franklin et al. 2013, which generally fall within the "Dry Upland Forest" described by Powell (2017; please refer to both Franklin et al. 2013 and Powell 2017 for specifics). Dry forest landscapes often include and are inter-mixed with grasslands (e.g. meadows, scab-flats, Pacific Northwest bunchgrass). These will be briefly discussed in this section; however, land use history, alterations to touchstones, common First Foods and their management are addressed in the shrub-steppe section (above).

Dry Forests have undergone a myriad of changes since Euro-American settlement, the most significant of which has been altered fire regimes. Prior to Euro-American settlement, fires in dry forests were primarily low severity, as frequent Native American prescribed fires reduced fuel loads and moderated the intensity and extent of wildfires (Taylor et al. 2016). Mixed-severity and high severity fires also occurred in dry forests, but to a lesser extent. When Native peoples were excluded from natural resource management activities and fire suppression became a primary management objective, fire regimes changed dramatically, affecting touchstone attributes. Other factors that have altered touchstones in dry forests include timber harvest, livestock grazing and the introduction of non-native species. Of the four touchstones, biotic integrity has been the most altered since Euro-American settlement, particularly in terms of forest composition and structure.

Alterations to Soil Stability— As noted above, fires regimes (size, frequency, severity) changed dramatically following Euro-American settlement. Fire affects soil stability and

Table 3. Common trees of dry conifer forests within CTUIR-ceded lands and some of their ecological attributes (Modified from Franklin et al. 2013).

Common Name	Species	Drought Resistance	Wildfire Resistance	Bark Beetle Risk	Climate Adapted?
Ponderosa pine	*Pinus ponderosa*	High	High	Moderate	Yes
Douglas-fir	*Pseudotsuga menzizii*	Moderate	Moderate	Moderate	Moderate
Western larch	*Larix occidentalis*	Moderate	High	Low	Yes
Grand (white) fir	*Abies grandis*	Low	Low	Moderate	No

health in a number of ways, including disrupting nutrient cycling, reducing biotic activity in the soil, increasing soil erosion, and reducing water infiltration into the soil (Norris 1990, McNabb and Swanson 1990, McNabb and Cromack 1990). The magnitude of fire impacts to soil attributes depends primarily on fire frequency and severity. Fire suppression, which began in the early 1900's resulted in increased stand density, fuel loads, and the abundance of fire intolerant species (e.g. grand-fir) within forest stands. As a result, fire regimes have changed from predominantly small, frequent, low-severity fires, to large, infrequent, high severity fires (Franklin et al. 2013). This alters soil attributes as increased fire severity reduces nutrients (especially nitrogen; McNabb and Cromack 1990), organic matter (Beschta 1990) and soil microorganisms (fungi, bacteria, etc.; Borchers and Perry 1990). Increased fire severity also increases injury and mortality rates of plants, whose roots help stabilize soil and prevent erosion. Alterations to soil stability attributes in turn affect other touchstones, principally hydrologic function and biotic integrity. Soil disturbance associated with timber harvest (e.g. roads, skid trails, landings) particularly on steep slopes, also affect soil stability by increasing erosion and negatively affecting hydrologic function, most notability water quality (Brooks et al. 2011).

Alterations to Hydrologic Function— The structure and composition of forests and hydrologic function across the landscape are intrinsically connected (Brooks et al. 2013). Increased tree density and canopy cover of dry forests due to changes in land management that accompanied Euro-American settlement can alter patterns of water capture, storage and release in addition to affecting water quality. While specific data is lacking for the dry conifer forests of the region, increased tree cover is associated with increased canopy interception and evapotranspiration, resulting in declines in water yield (Ahl and Woods 2006, Brooks et al. 2013). Fire and other disturbance agents that reduce tree cover (e.g. timber harvest) have been shown to increase water yield in the short-term, though as the size and severity of disturbance events increases, increased damage to soil stability occurs, reducing water infiltration, promoting overland flow (erosion) and increasing sedimentation and reduced water quality (Beschta 1990, Brooks et al. 2013).

Alterations to Landscape Pattern— Alterations to landscape pattern since Euro-American settlement, while not as readily visible as in the shrub-steppe, have been significant. The primary drivers of changes to landscape pattern have been timber harvest and altered fire regimes, which have affected three key landscape attributes. First, there has been a loss of spatial heterogeneity. Historically, the dry forest ecosystems were an uneven-aged mosaic of isolated trees, tree clusters, and forest openings including varied spatial arrangements and a diversity of structural characteristics (Larson and Churchill 2012, Franklin et al. 2013). This heterogeneity is integral to the function of dry forest landscapes and the production of ecosystem services including First Foods. Second, the loss of heterogeneity, increased connectivity of forest stands across the landscape. With fire suppression, increased connectivity of dense forest stands (beyond historic ranges of variation) increased the number of large stand-replacing fires, which were historically rare (Franklin and Agee 2003, Odion et al. 2014). Third, decades of timber harvest focused on large, drought tolerate species (e.g. Ponderosa pine); this eliminated or severely reduced large old-growth ponderosa pine stands, which are considered a key component to dry forest ecosystem resistance and resilience as well as ecosystem function (Henjum et al. 1994, Wisdom et al. 2000). These alterations have result in a landscape with a disproportionately large amount of forest stands that are either mid- or late successional closed canopy forest, while old growth open canopy forest stands are underrepresented (USDA Forest Service, Eastside Restoration report 2013). Alterations to landscape pattern have in turn, led to and contributed to alterations to biotic integrity (below).

Alterations to Biotic Integrity—Attributes of biotic integrity have changed substantially since Euro-American settlement. In terms of structure and composition, the combination of fire suppression and harvest of large, old-growth trees, resulted (1) increased tree densities, (2) increased abundances of less fire-tolerant species such as grand-fir, and (3) altered stand structure, with fewer large drought and fire tolerant individuals (e.g. ponderosa pine, western larch) and high densities of small, fire-intolerant species. These changes increased fuel loading of forest stands which increases the probability of large, high severity stand replacing fires. Additionally, increased tree densities increase competitive interactions among trees resulting in increased stress to drought, pathogens, bark beetle infestations and other disturbances resulting in losses of mature trees faster than they can be replaced (Lutz et al. 2009, Spies et al. 2011, Franklin et al. 2013). Finally, the loss of stand heterogeneity, particularly the loss of open, old growth stands affects wildlife species by eliminating important habitat elements

Figure 14. Ensuring connectivity between ecosystems is critical for big game that cross large elevation gradients each year in search of forage and cover. Here a herd of elk at the interface between shrub-steppe and dry conifer forest zones. Photo by E.J. Quaempts.

and reducing understory vegetation (forage). This homogenization of dry conifer forest structure and composition reduces biodiversity and negatively affects ecosystem function and the production of ecosystem services.

Dry Conifer Forest: Implications for First Foods

***Water and Salmon*—**With respect to Water and Salmon, soil stability and hydrologic function attributes within dry conifer forests should be of primary consideration. Soil erosion, increased overland flow and subsequent sedimentation of streams and rivers beyond natural ranges can affect habitat and water quality. Land management and natural resource use activities (e.g. timber harvest, recreation, fuels reduction treatments, prescribed fire) can affect the condition and function of these touchstone attributes, so management should include considerations to ensure the maintenance and functioning of soil stability, hydrologic function and other touchstones. It is important to stress that fire and other disturbance events (e.g. bark beetle outbreaks), that can and do alter touchstone attributes are fundamental components of healthy, properly functioning dry forest landscapes. Functional dry forest ecosystems are ones where disturbance events (timber harvest, wildfire, fuels reduction treatments, etc.) and regimes (frequency, size, severity), remain within the natural range of variation, and the dry conifer forest ecosystems maintain ecological resistance and resilience.

***Big Game*—** The health and function of dry forest ecosystems are important for the continued production of several First Foods in this group, including mule deer, rocky mountain elk, and whitetail deer. Alterations to touchstone attributes that affect forage, cover, and movement across the landscape should be primary considerations with respect to dry forest use, management and restoration activities. Attributes of biotic integrity, namely, vegetation composition and structure influence forage abundance and availability. The diet of these species includes a wide range of grass, forb, and shrub species, and their relative importance changes throughout the year; grass and forb species dominate the diet from spring through summer, while shrubs become an important component of diets from late summer through winter as grass and forb species senesce. Therefore, factors that affect understory plant composition, diversity, and structure also affect forage quantity and quality. Increased stand density and higher tree canopy cover caused by over a century of fire suppression reduces light in the understory, negatively affecting plant productivity and forage availability. In addition, fire suppression activities reduced the amount and distribution of early-successional forest stands which are important for the regeneration of many preferred forage species. These early succession post-fire stands are important forage areas for elk and deer (Vavra et al. 2004, Vavra et al. 2007, Long et al. 2008). Forage production can also be impacted by the invasion of dry forest understories by non-native species, the majority of which are unpalatable and/or have less nutritive quality than native species. Annual bromes (cheatgrass), medusahead, and ventenata all readily invade dry conifer forest reducing forage quantity and quality. Forage availability may also be affected by other land use activities, particularly grazing by livestock (e.g. cattle, horses, sheep). Livestock grazing is a common activity in dry forest ecosystems within CTUIR-ceded lands, and there is some diet overlap between the livestock and wild ungulates, particularly in spring (bunchgrass species) and late fall (deciduous woody shrubs), and high densities of livestock and wild ungulates may reduce forage availability. Reductions in available forage in dry conifer forests, in turn, may increase browse pressure in other areas, such as riparian ecosystems, whose health and functioning are important to other First Foods (Water, Salmon).

Dry conifer forest stand composition, diversity and structure (biotic integrity attributes) as well as spatial heterogeneity and patch size/shape (landscape pattern attributes) can affect Big Game abundance and health by altering the amount and distribution of security cover for these species. The uneven-aged mosaic of solitary trees, tree clusters, and forest openings that typified dry forest ecosystems prior to Euro-American settlement provided key security cover for elk and deer (tree clusters) surrounded by a matrix of areas of abundant forage (forest openings). Functional dry forest ecosystems would maintain this mosaic and include stands with higher tree densities that serve as cover.

Supporting Big Game production and abundance also requires consideration of landscape attributes, particularly connectivity and the spatial arrangement of patches. These are important not only to facilitate movement throughout dry forest zones, but also to support movement across the larger landscape as elk, deer and other species move between shrub-steppe, dry conifer, and moist conifer forest zones. Roads are well known barriers to the movement of elk and deer. Roads are thought to be a driving factor in determining elk distribution across seasons and landscapes (Lyon 1983). Elk avoid roads resulting in distribution shifts of populations away from roads and concerns about increased flight responses and associated energetic costs, reduced foraging time and reducing the total amount of effective habitat (Lyon 1983, Rowland et al. 2004). Roads also facilitate other human activities such as recreation, which can also affect habitat use and behavior of Big Game. Recent research shows that elk respond similarly to trail-based recreation (e.g. ATV riding, mountain biking, hiking, horseback riding) (Naylor et al. 2009, Wisdom et al. 2018). Mule deer also migrate long distances between summer and winter, and roads can impede or alter migratory routes affecting their abundance and population dynamics.

In summary, healthy, functional dry conifer forest ecosystems that support Big Game abundance and productivity are those that contain an uneven-aged mosaic of isolated trees, tree clusters, and forest openings including varied spatial arrangements and a diversity of structural characteristics that support key requirements, including forage, cover, and the ability to move across the landscape.

Roots— Several species of Roots are found in dry conifer forests, some of which can be locally abundant. Common roots include, yampa (*Perideridia gairdneri*), biscuitroot (cous, *L. cous*), wild onions (*Allium* spp.), wild hyacinth (*T. grandiflora*), camas (*C. quamash*), and yellow bell (*F. pudica*). The distribution and abundance of these species is highly variable and appears to be driven primarily by environmental variables (soil, slope, aspect, canopy cover, etc.). Species often occupy different niches within dry forests. Yampa and Spring Beauty, for example, are most commonly encountered in areas with a low overstory tree densities or near the edges of forest openings. Biscuitroot and wild onions are found in forest openings, often associated with clay soils (‘scab flats’), while camas is generally found in forest opening with deeper soils (Averett and Endress, unpublished data). These species all tend to be spring ephemerals. That is, they grow, flower, and then senesce in the spring and early summer. By mid-summer all above-ground evidence of their presence may be gone, making it difficult at times to properly determine their presence and abundance. Therefore, assessments and surveys for these roots must be conducted early in the growing season (~March to mid-June).

Figure 15. A meadow of cous (*L. cous*) embedded with the ponderosa pine-dominated dry conifer forests of the region. Photo by E.J. Quaempts.

As noted previously (see shrub-steppe section above), the natural history and ecology of these species is largely unknown making it difficult to clearly establish how alterations to touchstones impact Root availability and production or to develop management and restoration plans based on empirical data. In the most general terms, functional dry conifer forests are those whose soil stability, hydrologic function, landscape pattern, and biotic integrity attributes remain within historic natural ranges of variation in order so that these ecosystems remain capable of providing the roots that sustain the continuity of the Tribe's culture. Despite some uncertainties, it is likely that alterations to soil stability, hydrologic function and biotic integrity are most important in affecting the sustained production of roots. For example, changes in the composition and structure of dry conifer forests as a result of fire suppression, may reduce light availability in the understory, thereby negatively affect roots associated with open forest stands and forest edges (e.g. yampa). Open meadows and scab flats are often locations where, during timber harvest, logs are yarded and loaded and where slash piles are placed. These activities can increase soil disturbance and compaction, altering both soil stability and hydrologic function in ways that reduce productivity of roots. The role of fire, invasive species and herbivory in altering touchstone attributes with respect to root production is unclear.

Berries— In general, berries are not as abundant in dry conifer forests as in higher elevation moist conifer forests (see below), but a number of species are common in dry conifer forest understories. Commonly encountered species include serviceberry (*Amalanchier alnifolia*), black hawthorn (*Crataegus douglasii*), chokecherry (*Prunus virginiana*), and currants (*Ribes* spp.). Huckleberry (*Vaccinium membranaceum*) while largely associated with higher elevation moist conifer forests, can also be found in some dry forests, generally in low abundances with limited fruit production. In general, abundances of these species are lower in ponderosa-pine dominated stands that are associated with drier sites, while abundances increase in Doulas-fir, grand-fir and dry mixed conifer stands on sites with greater water availability (e.g. areas with deeper soils, greater precipitation, and/or more northerly aspects).

Implementing the upland vision with respect to berries in dry forests requires touchstone attributes, primarily associated with biotic integrity and landscape pattern to remain functional and within natural ranges of variation. Changes in the overstory structure and composition (e.g. increased stand density and canopy cover) due to management may affect understory conditions that would affect berry production. Fire, a natural component of functional dry forest ecosystems, will in the short term, negatively affect some of these species (e.g. serviceberry, Hall Defrees 2018), and recovery may take 20 years or more. For other species (e.g. huckleberry), these disturbances are critical for their establishment and growth. Therefore, ensuring a landscape mosaic of forest stands of varied successional stages is critical to continued production of berries.

Abundance and health of berries also depend on other factors such as herbivory by cattle, horses, elk and deer. Recent research indicates that recovery will be slower following fires in areas with high abundances of cattle, elk, and mule deer, as several of these species (e.g. serviceberry) are preferred forage in late summer and fall as grass and forb species senesce (Hall Defrees 2018). Increased browse can eliminate species in areas recovering from disturbance, as well as reducing berry production and availability as plants allocate more resources to replacing leaves at the expense of fruit production (Endress and Averett, unpublished data). Because of the myriad of factors affecting these species, use and management activities must not only consider touchstone attributes at the stand level, but also incorporate landscape level considerations ensure availability and production of berries across dry forests. A functional dry forest landscape maintains a mosaic of forest stands in a variety of conditions, from old-growth to recently disturbed in order to provide the variety of biological and environmental condition that supports the growth, establishment and health Berries and other First Foods.

Moist Conifer Forests

Moist forests occupy higher elevation areas within CTUIR-ceded lands. These forests are associated with cooler temperatures and greater precipitation (Franklin and Dyrness 1988) than other upland ecosystems in the region. For purposes of this document, moist conifer forests include forests classified Powell (2017) as "Moist Upland Forest,"and by Franklin et al. (2013) as "Moist Mixed Conifer" or "Moist Forest." Most Forests are generally bound by dry forests at lower elevation and, if elevations are sufficiently high, subalpine grasslands above (Franklin and Dyrness 1988, Johnson 2004). These forests are dominated by grand fir, Douglas-fir, and subalpine fir but also include lodgepole pine, western larch, ponderosa pine, and other species. Dozens of stand types have been identified within moist forests (see Franklin et al. 2013 and Powell 2017 for details), and stand type is heavily influenced by environmental factors (elevation, climate, soil characteristics, etc.) and fire regimes (frequency and severity). Fire frequency and severity varies considerably across moist conifer forests. Some stands have less frequent but more intense fire regimes, while other stands have fire regimes similar to dry forests (frequent low- to moderate severity fires). Stands with infrequent, high severity fires generally have high stem densities of primarily fire intolerant species (e.g. grand fir, subalpine fir), while stands with low- to moderate severity fire regimes have low density stands with a greater abundance of fire-tolerant species such as ponderosa pine, larch, and Douglas-fir. Variation in fire regimes and environmental factors created a heterogeneous landscape mosaic of forests stands that varied in their structure and composition.

Figure 16. Moist conifer forests dominated by species such as grand fir, subalpine fir, Douglass-fir, and western larch are important areas for berry production, particularly huckleberry and also serve a critical summer range for big game such as elk. Photos by B.A. Endress.

In general, alterations to ecological touchstones within moist forests have been less dramatic than those of shrub-steppe and dry forest ecosystems. Fire suppression and removal of large-old growth trees are two of the largest drivers of altered touchstones. Impacts of fire suppression has been less significant in moist forests than dry forests because many forest stands, particularly those at higher elevations, are adapted to low frequency, high severity (stand-replacing) fires, something that fire suppression has little effect on. Less dense moist conifer forest stands with historic fire regimes consisting of low- and moderate-severity fires have been more impacted by fire suppression. These stands share the same alterations to touchstones as the dry conifer forests described above (see Dry Forests). The only difference would be moist mixed-conifer forests would have a greater proportion of higher density stands. Historic timber harvest of large old-growth trees, particularly fire-tolerant species, have impacted forest composition and structure (biotic integrity), with potential impacts on wildlife habitat.

Alterations to Soil Stability—Large alterations to the capacity of moist conifer forest sites to stabilize and maintain soil structure and resources (soil, nutrients, organic matter, water) have not been noted within CTUIR ceded lands. Short-term impacts on soil stability do occur in response to disturbance events (timber harvest, wildfire, etc.), and the potential for long-term impacts on soil stability should be considered, particularly when vegetation is removed and soil is exposed. The greater precipitation and often steep slopes associated with moist conifer forests can increase soil erosion and loss of stability following severe disturbances. Higher elevation moist conifer forests (generally those dominated by grand fir, subalpine fir and/or lodgepole pine) historically were characterized by low frequency, high severity fires, which can drastically impact soil stability attributes. Indicators of reductions in soil stability include the presence of bareground, rills, and gullies. Therefore, in order to support the production of First Foods within moist conifer forests, it is important that management plans incorporate actions that facilitate and strengthen soil stability components (structure, chemical, biological) and limit the redistribution and loss of soil resources (e.g. nutrients, organic matter) by wind and water following disturbance events.

Alterations to Hydrologic Function—Alterations to hydrologic function across moist conifer forest stands have been less pronounced than in shrub-steppe and dry conifer forests. Wildfires, timber harvest, silvicultural treatments, road development and other activities that remove vegetation and disturb soil can impact a sites ability to capture, store, retain, and release water, but widespread alterations to hydrologic function have not been documented. The potential for negative impacts on hydrologic function remain and therefore ensuring a sites ability to not only function properly in terms of water capture, storage and release, but also retain its capacity to recover following disturbances is critically important to support the production of First Foods in moist conifer forests.

Alterations to Landscape Pattern— Alterations to landscape pattern since Euro-American settlement in moist forests are similar to those of dry conifer forests. Timber harvest, silviculture practices and fire suppression have led to a more homogenous forest landscape than existed prior to Euro-American settlement with declines in low-density moist forest stands (due to fire suppression) and fewer old-growth forest-stands (due to timber harvest). Much of the moist forest within CTUIR ceded lands is managed by the USDA Forest Service and is maintained as forest land. Thus, few changes in connectivity and spatial arrangement have occurred. At lower elevations near the dry conifer forest zone, fire regimes were historically more similar to dry forests and characterized by a mix of high-severity and low-severity regimes. Therefore, fire suppression in these stands (often mixed conifer stands dominated by grand-fir and Douglas fir, but also containing more fire tolerant species) has led to increase connectivity and homogenization, which can impact production of First Foods, particularly Big Game and Berries. Higher elevation forests, often dominated by grand fir, subalpine fir and/or lodgepole pine have not been as altered in terms of landscape pattern attributes.

Figure 17. The understory of moist conifer forests stands contain a wide range of grass, forb, and shrub species, providing important forage and security cover for elk and other wildlife. Photo by B.A. Endress.

Alterations to Biotic Integrity— Primary alterations to biotic integrity as a result of changes in moist conifer forest use and management since Euro-American settlement include changes to forest composition, structure, and species interactions. In terms of structure and composition, declines in fire-tolerant species as well old-growth forest stands, have occurred, particularly in the lower elevation moist mixed conifer stands (Franklin et al. 2013), with implications for the sustained production of First Foods, primarily Big Game and Berries. Increased stand density and overstory canopy cover reduces understory vegetation, forage quantity and quality, and fire suppression hinders the abundance of fire-dependent First Foods, such as huckleberry, which responds positively to fire disturbances. Factors that affect biotic integrity of shrub-steppe and dry conifer forests, such as non-native plant invasions, are currently not as relevant to moist conifer forests. Attributes of biotic integrity including diversity, structure and composition must be managed to maintain moist conifer forest communities that support and provide First Foods.

Moist Conifer Forest: Implications for First Foods

***Water and Salmon*—**The proper functioning of soil stability and hydrologic function attributes should be considered with respect to Water and Salmon. Streams that pass through moist conifer forests are often important for Salmonids (spawning and rearing), lamprey and associated species, and land management and disturbance events can remove vegetation and group cover, exposing soil and increasing soil erosion, overland flow and subsequent sedimentation of streams and rivers beyond natural ranges. This can affect stream habitat and water quality, so management should include considerations to ensure the maintenance and functioning of soil stability, hydrologic function and other touchstones. As noted above for dry conifer forests, fire and other disturbance events (e.g. bark beetle outbreaks) are also fundamental components of healthy, properly functioning moist conifer forests. Therefore, in order to support First Foods production, the goal is not to eliminate disturbances events but rather to ensure that disturbance events and regimes remain within the natural range of variation, and that ecological systems are capable of recovering touchstone attributes following disturbance.

***Big Game*—**Moist conifer forests serve as important summer range for mule deer, elk and other ungulates. As forage senesces at lower elevations in the summer, ungulates move up to higher elevation moist conifer forests. As such, the health and function of moist conifer forest ecosystems are important to support the health and availability of these First Foods. In particular, alterations to attributes discussed above for dry conifer forests (see above), namely alterations that affect forage, cover, and movement across the landscape are also relevant for moist conifer forests. Attributes of biotic integrity (composition, structure) have a large impact on forage abundance and availability. Thus, factors that affect understory plant composition, diversity, and structure will also affect forage quantity and quality. Fire suppression, particularly in the lower elevation moist mixed conifer forests, has increased stand density and canopy cover thereby reducing forage abundance in the understory, while also eliminating the amount of early-successional forests that are important forage resource areas. Livestock grazing is common in many moist conifer forests and high densities of livestock and wild ungulates may reduce forage availability and, as noted above, this may increase pressure on riparian ecosystems, whose health and functioning are important to other First Foods (Water, Salmon). Other considerations to management of Big Game includes to importance of appropriate security cover (e.g. thickets, coarse woody debris) and connectivity to promote movement across the landscape.

Figure 18. Bigleaf huckleberry (*V. membranaceaum*) is abundant in moist conifer forests across the region. Historically, Tribal members use prescribed fire to increase berry production (Fisher 2002, Hunn et al. 2015). Fire suppression has resulted in denser forest stands reducing light availability in the understory; it is thought that the increased shade and lack of fire reduces fruit production. Photos by E.J. Quaempts.

***Roots*—**Moist conifer forests are not primary locations for the digging and harvest of Roots. However, forest openings and meadows often contain many of these First Foods, and alterations to touchstones can affect the abundance and production of roots in moist conifer forests. These issues are covered in the dry conifer forest section above.

***Berries*—** Moist conifer forests are some of the most productive and important areas for berry harvest. Many berries, most notably, big huckleberry (*V. membranaceum*), grouse huckleberry (*V. scoparium*), and serviceberry (*A. alnifolia*) can occur in high abundances. In particular, huckleberry dominates the understory of several moist conifer forest types and is one of the most abundance understory shrubs throughout all grand fir and subalpine fir plant associations in the Blue and Wallowa Mountains (Johnson 2004). Not only is big huckleberry a key First Food for the CTUIR, fruit are an important part of the diet of many wildlife species.

Supporting the sustained production of Berries within moist conifer forests requires particular attention biotic integrity attributes. Despite the ecological and cultural importance of many of these species, especially big huckleberry, research on the ecology and management of these species is largely lacking. In general, understory species respond to the removal or loss of overstory trees (due to stand thinning, wild or prescribed fire, timber harvest, bark beetle outbreaks, etc.) with increased biomass and cover, especially for woody and/or clonal species such as big huckleberry (Bailey et al. 1998, Kerns et al. 2004). It is thought this positive response is due to a combination of increased light, water, nutrient availability, and soil temperatures associated with disturbance events. This matches well with the traditional ecological knowledge of Native peoples including the CTUIR, who have used fire to promote huckleberry production across western North America (Trusler and Johnson 2008, Hunn et al. 2015). Therefore, fire suppression efforts which have altered biotic integrity attributes and increased tree density and overstory canopy closure are likely to reduce fruit availability. While big huckleberry may respond positively to opening of the canopy, it remains unclear how different management actions will affect rates of recovery. For example, research in the Catherine Creek watershed in Union County found that huckleberry abundance and fruit production in forest stands that were thinned and burned nearly 30 years ago were highly variable and recovery may depend on fire intensity and environmental factors: the best predictors of huckleberry abundance and fruit density following timber harvest and prescribed fire were elevation and aspect (Holloway and Endress, 2017). How the canopy was opened may also affect berry production, and no research has explored how huckleberry responds to different disturbances (e.g. timber harvest, wildfire, fuels reduction treatments, prescribed fire), though Minore (1984) noted that for a different species of huckleberry, berry production increased when disturbance events had minimal impact on understory species.

While many unanswered questions remain regarding how alterations to touchstones affect the availability and production of berries in moist conifer forests, it is clear that it is essential to ensure ecological patterns and processes that result in a dynamic mosaic of forest patches of varied ages and stand structures are needed to support the continued production of berries and other First Foods.

Implementing the Upland Vision

To be successful, the upland vision must be clearly connected to use, management, and restoration actions. Figure 19, presents a flowchart connecting the overarching CTUIR First Foods-based mission to the upland vision and management actions. Here, we present an approach that links ecological touchstones and their component attributes to use, management and restoration of upland landscapes. This a general template that can be utilized and modified to develop management and restoration actions across upland ecosystems.

To successfully develop, plan, design and implement projects that support the upland vision and the CTUIR DNR mission, it is important to first: (1) develop a reference ecosystem model based on available knowledge, and (2) assess the current condition of touchstone attributes including the importance of the site for upland First Foods. A reference ecosystem model will contain and describe key attributes of soil stability, hydrologic function, biotic integrity and landscape pattern, and serve as the foundation with which to develop management priorities. Information from a range of sources can help develop a reference ecosystem model including field indicators, monitoring data, scientific reports, reference sites, historical records, and oral histories. A number of guides and reports are also useful. For example, for dry conifer forests (as well as for some mixed-moist conifer forests), Franklin et al. (2013) and Powell (2017) can help in reference ecosystem model development. In shrub-steppe and other rangeland ecosystems, resources such as the Rangeland Health Assessment (Pellant et al. 2005), Ecological Site Description (NRCS 2018) and the State and Transition Model concept (Bestelmeyer et al. 2017) assist in reference ecosystem development and also help evaluate and identify alterations to touchstone attributes and what that may mean for ecosystem health. Oral histories, site surveys and references such as Hunn et al. (2015) can help provide valuable information on what First Foods are (or should be) explicitly considered for a given location.

Two hypothetic examples of how project actions can connect to and support the upland vision are found in Table 4. Not only is it important to directly identify how management decisions are related to supporting or improvement touchstone attributes, it is also critically important to consider and mitigate for any potential negative consequence management actions may have on First Foods directly or indirectly.

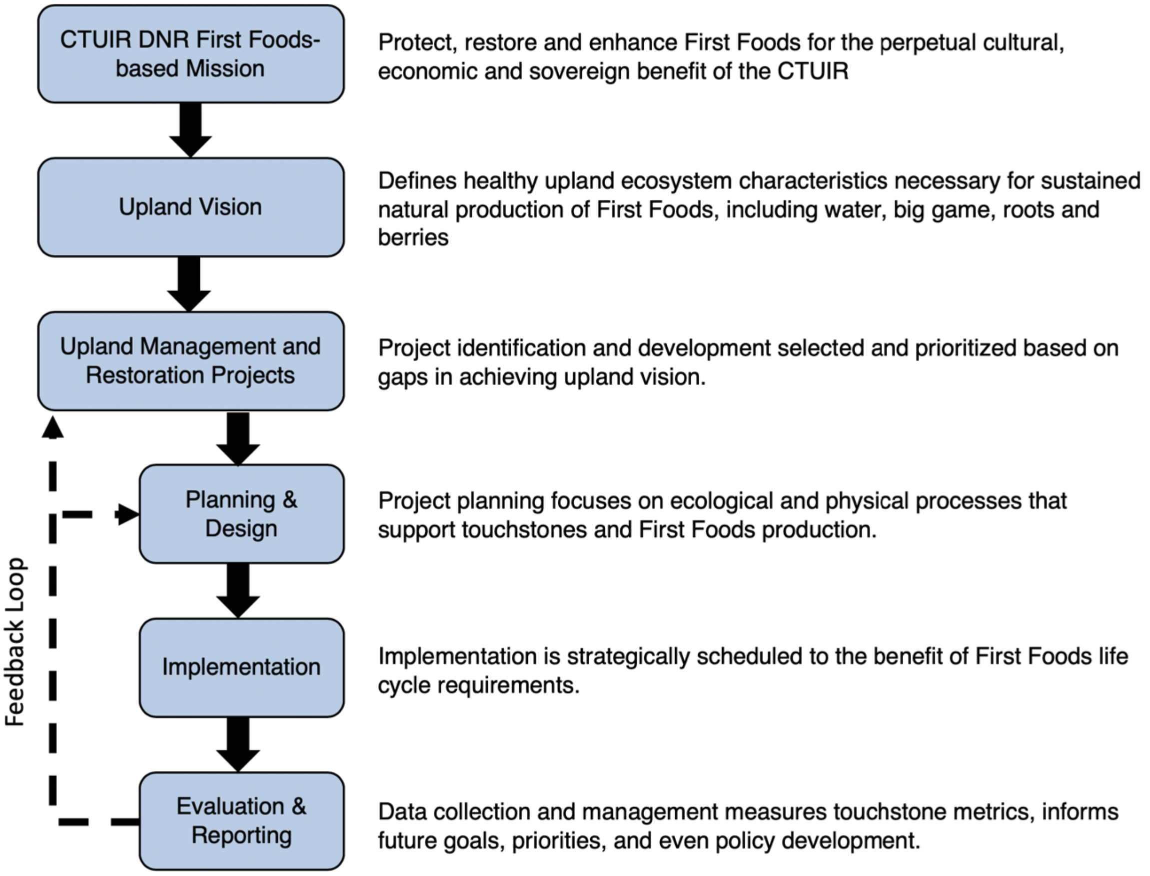

Figure 19. Flowchart describing relationship between the CTUIR DNR mission, vision and management

Table 4. Two hypothetical examples of projects, one in a shrub-steppe ecosystem (above) and the other in moist conifer forest (below), that link management activity, the relevant site-specific First Foods affected, and the touchstones to be addressed. The blue boxes with the "X" indicates touchstones addressed in the example management actions. The white indicates touchstones that are not addressed by project design, and the yellow boxes indicate touchstones that may be negatively impacted by management activities, which in turn may negatively impact First Foods, and therefore require specific consideration, scheduling requirements and/or mitigation action.

				CTUIR Upland Vision Touchstones and Attributes			
	Project Description	**First Food Group**	**Principal First Food Species**	**Soil Stability** Physical Chemical Biological	**Hydrologic Function** Capture Storage Release Quality	**Landscape Pattern** Patch size & extent Spatial arrangement Connectivity Heterogeneity	**Biotic Integrity** Composition Structure Species interactions First Foods
Shrub-Steppe	Shrub-steppe restoration including invasive plant control, seeding with native perennial grasses, rest from livestock grazing, protection of existing suppressed shrubs	Big Game	Mule Deer Elk	**X**	**X**	**X**	**X**
		Roots	Cous Bitterroot Wild Hyacinth	**X**	**X**		**X**
		Berries	Serviceberry				**X**
	Invasive plant control and seeding with native perennial grasses will primarily improve biotic integrity, with subsequent positive impacts on soil stability and hydrologic function. This benefits Big Game by improving winter range (increased forage quality and increase in spatial extent of improved winter range) and Roots by reducing/eliminating potential non-native competitors. Resting the site from livestock will directly improve soil stability, hydrologic function and biotic integrity by increasing vegetative cover, reducing soil compaction, increasing organic matter input into the soil, and promoting establishment of biological soil crust. This benefits both Big Game and Roots, and may also reduce browse pressure on serviceberry.						

				CTUIR Upland Vision Touchstones and Attributes			
	Project Description	**First Food Group**	**Principal First Food Species**	**Soil Stability** Physical Chemical Biological	**Hydrologic Function** Capture Storage Release Quality	**Landscape Pattern** Patch size & extent Spatial arrangement Connectivity Heterogeneity	**Biotic Integrity** Composition Structure Species interactions First Foods
Moist Conifer Forest	Fuels reduction treatment (mechanical and prescribed fire) including reduction of surface fuels, a decrease in crown density, and retaining large fire-resistant species. Implemented in a way that increases stand heterogeneity.	Big Game	Mule Deer Elk			**X**	**X**
		Berries	Huckleberry			**X**	**X**
	Fuels reduction treatments implemented in order to reduce high fuel loads as a result of decades of fire suppression will support ecosystem health and function. This management action supports Big Game by altering stand structure and composition (Biotic Integrity) which should improve summer range by increasing understory forage quantity and quality. Potential negative impacts which must be mediated include damage to soil stability and hydrological function during treatment which can ultimately affect biotic integrity and the availability of forage resources. Additionally it is important to ensure security cover for Big Game, and consider how stand management supports overall landscape pattern attributes that promote Big Game abundance and health. Management action also supports huckleberry by reintroducing fire to the stand and increasing light in the understory. It is important to recognize in the short term, huckleberry production may decline as a result of stand treatment, and this may inform the timing, extent and spatial configuration of fuels reduction across the landscape to ensure huckleberry availability. Minimizing damage to soil structure and stability during fuels treatments should promote huckleberry recovery.						

Implications of the First Foods Management Framework

The ultimate goal of this First Foods-focused management approach is to ensure the sustainable stewardship of natural ecosystems within CTUIR ceded lands. Using the long-term production and harvest of the full First Foods order as a benchmark for success helps ensure natural resource management and restoration priorities, plans, and actions support the continuity of Tribal cultural traditions, First Foods and the ecosystems in which they are found. Achieving this goal requires the proper functioning of ecological touchstones (soil stability, hydrologic function, landscape pattern, biotic integrity) across a large, diverse, dynamic and heterogeneous landscape. This has several management implications:

1. Management and restoration priorities should be based upon a thorough understanding of the touchstone attributes of an appropriate reference system. Reference ecosystems, which are assembled from available knowledge, represent a site's characteristics as they would have been prior to degradation (McDonald et al. 2016). This includes an understanding of a site's historic disturbance regimes and touchstone attributes, the degree to which these ecological attributes, patterns, and processes have deviated from reference conditions, and the underlying factors driving observed alterations. It is important to note that use of a reference ecosystem is not an attempt to immobilize or fix ecosystem characteristics, but rather to serve as a starting point to understand ecosystem structure and dynamics and identify restoration targets that incorporate natural variation as well as current and future environmental and/or land use changes (McDonald et al. 2016). This understanding provides an appropriate foundation with which to develop site-appropriate short and long-term management targets and goals.

2. Upland ecosystems are dynamic, and their structure, composition, and function are a product of a variety of interacting ecological processes, management activities and land use legacies. Therefore, long-term stewardship of First Foods requires management actions that address the underlying factors and processes that affect First Foods

Figure 20. Mule deer (*O. hemionus*) in a stand of bluebunch wheatgrass, a key forage species for many big game species. Deer numbers have declined across many areas of the CTUIR ceded-lands over the past several decades. Management efforts to support healthy and abundant mule deer populations should focus on repairing damaged touchstone attributes, some of which (e.g. connectivity) many cross ownership and management boundaries. Photo by E.J. Quaempts.

availability and production. For example, many areas of shrub-steppe are highly invaded by non-native annual grasses, reducing forage quality and quantity for elk, deer and other wildlife. Management actions that solely focus on eliminating the invasive annual grasses (e.g. herbicide application), do little to address the underlying ecological factors that caused the high abundances to begin with (James at al. 2010), which may be the result of a number of factors such as altered disturbance regimes that promote annual grasses, limited availability (sources) of native species to establish, or other ecological processes. Therefore, if one goal of the site is to increase winter forage for Big Game, then simply trying to control invasive annuals grasses is unlikely to be successful in reaching the goal in the long-term; management actions need to focus on the underlying cause of invasive plant dominance at the site. The ability to identify the driving factors that underlie the functioning (or lack thereof) of touchstone attributes is important to develop appropriate management goals and identify the methods by which to achieve those goals.

3. Key touchstone attributes vary across upland ecosystems, as does the distribution and abundance of First Foods. Therefore, management and restoration targets and goals will vary from site to site depending on the ecosystem, the degree to which touchstone attributes have been altered, the primary First Foods and their status, and the landscape context. Upland ecosystems of the CTUIR ceded-lands are incredibly diverse, and the distribution and abundance of First Foods as well as the factors influencing their productivity vary greatly. Additionally, alterations to touchstone attributes and their effects on First Foods range in scale, scope, and intensity. Therefore, appropriate site-specific targets and goals, as well as the methods and approaches to reach these goals will vary depending on these factors. Management and restoration goals must be site and context specific in order to have the highest chance of success.

4. Upland ecosystems within CTUIR-ceded lands are owned and managed by a diverse mix of individuals, communities, government and Tribal agencies. Many critical ecological processes necessary for the sustained production of First Foods cross ownership and management boundaries, and some managers may be unware of the importance of First Foods to CTUIR culture or their goals do not explicitly include stewardship of First Foods. Therefore, achieving the goal of sustained production of First Foods by natural ecosystems and the ability of Tribal members to harvest requires communication and close collaboration across land ownership and management boundaries. Large changes in land use, management and ownership have occurred since the Treaty of 1855. Many ecological processes operate at scales beyond the any particular site (e.g. wildfires, seasonal migration of elk, invasive species). Therefore, understanding and incorporating landscape context and connections between and among areas may be critical to successful stewardships at a local site. Engaging and when possible developing a shared vision for ecosystem and landscape attributes that support First Foods production should increase management and restoration success.

Figure 21. Roots (*L. cous*) and cupin. Photo by E.J. Quaempts.

Conclusion

First Foods have sustained tribal people since time immemorial and the relationship between First Foods and the Tribes is essential to the ongoing culture of the CTUIR. In recognition of this relationship, the CTUIR DNR adopted a First Foods-based mission focused on the protection, restoration and enhancement of First Foods. The targeted vision for healthy, resilient and dynamic upland ecosystems able to support the continued natural production of First Foods provides a framework to guide assessment, planning, management and restoration efforts and helps to ensure current and future management activities are aligned with and account for the protection and enhancement of First Foods.

Working towards this vision requires an understanding of the attributes that are vital to ecosystem health and First Foods production. These attributes, or touchstones, are central to the proper function of upland ecosystems and their ability to provide a range of ecosystem services, including First Foods. These include: 1) Soil Stability, 2) Hydrological Function, 3) Landscape Pattern, and 4) Biotic Integrity. Assessment and monitoring of the touchstones and their attributes provides a direct link between on-the-ground management, decision making, and the mission and vision of the CTUIR DNR. This framework may also be of use to non-Tribal land owners and managers within the CTUIR-ceded lands.

The First Foods-focused mission and upland vision highlight direct connections between the ecological health of upland ecosystems and the health and well-being of Tribal members. Focusing the CTUIR DNR's mission and upland vision on the management, protection and restoration of touchstone attributes that affect upland ecosystem health, supports the continued availability of First Foods now and into the future and strengthens the relationship between Tribal members and First Foods—a fundamental relationship that underlies the health, well-being and cultural identity of the Tribes.

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The Umatilla River Vision

Confederated Tribes of the Umatilla Indian Reservation
Department of Natural Resources

Vision: The Umatilla basin includes a healthy river capable of providing First Foods that sustain the continuity of the Tribe's culture. This vision requires a river that is dynamic, and shaped not only by physical and biological processes, but the interactions and interconnections between those processes.

By:

Krista L. Jones, Geoffrey C. Poole, Eric J. Quaempts, Scott O'Daniel, Tim Beechie

October 1, 2008

Revised May, 2011 by Eric J. Quaempts

Preface

In January of 2007, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Department of Natural Resources (DNR) adopted the following mission:

> *To protect, restore, and enhance the First Foods - water, salmon, deer, cous, and huckleberry - for the perpetual cultural, economic, and sovereign benefit of the CTUIR. We will accomplish this utilizing traditional ecological and cultural knowledge and science to inform: 1) population and habitat management goals and actions; and 2) natural resource policies and regulatory mechanisms.*

The First Foods are considered by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Department of Natural Resources (DNR) to constitute the minimum ecological products necessary to sustain CTUIR culture. The CTUIR DNR has a mission to protect First Foods and a long-term goal of restoring related foods in the order to provide a diverse table setting of native foods for the Tribal community. The mission was developed in response to long-standing and continuing community expressions of First Foods traditions, and community member requests that all First Foods be protected and restored for their respectful use now and in the future.

This document will assist Tribal and non-Tribal managers in moving the First Foods mission from concept to application. It identifies processes and conditions needed to sustain aquatic First Foods, information needed to inform their management, and potential management implications. It is my expectation that in applying the First Foods approach and the river vision, managers can focus on appropriate ecological processes that provide and sustain First Foods, and plan management actions accordingly.

While the vision described herein uses the Umatilla River as an example of how the First Foods approach can be used to guide water and water quality management, I anticipate that the "touchstones" described in this vision will have applications to other rivers in the CTUIR's areas of interest and co-management authority.

This document is not intended to replace or substitute for any other basin planning document developed by the Umatilla Tribes. Instead the ideas presented here are intended as touchstones for managers, to help ensure that planned management activities account for an appropriate breadth of ecological considerations and are aligned with one another in pursuit of the goals and needs of the Tribal community that depend upon rivers.

Eric J. Quaempts

Director, CTUIR Department of Natural Resources

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The development of the Umatilla River Vision was made possible by a generous and anonymous donation provided through Stoehl-Reeves. Conditions of the donation were that the funding be used to responsibly support water quality improvement efforts. By creating a unique, community-related vision that for years will guide and link the water-related work of multiple CTUIR programs, I hope that we have satisfied the donor's intentions.

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Authors

Krista L Jones – Krista holds the position of monitoring coordinator at the Lower Columbia River Estuary Partnership. Her areas of interest include Landscape Ecology, Stream Ecology, Geomorphology, Ichthyology, and Historical Ecology. She completed a B. S. and M.S. at the School of Ecology at the University of Georgia.

Geoffrey C. Poole **-** Geoff applies simulation models and GIS to study interactions among geomorphology, hydrology, and ecology in floodplain and river networks. He has operated an independent ecosystem research firm, Eco-metrics Inc., and is an associate professor at Montana State University.

Eric J. Quaempt*s* - Eric possesses a Bachelor’s in Wildlife Science from Oregon State University, 14 years of habitat and project management, and 4 years experience as DNR Director. His personal experiences with First Foods and the CTUIR community informed the initial development of the DNR First Foods mission.

Scott O’Daniel –Scott has employed remote sensing, GIS and field studies to address biological and physical processes in floodplains and hillslopes. He has earned a B.S. from Washington State University and a M.S. from the University of California, Santa Barbara.

Tim Beechie - Tim is currently the Science Coordinator for the NOAA Watershed Program, and Leader of the Ecosystem Processes Team. Since 1990, Tim has studied the natural development of landscapes and salmon habitat, evaluated the relative influences of different land uses on salmon habitat losses, and led the development of a process-based habitat restoration strategy. Tim completed his PhD at the University of Washington in 1998.

Introduction

The Department of Natural Resources (DNR) of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) has adopted a mission based on First Foods ritualistically served at tribal meals (Figure 1). This framework for natural resource management seeks to reflect the unique tribal values associated with natural resources and to emphasize ecological processes and services that are undervalued by westernized Euro-American natural resource strategies. The First Foods framework prioritizes efforts to re-naturalize processes that sustain First Foods and provides a direct and culturally appropriate means for monitoring and reporting restoration progress to the tribal community.

Sound river management and restoration are predicated upon the need to develop a systemic and holistic vision of a functional river (Independent Scientific Group 1996; Stanford et al. 1996; Ward et al. 2001; Jungwirth et al. 2002; Nilsson et al. 2007). Such a vision provides a framework for planning management or restoration efforts and an initial benchmark for assessing management success or failure. Similarly, a river vision provides the context necessary for understanding the role of any specific management decision or action in the context of other decisions or actions.

Our vision is as follows: *The Umatilla basin includes a healthy river capable of providing First Foods that sustain the continuity of the Tribe's culture. This vision requires a river that is dynamic, and shaped not only by physical and biological processes, but the interactions and interconnections between those processes.*

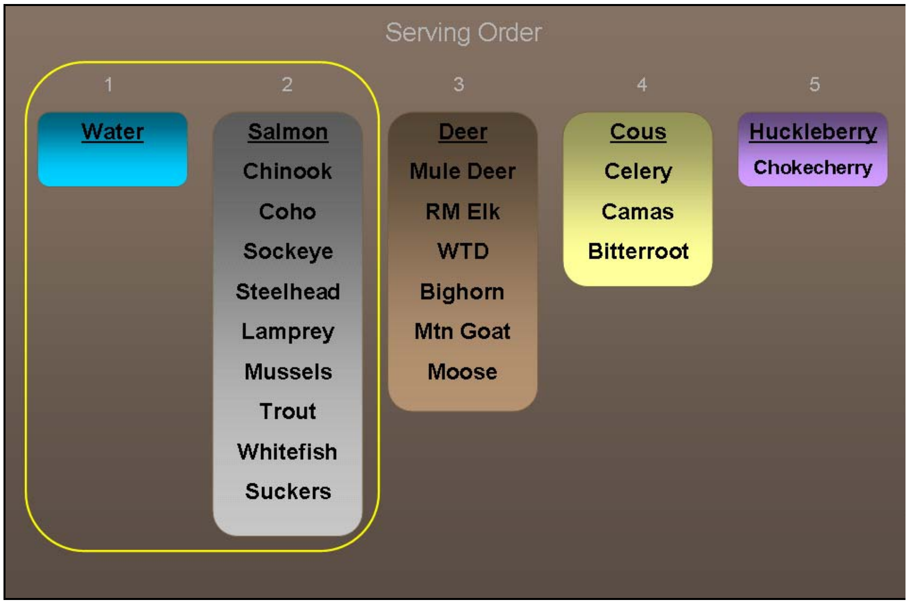
In this report, we outline a vision for desired ecological characteristics of the Umatilla River's water quality and water resource management, which will facilitate the sustained production of First Foods within the Umatilla Basin. These characteristics are founded on five fundamental "touchstones," including; 1) hydrology, 2) geomorphology, 3) connectivity, 4) native riparian vegetation, and 5) native aquatic biota.

The First Foods management framework adopts a broad definition of "water quality," incorporating the physical, chemical, biological, and ecological targets to assess the quality of water in the Umatilla River. Essentially, according to this framework, the ecological function and health of the Umatilla River become a holistic measure of water quality, and provide a pathway toward the restoration and maintenance of First Foods production.

Managing for First Foods

To provide context for the First Foods management framework, we begin by describing changes to ecosystem processes of the Umatilla River Basin resulting from the shift from a subsistence economy to an industrialized economy. We then present a "river vision" by highlighting attributes of the Umatilla River's hydrology, geomorphology, habitat and network connectivity, riverine biotic community, and riparian vegetation that are essential in the sustained production of First Foods for tribal consumption. Finally, we discuss implications of a mission focused on First Foods for management and restoration strategies.

In the tribal creation belief, the Creator asked the foods "who will take care of the Indian people?" Salmon was the first to promise, then other fish lined up behind



1	2	3	4	5
Water	Salmon	Deer	Cous	Huckleberry
	Chinook	Mule Deer	Celery	Chokecherry
	Coho	RM Elk	Camas	
	Sockeye	WTD	Bitterroot	
	Steelhead	Bighorn		
	Lamprey	Mtn Goat		
	Mussels	Moose		
	Trout			
	Whitefish			
	Suckers			

Figure 1. The First Foods serving order with a partial list of ecologically related species for each serving group. The yellow box highlights primary components guiding development of the river vision.

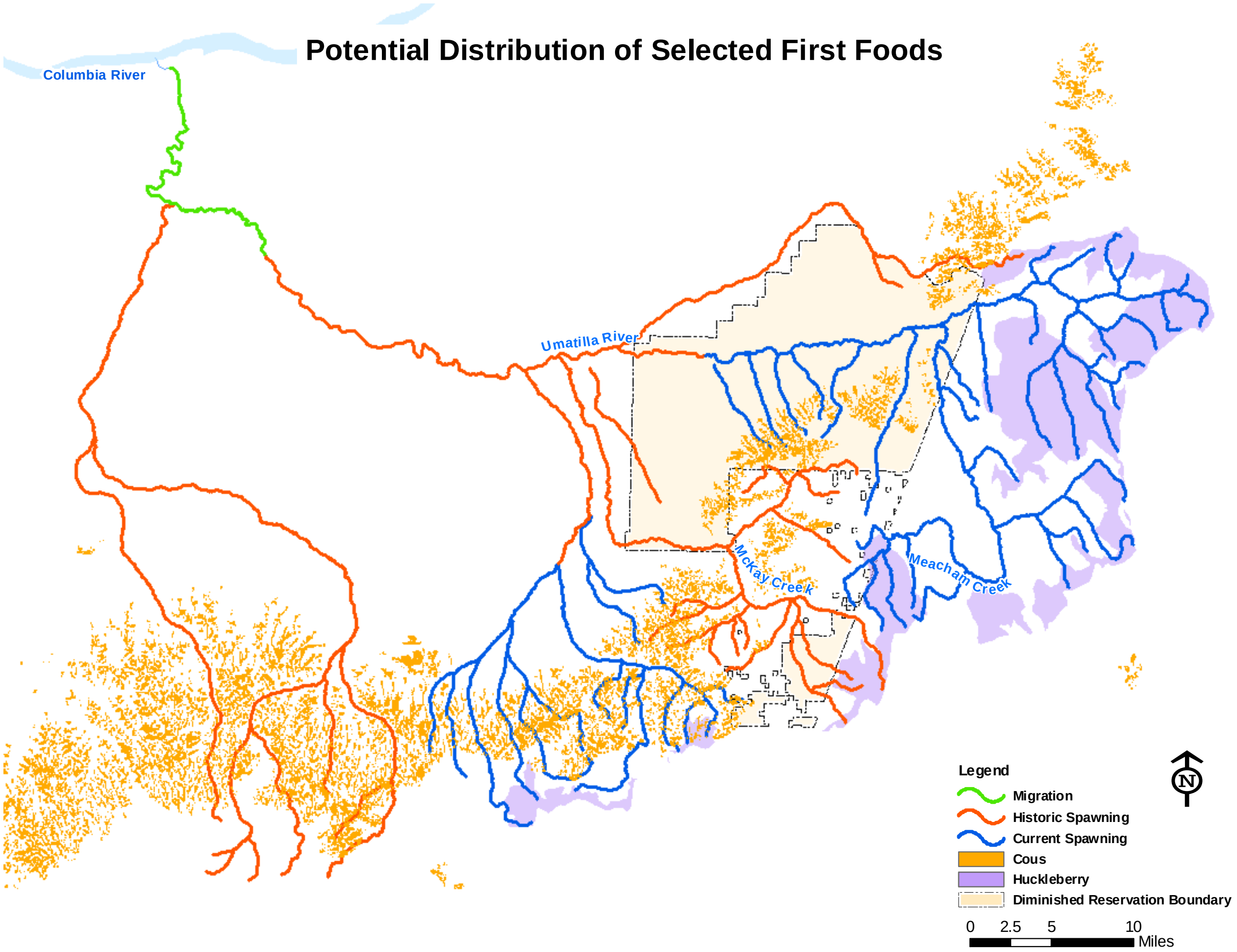


Figure 2. Potential distribution of First Foods across the Umatilla Basin, including historically salmonid-bearing streams and potential cous and huckleberry habitats.

salmon. Next was deer, than cous, then huckleberry. Each "First Food" represents groupings of ecologically related foods (Figure 1). The First Food serving ritual in the longhouse is based on this order and reminds people of the promise the foods made and the people's reciprocal responsibility to respectfully use and take care of the foods. The longevity and constancy of these foods and serving rituals across many generations and their recognition through First Food ceremonies demonstrate the cultural and nutritional value of First Foods to the CTUIR community. Even though the means to pursue, acquire, process, and prepare First Foods have changed dramatically following Euro-American settlement, the First Foods and their serving order have remained constant. First Foods have not been replaced in the serving ritual despite the availability of new, introduced foods. For instance, bass and wheat have not replaced salmon and cous. When new foods are served at tribal meals, they are not recognized in the serving ritual; instead, they are served after First Foods and with no formal order or sequence.

Historically, the availability of habitats for the propagation and harvesting of First Foods was facilitated by a usufruct land ownership system; tribal lands were a commons that tribal people could access and harvest. The tribe gathered First Foods from the river, floodplain, and upland habitats across the Umatilla Basin (Figure 2) and throughout the annual cycle. Water from the Umatilla River and tributaries supported river-derived foods (e.g., water and salmon) and sustained the tribe.

Euro-American settlement in the 1800s, culminating in the CTUIR's Treaty of June 9, 1855 (creating the Umatilla Indian Reservation; henceforth referred to as the Treaty of 1855), introduced an alternative paradigm

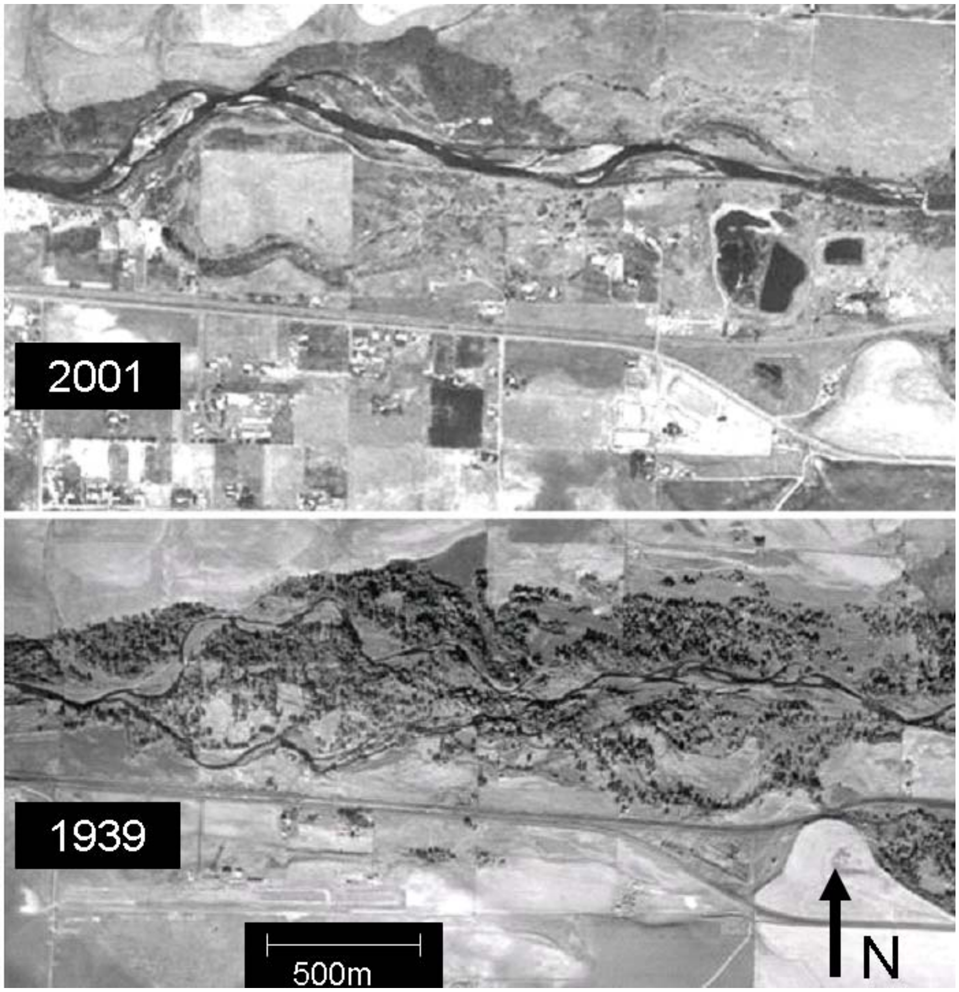


Figure 3. Images of the lower portion of the Mission Floodplain of the Umatilla River taken over the same extent from 1939 and 2001. The channel was dredged multiple times prior to 1965, simplifying the channel structure and reducing channel diversity.

of land ownership and resource use into the Umatilla Basin. In the Treaty of 1855, the United States government acquired 6.4 million acres of tribal lands, which were divided into parcels and distributed as property to mostly Euro-American settlers. Unlike the tribal system of common use of the land, the new proprietary system of land ownership created landowner rights to privately own, control, and exclusively determine use of property. Associated with this private ownership is an emphasis on resource extraction for the exclusive benefit of the owner, rather than the sustainable utilization of natural resources by and for the benefit of community members. Resource use following Euro-American settlement of the Umatilla Basin has primarily been privatized and extractive. For example, the riverscape has been altered by the channelization of the river network to facilitate farming, housing development, gravel mining, and other land uses (Figure 3). Water is extracted from the river and floodplain aquifer for crop irrigation and domestic use. River and floodplain gravels are mined and sold for use elsewhere.

Privatized and extractive use of natural resources has environmental consequences for the Umatilla Basin, including the degradation of ecosystem processes that once supported the natural production and harvesting of First Foods for consumption by tribal members. Additionally, private land ownership and extractive resource use have created challenges to basin-wide management of resources necessary to sustain First Foods. Foremost, the full First Food order cannot be realized within the boundaries of the Umatilla Indian reservation; the reservation is too small and does not provide the diversity of habitats necessary to acquire all First Foods (Figure 2). Recognizing this limitation, the Treaty of 1855 preserved a large aboriginal use area, “usual and accustomed” fishing stations, and rights to hunt and gather roots and berries so that tribal members could harvest and fulfill the First Foods order. The distribution of First Foods throughout the usual and accustomed areas creates relationships (including some conflicts) among the tribal community and private, state, and federal entities, particularly parties with explicit trust responsibilities to protect and sustain treaty-reserved resources. Thus, maintaining First Foods for tribal use requires integrative, holistic management of resources across the basin and cooperation between basin stakeholders.

Restricted access and degradation of the Umatilla River Basin can reduce the availability (and potentially nutritional quality) of First Foods, impacting the health of the tribal community. Restricted access to harvesting areas could eliminate First Foods from the longhouse if habitats supporting a First Food are rare and found only on private lands. Meanwhile, degradation results in reduced water quality, requiring additional purification of river water for drinking to remove pathogens, nutrients, and contaminants. Diminished abundances of fishes are insufficient to sustain the tribal community. Fish under physiological stress and with low prey abundance are apt to have reduced body fat and nutritional quality (McCullough et al. 2001). Contaminant loads in fishes may impede their safe consumption by the tribe (e.g., accumulation of Polybrominated Diphenyl Ether in Columbia River Whitefish; Rayne et al. 2003). This loss of traditional food resources exacerbates tribal health issues (e.g., poor fitness, diabetes). Studies have shown that food resource loss is associated with lifestyle changes (e.g., increasing sedentary lifestyle while decreasing cultural-specific activities and food diversity) and health concerns (e.g., increased diabetes, obesity, heart disease) (Kuhnlein and Receveur 1996). Thus, restoring tribal food resources is apt to benefit the health and culture of Umatilla tribe by providing traditional food choices and promoting activities (e.g., hunting, gathering, and fishing) that draw on tribal knowledge and skills.

First Foods is a cultural strategy for natural resource management that may be a useful counterweight to address limitations and unintended ecological consequences of privatized and extractive resource use. It incorporates spatial and phenological considerations because resources are used throughout the basin and year based on availability. It also integrates natural resources management with tribal resource needs. The initial presentation of water in tribal ceremonies underscores the importance of water both as a resource in its own right and as a critical resource for supporting the production of remaining First Foods. The range of river-derived foods in the salmon category reveals the use of the native aquatic community as First Food resources throughout the annual cycle. Additionally, First Foods may provide the appropriate context in which to report management and restoration progress to the tribal community. Each First Food and its grouping could be considered a potential unit for reporting metrics such as abundance, distribution, restoration efforts, restoration achievements, and policy and regulatory mechanisms. Ultimately, the most direct and culturally appropriate indication of the CTUIR DNR's progress is measured by the CTUIR community's continued ability to access, harvest, process, preserve, and share First Foods at the longhouse and in their homes.

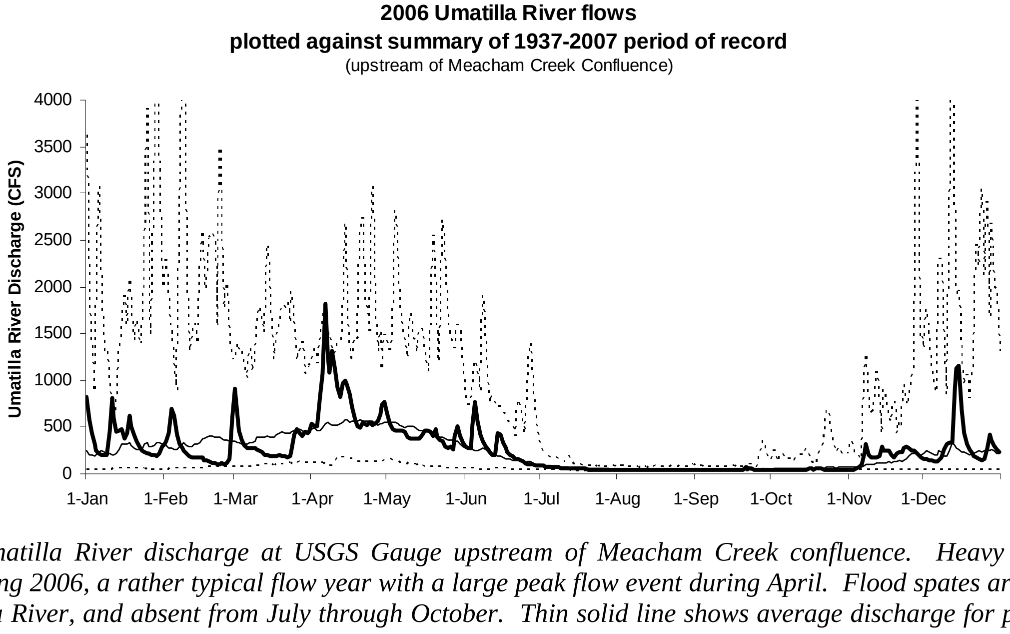


Figure 4. Umatilla River discharge at USGS Gauge upstream of Meacham Creek confluence. Heavy line represents discharge during 2006, a rather typical flow year with a large peak flow event during April. Flood spates are typically brief in the Umatilla River, and absent from July through October. Thin solid line shows average discharge for period of record (1937-2007). Thin dashed lines depict maximum and minimum flows observed for each date over period of record.

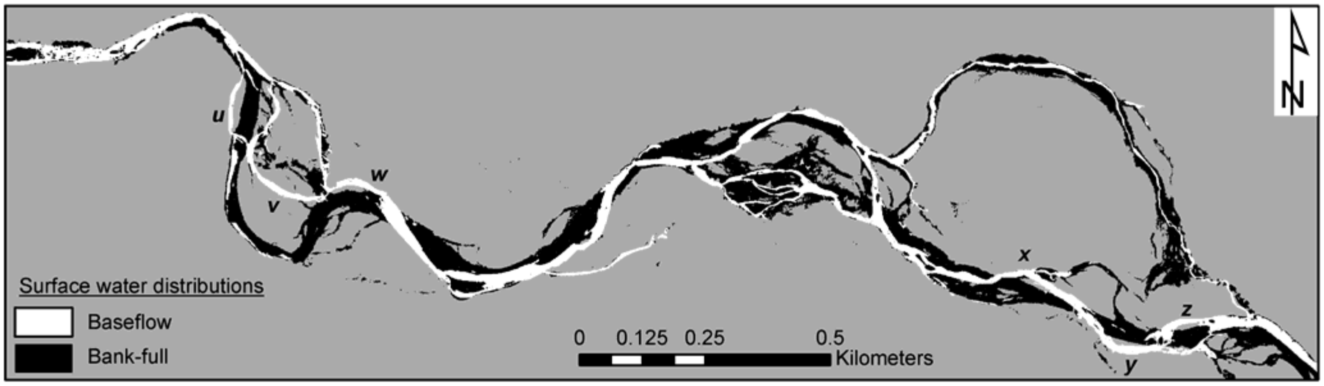


Figure 5. Surface water distributions derived from remote sensing data at bank-full flow (March 2003) and baseflow (July 2004) on the eastern portion of the Mission Floodplain (upstream from Mission, Oregon) on the Umatilla River,. Letters u-z show locations of channel migration that occurred between the two dates of data collection (Figure modified from Jones et al. In Press. Copyright © 2008 by Elsevier. Reprinted with permission from Elsevier).

The Umatilla River

The long-term production of riverine First Foods within the Umatilla Basin and across the usual and accustomed harvesting areas requires an ecologically healthy, or "functional" river. Although a functional river may be defined in many ways, for the purposes at hand, we define a functional Umatilla River as a dynamic river ecosystem that incorporates and expresses ecological processes that support the continued natural production of First Foods and utilization by the CTUIR community. This section provides a general overview of five components associated with a functional Umatilla River (water, geomorphology, habitat and network connectivity, riverine biotic community, and riparian vegetation) and changes in these components following Euro-American settlement that jeopardize the sustained availability of First Foods.

Water

Water is both a First Food, and a resource required to produce all other First Foods. Thus, within the First Foods management framework, the concept of "water quality" takes on a broader meaning. In addition to using conventional physio-chemical measures, evaluation of water quality in the Umatilla Basin must also include appropriate measure of biotic communities (e.g. native species abundance and diversity) (Karr 1993) and hydrologic processes (e.g., flow regime) associated with high ecological health (Poff et al. 1997). To be successful, then, the First Foods paradigm must integrate the methods and means of water resource management into the concept of "water quality." Regardless of water physio-chemistry, water quality is low anywhere water is managed in ways that are incompatible with the ecological integrity (or "health") of the river. Thus, high quality water must be adequate to support the sustainable production of First Foods in terms of its physical properties (e.g., appropriate temperature regime); chemical composition (free of pollutants), biotic constituents (native biotic community), and hydrology (e.g., timing and volume of river flow and spatial distribution of water throughout the Umatilla Basin).

Physiochemical aspects of water quality are well understood and closely managed and monitored under the U.S. Clean Water Act. In the 1990's managers started to address biotic aspects of water quality (Karr 1993). More recently, scientists have underscored the need to address hydrologic aspects of water quality (Stanford et al. 1996; Poff et al. 1997). Hydrologic aspects of water quality within the Umatilla River Basin center on the flow regime (pattern of water discharge) in the river, which follows a distinctive seasonal pattern (Figure 4). Substantial flood pulses occur in late winter and early spring following rain-on-snow and warm "Chinook" winter wind events. Low flows occur in the summer when groundwater inputs and occasional rain events in the Blue Mountains maintain river baseflows. Minimum flows observed in the dry months represent the approximate lower limit of discharge ranges necessary to sustain aquatic and riparian communities. Higher flows are important because they reshape the river channel, provide periodic hydrologic connections between the main channel and floodplain via flooding (Figure 5), and influence distributions of habitats for aquatic and riparian biota. Additionally, the spatial distribution of surface water across the floodplain drives the active and continuous exchange of water between the river channel and river gravels, as well as subsurface movement of river water through river gravels (Figure 6; see also: Jones et al. 2008; Poole et al. In Press).

Alterations to water: Both the quantity and physiochemical characteristics of water in the Umatilla River have been changed by land use activities. The historical timing and volume of surface water have been altered by water withdrawals for irrigation and domestic use (Figure 7). Changes to surface water flows affect a variety of river functions, including connections between habitats for aquatic biota and patterns of floodplain water movement (Poff et al. 1997; Malard et al. 2006). Water quality has been degraded by inputs of sediment, fertilizers, pesticides, and other contaminants. These inputs have possible consequences, such as altering the food web by increased growth of noxious weeds and algae and leading to the accumulation of contaminants in water, sediment, and aquatic organisms.

Geomorphology

The river channel is naturally “anabranched” (having multiple channels separated by stable islands), like many of the remaining free-flowing alluvial rivers in the western U.S. At baseflow, the main channel frequently divides into multiple channels and then re-converges (1939 image in Figure 3). Common geomorphic features within the bank-full scour zone include mid-channel and lateral bars and small spring channels. During peak discharge, flow in these multiple channels merge into a single main channel, while flood channels (which are inactive during baseflow) are activated, creating a different pattern of channel braiding (Figure 5). Channel structure is dynamic; in a natural state, the channels migrate laterally across the floodplain (Figure 5; see also

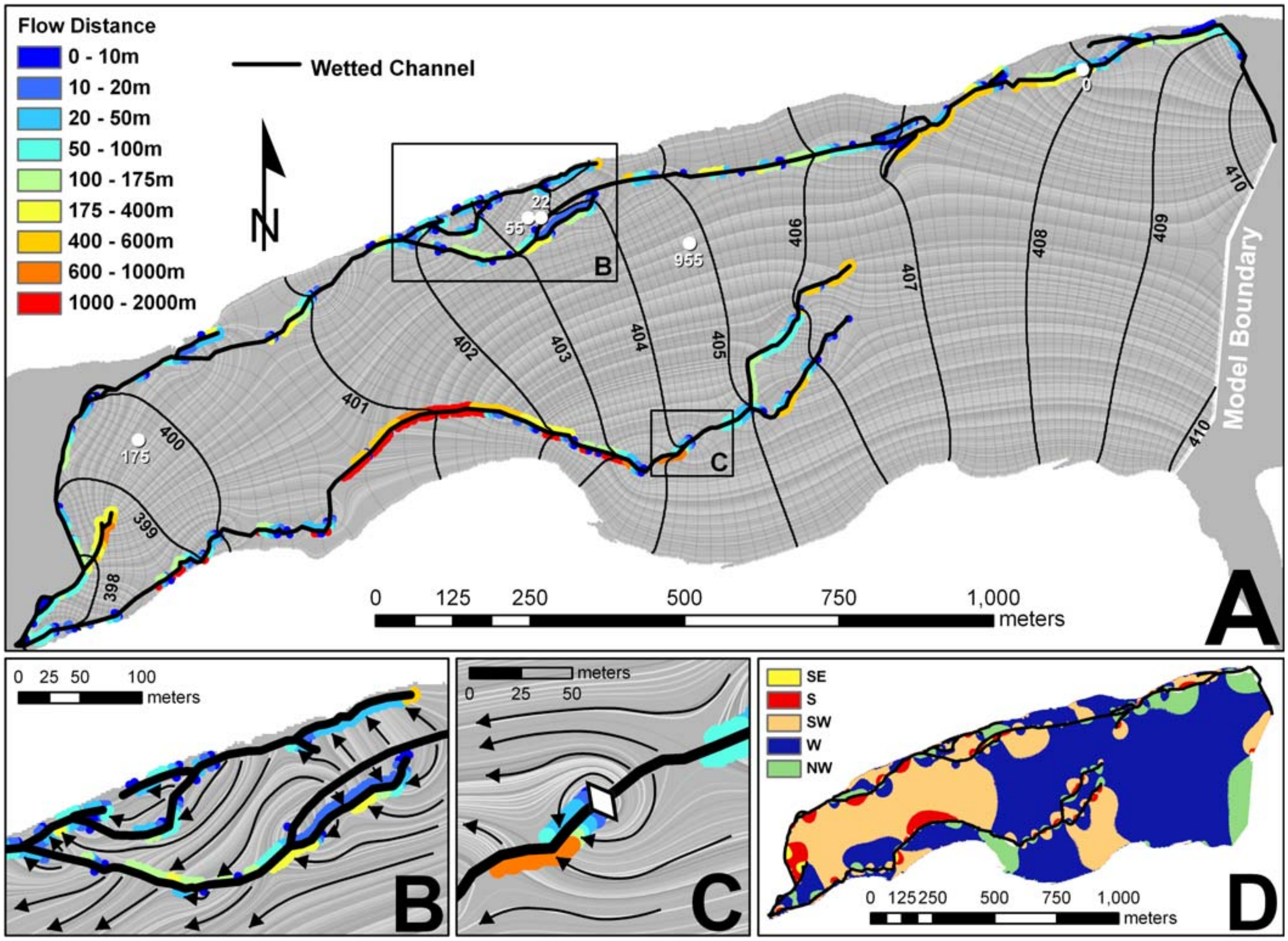


Figure 6. Model results from two-dimensional MODFLOW simulation of groundwater movement in the hyporheic zone of the Minthorn Springs section of Umatilla River Floodplain. (A) Map of simulated hyporheic flow paths. Heavy black lines show the center of active channels during baseflow 2004. Colors along the channels denote hyporheic flow path length at each point of hyporheic discharge to the channel. Lack of color along the channel denotes points of hyporheic recharge (i.e., hyporheic flow path length = 0). White dots show locations of hyporheic temperature loggers; white labels show length (m) of simulated flow path to each temperature sampling point. Black contours represent simulated water table elevations (m). Streamlines (background striations) indicate shape of groundwater flow paths. Inset boxes show locations of B and C. (B) Patterns of groundwater movement driven by differences in surface water elevation among the main and secondary channels. Colors and streamlines are as described in A. Arrows show direction of groundwater movement along flow paths. (C) Groundwater flow patterns and enhanced hyporheic exchange associated with a sharp "step" in the surface water elevation longitudinal profile; white diamond represents location of a beaver dam. Colors, streamlines, and arrows are as described in B. (D) Map of simulated groundwater flow direction across the alluvial aquifer, categorized into the 5 predominant cardinal and intercardinal directions of water movement on the floodplain (Figure and legend from Poole et al. In Press. Copyright © 2008 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.).

Latterell et al. 2006; Whited et al. 2007). The streambed consists of boulders, cobbles, gravels, pebbles, and sand, with finer particles being more prevalent in low gradient reaches. Following winter freshets, sediments are transported both longitudinally from the headwaters to the lower river system and laterally between the main channel and floodplain.

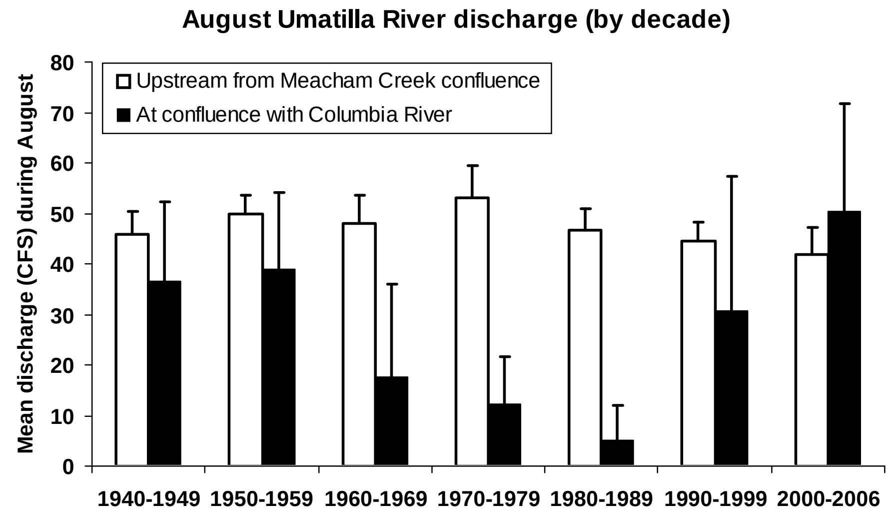


Figure 7. Inter-decadal variation in Umatilla River flows (±S.D.) Water draining from the Blue Mountains has provided the Umatilla River with consistent base flows over time (white bars). However, especially during the 1960s – 1980s, irrigation withdrawals captured most of this water, at times even drying up the Umatilla River before it reached its terminus at the Columbia River (black bars). In the early 1990s, anadromous salmon mitigation ensured that base flows were maintained in the lower section of the river. Despite the return of base flows to the river, the hydrology and channel condition over the majority of the river is still highly managed and altered. Agricultural withdrawals are still substantial. To mitigate for these withdrawals, river base flows have been augmented with water from McKay Reservoir and pump exchanges with the Columbia River

Alterations to geomorphology: Construction of flow control structures (e.g., levees and dikes) and dredging have simplified the complex geomorphology of the Umatilla River, which results naturally from both hydrologic processes and sediment transport. For instance, the lower half of the Mission Valley Floodplain was dredged repeatedly from the mid 1940's to the mid 1960's. Photos from 1939 and 2001 (Figure 3) illustrate the associated substantial loss in channel diversity. Such geomorphic alterations affect hydrologic patterns (e.g., flows are largely contained with the simplified channels), geomorphic processes, and water linkages between surface water habitats for aquatic biota (Malard et al. 2006; Poole et al. 2006; Poole et al. In Press).

Connectivity among habitats and across the river network

A functional Umatilla River is supported by flows of surface water and groundwater that physically transfer nutrients, sediment, energy, and organisms among stream habitats and across the Umatilla River network (Kondolf et al. 2006). This "hydrologic connectivity" (Ward and Stanford 1995; Pringle 2003) occurs longitudinally as tributaries flow into the larger Umatilla river system, laterally as river water during high flow events spreads out onto the adjacent floodplain (exchanging water between the main channel and secondary channels; Malard et al. 2006), and vertically as water moves bi-directionally between the river and underlying river gravels (Figure 6). Latteral connectivity is critical for maintaining biological diversity of floodplains and rivers (Amoros and Bornette 2002). Longitudinal connectivity flushes fine sediments downstream to depositional areas, maintaining clean, coarse benthic gravels for macroinvertebrate habitat and spawning habitats for First Foods fishes. Vertical connectivity moves nutrients between the main channel and hyporheic zone, where microbes can remove nutrients, improving water quality. Lastly, connectivity creates routes for aquatic organisms to move between instream habitats and migrate throughout the river network.

Alterations to connectivity: While longitudinal, lateral, and vertical connections are integral to the functioning of rivers such as the Umatilla River (Ward 1998), they are diminished by the construction of flow control structures (e.g., levees and dikes), channel incision, dredging, and increasing fine sediment inputs that reduce the vertical exchange of water (Kondolf et al. 2006).

Riverine biotic community: native community structure and health

The river's food web is supported in part by the primary production of periphyton, phytoplankton, and macrophytes and the breakdown of both terrestrial and aquatic derived organic matter by microbes, fungi, and bacteria (Vannote et al. 1980). Higher trophic levels, which rely upon this primary productivity, include macroinvertebrates, mussels, and fishes. Historically and recently, the Umatilla River has supported several salmon species (e.g chinook, coho, and steelhead), lamprey, trout, whitefish, suckers, and amphibians. Native fauna are adapted to specific instream conditions (e.g., temperature, flow, and streambed sediment) and supported by intact food web linkages (Ward and Tockner 2001; Woodward and Hildrew 2002).

Alterations to the native riverine community: Many native fishes have been extirpated (e.g., coho and chinook salmon, Nehlsen et al. 1991; Weitkamp et al. 1995; Myers et al. 1998), whereas others have declined dramatically because of reductions in surface water flow, available habitats, and network connectivity (e.g., steelhead, Nehlsen et al. 1991; Busby et al. 1996). Amphibians such as the Columbia spotted frog and Northern leopard frog are at-risk due to the loss of floodplain wetland habitats. Beaver populations have declined in the basin due to unregulated trapping. Meanwhile, non-native species have been introduced into the system, potentially adversely affecting the native community via predation and competition.

Riparian vegetation: native community structure and health

Willow, cottonwoods, conifer, and alder are common riparian trees along the Umatilla River. Growth and success of riparian vegetation are linked to river hydrology patterns. Life histories of riparian vegetation tend to depend on high flow events that inundate the floodplain for germination and seed dispersal. In addition, riparian vegetation uses river baseflows and groundwater for water sources in the dry, hot summer months. Beaver also influence riparian vegetation conditions in numerous ways, such as creating floodplain wetlands that expand habitats for different types of riparian vegetation (Figure 8). Riparian vegetation influences instream conditions by increasing bank stability, shading, inputs of large woody debris, and seasonal inputs of allocthonous material that fuel the river's food web (Gregory et al. 1991). Large wood is an important structural component in rivers, increasing habitat complexity and inducing pool formation (Gurnell et al. 2002). Floodplain wetlands provide habitat for salmonids (Pollock et al. 2004; Pollock et al. In Press). In particular, on the Umatilla River Floodplain, cottonwood is a keystone species that provides bank stability, cavities for nesting birds, and large wood inputs for aquatic habitat.

Figure 8. (a) Ponded water behind beaver dams in river side channels creates unique floodplain habitats that are substantively different from (b) free-flowing habitats of the main channel.

Alterations to native riparian vegetation: Following Euro-American settlement, native riparian vegetation has been dramatically reduced while some introduced riparian species (Table 1) have become established. Such changes in riparian abundance and composition affect the Umatilla River by altering large wood inputs, bank stability, leaf litter inputs that contribute organic matter to the river's food web, and habitats for riverine and riparian organisms.

The River Vision

Because the production of First Foods is tied to the hydrology, geomorphology, habitat and network connectivity, riverine biotic community, and riparian vegetation of the Umatilla River, a River Vision must address each of these topics. Here, we highlight attributes of these functional components and associated critical data needs relevant to the management of the Umatilla River for First Foods.

Water and Water Quality

A functional Umatilla River requires preserving or restoring the seasonal timing and volumes of river flows (Poff et al. 1997; Ward et al. 2001) necessary to support the production and harvest of First Foods. Baseflow conditions (low flows during the late summer and early autumn) in the Umatilla River determine the availability of aquatic habitats within the river as well as summertime hydrologic connectivity within the river network. Thus, summertime migrations of salmon, lamprey, and other species are influenced by the magnitude of baseflow. Baseflow in any given year also influences water quality (since concentrations or pollutants are influenced by flow volume) and even the temperature regime of the river. Importantly, prior to Euro-American settlement, baseflows were subject to natural climate cycles; baseflows in wet years were higher than baseflows in drought years. Thus, to support summertime connectivity with the rest of the Columbia River Basin and maintain summertime aquatic habitats, a functional Umatilla River would experience interannual variation in high and low baseflow conditions similar in magnitude and frequency to the interannual occurrence of high and low baseflows prior to Euro-American settlement.

In addition to baseflows, management planning for desired flow regimes in the Umatilla River requires consideration of the magnitude and frequency of peak flow events. Peak flow events maintain the dynamic nature of the floodplain morphology and channel pattern (Latterell et al. 2006; Whited et al. 2007), which facilitates the flux of river water through floodplain gravels and maintains a variety of aquatic habitats in the channel and across the floodplain. For examples, floods that are sufficient to mobilize the streambed are critical to the ecological function of the Umatilla River. Such high-flow events provide temporary surface water connections between main-channel and off-channel aquatic habitats, build and rearrange important channel and gravel-bar features across the floodplain thereby maintaining habitat diversity, enhance water movement through the floodplain aquifer by cleaning and sorting river sediments thereby facilitating hyporheic water flux, and recharge the alluvial aquifer with water (Stanford et al. 2005). A functional river, then, is dependent on the sufficient magnitude and frequency of flood events to maintain dynamic channel patterns and adequate water exchange rates between the channel and floodplain sediments.

Table 1. Some invasive plant species found on the Umatilla River Floodplain.

Common Name	**Scientific Name**
Diffuse knapweed	*Centaurea diffusa*
Spotted knapweed	*Centaurea maculosa*
Russian knapweed	*Acroptilon repens*
Vipers bugloss	*Echium vulgare*
Reed canarygrass	*Phalaris arundinacea*
Purple loosestrife	*Lythrum salicaria*
Canada thistle	*Cirsium arvense*
Indigo bush	*Dalea fremontii*
Dalmatian toadflax	*Linaria dalmatica*
Perennial pepperweed	*Lepidium latifolium*
Yellow iris	*Iris pseudacorusis*
Russian olive	*Elaeagnus angustifolia*
Black locust	*Robinia pseudoacacia*

Finally, the transitional periods between peak and baseflows are also ecologically important. The "falling lim" (reduction in river flow after a period of high water) of the annual hydrograph during the early summer can be ecologically important for spawning of fishes, establishment of cottonwoods, and maintenance of vernal pools on the floodplain for floodplain amphibians. Additionally, when rivers drop too rapidly from a peak flow to base flows, fish can be trapped in transient off-channel habitats on the floodplain that may dry up as the flood recedes. The hydrograph of a functional river, then, would include transitions between high flow events and low flow events that are compatible with maintenance of the native aquatic community of the river.

In addition to the volume of water in the channel, a functional river is defined by the physical, chemical, and biological aspects of water quality. The river should be free from pollutants (e.g., toxicants or excess nutrients) that impair drinking water supplies, alter stream water pH, and stress or kill native aquatic fauna. Maintenance of appropriate water temperature regimes (Poole et al. 2004), including cool temperatures during the summer, is especially important because water temperature influences dissolved oxygen concentrations, stress levels of aquatic organisms, growth of pathogens, and the competitive abilities of non-native fishes vs. native fishes. In short, a functional Umatilla River would have nutrient and contaminants levels that do not impede First Foods production and the utilization and safe consumption of First Foods by the tribal community.

Geomorphology

River morphology: A functional Umatilla River channel must be dynamic over time as peak flow events periodically reworked the channel pattern (Petts 2000). Such morphogenic processes create a variety of diverse channel features (e.g., riffles, pools, side channels, spring channels, and backwaters). Associated channel complexity also increases habitat heterogeneity (Stanford et al. 2005). Aquatic organisms often require different habitats for spawning, rearing, and adulthood. These habitats may be located in the main channel, tributaries, and off-channel habitats and utilized at various times throughout the day and/or various times of the year (Amoros and Bornette 2002). Such channel complexity also promotes hyporheic exchange (the bidirectional exchange of river water) between the channel and floodplain gravels (Figure 6; see also Poole et al. 2006). Within the hyporheic zone (the subsurface portion of floodplain gravels saturated by water from the river channel), bacteria, fungi, and other microbes process nutrients, such as nitrogen. Plants rooted in floodplain gravels also take up nutrients. Thus, where channel patterns are complex and hyporheic fluxes are high, plants and microbes have the opportunity to improve water quality (Brunke and Gonser 1997) as river water continually spirals between the channel and hyporheic zone on its downstream journey (Poole et al. In Press). A functional river, sustaining such physical and biological processes and river-dependent First Foods, would have a channel network maintained and reshaped over time by the river's hydrology.

Sediment: Alterations to the river's sediment regime also influence the availability of riverine First Foods (Megahan et al. 1992; Waters 1995). Historically, winter freshets drove pulses of coarse sediment from upland and headwater sources into the main Umatilla River and flushed fine sediments out of the system. Now, the sediment regime includes summertime pulses of fine sediments, resulting from small, intense storms that carry fine sediment into the main Umatilla channel from eroded banks on the lower tributaries and agriculture sources (e.g., along Wildhorse creek). These increasing fine sediment loads affect the aquatic community by smothering benthic habitats, thereby decreasing oxygen concentration within spawning gravels and affecting the macroinvertebrate community, and increasing turbidity, thereby reducing the foraging efficiency of

Box 1: Critical data needs for managing water and water quality.

- Sources of discharge data and associated sites and period of record
- Discharge rate that constitutes a channel-forming event
- Channel-forming events, their frequency, and required discharges
- Floodplain inundating events, their frequency, and required discharges
- Historical variability of low and high flows
- Expected flow conditions given future climate change
- Locations and rates of surface- and groundwater withdrawal
- Locations and duration of river dewatering
- Background nutrient concentrations and annual regimes
- Sources of water quality impairment
- Current toxicant levels in surface water and fishes
- Water quality relative to federal and state water quality standards
- Changes in water quality standards necessary to protect First Foods

fishes (Wood and Armitage 1997). By plugging the spaces between coarse gravels, fine sediments can also decrease the permeability of the streambed and reduce rates of hyporheic exchange (Brunke and Gonser 1997). The timing of these summertime sediment pulses may also affect the spawning, rearing, and migration success of aquatic species. Thus, the timing, volume, and particle sizes of sediment entering the Umatilla River must be managed to maintain aquatic communities that support and provide First Foods.

Box 2: Critical data needs for managing geomorphic processes.

- Location of incised channels within the network
- Locations of levees, dikes, and other flow control structures and dredging along the river network
- Locations of sediment sources (e.g., incised channels, logging, and agricultural lands) and associated timing and depositional areas within the basin
- Historical vs. current locations of spawning gravels
- Controls limiting the availability of spawning gravels
- Distributions of benthic habitats for mussels, lampreys, and fishes
- Riparian analysis to project expected large woody debris supplies across river network.

Connectivity among habitats and across the river network

Habitat linkages: Longitudinal, lateral, and vertical water flow in the Umatilla River network provides habitat connections that are necessary for supporting the riverine food web (Ward et al. 1999; Jansson et al. 2007) and First Foods. These hydrologic linkages may be limited in duration (e.g., when flood stage links floodplain habitats with the main river channel) or available throughout the year (e.g., surface water connections between tributaries and main river channel) (Ward and Stanford 1995). Regardless of duration, these physical connections provide aquatic organisms with "routes" between habitats and are necessary for organisms to complete their life cycles, thus supporting the riverine food web (Amoros and Bornette 2002) and sustaining First Foods. In particular, connectivity facilitates fish movement between habitats and river sections for spawning, feeding, and rearing activities. Facilitating passage for fish movement and migrations involves maintaining the river's hydrologic regime and eliminating potential barriers (such as culverts, diversion dams, and river sections that are dewatered or have temperature conditions lethal to salmon) across the main river channel, tributaries, and floodplain. Additionally, salmonids often use areas where hyporheic water enters the main channel (i.e., locations of high vertical connectivity) for spawning sites (Baxter and Hauer 2000; Geist et al. 2002). Thus, a functional Umatilla River would have connections among floodplain habitats and across the river network that are sufficient to support First Foods fishes throughout the annual cycle and particularly during critical movement and migration periods.

Lateral inundation: Managing the Umatilla River and floodplain to allow lateral inundation contributes to maintaining habitats for native riverine communities (Amoros and Bornette 2002; Malard et al. 2006). Constraining high flows concentrates stream power (and energy to move sediments) within the main channel, resulting in an incised channel with faster flows. Such altered hydrologic and geomorphic conditions reduce the range of habitats with depth and flow conditions suitable to native riverine species and promote channel incision, further diminishing habitat connectivity (Kondolf et al. 2006). Reductions in lateral inundation frequency also prevent suspended fine sediments from being deposited on the floodplain as high flow events recede. These sediments, then, remain within the main channel and are apt to smother benthic and spawning habitats. Thus, a functional Umatilla River would experience lateral inundation events following historical patterns and levels that can shape habitats for riverine organisms and allow for sediment deposition on the floodplain.

Likewise, the native riparian vegetation community is adapted to patterns of floodplain inundation (Rood et al. 2005). Inundation events scour floodplain soils, influence the germination of seedlings, and carry large wood into the river channel. Prevention of such events, then, may favor introduced or even non-riparian species over native riparian species. Thus, since rivers depend upon native riparian vegetation for many ecological functions, lateral inundation events (with seasonal patterns and levels comparable to the historical hydrograph) must be managed in the Umatilla River to contribute to the health and success of native riparian vegetation.

Box 3: Critical data needs for managing connectivity.

- Historical diversity of habitats and channel feature patterns on the floodplain
- Spatial and temporal patterns of tributary connections with the main channel
- Flow event levels influencing various riparian plant communities
- Location and timing of migration barriers, both physical and habitat-based (e.g., thermal barriers), for migratory biota.

Riverine biotic community

The second category of First Foods is salmon. The term "salmon" is used inclusively, and covers salmon species themselves, as well as mussels, lampreys, whitefish, suckers, and trout (Figure 1). These food resources for the tribal community generally require water free of pollutants, a range of water temperature conditions, and clean, coarse benthic gravels for habitat and spawning. These recognized-First Foods also have important ecological functions. For instance, mussels filter surface water, removing some toxicants from the water column, and thus are often considered bio-indicators of water chemistry conditions. Additionally, salmon carcasses are seasonal nutrient inputs to the Umatilla River, fueling the river's food web and increasing productivity (Gende et al. 2002). Enhanced productivity promotes the growth of the macroinvertebrate community and, in turn, the survival of juvenile salmon. Ecological contributions of First Foods such as mussels and fish feedback into promoting water quality and the success and growth of subsequent riverine First Foods.

Yet, mussels and fish are only a part of the Umatilla River's community. The Umatilla River also has a diverse macroinvertebrate community that is an integral component of the river's food web and a food resource for First Foods fishes. Like mussels and salmon, many types of macroinvertebrates (especially those upon which salmonids feed) have low tolerances for water quality impairment and specific benthic habitat requirements (e.g., coarse gravel vs. sand and low vs. high flow conditions) (Wood and Armitage 1997). Thus, management of the Umatilla River should protect water quality and habitat conditions so that native macroinvertebrates thrive in the Umatilla River.

Beaver are semi-aquatic organisms whose dam building activities contribute to a functional Umatilla River and the success of First Foods. In tributaries and secondary channels on floodplains, beavers build dams with riparian vegetation (Figure 8). These dams create pool habitats (increasing habitat complexity), boost sediment retention, promote retention and processing of organic matter and nutrients, and inundate areas making floodplain wetlands. Beavers likewise modify main channels, though beaver dams are rare in larger rivers because they generally cannot withstand flood flows (Pollock et al. 2004). Pools and wetlands created by beaver dams provide rearing habitat for juvenile salmonids such as coho salmon and steelhead (Pollock et al. In Press). Additionally, beaver dams affect hydrology patterns by raising stage and decreasing discharge, which in turn promote groundwater recharge, creation of localized groundwater upwelling (Figure 6C), and cool-water refugia (Pollock et al. 2007). Thus, because of the benefits of beaver activity (e.g., habitat creation, vertical connectivity, and water quality), beaver populations should be restored and managed in the Umatilla Basin.

Box 4: Critical data needs describing aquatic communities.

- Viable population sizes (e.g. VSP as defined for ESA) for First Foods fishes within the network
- Abundance and status of riverine First Foods
- Ecological roles of mussels, lamprey, whitefish, trout, and suckers
- Historic nutrient inputs from salmon carcasses
- Habitat utilization by fishes recognized as First Foods
- Distributions and densities of non-native species
- Distributions and habitat requirements of macroinvertebrates within the network
- Distributions habitat requirements of amphibians within the network
- Historical vs. current numbers and distributions of beaver and associated dam densities on the floodplain.

Riparian vegetation

A functional Umatilla River encompasses a diverse community of self-sustaining wild populations of native riparian vegetation. Vegetation increases bank stability, becomes large wood inputs, and provides shade (Gregory et al. 1991). These functions contribute to promoting First Foods, such as surface water and fishes. Increased bank stability reduces bank erosion, decreasing fine sediment inputs that can smother benthic and spawning habitats. Large wood in the channel, creating pool habitats for fishes, macroinvertebrates, and other aquatic biota (Gurnell et al. 2002). Additionally, large wood inputs can create debris dams (via pools formed by lodged wood or beaver dam construction) that retain sediment and nutrients and organic matter, allowing for processing by microbes and bacteria. Shade by riparian vegetation reduces solar radiation, potentially creating localized pockets of thermal refugia for aquatic organisms (Poole and Berman 2001). Lastly, leaf litter from riparian vegetation provides seasonal inputs of organic matter that fuel the Umatilla's food web (Vannote et al. 1980). Thus, increasing the abundance of native riparian vegetation and their success (via managing for lateral inundation events and beaver populations) are important management considerations for restoring and sustaining a functional Umatilla River.

Implications of the First Foods management framework

The end goal of the First Foods-focused management strategy is the sustainable stewardship of natural systems in CTUIR tribal lands, using the long-term production and harvesting of the full First Foods order by the tribe as a primary benchmark for success. Achieving this goal requires high water quality within the Umatilla River, including ecologically healthy hydrology, geomorphology, habitat and network connectivity, riverine biotic community, and riparian vegetation (Figure 9). Like the First Foods table settings, a functional Umatilla River would be dynamic throughout the annual cycle, yet consistent and reliable across decades. During winter, snowmelt water fills the main channel, causing the river to fill dry channels, inundate the floodplain, scour fine sediments from the streambed, and cut new channels with its high-energy flows. During summer, flows recede and the river abandons some old channels for new channels. These seasonal patterns vary between wet and dry years. The native riverine and riparian communities are adapted to and depend upon these dynamic physical conditions for their growth and survival. Thus, maintaining a functional Umatilla River for First Foods requires managing for the range of dynamic river conditions (and not simply static levels) throughout the year.

Box 5: Critical data needs for riparian vegetation management.

- Assess natural potential and range distributions of species (e.g., cottonwoods and other hardwoods)
- Quantify abundances and distributions of native riparian species
- Quantify abundances and distributions of introduced species
- Determine vegetation community typology and trends over time.
- Determine natural frequencies of cottonwoods and willows
- Quantify recruitment and retention rates for large wood

The inherent dynamic nature of the Umatilla River has the following five management implications:

1) *Commoditization of river resources is a substantial roadblock to the sustainability and longevity of First Foods and their utilization by tribal members.*

Treating river resources as commodities for extractive, private use emphasizes the use and trading of individual resource, rather than the importance of a functional river system supporting both human needs and ecosystem processes. A usufruct view of resource use is more compatible with management and restoration efforts in the Umatilla Basin. The current economic system, based on the concept of private property, is firmly entrenched within the Umatilla Basin. Although it may be neither feasible nor even desirable to attempt to supplant the existing economic system, efforts to maintain and restore tribal access to customary sites for harvesting First Foods is essential, and opportunities to encouraging usufruct land stewardship within the context of the current private property-based economy must be investigated in order to facilitate river restoration.

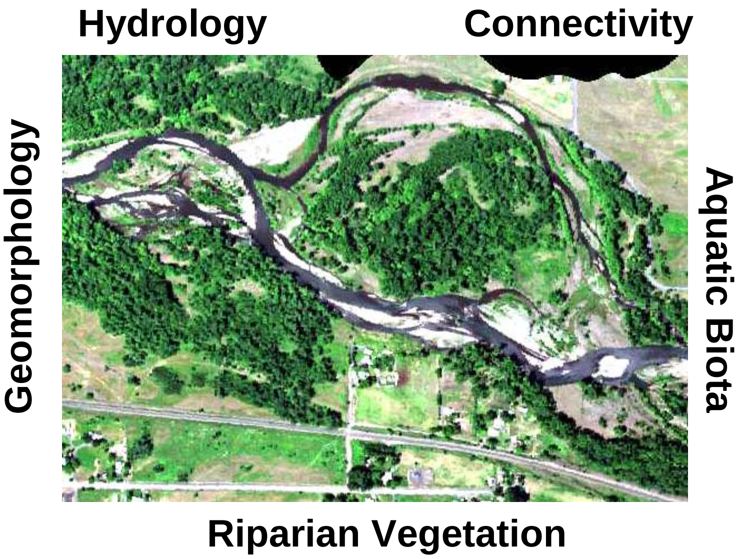


Figure 9: Key water quality management considerations to support First Foods production.

2) *Key river characteristics are variable throughout the river network. Therefore, while some management goals can be set for the basin, different river reaches require different management and restoration targets depending on the context and structure of the reach.*

For instance, high vs. low gradient reaches within the Umatilla network have different flow conditions and hence different streambed sediment compositions. In addition, reaches confined vs. unconfined by valley walls and bedrock have different hydrologic and channel patterns (Beechie et al. 2006). Unconfined reaches tend to have more distributed flows (and wider and shallower channels) while confined reaches have concentrated flows (and narrower and deeper channels). The range of reaches within the Umatilla River network contributes to the river's functioning and provides a diversity of habitats for First Foods fishes and riparian vegetation. Thus, management and restoration strategies to support the production of First Foods should be tailored to deal effectively with the range of reaches within the Umatilla Basin.

3) *Groundwater and surface water are a single resource and should be managed as such.*

High flow events in the Umatilla River recharge alluvial aquifers. Likewise, aquifers contribute flow to the Umatilla River, especially during the summertime. Thus, levels of groundwater and surface water are intricately linked as reductions in surface water levels may diminish groundwater levels (and vice versa). Where water table elevations are reduced below the elevation of the river surface, hyporheic exchange between the Umatilla River and floodplain and associated removal of nutrients from river water (and improvements to water quality) are lessened because hyporheic return flows to the river channel are reduced. In addition, alterations to the hydrology of the Umatilla River affect riverine and riparian communities; reductions in network and habitat connectivity essentially make habitats inaccessible for fishes while reductions in floodplain inundating events and water levels affect the success of native riparian vegetation. Thus, management of extractive water consumption of both surface water and groundwater must consider the hydrologic regime of the river (low flows, channel forming flows, and flow recession), habitat and network connectivity, inundation patterns, and riparian vegetation.

4) *While native riparian vegetation species are not recognized as First Foods, they are critical attributes of a functional Umatilla River capable of supporting First Foods.*

Native riparian vegetation has several important roles, such as providing shade, bank stability, large wood inputs into the river (which influence channel patterns), leaf litter inputs that are basal resources for the river's food web, and habitats for riparian and aquatic organisms. Thus, preservation and management of native riparian vegetation communities is critical to maintaining and restoring channel patterns, fish habitat, and therefore, a functional Umatilla River.

5) *Management of Umatilla River water quality to support First Foods requires restoration and maintenance of river processes, rather than simply emplacement of in-stream structures. As such, management and restoration strategies must identify mechanisms of influence and address ecological processes at relevant spatial and temporal scales and focus on renaturalization of riverine processes.*

A growing expertise in science-based river restoration approaches has been developing over the last decade. The cornerstone of such approaches is reconnecting rivers with their floodplain by re-establishing normative flow regimes, removing (or setting back, away from the river) flow constraining structures, and re-establishing the geomorphic and hydrological balance that created natural riverine habitats under which native aquatic communities evolved (Stanford et al. 1996; Poff et al. 1997; Beechie and Bolton 1999; Ward et al. 2001; Wohl et al. 2005; Jansson et al. 2007; Nilsson et al. 2007). Consider that management strategies are needed to address bank erosion on some Umatilla tributaries (e.g., Wildhorse Creek) since this erosion results in fine sediments entering the Umatilla River during the summer and possibly filling in salmon spawning and benthic habitats. One strategy may be to add structure such as “rip rap” (e.g., large rocks) to eroded banks to deflect flows and reduce further erosion. While this method may reduce erosion, it does not address the hydrologic mechanisms that lead to bank erosion. Worse still, rip rap creates other management problems by armoring riverbanks, diminishing channel-forming processes and increasing channel incision. An alternative approach would be to identify the possible factors causing high-energy flows (e.g., flow control structures concentrating flows upstream) and erosion potential (e.g., loss of riparian and bank vegetation, cattle access to river) and then determine actions to mitigate identified factors.

In the mainstem Umatialla River habitat restoration efforts should focus on: 1) restoration and maintenance of normative flow regimes (baseflow, peak flow, and flow recession patterns); 2) hydrologic connectivity of the floodplain with the channel, including reversal of past channelization and (where feasible) removal of artificial structures (e.g., dikes and levees) that constrain channel migration; 3) protection of floodplain plant communities; and 4) re-establishment of keystone species, such as beaver, on the floodplain. Such approaches would jumpstart the hydrologic and geomorphic processes (e.g., channel avulsion, large wood delivery, hyporheic water exchange, cottonwood regeneration) that create a healthy, dynamic mosaic of habitats to which native aquatic communities are adapted. The process of identifying and restoring normative river ecosystem processes (at appropriate spatial and temporal scales) is the surest means of achieving sustainable natural production of First Foods (Independent Scientific Group 1996).

Conclusions

The CTUIR DNR’s First Foods-focused mission aims to maintain a functional Umatilla Basin by embracing an expansive view of “water quality” that includes a functional river and associated processes for the sustained longevity of First Foods. This mission calls attention to the maintenance of water quality by focusing on the ecological health of the Umatilla River, which provides riverine First Foods (water and salmon). A target vision for a healthy Umatilla River reflects a river that is highly dynamic and shaped by not only physical and biological processes but also interactions and interconnections among those processes. Such a vision requires that managers incorporate several attributes of the Umatilla River into management and restoration strategies. Strategies should emphasize the importance of: 1) hydrology (including the timing, volume, and quality of water flows); 2) geomorphic processes; 3) longitudinal, lateral, and vertical connectivity among habitats and across the network; 4) the health of the riparian vegetative community; and 5) the health of the native aquatic species.

The First Foods-focused mission highlights direct linkages between the ecological health of the Umatilla River and the health and well-being of Umatilla tribal members. Degradation of the river, water quality, and associated ecological processes results in the loss of traditional tribal foods. This loss of food resources is linked to increasing occurrences of health issues (e.g., poor fitness, diabetes). In additional to providing a clean and healthy natural environment for tribal members and other residents of the Umatilla Basin, improving the availability of First Foods can contribute to sustaining tribal ceremonies, knowledge, and traditions that promote the physical health of tribal members. Finally, the First-focused mission provides resource managers in the basin with a framework for involving tribal members in management dialogues. Within such a framework, monitoring and restoration efforts can concentrate on improving the ecological functionality of the Umatilla River, which ultimately sustains First Foods.

Suggested additional reading (with abstracts)

Amoros, C. and G. Bornette (2002). "Connectivity and biocomplexity in waterbodies of riverine floodplains." Freshwater Biology **47**(4): 761-776.

1. In river corridors, water plays a key role in connecting various landscape patches. This 'hydrological connectivity' operates on the four dimensions of fluvial hydrosystems: longitudinal, lateral, vertical, and temporal. The present review focuses on: (1) lateral connectivity that links the main course of a river with floodplain waterbodies; and (2) vertical connectivity, the exchanges between the surface and groundwater via infiltration into the alluvial aquifer and exfiltration of phreatic water from the hillslope aquifer. 2. The biocomplexity of fluvial hydrosystems results from interactions between processes operating at various spatial and temporal scales. Differences in the nature and intensity of hydrological connectivity contribute to the spatial heterogeneity of riverine floodplains, which results in high alpha, beta and gamma diversity. Differences in connectivity also provide complementary habitats that are required for the parts of life cycles and life-cycles of some species. Hydrological connectivity also produces antagonistic effects, even within the same waterbody. 3. Two temporal scales are distinguished in connectivity dynamics. River level fluctuations within years lead to a pulsing connectivity that drives the functioning of floodplain ecosystems, namely the exchange of organic matter and inorganic nutrients and the shift between production and transport phases. On the scale of decades to centuries, the interactions between various processes increase the biocomplexity of floodplains; for example, river dynamics, which create highly connected waterbodies, compensate for succession that tends towards disconnection. Alternatively, river-bed incision leads to the reduction of fluvial dynamics and to the disconnection of waterbodies, although river incision may increase vertical connectivity where waterbodies are supplied by the hillslope aquifer.

Baxter, C. V. and F. R. Hauer (2000). "Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*)." Canadian Journal of Fisheries and Aquatic Sciences **57**(7): 1470-1481.

The distribution and abundance of bull trout (Salvelinus confluentus) spawning were affected by geomorphology and hyporheic groundwater - stream water exchange across multiple spatial scales in streams of the Swan River basin, northwestern Montana. Among spawning tributary streams, the abundance of bull trout redds increased with increased area of alluvial valley segments that were longitudinally confined by geomorphic knickpoints. Among all valley segment types, bull trout redds were primarily found in these bounded alluvial valley segments, which possessed complex patterns of hyporheic exchange and extensive upwelling zones. Bull trout used stream reaches for spawning that were strongly influenced by upwelling. However, within these selected reaches, bull trout redds were primarily located in transitional bedforms that possessed strong localized downwelling and high intragravel flow rates. The changing relationship of spawning habitat selection, in which bull trout selected upwelling zones at one spatial scale and downwelling zones at another spatial scale, emphasizes the importance of considering multiple spatial scales within a hierarchical geomorphic context when considering the ecology of this species or plans for bull trout conservation and restoration.

Beechie, T. and S. Bolton (1999). "An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds." Fisheries **24**(4): 6-15.

We present an approach to diagnosing salmonid habitat degradation and restoring habitat-forming processes that is focused on causes of habitat degradation rather than on effects of degradation. The approach is based on the understanding that salmonid stocks are adapted to local freshwater conditions and that their environments are naturally temporally dynamic. In this context, we define a goal of restoring the natural rates and magnitudes of habitat-forming processes, and we allow for locally defined restoration priorities. The goal requires that historical reconstruction focus on diagnosing disruptions to processes rather than conditions. Historical reconstruction defines the suite of restoration tasks, which then may be prioritized based on local biological objectives. We illustrate the use of this approach for two habitat-forming processes: sediment supply and stream shading. We also briefly contrast this approach to several others that may be used as components of a restoration strategy.

Beechie, T. J., M. Liermann, et al. (2006). "Channel pattern and river-floodplain dynamics of forested mountain river systems." Geomorphology **78**(1): 124-141.

Channel pattern effectively stratifies the dynamics of rivers and floodplains in forested mountain river systems of the Pacific Northwest, USA. Straight channels are least dynamic, with relatively slow floodplain turnover and floodplains dominated by old surfaces. Braided channels are most dynamic, with floodplain turnover as low as 25 years and predominantly young floodplain surfaces. Island-braided and meandering channels have intermediate dynamics, with moderately frequent disturbances (erosion of floodplain patches) maintaining a mix of old and young surfaces. Return intervals for the erosion of floodplains increase in the order of braided, island-braided, meandering, and straight (8, 33, 60, and 89 years, respectively). A threshold for the lateral migration of a channel occurs at a bankfull width of 15–20 m. The most likely mechanism underlying this threshold is that larger channels are deep enough to erode below the rooting zone of bank vegetation. Above this threshold, channels not confined between valley walls exhibit channel patterns distinguishable by slope and discharge, and slope–discharge domains can be used to predict channel patterns. Meandering and braided patterns are most consistently identified by the model, and prediction errors are largely associated with indistinct transitions among channel patterns that are adjacent in plots of slope against discharge. Locations of straight channels are difficult to identify accurately with the current model. The predicted spatial distribution of channel patterns reflects a downstream decline in channel slope, which is likely correlated with a declining ratio of bed load to suspended load. Ecological theory suggests that biological diversity should be highest where the intermediate disturbance regime of island-braided channels sustains high diversity of habitat and successional states through time.

Brunke, M. and T. Gonser (1997). "The ecological significance of exchange processes between rivers and groundwater." Freshwater Biology **37**(1): 1-33.

This review focuses on the connectivity between river and groundwater ecosystems, viewing them as linked components of a hydrological continuum. Ecological processes that maintain the integrity of both systems and those that are mediated by their ecotones are evaluated. The hyporheic zone, as the connecting ecotone, shows diverse gradients. Thus it can be characterized by hydrological, chemical, zoological and metabolic criteria. However, the characteristics of the hyporheic zone tend to vary widely in space and time as well as from system to system. The exact limits are difficult to designate and the construction of static concepts is inadequate for the representation of ecological processes. The hyporheic interstices are functionally a part of both the fluvial and groundwater ecosystems. The permeability of the ecotone depends on the hydraulic conductivity of the sediment layers which, because of their heterogeneity, form many flowpath connections between the stream and the catchment, from the small scale of a single microhabitat to the large scale of an entire alluvial aquifer. Local up- and downwellings are determined by geomorphologic features such as streambed topography, whereas large-scale exchange processes are determined mainly by the geological properties of the catchment. Colmation - clogging of the top layer of the channel sediments - includes all processes leading to a reduction of pore volume, consolidation of the sediment matrix, and decreased permeability of the stream bed. Consequently, colmation can hinder exchange processes between surface water and groundwater. Physicochemical gradients in the interstices result from several processes: (i) hyporheic flow pattern and the different properties of surface and groundwaters; (ii) retention, caused by the filtering effect of pore size and lithologic sorption as well as the transient storage of solutes caused by diminished water velocities; (iii) biogeochemical transformations in conjunction with local residence time. Each physicochemical parameter may develop its own vertical dynamics laterally from the active channel into the banks as well as longitudinally because of geomorphologic changes. The river-groundwater interface can act as a source or sink for dissolved organic matter, depending on the volume and direction of flow, dissolved organic carbon concentrations and biotic activity. Interstitial storage of particulate organic matter is influenced mainly by grain size distribution and by spates involving bedload movement that may import or release matter, depending on the season. After initial transient and abiotic storage, hyporheic organic matter is mobilized and transformed by the biota. Micro-organisms account for over 90% of the community respiration. In subterranean waters most bacteria are attached to surfaces and remain in a biofilm. Hyporheic interstices are functionally significant for phreatic and riverine metazoans because they act as a refuge against adverse conditions. The net flow direction exerts a dominant influence on interstitial colonization, but many other factors also seem to be important in structuring the hyporheos. The hyporheic corridor concept emphasizes connectivity and interactions between subterranean and surface flow on an ecosystem level for floodplain rivers. It is a complementary concept to others which focus on surficial processes in the lateral and longitudinal dimensions. The ecological integrity of groundwater and fluvial systems is often threatened by human activities: (i) by reducing connectivity; (ii) by altering exchange processes; and (iii) by toxic or organic contamination.

Busby, P. J., T. C. Wainwright, et al. (1996). Status review of west coast steelhead from Washington, Idaho, Oregon, and California. Springfield, VA, U.S. Dept of Commerce.

After considering available information on steelhead genetics, phylogeny and life history, freshwater ichthyogeography, and environmental features that may affect steelhead, the BRT identified 15 ESUs—12 for coastal steelhead and 3 for the inland form. The BRT reviewed population abundance data and other risk factors for these steelhead ESUs and concluded that five (Central California Coast, South-Central California Coast, Southern California, Central Valley, and Upper Columbia River) are presently in danger of extinction, five (Lower Columbia River, regon Coast, Klamath Mountains Province, Northern California, and Snake River Basin) are likely to become endangered in the foreseeable future, and four steelhead ESUs (Puget Sound, Olympic Peninsula, Southwest Washington, and Upper Willamette River) are not presently in significant danger of becoming extinct or endangered, although some individual stocks within these ESUs may be at risk. The BRT concluded that the remaining steelhead ESU (Middle Columbia River) is not presently in danger of extinction but was unable to reach a conclusion as to its risk of becoming endangered in the foreseeable future.

Geist, D. R., T. P. Hanrahna, et al. (2002). "Physiochemical characteristics of the hyporheic zone affect redd site selection by chum salmon and fall Chinook salmon in the Columbia River." North American Journal of Fisheries Management **22**: 1107-1085.

Chum salmon Oncorhynchus keta and fall chinook salmon O. tshawytscha spawned at separate locations in a side channel near Ives Island, Washington, in the Columbia River downstream of Bonneville Dam. We hypothesized that measurements of water depth, substrate size, and water velocity would not sufficiently explain the separation in spawning areas and began a 2-year investigation of physicochemical characteristics of the hyporheic zone. We found that chum salmon spawned in upwelling water that was significantly warmer than the surrounding river water. In contrast, fall chinook salmon constructed redds at downwelling sites, where there was no difference in temperature between the river and its bed. An understanding of the specific factors affecting chum salmon and fall chinook salmon redd site selection at Ives Island will be useful to resource managers attempting to maximize available salmonid spawning habitat within the constraints imposed by other water resource needs.

Gende, S. M., R. T. Edwards, et al. (2002). "Pacific salmon in aquatic and terrestrial ecosystems." BioScience **52**(10): 917-928.

Pacific salmon subsidize freshwater and terrestrial ecosystems through several pathways, which generates unique management and conservation issues but also provides valuable research opportunities. In A Sand County Almanac, Aldo Leopold (1949) described the incremental movement of atom X from headwaters to ocean, driven by the forces of gravity and discharge, to its ultimate “prison”in the sea. Understanding the implications and controls of “nutrient spiraling,” as this phenomenon has been termed, has driven much of recent stream ecosystem research (e.g., Peterson et al. 2001). Our current understanding of the phenomenon of salmon-derived nutrient input clearly shows that a small but important proportion of those atoms escape their “prison” to return in the bodies of ocean-dwelling organisms,whose behavior drives them back against gravity and stream discharge to penetrate the continent. Quantifying the ecological effects of this phenomenon and translating that understanding into useful conceptual and practical tools to better manage oceanic, freshwater, and terrestrial ecosystems -- without reference to the jurisdictional, organizational, and conceptual boundaries that currently inhibit us -- remains a challenge for scientists and managers alike.

Gregory, S. V., F. J. Swanson, et al. (1991). "An ecosystem perspective of riparian zones." Bioscience **41**(8): 540-551.

Riparian zones are the interfaces between terrestrial and aquatic ecosystems. As ecotones, they encompass sharp gradients of environmental factors, ecological processes, and plant communities. Riparian zones are not easily delineated but are comprised of mosaics of landforms, communities, and environments within the larger landscape. We propose a conceptual model of riparian zones that integrates the physical processes that shape valley-floor landscapes, the succession of terrestrial plant communities on these geomorphic surfaces, the formation of habitat, and the production of nutritional resources for aquatic ecosystems.

Gurnell, A. M., H. Piégay, et al. (2002). "Large Wood and Fluvial Processes." Freshwater Biology **47**: 601-619.

1. Large wood forms an important component of woodland river ecosystems. The relationship between large wood and the physical characteristics of river systems varies greatly with changes in the tree species of the marginal woodland, the climatic and hydrological regime, the fluvial geomorphological setting and the river and woodland management context. 2. Research on large wood and fluvial processes over the last 25 years has focussed on three main themes: the effects of wood on flow hydraulics; on the transfer of mineral and organic sediment, and on the geomorphology of river channels. 3. Analogies between wood and mineral sediment transfer processes (supply, mobility and river characteristics that affect retention) are found useful as a framework for synthesising current knowledge on large wood in rivers. 4. An important property of wood is its size when scaled to the size of the river channel. 'Small' channels are defined as those whose width is less than the majority of wood pieces (e.g. width < median wood piece length). 'Medium' channels have widths greater than the size of most wood pieces (e.g. width < upper quartile wood piece length), and 'Large' channels are wider than the length of all of the wood pieces delivered to them. 5. A conceptual framework defined here for evaluating the storage and dynamics of wood in rivers ranks the relative importance of hydrological characteristics (flow regime, sediment transport regime), wood characteristics (piece size, buoyancy, morphological complexity) and geomorphological characteristics (channel width, geomorphological style) in 'Small', 'Medium' and 'Large' rivers. 6. Wood pieces are large in comparison with river size in

'small' rivers, therefore they tend to remain close to where they are delivered to the river and provide important structures in the stream, controlling rather than responding to the hydrological and sediment transfer characteristics of the river. 7. For 'Medium' rivers, the combination of wood length and form becomes critical to the stability of wood within the channel. Wood accumulations form as a result of smaller or more mobile wood pieces accumulating behind key pieces. Wood transport is governed mainly by the flow regime and the buoyancy of the wood. Even quite large wood pieces may require partial burial to give them stability, so enhancing the importance of the sediment transport regime. 8. Wood dynamics in 'Large' rivers vary with the geometry of the channel (slope and channel pattern), which controls the delivery, mobility and breakage of wood, and also the characteristics of the riparian zone, from where the greatest volume of wood is introduced. Wood retention depends on the channel pattern and the distribution of flow velocity. A large amount is stored at the channel margins. The greater the contact between the active channel and the forested floodplain and islands, the greater the quantity of wood that is stored.

Independent Scientific Group (1996). Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Portland, OR, Northwest Power Planning Council.

The conceptual foundation presented here represents a new approach to salmon management and restoration in the Columbia River basin. It is one with which the region has little experience. The approach is based on the relationship between natural ecological functions and processes, including habitat diversity, complexity, and connectivity, and salmonid diversity and productivity.

Jansson, R., C. Nilsson, et al. (2007). "Restoring freshwater ecosystems in riverine landscapes: the roles of connectivity and recovery processes." Freshwater Biology **52**(4): 589-596.

1. This paper introduces key messages from a number of papers emanating from the Second International Symposium on Riverine Landscapes held in August 2004 in Sweden, focusing on river restoration. Together these papers provide an overview of the science of river restoration, and point out future research needs. 2. Restoration tests the feasibility of recreating complex ecosystems from more simple and degraded states, thereby presenting a major challenge to ecological science. Therefore, close cooperation between practitioners and scientists would be beneficial, but most river restoration projects are currently performed with little or no scientific involvement. 3. Key messages emanating from this series of papers are: The scope, i.e. the maximum and minimum spatial extent and temporal duration of habitat use, of species targeted for restoration should be acknowledged, so that all relevant stages in their life cycles are considered. Species that have been lost from a stream cannot be assumed to recolonize spontaneously, calling for strategies to ensure the return of target species to-be integrated into projects. Possible effects of invasive exotic species also need to be incorporated into project plans, either to minimize the impact of exotics, or to modify the expected outcome of restoration in cases where extirpation of exotics is impractical. 4. Restoration of important ecological processes often implies improving connectivity of the stream. For example, longitudinal and lateral connectivity can be enhanced by restoring fluvial dynamics on flood-suppressed rivers and by increasing water availability in rivers subject to water diversion or withdrawal, thereby increasing habitat and species diversity. Restoring links between surface and ground water flow enhances vertical connectivity and communities associated with the hyporheic zone. 5. Future restoration schemes should consider where in the catchment to locate projects to make restoration most effective, consider the cumulative effects of many small projects, and evaluate the potential to restore ecosystem processes under highly constrained conditions such as in urban areas. Moreover, restoration projects should be properly monitored to assess whether restoration has been successful, thus enabling adaptive management and learning for the future from both successful and unsuccessful restorations.

Jones, K. L., G. C. Poole, et al. (2008). "Geomorphology, hydrology, and aquatic vegetation drive seasonal hyporheic flow patterns across a gravel-dominated floodplain." Hydrological Processes. Forthcoming.

Across 1.7 km2 of the Umatilla River floodplain (Oregon, USA), we investigated the influences of an ephemeral tributary and perennial ‘spring channel’ (fed only by upwelling groundwater) on hyporheic hydrology. We derived maps of winter and summer water-table elevations from data collected at 46 monitoring wells and 19 stage gauges and used resulting maps to infer groundwater flow direction. Groundwater flow direction varied seasonally across the floodplain and was influenced by main channel stage, flooding, the tributary creek, and the location and direction of hyporheic exchange in the spring channel. Hyporheic exchange in the spring channel was evaluated with a geochemical mixing model, which confirmed patterns of floodplain groundwater movement inferred from water-table maps and showed that the spring channel was fed predominantly by hyporheic water from the floodplain aquifer (87% during winter, 80% during summer), with its remaining flow supplied by upslope groundwater from the adjacent catchment aquifer. Summertime growth of aquatic macrophytes in the spring channel also influenced patterns of hyporheic exchange and groundwater flow direction in the alluvial aquifer by increasing flow resistance in the spring channel, locally raising surface water stage and adjacent water-table elevation, and thereby altering the slope of the water-table in the hyporheic zone. The Umatilla River floodplain is larger than most sites where hyporheic hydrology has been investigated in detail. Yet, our results corroborate other research that has identified off-channel geomorphic features as important drivers of hyporheic hydrology, including previously published modeling efforts from a similar river and field observations from smaller streams.

Jungwirth, M., S. Muhar, et al. (2002). "Re-establishing and assessing ecological integrity in riverine landscapes." Freshwater Biology **47**(4): 867-888.

1. River-floodplain systems are among the most diverse and complex ecosystems. The lack of detailed information about functional relationships and processes at the landscape and catchment scale currently hampers assessment of their ecological status. 2. Intensive use and alteration of riverine landscapes by humans have led to severe degradation of river-floodplain systems, especially in highly industrialised countries. Recent water-related regulations and legislation focussing on high standards of ecological integrity back efforts to restore or rehabilitate these systems. 3. Most restoration projects in the past have suffered from a range of deficits, which pertain to project design, the planning process, the integration of associated disciplines, scaling issues and monitoring. 4. The so-called 'Leitbild' (i.e. a target vision) assumes a key role in river restoration and the assessment of ecological integrity in general. The development of such a Leitbild requires a multistep approach. Including explicitly the first step that defines the natural, type-specific reference condition (i.e. a visionary as opposed to an operational Leitbild), has great practical advantages for restoration efforts, primarily because it provides an objective benchmark, as is required by the European Water Framework Directive and other legal documents. 5. Clearly defined assessment criteria are crucial for evaluating ecological integrity, especially in the pre- and postrestoration monitoring phases. Criteria that reflect processes and functions should play a primary role in future assessments, so as to preserve and restore functional integrity as a fundamental component of ecological integrity. 6. Case studies on the Kissimmee River (U.S.A.), the Rhine River (Netherlands and Germany), and the Drau River (Austria) are used to illustrate the fundamental principles underlying successful restoration projects of river-floodplain systems.

Karr, J. R. (1993). "Defining and assessing ecological integrity - beyond water quality." Environmental Toxicology and Chemistry **12**(9): 1521-1531.

Emphasis in environmental protection is shifting from primary attention to human health to a more balanced consideration of human and ecological health. This shift provides opportunities and challenges to the scientific community. For example, success depends on development of operational definitions of ecological health and programs to measure that health. Ecological health is inextricably tied to concepts such as biological diversity and biological integrity. Water chemistry and toxicity testing have dominated water-quality programs for decades. Success in protecting the ecological health of water resources depends on our ability to supplement those methods with ecologically robust approaches. Existing definitions and approaches for measuring the quality of water resources provide a template to guide development of procedures to assess ecological health. Critical components of successful monitoring programs should include evaluations relative to regional expectations, use multimetric indexes that reflect the multivariate nature of biological systems, and include index components (metrics) that evaluate conditions from individual, population, assemblage, and landscape perspectives.

Kondolf, G. M., A. J. Boulton, et al. (2006). "Process-based ecological river restoration: Visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages." Ecology and Society **11**(2): 5.

Human impacts to aquatic ecosystems often involve changes in hydrologic connectivity and flow regime. Drawing upon examples in the literature and from our experience, we developed conceptual models and used simple bivariate plots to visualize human impacts and restoration efforts in terms of connectivity and flow dynamics. Human-induced changes in longitudinal, lateral, and vertical connectivity are often accompanied by changes in flow dynamics, but in our experience restoration efforts to date have more often restored connectivity than flow dynamics. Restoration actions have included removing dams to restore fish passage, reconnecting flow through artificially cut-off side channels, setting back or breaching levees, and removing fine sediment deposits that block vertical exchange with the bed, thereby partially restoring hydrologic connectivity, i.e., longitudinal, lateral, or vertical. Restorations have less commonly affected flow dynamics, presumably because of the social and economic importance of water diversions or flood control. Thus, as illustrated in these bivariate plots, the trajectories of ecological restoration are rarely parallel with degradation trajectories because restoration is politically and economically easier along some axes more than others.

Kuhnlein, H. V. and O. Receveur (1996). "Dietary change and traditional food systems of indigenous peoples." Annual Review of Nutrition **16**: 417-42.

Traditional food systems of indigenous peoples are defined as being composed of items from the local, natural environment that are culturally acceptable. Rapid dietary change of indigenous peoples worldwide is posing threats to use of this food and the traditional knowledge required for traditional food system maintainance. This review describes the many influences on choice of food by indigenous peoples, the qualities of traditional food systems, the forces of nondirected dietary change causing decline in use of traditional food systems, and the consequences of change for indigenous peoples. Several examples are given of dietary change research with indigenous peoples.

Latterell, J. J., J. S. Bechtold, et al. (2006). "Dynamic patch mosaics and channel movement in an unconfined river valley of the Olympic Mountains." Freshwater Biology **51**(3): 523-544.

1. River valleys resemble dynamic mosaics, composed of patches which are natural, transient features of the land surface produced by the joint action of a river and successional processes over years to centuries. They simultaneously regulate and reflect the distribution of stream energy and exchanges of sediment, wood and particulate organic matter between riparian and aquatic environments. 2. We determined the structure, composition, dynamics and origin of seven patch types at the reach scale in the Queets River valley in the temperate coastal forests of the Olympic Mountains, Washington (U.S.A.). Patch types included: (1) primary and (2) secondary channels; (3) pioneer bars; (4) developing and (5) established floodplains; and (6) transitional and (7) mature fluvial terraces. 3. Lateral channel movements strongly shape patch distribution, structure and dynamics. The primary channel moved laterally 13 m year(-1), on average from 1939 to 2002, but was highly variable among locations and over time. Mean lateral movement rates ranged from 1 to 59 m year(-1) and moving averages (2 km) ranged from 3 to 28 m year(-1) throughout the valley. 4. Each patch type exhibited characteristic vegetation, soil and accumulations of large wood. Pioneer bars contained peak stem density (69 778 stems ha(-1)) and volume of large wood (289 m(3) ha(-1)). Mature fluvial terraces contained the highest mean stem (1739 m(3) ha(-1)) and canopy volume (158 587 m(3) ha(-1)). These patches also contained the most soil nitrogen (537 kg ha(-1)) and carbon (5972 kg ha(-1)). 5. Patch half-life (the time required for half of the existing patches to be eroded) ranged from 21 to 401 years among forested patch types. Erosion rates were highest in pioneer bars (2.3% year(-1)) and developing floodplains (3.3% year(-1)), compared with only 0.17% year(-1) in mature fluvial terraces. New forests formed continually, as pioneering vegetation colonised 50% of the channel system within 18 years, often unsuccessfully. 6. In the Queets River, the structure, composition, and dynamics of the patchy riparian forest depends on the interplay between channel movements and biophysical feedbacks between large wood, living vegetation and geomorphic processes. The cycle of patch development perpetuates a shifting-mosaic of habitats within the river valley capable of supporting diverse biotic assemblages.

Malard, F., U. Uehlinger, et al. (2006). "Flood-pulse and riverscape dynamics in a braided glacial river." Ecology **87**(3): 704-716.

River ecosystems are increasingly viewed as dynamic riverscapes; their extent, composition, and configuration vary in response to the pulsing of discharge. Although compositional and configurational shifts in riverscapes are thought to control ecosystem processes and biodiversity, attempts to quantity riverscape dynamics of braided rivers are scarce. We Measured monthly changes in the length, spatial arrangement, and age distribution of clear (groundwater-fed) and turbid-water (glacial-fed) channels during two annual cycles in a braided glacial river. Biological data from concurrent studies were used to assess the effects of seasonal changes in the size and pattern of the riverscape on local zoobenthic density, Standing crop of epilithic algae, and spatiotemporal distribution of the hyporheos. The hydrological processes involved in the expansion-contraction cycle of the riverscape resulted in a complex, albeit predictable. pattern of change in the proportion and spatial arrangement of clear and turbid channels. On average, 30% of the riverscape was renewed at monthly intervals. Surface hydrological connectivity and the length Of turbid channels increased logarithmically with increasing discharge. The length of clear channels increased up to a threshold discharge of 1.5 m(3)/s, above which surface flooding resulted in the contraction and fragmentation of clear water bodies. Turbid channels exhibited a unimodal age distribution, whereas clear channels had two cohorts that appeared during the expansion and contraction phases. The renewal pattern and configuration of the riverscape changed little between years despite differences in discharge and the occurrence of several rainfall-induced spates. The density of benthic invertebrate communities in the main channel decreased with increasing size of aquatic habitats indicating that local zoobenthic density was Liffected by dilution-concentration effects. The disproportionate Increase in the proportion of glacial-fed habitats during summer high flows limited the standing crop of epilithic algae in this braided river. The spatial arrangement of inhospitable glacial-fed habitats probably impeded the colonization of newly created suitable habitats by invertebrates with poor dispersal capacities. Quantification of riverscape dynamics is critical to understanding how changes in size, composition, and configuration of braided rivers affect biodiversity, bioproduction, and ecosystem processes.

McCullough, D. A., S. A. Spalding, et al. (2001). Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonds. Seattle, US Environmental Protection Agency**:** 114.

The distribution, health, and survival of our native fish species are inextricably linked to the thermal environment. Temperature, perhaps more than any other environmental parameter, greatly affects the status of fish and other aquatic life. With respect to thermal effects, lethal temperatures do occur in the field and can be locally problematic in defining usable and unusable habitat. Sublethal effects of temperature determine the overall well-being and patterns of abundance of our native fish populations. Temperature exerts its control through its effect on the physiology of the individual species and their life stages. In addition, individuals within a species population vary in their responses (e.g., lethal, growth) to temperature, generally according to a bell-shaped distribution. As species individually or relative to one another experience temperatures outside their physiological optimum range, the mix of species present in any given waterbody may drastically change. Aside from direct mortality caused by very high temperatures, temperature influences the abundance and well-being of organisms by controlling their metabolic processes. Every species, including disease organisms, has optimal metabolic ranges. Community composition is shaped by the level of numerous components of the habitat system, including temperature, food, water, light, substrate, and so on, each of which can provide optimal or suboptimal conditions. Temperature is one of the single most influential determinants of habitat quality and can also act synergistically with other habitat elements. Temperature through its effect on physiology influences the ability of fish to grow, reproduce, compete for habitat, and escape predators. This issue paper examines the role of temperature in the physiology of the salmonids native to the Pacific Northwest, and the importance of lethal temperature effects compared with various types of sublethal effects in controlling the survival and health of native fishes.

Megahan, W. F., J. P. Ptoyondy, et al. (1992). Best management practices and cumulative effects from sedimentation in the South Fork Salmon River: an Idaho case study. Watershed Management: Balancing Sustainability and Environmental Change. R. J. Naiman. New York, Springer-Verlag**:** 401-414.

Poor land use, including intensive unregulated logging from 1940 through the mid-1960s, contributed to massive cumulative effects from sedimentation in Idaho's South Fork Salmon River (SFSR) by 1965. Severe damage to valuable salmon and steelhead habitat resulted. The BIOSED sediment yield prediction model was used to evaluate the effects of historical and alternative land management on Dollar Creek, a representative 46.1 km2 tribuatry watershed in the SFSR watershed. Present day management practices, properly implemented, have the potential of reducing sediment yields by about 45 to 94% compared with yields caused by the historical land use in Dollar Creek. Cumulative effects analysis is a useful tool for evaluating management alternatives. Some increases in sedimentation are unavoidable even using the most cautious logging and roading methods. However, much of the sediments in the SFSR and other drainages could have been avoided if logging and road construction had followed current best management practices.

Myers, J. M., R. G. Kope, et al. (1998). Status review of chinook salmon from Washington, Idaho, Oregon, and California. Springfield, VA, U.S. Department of Commerce**:** 443.

Previous status reviews conducted by the NMFS have identified three ESUs of chinook salmon in the Columbia River: Snake River fall-run (Waples et al. 1991), Snake River spring- and summer-run (Matthews and Waples 1991), and mid-Columbia River summer- and fall-run chinook salmon (Waknitz et al. 1995). In addition, prior to development of the ESU policy, the NMFS recognized Sacramento River winter chinook salmon as a "distinct population segment" under the ESA (NMFS 1987). In reviewing the biological and ecological information concerning west coast chinook salmon, the Biological Review Team (BRT) identified 11 additional ESUs for chinook salmon from Washington, Oregon, and California. Genetic data (from protein electrophoresis and DNA analysis) and tagging information were key factors considered for the reproductive isolation criterion, supplemented by inferences about barriers to migration created by natural features. Life-history differences were another important consideration in the designation of ESUs. The BRT utilized the classification system developed by Healey (1983, 1991) to describe the two races of chinook salmon: 1) ocean-type populations which typically migrate to seawater in their first year of life and spend most of their oceanic life in coastal waters, and 2) stream-type populations which migrate to sea as yearlings and often make extensive oceanic migrations. Genetic differences, as measured by variation in allozymes, indicate that the ocean- and stream-type races represent two major (and presumably monophyletic) evolutionary lineages. A number of additional factors were considered to be important in evaluations of ecological/genetic diversity, with data on life-history characteristics (especially ocean distribution, time of freshwater entry, age at smoltification and at maturation) and geographic, hydrological, and environmental characteristics being particularly informative.

For the purposes of this review, the BRT did not evaluate likely or possible effects of conservation measures and therefore did not make recommendations as to whether identified ESUs should be listed as threatened or endangered species. The BRT

did, however, draw scientific conclusions about the risk of extinction faced by ESUs under the assumption that present conditions will continue.

With respect to the 11 newly-identified ESUs, the BRT concluded that two (Sacramento River Spring Run and Upper Columbia River Spring Run) are at risk of extinction, primarily due to seriously depressed abundance. Five ESUs (Central Valley Fall Run, Southern Oregon and California Coast, Puget Sound, Lower Columbia River, and Upper Willamette River) are at risk of becoming endangered, due to a variety of factors. Only four ESUs (Upper Klamath and Trinity Rivers, Oregon Coast, Washington Coast, and Middle Columbia River Spring Run) are not at risk of extinction or endangerment.

Nehlsen, W., J. E. Williams, et al. (1991). "Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington." Fisheries **16**: 4-21.

The American Fisheries Society herein provides a list of depleted Pacific salmon, steelhead, and sea-run cutthroat stocks from California, Oregon, Idaho, and Washington, to accompany the list of rare inland fishes reported by Williams et al. (1989). The list includes 214 native naturally-spawning stocks: 101 at high risk of extinction, 58 at moderate risk of extinction, 54 of special concern, and one classified as threatened under the Endangered Species Act of 1973 and as endangered by the state of California. The decline in native salmon, steelhead, and sea-run cutthroat populations has resulted from habitat loss and damage, and inadequate passage and flows caused by hydropower, agriculture, logging, and other developments; overfishing, primarily of weaker stocks in mixed-stock fisheries; and negative interactions with other fishes, including nonnative hatchery salmon and steelhead. While some attempts at remedying these threats have been made, they have not been enough to prevent the broad decline of stocks along the West Coast. A new paradigm that advances habitat restoration and ecosystem function rather than hatchery production is needed for many of these stocks to survive and prosper into the next century.

Nilsson, C., R. Jansson, et al. (2007). "Restoring riverine landscapes: The challenge of identifying priorities, reference states, and techniques." Ecology and Society **12**(1): 16.

This special issue of Ecology and Society on restoring riverine landscapes draws together nine presentations from the Second International Symposium on Riverine Landscapes, convened in August 2004 in Storforsen, Sweden. We summarize three themes related to river restoration: (1) setting priorities, (2) identifying relevant reference conditions, and (3) choosing appropriate techniques. We discuss ways of developing river restoration and provide examples of future needs in sustaining functioning river ecosystems that can support human societies.

Petts, G. E. (2000). "A perspective on the abiotic processes sustaining the ecological integrity of running waters." Hydrobiologia **422**: 15-27.

Using selected examples of recent research, this paper illustrates the role of abiotic components within running-water ecosystems. The important role of temperature is acknowledged but the paper focuses on another key driver: physical stability, defined in relation to hydrological (frequency, duration and timing of inundation) and substratum parameters (channel dynamics, bedform and sediment size). The importance of this driver is illustrated by reference to four spatial scales. At the scale of the bedform, surface-water and groundwater interactions play an important role not least in driving energy exchanges and determining the temperature dynamics within the ecologically important surface layer of the bed sediments. At the reach scale, bedform development, channel form dynamics, and associated changing hydraulic conditions determine both benthic and riparian community patterns. At the catchment scale, new research has shown that the processes responsible for the formation of islands and divided channels play important roles in the functioning of fluvial hydrosystems. Finally, at the regional scale, the flow regime modified by the geomorphological history of the river over at least the past 16 000 years explains ecological patterns. The integration of hydro-geomorphological knowledge from all four scales of analysis is shown to be fundamental for understanding the ecological characteristics of running waters and for managing ecological integrity.

Poff, N. L., J. D. Allan, et al. (1997). "The natural flow regime. A paradigm for river conservation and restoration." BioScience **47**(11): 769-784.

The ecological integrity of river ecosystems depends on their natural dynamic character. The natural flow regime organizes and defines river ecosystems. In rivers, the physical structure of the environment and, thus, of the habitat, is defined largely by physical processes, especially the movement of water and sediment within the channel and between the channel and floodplain. To understand the biodiversity, production, and sustainability of river ecosystems, it is necessary to appreciate the central organizing role played by a dynamically varying physical environment. The physical habitat of a river includes sediment size and heterogeneity, channel and floodplain morphology, and other geomorphic features. These features form as

the available sediment, woody debris, and other transportable materials are moved and deposited by flow. Thus, habitat conditions associated with channels and floodplains vary among rivers in accordance with both flow characteristics and the type and the availability of transportable materials.

Pollock, M. M., T. J. Beechie, et al. (2007). "Geomorphic changes upstreams of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon." Earth Surface Processes and Landforms **32**: 1174-1185.

Channel incision is a widespread phenomenon throughout the dry interior Columbia River basin and other semi-arid regions of the world, which degrades stream habitat by fundamentally altering natural ecological, geomorphological and hydrological processes. We examined the extent of localized aggradation behind beaver dams on an incised stream in the interior Columbia River basin to assess the potential for using beaver, Castor canadensis, dams to restore such channels, and the effect of the aggradation on riparian habitat. We estimated aggradation rates behind 13 beaver dams between 1 and 6 years old on Bridge Creek, a tributary to the John Day River in eastern Oregon. Vertical aggradation rates are initially rapid, as high as 0.47 m yr(-1), as the entrenched channel fills, then level off to 0.075 m yr(-1) by year six, as the sediment begins accumulating on adjacent terraces. We found that a 0.5 m elevation contour above the stream channel approximately coincided with the extent of new riparian vegetation establishment. Therefore, we compared the area surrounding reaches upstream of beaver dams that were within 0.5 m elevation of the stream channel with adjacent reaches where no dams existed. We found that there was five times more area within 0.5 m elevation of the channel upstream of beaver dams, presumably because sediment accumulation had aggraded the channel. Our results suggest that restoration strategies that encourage the recolonization of streams by beaver can rapidly expand riparian habitat along incised streams.

Pollock, M. M., G. R. Pess, et al. (2004). "The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA." North American Journal of Fisheries Management **24**: 749-760.

The use of beaver (Castor canadensis) ponds by juvenile coho salmon (Oncorhynchus kisutch) and other fishes has been well established. However, the population-level effects on coho salmon resulting from the widespread removal of millions of beaver and their dams from Pacific Coast watersheds have not been examined. We assessed the current and historic distributions of beaver ponds and other coho salmon rearing habitat in the Stillaguamish River, a 1,771-km(2) drainage basin in Washington and found that the greatest reduction in coho salmon smolt production capacity originated from the extensive loss of beaver ponds. We estimated the current summer smolt production potential (SPP) to be 965,000 smolts, compared with a historic summer SPP of 2.5 million smolts. Overall, current summer habitat capacity was reduced by 61% compared with historic levels, most of the reduction resulting from the loss of beaver ponds. Current summer SPP from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with historic SPP. A more dramatic reduction in winter habitat capacity was found; the current winter SPP was estimated at 971,000 smolts, compared with a historic winter SPP of 7.1 million smolts. In terms of winter habitat capacity, we estimated a 94% reduction in beaver pond SPP a 68% loss in SPP of sloughs, a 9% loss in SPP of tributary habitat, and an overall SPP reduction of 86%. Most of the overall reduction resulted from the loss of beaver ponds. Our analysis suggests that summer habitat historically limited smolt production capacity, whereas both summer and winter habitats currently exert equal limits on production. Watershed-scale restoration activities designed to increase coho salmon production should emphasize the creation of ponds and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

Pollock, M. M., I. Tattam, et al. (In Press). "The association of juvenile steelhead and riparian vegetation with beaver dams in an incised stream in eastern Oregon." North American Journal of Fisheries Management.

In press; abstract not available.

Poole, G. C. and C. H. Berman (2001). "An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation." Environmental Management **27**(6): 787-802.

While external factors (drivers) determine the net heat energy and water delivered to a stream, the internal structure of a stream determines how heat and water will be distributed within and exchanged among a stream's components (channel, alluvial aquifer, and riparian zone/floodplain). Therefore, the interaction between external drivers of stream temperature and the internal structure of integrated stream systems ultimately determines channel water temperature. This paper presents a synoptic, ecologically based discussion of the external drivers of stream temperature, the internal structures and processes that insulate and buffer stream temperatures, and the mechanisms of human influence on stream temperature. It provides a holistic perspective on the diversity of natural dynamics and human activities that influence stream temperature, including discussions of the role of the hyporheic zone. Key management implications include: (1) Protecting or reestablishing in-stream flow is critical for restoring desirable thermal regimes in streams. (2) Modified riparian vegetation, groundwater dynamics, and channel morphology are all important pathways of human influence on channel-water temperature and each pathway should be addressed in management plans. (3) Stream temperature research and monitoring programs will be jeopardized by an inaccurate or incomplete conceptual understanding of complex temporal and spatial stream temperature response patterns to anthropogenic influences. (4) Analyses of land-use history and the historical vs contemporary structure of the stream channel, riparian zone, and alluvial aquifer are important prerequisites for applying mechanistic temperature models to develop management prescriptions to meet in-channel temperature goals.

Poole, G. C., J. B. Dunham, et al. (2004). "The case for regime-based water quality standards." BioScience **54**(2): 155-161.

Conventional water quality standards have been successful in reducing the concentration of toxic substances in US waters. However, conventional standards are based on simple thresholds and are therefore poorly structured to address human-caused imbalances in dynamic, natural water quality parameters, such as nutrients, sediment, and temperature. A more applicable type of water quality standard - a "regime standard" - would describe desirable distributions of conditions over space and time within a stream network. By mandating the protection and restoration of the aquatic ecosystem dynamics that are required to support beneficial uses in streams, well-designed regime standards would facilitate more effective strategies for management of natural water quality parameters.

Poole, G. C., S. J. O'Daniel, et al. (In Press). "Hydrologic spirals: the role of multiple interactive flow paths in stream ecosystems." River Research and Applications.

In this paper, we develop and illustrate the concept of “hydrologic spiraling” using a high-resolution (2 x 2 m grid cell) simulation of hyporheic hydrology across a 1.7 km2 section of the sand, gravel, and cobble floodplain aquifer of the upper Umatilla River of northeastern Oregon, USA. We parameterized the model using a continuous map of surface water stage derived from LIDAR remote sensing data. Model results reveal the presence of complex spatial patterns of hyporheic exchange across spatial scales. We use simulation results to describe streams as a collection of hierarchically organized, individual flow paths that spiral across ecotones within streams and knit together stream ecosystems. Such a view underscores the importance of: 1) gross hyporheic exchange rates in rivers, 2) the differing ecological roles of short and long hyporheic flow paths, and 3) the downstream movement of water and solutes outside of the stream channel (e.g., in the alluvial aquifer). Hydrologic spirals underscore important limitations of empirical measures of biotic solute uptake from streams and provide a needed hydrologic framework for emerging research foci in stream ecology such as hydrologic connectivity, spatial and temporal variation in biogeochemical cycling rates, and the role of stream geomorphology as a dominant control on stream ecosystem dynamics.

Poole, G. C., J. A. Stanford, et al. (2006). "Multiscale geomorphic drivers of groundwater flow paths: subsurface hydrologic dynamics and hyporheic habitat diversity." Journal of the North American Benthological Society **25**(2): 288-303.

Application of a hydrogeologic computer model underscored the importance of geomorphic controls on groundwater and surface-water flow dynamics in the Nyack Floodplain, a montane alluvial floodplain in Montana, USA. The model represented the floodplain as a hierarchy of geomorphic patches, which facilitated analysis of model results using independent (predictor) variables at multiple scales. The analyses revealed that geomorphic structures at various spatial scales interact with the flow regime to influence the direction, magnitude, and stability of hyporheic flow within individual floodplain patches. Specifically: 1) the hydrologic flow network within the hyporheic zone is more responsive to seasonal changes in river discharge if floodplain topography is complex and aquifer properties are heterogeneous, 2) simplification of internal patch structure across the floodplain eliminates the influence of fine-scale geomorphic structures on the stability of groundwater flow paths, although the influence of patch context remains, and 3) incremental changes in river discharge can abruptly and substantially restructure the relationship between river discharge and groundwater flow patterns when events such as inundation of previously dry flood channels occur on the floodplain. We believe that ecological theories of biodiversity can be used to understand interactions among geomorphic variation, hydrologic dynamics, and the maintenance of biodiversity in the hyporheic zone if abrupt reorganization and other variations in groundwater flow paths act as disturbances to hyporheic communities. From this perspective, we used model results to develop 4 hypotheses describing the potential for causal linkages among floodplain geomorphology, hyporheic flow-path variation, hyporheic habitat diversity/stability, and hyporheic community diversity.

Pringle, C. (2003). "What is hydrologic connectivity and why is it ecologically important?" Hydrological Processes **17**(13): 2685-2689.

Hydrologic connectivity is used here in an ecological context to refer to water-mediated transfer of matter, energy and/or organisms within or between elements of the hydrologic cycle. Hydrologic connectivity is essential to the ecological integrity of the landscape, and reduction or enhancement of this property by humans can have major negative environmental effects. Some of these effects are immediate, localized and, therefore, obvious. For example, with respect to migratory fish, a given dam may act to reduce hydrologic connectivity (by preventing or impeding migration up or downstream), whereas interbasin river transfers enhance this property by allowing the dispersal of fish into river basins outside of their range. Less obvious, are alterations in hydrologic connectivity that exhibit a time lag and manifest themselves at geographic locations far from the source of disturbance. An example concerns the cumulative effect of dams on transport of the inorganic dissolved solute silica. Dams and associated impoundments can reduce the transport of this compound, which becomes deposited in the bottoms of reservoirs. The cumulative effects of many dams along a river can potentially result in a reduction in the amount of silica delivered to coastal waters, with consequent negative effects on coastal food web structure that contribute to eutrophication.

Rayne, S., M. G. Ikonomou, et al. (2003). "Rapidly increasing polybrominated diphenyl ether concentrations in the Columbia River system from 1992 to 2000." Environmental Science & Technology **37**(13): 2847-2854.

Concentrations and congener patterns of 32 individual PBDE congeners from mono- through hexa-brominated were investigated in two fish species occupying similar habitats-but having different diets and trophic levels-and surficial sediments from several locations on the major river system of western North America, the Columbia River, in southeastern British Columbia, Canada. Total PBDE concentrations have increased by up to 12-fold over the period from 1992 to 2000 in mountain whitefish from the Columbia River, with a doubling period of 1.6 years. The rate at which PBDE concentrations are increasing in whitefish is greater than has been previously reported worldwide. At the current rate of increase, SigmaPBDE will surpass those of SigmaPCB by 2003 to become the most prevalent organo-halogen contaminant in this region. SigmaPBDE in whitefish from the mainstem of the Columbia River range up to 72 ng/g wet weight, concentrations that are 20-50-fold higher than in a nearby pristine watershed affected only by atmospheric contaminant transport. Conversely, SigmaPBDE in largescale suckers were approximately an order of magnitude lower than in whitefish, demonstrating the influence of biomagnification and feeding habits. Congener patterns in whitefish from the Columbia River directly correlated with the two major commercial penta-BDE mixtures in use and represent the first time free-swimming aquatic biota such as fish have been found to contain PBDE congener patterns so similar to commercial mixtures. PBDE concentrations in sediments were not linked to a variety of investigated point sources but were instead inversely correlated with the ratio of organic carbon:organic nitrogen in surficial sediments with a pattern suggesting the dominant influence of septic field inputs from the primarily rural population.

Rood, S. B., G. M. Samuelson, et al. (2005). "Managing river flows to restore floodplain forests." Frontiers in Ecology and the Environment **3**(4): 193-201.

River damming has dramatic environmental impacts and while changes due to reservoir flooding are immediate, downstream impacts are more spatially extensive. Downstream environments are influenced by the pattern of flow regulation, which also provides an opportunity for mitigation. We discuss impacts downstream from dams and recent case studies where collaborative efforts with dam operators have led to the recovery of more natural flow regimes. These restoration programs, in Nevada, USA, and Alberta, Canada, focused on the recovery of flow patterns during high flow years, because these are critical for riparian vegetation and sufficient water is available for both economic commitments and environmental needs. The restoration flows were developed using the “Recruitment Box Model”, which recommends high spring flows and then gradual flow decline for seedling survival. These flow regimes enabled extensive recruitment of cottonwoods and willows along previously impoverished reaches, and resulted in improvements to river and floodplain environments. Such restoration successes demonstrate how instream flow management can act as a broadly applicable tool for the restoration of floodplain forests.

Stanford, J. A., M. S. Lorang, et al. (2005). "The shifting habitat mosaic of river ecosystems." Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie **29**: 123-136.

A useful way to examine the problem of defining habitat per life stage is to think of landscapes as being composed of habitat mosaics. Indeed, landscape ecology in theory and practice attempts to define species (or population) distributions, abundances and productivity in context of patches or mosaics of biophysical space used by those species (or populations).

The dynamics of habitat mosaics and species responses to them, including complex biophysical feedbacks, perhaps is the essence of landscape ecology. Herein we examine river ecosystems in this dynamic habitat context. We present a general typology of floodplain structures or elements as a basis for habitat delineation. We argue that while the elements that define riverine habitats tend to persist in natural river systems (and are constrained or eliminated by human alteration), the distribution of the habitat patches (mosaics) changes spatially over time due to primary drivers, particularly flooding, channel avulsion, cut and fill alluviation (erosion and deposition of fine and coarse sediments), deposition of wood recruitment and regeneration of riparian vegetation. We call this phenomenon the shifting habitat mosaic and argue it is a fundamental process attribute of river ecosystems. We propose that the rather wide array of contemporary theories about river ecosystem structure and function are substantially unified by thinking of river ecosystems as a continuum of 3-dimensional shifting habitat mosaics from headwaters to the ocean.

Stanford, J. A., J. V. Ward, et al. (1996). "A general protocol for restoration of regulated rivers." Regulated Rivers: Research and Management **12**: 391-413.

Large catchment basins may be viewed as ecosystems in which natural and cultural attributes interact, Contemporary river ecology emphasizes the four-dimensional nature of the river continuum and the propensity for riverine biodiversity and bioproduction to be largely controlled by habitat maintenance processes, such as cut and fill alluviation mediated by catchment water yield. Stream regulation reduces annual flow amplitude, increases baseflow variation and changes temperature, mass transport and other important biophysical patterns and attributes, As a result, ecological connectivity between upstream and downstream reaches and between channels, ground waters and floodplains may be severed, Native biodiversity and bioproduction usually are reduced or changed and non-native biota proliferate. Regulated rivers regain normative attributes as distance from the dam increases and in relation to the mode of dam operation. Therefore, dam operations can be used to restructure altered temperature and flow regimes which, coupled with pollution abatement and management of non-native biota, enables natural processes to restore damaged habitats along the river's course. The expectation is recovery of depressed populations of native species, The protocol requires: restoring peak flows needed to reconnect and periodically reconfigure channel and floodplain habitats; stabilizing base-flows to revitalize food-webs in shallow water habitats; reconstituting seasonal temperature patterns (e.g. by construction of depth selective withdrawal systems on storage dams); maximizing dam passage to allow recovery of fish metapopulation structure; instituting a management belief system that relies upon natural habitat restoration and maintenance, as opposed to artificial propagation, installation of artificial instream structures (river engineering) and predator control; and, practising adaptive ecosystem management. Our restoration protocol should be viewed as an hypothesis derived from the principles of river ecology. Although restoration to aboriginal state is not expected, nor necessarily desired, recovering some large portion of the lost capacity to sustain native biodiversity and bioproduction is possible by management for processes that maintain normative habitat conditions. The cost may be less than expected because the river can do most of the work.

Vannote, R. L., G. W. Minshall, et al. (1980). "The river continuum concept." Canadian Journal of Fisheries and Aquatic Science **37**: 130-137.

From headwaters to mouth, the physical variables within a river system present a continous gradient of physical conditions. The gradient should elicit a series of responses within the constituent populations resulting in a continuum of biotix adjustments and consistens patterns of laoding, transport, utilization, and storage of organic matter along the length of a river. Based on the energy equilibrium theory of fluvial geomorphologists, we hypothesize that the structural and functional characteristics of stream communities are adapted to conform to the most probable position or mean state of the physical system. Downstream communities are structured to capitalize on upstream ineffeciencies.

Ward, J. V. (1998). "Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation." Biological Conservation **83**(3): 269-278.

The term riverine landscape implies a holistic geomorphic perspective of the extensive interconnected series of biotopes and environmental gradients that, with their biotic communities, constitute fluvial systems. Natural disturbance regimes maintain multiple interactive pathways (connectivity) across the riverine landscape. Disturbance and environmental gradients, acting in concert, result in a positive feedback between connectivity and spatio-temporal heterogeneity that leads to the broadscale patterns and processes responsible for high levels of biodiversity. Anthropogenic impacts such as flow regulation, channelization, and bank stabilization, by (1) disrupting natural disturbance regimes, (2) truncating environmental gradients, and (3) severing interactive pathways, eliminate upstream-downstream linkages and isolate river channels from riparian/floodplain systems and contiguous groundwater aquifers. These alterations interfere with successional trajectories, habitat diversification, migratory pathways and other processes, thereby reducing biodiversity. Ecosystem management is necessary to maintain or restore biodiversity at a landscape scale. To be effective, conservation efforts should be based on a solid conceptual foundation and a holistic understanding of natural river ecosystems. Such background knowledge is necessary to re-establish environmental gradients, to reconnect interactive pathways, and to reconstitute some semblance of the natural dynamics responsible for high levels of biodiversity. The challenge for the future lies in protecting the ecological integrity and biodiversity of aquatic systems in the face of increasing pressures on our freshwater resources. This will require integrating sound scientific principles with management perspectives that recognize floodplains and groundwaters as integral components of rivers and `that are based on sustaining, rather than suppressing, environmental heterogeneity.

Ward, J. V. and J. A. Stanford (1995). "Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation." Regulated Rivers: Research and Management **11**: 105-119.

The dynamic nature of alluvial floodplain rivers is a function of flow and sediment regimes interacting with the physiographic features and vegetation cover of the landscape. During seasonal inundation, the flood pulse forms a "moving littoral" that traverses the plain, increasing productivity and enhancing connectivity. The range of spatio-temporal connectivity between different biotypes, coupled with variable levels of natural disturbance, determine successional patterns and habitat heterogeneity that are responsible for maintaining the eological integrity of floodplain river systems. Flow regulations by dams, often compounded by other modifications such as levee construction, normally results in reduced connectivity and altered successional trajectories in downstream reaches. Flood peaks are typically reduced by river regualtion which reduces the frequency and extent of floodplain inundation. A reduction in channel-forming flows reduces channel migration, an important phenomenon in maintianing high levels of habitat diversity across floodplains. The seasonal timing of floods may be shifted by flow regualtions with major ramifications for aquatic and terrestiral biota. Truncations of sediment transport may result in channel degradation for many kilometers downstream from a dam. Deepening of the channel lowers the water table, which affects riparian vegetation dynamics and reduces the effective base level of tributaries, which results in rejuvenation and erosion. Ecological integrity in floodplain rivers is based in part on a diversity of water bodies with differing degrees of connectivity with the main river channel. Collectively, these water bodies occupy a wide range of successional stages, thereby forming a mosaic of habitat patches across the floodplain. This dieversity is maintianed by a balance between the trend toward terrestrializationa dn flow disturbances that renew connectivity and reset successional sequences. to counter the influence of river regulation, restoration efforts should focus on reestablishing dynamic connectivity between the channel and floodplain water bodies.

Ward, J. V. and K. Tockner (2001). "Biodiversity: towards a unifying theme for river ecology." Freshwater Biology **46**: 807-819.

1. A broadened concept of biodiversity, encompassing spatio-temporal heterogeneity, functional processes and species diversity, could provide a unifying theme for river ecology. 2. The theoretical foundations of stream ecology often do not reflect fully the crucial roles of spatial complexity and fluvial dynamics in natural river ecosystems, which has hindered conceptual advances and the effectiveness of efforts at conservation and restoration. 3. Inclusion of surface waters (lotic and lentic), subsurface waters (hyporheic and phreatic), riparian systems (in both constrained and floodplain reaches), and the ecotones between them (e.g. springs) as interacting components contributing to total biodiversity, is crucial for developing a holistic framework of rivers as ecosystems. 4. Measures of species diversity, including alpha, beta and gamma diversity, are a result of disturbance history, resource partitioning, habitat fragmentation and successional phenomena across the riverine landscape. A hierarchical approach to diversity in natural and altered river-floodplain ecosystems will enhance understanding of ecological phenomena operating at different scales along multidimensional environmental gradients. 5. Re-establishing functional diversity (e.g. hydrologic and successional processes) across the active corridor could serve as the focus of river conservation initiatives. Once functional processes have been reconstituted, habitat heterogeneity will increase, followed by corresponding increases in species diversity of aquatic and riparian biota.

Ward, J. V., K. Tockner, et al. (1999). "Biodiversity of floodplain river ecosystems: ecotones and connectivity." Regulated Rivers: Research and Management **15**: 125-139.

A high level of spatio-temporal heterogeneity makes riverine floodplains among the most species-rich environments known. Fluvial dynamics from floodplain play a major role in maintaining a diversity of lentic, lotic, and semi-aquatic habitat types, each represented by a diversity of successional stages. Ecotones are structurel and functional elements that result from and contribute to the spatio-temporal dynamics of riverine ecosystems. In floodplain rivers, ecotones and their adjoining patches are arrayed in hierarichical seiris across a range of scales. At a coarse scale of resolution, fringing floodplains are themselves complex ecotones between river channels and uplands. At finer scales, patches of various types and sizes form habitat and microhabitat diversity patterns. A broad spatio-temporal perspective, including patterns and processes across scales, is needed in order to gain insight into riverine biodiversity. We propose a hierarichical framework for examining diversity patterns in floodplain rivers. Various river management schemes disrupt the interactions that structure ecotones and alter the connectivity acorss transitions zones. Such disruptions occur both within and between hierarchical levels, invariably leading to reductions in biodiversity. Species richness data from the connected and disconnected floodplain of the Austrialian

Danube illustrate the clearly. In much of the world, species rich riverine/floodplain environments exist only as isolated fragments across the landscpae. In many large rivers, these islands of biodiversity are endangered ecosyste.s The fluvial dynamics that formed them have been severely altered. Without ecolocially sound restoration of disturbance regimes and connectivity, these remnants of biodiversity will proceed on unidirectional trajectories toward senescence, without rejuvenation. Principles of ecosystem management are necessary to sustain biodiveristy in fragmented riverine floodplains.

Ward, J. V., K. Tockner, et al. (2001). "Understanding natural patterns and processes in river corridors as the basis for effective river restoration." Regulated Rivers: Research & Management **17**: 311-323.

Running water ecology is a young science, the conceptual foundations of which were derived largely from research conducted in Europe and North America. However, virtually all European river corridors were substantially regulated well before the science of river ecology developed. While regulation of North American river systems occurred later than in European systems, river ecology also developed later. Therefore, there is a general impression of rivers as being much less heterogeneous and much more stable than they actually are in the natural state. The thesis of this paper is that established research and management concepts may fail to fully recognize the crucial roles of habitat heterogeneity and fluvial dynamics owing to a lack of fundamental knowledge of the structural and functional features of morphologically intact river corridors. Until quite recently, most concepts in river ecology were based on the implicit assumption that rivers are stable, single-thread channels isolated from adjacent floodplains. Unfortunately, many rivers are in just such a state, but it should be recognized that this is not the natural condition. This incomplete understanding constrains scientific advances in river ecology and renders management and restoration initiatives less effective. Examples are given of the high level of spatio-temporal heterogeneity that may be attained in rivers where natural processes still operate on a large scale. The objective of this paper is to promulgate a broader and more integrative understanding of natural processes in river corridors as a necessary prelude to effective river conservation and management.

Waters, T. F. (1995). "Sediment in streams: sources, biological effects, and control." American Fisheries Society Monograph **7**: 251 pages.

Human influence has been an accelerating factor in modifying the North American environment for only about 300 to 400 years. Obvious effects of such anthropogenic erosion and sediment deposition include loss of agricultural soils, decreased water-retention capacity of forest lands, increased flood frequency, and rapid filling of reservoirs. Less obvious, however (and until recently largely ignored), is sedimentation in small streams that affects biotic communities, reduces diversity of fish and other animal communities, and lowers the productivity of aquatic populations. The ultimate objective of this review is to encourage more effective management of sediment inputs to streams and to preserve biological integrity and productivity. The chief pragmatic goal is to assist in the improvement and maintenance of stream fisheries, but for other societal interests as well. Specific objectives are to: (1) identify the main causes or sources of anthropogenic inorganic sediment, (2) summarize the results of recent research on the effect of sediment upon stream biota, and (3) describe sediment control measures aimed at the preservation of viable stream communities and freshwater fisheries.

Weitkamp, L. A., T. C. Wainwright, et al. (1995). Status Review of Coho Salmon from Washington, Oregon, and California. Springfield, VA, U.S. Department of Commerce.

The term threatened species is defined as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. According to the ESA, the determination whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, the BRT did not evaluate likely or possible effects of conservation measures and, therefore, did not make recommendations as to whether identified ESUs should be listed as threatened or endangered species; rather, the BRT drew scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue. The resulting conclusions for each ESU follow. 1. Central California coast. There was unanimous agreement among the BRT that natural populations of coho salmon in this ESU are presently in danger of extinction. The chief reasons for this assessment were extremely low current abundance, especially compared to historical abundance, widespread local extinctions, clear downward trends in abundance, extensive habitat degradation and associated decreased carrying capacity, and a long history of artificial propagation with the use of non-native stocks. In addition, recent droughts and current ocean conditions may have further reduced run sizes. 2. Southern Oregon/northern California coasts. There was unanimous agreement among the BRT that coho salmon in this ESU are not in danger of extinction but are likely to become endangered in the foreseeable future if present trends continue. Current run size, the severe decline from historical run size, the frequency of local extinctions, long-term trends that are clearly downward, degraded habitat and associated reduction in carrying capacity, and widespread hatchery production using exotic stocks are all factors that contributed to the assessment. Like the central California ESU, recent droughts and current ocean conditions may have further reduced run sizes. 3. Oregon coast. The

BRT concluded that coho salmon in this ESU are not in danger of extinction but are likely to become endangered in the future if present trends continue. The BRT reached this conclusion based on low recent abundance estimates that are 5-10% of historical abundance estimates, clearly downward long-term trends, recent spawner-to-spawner ratios that are below replacement, extensive habitat degradation, and widespread hatchery production of coho salmon. Drought and current ocean conditions may have also reduced run sizes. 4. Lower Columbia River/southwest Washington coast. Previously, NMFS concluded that it could not identify any remaining natural populations of coho salmon in the lower Columbia River (excluding the Clackamas River) that warranted protection under the ESA. The Clackamas River produces moderate numbers of natural coho salmon. The BRT could not reach a definite conclusion regarding the relationship of Clackamas River late-run coho salmon to the historic lower Columbia River ESU. However, the BRT did conclude that if the Clackamas River late-run coho salmon is a native run that represents a remnant of a lower Columbia River ESU, the ESU is not presently in danger of extinction but is likely to become so in the foreseeable future if present conditions continue. 5. For southwest Washington coho salmon, uncertainty about the ancestry of coho salmon runs given high historical and current levels of artificial production prevented the BRT from reaching a definite conclusion regarding the relationship between coho salmon in that area and the historical lower Columbia River/southwest Washington ESU. If new information becomes available, the relationship and status of the ESU will be reexamined.

5. Olympic Peninsula. While there is continuing cause for concern about habitat destruction and hatchery practices within this ESU, the BRT concluded that there is sufficient native, natural, self-sustaining production of coho salmon that this ESU is not in danger of extinction and is not likely to become endangered in the foreseeable future unless conditions change substantially.

6. Puget Sound/Strait of Georgia. The BRT was concerned that if present trends continue, this ESU is likely to become endangered in the foreseeable future. Although current population abundance is near historical levels and recent trends in overall population abundance have not been downward, there is substantial uncertainty relating to several of the risk factors considered. These risk factors include widespread and intensive artificial propagation, high harvest rates, extensive habitat degradation, a recent dramatic decline in adult size, and unfavorable ocean conditions. Further consideration of this ESU is warranted to attempt to clarify some of these uncertainties.

Whited, D. C., M. S. Lorang, et al. (2007). "Climate, hydrologic disturbance, and succession: Drivers of floodplain pattern." Ecology **88**(4): 940-953.

Floodplains are among the world's most threatened ecosystems due to the pervasiveness of dams, levee systems, and other modifications to rivers. Few unaltered floodplains remain where we may examine their dynamics over decadal time scales. Our study provides a detailed examination of landscape change over a 60-year period (1945 - 2004) on the Nyack floodplain of the Middle Fork of the Flathead River, a free-flowing, gravel-bed river in northwest Montana, USA. We used historical aerial photographs and airborne and satellite imagery to delineate habitats (i.e., mature forest, regenerative forest, water, cobble) within the floodplain. We related changes in the distribution and size of these habitats to hydrologic disturbance and regional climate. Results show a relationship between changes in floodplain habitats and annual flood magnitude, as well as between hydrology and the cooling and warming phases of the Pacific Decadal Oscillation (PDO). Large magnitude floods and greater frequency of moderate floods were associated with the cooling phases of the PDO, resulting in a floodplain environment dominated by extensive restructuring and regeneration of floodplain habitats. Conversely, warming phases of the PDO corresponded with decreases in magnitude, duration, and frequency of critical flows, creating a floodplain environment dominated by late successional vegetation and low levels of physical restructuring. Over the 60-year time series, habitat change was widespread throughout the floodplain, though the relative abundances of the habitats did not change greatly. We conclude that the long- and short-term interactions of climate, floods, and plant succession produce a shifting habitat mosaic that is a fundamental attribute of natural floodplain ecosystems.

Wohl, E., P. L. Angermeier, et al. (2005). "River restoration." Water Resources Research **41**: W10301.

River restoration is at the forefront of applied hydrologic science. However, many river restoration projects are conducted with minimal scientific context. We propose two themes around which a research agenda to advance the scientific basis for river restoration can be built. First, because natural variability is an inherent feature of all river systems, we hypothesize that restoration of process is more likely to succeed than restoration aimed at a fixed end point. Second, because physical, chemical, and biological processes are interconnected in complex ways across watersheds and across timescales, we hypothesize that restoration projects are more likely to be successful in achieving goals if undertaken in the context of entire watersheds. To achieve restoration objectives, the science of river restoration must include (1) an explicit recognition of the known complexities and uncertainties, (2) continued development of a theoretical framework that enables us to identify generalities among river systems and to ask relevant questions, (3) enhancing the science and use of restoration monitoring

by measuring the most effective set of variables at the correct scales of measurement, (4) linking science and implementation, and (5) developing methods of restoration that are effective within existing constraints. Key limitations to river restoration include a lack of scientific knowledge of watershed-scale process dynamics, institutional structures that are poorly suited to large-scale adaptive management, and a lack of political support to reestablish delivery of the ecosystem amenities lost through river degradation. This paper outlines an approach for addressing these shortcomings.

Wood, P. J. and P. D. Armitage (1997). "Biological effects of fine sediment in the lotic environment." Environmental Management **21**(2): 203-217.

Although sedimentation is a naturally occurring phenomenon in rivers, land-use changes have resulted in an increase in anthropogenically induced fine sediment deposition. Poorly managed agricultural practices, mineral extraction, and construction can result in an increase in suspended solids and sedimentation in rivers and streams, leading to a decline in habitat quality. The nature and origins of fine sediments in the lotic environment are reviewed in relation to channel and nonchannel sources and the impact of human activity. Fine sediment transport and deposition are outlined in relation to variations in streamflow and particle size characteristics. A holistic approach to the problems associated with fine sediment is outlined to aid in the identification of sediment sources, transport, and deposition processes in the river catchment. The multiple causes and deleterious impacts associated with fine sediments on riverine habitats, primary producers, macroinvertebrates, and fisheries are identified and reviewed to provide river managers with a guide to source material. The restoration of rivers with fine sediment problems are discussed in relation to a holistic management framework to aid in the planning and undertaking of mitigation measures within both the river channel and surrounding catchment area.

Woodward, G. and A. G. Hildrew (2002). "Food web structure in riverine landscapes." Freshwater Biology **47**(4): 777-798.

1. Most research on freshwater (and other) food webs has focused on apparently discrete communities, in well-defined habitats at small spatial and temporal scales, whereas in reality food webs are embedded in complex landscapes, such as river corridors. Food web linkages across such landscapes may be crucial for ecological pattern and process, however. Here, we consider the importance of large scale influences upon lotic food webs across the three spatial dimensions and through time. 2. We assess the roles of biotic factors (e.g. predation, competition) and physical habitat features (e.g. geology, land-use, habitat fragmentation) in moulding food web structure at the landscape scale. As examples, external subsidies to lotic communities of nutrients, detritus and prey vary along the river corridor, and food web links are made and broken across the land-water interface with the rise and fall of the flood. 3. We identify several avenues of potentially fruitful research, particularly the need to quantify energy flow and population dynamics. Stoichiometric analysis of changes in C : N : P nutrient ratios over large spatial gradients (e.g. from river source to mouth, in forested versus agricultural catchments), offers a novel method of uniting energy flow and population dynamics to provide a more holistic view of riverine food webs from a landscape perspective. Macroecological approaches can be used to examine large-scale patterns in riverine food webs (e.g. trophic rank and species-area relationships). New multivariate statistical techniques can be used to examine community responses to environmental gradients and to assign traits to individual species (e.g. body-size, functional feeding group), to unravel the organisation and trophic structure of riverine food webs.